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Reconstructing contested landscapes

Dynamics, drivers and political framings of land use and land cover change, watershed transformations and coastal sedimentation in Java, Indonesia

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Diese Veröffentlichung ist eine leicht überarbeitete Version der ursprünglich eingereichten Dissertation. Es wurden redaktionelle Änderungen vorgenommen und indonesisch-sprachige Zusammenfassungen hinzugefügt.

Summary

Environmental governance involves regulation of complex, multi-scalar processes that are influenced by a broad range of interwoven factors. Some of these processes and their drivers are only rudimentarily understood. This particularly applies to watershed contexts. Watershed management is also confronted with a broad range of actors and sectors. It is prone to conflicts and politicisations. Thereby, specific political framings of environmental processes can confine debates, knowledge production and political action to a few selected issues and drivers and prevent other issues and drivers from being debated, explored and addressed. This can undermine the effectiveness of watershed management and lay the ground for unrealistic expectations.

The Indonesian island of Java is a prime example illustrating this. Substantial funds have been invested into watershed conservation to reduce upland degradation and the sedimentation of reservoirs, irrigation channels and coastal waters. Most efforts have targeted soil erosion on peasants' private lands by tree planting and terracing programmes. Despite long-standing investment, upland degradation is still considered a problem. In line with the spatial focus of political action, most research to date has focussed on soil erosion and cultivation practices on upland peasants' private lands. Other sediment sources, historical trajectories, and the political dimension of watershed management are underexplored. Also the knowledge of land use and land cover patterns and changes, a major determining factor of erosion and sedimentation, and their causes is limited.

My research explores these aspects with a focus on one of Java's priority areas for coastal and watershed management: the Segara Anakan lagoon and its catchment area. This shallow coastal lagoon on Java's south coast has rapidly shrunk due to riverine sediment input. To reduce sedimentation of the lagoon and adjacent irrigation schemes, the catchment has been targeted by particularly strong watershed conservation efforts. Yet, their effects are regarded as limited. My research combines a reconstruction of the historical dynamics of lagoon sedimentation, an exploration of watershed characteristics and transformations, and an analysis of land use and land cover change (LUCC) and its drivers with an inquiry into the trajectories and modes of watershed management, related political framings of environmental matters, and underlying political structures and interests. It thereby questions long-standing narratives about the drivers of high river sediment loads and coastal sedimentation and contributes new insight into the dynamics and causes of these processes. In this way, the research deconstructs simplistic narratives about watershed and coastal dynamics and reconstructs these dynamics. Conceptually, it combines political ecology, land change science and historical cartography. It also integrates knowledge from a broad range of research fields. Methodologically, the research combines remote sensing, mapping of land use and land cover and other watershed characteristics, analyses of historical maps, reviews of literature and documents, transect walks, semi-structured interviews with a broad range of actors from various political levels, and focus groups.

My engagement with the cartographic history of the region directs attention to the large but underutilised potential of historical maps for research into environmental histories. It also provides insight into the production, replication, gradual development, and ignorance of cartographic knowledge. It shows how information from complete but comparably inaccurate maps was reproduced over long periods of time, while information from more accurate but incomplete maps was continuously ignored. It also directs attention to the varying levels of accuracy within specific maps. Such insights are crucial in using historical maps for analysing environmental change. A core issue in the context of such analyses is the question of how accurate historical maps must be at minimum in order to be used for what kind of analysis. My research addresses this to date barely debated ques-

tion. It presents an approach to analysing historical maps with varying degrees of accuracy and proposes ratios between the rates of environmental change and quantitative map accuracy measures as well as combined uncertainty measures as indicators of the maps' analytical suitability and the reliability of results. This should be combined with a qualitative appraisal of map accuracy, taking into account carto-bibliographic information. The research demonstrates that in case of large magnitudes of environmental change an analysis of even fairly inaccurate historical maps can provide results with low levels of uncertainty. It also illustrates how qualitative analysis of very early, rather inaccurate maps and map makers' records can complement the analysis of more recent, quantitatively analysable maps – an approach that has barely been applied to date and that demarcates the limits and illustrates some pitfalls of cartographic inquiry into historical environmental change.

My shoreline reconstruction based on historical maps and satellite images shows that lagoon aggradation accelerated between 1857/60 and the late 1980s and early 1990s and slowed thereafter. In total, the lagoon's water surface area has declined by three fourths since 1857/60. My exploration of watershed characteristics and dynamics suggests that accelerated lagoon siltation has been the result of a much broader range of drivers than commonly presented in political and scientific debates. In addition to erosion on peasants' private lands, these drivers include profound watershed transformations induced by intensified resource extraction, in-migration and infrastructure development between the mid-19th century and the 1920s; contestations of state forests and plantation lands; state forest management practices; slope cuts to enlarge the agricultural land in valley floors; agricultural use of riparian zones; erosion and mass-movements from roads, trails and settlements; volcanic eruptions; and river channel and floodplain modifications. This synopsis suggests that the choice and expectations of interventions aimed at reducing river sediment loads and coastal sedimentation need to be reconsidered and that related debates and research agendas must be broadened to include the numerous factors beyond the scale of peasants' private agricultural plots.

Yet, peasants' private lands do constitute an important sediment source. However, soil conservation has improved, and tree cover has increased on these lands over the past 1.5 decades. The latter is the result of various factors, such as rising timber prices, off-farm employment, improved marketing opportunities, increased awareness among peasants about soil degradation and the potential of perennial crops, and the enhanced effectiveness of recent, more participatory tree planting programmes.

In contrast, on some of the state forest and plantation lands tree cover has declined and erosion increased. This is mainly a result of struggles over resource access and control. Following a history of exclusive, repressive forest management by the state forest corporation, many state forests were plundered during the political reformation in the late 1990s and early 2000s. Community forestry programmes aim to resolve these conflicts and combat illegal logging. However, their limited performance in building trust and a sense of ownership is reflected in scattered tree cover and crop cultivation with limited soil conservation, resulting in erosion. Crop cultivation on state forest lands has in some cases contributed to increased tree cover on peasants' private lands. While watershed protection programmes focus on the latter, degradation on state forest land is left to the outcome of struggles between the forest corporation and peasants. Yet, the programmes also aim at influencing these struggles by reducing peasants' use of state forest land. This dichotomy between state forest and peasants' private lands, the corresponding division of institutional responsibilities and the linking of struggles over maintenance of this dichotomy with watershed management undermine the effectiveness of the latter.

Some state forest and plantation areas are degraded as a result of conflicts over specific pieces of land. In these cases, peasants claim land ownership referring to displacements in the wake of political insurgencies and counter-insurgencies or illegitimate expansions of plantations in the 1950/60s. Strategic acts of contestation employed by the conflicting actors to assert their claims and tenure insecurity result in high erosion levels on these lands. The course and resolution of these tenure conflicts is a major determining factor of watershed degradation and river sediment loads. This part of the research also direct attention to tenure contestations as an important, but to date still underexplored cause of LUCC. Tenure contestations should be disentangled from other types of tenure insecurity in analysing their links with LUCC. Furthermore, the close links between factors, like historically rooted injustice, struggles over land and forest resources and related strategic acts, and LUCC questions the need or utility of the common separation into proximate and underlying causes of LUCC.

The framing of peasants' cultivation practices as the single-most important cause of watershed degradation is too simplistic as it neglects a large range of other factors. It is also linked with the political interest in upholding the tenure dichotomy between state forest and peasants' private lands. It has confined research and political action to a particular scale, i.e. peasants' private plots, and distracted attention from scales that are crucial to look at in aiming to better understand the processes that were to be managed: the entire catchment area comprising the whole range of sediment sources, the various causes of watershed characteristics and transformations, and historical trajectories. This confinement of the scales of observation in turn has contributed to the solidification of the political framings and confining of political debates to particular scales of intervention (upland peasants' private plots). These links help to explain the temporary persistence and dominance of specific political framings and related scales of knowledge production and political action.

Political power, interests and conflicts and specific framings of environmental matters have shaped and will continue to shape environmental management-related debates and action. Without assuming the possibility of a 'politically neutral', 'objective' search for something like an 'ideal' watershed management strategy, the research results suggest that the environmental outcomes of watershed and coastal management in Java could benefit from a broadened view on the entire range of historical and contemporary watershed characteristics and transformations and their drivers. The results also point to the need for an open societal debate that links watershed protection aims and strategies with the resolution of tenure conflicts and with future (re-)arrangements of the patterns of forest access and control. Such a debate should involve a reconsideration of the long-standing framing of professional state forest management as the epitome of watershed protection and acknowledge the role of peasants' mixed forests with regard to watershed conservation. Some of the dense, diverse, multi-layered, and only selectively logged forests that cover substantial portions of the peasants' private lands provide better watershed protection than some of the state forest corporation's rotationally clear cut monocultures of teak.

The research demonstrates the utility of linking analyses of environmental dynamics and their drivers with critical inquiry into related political framings and modes of action and the underlying political interests and struggles. It also illustrates that the combination of political ecology, land change science and historical cartography and the integration of fractured knowledge from different disciplines generates insights that would remain hidden if the inquiry adhered to one particular research field. Many of the most insightful findings of this research were generated through the combination or at the intersection of the different themes, approaches and methods.

Ringkasan

Tata kelola lingkungan mencakup regulasi tentang proses yang kompleks dan multiskala yang dipengaruhi oleh berbagai faktor yang saling bersinggungan. Beberapa proses ini dan pemicunya belum dipahami secara sempurna. Hal ini berlaku khususnya pada konteks daerah aliran sungai. Manajemen daerah aliran sungai juga dihadapkan pada sejumlah aktor dan sektor, sehingga rentan terhadap konflik dan politisasi. Oleh karenanya, framing politik tertentu tentang proses-proses terkait lingkungan dapat membatasi perdebatan, penciptaan pengetahuan, dan tindakan politik ke sejumlah kecil masalah dan pemicu tertentu, serta menghambat perdebatan, pemahaman, dan pembahasan tentang masalah dan pemicu lain. Hal ini dapat melemahkan keefektifan manajemen daerah aliran sungai dan memicu munculnya harapan yang tidak realistis.

Pulau Jawa di Indonesia adalah contoh terbaik yang menggambarkan hal ini. Sejumlah besar dana telah diinvestasikan untuk konservasi daerah aliran sungai untuk mengurangi degradasi dataran tinggi dan sedimentasi waduk, saluran irigasi, dan perairan pesisir. Sebagian besar upaya ditujukan pada erosi tanah di lahan pribadi petani dengan program penanaman pohon dan pembuatan terasering. Meskipun terdapat investasi jangka panjang, degradasi dataran tinggi masih dianggap sebagai masalah. Sejalan dengan fokus spasial pada aksi politik, sebagian besar penelitian hingga saat ini berfokus pada erosi tanah dan praktik cocok tanam di lahan pribadi petani di dataran tinggi. Sumber sedimen lainnya, lintasan historis, dan dimensi politik dari manajemen daerah aliran sungai tidak banyak didalami. Selain itu, pengetahuan tentang pola dan perubahan pemanfaatan lahan dan tutupan lahan, faktor penentu utama erosi dan sedimentasi, beserta penyebabnya, masih terbatas.

Penelitian saya mendalami aspek-aspek ini dengan fokus pada salah satu wilayah prioritas untuk manajemen pesisir dan daerah aliran sungai di Pulau Jawa: Laguna Segara Anakan dan daerah tangkapan airnya. Laguna pesisir yang dangkal di pantai selatan Jawa ini telah menyusut dengan cepat karena masukan sedimen sungai. Untuk mengurangi sedimentasi laguna dan skema irigasi di dekatnya, daerah tangkapan air menjadi sasaran dalam upaya konservasi daerah aliran sungai yang masif. Namun, dampaknya dianggap masih terbatas. Penelitian saya menggabungkan rekonstruksi dinamika historis sedimentasi laguna, eksplorasi tentang karakter dan transformasi daerah aliran sungai, analisis tentang perubahan pemanfaatan lahan dan tutupan lahan (land use and land cover change/LUCC) beserta pemicunya dengan menyelidiki lintasan dan mode manajemen daerah aliran sungai, framing politik terkait tentang masalah lingkungan, serta struktur dan kepentingan politik yang mendasari. Penelitian saya mempertanyakan narasi lama tentang pemicu tingginya beban sedimen sungai dan sedimentasi pesisir, serta menghadirkan pemikiran baru tentang dinamika dan penyebab proses ini. Dengan demikian, penelitian ini mendekonstruksi narasi sederhana tentang dinamika pesisir dan daerah aliran sungai, serta merekonstruksi dinamika ini. Secara konseptual, penelitian ini menggabungkan ekologi politik, ilmu perubahan lahan, dan kartografi historis. Penelitian ini juga mengintegrasikan pengetahuan dari berbagai bidang penelitian. Dari segi metodologi, penelitian ini menggabungkan pengindraan jauh, pemetaan pemanfaatan lahan, tutupan lahan, dan karakter daerah aliran sungai lainnya, analisis peta historis, tinjauan terhadap literatur dan dokumen, transect walk, wawancara semi-terstruktur dengan sejumlah aktor dari berbagai tingkat politik dan kelompok fokus.

Keterlibatan saya dengan sejarah kartografis wilayah tersebut menekankan potensi yang besar namun kurang dimanfaatkan pada peta historis untuk meneliti sejarah lingkungan. Dari keterlibatan tersebut, saya mendapatkan wawasan tentang pembuatan, replikasi, perkembangan bertahap, dan pengabaian atas pengetahuan kartografis. Saya juga mendapatkan wawasan tentang bagaimana

informasi dari peta yang lengkap namun tidak akurat diperbanyak untuk jangka waktu yang lama, sedangkan informasi dari peta yang lebih akurat namun tidak lengkap terus-menerus diabaikan. Perhatian saya juga terfokus pada berbagai tingkat akurasi dalam peta tertentu. Pengetahuan tersebut penting dalam pemanfaatan peta historis untuk menganalisis perubahan historis. Masalah utama dalam konteks analisis tersebut adalah pertanyaan tentang tingkat akurasi minimum yang harus dimiliki peta historis untuk digunakan dalam analisis jenis tertentu. Penelitian saya membahas pertanyaan yang hingga kini masih diperdebatkan ini. Penelitian ini menyajikan pendekatan untuk menganalisis peta historis dengan berbagai derajat akurasi, mengajukan rasio antara laju perubahan lingkungan dan pengukuran akurasi peta kuantitatif, serta gabungan pengukuran ketidakpastian sebagai indikator kesesuaian analitis peta dan reliabilitas hasil. Ini harus digabungkan dengan penilaian kualitatif terhadap akurasi peta, dengan menyertakan informasi karto-bibliografis. Penelitian ini menunjukkan bahwa pada kasus besarnya magnitudo perubahan lingkungan, analisis tentang peta historis yang kurang akurat pun dapat memberikan hasil dengan tingkat ketidakpastian yang rendah. Penelitian ini juga menggambarkan bagaimana analisis kualitatif tentang peta yang sangat awal dan kurang akurat serta catatan pembuat peta dapat melengkapi analisis peta yang lebih baru dan dapat dianalisis secara kuantitatif – pendekatan yang masih jarang diterapkan saat ini dan yang memperjelas batasan serta menggambarkan sejumlah kekurangan penelitian kartografis tentang perubahan lingkungan secara historis.

Rekonstruksi saya tentang garis pantai berdasarkan peta historis dan gambar satelit menunjukkan bahwa agradasi laguna terjadi semakin cepat antara tahun 1857/1860, akhir 1980an, awal 1990an, dan melambat sesudahnya. Secara menyeluruh, area permukaan air laguna telah berkurang sebanyak tiga perempat bagiannya sejak tahun 1857/1860. Eksplorasi saya tentang karakter dan dinamika daerah aliran sungai menunjukkan bahwa pelumpuran laguna yang semakin cepat disebabkan oleh pemicu yang lebih beragam dari yang umumnya disebutkan dalam perdebatan politik dan ilmiah. Selain erosi di lahan pribadi petani, termasuk dalam pemicu ini adalah modifikasi daerah aliran sungai besar-besaran yang disebabkan oleh ekstraksi sumber daya yang lebih intensif, migrasi masuk dan perkembangan infrastruktur antara pertengahan abad ke-19 dan tahun 1920an; sengketa hutan negara dan lahan perkebunan; praktik manajemen hutan negara; lereng buatan untuk memperluas lahan pertanian di dasar lembah; pemanfaatan zona riparian untuk pertanian; erosi dan pergerakan massal dari jalan raya, jalan setapak, dan permukiman; erupsi vulkanis; serta modifikasi kanal sungai dan dataran banjir. Sinopsis ini menunjukkan bahwa pilihan dan harapan intervensi yang ditujukan untuk mengurangi beban sedimen sungai dan sedimentasi pesisir harus dipertimbangkan kembali, dan bahwa perdebatan dan agenda penelitian terkait harus diperluas untuk mencakup berbagai faktor selain ukuran lahan pertanian pribadi milik petani.

Namun, lahan pribadi petani memang merupakan sumber sedimen yang penting. Kendati demikian, konservasi tanah telah meningkat, dan tutupan pohon pada lahan ini telah meningkat selama 1,5 dekade terakhir. Peningkatan tersebut disebabkan oleh berbagai faktor, seperti meningkatnya harga kayu, lapangan kerja di luar pertanian (off-farm employment), kesempatan pemasaran, meningkatnya kesadaran petani tentang degradasi tanah dan potensi tanaman tahunan, serta meningkatnya keefektifan program penanaman pohon baru-baru ini yang lebih partisipatoris.

Sebaliknya, di sejumlah hutan negara dan lahan perkebunan, tutupan pohon menurun dan erosi meningkat. Hal ini diakibatkan terutama oleh perjuangan untuk memperoleh akses dan kendali atas sumber daya. Setelah riwayat manajemen hutan yang eksklusif dan represif oleh perusahaan hutan negara, banyak hutan negara yang dijarah selama reformasi politik pada akhir tahun 1990an dan awal 2000an. Program kehutanan masyarakat bertujuan untuk menyelesaikan konflik ini dan memerangi pembalakan liar. Namun, terbatasnya kinerja program tersebut dalam membangun kepercayaan dan rasa kepemilikan terlihat dalam tutupan pohon terbatas dan penanaman tanaman dengan konservasi tanah yang rendah, yang mengakibatkan erosi. Pada beberapa kasus, penanaman tanaman di lahan hutan negara meningkatkan tutupan pohon pada lahan pribadi petani. Program perlindungan daerah aliran sungai berfokus pada lahan pribadi petani, sedangkan degradasi lahan hutan adalah akibat dari sengketa antara perusahaan hutan dan petani. Namun, program tersebut juga bertujuan untuk memengaruhi perjuangan ini dengan mengurangi pemanfaatan lahan hutan negara oleh petani. Dikotomi antara hutan negara dan lahan pribadi petani, pembagian terkait tanggung jawab institusional, serta hubungan dipertahankannya dikotomi ini dengan manajemen daerah aliran sungai, melemahkan keefektifan manajemen tersebut.

Sejumlah area hutan negara dan perkebunan mengalami degradasi yang disebabkan oleh konflik pada bagian lahan tertentu. Pada kasus-kasus ini, petani mengeklaim kepemilikan lahan dengan merujuk pada pemindahan paksa akibat pemberontakan dan perlawanan politik balik atau perluasan perkebunan secara tidak sah pada tahun 1950/1960an. Tindakan strategis sengketa yang dilakukan oleh para aktor yang bersengketa untuk mengajukan tuntutan mereka dan ketidakpastian kepemilikan lahan mengakibatkan tingginya tingkat erosi lahan ini. Arah dan penyelesaian konflik kepemilikan lahan ini adalah faktor penentu degradasi daerah aliran sungai dan beban sedimen sungai. Bagian penelitian ini juga berfokus pada sengketa kepemilikan lahan sebagai penyebab LUCC yang penting namun hingga saat ini masih kurang didalami. Sengketa kepemilikan lahan harus dipisahkan dari jenis ketidakpastian kepemilikan lahan lainnya dalam menganalisis hubungan sengketa tersebut dengan LUCC. Selain itu, dekatnya hubungan antara faktor-faktor, seperti ketidakadilan yang mengakar secara historis, perjuangan untuk memperoleh sumber daya lahan dan hutan, serta tindakan strategis terkait, dan LUCC mempertanyakan pentingnya atau manfaatnya pemisahan yang lazim menjadi penyebab pokok dan terperinci dari LUCC.

Framing praktik penanaman oleh petani sebagai penyebab utama degradasi daerah aliran sungai terlalu sederhana karena mengabaikan berbagai faktor lainnya. Hal itu juga terkait dengan kepentingan politik dalam mempertahankan dikotomi kepemilikan lahan antara hutan negara dan lahan pribadi petani. Hal itu telah membatasi penelitian dan tindakan politik ke cakupan tertentu, yaitu lahan pribadi petani, dan menjauhkan perhatian dari cakupan yang penting untuk diperhatikan guna memahami dengan lebih baik proses yang akan dikelola: keseluruhan daerah tangkapan air yang terdiri dari berbagai sumber sedimen, beragam penyebab karakter dan transformasi daerah aliran sungai, dan lintasan historis. Pembatasan cakupan pengamatan ini kemudian berperan dalam pemadatan framing politik dan pembatasan perdebatan politik ke cakupan tertentu intervensi (lahan pribadi petani di dataran tinggi). Hubungan ini membantu menjelaskan kegigihan sementara dan dominasi framing politik tertentu dan cakupan terkait tentang produksi pengetahuan dan tindakan politik.

Kekuasaan politik, kepentingan, dan konflik, serta framing tertentu tentang masalah lingkungan telah memengaruhi dan akan terus memengaruhi perdebatan dan tindakan terkait manajemen lingkungan. Tanpa adanya kemungkinan tentang pencarian yang 'netral secara politik', 'objektif' akan sesuatu seperti strategi manajemen daerah aliran sungai yang 'ideal', hasil penelitian menunjukkan bahwa hasil terkait lingkungan dari manajemen daerah aliran sungai dan pesisir di Pulau Jawa dapat diuntungkan dari diperluasnya pandangan tentang keseluruhan karakter dan transformasi daerah aliran sungai di masa lampau dan masa kini, beserta pemicunya. Hasil tersebut juga mengacu pada diperlukannya perdebatan terbuka yang mengaitkan tujuan dan strategi perlindungan daerah aliran sungai dengan penyelesaian konflik kepemilikan lahan dan dengan pengaturan (ulang) pola akses dan kendali hutan. Perdebatan tersebut harus mencakup pertimbangan ulang framing jangka panjang tentang manajemen hutan negara secara profesional sebagai simbol perlindungan daerah aliran sungai serta mengakui peran kebun campuran milik petani dalam kaitannya dengan konservasi daerah aliran sungai. Sejumlah hutan yang padat, beragam, berlapis banyak, dan hanya ditebang secara selektif yang menutupi bagian yang besar dari lahan pribadi petani memberikan perlindungan yang lebih baik bagi daerah aliran sungai dibandingkan sejumlah monokultur jati tebang habis berotasi milik perusahaan hutan.

Penelitian ini menunjukkan manfaat dari menautkan analisis dinamika lingkungan dan pemicunya dengan penyelidikan kritis untuk mendalami framing politik terkait, mode tindakan, dan kepentingan dan perjuangan politik yang mendasari. Penelitian ini juga menggambarkan kombinasi ekologi politik, ilmu perubahan lahan, dan kartografi historis, serta integrasi pengetahuan yang terpisah-pisah dari berbagai disiplin menghasilkan pandangan yang akan tetap tersembunyi jika penyelidikan tersebut dikaitkan dengan satu bidang penelitian tertentu. Banyak temuan paling cemerlang dalam penelitian ini dihasilkan dari kombinasi atau pada persimpangan tema, pendekatan, dan metode yang berbeda-beda.

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List of research papers

Paper 1: **Lukas, M.C. (2014): Cartographic Reconstruction of Historical Environmental Change. Cartographic Perspectives, 78: 5-24. doi: 10.14714/CP78.1218**
Status: published

Paper 2: **Lukas, M.C. (2015): Neglected Treasures. Linking Historical Cartography with Environmental Changes in Java, Indonesia. Cartographica, 50(3).**
Status: Accepted for publication, forthcoming in Issue 50(3), 2015

Paper 3: **Lukas, M.C. Widening the Scope: Exploring the Drivers of Coastal Sedimentation in Java, Indonesia.**
Status: under review (Regional Environmental Change)

Paper 4: **Lukas, M.C. (2014): Eroding Battlefields: Land Degradation in Java Reconsidered. Geoforum, 56: 87-100. doi: 10.1016/j.geoforum.2014.06.010**
Status: published

Outreach: The article "received more views than 10 out of 10 similar publications, (of the same age and type) in the same journal" (Elsevier Research Dashboard). By 31.07.2015, it was viewed 1,349 times via the journal homepage.

Paper 5: **Lukas, M.C. Tenure contestation: An Important Cause of Land Cover Change.**
Status: under review (Annals of the American Association of Geographers)

Paper 6: **Lukas, M.C. Watershed conservation in Java, Indonesia: Trapped in a tenure dichotomy.**
Status: Manuscript prepared for submission

Paper 7: **Lukas, M.C. and M. Flitner. Scalar fixes of Environmental Management in Java, Indonesia.**
Status: under review (Environment and Planning A)

Contribution to co-authored manuscript: M.C. Lukas conducted field research, produced the first draft of the paper and contributed to subsequent revisions of the paper.

Paper 8: **Lukas, M.C. (2013): Political Transformation and Watershed Governance in Java: Actors and Interests. In: Muradian, R. and Rival, L.M. (eds.): Governing the Provision of Ecosystem Services, 111-32. Dordrecht, New York: Springer.**
Status: published. Note: This book chapter represents a research output produced in an early stage of the research project.

List of abbreviations

BPDAS	Balai Pengelolaan Daerah Aliran Sungai (regional watershed management centres)
LUCC	Land use and land cover change
LUC(C)	Land use and land cover (change). This abbreviation refers to both land use and land cover patterns and changes
GIS	Geographical Information Systems
USAID	U.S. Agency for International Development
IHDP	International Human Dimensions Programme on Global Environmental Change
IGBP	International Geosphere-Biosphere Programme

I. Synopsis

1 Introduction

Watershed management is concerned with processes that are complex, variable and often only rudimentarily understood. The connections between various physical processes within river basins, like erosion or mass movements, riverine sediment transport, and coastal sedimentation, are difficult to assess individually in their entire complexity. These processes in turn are influenced by a wide range of natural and human factors that interact over various temporal and spatial scales; some of them at scales far broader than the river basin. To identify and quantify causal links between these various interwoven factors *or drivers* and particular processes remains a major challenge in most parts of the world. Furthermore, watershed management connects and is confronted with a broad range of actors and various sectors and is prone to conflict and politicisations. These conflicts and politicisations in turn shape political debates over watershed processes and influence knowledge production. Thereby, specific political framings can confine debates, political action and research to a few selected issues and drivers for decades, while preventing other issues and drivers from being debated, explored and addressed. This can undermine the effectiveness of watershed management efforts and lay the ground for unrealistic expectations thereof.

The Indonesian island of Java is a prime example illustrating these aspects. The island constitutes a global hotspot of riverine sediment transport to the oceans (Lvovich et al. 1991, Walling & Webb 1996). River sediment loads are naturally high due to the islands' mountainous relief, high-intensity monsoon rainfalls and tectonic activity. The interaction of this dynamic environment with profound anthropogenic impacts results in high erosion and sedimentation rates (cf. Lavigne & Gunnell 2006). Erosion in the uplands and the sedimentation of rivers, reservoirs, irrigation channels, and coastal waters as well as seasonal flooding, have long been debated as some of the major environmental issues in Java.

Concerns over the impacts of deforestation and upland degradation on dry season water flows and flood frequency in the lowlands were raised along with calls and measures for forest preservation, as early as the beginning of the 20th century (Coster 1936, 1938, de Haan 1936a, 1936b, Kerbert 1916, Oosterling 1927, Zwart 1928, 1932). From the 1960s onwards, river basin and watershed management have been issues of national political importance. Following the establishment of General Suharto's New Order regime in 1965, some of Java's major river basins, including the Solo, Brantas and Citanduy basins, were targeted by partly internationally funded river basin development projects. These projects were part of a worldwide surge in river basin development as a modernisation strategy (see Ekbladh 2002, Molle 2009). They focussed on expanding lowland agriculture and constructing irrigation schemes, flood protection structures and reservoirs. They also involved the delineation of watersheds and the establishment of river basin authorities (see e.g. PRC-ECI 1975, USAID 1981).

In the 1970/80s, political attention turned to the uplands. Since then, substantial funds have been invested in upland conservation in the frame of internationally funded projects and continuous national watershed management and regreening programmes, implemented mainly under the Ministry of Forestry. These projects and programmes have focussed on agricultural extension, field terracing and tree planting. Despite substantial funds invested, upland degradation, high river sediment loads and coastal sedimentation continue to be debated as major issues. The effects of the upland conservation programmes have been viewed as rather limited. This has been attributed, among other things, to shortcomings in programme design and implementation with overly standardised approaches, the promotion of only one type of terracing regardless of varying soil, landscape and social conditions, and site selection being based on how to best fit pre-designed terracing techniques rather than on an assessment of erosion potential (Purwanto 1999: Chapters 3, 4, 11, USAID 1984, 1985). It has also been noted that field terraces were often not adequately maintained (Purwanto 1999, Chapters 3-4), that land tenants hesitated to invest in soil conservation (Purwanto 1999, Chapters 3-4), and that the programmes generally failed to raise farmers' awareness of erosion issues (ADB 1996).

Most related research has focussed on upland farmers' private plots. Comparably few authors have looked beyond the effectiveness of the individual projects and programmes implemented and have explored other causes of high river sediment loads and coastal sedimentation. My review of literature and project documents, along with first exploratory interviews with representatives of governmental organisations and university staff in the early stages of my research, showed that concrete knowledge of the longer-term dynamics of riverine sediment transport, the various sediment sources and the related causal factors, was limited. Also, land use and land cover patterns and changes [LU(C)] and particularly their causes have not been the subject of much research. Despite this lack of concrete knowledge, the debates about the causes of upland degradation, high river sediment loads and coastal sedimentation have largely focussed with surprising certainty on population pressure and upland farmers' cultivation practices.

Population densities are in fact extremely high in Java. It is hence no surprise that the island has served as a prime example in debates over the environmentally and socially destructive nexus of rapid population growth, poverty and environmental degradation. Java experienced a long period of high population growth, with the number of people increasing from 5-10 million in the early 19th century to 60 million around 1960 and 145 million at present (BPS 2015b, Hugo et al. 1987, Peper 1970, Raffles 1817). In particular, the extraordinarily high rural population densities, which are among the highest in the world, provoked gloomy prophecies, such as Clifford Geertz's (1963) 'agricultural involution'. Although Geertz's prophecy of social and economic disaster was exposed as a superficial analysis (see e.g. White 1983) and obviously proved wrong, concerns over the adverse impacts of the growing population on the environment have proliferated, particularly from the 1970/80s onwards.

The expansion of rainfed agriculture on slopy land since the late 19th century, to which the growing rural population densities have contributed, has undeniably caused soil degradation and increased erosion rates in parts of the island. This has been the subject of much research (see e.g. Barbier 1990, Donner 1987, Magrath & Arens 1989, Nibbering & Graaff 1998, Palte 1989, Purwanto 1999, Repetto 1986, Rudiarto & Doppler 2013, van Dijk et al. 2004). However, in other parts of Java, and with regard to the sediment yields of entire river basins, solely blaming farmers' cultivation practices is not adequately substantiated by empirical evidence and seems to have distracted attention from exploring and addressing other causes of high erosion and sedimentation rates (see also Diemont et al. 1991, Schweithelm 1988, 1989). Some recent research has directed attention to other sediment sources, such as trails, roads and settlements (Purwanto 1999: Chapter 7, Rijsdijk 2005, Rijsdijk et al. 2007a, Rijsdijk et al. 2007b). However, political and scholarly debates in Java and watershed conservation efforts have largely remained focussed on upland farmers' private plots.

My research looks beyond the scale of upland farmers' private plots. It explores watershed characteristics and transformations with a particular focus on land use and land cover changes (LUCC) and their drivers in one of Java's major river basins: the catchment area of the Segara Anakan lagoon, including the catchment of the Citanduy River. This region is a long-standing priority area for watershed management efforts. The research broadens the view on the causes of high river sediment loads and coastal sedimentation and exposes struggles over forest and plantation land as an important cause of LUCC and land degradation. Moreover, it explores the links between struggles over forest management and control, watershed management and the related confinement of debates and political action to upland farmers' private plots.

The next chapter provides a brief overview of the research area and the major watershed management interventions in this region, as well as a review of the knowledge and debates on watershed dynamics and coastal sedimentation. The following chapters outline the aims of the research, sketch the conceptual approaches and methods used and briefly summarise some of the major results. The research results, their discussion and their links with the literature, and related conclusions are contained in the eight research papers that are presented in the following and main part of this thesis.

2 Background and state of the art

The first two sections of this chapter provide a brief overview of the study area, the Segara Anakan lagoon and its catchment, and of the major environmental management interventions in this region. The following section shows that watershed management and related debates have to a considerable extent relied on assumptions, while the knowledge of watershed processes is limited.

2.1 The research area

Segara Anakan ('Child of the Sea') is a shallow coastal lagoon on the south coast of Central Java (Figure 1). It is protected from the Indian Ocean by the island of Nusa Kambangan and forms the estuary of the Citanduy, Cibeureum and Cikonde Rivers. Two tidal channels, one to the west and one to the east of Nusa Kambangan, connect the lagoon with the ocean.

The lagoon's catchment area comprises approximately 450,000ha, about three quarters of which constitutes the catchment of the Citanduy River. This area is marked by volcanic mountains and flat river basins in its uppermost (north-western) part, sedimentary mountain ranges in its north-eastern, southern and central parts, and a large alluvial river basin surrounding the lagoon. As in most other areas of Java, the main types of land use/cover in the catchment area comprise irrigated rice field agriculture (*sawah*), rainfed agriculture (*tegal*), small holder (mixed) forests (*kebun campuran*), settlements with house gardens (*pekarangan*), plantations (*perkebunan*), and state forests (*hutan negara*). The region's tropical monsoon climate is marked by heavy, occasionally also continuous, rainfalls mainly between November and April and a dry season between May and October. Average annual rainfall is 3,000-3,500mm (Weatherbase 2014). Almost the entire area belongs to three districts in two provinces: Tasikmalaya and Ciamis in the province of West Java, and Cilacap in the province of Central Java.

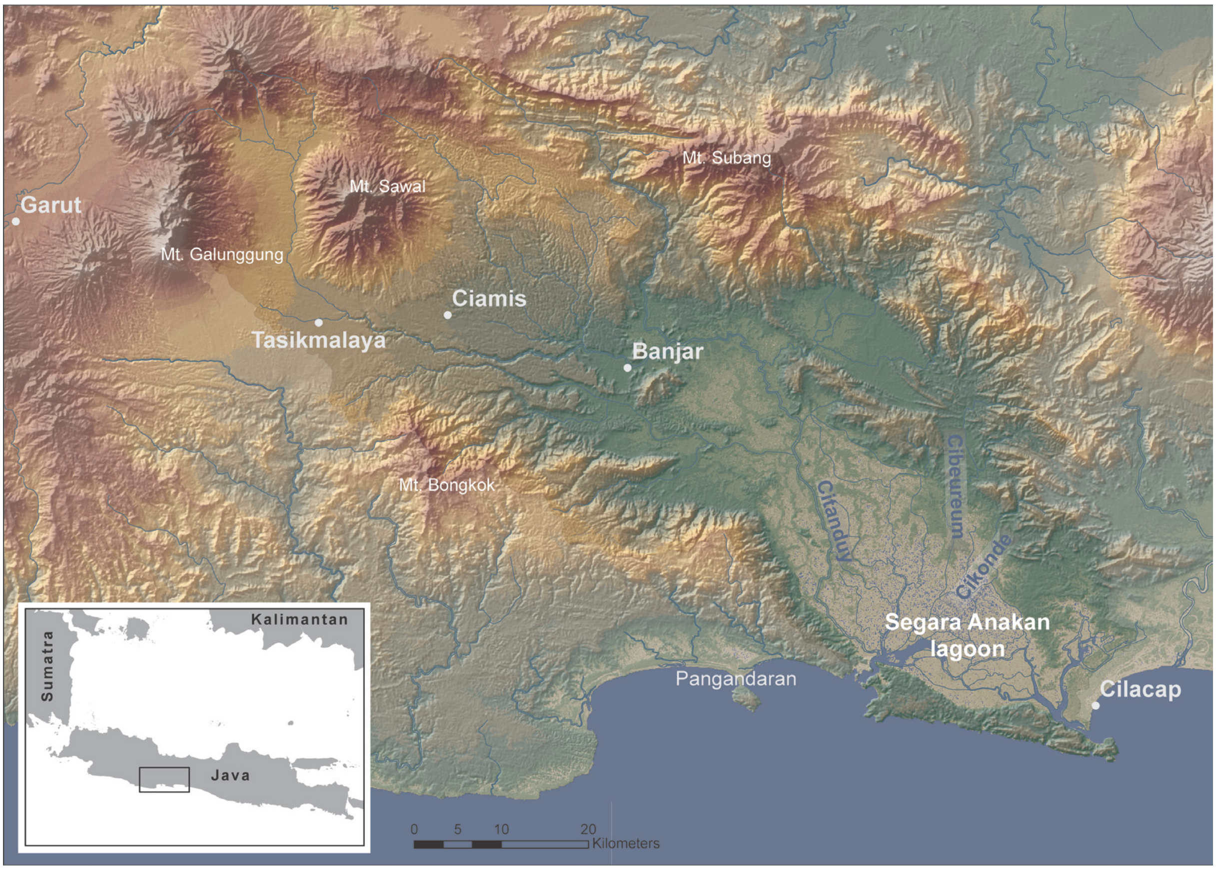

Figure 1: Location of the study area

2.2 Major environmental management interventions and transformations

The Segara Anakan lagoon and its catchment have long been one of Java's priority areas for river basin development, and watershed and coastal management initiatives. A series of spatially shifting management interventions has both transformed the area and aimed at managing or halting environmental transformations.

Between the 1930s and 1970s, larger-scale river-related interventions in the region focussed on agricultural reclamation and flood protection in the lower river basin north and northwest of the Segara Anakan lagoon. They gradually converted one of the largest swamp areas of Java (*Rawa Lakbok*) into a 'rice bowl'. River shortening and embankments and agricultural reclamation were pushed forward in the 1930s and continued during the Japanese occupation in the 1940s (see PRC-ECI 1975, Satō 1994, Satō 2006). In line with these developments, an ambitious plan for the enclosing, draining and agricultural reclamation of the Segara Anakan lagoon was put forward (van Blommestein 1948), yet never implemented. From 1969 onwards, agricultural reclamation of the lower river basin along with river channelling and embankments and the construction of irrigation schemes was advanced in the frame of the Citanduy I Project (PRC-ECI 1975, USAID 1981), one of the first large river basin development projects in Java, financed by the U.S. Agency for International Development (USAID).

Although agricultural reclamation of the lower river basin was continued in the 1970s and 1980s, political attention during this period gradually shifted to upland and lagoon conservation. Both upland degradation and sedimentation of the Segara Anakan lagoon were identified as threats to agriculture in the lower river basin. Upland degradation was believed to cause dry season water shortages, flooding, and sedimentation of irrigation channels, and sedimentation of the lagoon impaired drainage of the irrigation network (see PRC-ECI 1987). In addition, the Segara Anakan lagoon started to be seen as a valuable ecosystem and an important economic backbone of lagoon and coastal fishers (see Bird et al. 1982). Hence, preservation of the lagoon and soil conservation in the uplands have since been in the centre of environmental management related debates and action.

The Segara Anakan lagoon comprises the largest mangrove forest on Java's south coast. With its variety of habitats that link marine and freshwater areas, its biological diversity and its function as a spawning ground for shrimp, the lagoon has not only been regarded as ecologically valuable, but also provides a source of livelihood for many people in the adjoining villages of Kampung Laut as well as for offshore fishers (see e.g. Bird et al. 1982, Dudley 2000, Nordhaus et al. 2009, Olive 1997, White et al. 1989, Yuwono et al. 2007). The lagoon has undergone profound social-ecological transformations, with sedimentation being a main dimension and driver of change. Riverine sediment input has drastically reduced the size of the lagoon (see e.g. Hadisumarno 1964, Hadisumarno 1979, PRC-ECI 1987), altered its ecological characteristics, and contributed in combination with fishing pressure to declining fish stocks, which has undermined the viability of fishing, once the dominant livelihood strategy in Kampung Laut (Amin & Hariati 1991, Dudley 2000, Olive 1997, Purba 1991, Sudjastani 1982). While marine resources have diminished, agricultural utilisation of some of the new land created by sedimentation and of former mangrove areas has become a new source of livelihood for local residents and immigrants from other parts of Java (Ardli & Wolff 2008, 2009, Olive 1997, Reichel 2007).

The unique character of the lagoon and its profound social-ecological transformations, which I have only briefly sketched here, has attracted a great deal of research and political interest. Ecological characteristics and processes, local livelihoods and social transformations, as well as natural resource uses and environmental degradation, in the lagoon have repeatedly been the subject of research over the past decades (see e.g. Ardli & Wolff 2009, Bird et al. 1982, Djohan 2007, Dudley 2000, Hadisumarno 1964, Herbon 2011, Hinrichs et al. 2009, Holtermann et al. 2009, Jennerjahn et al. 2009, Jennerjahn & Yuwono 2009, Moll 2011, Nordhaus et al. 2009, Olive 1997, Prayitno 2001, Purba 1991, Reichel et al. 2009, Schwerdtner Máñez 2010, Sudjastani 1982, Surywati 2012, Trianto 2002, White et al. 1989, Yuwono et al. 2007). Most scholars and political actors have shared the view that, as was summarised by Purba (1991:143), the "Segara Anakan is a unique coastal ecosystem and an important coastal resource. However, its ecological functions are deteriorating due to poor upland management and high sedimentation rates."

The framing of sedimentation as a threat to the unique, valuable lagoon ecosystem and to local residents, as well as ongoing environmental degradation, have provided the rationale for a series of partly internationally funded management interventions in the lagoon and for particularly strong efforts towards soil conservation in its watershed.

One of the major management interventions in the lagoon was the Segara Anakan Conservation and Development Project (SACDP), implemented between 1996 and 2005. It included sediment dredging, the diversion of the Cimeneng/Cikonde River into the Cibeureum River to raise the portion of sediments that is flushed out into the ocean instead of being deposited within the lagoon, mangrove rehabilitation, aquaculture development, and upland conservation (ADB 1996, 2006, ECI 1994). As the planned diversion of the Citanduy River directly into the sea was stopped due to opposition from a neighbouring coastal community and dredging obviously had only temporary effects, the aim of halting lagoon sedimentation was not achieved. Also, aquaculture development largely failed to provide alternative livelihoods, as local residents barely benefitted and hence plundered the ponds (Reichel 2007, Reichel et al. 2009). After more than three decades of research and management interventions, the project and research reports focussed on the Segara Anakan lagoon fill entire book shelves. Yet, the most fundamental issues, like sedimentation, diminishing fisheries, and mangrove degradation persist.

To reduce sedimentation of the lagoon and of adjacent irrigation channels, to improve dry season water flows and to lower the flood risk in the newly reclaimed areas of the lower river basin, the lagoon's watershed has been targeted by particularly strong upland conservation efforts since the 1970s. In the frame of the USAID-funded 'Citanduy I' (1969-1981) and 'Citanduy II' (1981-1988) projects, the area became the site of implementation of some of the first pilot projects for upland conservation (Tim Koordinasi Wilayah 1989). The Citanduy projects, the Segara Anakan Conservation and Development Project, and other watershed conservation efforts complemented the Ministry of Forestry's soil conservation and regreening programmes carried out throughout Java. These programmes focussed on tree planting and the promotion of upland technology packages, comprising bench terracing, altered crop combinations and agricultural inputs. The standardised approaches of these programmes have repeatedly been the subject of critique (see Chapter 1). Also the unintended entanglement of the regular regreening programmes with the internationally funded projects was critically evaluated (USAID 1984, 1985). Although the programmes and projects considerably raised the proportion of agricultural land within the lagoon's catchment area being terraced, their effects on riverine sediment loads and coastal sedimentation are uncertain and regarded as rather limited (see ADB 1996, Huszar & Cochrane 1990, Schweithelm 1988, 1989).

2.3 Watershed dynamics and coastal sedimentation: Much debate but limited knowledge

Apart from the critique of the individual programmes, the causes for the obviously limited effects of the conservation efforts on downstream sediment loads have scarcely been debated more broadly. One of the few experts who has taken a different, wider perspective on the entire watershed looking beyond farmers' private agricultural plots was J. Schweithelm, the external watershed planning consultant of the Citanduy II Project. Upon project completion, he noted that "[t]he bench terraces and other soil conservation measures have in most cases reduced on-site erosion rates, but this reduction represents a very small part of sediment production from the entire basin" (Schweithelm 1988:5). His notion stands in stark contrast to the common and rarely questioned framing of upland farmers' private plots as the single most important sediment source. Has the continued focus of debates and interventions on upland farmers' private plots distracted attention from exploring other drivers of high river sediment loads and lagoon sedimentation throughout the watershed, and has this contributed to the limited effectiveness of the watershed conservation efforts?

Only paying attention to a single component of the sediment delivery system, such as erosion on upland farmers' private plots, renders strategies aiming at reduced river sediment loads ineffective (Walling & Collins 2008). Designing effective sediment mitigation strategies and evaluating their impacts require an understanding of the major sediment sources, sinks, and fluxes within a watershed (Meybeck & Vorosmarty 2005, Walling & Collins 2008). However, the roles of various sediment sources, the interlinked physical processes of erosion and mass movements, sediment accumulation and transport throughout the catchment, and coastal sedimentation, let alone the numerous multi-scalar and interwoven natural and anthropogenic factors influencing these processes are not adequately understood in most parts of the world (Meybeck & Vorosmarty 2005, Milliman & Syvitski 1992, Walling & Collins 2008). The anthropogenic influences on physical processes in turn are linked to complex societal structures and processes, which are also often not well understood [cf. Blaikie's (1985) 'chains of explanation' or Geist and Lambin's (2001) proximate and underlying causes of LUCC]. Furthermore, causal relationships are often site-specific. For example, the effects of vegetation cover on erosion, stream flows and their seasonality varies widely between localities, and the knowledge of these relationships is controversial and the subject of revision and refinement (see Bruijnzeel 2004, Calder 2005, Calder & Aylward 2006).

This complexity and variability and the limited knowledge of watershed processes and their various interwoven drivers render debates on watershed processes highly prone to politicisation. Vice versa, political interests not only shape debates on watershed processes but also the related ways and confinements of knowledge production and the consideration of existing knowledge. Hence, watershed management and related debates are often marked by assumptions or myths that are not adequately supported by empirical evidence (cf. Forsyth 1996, 1998, Forsyth & Walker 2008, Ives & Messerli 1989), and sometimes commonly held assumptions contrast with the few existing pieces of knowledge and evidence (Bruijnzeel 2004, Calder 2005, Calder & Aylward 2006).

Although the Segara Anakan lagoon with its catchment area has been a priority area for coastal and watershed management in Java for decades, the knowledge of the temporal dynamics and particularly of the drivers of lagoon sedimentation is rather limited. Reducing river sediment loads and lagoon sedimentation, flood risk and seasonal waters shortages have been the main rationales for watershed conservation. Yet, no watershed-wide research on the various drivers of lagoon sedimentation and on the links between watershed characteristics and flood risk or seasonal water shortages has been conducted. Whereas the lagoon has become one of the hotspots of environment-related research in Java, its catchment area has scarcely been the subject of study. The upland conservation efforts that were considered crucial for the preservation of the lagoon were therefore apparently not based on adequate knowledge of the various drivers of lagoon sedimentation, but on assumptions.

After years of support for upland conservation with the aim of reducing lagoon sedimentation and flood risk, an evaluation of the Citanduy II project revealed that "Little has been learned about the sources of erosion. […] [T]here is much opinion but little fact" (USAID 1985:9). J. Schweithelm, the project's watershed planning consultant, clearly critiqued the reliance of debates and interventions on assumptions and the lack of adequate research. He also presumed that upland farmers' private plots, which have always been seen as the single-most important cause of high river sediment loads and lagoon sedimentation, are actually not the major sediment source. He stated that:

> "Land use in the uplands was seen to be very bad, and closely linked to overpopulation, poor farming practices, and deforestation. Ecologically unsound land use was assumed to cause significant increases in downstream sedimentation, but dominant erosion processes or sediment source areas were not identified. […] little is actually known about soil erosion in the complex conditions in upland Java. […] [A] thorough sediment study of the Citanduy Basin would reveal that privately-owned upland farms [the main target of the project] contribute a small part of the sediment load of the Citanduy River" (Schweithelm 1988:5-6).

2.3.1 Narratives about the drivers of lagoon sedimentation

The situation described by J. Schweithelm in the 1980s has hardly changed since then. An analysis of sediment transport dynamics in the lower Citanduy River conducted since then suggests that within-channel storage of sediments is low, i.e. that sediments are transported into the lagoon relatively quickly (Stevens 1994). However, the various sediment sources throughout the entire catchment and their underlying causes have barely been the subject of study. My interviews showed that in the absence of concrete knowledge, representatives of governmental organisations and university staff commonly link high river sediment loads and lagoon sedimentation to ‘population pressure’ and ‘poor’, ‘destructive’, or ‘unsustainable’ farming practices in the uplands. The following quote of representatives of the Ministry of Forestry and the Solo river basin management authority in the 1980s largely represents the commonly held view on the causes of high river sediment loads in Java until today:

> “Problems of sedimentation in Indonesia are basically caused by population problems (i.e. high population density, high population growth and unequal distribution) and improper use of the land without appropriate soil conservation measures” (Sutadipradja & Hardjowitjitro 1984:146, also see Hardjowitjitro 1981.

This discourse is widely reflected in the literature related to the Segara Anakan lagoon. Lagoon sedimentation has been attributed, for example, to:

- “overcutting and destructive slash and burn practices” (PRC-ECI 1987:1-8).
- “poor upland management” (Purba 1991:143).
- “deforestation and poor agricultural management practices in the upland areas of the Citanduy river basin” (Olive 1997:103).
- “unsustainable land use practices in the hinterland” (Yuwono et al. 2007:62).
- “deforestation and poor agricultural management practices in the upland areas of the Citanduy river basin” (Ardli & Wolff 2009:241).
- “unsustainable land use practices outside the lagoon” (Hinrichs et al. 2009:275).
- “poor upland agricultural practices” (Jennerjahn et al. 2009:260).
- “shifting cultivation and the associated clear-cutting in the lagoon’s hinterland (Reichel et al. 2009:337).
- “the increasing of population [and related] cultivation activities in upland area” (Nandi 2015:52-53).

These notions are not only vague and merely reflect political discourses, but they are also partly erroneous. For example, shifting cultivation ceased to exist in this region many decades ago. Only a few authors have recognised that the knowledge of watershed characteristics was in fact limited and have thus put forward their notion about the causes of lagoon sedimentation more cautiously:

> “Although no studies have documented changes in land use in Citanduy Basin, increasing soil erosion due to poorly planned land use is believed to be causing increased sediment delivery to river basins.” (ASEAN/US CRMP 1992:39)

Other causes of lagoon sedimentation have been mentioned less frequently and with less emphasis in the literature. They include eruptions of Mount Galunggung in the lagoon’s catchment area (e.g. Junghuhn 1854, Nandi 2015, PRC-ECI 1987), and agricultural reclamation along with the river straightening and flood protection measures implemented in the frame of the river basin development projects (ADB 2006, PRC-ECI 1987, Purba 1991, Tim Koordinasi Wilayah 1989). Very few authors have referred to a larger range of sediment sources. They include Schweithelm (1988, 1989) and ECI (1975). In addition to upland agriculture, the latter report also mentioned forestry management practices (particularly the clear-cutting of teak) as well as settlements, and trails and roads as causes of increased river sediment loads.

The next two sections summarise the knowledge of the temporal dynamics of sedimentation in the Segara Anakan lagoon, of the causes of high river sediment loads, and of watershed dynamics in general. The latter incorporates findings from other parts of Java.

2.3.2 Knowledge of the temporal dynamics of lagoon sedimentation

Information about the longer-term dynamics of riverine sediment transport and coastal sedimentation could help in exploring the roles of the various determining factors. However, historical time series of river sediment loads for Java's rivers either do not exist or only cover the past few decades and are unreliable (see PRC-ECI 1987, Seckler 1987). This situation applies to most rivers worldwide (Walling & Fang 2003, Walling & Webb 1996). In this context, the Segara Anakan lagoon represents a valuable sediment archive whose analysis can help to reconstruct the longer-term dynamics of sedimentation and of watershed transformations. There are two obvious approaches to analysing the historical dynamics of lagoon sedimentation: (a) analysing shoreline changes using historical maps and satellite images, and (b) analysing the depth, age and composition of sediments (i.e. analysing sediment cores). Both approaches have already been used.

Cartographic and quantitative documentation of lagoon shoreline changes goes back to Schaafsma (1926). Comparing topographic maps from 1898/1901 and 1924, he detected shoreline aggradation rates of 200-300m over 25 years in the northern and eastern parts of the lagoon and documented the emergence of a first larger island in the lagoon's western part. Hadisumarno (1964) is the second oldest source quantitatively documenting shoreline aggradation. He delineated shoreline changes between 1900 and 1964, based on topographic maps, aerial photographs and field observations. He later expanded the temporal scale of his analysis using a satellite image from 1978 (Hadisumarno 1979). Similar shoreline reconstructions were later included in a number of project documents (ASEAN/US CRMP 1992, ECI 1994, PRC-ECI 1987, Soewondho 1984).

However, all these analyses are confined to the 20th century, lack adequate documentation of data sources, methods, and map accuracy, and are partly erroneous. For example, Hadisumarno (1964; 1979) neglected the time gaps between the dates of the cartographic surveys and the publication dates of the maps that he used. As a result, he erroneously detected a dramatic acceleration in the aggradation of the lagoon's eastern shoreline from 5m per year between 1900 and 1940 to 54m between 1940 and 1946. He interpreted this as a result of "deforestation within the river catchment area of Citandui during the Japanese occupation," (Hadisumarno 1979:49). However, in fact the dramatic increase in his aggradation rates largely resulted from his neglecting the fact that the maps dated from the 1940s were based on surveys carried out in the 1920s. The same error appears in the shoreline reconstructions subsequently included in various project plans and reports (ASEAN/US CRMP 1992, ECI 1994, PRC-ECI 1987, Soewondho 1984). A well-documented shoreline change analysis is contained in Ardli and Wolff's (2008, 2009) study of LUCC in the Segara Anakan lagoon, but it only covers the period from the 1970s onwards. The shoreline aggradation data contained in Tejakusuma (2006) covers the entire twentieth century, but no information regarding the data sources and methods is presented. As with the works discussed above, the data is obviously biased by the fallacy of mistaking the maps' publication dates for the dates of mapping.

While these shoreline change analyses covered the 20th century only, the sediment core analyses conducted by Dewi et al. (1979) and Kastanja (2001) aimed at analysing longer-term dynamics. Their explanatory value with regard to sedimentation during the past few decades and centuries is, however, rather limited. Dewi et al. (1979:7) concluded that "recent sedimentation is considerably higher than average sedimentation during the past 30,000 years." Kastanja's (2001) findings indicate an increased influx of material of volcanic origin in the more recent past.

To sum up, the historical dynamics of lagoon sedimentation have been documented based on historical maps and satellite images. However, these analyses cover the 20th century only, are partly erroneous and tend to lack adequate documentation of methods, data sources and map accuracy. The sediment core analyses carried out to date have provided only limited additional insight into the historical dynamics of lagoon sedimentation.

2.3.3 Knowledge of the drivers of high river sediment loads and lagoon sedimentation

Knowledge of the causes of high river sediment loads and lagoon sedimentation and of watershed characteristics and transformations is clearly limited. As noted above, no watershed-wide research on the various sediment sources and their underlying causes has been undertaken in the Segara Anakan region. This situation also applies to the whole of Java, with the exception of a few small subcatchments, for which a number of sediment sources were identified: the catchment of the upper Konto River in East Java (Nibbering & Graaff 1998, Rijsdijk 2005, Rijsdijk et al. 2007a, Rijsdijk et al. 2007b) and the catchment of the Cikumutuk River in West Java (Purwanto 1999, van Dijk 2002). In the case of the upper Konto River, the relative contributions of the various sediment sources to total river sediment loads were estimated. This research showed that apart from surface erosion on rainfed agricultural land, also roads, trails and settlement areas as well as gullying, riparian mass wasting and bank erosion contributed substantially to total river sediment loads (Rijsdijk 2005, Rijsdijk et al. 2007a, Rijsdijk et al. 2007b). These sediment sources have otherwise been largely neglected in debates and research.

In line with the framing of upland farmers' private agricultural plots as the single-most important sediment source in watershed management-related debates, corresponding research in Java has mainly focussed on surface erosion on farmers' rainfed agricultural land and on cultivation practices (e.g. Barbier 1990, Donner 1987, Palte 1989, Repetto 1986, van Dijk et al. 2004). The underlying social and political factors or 'chains of explanation' (Blaikie 1985), including questions of resource access and control, have received comparably little attention in soil, watershed and LUCC studies (exceptions include Hardjono 1987, Purwanto 1999). Also other sediment sources and areas, including plantations and state forest territories, have been largely excluded from political debates, though their roles have been acknowledged or analysed by a few scholars (e.g. Carson 1989, Kusumandari & Mitchell 1997, Savitri 2006, Widjajani et al. 2011).

LUC(C) is one of the major factors determining erosion and sedimentation dynamics. Compared to the scholarship focussing on soil erosion on agricultural plots, the amount of research on LUCC and its drivers in Java has clearly been more limited. A major focus of the LUCC studies conducted since the 1990s was the expansion of urban and industrial land uses and corresponding declines in agricultural land (e.g. Dimyati et al. 1996, Firman 1997, 2000, Yunus & Harini 2005). The research by Lavigne and Gunnell (2006), which focussed on the upper slopes of some of Java's volcanoes, constitutes one of the few studies in non-urban environments of Java that closely linked an analysis of the dynamics of LUCC with related social dynamics and driving forces. Most other studies have been desk-based and confined to remote sensing, with no or only limited ground truthing and without any empirical analysis of the drivers of LUCC, at best using a few selected macro-level indicators to support existing narratives (e.g. Astisiasari 2008, Kurniawan & Krol 2014, Parwali et al. 2006, Prasetyo 2004, Yekti et al. 2013). This also applies to the few LUCC studies conducted in the catchment area of the Segara Anakan lagoon (Astisiasari 2008, Parwali et al. 2006, Prasetyo 2004, Yekti et al. 2013). Furthermore, the results contained in these studies are partly erroneous. For example, Parwali et al. (2006), who analysed LUCC in the eastern part of the lagoon's catchment area, detected a 16-fold increase in rural settlement areas and an 11-fold increase in the plantation area between 1978 and 2003, both of which are unrealistic. The same applies to the results by Yekti et al. (2013), who detected a 17-fold increase in the area under irrigated agriculture in the lagoon's catchment between 1991 and 2003. Some of the land cover patterns detected in the frame of the desk-based analyses by Prasetyo (2004) and Astisiasari (2008) also proved erroneous during my field research.

Such desk-based LUCC analyses are not only prone to yielding erroneous land cover data. They also risk substantiating existing, often simplistic narratives about the drivers of LUCC without contributing any new insight into factors that were previously neglected. For example, Verburg et al. (1999) relied for their desk-based simulation of LUCC for the whole of Java on a set of selected macro-level indicators, including numerous variables related to population densities and physical geographical characteristics but excluding tenure. They also a priori excluded state forest territories from their analysis by simply equating forest cover with the area officially designated state forest, assuming that these forests are protected and hence no forest cover change occurs. In this way, the study a priori excluded large areas (state forests) and major causes of LUCC (e.g. tenure form, tenure contestations, state forest management practices) from the analysis.

Since state forest territories constitute about one quarter of the land area of Java (BPS 2015a), they must be part of any broader-scale analysis of LUCC and watershed dynamics and of related political debates. State forests and their professional management by the state forest corporation (P.T. Perum Perhutani) have been commonly framed as the epitome of watershed conservation in Java (cf. Galudra & Sirait 2006) – a notion that has hardly been questioned. The socio-political history and repressive nature of state forest management from the colonial period until the end of General Suharto's New Order Regime (1965-1997) has been critically analysed, most notably by Nancy Peluso (Peluso 1992, Peluso 1993). Her study of the historical political economy of forest management, entitled "Rich forests, poor people […]" (Peluso 1992) was published around the same time as an International Symposium in Yogakarta, Java hailed "One century of sustainable forest management with special reference to teak in Java" (Simon et al. 1992).

Only a few authors have questioned the common notion of professional state forest management being the epitome of watershed protection. One of them is Carson (1989), who estimated that Java's teak plantations managed by the state forest corporation were marked by surface erosion rates that were similarly high to those on rainfed agricultural land and considerably higher than those in some of the forest areas that were considered 'degraded'. Nibbering (1988) documented degradation in state forests resulting from illegal resource extractions by the local population. Also Magrath and Arens (1989) incorporated degraded forest areas in their estimate of the costs of soil erosion in Java. However, given the lack of alternative sources of information, the authors had to base their model on official land use/cover statistics, which were obviously erroneous. The data of critical, i.e. erosion-prone, lands from the Ministry of Forestry's Directorate-General of Reforestation and Rehabilitation provided in Whitten et al. (1996) illustrates the lack, unreliability or biased nature of official statistics related to land use and erosion: The extent of critical land within the state forest territories of Central and East Java was given as nil, which was of course far from reality (cf. Nibbering 1988).

The possibilities, commitment, methods and objectivity of assessing critical, i.e. erosion-prone, lands have undoubtedly improved over the past years, particularly with the establishment of regional watershed management centres (BPDAS, *Balai Pengelolaan Daerah Aliran Sungai*) (cf. Anwar 2005). Yet, the causes of LUC(C) and of critical land in the catchment area of the Segara Anakan lagoon and in most parts of Java remain underexplored.

2.4 Summary

To sum up, preservation of the Segara Anakan lagoon and halting the sedimentation thereof has been a major imperative of environment-related management interventions in the region for decades. Whereas the lagoon has become a hotspot of research, its catchment area, including the drivers of lagoon sedimentation, has been the subject of very little study. Instead, the debates on the drivers of sedimentation have relied on assumptions, which have been discursively solidified as seemingly unquestionable facts. These assumptions have mainly focussed on cultivation practices on upland farmers' private plots as the single-most important cause of high river sediment loads and lagoon sedimentation. Upland agriculture has also been seen as an important cause of low dry season water flows and of flooding in the lowlands. In line with these narratives, watershed management interventions have, similarly to the rest of Java, for decades mainly focussed on terracing and tree planting programmes on upland farmers' private land. Though these programmes have had positive effects, the discursive establishment of upland farmers' private plots as the single-most important sediment source has obviously distracted attention from other drivers of high river sediment loads and lagoon sedimentation. This situation bears similarity to the 'Himalayan Degradation' hypothesis, where upland farmers are one-sidedly blamed for sedimentation, flooding and seasonal water shortages downstream (Forsyth 1996, Ives & Messerli 1989).

3 Rationale, aims and scope of the research

Substantial funds and effort have been invested into watershed and coastal zone management in Java over the past decades. Yet, most issues that these management interventions have aimed to address persist. Focussing on the example of high river sediment loads and the sedimentation of the Segara Anakan lagoon, Chapters 1 and 2 have shown that the knowledge about watershed processes, their drivers and related societal dynamics is very limited and that corresponding debates and management interventions have been largely based on assumptions. These assumptions seem to be only partial explanations of the issues that have been targeted by the interventions. Their discursive solidification as seemingly unquestionable facts has obviously distracted attention from exploring a broader range of watershed processes and their drivers, beyond the scale of upland farmers' private plots. Such an open-ended exploration of watershed processes and their drivers is an important foundation for effective watershed and coastal zone management. In addition, it is crucial to analyse past and current modes of watershed governance and to thereby pay attention to why debates and research are confined to particular drivers, while neglecting others.

Accordingly, the research presented in this thesis broadly aims at contributing to an improved understanding of the dynamics and drivers of lagoon sedimentation and of watershed processes and of the linkages between discursive framings of these processes, related management interventions and socio-political structures and dynamics. It thereby questions long-standing narratives about the drivers of high river sediment loads and coastal sedimentation and contributes new insight into the dynamics and causes of these processes. In this way, the research both deconstructs simplistic assumptions about watershed and coastal dynamics and reconstructs these dynamics.

Chapters 1 and 2 have shown that:

- There is a general lack of research on watershed dynamics and their linkages with coastal processes in Java.
- The knowledge of the historical dynamics of riverine sediment transport and coastal sedimentation (which could support exploring its drivers) is limited for the whole of Java, since historical records are largely missing or unreliable, or since existing documentations are erroneous and cover the 20th century only.
- The whole range of drivers of high river sediment loads throughout entire watersheds and their causes have scarcely been explored in Java, with the exception of a few small sub-catchments.
- The dynamics, and in particular the drivers of LUCC, one important determinant of potential erosion and riverine sediment loads, are underexplored in Java, due to the general lack of research and the desk-based nature of most studies, with a focus on macro-level indicators and remote sensing without (sufficient) ground truthing and without inquiry into the causes of the LUCC detected.
- In the absence of adequate knowledge, debates about the causes of upland degradation and coastal sedimentation have been dominated by assumptions. These assumptions have focussed on cultivation practices on contemporary upland farmers' private plots, i.e. on one of numerous potential sediment sources in a contemporary snapshot, while neglecting other sites and sediment sources, the related societal drivers, and the historical dimension. This has a priori limited the range of governance and management options considered and hence limited the potential effectiveness of watershed management efforts.

Therefore, and in the context of the specific social-ecological dynamics and the history of management interventions in the Segara Anakan lagoon region, this research specifically aimed at:

- Exploring the major watershed and coastal management interventions in the Segara Anakan lagoon and its catchment area, paying attention to the roles, interests and power relations of various actors, the underlying socio-political contexts and the related framings of environmental matters in the region.
- Reconstructing the historical dynamics of shoreline aggradation in the Segara Anakan lagoon, based on historical cartographic material and satellite images.
- Broadening the debate on the causes of high river sediment loads and lagoon sedimentation by exploring historical and contemporary watershed characteristics and modifications throughout the entire catchment area and their drivers.
- Analysing LUCC and its drivers in the catchment area of the Segara Anakan lagoon, combining remote sensing, land use/cover mapping throughout the catchment area, and a series of social-scientific case studies.

To achieve these aims, the research combined a variety of approaches and methods. It combined political ecology, land change science, and historical cartography, and integrated findings from natural scientific research. It applied and linked a wide range of different research methods, including qualitative and quantitative analyses of historical maps, remote sensing, land use/cover mapping, transect walks, semi-structured interviews with a large range of actors, and focus groups.

The embedding of the research within the research programme SPICE II (see Preface) predetermined its regional focus to the Segara Anakan lagoon and its catchment area. Apart from that, the scope of the research was not strictly determined beforehand. In analysing LUCC, in exploring various other watershed characteristics and modifications, and in reconstructing the temporal dynamics of lagoon shoreline aggradation, the research aimed at expanding its analytical time scale as far back as the availability and accuracy of historical cartographic material, satellite images and historical records and secondary literature allowed. Depending on the material used, the different components of the research could cover different time spans: e.g. the period from around 1700 to the 1850s in case of the qualitative analysis of the earliest historical maps, the period from the 1850s to the 1920s in case of the quantitative analysis of historical maps, the period from the 1960s to 2015 in the case of the analysis of satellite images, and the period from the early to mid-19th century onwards for the exploration of major watershed transformations (see Chapter 5 on research methods).

The analysis of the drivers of LUCC took the form of case studies in different parts of the lagoon's catchment area. It started from the physical LUCC areas identified in satellite images and then open-endedly, i.e. without any pre-determined scalar confinement, explored the various drivers of these changes, as they appeared to be relevant during field research. The drivers of LUCC uncovered in this way are diverse and situated on various scales. Similarly, in exploring management interventions implemented in the area, the related socio-political contexts and framings, and the roles and interests of various actors, the research aimed at openly covering the scales that appeared to be relevant, from upland farmers' plots to national political aims and global discourses.

In addition to contributing to an improved understanding of environmental dynamics and their drivers in the Segara Anakan region and of related political framings and management issues, i.e. research results that are particularly relevant to the Segara Anakan region, Java and Indonesia, the research also contributes conceptually, methodologically and empirically to broader (global) debates. These contributions relate, for example, to:

- The potential, approaches, methods and limits of using historical cartographic material with varying levels of accuracy for analysing environmental changes.
- The gradual development, replication and ignorance of cartographic knowledge.
- The linking of political ecology and land change science.
- The role of tenure contestations as an important, though neglected driver of LUCC.
- The links between struggles over forest resources and watershed management.
- The conceptual debate on scale in the context of environmental governance, particularly the consolidation and temporal persistence of particular 'scalar fixes' of environmental politics.

4 Conceptual approaches

A determining feature of the research presented in this thesis is its use and combination of a number of approaches and methods that are rooted in different (sub-) disciplines. While engaging with such a variety of approaches and methods and related strains of literature proved highly challenging, it was this combination of approaches and methods that generated some of the most insightful research results. It also created numerous possibilities for cross-fertilisation and the cross-validation of results during the research process. This chapter sketches the major research approaches used (political ecology, land change science, and historical cartography) and how they were combined. Rather than providing a general, comprehensive overview of each of these approaches, the following sections focus on the aspects that are most relevant in the context of the research presented in this thesis.

4.1 Political ecology

Political ecology emerged in the 1970/80s as a reaction to an 'apolitical' ecology that viewed environmental degradation mainly as a result of the continuously rising resource use pressure posed by a growing human population without unpacking the underlying societal structures and dynamics and particularly the political-economic forces that shaped human-nature relations (see Blaikie & Brookfield 1987c, Blaikie 1985, Bridge et al. 2015a, Watts 2012). Research on environmental issues, such as land degradation, had been dominated by the natural sciences, while the societal drivers and the political framings and responses to these issues, clearly subjects of social-scientific inquiry, had long been neglected by the social sciences (Blaikie & Brookfield 1987a). With his 'Political economy of soil erosion' Blaikie (1985) laid a major foundation for the development of political ecology as a research field. Through 'chains of explanation' he linked environmental degradation with the decisions and practices of natural resource users and the wider economic and political forces within society. He thereby emphasised the role of political-economic circumstances in explaining why farmers engaged in land use practices that caused environmental degradation. In a subsequent edited book, Blaikie and Brookfield (1987a:17) defined political ecology as "the concerns of ecology and a broadly defined political economy".

Political ecology has since rapidly grown in popularity. While the approach is not (yet) widely diffused within German-speaking geography (contributions include Coy & Krings 1999, Coy & Neuburger 2008, Flitner 1999, 2001, Flitner 2007, Flitner 2008, Graefe 2006, Krings 2008, Krings & Müller 2001, Müller 1999, Neuburger 2000, Nüsser 2008), it has emerged as a major field of environment-related research at Anglo-American universities. With its growth in popularity, the field has diversified into a broad range of approaches and research topics. Reflecting on this diversification, Watts (2012:547) noted that "[p]olitical ecology has in a sense almost dissolved itself over the past two decades as scholars have sought to extend its reach". This section aims neither at exploring the emergence of political ecology nor at providing an overview which remotely does justice to the large contemporary diversity of the field. Such overviews have been provided elsewhere (e.g. Bryant 1998, Bryant & Bailey 1997, Krings 2008, Krings & Müller 2001, Neumann 2014, Watts 2000, Watts 2012) and are the subject of two forthcoming comprehensive handbooks: 'The Routledge Handbook of Political Ecology' (Bridge et al. 2015b) and the 'International Handbook of Political Ecology' (Bryant 2015). This section rather confines itself to sketching some major features, research themes and debates from the field of political ecology that are particularly relevant in the context of the research presented in this thesis.

4.1.1 Features and research themes

With varying degrees of emphasis, political ecology scholarship links environmental conditions and dynamics and discursive framings thereof with natural resource uses, patterns of and conflicts over resource assess and control, actor-specific interests and power relations, political-economic structures and modes of political action, and questions of social justice. Much of the political ecology scholarship has focussed on the political, and clearly less on the ecological dimensions of environmental issues. This is reflected in various definitions that describe political ecology as an approach which “has sought primarily to understand the political dynamics surrounding material and discursive struggles over the environment” Bryant (1998:89), which explores “the political dimensions of human-environment interaction” (Bryant & Bailey 1997:17), or which is applied to “a very broad set of concerns that revolve around societies’ relationships with the non-human environment” (Bridge et al. 2015a:3). Also Watts (2000:257) and Paulson et al. (2004:17) described political ecology as an approach that seeks to understand complex human-environment relations, but that does so mainly by focussing on the specific societal dimensions of environmental issues and dynamics, particularly the patterns of resource access and control. The tension that arises from political ecology’s ambition of linking societal and ecological dynamics and the actual focus of much scholarship on selected societal dimensions of environmental issues is explored in Section 4.1.6.

Some of the main features shared by most political ecology scholarship are actor-oriented approaches with a close examination of the roles, interests and strategies of and the power relations between actors; a focus on questions of resource access and control; the acknowledgement of social constructions of the environment; and multi-scalar analyses (Krings 2008). Political ecology is a suitable approach to analyse conflicts over environmental issues or development endeavours and the discursive and material strategies employed in such conflicts (e.g. Coy & Neuburger 2008, Towers 2000) or to explore the socially uneven distribution of the negative effects of environmental issues, such as water and air pollution or traffic noise and related conflicts (e.g. Flitner 2007, Flitner 2008, Véron 2006). Instead of engaging in the search for harmonising conflict resolution strategies, political ecology has a pronounced focus on conflict-oriented research aiming to reveal structural and discursive power relations, conflicting interests, and injustices (Krings & Müller 2001).

A substantial portion of political ecology scholarship has focussed on questioning partly long-standing narratives about the nature and causes of environmental degradation. Many studies have exposed narratives which focussed on demographic factors and peasants’ agricultural practices as simplistic explanations and provided new insight into the causes of environmental degradation (e.g. Ives & Messerli 1989, Kull 2004, Leach & Mearns 1996). In this context, post-structuralist discourse-analytical approaches, which consider the environment as socially constructed, have played a central role since the 1990s. These approaches focus on analysing political framings of environmental issues or conflicts and on linking these framings with the political structures and interests in which they are embedded and with ways of knowledge production or with justifications of particular patterns of resources access and control (see e.g. Escobar 1996, Forsyth 2003, Fortmann 1995, Peet & Watts 1996). Applying discourse-analytical approaches and analysing material social-ecological dynamics with varying degrees of emphasis and depth, political ecologists have questioned established explanations of environmental issues and their drivers and critiqued corresponding environmental policies and interventions as inappropriate, ineffective or socially detrimental in many parts of the world (Batterbury et al. 1997, Brookfield 1999, Fairhead & Leach 1995, Forsyth 1996, Forsyth & Walker 2008, Ives & Messerli 1989, Klein 2002, Leach & Mearns 1996, Preston et al. 1997).

The patterns of access to and control over natural resources and related conflicts are one of the central concerns of political ecology. They play a role across many research themes and have been the core topic of numerous studies (e.g. Bryant 1997, Gezon 2006, Guha 2000, Jewitt 1995, Peluso 1992, Peluso 1993, Peluso & Watts 2001). One of them, Peluso’s (1992) in-depth account of the historical trajectories of forest access and control in Java, provided valuable background information that helped me to situate some of the LUCC that I explored in the Segara Anakan lagoon’s catchment area in the longer-term historical context.

4.1.2 'Inscriptions' of struggles over resources in the environment

Land and other kinds of environmental degradation, as well as struggles over resource access and control, are core topics in political ecology. Yet, the number of studies that have established direct causal links between struggles over resources and environmental degradation is comparably limited. To some extent, this is certainly related to the fact that many studies that focus mainly on analysing discursive framings of environmental issues and patterns of resource access and control do not necessarily analyse environmental conditions and dynamics with a similar level of depth. Furthermore, natural resource use practices and their effects on the environment are in most cases related to particular patterns of resource access and control, but are not necessarily the direct result or part of ongoing struggles over resources.

In a number of the case studies that I conducted in the catchment area of the Segara Anakan lagoon, I found LUCC and soil erosion to be a direct outcome of the strategies or tactics[1] employed by opposing actors in ongoing struggles over resources (see Research Papers 4-6). Such direct links between strategic acts of resource contestation and environmental conditions are also contained in the work of Peluso (1992), who described the effects of struggles over forest land and trees on the condition of state forests in Java from colonial times until the 1980s, and in the work of Kull (2004), who found that landscape burning in Madagascar was to some extent related to struggles over resource access and character. Although fire was mainly used as a land management tool, Kull (2004) noted that some of the forest fires were the result of conflicts over resources, in that forest stands were sometimes destroyed by poorer farmers who "may burn out of frustration" (p. 69) about richer farmers' tree plantings that establish legal claims over land.

In linking the physical LUCC that I detected in satellite images with the causes of these changes that I explored in the frame of social-scientific case studies and in communicating the respective results, I found Bryant and Bailey's notion of 'inscriptions' useful. Shedding light on how power relations are 'inscribed' in the environment, Bryant and Bailey noted that the shaping of natural resource uses by powerful actors is often visibly 'inscribed' in the environment "through land, air and water alterations" (Bryant 1998:86), such as felled forests, timber plantations, cotton fields, dams, or toxic waste dumps, while the patterns of resistance of the less powerful "are often more difficult to discern in the environment" (Bryant & Bailey 1997:43). The latter may include 'illegal' exploitation of resources (Bryant & Bailey 1997), which has been a widespread phenomenon in Indonesia's forests for decades (Nibbering 1988, Peluso 1992), uprooting of plantation trees (see Gerber 2010), or forest clearance in national parks (Bailey 1996, quoted in Bryant & Bailey 1997). However, the 'inscriptions' of control and resistance and of struggles over resources in physical landscapes have not been the core focus or starting point of much political ecology scholarship. The perhaps most notable exception is the study by Aldrich et al. (2011), which contains a meticulous analysis of the causal links between a conflict over a largeholding in Pará, Brazil and LUCC. I argue that conceptualising land cover changes as 'inscriptions' of societal structures and dynamics supports the linking of political ecology and land change science (see Section 4.2). My empirical research on LUCC and its drivers showed that the effects of the resistance of the 'less powerful' constitute some of the boldest 'inscriptions' in the landscape of the Segara Anakan lagoon's catchment area (see Research Papers 4 and 5).

[1] A clear-cut distinction between strategies and tactics as proposed by Perramond (2007) proved rather unfeasible and was not essential in the context of my case studies. I therefore mainly use the term 'strategy' and 'strategic' in referring to strategic-tactical acts.

4.1.3 Scale in political ecology

Questions of scale have been a major research theme in political ecology scholarship and are relevant in the research presented in this thesis in a number of ways. As noted in the introduction (Chapter 1), watershed and coastal zone management is confronted with a particularly large complexity of interwoven social-ecological processes that operate on and across various scales (see also Snelgrove et al. 2009). These processes are influenced by a multitude of factors and actors, many of which operate on scales far beyond the boundaries of the watershed. These watershed and coastal processes and their drivers in turn can be analysed at different scales, framed by scalar narratives (or politics of scale), and managed at particular scales. In Java most analyses of watershed issues have been snapshot studies focussing on the scale of peasants' contemporary private plots, and most corresponding management interventions (terracing and tree planting programmes) have targeted the same scale (see Chapters 1 and 2). These scales do not necessarily a priori exist, but are socially constructed through framings, ways of knowledge production or interventions. The pronounced multi-scalar nature of watershed processes and their drivers combined with various social constructions of scale in framing, analysing and managing these processes render watershed-related research a particularly fertile ground for both the application and the further refinement of concepts of geographical scale.

Scale issues have been a main subject of political ecology scholarship over the past decades, in the sense of both the analytical scales applied in political ecology research and the social construction of scale. Multi-scalar analyses have been a main feature, or "a hallmark" (Neumann 2014:6), of political ecology from its onset, starting with Blaikie's (1985) chains of explanation. Batterbury and Bebbington (1999) also highlighted the importance of conducting analyses across both temporal and spatial scales. Bryant and Bailey (1997:32) aptly sketched the need for multi-scalar analyses while at the same time pointing to the social construction of scale by noting that "the existence of a whole host of environmental problems at different scales cannot be adequately understood without recognising simultaneously that different actors contribute to, are affected by, or seek to resolve, environmental problems at different scales". Zimmerer and Bassett (2003a) also called on political ecologists to further explore the interplay between scalar politics and ecological scales.

This section briefly explores some of the literature related to the social construction of scale. Section 4.5 discusses considerations related to my own analytical scales in this research.

In analysing spatial shifts of production and their underlying political-economic forces of scalar restructuring, political economists like Taylor (1982) and Smith (1992) called attention to the political construction of scale and thereby contributed to the initiation of an intensive debate on geographical scale (see, e.g. Brenner 1997, Brenner 2001, Delaney & Leitner 1997, Jessop et al. 2008, Manson 2008, Marston 2000, Marston & Smith 2001, Neumann 2009, Sayre 2005, Swyngedouw 1997). Committed to constructivist points of view, this debate proposes that scales are neither unproblematic, objective tools facilitating the analysis of complex realities nor are they pre-given entities, "awaiting discovery" (Delaney & Leitner 1997:94). They are rather seen as socially constructed and are constantly reworked in socio-political struggles. They are fluid and dynamic, often contradictory and contested, but "constitute social, economic and political processes" (Delaney & Leitner 1997:93) and hence produce real socio-spatial outcomes (Brenner 2001, Brown & Purcell 2005, Marston 2000). Social actors strategically apply particular scales or a combination thereof in order to pursue particular political or economic outcomes or legitimise certain actions and interventions (Bolin et al. 2008, Brown & Purcell 2005, Kurtz 2003, Towers 2000). This politics of scale was defined by Zulu (2009:688) as a situation "where different actors construct, modify and contest the spatial extent, content, and resolution of information and decisions". The resulting scalar (re-)configurations not only shape the outcomes of political struggles, but alter, for example, institutions, power relations, resource access, and environmental conditions (Zulu 2009). This renders attention to scale highly relevant in political ecology (Brown & Purcell 2005). Instead of being entrapped in a preconceived set of hierarchical scales, which was criticised by Marston et al. (2005:422), who proposed the need to “expurgate scale from the geographic vocabulary” in favour of a “flat ontology”, political ecology research should focus on the processes of scale making. As noted by Moore (2008), it should focus on the processes “through which specific scalar configurations solidify in consciousness and practice, and the effects these developments have upon social, political and cultural relations” (p. 214), because “the tendency to partition the social world into hierarchically ordered spatial ‘containers’ is what we want to explain – not explain things with” (p. 212).

Paying attention to the discursive constructions of scale can help to explain the formation and temporary persistence of particular political framings of environmental issues and processes. Rangan and Kull’s (2009) three-dimensional scale concept, comprising operational, observational and interpretive scales, can support such inquiry. Thereby, operational scale refers to the configurations of social and ecological processes; observational scale refers to examination and measurement; and interpretive scale refers to scientific and political discourses which “extrapolate and translate across and between observational and operational scales” (Rangan & Kull 2009:40). Building on Rangan and Kull’s (2009) conceptualisation of scale and on Hajer’s (2000) conceptualisation of ‘problem closure’, which explains how particular framings of an issue can determine the ways of or limit further knowledge production, Research Paper 7 of this thesis (Lukas & Flitner 2015) proposes a heuristics of scalar environmental politics that supports analyses of the links between political framings, knowledge production and political intervention. It helps to explain the long-lasting narrow focus of political and scientific debates about the causes of high river sediment loads and coastal sedimentation in Java and of the corresponding watershed conservation efforts on the scale of upland peasants’ private plots (see Chapters 1 and 2) and the fact that scales of observation have not been modified or extended in order to explore other important sediment sources throughout the entire catchment area and their causes (see Section 4.5 regarding my own scales of analysis).

The human-geographical debate on scale and its political construction has to date largely focussed on the spatial and hierarchical aspects of scale. Its temporal aspect has barely been discussed and conceptualised in the otherwise extensive literature on scale. My empirical research, which shows that historical factors and transformations have been neglected in debates over the causes of high river sediment loads and seasonal flooding in the Segara Anakan region, directs attention to the relevance of time scales in political framings of environmental matters. The works by Bolin et al. (2008) and McCann (2003) are two of the few examples that have paid attention to the temporal aspects of scale. McCann (2003) found that scalar urban politics often combined framings of spatial and temporal scale. Bolin et al. (2008), in their analysis of water conflicts in Arizona, briefly remarked on the role of time scales in a political dispute in which citizen groups, referring to concerns regarding the long-term sustainability of water resources, used “moral claims of obligations to the future” (p. 1501) as a rhetorical strategy to challenge a proposed pipeline project. Otherwise, the temporal aspect of scale has at best been acknowledged in that spatial-hierarchical scales are continuously being made and remade over time (Brown & Purcell 2005) and that existing scalar arrangements shape future configurations. The limited attention to time scales is surprising, given that environmental changes often result from different processes, operating over different time-scales (Robertson et al. 2000), and hence, depending on the time scale that one chooses for one’s analysis, one may only arrive at partial explanations. Consequently, analysing historical trajectories of social-ecological processes can reveal factors that have been disregarded in common framings of such processes and thereby raise questions about the adequacy of or the expectations regarding the corresponding modes of political action. The importance of historical inquiry is further explored in the next section.

4.1.4 History in political ecology – intersections with environmental history

Analysing historical trajectories of social-ecological processes is often crucial for a realistic understanding of contemporary environmental issues, conditions and dynamics, for comprehending the background and adequacy of related political framings and modes of political action, and for exploring (alternative) options of addressing or influencing them, because:

(1) Current social-ecological conditions and processes are considerably shaped by their historical trajectories.

(2) The nature and pace of contemporary dynamics often can only be realistically appraised against the backdrop of past developments.

(3) Analysing historical trajectories that comprise periods during which the roles and relative importance of various interacting processes and drivers has changed can enable us to better identify and differentiate the roles of various natural and anthropogenic drivers of environmental change. This can be particularly important in the case of highly complex social-ecological dynamics that are driven by a large range of interacting factors and drivers that operate over and across a multitude of spatial, temporal and hierarchical scales, which particularly applies to watershed processes.

(4) Knowledge of the former existence and condition of ecosystems, including of species abundances, which is often not preserved within living memory, is important since it exposes the magnitude of environmental change and degradation, helps to appraise the necessity and adequacy of management approaches, and influences peoples' preferences of future environmental conditions and the choice of respective management options (see e.g. Hanley et al. 2009, Lotze et al. 2006, Pauly 1995).

(5) Knowledge of the historical trajectories of change supports the evaluation of management efforts.

(6) Exploring both historical trajectories of social-ecological dynamics and historical trajectories of political framings of these dynamics can call into question existing narratives or complement existing knowledge with new empirical insight. It also helps to better understand the historical roots of political framings. Such combined inquiry into historical social-ecological dynamics, the formation of related political framings and the degree to which such framings realistically reflect social-ecological dynamics can be a particular strength of historical political ecology.

Understanding the roles of and interactions between the entire range of natural and human drivers of environmental dynamics across different scales carries both great potential and poses a major challenge to reconstructing historical environmental change. Differentiating the various drivers is an intricate task, not least because various and all-pervasive anthropogenic factors have not only tremendously altered environmental conditions and processes but have dramatically increased the range and complexity of the set of interwoven factors and drivers. Along these lines, Research Paper 3 of this thesis provides an overview of a broad range of factors that have contributed to increased river sediment loads and accelerated sedimentation of the Segara Anakan lagoon.

An important consideration in reconstructing historical social-ecological dynamics is the choice of analytical time scales. They can influence the range and roles of the drivers of environmental change detected and hence our conclusions (cf. Batterbury & Bebbington 1999, Chapman & Driver 1996), or as aptly noted by Cronon (1992:1364) in the context of his comparative analysis of different environmental narratives: "[…] where one chooses to begin and end a story profoundly alters its shape and meaning". Which analytical time scale is appropriate and feasible then? How far do we have to go back in time to gain an as realistic understanding of social-ecological dynamics as possible? The time scales of historical inquiry obviously depend on the kind of environmental changes, the range and temporal scales of its drivers, the data existing, and the methods at one's disposal. However, in general, for a realistic understanding of the roles of natural and anthropogenic drivers, it is especially insightful to incorporate times of transition from mainly nature-dominated to human-dominated landscapes (Batterbury & Bebbington 1999, Messerli et al. 2000).

In addition to the research methods used, the availability of existing knowledge that can be incorporated and of material that can be analysed (e.g. satellite images and historical maps) determine the thematic scope and the time scales of inquiry into historical social-ecological changes. It is often particularly fruitful to combine various methods and a large variety of existing knowledge from different disciplines. The analysis of riverine sediment transport and its causal factors in the Yellow River over the past 2,300 years by Xu (2003) illustrates the potential of combining various pieces of knowledge and evidence from different disciplines and different time scales. In case of less documented areas, the smaller amount of previous research results or records constrains the scope and/or time scale of historical reconstructions, especially if one does not have a larger multi-disciplinary research team at one's disposal. Depending on the scope and the time scale that one's research is able to cover, its results should be regarded as a number of pieces of knowledge, as fractional explanations, that can and should be combined with other research results and in that way contribute to a better understanding of the nature and drivers of social-ecological changes rather than necessarily framing fractional explanations as a 'new truth' that completely overturns existing explanations (cf. Section 4.1.5).

Given the strong rationale for historical inquiry summarised above, it is no surprise that exploring historical trajectories of human-nature interactions has been a growing field of research the past decades. It has been shaped by scholars from a variety of disciplines, including geography and history. A diverse and dynamically expanding range of such research has been conducted under the "euphonious and readily understood label" 'Environmental history' (Wynn 2012:199). Some of the research assigned to this "broad and diffuse field" (Wynn 2012:199) also pays attention to political aspects and social constructions of the environment (see Wynn 2012 for an overview, also see Sörlin & Warde 2007), i.e. aspects that belong to the core concerns of political ecology, though with clearly less emphasis. There have also been debates among environmental historians over the need to engage more in social and political theory and over the normative political rationales of the research field. Such rationales have considerably shaped political ecology. For example, Sörlin and Warde (2007:122) noted that "How and with what purpose we write environmental history is crucial not just the fact that we write it". The question of normative rationales and of an engagement in the politics in environmental history was further explored in a review by Cooper (2010).

Some political ecologists in turn also pay thorough attention to historical trajectories of human-nature interactions, the core theme of environmental historians. Yet, compared to the work of environmental historians, political ecologists' historical inquiry tends to be less the core focus of analysis, but serves more as a means to better understand contemporary struggles over environmental matters. Much political ecology scholarship also tends to pay comparably less attention to material environmental conditions and dynamics, but more attention to political factors and questions of resource access and control than that of many environmental historians.

The importance of historical inquiry has been noted and reflected in some political ecology scholarship from its beginning, though it is not a core commonality throughout the field. Blaikie and Brookfield (1987c) already noted the need to take into account historical developments in analysing nature-society relations. Accordingly, they emphasised that the relationships of the “land manager” to the environment must “be understood in a historical, political and economic context.” (Blaikie & Brookfield 1987b:239). Leach and Mearns (1996:5) also noted that the existing knowledge about environmental changes was often based on “snap-shot views of its current state or on data gathered over a few years at most” while a proper understanding of environmental dynamics often required “historical and ‘time-series’ data”. A large number of political ecology studies have demonstrated the importance of taking into account the historical dimension in trying to better understand contemporary environmental conditions and changes, resource use practices, patterns of resources access and control, or the inadequacies of management interventions (e.g. Bryant 1997, Kull 2004, Leach & Mearns 1996, Peluso 1992, Turner 1999b).

Numerous political ecologists have incorporated historical inquiry into their research, though without necessarily framing their work as ‘historical political ecologies’. Only a few authors have explicitly aimed at conceptualising ‘historical political ecology’ as a distinct research theme (Brannstrom 2004, Davis 2009, Offen 2004) or have labelled their empirical studies as ‘historical political ecologies’ (e.g. Pires 2012). As noted by Davis (2009:285), “[h]istorical political ecology is arguably one of the least visible widely recognised research areas within political ecology”. Offen (2004:21) suggested a historical political ecology can be understood as “a field-informed interpretation of society-nature relations in the past (e.g., material, ideological, legal, spiritual), how and why those relations have changed (or not changed) over time and space, and the significance of those interpretations for improving social justice and nature conservation today”.

Historical political ecology shares common ground with scholarship conducted under the label of environmental history, and I argue that there is scope for fruitful collaboration between the two. Both environmental history and some parts of political ecology scholarship analyse historical trajectories of human-nature interactions over time. Environmental history tends to be more dedicated to analysing material environmental conditions and changes than much of the political ecology scholarship (see Section 4.1.6). As such, in comparison to political ecology, environmental history tends to pay less attention to broader political-economic factors, the roles, interests and strategies of and the power relations between various actors, questions of resource access and control, and social constructions of environmental issues and changes. I argue that these distinct emphases and strengths of environmental history and political ecology provide significant potential for fruitful exchange. In fact, the boundaries of both of these broad and diverse research fields are fuzzy, and some scholarship, including parts of my own research presented here, could be framed under the labels of both environmental history and political ecology. Also my application of historical cartography and land change science marks an intersection between political ecology and environmental history.

4.1.5 The construction and dismantling of environmental myths

As noted above, the questioning and dismantling of inaccurate or at least simplistic and misleading ‘environmental narratives’, ‘orthodoxies’ or ‘myths’ about the nature and causes of environmental change has been one of the major aims and research themes in political ecology. The questioning of simplistic assumptions about environmental degradation in the Himalayas by Ives and Messerli (1989), Leach and Mearns's (1996) 'Lie of the Land', Forsyth's and Walker's research on the political aspects of upland degradation and forest management in Thailand (Forsyth 1996, Forsyth & Walker 2008), Klein's (2002) and Kull's (2004) work that aimed at questioning deforestation narratives in Madagascar, Brookfield's (1999) analysis of gullying and historical soil erosion on St. Kitts Island and in Europe, and studies that dismantled common narratives about the negative environmental impacts of shifting cultivation as being exaggerated (Scholz & Brauns 1997, Sillitoe 1993, 1998, Sillitoe & Shiel 1999) are just a few examples of many studies (not exclusively by scholars who regard themselves as political ecologists) that have called into question sometimes long-standing and commonly held assumptions about the nature and drivers of environmental degradation and the adequacy of related management approaches. These and many other studies have shown that common understandings about environmental changes are sometimes based on "outdated, partial, or erroneous accounts of change" (Batterbury et al. 1997:127). In the absence of thorough knowledge, these 'common understandings' often represent political framings. In many cases, political ecologists have critically analysed the political construction of 'environmental orthodoxies' or 'myths' by linking them to socio-political structures, power relations and the interests of particular actors.

Forsyth defined the terms 'environmental orthodoxies', 'environmental narratives' or 'myths', as used by political ecologists, as:

- "commonly-held explanations of environmental degradation which, on closer inspection, do not match available evidence." (Forsyth 1998:109).
- "simplified explanations of environmental cause-and-effect that emerge in contexts where environmental knowledge and visions of social order are mutually dependent" (Forsyth 2008:35).
- "common explanations of environmental problems that are considered to be simplistic *and* inaccurate" (Forsyth 2003:24).

In the context of my research in the Segara Anakan region, I use these terms (mainly 'simplistic narrative') to refer to explanations of environmental problems that are simplistic, but *not* necessarily completely inaccurate. The common explanation of high river sediment loads and lagoon sedimentation as a result of upland farmers' cultivation practices is simplistic, since it neglects a large range of other drivers. However, it is not completely inaccurate, since erosion on upland farmers' private plots undeniably contributes to high river sediment loads in Java (see Chapters 1 and 2).

As noted above, environmental conditions and changes in general, and watershed and coastal dynamics in particular, are the result of various interwoven processes and factors that operate on and across various temporal, spatial and hierarchal scales. Often far from being understood and empirically documented in their entire complexity, these processes are viewed, interpreted and attempts are made to manage them. The more complex and the less understood these environmental processes are, the more arbitrarily they can be framed in various ways. In case of a large range of interwoven factors and processes that are not sufficiently understood, attention may tend to focus on a few factors while neglecting others, or the various factors are arbitrarily rated by relative importance. This selective inclusion and exclusion of factors is easily influenced by assumptions, paradigms, generalisations, individual views and positions, and political agendas (see e.g. Batterbury et al. 1997, Brookfield 1999, Forsyth 2003, Sillitoe 1998). Brookfield (1999:7) aptly noted that "[i]t is very tempting, using all the prejudices derived from one's own intellectual formation and from common belief as expressed in the literature, to plump readily for one particular explanation, whether this be geophysical or human."

In analysing a number of Great Plains histories, Cronon (1992) compellingly documented how different historians describing the environmental history of the same area during the same period and based on identical material wrote entirely different stories and arrived at completely different conclusions. He noted that:

> "[…] we configure the events of the past into causal sequences – stories – that order and simplify those events to give them new meanings. We do so because narrative is the chief literary form that tries to find meaning in an overwhelmingly crowded and disordered chronological reality" […] "By writing stories about environmental change, we divide the causal relationships of an ecosystem with a rhetorical razor that defines included and excluded, relevant and irrelevant […]" and (Cronon 1992:1349).

Brookfield (1999:6), not referring to the narratives of historians, similarly remarked that "it is too easy to treat the association of observations or events as erroneously implying cause and effect." Our descriptions of the world and our values and assumptions are so closely intertwined that they can never be fully separated (Cronon 1996).

Such narratives simplify complex, not sufficiently understood social-ecological realities into plausible, but likely simplified and distorted, explanations that provide clear-cut rationales for political action, which then contributes to their strength and credibility (Leach & Mearns 1996, Roe 1994). They often reflect political objectives. As Forsyth (1998:108) noted "policy actors, aid organizations or governments for instance shape the image of crisis this way or that, by selecting data to match their own policy objectives.".

These narratives or framings can be actor specific and change over time, but they can also persist and dominate mainstream political discourses and action for decades. As noted by Klein (2002:191), narratives, once created and repeated multiple times, become "institutionalised as facts", guiding policy. They limit the range of possible political courses of action debated (Forsyth 2005:166) and shape research objectives and hence further knowledge generation (Hajer 2000). Hajer (2000) conceptualised the establishment of such framings as mainstream discourse that delimits further knowledge generation and thereby contributes to its own solidification as 'problem closure'. As Research Paper 7 of this thesis shows, the link between political framings and the ***scales*** of knowledge production can be crucial in explaining the persistence of such framings. The review of debates and existing knowledge about the causes of high river sediment loads in Java provided in Chapters 1 and 2 suggests that the framing of upland farmers' private plots as the single-most important sediment source has obviously served as a satisfactory explanation that rendered further, more open-ended research unnecessary. Research paper 7 explores the political background of this framing and shows how it confined further knowledge production by largely delimiting observational scales to upland farmers' private plots.

Political ecologists' eagerness to overturn common understandings about the nature of environmental issues and changes has undoubtedly contributed to fruitful debates about and to an improved understanding of environmental issues. Yet, at the same time, it carries the risk of downplaying environmental issues (as was acknowledged, for example, by Batterbury et al. 1997, Forsyth 2003) and of producing new erroneous accounts of environmental change. As noted by Batterbury et al. (1997:127), "although it may now be fashionable to condemn simplistic crisis-driven explanatory models as 'myths' […], criticising such orthodoxies may be counterproductive if this denies the existence of real environmental problems or human impacts".

The controversy over environmental degradation in the uplands of Madagascar (see Klein 2002, Kull 2004, Pollini 2010) is an illustrative example showing how political ecologists, through critically questioning existing narratives and constructing counter-narratives, can produce additional insight into environmental issues, but thereby also produce new narratives that might be as simplistic and/or provide as inaccurate a reflection of the material social-ecological conditions and processes as the established narrative that was to be dismantled. Kull (2004) and Klein (2002) aimed at dismantling the narrative that the highlands of Madagascar were previously completely covered with forest and have been heavily deforested and degraded as a result of traditional land uses. In doing so, the authors developed counter-narratives that downplayed the environmental issue and the role of peasants' agricultural practices or human agency in general. These counter-narratives were shown by Pollini (2010) to be another simplistic, misleading political narrative, resulting from an ideological framing of the issue.

This example illustrates the risk of one of political ecology's main tenets, namely the "normative political commitment to social justice and structural political change" (Bridge et al. 2015a:8), to produce erroneous accounts of environmental issues, or at least new social constructions thereof that are partial, simplistic political representations of the social-ecological dynamics under study. Pollini (2010:717) points to "tensions between the political agenda that political ecologists support and the will to conduct research work that follows the best scientific standards and that sticks to empirical data". Also Vayda and Walters (1999) pointed to the fallacy of many political ecologists' political agendas that romanticised local communities and a priori regarded the devolution of control over resources to them and the mitigation of influences from the broader political-economic system as a panacea for enhanced environmental sustainability.

No matter whether the political-ecological counter-narrative produced represents a more or less accurate or complete representation of the object or processes under study than the narrative it aims to question, it has value in that it can trigger productive debates and additional research resulting in a more complete and realistic picture of the material social-ecological conditions and processes. Furthermore, different narratives with their distinct pieces of evidence can often fruitfully be combined as part of an effort to generate a more realistic, more complete picture of the conditions and processes analysed (see Pollini 2010). In this way, the production of different narratives and counter-narratives and critical reflection on the foundations and the explanatory value of their distinct pieces of evidence can help us to get closer to a realistic understanding of social-ecological processes and their drivers. Notwithstanding this general utility of counter-narratives, I share the concern that a political ecology that too fundamentally completely rejects existing pieces of knowledge as wrong and power-laden political narratives and aims to replace them by new counter-narratives based on overly selective, partial analyses that are shaped by political objectives undermines its various strengths and runs the risk of being seen as mere politics.

Against this backdrop, I consider it crucial to pay adequate attention to social-ecological (including physical environmental) processes and their drivers (as further explored in Section 4.1.6) by taking into account existing pieces of knowledge about these processes without a priori rejecting them and/or by contributing new knowledge about these processes that complements existing pieces of knowledge, without necessarily having to overturn them. I hence take a political ecology approach that combines an open-ended analysis of social-ecological processes (including of physical environmental changes) and their drivers with an inquiry into the political framings of these processes and the related modes of political action. While critically questioning existing narratives (i.e. the upland degradation discourse focussing on unsustainable cultivation practices on farmers' private land as a major cause of high river sediment loads and lagoon sedimentation) and their links with political interests and the modes of knowledge production, I do not a priori dismiss these narratives as wrong but, based on the review presented in Chapters 1 and 2, regard them as a partial explanation, which my own analysis of social-ecological conditions and processes might challenge or complement with additional pieces of knowledge.

4.1.6 The ecology in political ecology

The fact that much political ecology scholarship has, particularly following the 'cultural turn', focussed on analysing discursive framings of environmental issues and dynamics and related political struggles and interests and power relations, while paying only limited attention to the environmental issues and dynamics themselves, has been the subject of controversial discussions. Although there are political ecologists who engage with similar depth in both environmental and societal dynamics (e.g. Turner 1999a, Turner 1999b, Zimmerer & Bassett 2003b), most political ecology scholarship has clearly put more emphasis on analysing the political rather than the ecological dimension of environmental issues. Bryant and Bailey (1997) related this to the emergence of the research field as a response to the apolitical nature of most previous research on environmental issues, the domination of political factors over natural ones in shaping human-environment relations, and the social science background of most political ecologists. The authors additionally justified the prime focus on political processes by arguing that both the development of and solutions to environmental problems lie within the political realm.

Perhaps the most vehement critique of this emphasis of political over ecological factors was put forward by Vayda and Walters (1999). While acknowledging the contribution of political ecology scholarship to a better understanding of the previously underexplored influence of political factors, the authors expressed concern over the fact that much of the scholarship has focussed on politics and discourses to a degree that the analysis of bio-physical changes has faded into the background of political ecology inquiry. They critiqued that many political ecologists "insist that political influences – especially political influences from the outside, from the so-called *wider* political-economic system – are *always* important, arguably more important than anything else, and should accordingly be given priority in research" (p. 168). This, according to the authors, results in "question-begging research" (Vayda & Walters 1999:168) that pays attention only to selected explanations of environmental change that are a priori assumed important, based on judgements, theories or biases, while dismissing a large range of other factors and their interactions (cf. Section 4.1.5). The authors further argued:

> "Moreover, some political ecologists do not even deal with literally the influence of politics in effecting environmental change but rather deal only with politics, albeit politics somehow related to the environment. Indeed it may not be an exaggeration to say that overreaction to the 'ecology without politics' of three decades ago is resulting now in a 'politics without ecology'" (Vayda & Walters 1999:168).

Also Walker (2005:78), who engaged in the accusations put forward by Vayda and Walters (1999), agreed that "in much contemporary political ecology the 'concerns of ecology' […] become primarily questions of power, struggle and representation, while the connections of these struggles to the biophysical environment remain unexamined". Similarly, Zimmerer and Bassett (2003a:1) noted that within political ecology, "rarely does one find a synthesis of the political and ecological processes whose outcomes produce distinctive problems and suggest particular solutions". Walker (2005) also expressed concern over the friction within political ecology about the engagement with environmental processes and noted that the limited extent of such engagement was to some degree both a result of and contributed to the limited number of scholars with a natural science or physical geography background in political ecology.

As an alternative to overly political approaches that neglect actual environmental dynamics, Vayda and Walters proposed an approach termed ‘event ecology’ (Vayda & Walters 1999, Walters & Vayda 2009). This approach includes a thorough appraisal of actual environmental changes and does not presume the relevance of particular (political) factors. It thereby “lessens the likelihood of inaccurate or erroneous claims about the environment on the basis of preconceived theoretical ideas or agendas” (Vayda & Walters 1999:176). Accordingly, the research starts with an analysis of bio-physical events or changes and then constructs “causal histories of interrelated social and biophysical events” without rigid a priori assumptions (Walters & Vayda 2009:534). Research in event ecology is “guided by open-ended questions about why specific environmental changes of interest (i.e., events) have occurred. It then seeks to explain such changes by making causal connections to prior events, in so doing constructing causal chains backward in time and usually outward in space from effects to causes” (Walters & Vayda 2009:537).

Vayda’s and Walters’ event ecology has a number of strengths that are undoubtedly worth consideration and accommodation in political ecology scholarship: it does not just treat the environment as a backdrop for the analysis of political-economic struggles, but focusses on the interaction between natural and societal processes, and it urges doing so in a more open-ended way. Both of these factors reduce the danger of producing new political narratives about environmental issues based on overly normative-political research agendas (cf. Section 4.1.5). However, while the focus of much political ecology scholarship on political factors, its political-normative research rationales, and its neglect of or its superficial or partial look at environmental processes can be seen as an overreaction to the mainly apolitical nature of much previous research on environmental issues, Vayda’s and Walters’ event ecology in turn can be critiqued for posing the risk of not paying sufficient attention to social and political-economic structures and discursive framings and for neglecting dynamics in human-nature relations that do not necessarily precipitate specific visible events, i.e. specific environmental changes (see e.g. Perramond 2007, Pollini 2010). Perramond (2007:503) noted that “event ecology simply ignores the substance of political-economic realities, hoping for an ecological and synchronic moment to provide clarity”.

Proposing a more integrative approach, Zimmerer and Bassett (2003a) called for a “natural turn” in political ecology. They called for an approach that “strives to engage both the ecological and the political dimensions of environmental issues in a more balanced and integrated manner” (p. 1); an approach that “views the environment not simply as a stage or arena in which struggles over resource access and control take place” (p. 3), but that also pays due attention to environmental dynamics, though without losing sight of the roles of social-economic aspects and discursive political framings of the environment.

Sharing the concerns of Vayda and Walters (1999), Zimmerer and Bassett (2003a), Pollini (2010) and others over the (sometimes partial, ideologically driven) focus of some political ecology scholarship on political aspects and its neglect of environmental processes, I view the synthesising engagement with both the material environmental conditions and processes and the related societal factors as a major strength or *potential* of political ecology that is worth keeping and further developing. Although I regard Vayda and Walters’ event ecology as a fruitful approach in various political ecology research contexts and find that large parts of my own research presented in this thesis are in line with this approach, I do not share the view that the analysis *must always* start from specific environmental changes. The inquiry may also start from environmental discourses or policies or from specific conflicts over environmental issues or natural resources and then seek to unravel both the related societal and material environmental factors and processes. Some political ecology scholarship that focusses more on the socio-political dimension of environmental issues could, depending on the state of knowledge about the (material) environmental conditions and processes related to the subject of inquiry, perhaps benefit from incorporating (more) existing knowledge about material environmental conditions and processes contained in different strains of literature. Not every piece of existing knowledge necessarily needs to be discarded as part of the political discourse that a political ecology study might a priori aim at questioning.

In the context of my own research project presented here, I would have found it problematic to pay attention only to the discursive framings of watershed processes and related questions of political power and interest, without analysing material environmental processes. If I had confined my analysis to the political framings of lagoon sedimentation and watershed processes without analysing some of these processes, I would not have been able to make any judgement as to what extent the dominant discourses, for example, about the causes of lagoon sedimentation, are likely to be an adequate explanation or not. Only by analysing some of the environmental dynamics (i.e. the temporal dynamics of lagoon sedimentation, LUCC and other watershed transformations) and their drivers through remote sensing, land use/cover mapping, historical cartographic analysis, interviews, and material from different strains of literature, could I expose the dominant discourse that focussed on population pressure and cultivation practices on upland farmers' private plots as the single-most important cause of lagoon sedimentation as a simplified, partial explanation.

My research hence combined an analysis of material environmental processes and their drivers in the Segara Anakan region with critical inquiry into the political framings of these processes and the related interventions aimed at managing them. The following two sections briefly shed light on the two main approaches that I used in analysing environmental dynamics. They are rooted in land change science and historical cartography. While elements of land change science (remote sensing) have been increasingly incorporated in some political ecology scholarship over the past years, historical-cartographic inquiry is less common, although it provides significant potential for reconstructing historical environmental change.

4.2 Land change science

LUCC is a highly cross-cutting theme, linked to a large diversity of social-ecological issues and dynamics, such as climate change via its effects on surface albedo and carbon cycles, water cycles and various watershed processes, biogeochemical processes, as well as to soil degradation, biodiversity, food production, and the livelihoods of billions of land users. Consequently, research on LUCC connects a large range of natural and social scientific research fields. The emergence of land change science as an interdisciplinary research theme has substantially intensified the connections between these various research fields over the past two decades. The recognition of LUCC as an important dimension of global environmental change and the consequential establishment of the Land Use and Land Cover Change Project and its successor, the Global Land Project under the auspices of the International Geosphere-Biosphere Programme (IGBP) and the International Human Dimensions Programme on Global Environmental Change (IHDP) have played an important role in this (see Lambin et al. 1999, Lambin & Geist 2006, Turner et al. 1995).

Previously, LUCC scholarship primarily focussed on methodological and technical considerations to advance the possibilities, accuracy and efficiency of land cover detection, while the drivers of LUCC remained rather underexplored (cf. Geist & Lambin 2001, Lambin et al. 2003, Turner 2002). This has changed since the mid-1990s with the promotion of multi-scalar and interdisciplinary approaches, linking remote sensing and Geographical Information Systems (GIS) with environmental and social sciences (see Geist & Lambin 2001, Turner 2002). Gaining an improved understanding of the drivers of LUCC has been a major goal of the Land Use and Land Cover Change Project and the Global Land Project (see Lambin et al. 1999, Lambin & Geist 2006, Turner et al. 1995). These projects contributed to advancements in the conceptualisation of the drivers of LUCC and promoted the linking of broader scale assessments of land cover change with case studies that provide explanatory insight into the trajectories and drivers of these dynamics (Lambin et al. 1999, Turner et al. 1995). Previously, such links had barely been established, due to the methodological difficulties of integrating the diversity and complexity of local circumstances and respective qualitative information into broader-scale assessments. The latter thus remained based on selected macro variables (for an example see Verburg et al. 1999). A number of meta-analyses that synthesised findings from a large number of site-specific case studies have since considerably improved our understanding of the wide range and the different roles of the various causes of LUCC (see Geist & Lambin 2001, 2002, Geist et al. 2006, Magliocca et al. 2015, Rudel et al. 2009, Rudel 2005, 2008).

The causes of LUCC have come to be conceptualised most commonly as a diverse set of proximate and underlying causes (Geist & Lambin 2001, Lambin et al. 1999, Turner et al. 1993). This conceptualisation bears similarities with Blaikie's (1985) chains of explanation. Proximate causes are "human activities (land uses) that directly affect the environment" at the local level (Geist & Lambin 2001:5). They include agricultural expansion, for example in the form of shifting cultivation, permanent cultivation, cattle ranching, and colonisation/transmigration; wood extraction, for example, for timber, fuelwood and charcoal production; and infrastructure extension, including, for example, transport infrastructure, settlement expansion and private enterprise infrastructure (Geist & Lambin 2001). Underlying causes are "fundamental forces that underpin the more obvious or proximate causes […]. They can be seen as a complex of social, political, economic, technological, and cultural variables that constitute initial conditions in the human-environment relations that are structural (or systematic) in nature." (Geist & Lambin 2001:8). They include a wide variety of factors, ranging from market developments, formal and informal policies and property rights regimes to changes in agricultural and forestry-related technologies to public and individual values, beliefs and behaviours, and demographic developments. Since LUCC often results from a large range of interwoven drivers that operate on and across different scales, it is a challenging task to gain a realistic understanding of the whole range and relative importance of and the linkages between the various drivers. As noted by Kaimowitz and Angelsen (1998), it is often more difficult to clearly link land cover change with underlying than with proximate factors, since causal relationships to underlying factors are less direct, and related data is often lacking. Pointing to the interconnectedness of various factors, Geist and Lambin (2001:99) noted that the divide between proximate and underlying causes will probably have to be overcome, "to allow for more complex interplays of human agency and structure in processes of land change."

The promotion of interdisciplinary research and of case study approaches whose findings are linked to broader-scale assessments, along with the conceptualisation of a wide range of causes of LUCC, have resulted in much of the LUCC scholarship moving away from simplified assumption-based models and reliance on a few related macro-indicators, like population density, towards a more realistic, empirically grounded understanding that takes into account the complexity of the site-specific, interwoven, multi-scalar processes and drivers of LUCC (see Lambin et al. 2003, Lambin et al. 2006, Lambin et al. 2001, Turner 2002). Yet, in many parts of the world the understanding of the drivers of LUCC is still very limited and widely based on assumptions and often misleading results of largely desk-based analyses that relied on remote sensing and selected macro-level indicators without any (thorough) field research. This also applies to Java, as Chapter 2 has shown. By relying on macro-level indicators chosen based on pre-existing assumptions and limited and sometimes erroneous data, such studies tend to contribute no or very few new insights into the range of drivers of LUCC and instead reinforce simplistic narratives. For example, Verburg et al. (1999) based their simulation of LUCC for the whole of Java on a set of selected macro-level indicators, including numerous demographic variables, while excluding tenure and erroneously presuming that no LUCC occurs in state forest areas. The lack of reliable area-wide data on land tenure in Java and widespread tenure contestations, resulting in differing de jure and de facto tenure, indeed make it difficult to incorporate tenure in such a macro-level analysis. In this way, the confinement to desk-based, macro-level analyses and the lack of site-specific, empirical in-depth studies or the lacking acknowledgement of the results of such studies in broader-scale analyses contributes to the persistence of simplified assumptions or 'myths' (cf. Lambin et al. 2001) about the drivers of LUCC.

In this context, the linking of land change science and political ecology is a highly promising research agenda. Field research-based inquiry into the site-specific causes of LUCC and the complex set of underlying factors, as promoted by the Land Use and Land Cover Change Project and the Global Land Project, is a strength of political ecology. Many of the factors that have been acknowledged as proximate and underlying causes of LUCC (see Geist & Lambin 2001), including, for example, property right regimes and informal policies, have long been classic subjects of political ecology scholarship.

The potential of political ecology to contribute to land change science was acknowledged within the Land Use and Land Cover Change Project (see Brannstrom & Vadjunec 2013a, Geist 1999, Lambin et al. 1999) and in fact, political ecologists contributed to shaping the project (Turner et al. 1995). However, the increasing fragmentation of political ecology; the limited engagement of much scholarship with material environmental dynamics (see Section 4.1.6); the tendency of some political ecologists to suspect land change science scholarship as being part of problematic social-political structures and power relations; and differences over the conceptualisation of the drivers of LUCC, with political ecologists critiquing simplifications in land cover classifications and modelling approaches and the inclusion of demographic variables, have impeded larger-scale integration of land change science and political ecology (see Brannstrom & Vadjunec 2013a).

Although the problem framings and analytical approaches of land change science and political ecology can differ considerably, both research fields share much common ground (see Turner & Robbins 2008, Turner 2003b). I argue that instead of focussing on questioning the approaches used by scholars from the other research field, both land change science and political ecology can significantly benefit from exchange and integrated approaches and thereby contribute to an advanced understanding of LUCC and its drivers and to respective political debates.

While land change science has its strength in analysing patterns and dynamics, in remote sensing techniques and in broader scale and quantitative analyses, the political ecologists who pay explicit attention to material environmental dynamics and their drivers are in a prime position to contribute knowledge on the causes and framings of these patterns and dynamics. LUCC and related issues have always been and will certainly continue to be a major subject of inquiry in political ecology. Integrating approaches and methods from land change science provides significant potential for (re)integrating 'the ecology' in political ecology (cf. Section 4.1.6), for generating new knowledge of

LUCC and its drivers, for this knowledge to be taken up and further expanded by scholars from other research fields, and for creating interfaces for collaborations with land change science.

This potential has been increasingly utilised over the past 1.5 decades. The scholarship at the intersection of political ecology and land change science includes, for example:

- Basett and Zuéli's combination of an analysis of aerial photographs and vegetation with social-scientific research to better understand the links between land use and vegetation in agro-pastoral areas of Côte d'Ivoire (Bassett & Zuéli 2003, Bassett & Zuéli 2000).
- Turner's (2003a) combination of remote sensing, soil and plant sampling and social-scientific surveys and interviews to analyse the links between varying rangeland conditions and herd management.
- Kull's (2004) use of aerial photographs, historical maps and landscape photos to question narratives about declining tapia woodlands in Madagascar.
- The combination of GIS and political ecology research on LUCC in southern Africa by McCusker and Weiner (2003) and McCusker and Ramudzuli (2007).
- Robbin's (2003) analysis of diverging actor-specific views on land cover changes and the definition of land cover categories.

Brannstrom and Vadjunec's (2013b) edited book that is entirely devoted to research connecting land change science and political ecology marks a culmination of the increasing research interest at the intersection of these two research fields.

However, the degree to which political ecologists have actually linked remote sensing and social-scientific research greatly varies. The meticulous documentation of the links between land cover change and tenure contestations in Pará, Brazil by Aldrich et al. (2011) is a prime example of a study that at its core integrates remote sensing and political ecology. In contrast, Gezon's (2006) ethnographic analysis of conflicts over natural resources in Northern Madagascar and Lichtenthäler's (2003) study on water resource allocation and management in Northern Yemen include aerial photographs and satellite images. However, this material is not closely linked with the social-scientific research and the presentation of the respective results.

Robbins (2003) and McCusker and Weiner (2003) illustrated how political ecology can question the objectivity of remote sensing analyses. They showed that satellite images can be interpreted and classified in different ways by different actors depending on their interest-specific framings of land cover patterns. However, the improved availability of high and very high resolution satellite images has tremendously reduced the risk of erroneous image analyses, and remote sensing scholars are usually aware of the limitations and different kinds of errors and error rates of their analyses, although this does not apply to some of the LUCC analyses carried out in the Segara Anakan region (see Chapter 2). Yet, the designation of land cover classes and the valuation of different kinds of land cover can always vary depending on actor-specific interests and framings.

The combination of land change science and political ecology can be particularly fruitful in analysing the links between land cover patterns and changes and tenure, a long-standing research field that has been the focus of renewed interest over the past years. Tenure is one of the most critical determinants of land cover patterns and changes, but had long been underrepresented in much of the LUCC scholarship. The widespread lack of reliable area-wide tenure data makes it difficult to incorporate into broader-scale, macro-level-indicator-based LUCC analyses. Long-standing debates on the links between tenure and resource utilisation are mainly rooted in economic scholarship. They have largely focussed on the dichotomy between private and common-pool resources, without establishing a general conclusion as to which is more likely to contribute to sustainable resource management (see Bonilla-Moheno et al. 2013). The past few years have witnessed increasing research interest on the links between tenure and LUC(C) (see e.g. Araujo et al. 2009, Bonilla-Moheno et al. 2013, Buntaine et al. 2014, D'Antona et al. 2006, DiGiano et al. 2013, Farley et al. 2012, Paneque-Gálvez et al. 2013, Vergara-Asenjo & Potvin 2014, Wannasai & Shrestha 2008). This research reflects both the critical role of tenure with regard to LUC(C) and the still limited knowledge on the various effects (also see Bowler et al. 2010, Robinson et al. 2014). There is a need to better and more systematically understand the causal links between the various forms of tenure and tenure security and LUC(C). Particularly, the varied links between tenure (in)security and LUC(C) have not been well covered by empirical research until recently. Research Paper 5 of this thesis contains a more comprehensive review of literature on the links between tenure form and security and LUC(C) and argues that the various kinds of tenure insecurity, including tenure contestation, should be disentangled and their links with LUC(C) be assessed separately. The paper explores the links between tenure contestation and LUCC, based on empirical research results from the Segara Anakan region.

Although tenure contestations are widespread in most 'developing countries' (Coy 2001), their links with LUCC are clearly underexplored to date. The limited engagement of land change science with tenure contestations can be attributed to the analytical conflation of situations of tenure contestation with other situations of tenure insecurity; the lack of reliable, area-wide data on tenure; scholars' above-mentioned long-standing focus on remote sensing, macro-indicators and broader-scale models; their tendency to neglect historical socio-political developments; their emphasis on the individual decision making of isolated actors while neglecting struggles over resources and the roles of strategic actions and interactions between different actors as a driver of LUCC (cf. Aldrich et al. 2011). Such actions can include, for example, the burning of forest stands, the felling of trees or the pulling out of tree seedlings planted by competing actors.

Political ecology with its actor-oriented approaches (see Section 4.1), its focus on patterns of and struggles over resource access and control, and its consideration of historical trajectories (see Section 4.1.4) is in a prime position to contribute to an improved understanding of the links between tenure contestation and LUC(C). Political ecology scholarship comprises various examples where the strategic interactions between competing actors in struggles over resource access and control obviously affected land cover. For example, Dennis et al. (2005) identified intentional burning in the context of tenure or land-use disputes as a major cause of forest fires in Borneo and Sumatra; Kull (2002, 2004) found that poorer farmers burnt richer farmers' tree plantings out of frustration over related tenure claims in Madagascar; and Peluso's (1992) and Bryant's (1997) historical accounts of struggles over forest resources in Java and Burma respectively contain examples of burning and timber thefts. However, in most cases, political ecologists have not explicitly analysed and visualised the effects of such struggles on land cover (cf. Section 4.1.2 and 4.1.6). Combining approaches from land change science and political ecology provides significant potential in this context, as the study by Aldrich et al. (2011) illustrates. Understanding and analysing LUC(C) as 'inscriptions' of struggles over resources or of societal structures and dynamics combines land change science and political ecology in a new research endeavour that can provide additional insights.

What should be the starting point of such a research endeavour? Turner and Robbins (2008:303) noted that, in contrast to land change science, which usually aims at systematically assessing area-wide LUC(C) and their immediate and (mainly theory-based) distal causes, political ecologists typically select cases "as informed by theory that stresses the role of distal or exogenous processes that usually operate to disadvantage local land managers and are often captured in social conflict and land or resource degradation". I see in both of these approaches a particular strength and a particular problem. The strength of land change science is its area-wide analysis of LUC(C). Its tendency to link these patterns or changes with a pre-conceived set of possible causes is problematic, since this may a priori exclude crucial factors from the analysis. The strength of the political ecology approach could then be seen in its targeted focus on factors that are believed to be neglected by land change science. However, this is also problematic, since selectively choosing very few specific sites or highlighting particular dynamics as they fit into the normative considerations of political ecology scholars while neglecting other sites or dynamics can easily produce new erroneous accounts or 'simplistic narratives' of environmental dynamics and their drivers (cf. Section 4.1.5). Harsh critics could argue that environmental dynamics are then not the major subject of analysis, but only a backdrop onto which particular concerns of political-economic relations and social justice are projected (cf. Section 4.1.6). Thereby, particular sections of the environment or particular environmental dynamics and their drivers are illuminated, while others are neglected. Communicating the results of such case studies as complements to, rather than necessarily as replacements of existing pieces of, empirical evidence appears important in this context (see Section 4.1.5).

In conducting the research presented in this thesis, I aimed at combining land change science and political ecology in a way that utilises the strengths and minimises the weaknesses of each of these approaches. I chose an area-wide analysis of LUCC in the entire catchment of the Segara Anakan lagoon as the starting of the research (the strength of land change science). In conducting this LUCC analysis, I combined remote sensing with land use/cover mapping throughout the area to minimise biased interpretations of the satellite images (which was a weakness of the previous desk-based LUCC analyses reviewed in Chapter 2). I then selected some of the LUCC areas identified in the satellite images for subsequent case studies that open-endedly analysed the drivers of LUCC (the strength of political ecological and other qualitative social-scientific field research). In selecting these areas, I aimed at covering different kinds of LUCC, different parts of the catchment area and some of the hotspots of LUCC. Hence, my selection did *not* favour specific cases where exogenous processes negatively affecting local peasants or social conflicts were supposed beforehand (the aspect discussed above as a potential problem of political ecology). My approach in this part of the research project of choosing an area-wide LUCC analysis as the starting point and then exploring the drivers of these changes without a priori assumptions is in line with Vayda and Walters' (1999) 'event ecology'. Integration of land change science and political ecology was the core of this part of the research. The methodological approach of integrating remote sensing and the social-scientific research will be outlined in Section 4.4 and in Chapter 5.

4.3 Historical cartography

Historical maps hold significant potential for reconstructing historical environmental change. Yet, they have barely been utilised in political ecology research. The few studies that I found include Brookfield (1999), who used historical maps in his analysis of the nature and causes of soil degradation, and Börjeson et al. (2008) who used a historical map from the 1930s to add historical depth to their LUCC analysis in Northeast Tanzania. Sluyter (2003) did not use historical maps, but created new maps visualising the spread of livestock in the Veracruz lowlands of Mexico from the 16^{th} century onwards based on land-grant documents.

Section 4.1.4 explored the relevance of historical perspectives for a better understanding of contemporary social-ecological conditions and processes. If historical research aims at analysing spatial patterns and dynamics and is to cover a larger time span than only the past few decades, the range of possible data sources that can be used is limited. Satellite images only cover the period from the 1970s (in exceptional cases from the 1960s) onwards. Aerial photographs sometimes allow looking as far back as to the 1940s (see e.g. Kull 2013), but their availability is limited. For periods prior to the earliest aerial photographs and satellite images, historical maps are often the only sources of spatial information that is feasible to analyse. Alternative sources of such information do not exist, are place-based (e.g. records of particular locations, archaeological artefacts), or cannot feasibly be analysed with a spatial coverage and resolution similar to that provided by maps (e.g. sediment archives in the case of the Segara Anakan lagoon).

Historical maps in fact provide a treasure of information that has barely been utilised to date in many parts of the world. Nearly half a century ago, Koeman (1968) and Harley (1968) remarked that historical cartography had focussed on carto-bibliography and map-makers' biographies, while the value of historical evidence contained in maps was largely neglected. Since then, historical cartographers have still expanded the knowledge of historical maps, their producers and the processes of their production, and the digitization and reproduction of archival material has tremendously enhanced the accessibility of historical maps. In the case of Java, the work by historical cartographers, like Schilder (1976, 1978, 1981), the publication of a number of brilliant atlases with facsimile reproductions of and background information about a large amount of historical maps (Knaap et al. 2007, Roever & Brommer 2008, Schilder & Kok 2010, Schilder et al. 2006, Suárez 1999, van Diessen & Ormeling 2003), and the map collections of, among others, the Royal Tropical Institute and The Netherlands National Archives provide an outstanding basis for research into historical environmental changes. Furthermore, GIS facilitate accuracy assessments of historical maps and their linking with recent spatial information.

An increasing number of studies demonstrate the utility of historical maps for analysing historical environmental conditions and changes. Historical maps have been used to analyse a broad range of environmental phenomena, including coastal features (Crowell et al. 1991, Hadisumarno 1964, 1979, Hermawan 2003, Jabaloy-Sánchez et al. 2010, Levin 2006, Marfai et al. 2008, Monmonier 2008, Sudarsono 2011), land use and structural landscape characteristics (Haase et al. 2007, Schaffer et al. 2015, Stäuble et al. 2008, Varga et al. 2013), settlement processes (Levin et al. 2010), agricultural histories (Pearson & Collier 1998), soil degradation (Brookfield 1999), salt marsh losses (Bromberg & Bertness 2005), river channel changes (Słowik 2013), and historical sites of industrial production and pollution (Leonard & Spellane 2013). Historical maps can also help to verify or dismantle narratives about past environmental changes and political events (e.g., Brookfield 1999; Pearson 2005). Yet, most of the potential that historical maps combined with the knowledge about these maps created by historical cartographers provide for reconstructing historical environmental changes remains unrealised to date.

Notwithstanding the large potential of historical maps for analysing environmental changes, their limited availability and accuracy pose constraints. The further an analysis is extended into the past, the larger these constraints. This is a dilemma, given that analyses of environmental changes are particularly meaningful if they incorporate transitions from mainly nature-dominated to mainly human-dominated landscapes (cf. Batterbury & Bebbington 1999, Messerli et al. 2000). In many parts of the world, the era of reasonably accurate, area-wide mapping did not start before the beginning of the era of major anthropogenic environmental change. Hence, there is an interest (and it was also my aim in this research) to expand the historical-cartographic analysis of environmental changes as far back as the availability and accuracy of the earliest maps allow. In addition to a large temporal scale, also a large temporal resolution of analysis contributes to a better understanding of environmental changes.

Maximising the temporal scale and resolution of analysis requires a particularly intensive engagement with the cartographic history of the target region and with questions of map accuracy. Compiling a systematic and complete account of historical maps of the target region, gathering knowledge about map makers and map making processes, and documenting the gradual evolution of cartographic knowledge over time (an approach termed the carto-genealogical method, see Harley 1968, Rubin 1990) helps to maximise the scale and resolution of analysis and to evaluate the maps' reliability. It also exposes the (unacknowledged) borrowing of (accurate as well as erroneous or outdated) information between map makers, which occurred throughout history (see e.g. Crone 1961, Pedley , Polk 1995). This is crucial to avoid potential biases. Previous studies that reconstructed the historical shorelines in the Segara Anakan region illustrate some of the pitfalls caused by a lack of attention to map making processes and the copying of information (see Chapter 2.3.2).

Such intensive engagement with cartographic history, with questions of map accuracy and with the methods of accuracy assessment poses a challenge for scholars who are rooted in non-cartographic research fields. Yet, I argue, and as my research illustrates, that this engagement is necessary and can be fruitful. Research Papers 1 and 2 of this thesis show that such engagement not only improves the scope, resolution and accuracy of the analysis of historical environmental change, but can also contribute to historical cartography, for example, by providing insight into the gradual development and replication as well as the ignorance of cartographic knowledge and by evaluations of map accuracy in light of the maps' utilisation for reconstructing historical environmental change.

Such reconstructions are confronted with cartographic material of varying levels of accuracy. The temporal scale of most studies has been confined to the periods covered by maps that are sufficiently accurate for georectification and quantitative analysis (exceptions include Forbes et al. 2004, Winterbottom 2000). The engagement with earlier, less accurate maps and related carto-bibliographies, map making processes and map-makers' records, in contrast, has largely remained the domain of historical cartographers, with limited application in historical environmental research. Research Paper 2 of this thesis demonstrates that a qualitative analysis of early, less accurate maps, combined with an exploration of the processes of their production and a review of map-makers' records, can contribute at least qualitative information about environmental conditions prior to the production of more accurate maps. An important question at the intersection of historical cartography and research fields like historical political ecology or environmental history is: how accurate does the cartographic material need to be, at minimum, in order to be used for which kind of analysis? This question is addressed in Research Paper 1.

4.4 Combining approaches: The core of this research

As Chapters 1 and 2 have shown, in Java, one of the global hotspots of riverine sediment transport to the oceans and perhaps one of the global hotspots of related watershed management efforts, simplistic narratives continue to dominate societal discourses about upland degradation, river water flows and coastal sedimentation. The knowledge of watershed processes in Java in general, and of the causes of high river sediment loads and the sedimentation of the Segara Anakan lagoon in particular, is limited. LUCC and its causes also remain underexplored. No watershed-wide analysis of the various sediment sources, their underlying causes, and their relative roles has been undertaken, and the existing pieces of knowledge are fragmented between different scientific communities. In the absence of adequate knowledge, these processes have been framed by narratives, with a focus on blaming cultivation practices on upland farmers' private plots as the single-most important watershed-related issue, as the major cause of high river sediment loads, lagoon sedimentation, seasonal water shortages, and flooding. With regard to river sediment loads and lagoon sedimentation, these narratives are not completely false, but they provide only a partial, misleading explanation. The decade-long persistence of these narratives is obviously related to political factors and the confinement of research agendas in line with these narratives, with the latter rendering further inquiry into the other causes of high river sediment loads unnecessary. The lack of intersection between scientific communities and the lack of interdisciplinary approaches have contributed to impede the generation of adequate knowledge, for example, with sediment yields measured by river engineers, on-site erosion measured by agronomists (cf. Bruijnzeel 2004) and the other sediment sources being neglected; with land cover changes detected by remote sensing specialists without adequate ground truthing and without any inquiry into the drivers of LUCC; with historical trajectories of watershed transformations being neglected; and with a lot of research being confined to the Segara Anakan lagoon without looking into its catchment area, from where the riverine fluxes that affect the lagoon originate.

This situation and the complexity of the watershed processes with a large range of interwoven factors calls for geographical research that works across scales, that analyses spatial patterns and dynamics throughout the entire catchment, that integrates historical trajectories, and that combines approaches and existing evidence from different disciplines or research fields in analysing both (1) the material environmental dynamics and their drivers, and (2) the related political interests, framings and responses. Without the first, there is no adequate basis for a critical evaluation of the second. And without the second, some of the drivers of the material environmental dynamics, the links between political framings, knowledge generation and political interventions, and the (political) challenges of watershed and coastal governance would remain hidden.

My primary point of departure was to contribute to an improved understanding of the social-ecological dynamics and their drivers, the factors underlying the dominant framings of watershed issues, and the environmental governance-related challenges that have been sketched above and in Chapters 1 and 2. This attitude facilitated my integration of various approaches and methods as they appeared helpful without too many prejudices and considerations of boundaries between disciplines or research fields. Integration of different approaches is a core feature of this thesis. This approach proved fruitful and challenging at the same time.

My research links several core themes of political ecology: It critically explores political framings of environmental issues, their formation and persistence and related modes of political action; it analyses struggles over resource access and control and directly links them with material environmental conditions and changes; it incorporates and contributes to the debate on geographical scale; and it links the modes of watershed governance to the roles, interests and power relations of various actors and broader political dynamics. The research connects these political ecology themes with land change science, debates on tenure and LUCC, and historical cartography. The combination of approaches and methods allowed for cross-validation and cross-fertilisation. Many of the major research results were generated through the combination and at the intersections of these research themes and approaches. For example, without my satellite image-based analysis of LUCC throughout the lagoon's catchment area, I would not have uncovered various cases of historically rooted struggles of resource access and control that caused LUCC and degradation. Without political ecology-infused social-scientific field research, the results of the satellite image processing would not offer much insight. Without the historical-cartographic reconstruction of lagoon shoreline aggradation, my exploration of the various watershed transformations and potential sediment sources would not have much meaning. At the same time, the different parts of the research also contribute to debates within the distinct research fields outlined above, and the related research papers have been published in or submitted to corresponding journals.

While fruitful in these various ways, the integration of such a large range of different approaches and methods and of knowledge from numerous research fields, combined with the large size of the research area and the very open-ended, multi-scalar character of the research, proved highly challenging. To be sufficiently rooted in various strains of literature on topics as diverse as, for example, political ecology approaches, debates on geographical scale, land change science, the methods of satellite image processing and map accuracy assessment, historical cartography, soil erosion and riverine sediment transport, forest and watershed management, and the colonial history of Java, on its own was time-consuming. Conducting this research in a way that meets the methodological standards of the various research fields incorporated and analysing the large range of empirical material was also challenging and could have been the task of a whole research team. Notwithstanding these challenges, I would integrate the same approaches if I were to conduct this research again.

4.5 Scales of analysis

Section 4.1.3 shed light on the human-geographical debate on the social construction of scale. It noted that conceptual insights from this debate can support the analysis of the scalar configurations of political framings, knowledge production and political action in watershed contexts. It also highlighted that this can help to explain the long-lasting confinement of watershed-related research and political action in Java to the scale of contemporary upland peasants' private plots (an aspect that is further explored in Research Paper 7).

This section briefly explores considerations regarding the choice of my own analytical scales in analysing watershed and coastal processes and their drivers, i.e. considerations regarding the choice of my own observational scales. In order to avoid being trapped by existing political framings, these obviously must not be confined to contemporary upland peasants' private plots. As explored in Chapters 1 and 2, debates on the causes of high river sediment loads in Java and the sedimentation of the Segara Anakan lagoon have focussed on upland peasants' contemporary private agricultural plots, i.e. on one of various sediment sources in a contemporary snapshot, while the whole range of other sediment sources and watershed transformations, including LUCC, throughout the entire catchment area, their underlying causes and the historical dimension have been largely neglected. Consequently, my own research aimed at covering larger scales deemed most relevant for gaining an improved understanding of the social-ecological processes related to high river sediment loads and lagoon sedimentation. Which scales seemed most relevant? Which social-ecological processes was I able to analyse at which scales?

Depending on its scales of analysis, research can generate different results (cf. Batterbury & Bebbington 1999). For example, broader scale land cover change analyses based on low resolution satellite images or official statistical data and selected macro-level indicators yield different findings than case studies based on high resolution satellite images or aerial photographs and intensive field research. The study of LUCC in the whole of Java by Verburg et al. (1999), which was discussed in

Section 2.3.3, illustrates the risk of producing misleading results if the scale of analysis is too broad. As explored in Section 4.2, the fact that broader-scale LUCC analyses based on remote sensing and macro-level indicators often failed to provide sufficiently rich insight into the various causes of LUCC has been acknowledged and started to be addressed since the mid- to late 1990s. At the other extreme, conducting a single village-level case study within the catchment area of the Segara Anakan lagoon could potentially provide rich insight into local social conditions and dynamics and their effects on land use practices, but without gaining any overview of LUCC and its various drivers throughout the entire catchment area.

My research therefore combined an analysis of LUCC based on remote sensing and land use/cover mapping throughout the entire catchment area of the Segara Anakan lagoon with a series of case studies that explored the drivers of these LUCC through social-scientific field research, with the LUCC patches detected in the satellite images as starting points, but also paying attention to local LUCC not visible in the satellite images. The spatial scale of my analysis of physical LUCC hence comprised the entire catchment of the Segara Anakan lagoon. This was complemented with additional insights from local-level case studies. With regard to the temporal scales of my analysis, from the beginning I tried to take into account historical trajectories, and approach which repeatedly proved necessary and fruitful over the course of the various parts of the empirical research. The temporal scale of the area-wide LUCC analysis was confined by the availability of the earliest satellite images for the entire catchment area, starting with Landsat MSS in the 1970s, and the earliest historical maps (from the 1920s) that comprised sufficiently detailed land use/cover information and that were utilised in the frame of some of the case studies. In exploring the drivers of LUCC I did not a priori confine the scales of analysis, but started from the physical LUCC observed and flexibly explored their drivers going back in time and expanding in terms of spatial-hierarchical scales as it appeared relevant during the empirical research.

In addition to LUCC, I explored a broad range of watershed characteristics and transformations, with the major aim of providing an overview of an as large as possible range of causes of high river sediment loads. This part of the research aimed at broadening the view, which had mainly been confined to upland farmers' private plots to date, to the entire catchment area and a broad range of sediment sources and altered sediment transport dynamics. It incorporated findings from the LUCC analysis, observations of watershed characteristics made during a number of extensive field research periods, semi-structured interviews with various actors, historical maps, and information from different strands of literature. The analytical scale of this part of the research encompassed the entire catchment of the Segara Anakan lagoon, although information from particular localities as well as coarser information related to the whole of Java was incorporated since data, particularly about longer-term developments is limited. The temporal scale of analysis extended as far back as the availability of information allowed. Similarly, my analysis of the temporal dynamics of lagoon shoreline aggradation extended as far backwards in time as the availability and accuracy of satellite images and historical maps permitted.

Both the analysis of lagoon shoreline changes and the exploration of watershed transformations were confined by the availability of historical maps and records to the period from the mid-19th century onwards. This analytical time scale corresponds to the period of unprecedented anthropogenic transformations in large parts of the study area (see Research Paper 3), and hence covers a major transition phase from a comparably more nature-dominated to a comparably more human-dominated landscape, which potentially supports an appraisal of the various drivers of change (Messerli et al. 2000). This analytical time scale also marks a period that Cooke (1992) referred to as the 'recent past' that is often neglected in favour of studies on either long-term or contemporary environmental dynamics. Knowledge of both lagoon sedimentation and watershed transformations over this period is limited to date (see Section 2.3).

To sum up, with the aim of my own observational scales resembling the operational scales of a broad range of social-ecological processes as closely as possible, my research combined various analyses at a range of different scales. It aimed at broadening the view spatially, temporally and hierarchically (beyond the upland farmers' private plots) onto a larger range of social-ecological processes that are relevant for an improved understanding of the dynamics and causes of high river sediment loads and lagoon sedimentation.

5 Research methods

The research combined remote sensing, land use/cover mapping, transect walks, and the analysis of historical cartographic material with an analysis of literature and documents, semi-structured interviews with a large range of actors, from local residents to representatives of organisations from various political levels, and a few focus groups. The conceptual approaches upon which this combination of methods is based and considerations regarding the chosen scales of analysis, were discussed in Chapter 4. The following sub-sections briefly describe the various methods used.

5.1 Analysis of literature and documents

As noted above, knowledge about watershed processes and transformations and coastal sedimentation and their temporal dynamics and drivers is scarce. Furthermore, the existing pieces of knowledge are fragmented between different natural- and social-scientific communities, such as historians and a few political ecologists who analysed colonial policies and land and forest management, soil scientists who measured erosion on individual plots and constructed sediment budgets for small sub-watersheds in other parts of Java, and researchers whose work focussed on the coastal area, i.e. the Segara Anakan lagoon, without looking into the adjacent catchment areas. One part of my research reviewed and linked information from these and various other strains of literature and connected them with my own empirical results. This linking of numerous isolated pieces of knowledge helped to compile a more comprehensive picture of the various watershed transformations that occurred since the mid-19th century and of sediment sources, thereby broadening the understanding of the large range of drivers of coastal sedimentation. This is particularly reflected in Research Paper 3.

As briefly explored in Section 2.2, the Segara Anakan lagoon and its catchment have long been a hotspot of environmental management interventions. One part of my research focussed on gathering and reviewing a large number of documents compiled in the frame of these interventions. Combined with the semi-structured interviews conducted with a broad range of actors this document analysis served to provide insight into the spatial-temporal and thematic shifts of political intervention throughout the region, the related political interests and framings, and the effects of these interventions. The results of this part of the research were mainly incorporated in Research Papers 3, 7 and 8.

5.2 Reconstruction of lagoon shoreline changes

To analyse the historical dynamics of sedimentation of the Segara Anakan lagoon, I reconstructed historical shorelines and determined changes in the lagoon's water surface area, based on satellite images and historical maps. As noted in Sections 4.3 and 4.5, I aimed at maximising the temporal scale and resolution of this analysis. This necessitated a thorough exploration of the cartographic history of the region and intensive engagement with questions of map accuracy, and exposed the limits of quantitative and qualitative cartographic analyses of historical environmental change.

I gathered an as complete a set of historical maps of the area as possible, ordered them in a temporal sequence, connected them with information on map makers and map making processes, assessed their accuracy, and identified similarities and differences between the various maps. I thereby analysed the evolution of cartographic knowledge over time, paying attention also to the borrowing of information between map makers and the ignorance of cartographic knowledge by subsequent map makers. In total, I gathered more than 50 historical maps and map series produced between the 16th century and the 1950s from various libraries and archives worldwide. My most important sources of historical maps and related background information included: The Netherlands National Archives, the Netherlands Royal Tropical Institute, the National Library of Australia, the Indonesian National Library, the German National Library, the Bayerische Staatsbibliothek, the Sächsische Landes-, Staats- und Universitätsbibliothek, the Earth Sciences and Map Library of the University of California at Berkeley, the Perry-Castañeda Library at the University of Texas, and a number of other libraries and antiquarian shops worldwide; as well as publications of previous research by historical cartographers (Schilder 1978, 1981, Thomaz 1995) and a number of atlases containing facsimile reproductions of historical maps and related background information (Knaap et al. 2007, Schilder et al. 2006, van Diessen & Ormeling 2003). In addition, I analysed the notes and reports made during the early mapping voyages by Cornelius Coops in 1698 (Coops 1698) and Albert van Petten in 1711 (contained in de Haan 1911). Providing a complete account of all maps and map series gathered would go beyond the scope of this thesis. An overview of those maps that contributed additional topographic information to previously existing maps, along with related background information, is provided in Research Papers 1 and 2.

In an effort to gather updated topographic information for the period between the topographic surveys in the 1920s and the recording of the first Landsat satellite images in the 1970s, an extensive search for aerial photographs possibly recorded by air force commandos during World War II was conducted. However, no relevant material could be retrieved from any of the more than 30 libraries, archives, military and other organisations searched or contacted worldwide. For the period from 1962 until 2013, an image of the Corona mission, an optical reconnaissance satellite mission launched in 1962 by the U.S. Air Force, and a series of Landsat MSS, TM and ETM+ images were gathered from the U.S. Geological Survey and from BTIC Dataport, Indonesia. In addition, a number of SPOT images were acquired.

An accuracy assessment was conducted for the historical maps, paying attention to four different dimensions of map accuracy (cf. Blakemore & Harley 1980, Jenny & Hurni 2011, Laxton 1976, Levin 2006): (1) topographic accuracy, (2) chronometric accuracy, (3) geodetic accuracy (or coordinate grid accuracy), and (4) planimetric accuracy (or feature or geometric accuracy). For the planimetric accuracy assessment and the subsequent shoreline reconstruction, selected maps (see Table 1 in Research Paper 2) were scanned, if not acquired in digital form. The single map sheets of the map series were either aligned manually using Adobe Photoshop (maps from 1857/60 and 1897/1901) or processed separately (maps from 1924/26). The maps and the Corona image were georectified in ArcGIS, based on the most recent topographic maps (Peta Rupabumi, 1:25,000, produced by BAKOSURTANAL in 1997/98, based on surveys in 1993/94), using UTM Zone 49S (WGS 1984) as a common grid coordinate system, and performing 1st, 2nd, and 3rd order polynomial transformations. Depending on the topographic accuracy of the maps and the magnitude of environmental change, between 11 and 31 ground control points were used for georectification. Most ground control points were identified based on topographic features, such as river intersections, bays, and capes (see Figure 5 of Research Paper 1 for an example). The resulting root mean square error (RMSE), the residual error after transformation, is influenced by inaccuracies related to scanning resolution, the selection of control points, and possible though negligible geodetic inaccuracies, but can be assumed to mainly reflect the historical maps' planimetric accuracy.

Based on this quantitative as well as on a qualitative area- specific accuracy assessment, the historical maps from 1857‑60, 1897‑1901, and 1924/26 (3rd order polynomial transformation) and the Corona image were identified as suitable for a quantitative shoreline change analysis. These maps, the Corona image and a number of Landsat images and a SPOT image, which were georectified with negligibly small RMSEs if not acquired in pre-processed form, were overlayed in ArcGIS. On this basis, historical shorelines were manually delineated.

The suitability of historical maps for analysing environmental changes not only depends on the maps' accuracy, but also on the magnitude of the environmental changes (cf. Levin 2006). Therefore, the environmental change rates were in a next step linked with the quantitative map accuracy measures to assess the maps suitability for this analysis and to evaluate the reliability of results. This has not often been done in previous studies. While some work by historical cartographers has been entirely devoted to the analysis of map accuracy, (Bönisch 1967, Jenny 2006, Jenny & Hurni 2011, Nell 2009), scholars from other disciplines who used historical maps for analysing environmental changes did not always link their results with map accuracy measures, although they provided georectification errors (Bromberg & Bertness 2005, Jabaloy-Sánchez et al. 2010, Khromova et al. 2006; see Levin 2006 for an exception). Based on the shoreline change analysis and the map accuracy assessment, I proposed and determined ratios between environmental change rates and planimetric map accuracy and combined uncertainty measures as quantitative indicators for the suitability of the historical maps for analysing historical environmental changes. The resulting ratios and measures and the steps of their calculation are contained in Research Paper 1.

In a next step, I determined the lagoon's historical water surface areas, based on the shoreline delineations and using the analytical tools of ArcGIS. Based on the quantitative map accuracy measures and the shoreline lengths, I determined an areal error as a measure of the reliability of results. The method of calculation and the results are contained in Research Paper 3.

In addition to this quantitative analysis of satellite images and the more recent historical maps, I used the earlier, less accurate maps, along with some of the map makers' records, for a qualitative analysis. The results thereof and a discussion of the potentials, limits and pitfalls of historical cartographic analyses of historical environmental change are contained in Research Paper 2.

Given the lack of historical bathymetric data, my reconstruction of the temporal dynamics of lagoon sedimentation is confined to providing only a two-dimensional picture. This and the other limitations of this analysis are discussed in Research Papers 1 and 3.

5.3 Analysis of LUCC in the lagoon's catchment area

Sections 4.2 and 4.4 already explored how I conceptually linked land change science and political ecology. To analyse the dynamics and drivers of LUCC, I combined an area-wide analysis of satellite images and land use/cover mapping throughout large parts of the catchment area with case studies that comprised semi-structured interviews, focus groups and transect walks and in some cases also incorporated an analysis of historical maps and more recent high resolution satellite images.

In a first step, I identified areas with LUCC throughout the lagoon's catchment area, based on visual analysis of satellite images and the results of land use/cover mapping. For this purpose, satellite images (Landsat MSS, TM, ETM+ from the U.S. Geological Survey and from BTIC Dataport, Indonesia and SPOT 1, 2, 3, 5) taken between 1976/78 and 2007/2011 were acquired. As determined by the availability and quality of the images and aiming at covering the entire catchment area with three analytical intervals of similar length, I selected images from 1976/78 (Landsat MSS), 1991 (Landsat TM), 2001 (Landsat ETM+), and 2006/07 (SPOT 2 and 5) as the main basis for the analysis. In order to compensate for cloud cover in a few areas within this set of images and to later increase the temporal resolution of analysis for the LUCC areas identified based on this set of images, I also included the other satellite images in ArcGIS.

I acquired the most recent topographic maps at a scale of 1:25,000[2] from the national state mapping agency. A total of 41 map sheets were needed to cover the Segara Anakan lagoon and its entire catchment area. These maps were scanned, cropped using Coral Draw, and georectified in ArcGIS. On the basis of these topographic maps and pre-processed satellite images, I georeferenced the satellite images that were not acquired in georectified form. I then generated false colour composites from the green, red and near infrared bands of the satellite images.

Following a first visual analysis of the major land cover patterns visible in the satellite images, I mapped land use/cover throughout large parts of the catchment area, using a camera to document land use/cover, a GPS to track the mapping locations, topographic maps to record place-based information, a notebook to record observations and information retrieved in the frame of spontaneous interviews conducted with residents, and a motor cycle as a means of transport.

In a next step, I visually interpreted the satellite images again, taking into account the results of the land use/cover mapping to gain a thorough overview of the major land use/cover patterns throughout the region. I then identified the areas with LUCC by visual analysis through flicking between images and identifying differences between them, particularly in tone, texture, patterns and shapes (Campbell & Wynne 2011, Lillesand et al. 2008) and taking into account the results of the land use/cover mapping and my already fairly intimate knowledge of the area. In this way, I identified and delineated a total of 297 LUCC areas throughout the catchment area (see Figure 2). In a next step, I overlayed these LUCC areas onto the topographic maps, partitioned this data into map sheets and used them in printed form during the social-scientific case studies conducted thereafter.

The case studies verified the LUCC identified in the satellite images, explored the LUCC dynamics in more detail at the local level and particularly analysed the drivers of the LUCC. In selecting case study areas, I aimed at covering the different parts of the catchment area, some of the hotspots of LUCC and erosion-prone land, and a wide variety of different cases. The case studies covered 60 of the 297 LUCC areas identified (see Figure 2).

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[2] Peta Rupabumi, produced by the Badan Koordinasi Survey dan Pemetaan Nasional (BAKOSURTANAL) in 1997-98, based on surveys carried out in 1993-94, 1:25,000, 41 map sheets.

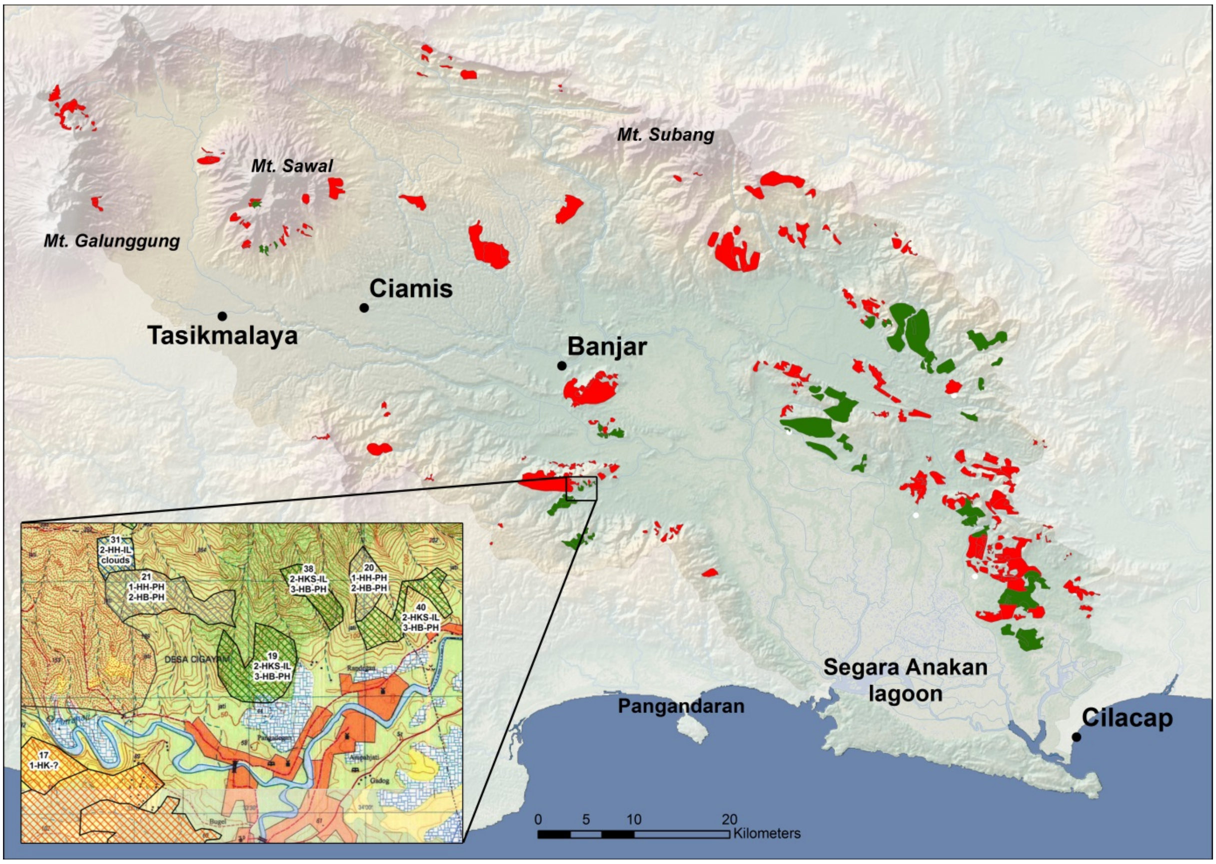

Figure 2: LUCC areas identified based on the analysis of satellite images. 60 (green signature) of the 297 LUCC areas were covered by the case studies.

To further specify the timings of some of the LUCC (i.e. to increase the temporal resolution of analysis), I also looked at some of the other satellite images prior to or while conducting the case studies. In addition, I analysed historical topographic maps for the case study areas to extend the temporal scale of analysis further into the past. These maps were acquired from the Indonesian National Library and the Netherlands Royal Tropical Institute: (1) one map series from 1910-15, comprising 21 map sheets at a scale of 1:20,000[3] covering parts of the catchment area, and (2) one map series based on survey data from the 1920s[4], comprising 23 map sheets at a scale of 1:50,000. All these map sheets were scanned, georectified and overlayed with the satellite images and the more recent topographic maps in ArcGIS. Using these historical maps in addition to the satellite images proved particularly valuable in the case studies that documented LUCC that was rooted in the dislocation of entire villages in the 1950/60s (see Research Paper 4).

In the frame of the case studies, I conducted semi-structured interviews with village representatives, community groups, farmers, elderly people, and other village residents as well as with representatives of district and sub-district governmental organisations, the local offices of the state forest corporation, and non-governmental organisations. The interviews were mostly conducted in Indonesian. In a few cases, where elderly people were not fluent in Indonesian, the interviews were partly con-

[3] Java, Res. Preanger Regentschappen, Topographische Inrichting Batavia, 1910-15, 1:20,000, 21 map sheets, Netherlands Royal Tropical Institute (KIT)

[4] Topographical map of Java, Middle (and West), TDNI, Land tax revision brigades; 1:50,000, reprints from 1938-42, 23 map sheets, Netherlands Royal Tropical Institute (KIT), Indonesian National Library.

ducted in Javanese or Sundanese. During most interviews I was accompanied by students from the Universitas Gadjah Mada, Yogyakarta and the Universitas Jenderal Soedirman, Purwokerto, who translated at times when I was not able to (entirely) comprehend respondents' replies.

The interviews took an inductive approach, especially during the first part, with broad, open-ended questions. An English version of an example of an interview guideline is provided in the Appendix. These broad, open-ended questions only served as a starting point. Depending on the information provided, the interviews then covered various issues and dynamics as they appeared relevant in explaining the causes of LUCC and in exploring watershed dynamics and environmental management approaches. In most cases, the respondents started to provide information related to the specific LUCC areas that I had identified in the satellite images without being prompted to do so. I then tried to steer the discussion by asking more open-ended questions about these particular LUCC areas, without providing information about the changes that I had detected in the satellite images and without showing my LUCC maps. This approach provided an excellent opportunity to cross-validate the information provided by the respondents with the results of my LUCC analysis. In almost all cases, the information provided by the respondents seamlessly matched the results of my LUCC analysis, and there was no case where small deviations could not be clarified. During the last part of the interviews, I incorporated the LUCC maps and discussed the results of my satellite image analysis with the respondents. This usually generated additional discussion and provided the opportunity to further specify information about the timing, drivers and specific localities of LUCC. In this way the results of the satellite image processing and of the semi-structured interviews, the information about physical environmental changes and their causes and the related societal dynamics as well as the spatial and non-spatial pieces of information were directly linked and constantly cross-validated. The direct linking of these different kinds of information from different sources also provided opportunities for cross-fertilisation.

The semi-structured interviews were complemented by transect walks to gain a more detailed overview of local land use/cover patterns and to discuss these patterns and the LUCC changes with local residents on-site. In some case studies, focus groups were also conducted with between three and seven village residents. These focus groups covered the same topics as the semi-structured interviews, used questions from the same interview guidelines as a starting point and served to gather information and viewpoints from a number of respondents at once and to generate discussion among them which led to issues being discussed that might not have come up in face-to-face semi-structured interviews. During my stays in the case study areas I obtained additional insights in the frame of informal discussions with my hosts and various people met coincidently as well as by observation of village conditions, village life and the interactions of different actors, for example between villagers and staff members of the state forest corporation. This undoubtedly supported my understanding of many of the dynamics (and particularly of the conflicts) analysed.

The results of the satellite image- and case study-based LUCC analysis are presented in Research Papers 4, 5 and 6. Research papers 3, 7 and 8 also include selected results of this part of the research in a condensed form.

5.4 Observations and analysis of watershed characteristics and dynamics

In addition to the satellite image- and case study-based LUCC analysis described in the above section, I observed and analysed various other watershed characteristics and dynamics during field research stays in the area, some of which lasted for several months. These observations have been incorporated in various research papers, particularly in Research Paper 3. They include observations of land cover patterns and land uses; of forest management practices; of sediment sources, such as road cuts, trails, settlement areas, and agricultural and forest land; of landslides and the condition of riparian zones; and of other landscape modifications. The latter include the gradual expansion of wet rice fields in valley floors by digging back the foot of the hill slopes and discarding the excavated soil into channels and streams. This practice, which is called 'ngaguguntur', contributes to increased river sediment loads. In the frame of one of the case studies I mapped the area transformed by ngaguguntur in order to get an idea of the approximate magnitude of the contribution of this practice to river sediment loads. In addition, I estimated the change in the total area covered by settlements in the entire catchment area by comparing historical topographic maps reflecting the situation in the 1920s[5] with the recent topographic maps[6] from the 1990s. Using the classification tools in ArcGIS, I extracted the settlement areas from each of the 23 + 41 digitised map sheets separately, converted them into shape files, simplified and manually corrected them, and calculated their total sizes.

5.5 Semi-structured interviews with representatives of governmental and non-governmental organisations

In addition to the semi-structured interviews conducted in the frame of the watershed case studies (see Section 5.3), I conducted semi-structured interviews with representatives of the river basin and watershed management authorities; the Segara Anakan lagoon management authority; regional planning authorities at the district and province level; environmental protection agencies, agricultural extension offices and river management offices at the district level; the state forest corporation on various levels from local field offices to the national headquarter; the Ministry of Forestry; and a number of national and regional non-governmental organisations. These interviews covered various issues related to forest, watershed and lagoon management.

6 Summary of major results and introduction to the research papers

The research results, discussion, links with the literature, and related conclusions are contained in the eight research papers that are presented in the following and main part of this thesis. As such, they are not repeated here. Rather, this chapter is confined to briefly summarising selected results across the different research papers. Its main purpose is to introduce and connect these papers.

One part of the research project reconstructed the historical dynamics of shoreline aggradation in the Segara Anakan lagoon. The siltation of the lagoon has been the subject of major concern and of costly political interventions for decades. Yet, the knowledge of its historical dynamics and its drivers is limited. To reconstruct shoreline aggradation with as large a temporal scale and as high a temporal resolution of analysis as possible, I engaged intensively with the cartographic history of the region. This engagement not only supported my analysis of shoreline changes, but vice versa, my intensive

[5] Topographical map of Java, Middle (and West), TDNI, Land tax revision brigades; 1:50,000, reprints from 1938-42, 23 map sheets, Netherlands Royal Tropical Institute (KIT), Indonesian National Library.

[6] Peta Rupabumi', produced by the Badan Koordinasi Survey dan Pemetaan Nasional (BAKOSURTANAL) in 1997-98, based on surveys carried out in 1993-94, 1:25,000, 41 map sheets.

engagement with the historical maps in reconstructing environmental changes also contributed to historical cartography. It provided insight into the production, replication, gradual development, and ignorance of cartographic knowledge (Research Paper 2). It showed how topographic information from complete but comparably inaccurate maps was repeatedly reproduced over long periods of time, while information from more accurate but incomplete maps was continuously ignored. It also revealed that historical maps that are valued as the most accurate and most complete of their time can comprise sections that only represent information borrowed from the least accurate earlier maps existing (Research Paper 2). Such insights, along with a careful analysis of map accuracy, are crucial in using the maps' contents for reconstructing historical environmental changes.

One of the core issues that I encountered during the research process was the question of how accurate historical maps must be at minimum in order to be used for what kind of analysis. This question has barely been debated in the literature to date. It is addressed in Research Paper 1. This paper presents a methodological approach to analysing historical spatial information with varying degrees of accuracy. It proposes ratios between the rates of environmental change and quantitative map accuracy measures as indicators of the maps' analytical suitability, as well as combined uncertainty measures as indicators for the reliability of results. The paper demonstrates that in case of large magnitudes of environmental change, and especially in case of single-directed spatial changes, an analysis of even fairly inaccurate historical maps can provide results with low levels of uncertainty. Yet, large magnitudes of environmental change, particularly if combined with relatively low levels of topographic map accuracy, can also constrain the analysis of historical maps. Research Paper 1 presents (to my knowledge) the first quantitative accuracy analysis for historical maps of Java. However, it also shows that quantitative accuracy assessments should be combined with a qualitative appraisal taking into account carto-bibliographic information and the different dimensions of map accuracy.

The material and results presented in Research Papers 1 and 2 demonstrate the large but underutilised potential of the historical cartographic material of insular Southeast Asia for research into environmental histories. While Research Paper 1 reconstructs shoreline aggradation in the Segara Anakan lagoon based on the more accurate, quantitatively analysable maps from the mid-19th century onwards and on a series of satellite images, Research Paper 2 extends the analysis further back into the past (up to the late 17th century), based on a qualitative analysis of earlier maps and map makers' records, an approach that has barely been applied to date in studies of historical environmental change. It demarcates the limits and illustrates potential pitfalls of historical cartographic inquiry into environmental change.

The results of the shoreline change analysis presented in Research Paper 1 illustrate the rapid pace of lagoon siltation. They provide a two-dimensional picture of its temporal dynamics since the mid-19th century. Based on these results and taking into account uncertainty measures, I computed historical water surface areas, which are presented in Research Paper 3. Accordingly, the lagoon's water surface area declined by about three fourths between 1857/60 and 2013. The pace of this process accelerated between 1857/60 and the late 1980s / early 1990s and slowed thereafter. This analysis, whose analytical time scale was confined by the earliest, quantitatively analysable maps, covers perhaps the most important period, for it documents a transition from relatively slow aggradation in the 19th century to more rapid aggradation thereafter.

Research Paper 3 links these temporal dynamics of shoreline aggradation in the Segara Anakan lagoon with a record of environmental transformations in its catchment area. It shows that the period around the mid-19th century marked the beginning of particularly profound anthropogenic transformations in this region. Thus, the periods of intensifying anthropogenic impact and of the production of the earliest, quantitatively analysable maps approximately coincide in this region. The relative timings of intensifying anthropogenic impact and of enhanced mapping in large part determine the fruitfulness of cartographic inquiry into environmental histories. In other parts of Java where anthropogenic impacts were more profound at a much earlier time, some of the major transformations are not covered by the earliest quantitatively analysable maps.

The account of historical and contemporary watershed characteristics and transformations provided in Research Paper 3 shows that accelerated lagoon siltation was the result of a much broader range of drivers than commonly presented in political and scientific debates. In addition to rainfed agriculture on farmers' private lands, these drivers include compulsory coffee cultivation in the 18th and particularly 19th century; timber extraction, infrastructure developments, plantation development and in-migration between the mid-19th century and the 1920s; clearing of state forests and plantations in the 1940/50s; contestations of state forests and plantation lands; state forest management practices; slope cuts to enlarge the area of irrigated rice fields in valley floors; agricultural use of riparian zones; erosion and mass-movements from roads, trails and settlements; volcanic eruptions; and river channel and floodplain modifications. More information on all these drivers and a discussion of factors that may have slowed lagoon siltation are contained in Research Paper 3. LUC(C) and degradation on state forest and plantation lands and on peasants' private lands and their causes and related implications are explored in detail in Research Papers 4-6.

Quantifying the effects of these various drivers goes beyond the scope of the research presented here, would require a large research team involving the natural sciences, and generally remains a major challenge for such large river catchments worldwide. Notwithstanding this limitation, the synopsis of watershed characteristics and modifications presented in Research Paper 3 provides a more complete picture of the causes of lagoon sedimentation than has been drawn to date. It shows that the sole blaming of contemporary upland peasants' private plots for high river sediment loads and coastal sedimentation is too simplistic as it neglects a large range of other sediment sources. The findings suggest that both the choice and expectations of interventions aimed at reducing river sediment loads and coastal sedimentation need to be reconsidered and that related debates and research agendas must be broadened (see Research Paper 3). High river sediment loads and coastal sedimentation have to be seen as a result of not only present characteristics of particular sections of the landscape, i.e. peasants' private agricultural plots, but of a whole record of historical landscape modifications throughout the entire catchment area. Accordingly, the possible effects of increased tree cover and soil conservation measures on peasants' private lands on downstream sediment loads, though highly desirable for the sake of sustaining soil productivity, are more limited than commonly assumed.

Yet, peasants' private lands do constitute an important sediment source, and soil degradation on some of these lands is an issue. The effects of the long-standing regreening and watershed management programmes with regard to tree cover on farmers' private lands remained relatively limited until the 1990s. Since then, tree cover on peasants' private lands has increased in many parts of the catchment area, as my research has shown (see Research Paper 6). My case studies revealed that this trend is the result of various partly interwoven factors, including rising timber prices, peasants' generally increased interest in perennial crops, off-farm employments enabling them to shift from annual to perennial crops, experiences with declining soil fertility, and the presence of local marketing opportunities for timber. The regreening and watershed management programmes have also supported this trend. Over time, they have contributed to increased awareness regarding the benefits of tree planting, often via pioneering farmers, and their effectiveness has improved in the recent past as a result of more participatory approaches and farmers' generally increased interest in trees (see Research Paper 6).

Contrary to these developments on peasants' private lands, the erosion potential on some of the state forest and plantation lands has markedly increased. Struggles over the access to and control of these lands are the major cause of reduced tree cover and land degradation. Following a history of exclusive and repressive forest management by the state forest company, many state forest lands were plundered during the political reformation following the fall of the Suharto regime in 1997/98. Reduced tree cover and the cultivation of annual crops by peasants result in erosion in some of these areas. Community forestry programmes are the main approach to resolving conflicts between the state forest company and peasants, to combat illegal logging and to establish a socially, economically and environmentally more sustainable forest management regime (see Research Paper 6). However, the performance of these programmes in building trust and a sense of ownership on the side of the peasants remains a major (historically rooted) challenge. This is reflected in scattered tree cover and crop cultivation with limited soil conservation, resulting in erosion.

Research Paper 6 analyses the diverging trends of tree cover and degradation levels on state forest lands and on peasants' private lands, their causes and their linkages. It reveals that in some cases, scattered tree cover and crop cultivation on state forest lands is causally linked with increasing tree cover on peasants' private lands. It argues that the dichotomy between state forest lands and peasants' private lands, the corresponding division of institutional responsibilities, and struggles over maintenance of this dichotomy are linked with and undermine the effectiveness of watershed conservation efforts. While watershed conservation programmes continue to focus on peasants' private lands, erosion in the state forest territories is left to the outcome of struggles between the state forest corporation and peasants. The state forest territories lie beyond the spatial responsibility of watershed, soil conservation and agricultural extension authorities (Research Paper 6). However, their programmes targeting peasants' private lands not only aim at soil conservation but also pursue the political goal of influencing the struggles between the state forest corporation and peasants by encouraging the latter to refrain from using state forest land (see Research Papers 6 and 7).

In addition to these struggles over forest access and control, which are mediated by community forestry programmes (Research Paper 6), some state forest and plantation lands are degraded as a result of conflicts over specific pieces of land. In these cases, peasants claim ownership over state forest or plantation land for historical reasons. These claims are rooted in displacements of peasants or entire villages in the wake of a series of political insurgencies and counter-insurgencies in the 1950/60s or in illegitimate expansions of former Dutch plantations when they were transferred to Indonesian ownership in the 1950/60s. Research Paper 4 presents a detailed account of a conflict that goes back to two violent displacements, first in the wake of the brutal Dar'ul Islam insurgency and the state military's counterinsurgency in the 1950s, and second in the wake of the 'anti-communist' massacres that were part of the formation of Suharto's repressive military regime. The former land of the peasants was incorporated into the state forest territory and henceforth managed by the state forest corporation. The return of the displaced following the fall of Suharto's New Order regime, their struggle for the land and related confrontations with the state forest corporation have turned the land into an erosion-prone 'battlefield' (see Research Paper 4). Research Paper 5 presents a number of land conflicts where peasants claim ownership over plantation land with the argument that they or their ancestors were displaced from the land as a result of illegitimate expansions of these plantation territories in the 1950/60s. The paper links the empirical findings with the ongoing scholarly debate over the links between tenure security and LUCC. It argues for the need to disaggregate the different types of tenure insecurity and to assess their effects on land cover separately. The paper directs attention to tenure contestations as an important, but underexplored cause of LUCC. In the case studies presented in Research Papers 4-6, factors like historically rooted injustice, struggles over land and forest resources and related strategic acts of contestation are so closely linked with LUCC that a separation into proximate and underlying causes of LUCC appears unnecessary or even inappropriate (cf. Section 4.2).

In all cases presented in Research Papers 4 and 5, LUCC and land degradation are the result of tenure insecurity and the strategic acts of contestation employed by conflicting actors to assert their claims. These strategic acts include forest clearing and burning, the planting of trees and crops, or the uprooting of seedlings. Some of the contested areas belong to the most erosion-prone lands within the study region. The course of the land conflicts is the main factor determining future land use and potential levels of erosion. Research Paper 5 documents that, following the resolution of tenure conflicts, the contested lands started to be converted into less erosion-prone mosaics of terraced rice fields and mixed forests or back into tree-covered plantations.

Building on the results of my analysis of the temporal dynamics of lagoon sedimentation (Research Papers 1-2) and its causes (Research Papers 3-6), of LUCC and its drivers (Research Papers 4-6), and of watershed and forest management (Research Paper 6), Research Papers 7 and 8 explore historical trajectories and current modes of forest and watershed governance and related challenges more broadly. Building on the empirical findings and the human-geographical debate on scale, Research Paper 7 explores links between political framings of environmental matters and the scales of observation and intervention. This helps to explain the temporary persistence and dominance of specific political framings and related scales of knowledge production and political action. The interpretive framing of upland peasants' private plots as the single-most important sediment source has favoured a particular scale of observation (upland peasants' private plots) and thereby distracted attention from scales that are crucial to look at in aiming to better understand the social-ecological processes that were to be managed: the entire catchment of the Segara Anakan lagoon comprising the whole range of sediment sources, the various multi-scalar causes of watershed characteristics and transformations and historical trajectories. This in turn has contributed to the solidification of the political framings and confined political debates to particular scales of intervention (upland peasants' private plots).

Political power, interests and conflicts and specific framings of environmental matters have considerably shaped and will continue to shape environmental management-related debates and action. Without assuming the possibility of a 'politically neutral', 'objective' search for something like an 'ideal' watershed management strategy, my research results suggest that the debate on watershed and coastal management in Java and the environmental outcomes of related management efforts could benefit from a broadened view on the entire range of watershed characteristics and transformations and their drivers. The results also point to the need for an open societal debate that links watershed protection aims and strategies with the resolution of tenure conflicts and with future (re-)arrangements of the patterns of forest access and control (see Research Paper 6). Such a debate should involve a reconsideration of the long-standing framing of professional state forest management as the epitome of watershed protection and acknowledge the role of peasants' mixed forests with regard to watershed conservation. Many of the often very dense, diverse, multi-layered, and only selectively logged forests that cover substantial portions of the peasants' private lands provide better watershed protection than some of the state forest corporation's rotationally clear cut monocultures of teak.

The research presented in this thesis linked an analysis of environmental dynamics and their drivers, of related political framings and the underlying political dynamics and interests, and of the related modes of political action. It thereby combined a number of approaches and methods rooted in different disciplines, spanned a broad range of themes and integrated the historical dimension. The engagement with this large variety of themes, approaches, methods and strains of literature, combined with the substantial size of the research area, proved highly challenging and at the same time, very fruitful. Many of the most insightful findings were generated through the combination or at the intersection of the different themes, approaches and methods.

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II. Research papers

Research Paper 1

Lukas, M.C. (2014): Cartographic Reconstruction of Historical Environmental Change. Cartographic Perspectives, 78: 5-24. doi: 10.14714/CP78.1218

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Lukas, M.C. (2014): Cartographic Reconstruction of Historical Environmental Change. Cartographic Perspectives, 78: 5-24. doi: 10.14714/CP78.1218

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Abstrak (Abstract, translated into Indonesian)

Peta historis memberikan potensi besar untuk meneliti perubahan lingkungan secara historis. Namun, terbatasnya ketersediaan dan akurasi material kartografis awal membatasi skala waktu analitis dalam penelitian dan memunculkan tantangan metodologis. Pertimbangan penting dalam konteks ini adalah permasalahan: minimal harus seberapa akuratkah peta historis agar dapat digunakan dalam analisis tertentu. Pertanyaan ini dibahas di sini, berdasarkan contoh analisis gabungan terhadap peta historis dan gambar satelit yang ditujukan untuk merekonstruksi agradasi garis pantai di Laguna Segara Anakan di pantai selatan Pulau Jawa. Saya menampilkan pendekatan metodologis praktis untuk menganalisis informasi spasial historis yang memiliki derajat akurasi yang berbeda-beda. Pada contoh yang disajikan, pendekatan ini mengaitkan penilaian akurasi peta historis terpilih wilayah tersebut dengan analisis perubahan garis pantai laguna. Sebagai indikator untuk kesesuaian analitis peta dan reliabilitas hasil, saya mengajukan rasio antara laju perubahan lingkungan dan pengukuran akurasi peta kuantitatif, serta gabungan pengukuran ketidakpastian. Contoh empirisnya menunjukkan bahwa pada kasus besarnya magnitudo perubahan lingkungan, analisis tentang peta historis yang kurang akurat pun dapat memberikan hasil dengan tingkat ketidakpastian yang mengherankan rendahnya. Namun, besarnya magnitudo perubahan lingkungan juga dapat menghambat analisis peta historis. Analisis kuantitatif tentang akurasi dan konten peta historis harus diiringi dengan penilaian kualitatif yang menyertakan informasi karto-bibliografis dan berbagai dimensi akurasi peta. Peta tentang perubahan yang disajikan dalam makalah ini dapat mendukung penelitian lebih lanjut tentang dinamika dan pemicu perubahan lingkungan di wilayah Laguna Segara Anakan.

Kata Kunci

peta historis; kartografi historis; keandalan peta; akurasi peta; akurasi planimetris; perubahan lingkungan secara historis; rekonstruksi garis pantai; sedimentasi pesisir; Laguna Segara Anakan; Jawa; Indonesia

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Cartographic Reconstruction of Historical Environmental Change

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Historical maps provide large potential for research into historical environmental change. However, the limited availability and accuracy of early cartographic material restricts the analytical time scale of inquiry and poses methodological challenges. An important consideration in this context is the question: at minimum, how accurate must historical maps be in order to be used for which kind of analysis. This question is addressed here, based on the example of a combined analysis of historical maps and satellite images that aimed at reconstructing shoreline aggradation in the Segara Anakan lagoon on the south coast of Java. I present a practical methodological approach to analyzing historical spatial information which has varying degrees of accuracy. In the example presented, this apporach links an accuracy assessment of selected historical maps of the region with a lagoon shoreline change analysis. As indicators for the maps' analytical suitability and the reliability of results, I propose ratios between environmental change rates and quantitative map accuracy measures, as well as combined uncertainty measures. The empirical example demonstrates that in case of large magnitudes of environmental change an analysis of even fairly inaccurate historical maps can provide results with surprisingly low levels of uncertainty. However, large magnitudes of environmental change can also constrain the analysis of historical maps. Quantitative analyses of the accuracy and the contents of historical maps should be accompanied by a qualitative appraisal taking into account carto-bibliographic information and the various dimensions of map accuracy. The maps of change presented in this paper may support further inquiry into the dynamics and drivers of environmental change in the Segara Anakan lagoon region.

KEYWORDS: historical maps; historical cartography; map reliability; map accuracy; planimetric accuracy; historical environmental change; shoreline reconstruction; coastal sedimentation; Segara Anakan lagoon; Java; Indonesia

INTRODUCTION

Historical maps are often the only source of historical spatial information. The digitization and reproduction of archival material has tremendously enhanced the accessibility of historical maps, while GIS has made accuracy assessment, correction, and analysis possible and efficient. This in turn facilitates the linking of historical maps with recent spatial information, providing larger potential than ever for research into environmental histories. Historical maps, often embedded in GIS, have proven valuable for the analysis of land use / cover changes (Haase et al. 2007), coastal features (Crowell, Leatherman, and Buckley 1991; Jabaloy-Sanchez et al. 2010; Levin 2006; Monmonier 2008), settlement processes (Levin, Kark, and Galilee 2010), agricultural histories (Pearson and Collier 1998), soil degradation (Brookfield 1999), salt marsh losses (Bromberg and Bertness 2005), and river meanders (Słowik 2013). Historical maps can help to verify, concretize, or dismantle narratives about past environmental changes and political events (e.g., Brookfield 1999; Pearson 2005).

Knowledge about past environmental changes is crucial for a realistic understanding of contemporary environmental issues, because current conditions and processes are partly an outcome of long-term developments, and the nature and pace of current dynamics can only be realistically evaluated against the backdrop of past developments. In this context, our choice of analytical time scales is an important consideration, since it may influence our results and conclusions (Batterbury and Bebbington 1999;

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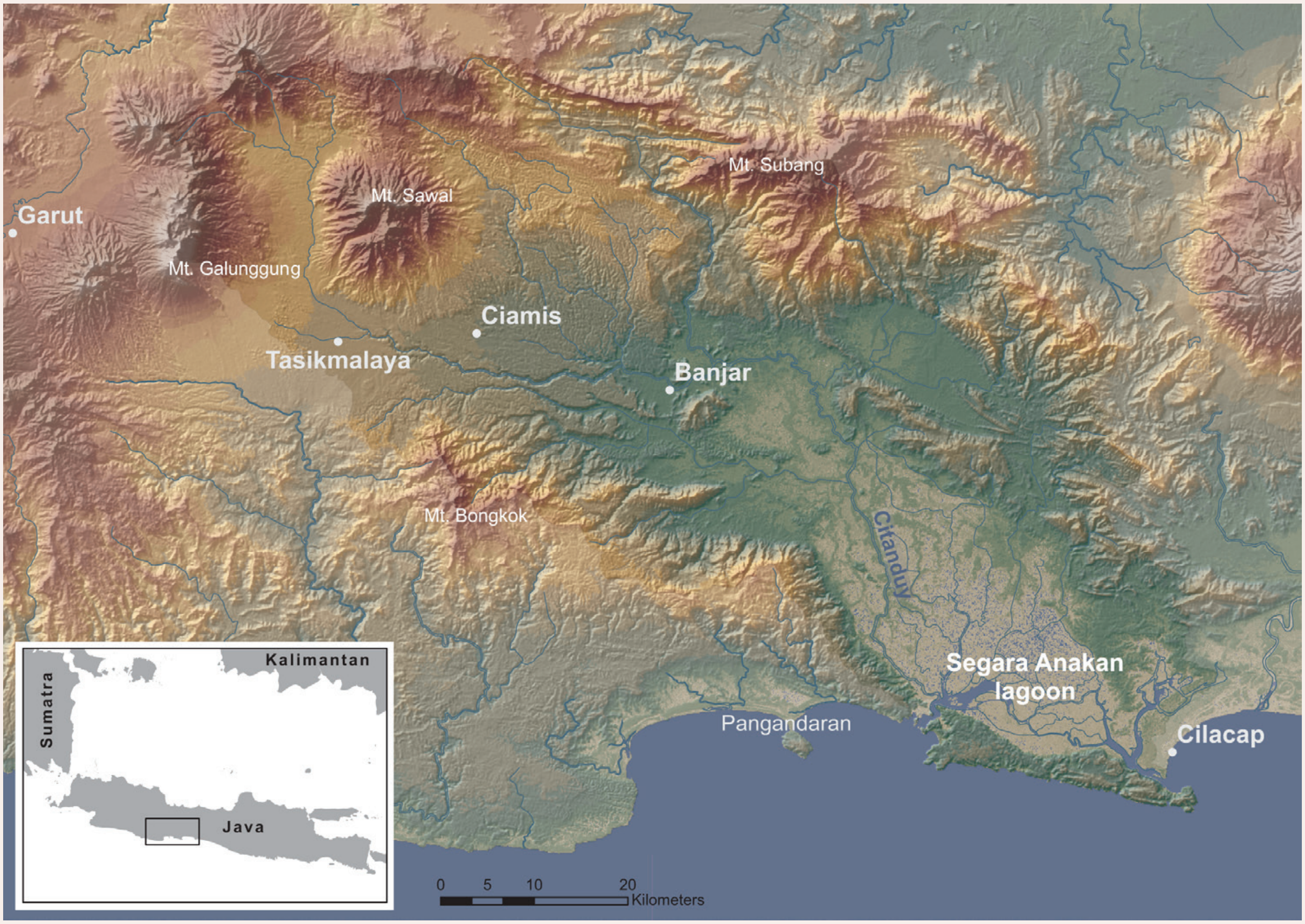

__Figure 1.__ Location of the Segara Anakan lagoon and its catchment area on the south coast of Java.

Chapman and Driver 1996). For a realistic understanding of anthropogenic drivers, it is particularly interesting and meaningful to incorporate times of transition from mainly nature-dominated to human-dominated landscapes (Batterbury and Bebbington 1999; Messerli et al. 2000).

However, the further we expand our analytical time scale into the past, the more our inquiry is constrained by the limited availability and accuracy of historical cartographic material. While contemporary remotely sensed material provides very precise and accurate images of almost the entire world at resolutions of a few meters or less, historical topographic maps from the nineteenth or early twentieth century may be marked by inaccuracies of tens or hundreds of meters, and earlier charts may only depict a small range of selected topographic features and include completely uncharted territories. In this context, careful evaluation of the cartographic material's reliability is crucial. This should include a thorough exploration of the history of mapping of the target region, the gathering of knowledge about mapmakers and mapmaking processes, and a careful examination of the maps' accuracy (Levin 2006; Jenny 2006). One important question at this juncture is: how accurate does the cartographic material need to be, at minimum, in order to be used for which kind of analysis?

I address this question here, based on the example of a combined analysis of historical maps and satellite images which aimed at reconstructing shoreline aggradation in the Segara Anakan lagoon on the south coast of Java. I present some of the valuable but largely underutilized historical cartographic material of the region and an assessment of its accuracy. Linking map accuracy with the results of the shoreline change analysis, I propose ratios between environmental change rates and quantitative map accuracy measures, as well as combined uncertainty measures as indicators for the maps' analytical suitability and the reliability of results.

RATIONALE AND CONTEXT: THE SHRINKING SEGARA ANAKAN LAGOON

The research presented here aimed at contributing to an improved understanding of environmental changes in the Segara Anakan lagoon. This shallow coastal lagoon on Java's south coast (Figure 1) has been heavily impacted by riverine sediments. Rapid aggradation is said to have contributed to a vicious cycle of diminishing marine resources, environmental degradation and poverty (Bird, Soegiarto, and Soegiarto 1980; Dudley 2000; Olive 1997; White, Martosubroto, and Sadorra 1989; Yuwono et al. 2007; Purba 1991).

Despite a long record of research and political interventions in the area, knowledge of the historical dynamics and drivers of sedimentation remains limited, and related discussions have been dominated by political discourses (Lukas 2013; 2014). While these discourses have focused on upland agriculture, other drivers of sedimentation have been neglected (ibid.). Knowledge of the temporal dynamics of lagoon sedimentation may contribute to exploring its various drivers. In this context, the research presented here aimed at reconstructing lagoon shoreline aggradation, with an analytical time scale expanding as far back as the availability and accuracy of historical cartographic material allowed. The results—a delineation of historical shorelines—illustrate the rapid pace of transformation and provide a rough, albeit only two-dimensional, picture of the temporal dynamics of lagoon sedimentation. The maps of change presented below may support further research into the environmental history of this area.

Historical shoreline reconstructions of the Segara Anakan lagoon already exist (Schaafsma 1926; Hadisumarno 1964; Hadisumarno 1979; ASEAN/US CRMP 1992; PRC-ECI 1987; Soewondho 1984; ECI 1994; Tejakusuma 2006). However, these analyses only cover the twentieth century and lack adequate documentation of data sources, methods, and map accuracy. In addition, their results are partly erroneous. For example, Hadisumarno (1964; 1979) did not pay attention to the time gap between the dates of surveys and map publication. The dramatic increase in his annual aggradation rates for the lagoon's eastern shoreline from 5m for the period 1900–1940 to 54m for the period 1940–1946, which he interpreted as a result of "deforestation within the river catchment area of Citandui during the Japanese occupation," (49) in fact largely resulted from his neglecting the fact that the maps from the 1940s were based on surveys already carried out in the 1920s. The same error appears in the shoreline change maps subsequently included in various project documents (ASEAN/US CRMP 1992; PRC-ECI 1987; Soewondho 1984; ECI 1994). A well-documented shoreline change analysis is contained in the findings of a land use change analysis by Ardli and Wolff (2008; 2009), but it only covers the period from the 1970s onwards.

ACCURACY OF THE HISTORICAL MAPS OF JAVA'S SOUTH COAST

The errors in previous shoreline change analyses underline the importance of obtaining background information about mapmakers and mapmaking processes before using the content of the cartographic material for analysis. Systematically gathering as complete an account of historical maps of an area as possible, ordering them in a temporal sequence, connecting them with information on the processes of their making, and analyzing their accuracy supports the selection of the most suitable material, with as small a temporal resolution and as large a temporal scale as possible, and helps to realistically assess the varying reliability of the material.

OVERVIEW OF THE MATERIAL

As a basis of the research presented here, more than 50 different historical maps and map series produced between the sixteenth and twentieth century were gathered from various libraries and archives worldwide. An overview of this material along with information about mapmakers and mapmaking processes is provided in Lukas (forthcoming). Accordingly, the earliest known maps of the Segara Anakan lagoon or parts thereof go back to cartographic expeditions undertaken on behalf of the United (Dutch) East India Company in 1698, 1711, and 1739 (Schilder 1981; Schilder 1978; Knaap et al. 2007). The manuscript sea charts drawn during these voyages remained the only original cartographic documentation of the lagoon until the early nineteenth century. One of them is depicted in Figure 2. The first fairly detailed maps of the entire lagoon were produced in 1809 by Jan Theunis Busscher (Figure 3) and in 1813–15 as part of the first systematic topographic large-scale mapping of Java (Figure 4). Additional increasingly detailed maps were produced

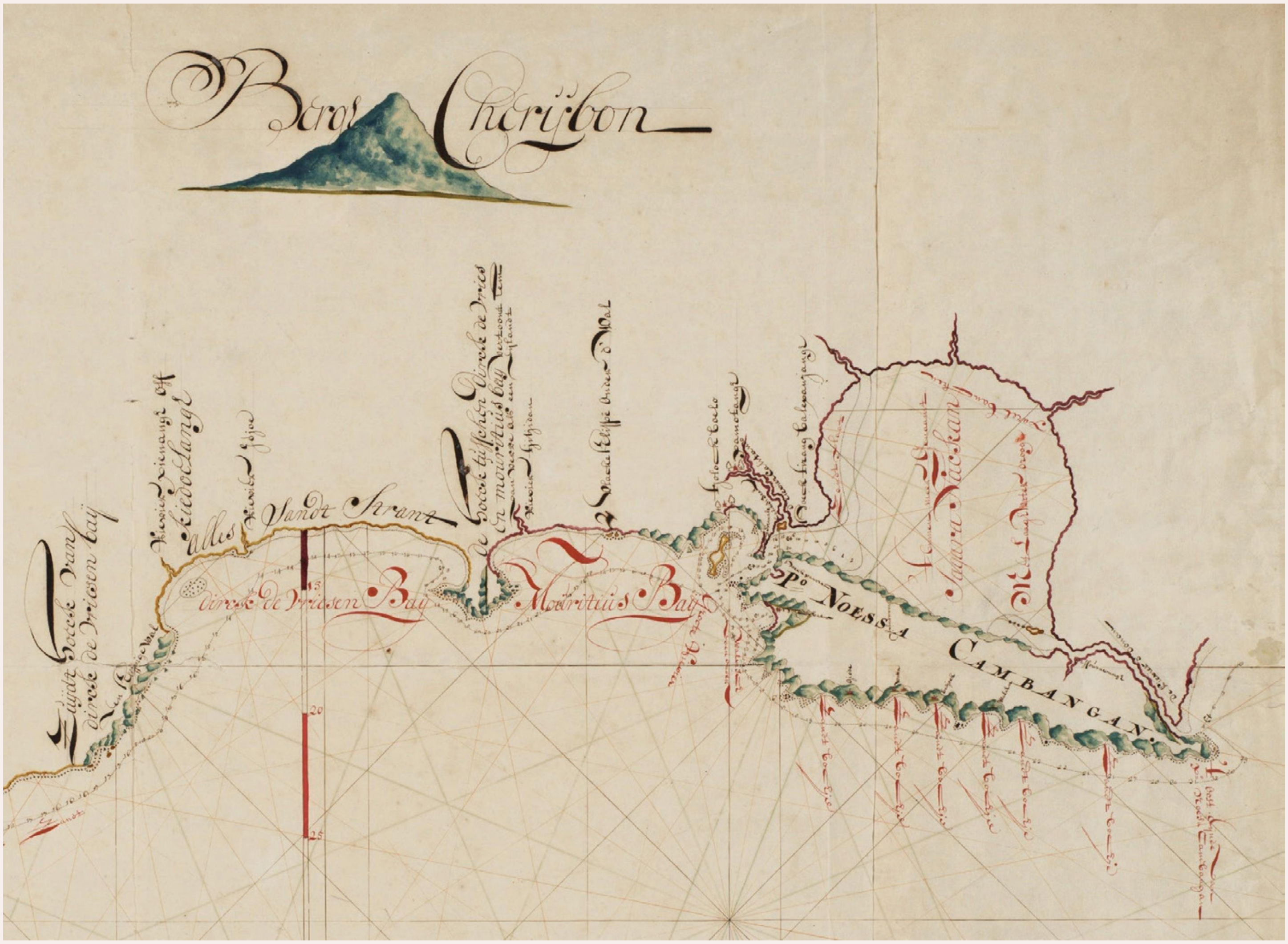

Figure 2. *This section of the manuscript sea chart drawn by Cornelius Coops in 1698 is the earliest known map of the Segara Anakan lagoon. Original scale: approx. 1:140,000. Retrieved from the Netherlands National Archives in The Hague.*

Figure 3. *Map of the Segara Anakan lagoon, drawn by Jan Theunis Busscher in 1809. Original scale: 1:76,000. Retrieved from the Netherlands National Archives in The Hague.*

Figure 4. *Section of Sheet 20 of the* Kaart der Preanger Regentschappen en Crawang, *based on surveys carried out between 1813 and 1815. Original scale: 1:114,000. Retrieved from the Netherlands National Archives in The Hague.*

Figure 5. *Section of the* Topographische Kaart van de Residentie Banjoemaas, *based on surveys carried out between 1857 and 1860. Original scale: 1:100,000. Retrieved from the Netherlands Royal Tropical Institute (KIT). The red points represent the ground control points used for georectification.*

Figure 6. *Topographic map of Java, Residency Banjoemas, produced by the Topographical Service in the Netherlands East Indies (TDNI), based on surveys carried out between 1897 and 1901. Compilation of sections of map sheets III, IV, VII, and VIII. Original scale: 1:100,000. Retrieved from KIT.*

Figure 7. *Topographic map of Java, Middle and West Java, produced by TDNI, mainly based on surveys carried out between 1924 and 1926. Compilation of sections of map sheets 42/XLI D, 43/XLI C, 43/XLI D, 42/XLII B, 43/XLII A, 43/XLI D. Original scale: 1:50,000. Retrieved from KIT.*

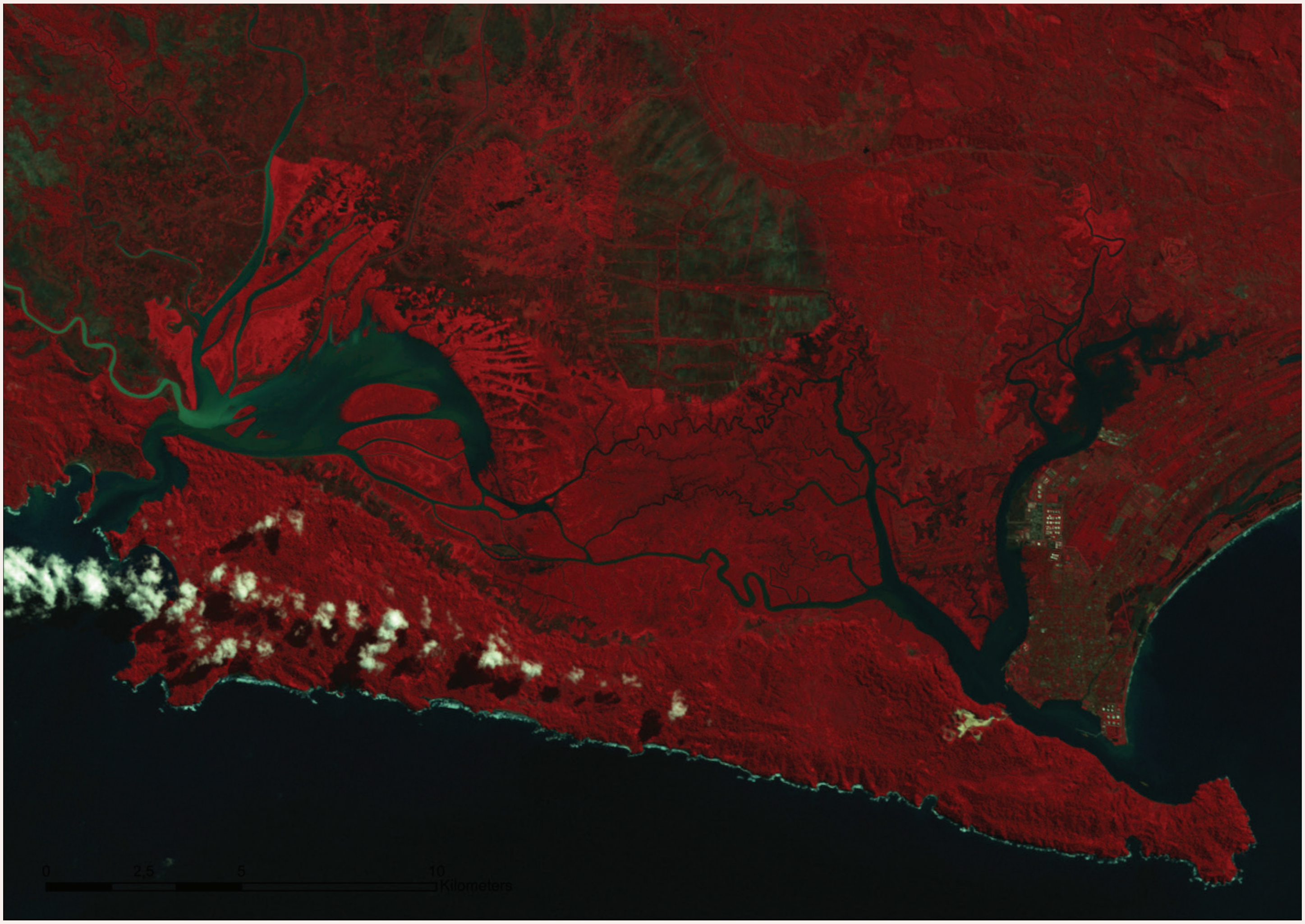

Figure 8. *Section of a Landsat image depicting the Segara Anakan lagoon in 1993. Landsat TM, resolution: 30m, date of acquisition: 23.05.1993. Retrieved from BTIC Dataport, Indonesia.*

as part of subsequent topographic surveys in 1857–60, 1901–04 and 1924–26 (Figures 5–7). A map series produced by the US Army between 1939 and 1944 did not provide new topographic information, but was based on the previous topographic maps. Following several decades without any update of the cartographic knowledge of this area, a Corona satellite image from 1962 is the next temporal layer of lagoon shoreline information that could be found (available from the US Geological Survey). From the 1970s, Landsat images provide an easily accessible basis for analyzing environmental changes in most parts of the world, including the Segara Anakan lagoon (also available from the USGS). And since the 1980–90s, remotely sensed data from various satellite missions offer analytical possibilities that, with regard to temporal and spatial resolution and accuracy, completely outshine those provided by early topographic maps from the nineteenth century, not to mention the early manuscript sea charts from the seventeenth and eighteenth century.

A brief glance at the historical cartographic material outlined above unsurprisingly indicates that the reliability of the material continuously declines the further we go back in time. Yet if the temporal scale of our analysis is to cover more than only the past few decades—and to truly understand today's environmental dynamics often requires looking further back—we need to combine the analysis of satellite images with the analysis of clearly less accurate early topographic maps. An important consideration in this context is the question where the extent of map inaccuracy delimits the temporal scale of a historical cartographic analysis. The next two sections outline the dimensions of map accuracy and present an accuracy analysis of selected historical maps of the Segara Anakan lagoon region.

DIMENSIONS OF MAP ACCURACY

The accuracy of historical maps is affected by factors like topographic knowledge, the methods of surveying, map drawing, and reproduction as well as paper deformation processes, such as shrinking or stretching (Jenny and Hurni 2011). The contribution of each of these factors can often not be determined (Jenny 2006). Following Laxton (1976), Blakemore and Harley (1980), Levin et al. (2006; 2010), and Jenny and Hurni (2011), accuracy assessment can comprise four dimensions: (1) *topographic accuracy*, referring to the quantity and quality of information about landscape features; (2) *chronometric accuracy*, referring to the dating of the map and the information therein; (3) *geodetic accuracy* (or *coordinate grid accuracy*), referring to the positioning of the map in the coordinate system; and (4) *planimetric accuracy* (or *feature* or *geometric accuracy*), referring to the positions, distances, areas, and angles of features on the map as compared to those in reality.

1. The *topographic accuracy* of the maps of Java's south coast continuously increased over time, with the early manuscript sea charts of the seventeenth and eighteenth century only depicting a few major bays and capes and at best showing a rough outline of (parts of) the Segara Anakan lagoon (see Figure 2), and the topographic maps from 1860, 1901–1904 and 1924–26 depicting shorelines and various other topographic features with increasing completeness (see Figures 5–7).

2. The errors in earlier historical cartographic analyses of the Segara Anakan lagoon caused by ignoring the time gaps between survey dates and the maps' publication dates demonstrate the importance of assessing the *chronometric accuracy* of the material. Dating the information contained in historical maps may require knowledge of mapmakers and mapmaking processes. Access to this information has greatly improved with the digitization and reproduction of archival material in recent years. The surveying and publication dates of the maps depicted in Figures 2–7 are provided in Table 1. Based on this, the shoreline data that were extracted from the maps and that are presented below are consequently dated in line with the year of topographic data collection rather than the year of map publication.

3. Assessing the *geodetic accuracy* of the maps presented is rather problematic, since in most cases no coordinates and gridlines are depicted, and map projections are unknown. This is often the case with historical maps (Jenny and Hurni 2011). Many of the earlier maps of Java from the seventeenth and eighteenth century were not yet based on conformal projections, even though the conformal Mercator projection had been introduced as early as around 1570 (Schilder et al. 2006, 22). Geodetic inaccuracy can lead to errors in the positioning of features. However, such errors are often of minor importance in relation to planimetric inaccuracies (Jenny and Hurni 2011; Locke and Wyckoff 1993). This can be assumed to be particularly true in case of the research presented here, given the small size of the study area, the comparably large scale of the maps and the location close to the equator. The non-existence of any systematic single-directed deviation in the maps presented, as indicated by the displacement vectors, which visualize positional errors after georectification, confirms that potential geodetic inaccuracy is of minor importance.

4. *The planimetric accuracy* can be quantified by comparing the locations of features on historical maps with their "true" locations on more accurate, recent topographic maps, on remotely sensed images, or as measured in the field using GPS (Levin, Kark, and Galilee 2010). By comparing the positions of at least four such locations with the help of tools included in programs such as ArcGIS or MapAnalyst, the Root Mean Square Error (RMSE) can, in the case of negligibly small geodetic inaccuracies, be determined as the median planimetric location error. It can be given in millimeters at map scale or in meters at real world scale. With MapAnalyst, the extent and spatial variation of this error can be visualized in the form of distortion grids or displacement vectors (Jenny 2006; Jenny and Hurni 2011). The planimetric accuracy of historical maps differs greatly depending on the period and the region, but also on the scale of the maps. An example of very early maps with exceptionally high levels of planimetric accuracy are those drawn of the region around Dresden, Germany by M. Öder in the late sixteenth century. With mean planimetric errors of only about 100m at real world scale, they are perhaps the most

accurate maps of their time worldwide (Bönisch 1967). Levin, Kark, and Galilee (2010), to mention one more example out of a larger number of similar studies, determined mean errors between 71m and 780m at real world scale for historical maps of Palestine produced between 1880 and 1946 at scales between 1:20,000 and 1:250,000, and errors at a magnitude of several kilometers for maps produced earlier.

QUANTITATIVE PLANIMETRIC ACCURACY ASSESSMENT

For the maps depicted in Figures 2–7 and the Corona image, median planimetric errors were determined by comparing point locations identified on the historical material against those on recent topographic maps, applying the following steps:

The maps were scanned, if not acquired in digital form. In case of the maps from 1857/60 and 1897/1901, the single map sheets were aligned manually to form one file. In case of the map from 1924/26, the single map sheets were processed separately. Using ArcGIS, the maps were then georectified according to the most recent topographic maps: Peta Rupabumi, 1:25,000, produced by BAKOSURTANAL in 1997–98, based on surveys in 1993–94 (8 map sheets). Georectification, by aligning map features to their real world position, brings the historical maps into coincidence or at least a best geometric fit with recent maps and satellite images within one common coordinate grid system. At the same time it provides the RMSE as a quantitative measure of the original map's accuracy. In line with the recent topographic maps, UTM Zone 49S (WGS 1984) was used as a common coordinate grid system. Georectification requires a minimum of four control points. Depending on the map and its topographic accuracy, between 11 and 31 control points were selected on each of the historical maps and aligned with their actual geographical position by linking them with their equivalent on the recent topographic maps (see Table 1). The considerable magnitude of environmental change, i.e. of sedimentation, river regulations, and settlement development (see Figures 2–8), limited the number and constrained equal distribution of control points, particularly in the northern part of the lagoon and the adjacent land areas. This rendered an assessment of spatial variations in map accuracy, as was done by Levin (2006), unfeasible. Most ground control points were identified based on topographic features, such as river intersections, bays, and capes (see Figure 5). Based on the control points, 1st, 2nd, and 3rd order polynomial transformations were performed. The resulting RMSE represent the residual error after transformation: the differences between the position of the control points after georectification and their actual geographic location. In addition to small methodological inaccuracies related to scanning resolution, the selection of control points, and possible—but negligible—geodetic inaccuracies, the RMSE in case of the maps analyzed can be assumed to mainly reflect the historical maps' planimetric accuracy.

Table 1 provides an overview of the historical maps analyzed and presents the results of the quantitative accuracy assessment. Not surprisingly, the later the maps were created, the higher their planimetric accuracy.

The earliest maps that were drawn as part of the charting expeditions between 1698 and 1739 are barely accurate enough to be georectified. Their limited topographic accuracy, resulting in a lack of suitable control points, and the collinearity of the few control points that could be identified constrained georectification and the determination of any mean planimetric errors by the means described above. The median error of 1510.5m (1st order polynomial transformation) for Coops' map can therefore not be compared with the results for any other maps. Due to their limited topographic and planimetric accuracy, these early sea charts could not be used for a quantitative analysis of shoreline changes. However, qualitative interpretation of these maps may provide information supporting the exploration of possible longer-term shoreline developments at times prior to the production of the earliest more accurate and quantitatively analyzable maps (see Lukas [forthcoming]).

The considerable difference between the median errors received for J. T. Busscher's map and the *Kaart der Preanger Regentschappen*, both of which were produced within the first two decades of the nineteenth century, demonstrates the usefulness of a quantitative planimetric accuracy assessment. Visual comparison of the two maps (Figures 3 and 4) and their comparison with the Residency map from 1857 (Figure 5) suggest that Busscher mapped the eastern shoreline of the lagoon's open water surface area with a higher level of topographic accuracy than the producers of the *Kaart der Preanger Regentschappen*, which simply depicts the eastern shoreline as a straight line, indicating

Map Title or Description; Surveyor or Editor; Scale	Year of Production / Publication	Year(s) of Topographic Data Collection	Library, Archive, and/or Source of Reproduction	Number of Ground Control Points	Median Error (≈ Median Planimetric Error) at Real World Scale, Per Polynomial Transformation (m)			Suitability for Analysis of Historical Environmental Change
					1st Order	2nd Order	3rd Order	
Manuscript maps of charting expeditions by Cornelius Coops, Albert van Petten, and Paulus Paulusz; map scales between approx. 1:120,000 and 1:500,000	1698, 1711, 1739	1698, 1711, 1739	Netherlands National Archives in The Hague, see Schilder (1981) and Knaap et al. (2007)	For map by Cornelius Coops (1698): 8	(1510.5)	728.4	not applicable	For qualitative analysis only
De Baay Segara-Annakkan of de Kinder Zee Met het daarvoor gelegene Eiland Noessa-Kambang, gelegen aan Java's Zuider Zee Strand; by Jan Theunis Busscher; 1:76,000	1809	1809	Netherlands National Archives in The Hague	11	1460.9	915.0	not applicable	For qualitative analysis only
Kaart der Preanger Regentschappen en Crawang, gecoppieerd naar die van den Heer Beetjes door J. T. Bik; 1:114,000	1817	1813–1815	Netherlands National Archives in The Hague, see Knaap et al. (2007)	11	582.3	297.4	112.0	For qualitative analysis only
Topographische Kaart van de Residentie Banjoemaas (Map Sheets I and II); under the direction of the Kolonel Direktur der Genie W.C. von Schierbrand by the Kapitein der Infanterie W. Beijerink; 1:100,000	1860	1857–1860	KIT; Sächsische Landesbibliothek, Staats- und Universitätsbibliothek Dresden	26	192.0	158.3	127.0	Suitable for quantitative analysis
Topographical map of Java, Residency Banjoemas (Map Sheets III, IV, VII, and VIII); TDNI, Land tax survey brigades; 1:100,000	1901–1904	1897–1901	KIT	31	87.1	60.3	46.0	Suitable for quantitative analysis
Topographical map of Java, Middle (and West), Map Sheets 42/XLI D, 43/XLI C, 43/XLI D, 42/XLII B, 43/XLII A, 43/XLI D); TDNI, Land tax revision brigades; 1:50,000	1925–29 (Sheet 42/XLII B: 1942), reprints from 1938–42	1924–1926	KIT	For Map Sheet 43/XLII A: 13	51.1	34.5	27.3	Suitable for quantitative analysis

Table 1. *Results of an accuracy assessment for selected historical maps of the Segara Anakan lagoon.*

a lack of topographic knowledge. However, the result of the quantitative analysis shows that Busscher's map is clearly generally less accurate than the *Kaart der Preanger Regentschappen* (see Table 1), and this is important to consider when using the maps' contents for analysis.

The median errors obtained (see Table 1) are very large as compared to modern maps or satellite images, but they are comparable to the results obtained by other scholars for historical maps. Taking into account the different map scales and years of production, the median errors obtained for the maps produced between 1813/15 and 1924/26 are in a similar order of magnitude as those of the historical maps of Palestine analyzed by Levin et al. (Levin, Kark, and Galilee 2010; Levin 2006), the historical maps of North Carolina analyzed by Lloyd and Gilmartin (1987), and the historical maps of England that Bromberg and Bertness (2005) used to analyze salt marsh losses. In comparison extremely accurate are the Saxon Mile Sheets from 1780–84 for which Walz (2008) achieved a mean spatial accuracy of only 24m, and the nautical chart of the Adra River delta in southeast Spain from 1855 for which Jabaloy-Sanchez et al. (2010) found an RMSE of 11.5m.

Preparing a systematic overview of the historical maps of an area including related carto-bibliographic information (see Lukas [forthcoming]) and results of an accuracy assessment (Table 1) provides a solid basis for a cartographic analysis of historical environmental change. However, based on this information and the quantitative accuracy measures alone, the question posed at the beginning—*how accurate the cartographic material needs to be at minimum in order to be used for which kind of analysis*—cannot be conclusively answered yet. As was noted by Levin (2006) and as will be demonstrated below, the analytical suitability of historical maps also depends on the magnitude of the environmental changes to be investigated; in other words the maps' reliability depends on both their accuracy and their utilization. Therefore the next section presents the methods and results of the shoreline change analysis carried out, before the following section returns to the question of map accuracy.

RECONSTRUCTING THE LAGOON'S HISTORICAL WATER SURFACE AREA

Analysis of shoreline variability and related methodological challenges has been a growing research field in the past two decades (see, for example, Boak and Turner [2005], Crowell, Leatherman, and Buckley [1991], Moore [2000], and Monmonier [2008]). Knowledge of past shoreline changes can be relevant for various contemporary management issues, including ecological, legal, regulatory, and engineering questions. In case of ocean shorelines, the accurate detection of the land-water boundary is constrained by its great fluctuating variability over various time scales, caused by waves, currents, tides, and temporally variable accumulation and erosion processes. Therefore, identification and mapping of contemporary shorelines, let alone their historical reconstruction, remains a methodological challenge.

In the case of the Segara Anakan lagoon, fluctuating variability is largely confined to the influence of tides and is thus less problematic than in case of open ocean shorelines. Yet the fuzzy, barely visible character of the land-water boundary within the mangrove forest areas potentially introduces uncertainty. However, since aggradation has consistently been accompanied by the expansion of mangroves or other vegetation, the most practical and fairly accurate approach is to define the water surface area of the lagoon as the area that is covered by water at high tide but that is not vegetated. This area is demarcated from the sea by the two tidal channels and comprises the lower reaches of the tributary rivers. It also includes the entire channel network in the eastern part of the lagoon and the areas of the pile villages, which existed within the open water surface area until the first half of the twentieth century and which are depicted in the respective maps (see Figures 4–7).

Based on the quantitative accuracy assessment of the historical maps presented in Table 1 and a qualitative area-specific comparison of these maps, the historical maps from 1857–60, 1897–1901, and 1924/26 were selected as a solid basis for the shoreline change analysis. The quantitative accuracy assessment also suggests including the map from 1813/15. However, qualitative comparison and overlay of this map with the more recent maps indicates its limited accuracy particularly in the areas affected by shoreline changes—areas where the limited topographic accuracy of the map and the environmental changes themselves did not allow for the identification of suitable control points. The unrealistically straight line that represents the eastern shoreline in this map (see Figure 4, compared with the maps from 1809 and 1857–60, shown in Figures 3 and 5) indicates the mapmakers' limited knowledge of this part of the lagoon and hence low levels of topographic accuracy in this section of the map.

In addition to the historical maps, one section of a Corona Satellite Image, taken in 1962 and scanned with a resolution of 1,800 dpi, was georectified on the basis of the recent topographic maps, using a 2nd order polynomial transformation, with an RMSE of 14.1m. In addition, a number of satellite images taken between 1973 and 2013 (see Table 2) were georectified with negligibly small RMSEs, if not acquired in pre-processed form.

On the basis of the three historical maps (3rd order polynomial transformation) and the satellite images, the historical course of the Segara Anakan lagoon's shorelines was

Type of Data	Date of Acquisition	Spatial Resolution
Corona, FTV-1126, Mission No. 9034	17.05.1962	140m
Landsat MSS	01.08.1973	79m
Landsat MSS	21.06.1983	79m
Landsat TM	23.05.1993	30m
Landsat ETM+	03.03.2013	30m

Table 2. *Satellite images used for shoreline reconstruction in combination with the historical maps (The Landsat TM image was acquired from BTIC Dataport, Indonesia; all other images were acquired from USGS).*

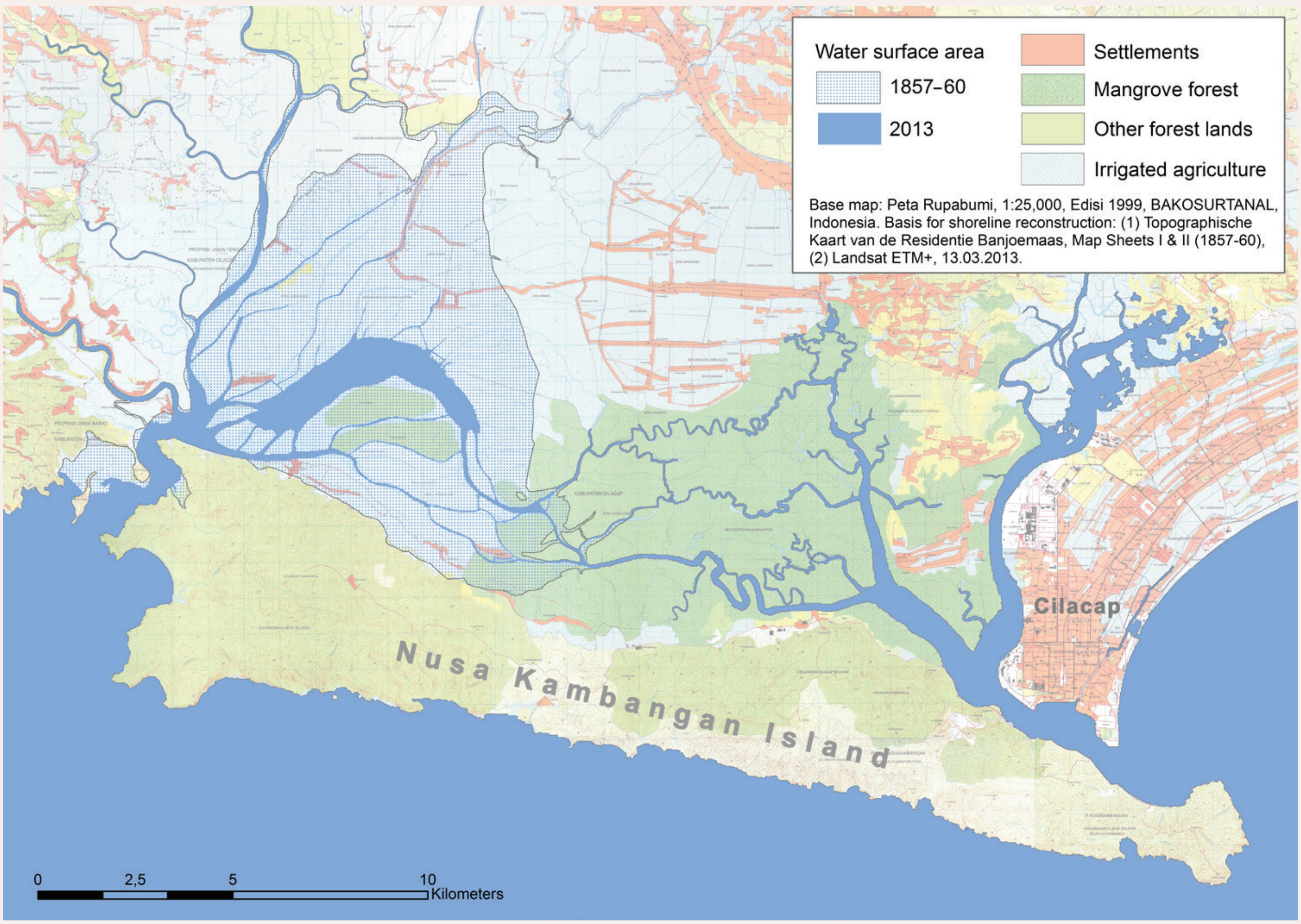

Figure 9. *Change in the water surface area of the Segara Anakan lagoon between 1857/60 and 2013. Most of the silted-up area is presently covered by (partly degraded) mangroves and shrubs, (partly abandoned) aquaculture ponds, agricultural fields, and settlements (c.f. Ardli and Wolff [2009]).*

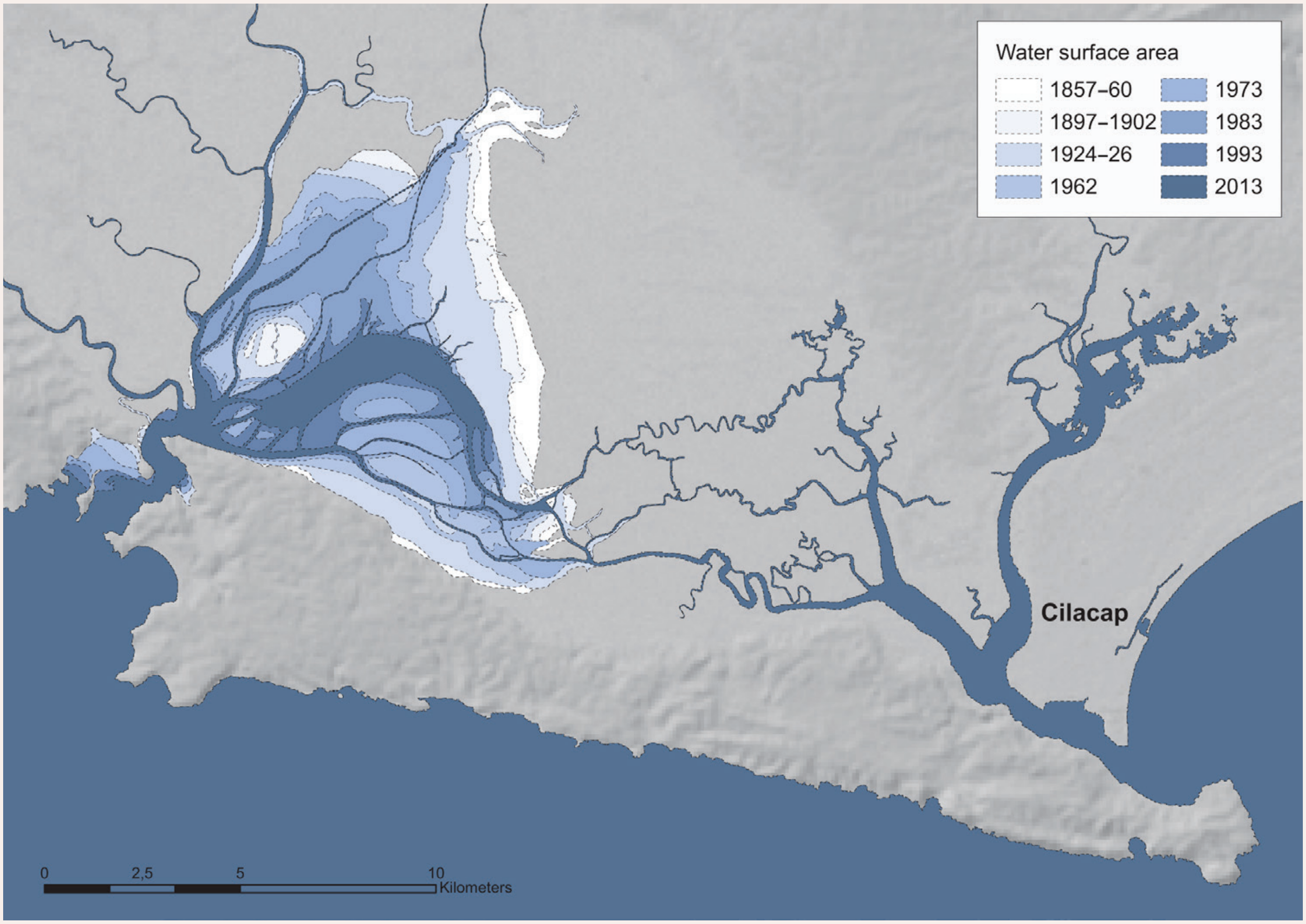

Figure 10. The reconstructed historical lagoon shorelines illustrate the siltation process between 1857/60 and 2013. Base map: SRTM (Shuttle Radar Topography Mission), available from the USGS. Reconstructed shorelines based on maps and satellite images listed in Tables 1 and 2.

manually delineated. Figures 9 and 10 present the results. They depict the dramatic decline in the lagoon's water surface area, providing a two-dimensional picture of lagoon sedimentation between 1857/60 and 2013. Shoreline aggradation accelerated between 1857/60 and the late 1980s or early 1990s and slowed down thereafter. The latter is partly related to lagoon dredging in the early 2000s (ADB 2006), but might also reflect the possibility of approaching a state where the proportion of riverine sediment input that is ***not*** deposited in the lagoon but carried out into the ocean increases in line with the shrinking of the water body.

Critically questioning these results, one could argue that it is uncertain whether the makers of the historical maps followed a similar approach in defining the lagoon's shorelines as has been used in analyzing their maps. Some of the historical maps indicate that water depths were already fairly low in parts of the lagoon. For example, Busscher's map from 1809 (Figure 4) delineates deeper channels from the surrounding shallower water areas, using different signatures. It could be argued that the differences in the course of shorelines and in the number and size of islands situated within the lagoon on the various historical maps do not indicate physical changes, but result from different approaches of different mapmakers in delineating shorelines. However, a number of considerations clearly support the conclusion that the major differences between the maps do reflect real physical changes (i.e., aggradation): (1) certain islands, such as those at the south-eastern edge of the open water surface area, were consistently drawn by all map makers with increasing sizes over time; (2) other islands, such as those in the western part of the lagoon, were not depicted on earlier maps but were later drawn by all mapmakers with increasing sizes over time; (3) the northern and eastern shorelines of the lagoon were over time depicted further and further to the south and west respectively, while the location of other (also vegetated) shoreline sections that were not affected by sedimentation (e.g., within the eastern channel network) did not vary between map makers and over time; and (4) the early spatiotemporal trends observed on the time sequence of historical maps continued during the period covered by remotely sensed data.

However, a major limitation of this historical cartographic analysis of aggradation is its confinement to the water surface area, while changes in water depth remain unknown. An analysis of the latter would require a time series of historical depth soundings with a high spatial resolution, which does not exist. In addition, changes of the lagoon's water surface area and even of its volume cannot be directly translated into temporal changes of riverine sediment input, since the proportion of sediments that is deposited in the lagoon and not transported out to the ocean must have changed over time. Nevertheless, given the large magnitude of change in aggradation rates, it seems plausible to assume that the historical cartographic reconstruction of the water surface area presented here provides at least a rough picture of the temporal dynamics of riverine sediment input, albeit not with proportionality. In a next step, a time sequence of the various potential drivers of sedimentation or information from sediment core analyses could be combined with the maps of change presented here.

LINKING MAP ACCURACY WITH ENVIRONMENTAL CHANGE RATES

Finally, the results of the shoreline change analysis presented in Figures 9 and 10 should be linked with the quantitative map accuracy measures. This is part of the necessary critical reflection on the methodological approach used and, at the same time, brings us back to the question posed at the beginning: *how accurate does historical cartographic material need to be at minimum in order to be used for which kind of analysis?* The "required" or "minimum" accuracy level of historical maps for analyzing environmental changes depends considerably on the kind and magnitude of the changes to be analyzed. Table 3 links the median planimetric errors of the historical maps used with the rates of shoreline change detected. It shows that the rates of shoreline change were so extraordinarily high that they clearly exceed the magnitude of potential uncertainty introduced by map inaccuracies and the analytical process.

Ratios between the rates of the environmental changes to be analyzed and planimetric map accuracy may serve as a general quantitative indicator for the analytical suitability of historical maps. The ratio r is determined as follows:

$$r = \frac{s}{\Delta x_{1,2}}$$

where s is the total shoreline change rate during the respective period and $\Delta x_{1,2}$ the median planimetric errors of the respective maps (Map 1, 2) at real world scale.

In the research presented here, the ratios r calculated for the different shoreline sections and maps indicate that the shoreline change rates detected were in almost all cases between 6.5 and 106.4 times higher than the median planimetric errors of the respective maps (see Table 3). Such high ratios between environmental change rates and map inaccuracy clearly indicate the historical maps' suitability for detecting environmental changes with potential errors that are acceptably small for most purposes. In the case of the map from 1857/60 (when overlayed with the map from 1897/1901), the ratios between environmental change rate and median planimetric error of 2.4–6.4, depending on the shoreline section, indicate higher levels of uncertainty, but also show that the changes detected still clearly exceed the levels of potential inaccuracy. When analyzing a time-sequential series of maps to detect spatial changes continuously directed in one single direction (as in the research presented here), comparably low ratios between environmental change rates and map inaccuracy may usually still be acceptable, while analysis of fluctuating environmental changes may require higher levels of planimetric map accuracy.

While the ratios proposed above provide a practical and easy to calculate indicator for the suitability of historical maps for particular analytical purposes, the reliability of the actual results from cartographic analyses may be quantified using combined uncertainty measures. As environmental change rates are usually based on information from

Period	Total Shoreline Change Rate (s in m)		Annual Shoreline Change Rate (s_a in m)		Median Planimetric Error at Real World Scale (in m)		Ratio r Between Rate of Shoreline Change and Median Planimetric Error $r = \frac{s}{\Delta x_{1,2}}$				Digitization-operator Error		Combined Uncertainty of Shoreline Change Rates (Δy in m) $\Delta y = \sqrt{\Delta x_1^2 + \Delta x_2^2 + \Delta d_1^2 + \Delta d_2^2}$	Combined Uncertainty of Shoreline Change Rates ($\Delta y/s$)	
							Northern Shoreline		Eastern Shoreline						
	Northern Shoreline	Eastern Shoreline	Northern shoreline	Eastern shoreline	Map / Image 1 (Δx_1)	Map / Image 2 (Δx_2)	Map / Image 1	Map / Image 2	Map / Image 1	Map / Image 2	Map / Image 1 (Δd_1 in m at real world scale)	Map / Image 2 (Δd_2 in m at real world scale)		Northern Shoreline	Eastern Shoreline
1857/60–1897/1901	no major change	300–815	n.a.	7.5–20.4	127.0	46.0	n.a.	n.a.	2.4–6.4	6.5–17.7	35.0	35.0	143.9	n.a.	17.7%–48.0%
1897/1901–1924/26	400	300–450	15.4	11.5–17.3	46.0	27.3	8.7	14.7	6.5–9.8	11.0–16.5	35.0	17.5	66.3	16.6%	14.7–22.1%
1924/26–1962	500–800	500–1500	13.5–21.6	13.5–40.5	27.3	14.1	18.3–29.3	35.5–65.7	18.3–54.9	35.5–106.4	17.5	37.0	51.2	6.4%–10.2%	3.4%–10.2%
1857/60–2013*	3,200–4,800	n.a.	20.8–31.2	n.a.	127.0	5.6*	25.2–37.8	571.4–857.1	n.a.	n.a.	35.0	8.0	132.1	2.8%–4.1%	n.a.
1897/1901–2013*	3,200–4,400	n.a.	28.1–38.6	n.a.	46.0	5.6*	69.6–95.6	571.4–785.7	n.a.	n.a.	35.0	8.0	58.6	1.3%–1.8%	n.a.

Table 3. *Linking the magnitudes of environmental change with map accuracy measures to evaluate the reliability of results.*
**For the Landsat ETM+ image (03.03.2013), the total RMSE, based on the GSP residual report by the USGS, has been used.*

two different maps or images, their uncertainty Δy can be derived from the respective maps' planimetric errors Δx_1 and Δx_2, applying the law of propagation of uncertainty:

$$\Delta y = \sqrt{\Delta x_1^{\,2} + \Delta x_2^{\,2}}$$

In addition, a digitization-operator error has been incorporated in determining the uncertainty of shoreline change rates (based on Crowell, Leatherman, and Buckley 1991; M.-Muslim, Foody, and Atkinson 2007). In case of the historical maps, digitization and operator errors are estimated at 0.25mm each at map scale (following Crowell, Leatherman, and Buckley [1991]), resulting in a combined digitization-operator error $\Delta d_{1,2}$ of 0.35mm at map scale:

$$\Delta d_{1,2} = \sqrt{0.25mm^2 + 0.25mm^2}$$

Table 3 lists the ground distance equivalent of the digitization-operator error based on the individual map scales. In case of the aerial photographs and satellite images, estimates of the positional accuracy of the shorelines detected are based on M.-Muslim, Foody, and Atkinson (2007), who determined shoreline prediction accuracies depending on the spatial resolution of the satellite images of 3.16–4.25m in case of a resolution of 16m and 5.73–8.67m in case of a resolution of 32m. Based on these results and assuming a near-proportional relationship between resolution and positional accuracies determined, positional accuracies of 8m in case of the Landsat ETM+ image from 2013 (30m spatial resolution) and of 37m in case of the Corona image from 1962 (140m spatial resolution) were used.

Thus, based on the respective maps' planimetric errors Δx_1 and Δx_2 and the respective digitization-operator errors Δd_1 and Δd_2, the combined uncertainty is determined as follows:

$$\Delta y = \sqrt{\Delta x_1^{\,2} + \Delta x_2^{\,2} + \Delta d_1^{\,2} + \Delta d_2^{\,2}}$$

The combined uncertainty measures can be expressed in absolute (Δy) or relative ($\Delta y/s$ as a percentage of the shoreline change rate) terms. As shown in Table 3, the shoreline change rates detected for the period 1857/60–1897/1901 are marked by uncertainties of 17.7–48.0%, depending on the shoreline section, while the shoreline change rates detected for the period 1924/26–1962 are marked by uncertainty levels of only 3.4–10.2%.

The lower two rows of Table 3 clearly illustrate the dependence of the "required" or "minimum" levels of map accuracy on the rates of the environmental changes to be analyzed. When analyzing shoreline change rates for the entire period from 1857/60 to 2013, even the use of the comparably inaccurate map from 1857/60 yields results that are marked by uncertainty levels of only 2.8–4.1%, because the shoreline change rates for this period exceed the map inaccuracy measure by a factor of 25–38.

The number of studies that have directly linked environmental change rates with quantitative map accuracy measures is relatively limited to date. While some cartographers' work is completely devoted to the analysis of map accuracy (e.g., Jenny and Hurni [2011], Jenny [2006], Bönisch [1967], Nell [2009]), other scholars who used historical maps for analyzing environmental changes did partly not link their results with map accuracy measures, though they provided georectification errors (e.g. Khromova et al. [2006], Jabaloy-Sanchez et al. [2010], Bromberg, and Bertness [2005]). A comparison of the georectification errors provided by the authors with the environmental change rates detected shows, in case of the study of salt marsh losses by Bromberg and Bertness (2005), that environmental change rates clearly exceeded potential errors introduced by planimetric map accuracy. In fact, since many of the analyzed salt marshes were completely lost, planimetric map accuracy seems less relevant than topographic accuracy. In case of the study of Jabaloy-Sanchez et al. (2010), who reconstructed coastline changes in the Adra River Delta, the georectification result (RMSE of 11.5m for a map from 1855 and 237.3m for a map from 1873/76) combined with the shoreline change rate they detected for this period (16m per year, thus about 288m in total from 1855 to 1873) yields ratios between environmental change rate and RMSE of 25.0 for the map from 1855, but of only 1.2 for the map from 1873. The latter indicates high uncertainty of results. Also Tanaka et al. (2007), who analyzed coastline changes in the Miyagi and Fukushima Prefectures in Japan, did not link their quantitative map accuracy measures with the coastline changes identified. Their georectification results (RMSE <40m) and their shoreline change rates of about 220–550m between 1801 and 1904, as depicted in a map, yield ratios between environmental change rate and map accuracy measures of at least 5.6–14.1.

The work of Levin (2006) is one of the few studies that directly links map accuracy and environmental change rates. His dune movement rates of 3.98–6.32m/year and his maximum data resolution error (which in addition to the RMSE comprises a survey, digitization, and feature-boundary error) of 2.96m/year yield a ratio of 1.3–2.1, indicating relatively high levels of uncertainty. Also Salerno et al. (2008) compared environmental change rates with map accuracy. They analyzed surface area variations of glaciers in Nepal, comparing maps from the 1950s and the early 1990s. Linking their areal errors of 0.1 to 3.6km² for individual glaciers with the surface differences of 0.1 to 6.1km² detected for the respective glaciers, the ratios between environmental change rates and analytical accuracy varied between 0.6 and 10.0. That is, in one case (r = 0.6) the uncertainty measure exceeded the glacier change rate detected.

The quantitative measures proposed above support the appraisal of the historical maps' suitability for analyzing environmental changes. Yet, in some cases, and this particularly applies to maps with higher levels of inaccuracy, quantitative measures alone might not be sufficient to assess the maps' suitability for analysis. The example of the *Kaart der Preanger Regentschappen en Crawang* from 1813/15 illustrates this. While the RMSEs obtained for this map are somewhat comparable to those obtained for the map from 1857/60, qualitative comparison and overlay of this map with more recent maps show its comparatively low level of reliability, particularly in areas where the limited topographic accuracy combined with shoreline changes did not allow for the identification of ground control points. Also the contradicting comparison of topographic and planimetric accuracy between the map from 1813/15 and the map by J. T. Busscher from 1809 noted above supports the argument that quantitative accuracy measures should be combined with a qualitative, sometimes area-specific, appraisal of the other dimensions of accuracy.

CONCLUSION

The case of the shrinking Segara Anakan lagoon presented in this paper illustrates the large, to date clearly underutilized, potential of the historical cartographic material of Southeast Asia for analyzing spatial-temporal patterns of historical environmental changes. In the case presented, a combined analysis of historical maps and recent satellite images is the most obvious, most feasible, and—in terms of spatial coverage and resolution—also the most complete approach to analyze historical shoreline dynamics. However, the limited availability and accuracy of early historical cartographic material limits the temporal scale of analysis, poses methodological challenges, and introduces uncertainty.

The shoreline change analysis presented demonstrates that the question of how accurate historical cartographic material needs to be at minimum in order to be used for quantitatively reconstructing historical environmental changes considerably depends on the kind and magnitude of the dynamics to be analyzed. On the one hand, large magnitudes of environmental change potentially constrain the accuracy analysis and rectification of historical maps due to the resulting lack of suitable control points. On the other hand, the larger the magnitude of the environmental changes to be analyzed, the higher the levels of planimetric map inaccuracy that are acceptable.

Hence, determining ratios between environmental change rates and median planimetric map accuracy is crucial to assess a map's suitability for quantitative analysis. This should be combined with a qualitative appraisal of the maps, taking into account carto-bibliographic information and the various dimensions of map accuracy. In the case presented here, ratios between environmental change rates and median planimetric errors of mostly between 6.5 and >100 clearly indicate the maps' suitability for quantitative analysis. In case of analyzing continuous, single-directed environmental changes using a time-sequential series of maps, lower ratios between environmental change rates and planimetric map accuracy may be acceptable than in case of fluctuating changes.

Combined uncertainty measures, derived from the planimetric accuracies of the maps or images used and the environmental change rates detected, indicate the reliability of the results from cartographic analyses. In the case presented here, the uncertainty of the shoreline change rates detected for the historical time spans vary between 3 and 48%, depending on the period (i.e. the maps used) and the shoreline section. In the case of large magnitudes of environmental change, the use of even fairly inaccurate historical maps with planimetric accuracy levels of, for example 127m, in combination with recent satellite images, can provide surprisingly precise environmental change rates, with uncertainty levels of only 1–4%.

Last but not least, the results of the shoreline change analysis—the maps of change presented here—may be regarded as one milestone towards a better understanding of environmental changes in the Segara Anakan lagoon region and support further inquiry into the long-term dynamics and drivers of lagoon transformation.

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Research Paper 2

Lukas, M.C. (2015): Neglected Treasures. Linking Historical Cartography with Environmental Changes in Java, Indonesia. Cartographica.

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Abstrak (Abstract, translated into Indonesian)

Material kartografis historis di Asia Tenggara merupakan potensi yang signifikan untuk meneliti perubahan lingkungan di masa lampau. Akan tetapi, sebagian besar potensi ini belum disadari. Artikel ini mendalami kartografi historis daerah Laguna Segara Anakan di pantai selatan Pulau Jawa dalam konteks analisis perubahan garis pantai. Artikel ini menunjukkan bagaimana kartografi historis mendukung analisis perubahan lingkungan dan juga sebaliknya. Mendalami secara saksama sejarah kartografis daerah sasaran membantu memaksimalkan skala temporal dan resolusi analisis; memberikan wawasan tentang perkembangan bertahap dan replikasi, serta pengabaian atas pengetahuan kartografis; dan mendukung penilaian tentang keandalan peta, yang semuanya membantu mencegah adanya kekurangan analitis. Melengkapi analisis kuantitatif tentang material kartografis yang lebih baru dan relatif akurat dengan peta yang sangat awal dan kurang akurat dan catatan dari pembuat peta memungkinkan skala temporal pada penelitian lingkungan di masa lampau untuk diperluas semakin jauh ke masa lalu. Pada saat yang sama, hal ini mengungkap keterbatasan dan kekurangan analisis kartografis historis tentang perubahan lingkungan. Analisis penulis tentang peta awal Laguna Segara Anakan menunjukkan bagaimana informasi dari peta yang lengkap namun relatif tidak akurat telah berulang kali diperbanyak oleh pembuat-pempuat peta selama sekitar satu abad, sedangkan informasi dari peta yang lebih akurat namun tidak lengkap terus-menerus diabaikan.

Kata Kunci

Laguna Segara Anakan, kartografi historis, sejarah peta, pembuatan dan replikasi peta, akurasi peta, diagram laut, perubahan lingkungan masa lampau, sejarah lingkungan, rekonstruksi garis pantai

Neglected treasures

Linking historical cartography with environmental changes in Java, Indonesia

Martin C. Lukas[1]

Abstract

This paper directs attention to the large, but underutilised potential of the historical cartographic material of insular Southeast Asia for research into historical environmental changes. It explores the cartographic history of the Segara Anakan lagoon region on Java's south coast in the context of a lagoon shoreline change analysis. The paper demonstrates how qualitative analysis of the charts and written records from early mapping voyages can complement the quantitative analysis of more recent, more accurate maps, illustrates some limits and pitfalls of historical cartographic inquiry, and provides insight into the gradual development and replication, but also the ignorance of cartographic knowledge.

Key words

Segara Anakan lagoon, historical cartography, history of maps, map production and replication, map accuracy, sea charts, historical environmental change, environmental history, shoreline reconstruction.

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Introduction

Nearly half a century ago, Koeman (1968) and Harley (1968) remarked that historical cartography had focussed on carto-bibliography and map-makers' biographies, while the value of historical evidence contained in maps was largely neglected. Since then, historical maps have increasingly been used for research into historical conditions and dynamics. This has involved intensified connections between cartography and other disciplines and is related to the increased societal interest in understanding environmental changes. Historical maps have been used to analyse a broad range of environmental phenomena, including coastal features (Crowell, Leatherman, and Buckley 1991, Jabaloy-Sanchez and others 2010, Levin 2006, Monmonier 2008), land use and structural landscape characteristics (Haase and others 2007, Stäuble, Martin, and Reynard 2008), settlement processes (Levin, Kark, and Galilee 2010), agricultural histories (Pearson, and Collier 1998), soil degradation (Brookfield 1999), salt marsh losses (Bromberg, and Bertness 2005), and historical sites of industrial production and pollution (Leonard, and Spellane 2013). Yet, most of the potential of historical cartographic material for research into environmental changes remains untouched until today. This is particularly true for insular Southeast Asia.

Only few cartographers devoted attention to the historical maps of this region until recently. One of them is Günter Schilder, whose decade-long meticulous research into the cartographic history of the Netherlands East Indies deserves special appreciation (Schilder 1981, 1978, 1976). His and some other cartographers' research culminated in the publication of a number of brilliant atlases with facsimile reproductions of and background information about a large amount of historical maps (van Diessen, and Ormeling 2003, Knaap and others 2007, Schilder and others 2006, Roever, and Brommer 2008, Schilder, and Kok 2010, Suárez 1999). These atlases together with the map collections of, among others, the Royal Tropical Institute (KIT) in Amsterdam and The Netherlands National Archives provide an outstanding basis for research into historical environmental changes in insular Southeast Asia.

However, only few scholars have used this 'treasure' for analysing environmental and other dynamics. They include Raes and others (2009) on the use of historical maps to identify localities of specimen collections in Borneo; Marfai and others (2008), Hermawan (2003) and Sudarsono (2011), who reconstructed historical shorelines and river deltas on Java's north coast; Qomarun and Prayitno (2007), who analysed historical urban transformations in Solo, Java; as well as Schaafsma (1926) and Hadisumarno (1964, 1979), who analysed shoreline aggradation in the Segara Anakan lagoon.

This lagoon on Java's south coast (Figure 1) is the subject of the research presented in this paper. The Segara Anakan lagoon has undergone profound social-ecological transformations. Due to riverine sediment input, its water surface area has shrunk to one fourth of its previous extent within the past 1.5 centuries. This process has been seen mainly as a threat to the ecosystem and to local livelihoods for the last decades (see e.g. Bird, Soegiarto, and Rosengren 1982, Olive 1997, White, Martosubroto, and Sadorra 1989, Purba 1991, Yuwono and others 2007). Political discourses have framed upland agriculture as the single-most important cause of lagoon sedimentation, while neglecting a large range of other drivers (see Lukas, and Flitner under review, Lukas under review-b). This has contributed to the limited effectiveness of decade-long interventions aimed at halting sedimentation (see e.g. Schweithelm 1989). The knowledge of the longer-term dynamics and drivers of sedimentation is very limited. Data on river sediment loads covers the past 30 years only and is not reliable; and previous shoreline change analyses cover the 20th century only and are biased. Knowledge on the temporal dynamics of sedimentation is crucial for exploring the range and relative importance of its drivers, which include a large range of processes and transformations in the lagoon's catchment area (Lukas under review-b).

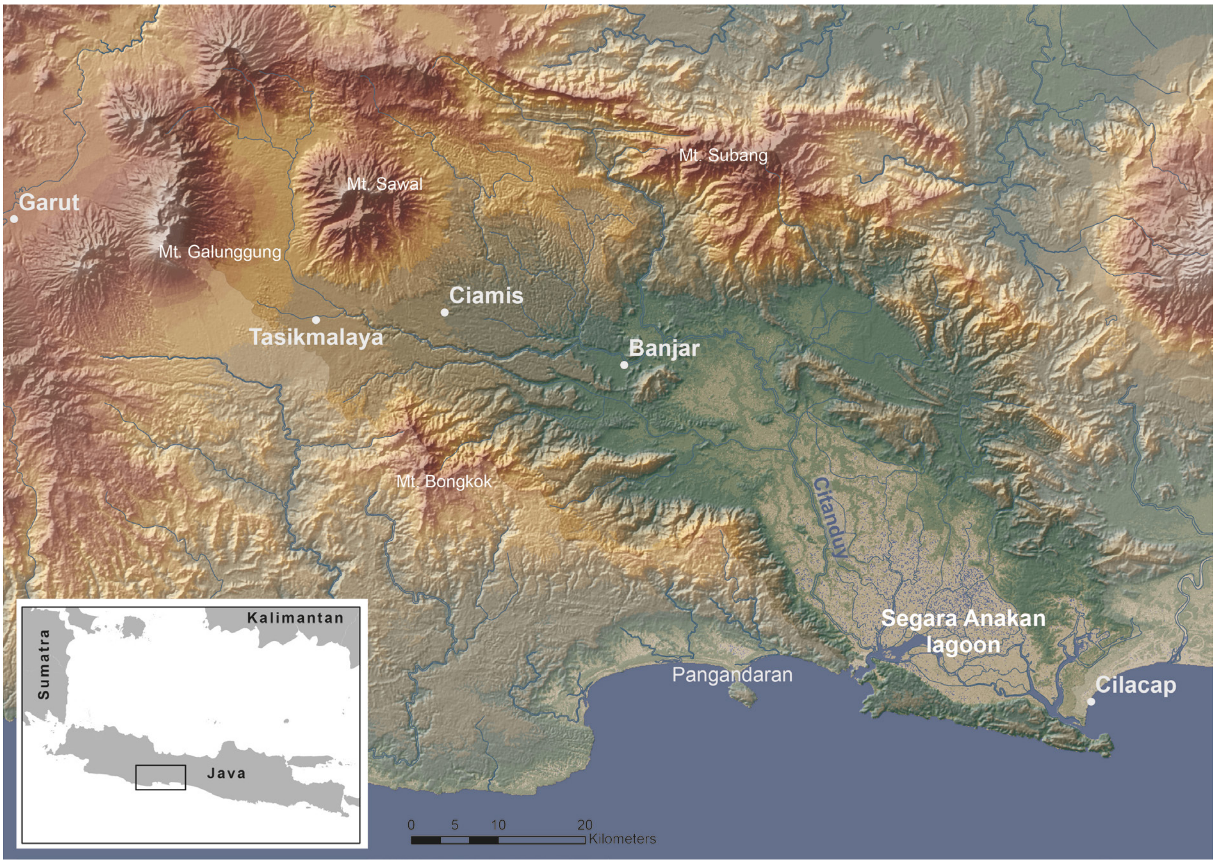

Figure 1: Location of the Segara Anakan lagoon and its catchment area on the south coast of Java.

To analyse the dynamics of sedimentation, I delved into the cartographic history of the region. Historical maps provide the only source of area-wide information about the historical size of the lagoon that is feasible to analyse. Yet, as my research illustrates, the limited availability and accuracy of historical maps limit the temporal scale and resolution of such an analysis, and the borrowing of information between map-makers can introduce biases.

The next section explores some of these limits and pitfalls of historical-cartographic analyses of environmental changes. It consequently proposes an approach that includes a thorough engagement with the cartographic history of the study area and combines a quantitative analysis of more accurate maps with a qualitative analysis of very early, rather inaccurate maps and of map-makers' records. Based on an exploration of the cartographic history of the Segara Anakan lagoon in the subsequent section, I present a quantitative analysis of lagoon shoreline changes and discuss its limitations. The remaining part of the paper presents an attempt to extend the time scale of this quantitative analysis further into the past by a qualitative analysis of sea charts from the late 17th and early 18th century. This demonstrates the utility of analysing map-makers' records and defines the limits and illustrates potential pitfalls of historical cartographic inquiry into environmental changes. Vice versa, it also shows how the engagement with historical maps in reconstructing environmental changes contributes to historical cartography. The case presented reveals how topographic information from complete, though comparably inaccurate maps is repeatedly reproduced, while information from more accurate but incomplete maps is consistently ignored. It also shows that maps valued as the most accurate and complete of their time as a whole can comprise sections with information copied from some of the least accurate earlier maps.

Historical-cartographic analysis of environmental changes: Limits, pitfalls and approaches

Historical maps provide large potential for analysing environmental changes. However, the further such an analysis is to extend into the past, the more it is constrained by the limited accuracy and availability of historical maps. This is a dilemma, given that analyses of environmental changes are particularly meaningful if they incorporate transitions from mainly nature-dominated to mainly human-dominated landscapes (Batterbury, and Bebbington 1999, Messerli and others 2000). In many parts of the world, the era of reasonably accurate, area-wide mapping did not start before the beginning of the era of major anthropogenic environmental change. This poses a major limitation to historical-cartographic inquiry. The quality and timing of the earliest maps define this limit. They determine the maximum temporal scale of analysis. In contrast to more recent material, the earliest maps are mostly not accurate enough for georectification and quantitative analysis. Yet, their qualitative analysis, combined with an exploration of the processes of their production and a review of map-makers' records can contribute at least qualitative information about environmental conditions prior to the production of more accurate maps.

However, most cartographic analyses of historical environmental changes have been confined to the periods covered by maps that are sufficiently accurate for georectification and quantitative analysis. The qualitative analysis of earlier, less accurate maps and of related carto-bibliographies, map making processes and map-makers' records, in contrast, has largely remained the domain of historical cartographers, with limited application in historical environmental research. The few studies that have qualitatively analysed early maps in reconstructing environmental changes include Forbes and others (2004) on shoreline responses to storms in the Gulf of St. Lawrence from the mid-18th century and Winterbottom (2000), who complemented a quantitative analysis of river channel changes in Scotland since the 1860s with a qualitative analysis of a less accurate map from 1755.

While the limited availability and accuracy of early maps limit the temporal scale of analysis, intermediate periods without cartographic surveys of the study area limit its temporal resolution. In this context, a thorough exploration of the region's cartographic history is crucial. Such an exploration involves the gathering of background information about map-makers and map making processes and the compilation of a systematic and complete account of historical maps. The process of my research has shown that this greatly helps to evaluate the maps' reliability and provides the basis for selecting the most suitable material for an analysis of environmental changes with an as high temporal resolution as possible. Also the work by Levin (2006) and Levin, Kark and Galilee (2010) demonstrates the utility of intensive engagement with the historical cartography of a region in reconstructing historical environmental, or in their case, settlement dynamics.

My research also showed that intensive engagement with the region's cartographic history helps to avoid biases by revealing how map-makers borrowed information from each other. Such borrowing was common throughout history, in earlier times usually without acknowledgement. Plagiarism of information and style was widespread, for example, among rival commercial map-makers throughout Europe between the 16th and 18th centuries (Smith 1986, Pedley). The borrowing of information from previous maps and its combination with updated or more accurate information has been an integral part of the gradual development of cartographic knowledge. However, sometimes the information copied and spread was inaccurate and/or out-dated. The depiction of California as an island on various maps in the 17th and 18th centuries is a good example of map-makers consistently borrowing information from earlier less accurate sources against better knowledge (see Polk 1995). Also erroneous borrowing from earlier maps introduced inaccuracies into the chains of copied maps (e.g. Crone 1961). Hence, documenting chains of copies and identifying the original maps, an approach termed carto-genealogical method (see Rubin 1990) or more broadly, comparative cartography, which documents the gradual development of cartographic knowledge over time (Harley 1968), has been a major field of historical cartography. This approach that regards each map "as part of an evolutionary sequence […] through which […] mutual indebtedness and innovation are established" (Harley 1968) helps to reveal the chains of borrowing and to assess the maps' reliability, both of which is crucial in cartographically reconstructing environmental changes.

Biases in previous shoreline reconstructions of the Segara Anakan lagoon illustrate the pitfalls caused by lacking attention to map making processes and the copying of information.

For example, Hadisumarno (1964, 1979) ignored that the topographic maps produced by the U.S. Army in the 1940s were based on Dutch maps from the 1920s. Hence, the sudden rise in his annual aggradation rates for the eastern shoreline from 5m (1900-1940) to 54m (1940-1946), which Hadisumarno (1979, 49) related to 'deforestation within the river catchment area of Citandui during the Japanese occupation' actually resulted from the fact that the shoreline data that he assumed to reflect the situation in 1940 was based on surveys conducted in the 1920s. The same bias appears in the shoreline change maps subsequently included in various project plans and reports (ASEAN/US CRMP 1992, PRC-ECI 1987, Soewondho 1984, ECI 1994). This bias could have been easily avoided by paying attention to the documentation contained on the map sheets. In the case of earlier maps, in contrast, the borrowing of information is mostly not acknowledged, but can only be revealed by a comparative analysis of the entire sequence of maps and inquiry into map making processes.

To sum up, a thorough exploration of the cartographic history of the study area supports historical-cartographic analyses of environmental changes in various ways. A review of the early history of mapping and the integration of a qualitative analysis of early maps and map-makers' records allows maximising the temporal scale of analysis. Gathering a complete account of historical maps, comparing these maps, and linking them with information about map-makers and map making processes allows maximising the temporal resolution of analysis and helps to evaluate the maps' reliability, to reveal the borrowing of information between map-makers, and hence to avoid potential pitfalls.

Therefore, the next section explores the cartographic history of Java's south coast, paying particular attention to the Segara Anakan lagoon. This is not only the basis for the shoreline change analysis in the subsequent section, but also provides insight into the gradual development and replication as well as the ignorance of cartographic knowledge. The review of this underutilised material and its sources shall also encourage its use by other scholars.

Cartographic history of the Segara Anakan lagoon

As a basis for my shoreline change analysis, the temporal scale and resolution of which I aimed to maximise, I gathered more than 50 maps and map series produced between the 16th and 20th century from various libraries and archives worldwide. The following chronological account along with Table 1 focus on the maps that contributed additional topographic information to previously existing maps.

From early sea charts to systematic topographic surveys: overview of map-makers and sources

In many parts of the Indonesian archipelago, the sea charts drawn by the Portuguese and Dutch starting in the 16th century provided the first known cartographic records (see Thomaz 1995, Schilder and others 2006, Schwartzberg 1994). The earliest preserved charts roughly sketching Java as an island were drawn by the Portuguese 1513-1519 (see Thomaz 1995, Suárez 1999). While the topographic knowledge of Java's north coast slightly improved during the following decades, its south coast remained largely unknown to the Europeans. Following the sighting of Australia in the 1530s, Java was even believed to be part of Australia. This is reflected in various Portuguese charts drawn 1535-1561 with the southern part of Java depicted as uncharted territory without any coastline (see Thomaz 1995).

The first known European landfall on Java's south coast by Francis Drake in 1580 and a first Dutch voyage led by Cornelius de Houtman in 1595-97 ascertained that Java was an island (Suárez 1999, Schilder, and Kok 2010). This is reflected in various maps drawn thereafter, including the map of Java by John van Linschoten from 1598[2] and the map of the East Indian Archipelago by Jodocus Hondius from 1606[3]. Both maps illustrate the immense gap between the topographic knowledge of Java's north as compared to its barely known south coast.

Around 1700, the leadership in the cartography of Southeast Asia was taken over by the Dutch, whose trading ships regularly arrived in West Java, where they set up trading posts and established Batavia. In line with its economic and administrative primacy in the Netherlands East Indies, Java was cartographically clearly more documented during the following centuries than the other islands of the archipelago. By the late 19th century, the island belonged to the best cartographically documented colonial areas in the tropics (van Diessen, and Ormeling 2003). The cartographic activities were first dominated by the United Dutch East India Company (VOC), which governed the relations between Java and The Netherlands (Schilder and others 2006, Knaap and others 2007). From 1864, this task was taken over by the Topographical Service in the Netherlands East Indies (TDNI) (ibid.).

The cartographic material produced by the VOC and the TDNI over the course of three centuries represents a treasure for research into historical environmental changes. Most of this material is preserved in The Netherlands National Archives in The Hague and the KIT in Amsterdam. In addition, the collections of the National Libraries of Indonesia, Australia and Germany and various other libraries and antiquarian shops comprise historical maps of Indonesia. The digitisation of many of these collections (see Levi 2009) and the compilation of the Comprehensive Atlases of the Netherlands East Indies (van Diessen, and Ormeling 2003) and the Dutch United East India Company (Knaap and others 2007, Schilder and others 2006)[4] along with the account of VOC manuscript charts by Schilder and Kok (2010) have tremendously enhanced the access to this material and to related background information.

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[2] This map is contained in the collections of the Royal Tropical Institute (KIT) in Amsterdam.

[3] This map is contained in the collections of the National Library of Australia.

[4] The Comprehensive Atlas of the Dutch United East India Company comprises seven volumes, only two of which are quoted here. The entire Atlas Series greatly supports cartographically based historical research in the regions covered: Volume I: Atlas Isaak de Graaf / Atlas Amsterdam, covering all the VOC's settlements and territorial possessions in Asia and Africa between 1691 and 1704; Volume II: Java and Madura; Volume III: Malay Archipelago and Oceania; Volume IV: Ceylon; Volume V: Africa; Volume VI: India, Persia and Arabian Peninsula; Volume VII: East Asia, Burma to Japan.

In addition to the material produced by the VOC and the TDNI, Carl Gustav Ekeberg, who was associated with the Swedish East India Company, produced detailed charts of some sections of Java's south coast.

Early sea charts: Production, replication and ignorance of cartographic knowledge (seventeenth and eighteenth century)

Whereas the sea routes through the Sunda Strait and along Java's north coast had already been charted fairly accurately in the early 17th century, Java's inaccessible and economically unimportant south coast was not systematically mapped before the 1690s (Schilder 1978, Knaap and others 2007). Until then, the knowledge of this coast was based on observations by seafarers who accidently missed the Sunda Strait and thus drifted to Java's south coast (Schilder 1978). The topographic knowledge they gained during these involuntary detours is reflected in the *Kaart van de Javaanse Zee*, drawn by the VOC's first official map-maker, Hessel Gerritsz, in 1628 (Schilder 1978, Schilder, and Kok 2010). It is the earliest preserved map providing a rough outline of Java's south coast (Schilder 1978). It depicts the western outlet of the Segara Anakan lagoon, but does not show any indication of the lagoon itself. The same applies to the maps published between the 1650s and 1680s.

In 1692 and 1698, the VOC sent the first exploratory expeditions to chart Java's south coast (Schilder 1978, 1981). During the first of these expeditions, cartographer Hendrick Jansen Roos produced rough charts of the bays west and east of Nusakambangan, but he did not map the Segara Anakan lagoon. The second expedition was led by Cornelius Coops. He received the explicit instruction to explore the Segara Anakan lagoon (Schilder 1981, 93). Coops, as judged by Knaap and others (2007, 64), composed 'a remarkably accurate survey' of the south coast. One of his four charts represents the earliest known map of the Segara Anakan lagoon (Figure 2). The topographic information from his manuscript charts was incorporated into various maps of Java produced around 1700[5].

Since Governor-General van Riebeeck was not satisfied with Coops' results, additional charting expeditions were undertaken in 1711 under the leadership of Albert van Petten and in 1739 under the leadership of Paulus Paulusz (Schilder 1978, 1981). The charts drawn by van Petten, as identified by Schilder (1978), are contained in The Netherlands National Archives, and parts of his 'daily notes' and his 'report and extensive account' are contained in de Haan (1911). While in drawing the outlines of the bays west and east of Nusakambangan, van Petten seems to have extensively borrowed from Coops' maps, he drew the eastern part of the Segara Anakan lagoon clearly more accurately than Coops had done (see Figure 3). This aspect, which will be further discussed below, is not only relevant in exploring the dynamics of lagoon sedimentation, but also interesting with regard to the replication and ignorance of cartographic knowledge.

[5] See the maps contained in The Netherlands National Archives and the reproductions in Schilder and others 2006 and in Knaap and others 2007.

The subsequent voyage by Paulusz in 1739 was mandated with the task of taking depth soundings in the Segara Anakan lagoon region (Schilder 1981, 1978). However, the chart drawn by Paulusz did not contribute any additional topographic information of this region. According to his report (Paulusz 1739), their ship reached the lagoon's eastern outlet and took anchorage there, but was carried away to the western end of Dirk de Vries Bay (west of Pangandaran, see Figure 1) by strong winds and currents during the next night. Paulusz thus neither mapped Nusakambangan Island nor did he enter the lagoon. Therefore, the lagoon's outline in his map is completely based on Coops' map. Schilder (1981, 104) valued Paulusz' map as 'the best sea chart of the South Coast of Java' until the end of the VOC administration. However, for the Segara Anakan lagoon region Paulusz' map did not add any further details to the map drawn by Coops. Van Petten's map, in contrast, provides a clearly more detailed outline of parts of the eastern lagoon and, as will be shown in the next section, is also more accurate than Coops' map. However, the additional, more detailed and more accurate information contained in van Petten's map was neither taken up by Paulusz nor was it incorporated into any maps produced and published thereafter until the early 19th century.

That Paulusz and other map-makers and publishers thereafter consistently copied from Coops' rather inaccurate chart of the Segara Anakan lagoon, while not borrowing from van Petten's more detailed and more accurate chart, might be due to the fact that the latter depicts only parts of and not the entire lagoon[6]. That is, subsequent map-makers relied on Coops' complete albeit inaccurate and less detailed chart rather than on van Petten's more accurate and more detailed but incomplete one. This is reflected in the various maps produced by commercial map-makers like the Van Keulen Company (see the maps contained in the KIT, see Schilder, and Kok 2010), in the map drawn by Francois Valentyn in 1725-27 (contained in The Netherlands National Archives), and in a map drawn by Ekeberg in 1774 (contained in the Kriksarkivet Stockholm, also see Arne 1959). Ekeberg produced this map a few years before conducting his own surveys, largely based on Paulusz' chart (Arne 1959). This is clearly reflected in his outline of the Segara Anakan lagoon, which is thus also based on Coops' chart. My review of all available cartographic material of the region shows that the outline of the Segara Anakan lagoon in all maps and atlases produced until 1809 at various scales is based on Coops' map from 1698, while the more detailed and more accurate knowledge contained in van Petten's map was consistently ignored.

[6] Special thanks to Ferjan Ormeling.

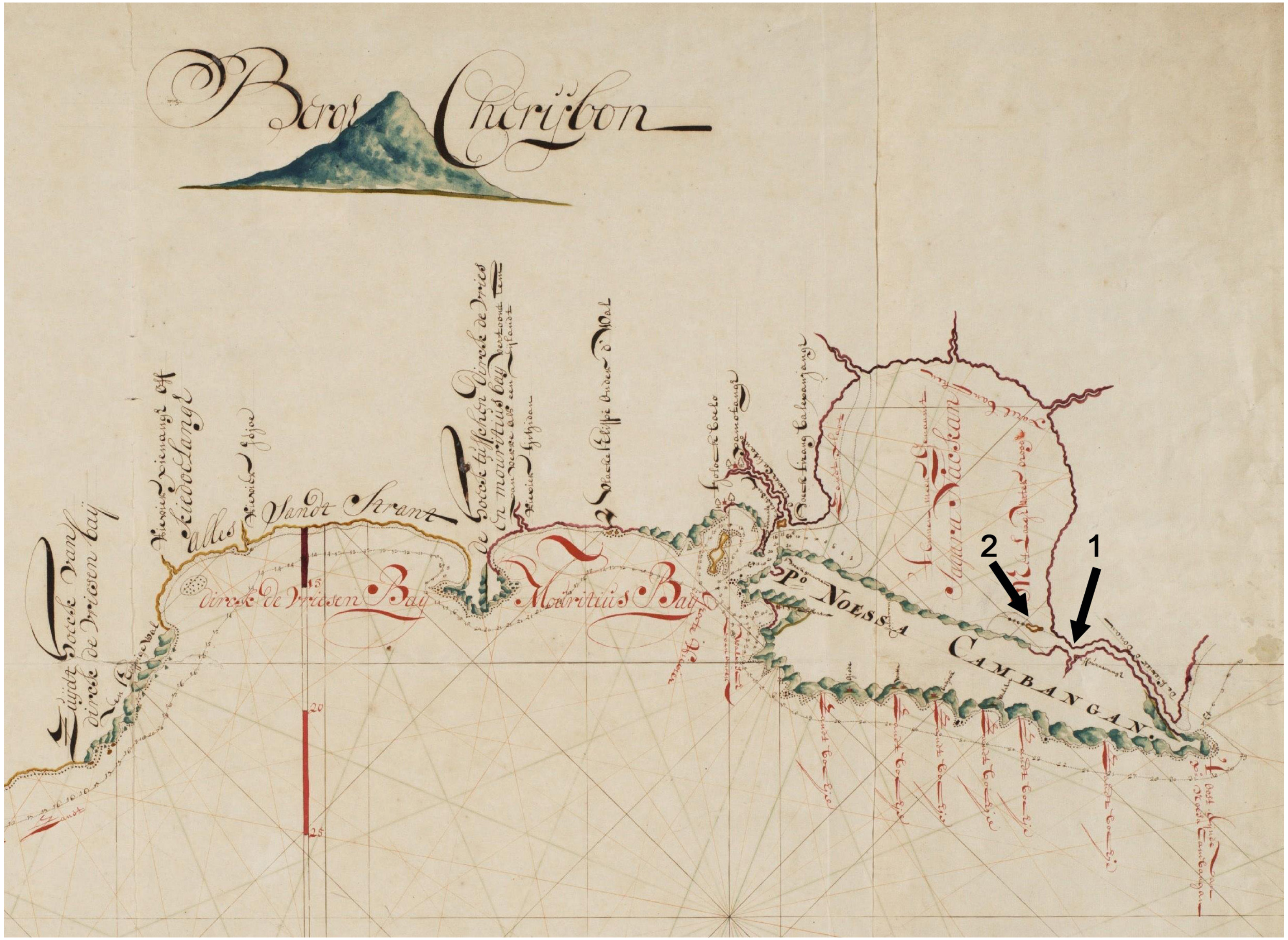

Figure 2: This section of the manuscript sea chart drawn by Cornelius Coops in 1698 represents the earliest known map of the Segara Anakan lagoon; retrieved from the Netherlands National Archives in The Hague. The arrows illustrate the discussion of Coops' and van Petten's travelling routes in the text.

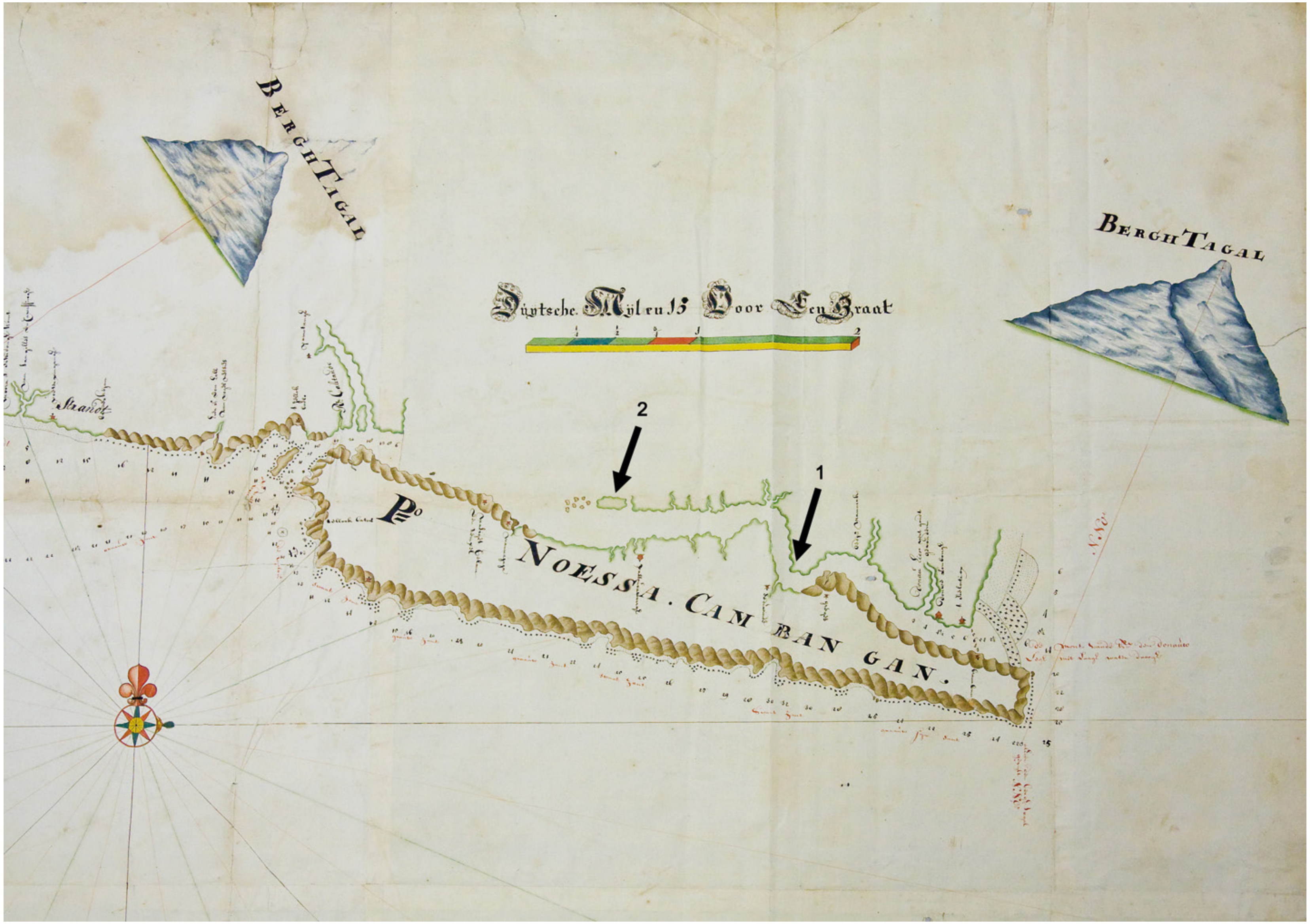

Figure 3: Section of the manuscript sea chart drawn by Albert van Petten in 1711; retrieved from the Netherlands National Archives in The Hague. The arrows illustrate the discussion of Coops' and van Petten's travelling routes in the text.

Following the four mapping voyages between 1692 and 1739, the cartographic knowledge of most of Java's south coast was not further developed until the early 19th century. The maps produced during this period were merely enriched with topographic information of the inland areas. An exception is the maps drawn by Ekeberg in the early 1780s. Ekeberg, who was associated with the Swedish East India Company, undertook a number of voyages to the East Indies, during which he produced very detailed maps of the bays east and west of Nusakambangan and the outlets of the Segara Anakan lagoon (Figure 4). However, he did unfortunately not map the lagoon itself. His maps were published by A. Dalrymple, a leading hydrographer of the British East India Company, and are contained, among others, in the collections of the Bayerische Staatsbibliothek[7]. These maps and the connections between Ekeberg and Dalrymple have to my knowledge not been explored yet by cartographers.

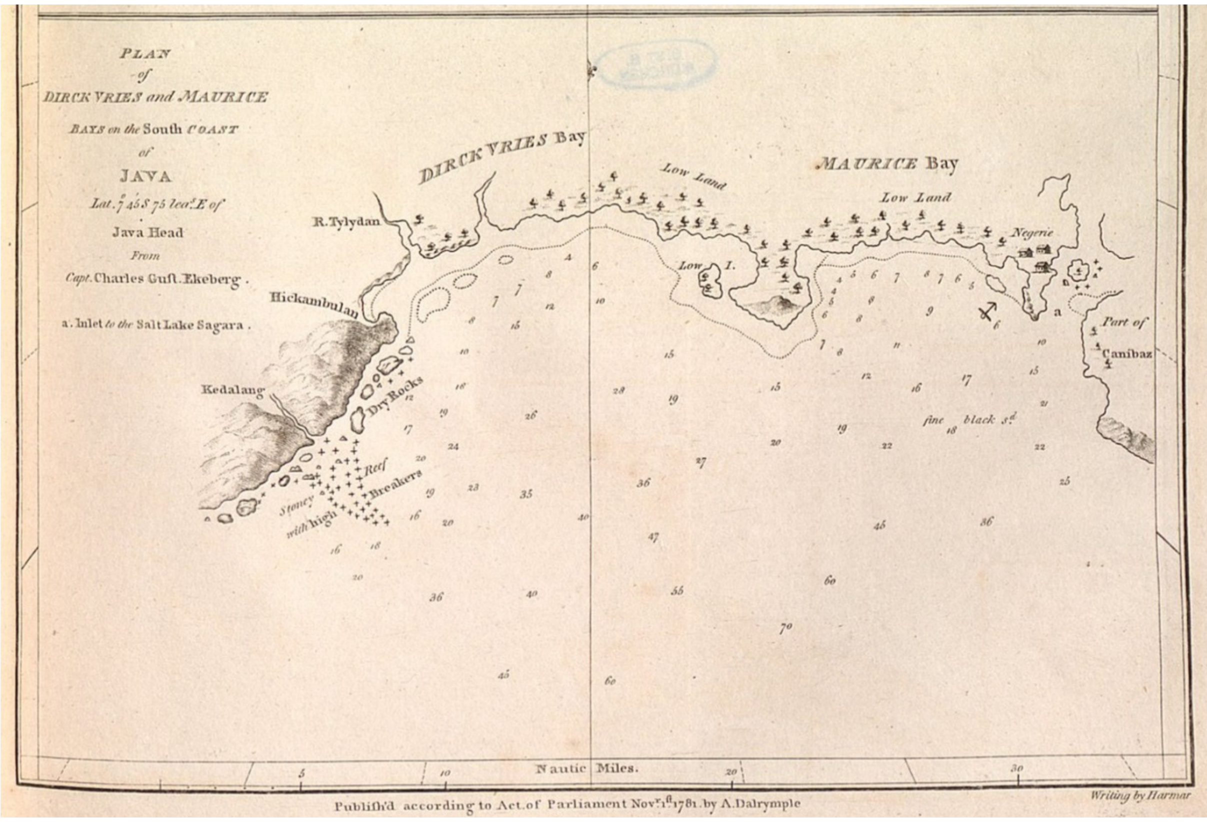

Figure 4: The maps drawn by Carl Gustav Ekeberg in the early 1780s depicts the bays east and west of the Segara Anakan lagoon clearly more accurately than any of the earlier maps (the map reproduced here depicts the bays west of the Segara Anakan lagoon). However, Ekeberg did not map the Segara Anakan lagoon.

[7] One sheet comprises the following two maps: (1) Plan of Vinkops or Wine-Coopers Point and Bay on Java, (2) Plan of Dirck Vries and Maurice Bays on the South Coast of Java, both from Capt. Charles Gust. Ekeberg. Published according to Act of Parliament Nov. 1st 1781 by A. Dalrymple. The other sheet comprises three maps, depicting 'Turtle Bay', 'Patietan Bay', and 'Flittermous Bay', all on the south coast of Java. Published according to Act of Parliament Feb. 17th 1782 by A. Dalrymple.

Systematic topographic surveys (19th and early 20th century)

The first large-scale mapping of Java was begun under the Dutch in the 1790s and pushed forward during the English Interregnum 1811-1816 (Knaap and others 2007). The resulting topographic map series of the Priangan Regency from 1813-1815 comprises one of the two earliest maps depicting the entire Segara Anakan lagoon (Figure 5) with an accuracy that allows for georectification without resulting in a distorted image. These maps were obviously not published immediately (see Olivier 1829), but biographical information of the map-maker J.T. Bik (Molhuysen, and Blok 1930) indicates that there was no major time gap between the dates of mapping and map production.

A second similarly accurate map was produced by Jan Theunis Busscher in 1809 (Figure 6), obviously independent from the above-mentioned mapping mission. Busscher conducted hydrographical observations along the coasts of Java and other islands from 1808 until 1811 (Gommans, and van Diessen 2010). His map represents the earliest documentation of water depths within the lagoon. However, his bathymetric data is confined to the main fairways and hence does not allow for a three-dimensional reconstruction of the lagoon's waterbody. The same applies to the shoreline and bathymetric surveys of the lagoon's outlets conducted during the English Interregnum[8] and a shoreline and bathymetric map of the eastern outlet[9], the production of which 1848-1857 was certainly related to the construction of the nearby port of Cilacap. Both drawings are extremely detailed, but only cover the lagoon's outlets.

Between 1849 and 1882/86, a complete topographic mapping, including the first triangulation, of the whole of Java was carried out (van Diessen, and Ormeling 2003, Schuitenvoerder 1920). The resulting maps at a scale of 1:100,000 are clearly more detailed than all previous topographic maps. The residency map of Banjoemaas, produced 1857-60, comprises a detailed outline of the Segara Anakan lagoon (see Figure 7). It is the earliest map that I found accurate enough for a quantitative shoreline change analysis.

Starting in 1896, a first revision of the topographic information of Java was carried out (van Diessen, and Ormeling 2003). The resulting topographic map series comprises three map sheets of the Segara Anakan lagoon (see Figure 8), which I used for the quantitative shoreline change analysis. A second revision of the topographic data that was begun in 1924 led to the production of a new map series at a scale of 1:50,000 (see Figure 9). Five of the map sheets covering the Segara Anakan lagoon are based on surveys conducted in 1924-26,

[8] It is remarkable that the results of these surveys of the lagoon's outlets were included in separate detailed drawings on a map of the whole of Java at a scale of 1:800,000 that was published in 1817 (A map of Java, chiefly from surveys made during the British Administration, constructed in illustration of an Account of Java, by Thomas Stamford Raffles Esq. and engraved by J. Walker). This map is contained in several libraries and archives, including the German National Library.

[9] 'Het zeegat en de reede van Tjilatjap', trigonometrisch opgenomen door den luitenant ter zee J. Groll. Uitgave Batavia, 1857. Contained in The Netherlands National Archives.

while one sheet, covering the western outlet is based on surveys conducted in 1940/41. Since no shoreline aggradation occurred in this area, this map sheet could be used for the quantitative shoreline reconstruction along with the other map sheets[10].

[10] The six map sheets, retrieved from KIT and used for the quantitative shoreline change analysis are reprints of the original maps. These reprints were produced between 1938 and 1942.

Figure 5: Section of Sheet 20 of the Kaart der Preanger Regentschappen en Crawang, based on surveys carried out between 1813 and 1815; retrieved from the Netherlands National Archives in The Hague.

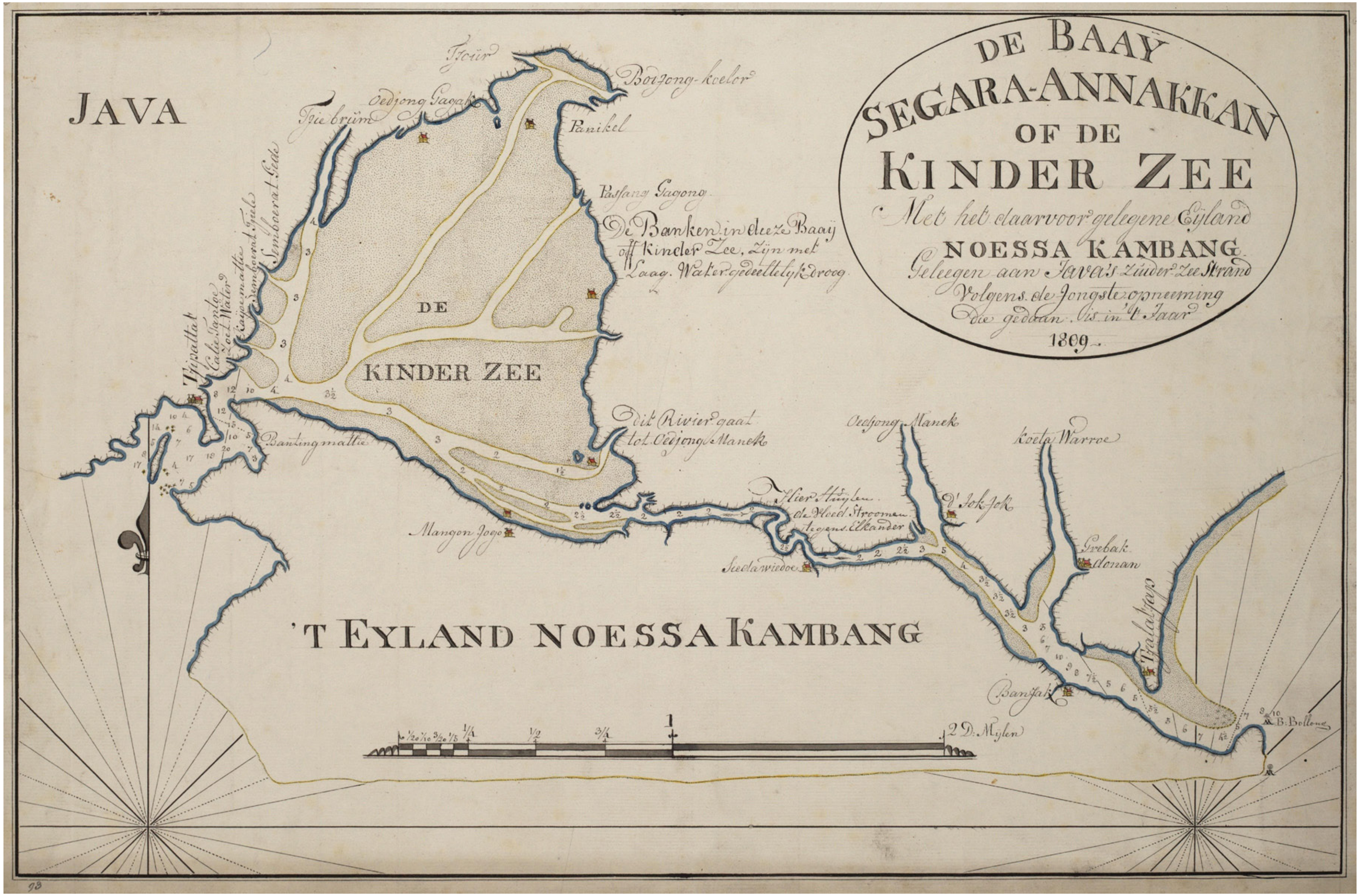

Figure 6: Map of the Segara Anakan lagoon, drawn by Jan Theunis Busscher in 1809; retrieved from the Netherlands National Archives in The Hague.

Figure 7: Section of the Topographische Kaart van de Residentie Banjoemaas, based on surveys carried out between 1857 and 1860; retrieved from KIT.

Figure 8: Topographic map of Java, Residency Banjoemas, produced by TDNI, based on surveys carried out between 1897 and 1901; compilation of sections of Map Sheets III, IV en VIII, VII; retrieved from KIT.

Figure 9: Topographic map of Java, Middle and West Java, produced by TDNI, mainly based on surveys carried out between 1924 and 1926; compilation of sections of Map sheets 42 / XLI D, 43 / XLI C, 43 / XLI D, 42 / XLII B, 43 / XLII A, 43 / XLI D; retrieved from KIT.

No updates for decades (1920s-1960s): Limits to the temporal scale of analysis

Following the production of the topographic map series in the 1920s, no systematic mapping of Java was conducted for decades. The resulting lack of updated cartographic information for the period 1924/26-1960s clearly limits the temporal resolution of cartographic inquiries into historical environmental changes. The maps printed during this period were based on already existing information. For example, the maps prepared under the direction of the U.S. Army's Chief of Engineers during World War II (Java & Madura 1:50,000) are based on earlier Dutch maps, which in turn are based on the surveys conducted in the 1920s. Though these maps did not contribute any new topographic information, I have included them in Table 1 to show the time gap between data collection and map publication. This time gap, or in other words, the borrowing of information from earlier maps, had been neglected by Hadisumarno (1964, 1979) and others. Also the maps printed by the Japanese during their occupation of Java 1942-1945 (contained in the Earth Sciences and Map Library of the University of California at Berkeley) were based on the Dutch maps from the 1920s. The same applies to a map series of Java produced by the U.S. Army Map Service in 1954 at a scale of 1:250,000 (contained in the Perry-Castañeda Library at the University of Texas).

Only the Peta Ichtisar Djawa-Madura, a topographic map series produced by the Indonesian Direktorat Topografi between 1956 and 1961 at a scale of 1:250,000 (contained in the Australian National Library), comprises updated topographic information. However, since the information was updated only for parts of the lagoon and due to its small scale, this map cannot be used for reconstructing historical shorelines, and its qualitative analysis does also not provide significant new insight.

Also an extensive, time-consuming search for aerial photographs possibly recorded by various air force commandos during World War II has not yielded any results. A few of the more than 30 libraries, archives, military and other organisations searched or contacted worldwide might hold relevant material, but finding it within millions of uncatalogued photographs remains a challenge. Furthermore, a large portion of the material was destroyed in theatre during retreat or thereafter. The aerial photographs recorded by the Dutch reconnaissance pilot van Breemen, which are contained in the Netherlands Institute of Military History, comprise images of the eastern part of the lagoon, but not of the western part which was affected by sedimentation. To the material from aerial surveys, which were likely conducted by the Indonesian Army Topographic Service in 1946, I could not get access.

Satellite images: A new era of mapping (1960s onwards)

Thus, following the topographic surveys of the 1920s, the next temporal layer of lagoon shoreline information gathered is an image of the Corona Satellite Mission FTV-1126, an optical reconnaissance satellite mission launched in 1962 by the U.S. Air Force. From the early 1970s, Landsat and other satellite images provide an easily accessible basis for analysing environmental changes with accuracy levels and temporal and spatial resolutions that completely outshine those provided by early topographic maps from the 19th century, not to mention the manuscript sea charts from the 17th and 18th century.

Table 1: Chronological overview of the historical maps of Java’s south coast / the Segara Anakan lagoon. Out of more than 50 historical maps and map series gathered, the table mainly lists the maps that contributed additional topographic information to previously existing maps.

Map title or description	Surveyor/ Editor	Year of map production / publication	Year of topographic data collection	Scale	Library, archive, and / or source of reproduction	Description	Suitability for analysis of historical environmental change
Various sketches of the Malay Archipelago	Francisco Rodrigues, Pedro Reinel, Lopo Homem & Reinéis	1513-1519			Various libraries, see Thomaz 1995 (Thomaz 1995)	Earliest known charts roughly sketching Java as an island.	Not suitable
‘Insul Indi orientalis’	Jodocus Hondius	1600-1612		approx. 1:16,000000	National Library of Australia	Rough outline of Java’s north coast, south coast unknown.	Not suitable
‘Kaart van Java, de Javazee en aanliggende Kusten‘	Hessel Gerritsz	1628		approx. 1:1,630,000	Bibliothèke Nationale Paris; see Schilder (1981) and Knaap and others (2007)	Earliest preserved map providing a very rough outline of Java’s south coast.	Not suitable
‘Kaart van het island Java en Madura’	unknown	1680		approx. 1:928,000	Schilder and others (2006)	Improved topographic knowledge of Java’s north coast only.	Not suitable
‘De Baij van Dirck de Vries en Mauritius ende Schildpadts Baij’ (charting expedition 1692)	Hendrick Jansen Roos	1692	1692	approx. 1:65,000	Bibliothèke Nationale Paris, see Schilder (1981)	Earliest more detailed map of one section of Java’s south coast (bays east and west of Nusakambangan Island).	Not suitable

Map title or description	Surveyor/ Editor	Year of map production / publication	Year of topographic data collection	Scale	Library, archive, and / or source of reproduction	Description	Suitability for analysis of historical environmental change
Four manuscript maps of charting expedition 1698	Cornelius Coops	1698	1698	approx. 1:140,000	Netherlands National Archives, see Schilder (1981) and Knaap and others (2007)	Fairly accurate map of Java's south coast, earliest known map of the Segara Anakan lagoon.	For qualitative analysis only
'5 Caerten van de Suijd-hoek van het Eijland Noessa Cambangan tot inde Straat Sunda'	Albert van Petten	1711	1711	approx. 1:120,000	Netherlands National Archives, partial reproductions in Schilder (1981) and Knaap and others (2007)	Map of the western section of Java's south coast, based on Cornelius Coops' map, adding additional topographic details for parts of the Segara Anakan lagoon and depth soundings.	For qualitative analysis only
'Generale pas caart van de zuyd cust Java ondersogt inde jaare MDCCXXXIX/PP'	Paulus Paulusz	1739	1739	1:500,000	Netherlands National Archives, see Schilder (1981) and Knaap and others (2007)	Outline of Java's entire south coast, partly based on Cornelius Coops' map, adding more details in some areas, not including the Segara Anakan lagoon.	For qualitative analysis only
De Baay Segara-Annakkan of de Kinder Zee Met het daarvoor gelegene Eiland Noessa-Kambang, gelegen aan Java's Zuider Zee Strand	Jan Theunis Busscher	1809	1809	1:76,000	Netherlands National Archives	First complete and fairly detailed map of the Segara Anakan lagoon	For qualitative analysis only

Map title or description	Surveyor/ Editor	Year of map production / publication	Year of topographic data collection	Scale	Library, archive, and / or source of reproduction	Description	Suitability for analysis of historical environmental change
Kaart der Preanger Regentschappen en Crawang, gecoppieerd naar die van den Heer Beetjes door J.T. Bik	Under Lieutenant-Colonel Pieter Jacob Beetjes	1817	1813-1815	1:114,000	Netherlands National Archives, see Knaap and others (2007)	Map Series, each of which was produced for most or all parts of Java. All these map series comprise a complete outline of the Segara Anakan lagoon with increasing accuracy over time.	For qualitative analysis only
Topographische Kaart van de Residentie Banjoemaas	Under direction of the Kolonel Direktur der Genie W.C. von Schierbrand by the Kapitein der Infanterie W. Beijerink	1860	1857-1860	1:100,000	KIT; Sächsische Landesbibliothek, Staats- und Universitätsbibliothek Dresden	Map Series, each of which was produced for most or all parts of Java. All these map series comprise a complete outline of the Segara Anakan lagoon with increasing accuracy over time.	Suitable for quantitative analysis
Topographic map of Java, Residency Banjoemas (Map Sheets III, IV en VIII, VII)	TDNI, Land tax survey brigades	1901-1904	1897-1901	1:100,000	KIT		Suitable for quantitative analysis

Map title or description	Surveyor/ Editor	Year of map production / publication	Year of topographic data collection	Scale	Library, archive, and / or source of reproduction	Description	Suitability for analysis of historical environmental change
Topographic map of Java, Middle (and West) Java (Map sheets 42/XLID, 43/XLIC, 43/XLID, 42/XLIIB, 43/XLIIA, 43/XLID)	TDNI, Land tax revision brigades	1925-29, (1942), reprints 1938-42	1924-26, (1940-41)	1:50,000	KIT		Suitable for quantitative analysis
Topographic map of Java and Madura (same map sheets as above)	Under direction of the Chief of Engineers, U.S. Army	1939-1944	Mainly 1920s	1:50,000	Indonesian National Library	Reproduction based on previous topographic map series.	To assure chronometric accuracy use original maps.
Peta Ichtisar Djawa-Madura, Map sheet 12 (Purwokerto)	Balai Geografi Djatop, for Direktorat Topografi Angkatan Darat, TNI (Indonesian National Army)	1959	Data from maps published 1938-1944; partial update	1:250,000	National Library of Australia in Canberra	Topographic data largely based on Dutch maps from 1920s; but partial updates for southern parts of the lagoon.	Only limited qualitative analysis, since only partial update and due to small scale.

Cartographic reconstruction of historical shoreline changes

Quantitative analysis of the material from the 19th and 20th centuries

Following a quantitative assessment of the planimetric accuracies of the historical maps listed in Table 1, the maps from the mid-19th century onwards, the Corona image, and a number of more recent satellite images were overlayed, using ArcGIS, and used for delineating historical lagoon shorelines. An outline of the methodological approach, the results of the quantitative accuracy assessment, and a discussion of the links between map accuracy and environmental change rates are contained in Lukas (under review-a). Figure 10 depicts the results: a rapid decline in the lagoon's water surface area, which accelerated between 1857-60 and the 1980s.

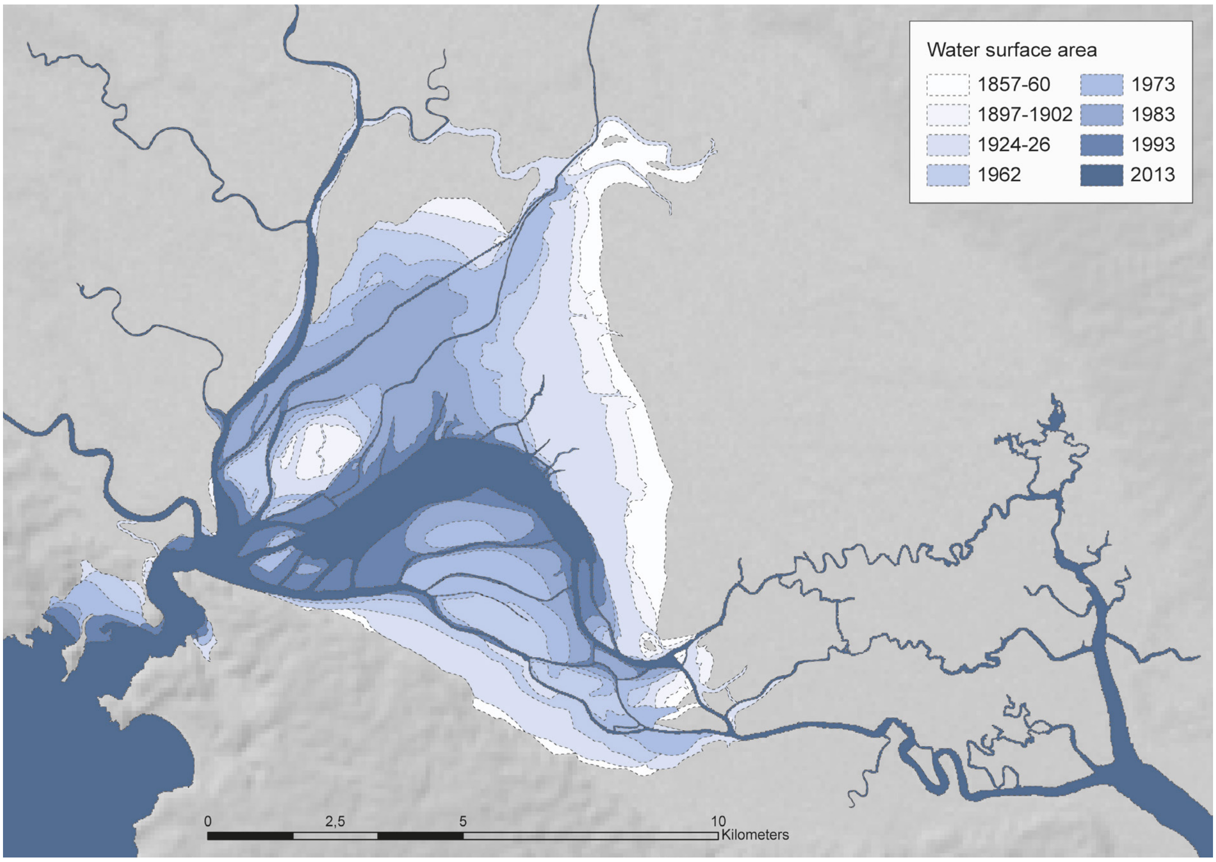

Figure 10: Change in the water surface area of the Segara Anakan lagoon 1857/60-2013, based on the quantitatively analysable historical maps listed in Table 1 (1857-60, 1897-1901, 1924-26) and a series of satellite images (1960s onwards). Base map: SRTM (Shuttle Radar Topography Mission), available from the U.S. Geological Survey.

The results of this cartographic analysis may support further research into the dynamics and drivers of lagoon sedimentation. For example, in a next step, the decline in the lagoon's water surface area can be linked to the various sediment sources and transformations in its catchment area (see Lukas under review-b) or to an analysis of sediment cores.

Limitations of the quantitative shoreline change analysis

The limitations of historical cartographic research into environmental changes that have been explored above fully apply to the case of the Segara Anakan lagoon. Since the bathymetric data contained in some of the historical maps is confined to the lagoon's main fairways or its outlets only, the cartographic analysis can provide only a two-dimensional picture of lagoon sedimentation. In addition, the temporal scale and resolution of the analysis as confined by the cartographic material available limit the results' interpretability. My exploration of the cartographic history of the region, briefly sketched in the above section, helped to maximise the temporal scale and resolution of the quantitative analysis and to avoid pitfalls related to the borrowing of information. The maps from the early 19th century mark the limit of the temporal scale of the quantitative shoreline change analysis. They and the earlier sea charts are not accurate enough for a quantitative analysis.

Are the analytical time scale and the resolution of this quantitative analysis appropriate for a realistic understanding of the temporal dynamics of sedimentation? Since environmental changes often result from various processes operating over different time-scales, the analytical scales we choose influence our results and conclusions (Batterbury, and Bebbington 1999, Chapman, and Driver 1996). The quantitative analysis presented in Figure 10 covers perhaps the most important period, since it documents a transition from relatively low aggradation rates in the 19th century to more rapid aggradation thereafter. This development can be linked to various dynamics in the lagoon's watershed, which are related, for example, to coffee cultivation; timber extraction; plantation, transport infrastructure and settlement development; the expansion of agriculture; forest management practices; the contestation and degradation of state forests and plantations; river channelling and embankments, and volcanic eruptions (Lukas under review-b). Since some of these dynamics begun prior to the mid-19th century, an extended analytical time scale of the historical cartographic shoreline change analysis is desirable. This could also ascertain whether the 19th century really represents the end of a long period with slow aggradation or whether it was preceded by other periods with higher aggradation rates. In addition, shoreline information for the period 1920s-1960s could further support the linking of the aggradation process with the various watershed dynamics during this period.

Qualitative analysis of a topographic map from 1955

Qualitative interpretation of less accurate or less complete and therefore not quantitatively analysable cartographic material could help to increase the temporal resolution of analysis. As identified in the regional cartographic history in the above section, the Peta Ichtisar Djawa-Madura, produced by the Indonesian Direktorat Topografi in 1955 represents the only updated cartographic information for the period 1920s-1960s. It sketches a few small islands in the southern part of the lagoon that are not shown on the maps of the 1920s and for the first time depicts the village of Klaces attached to Nusakambangan Island. Both changes result from sedimentation. However, since the topographic information for the lagoon's northern part was not updated and due to the very small scale of this map (1:250,000), the additional qualitative insight it provides is very limited, particularly in the light of the Corona Image from 1962 that gives a clearly more accurate picture of these new islands and the entire lagoon.

Qualitative analysis of the early sea charts from around 1700

The remaining part of the paper presents an attempt to extend the temporal scale of analysis further into the past, based on a qualitative analysis of the manuscript charts drawn in the frame of the expeditions to Java's south coast on behalf of the VOC in 1698, 1711, and 1739. These maps are clearly not accurate enough for a quantitative analysis, but their qualitative analysis (cf. Harley 1968), i.e. a qualitative visual comparison of outlines and features and their locations, combined with an examination of the map-makers' records, at least contributes ideas of what the lagoon might have looked like, provides insight into the production and reliability of these maps, reveals potential pitfalls, and demarcates the limit of historical cartographic inquiry into environmental change with regard to temporal scale.

The regional cartographic history in the previous section showed that Paulusz, who led the mapping voyage in 1739, did not enter the lagoon and instead copied its outline from Coops' map. Hence, in trying to explore early historical environmental changes, only the maps of Coops from 1698 and of van Petten from 1739 deserve attention.

Coops' chart, the earliest known map of the Segara Anakan lagoon (Figure 2), suggests that the lagoon's open water surface area was clearly larger in 1698 than around 1809/15 (compare Figure 2 with Figures 5 and 6). This interpretation is based on two observations: the much larger east-west dimension of the lagoon in proportion to that of Nusakambangan Island on Coops' map, and the seemingly fairly detailed drawing of the channel from the eastern outlet, along the northern shore of Nusakambangan up to the location where a stream from Nusakambangan enters the lagoon (see Arrow 1 in Figure 2), not far west of which Coops depicted the beginning of the lagoon's large open water surface area. If this was roughly correct, the eastern shoreline of the lagoon would have moved to the west by about 4.5km between 1698 and 1857/60. This would correspond to higher annual aggradation rates than during the following period from 1857/60 to 1897/1901.

Based on the chart drawn by van Petten during the next expedition in 1711 (Figure 3), one comes to a completely different and more realistic conclusion. Even though van Petten did not even delineate most of the lagoon, his very detailed and fairly accurate charting of the eastern channel provides new insight. His drawing of this channel from the eastern outlet, along the northern shore of Nusakambangan Island, past the location where a stream from Nusakambangan enters the lagoon (see Arrow 1 in Figure 3) up to a little island just west of the northern shoreline of the eastern channel (see Arrow 2 in Figure 3) that marks the beginning of the lagoon's large open water surface area, the boundaries of which van Petten did not depict, is very detailed. This drawing indicates fairly clearly that the east-west dimension of the lagoon (at least in its southern part) in proportion to that of Nusakambangan Island and of the eastern channel did **not** change between 1711 and 1809/15 (compare Figure 3 with Figures 4-5). Two kinds of evidence substantiate that this conclusion based on van Petten's map is more realistic: (1) the reconstruction of Coops' and van Petten's voyages, based on their written records, and (2) the superiority of van Petten's map in terms of detail and accuracy.

Van Petten, according to his daily notes, quoted by de Haan (1911), arrived with his crew at 'Tjellok Bator' (depicted as Solok Batoer on the map from 1857, see Figure 7) at the western end of Nusakambangan Island on 17 July 1711, where they spent one day. On 19 July they went by boat through the lagoon to the Donan River at Cilacap and subsequently spent three days in the easternmost part of the lagoon. They went back on 23 July and spend three days in the area around the estuary of the Citanduy River and the lagoon's western outlet. On 27/28 July they went once again through the lagoon to Cilacap and returned to the lagoon's western outlet, from where they finally left to Mauritius Bay. Hence, van Petten spent a total of eleven days in the lagoon area and passed through the lagoon and the eastern channel along Nusakambangan four times. The fairly detailed topographic knowledge that he must have acquired during his relatively long stay is reflected in his chart, which is not only exceptionally detailed but also fairly accurate. I attempted to georectify this chart, based on the topographic map from 1901/04 and using eight control points, and received a fairly accurate overlay and an RMSE of 793m at map scale in case of 1st order polynomial transformation and of 592m in case of 2nd order polynomial transformation[11].

Coops' chart, in contrast, is barely possible to be georectified. Using eight control points, georectification results in a twisted image and an RMSE of 1511 and 728m for 1st and 2nd order polynomial transformation respectively. The report from his voyage (Coops 1698) and a comparison of his chart with that from van Petten provides a possible explanation of his inaccurate mapping of the lagoon's proportions. Coops and his crew, coming from the east, first approached the lagoon's eastern outlet, then sailed along the south coast of Nusakambangan Island and entered the lagoon through its western outlet, from where they went by boat into the lower portion of the Citanduy River and then along the northern shore of Nusakambangan up to Manonjaya Passourawangh. The latter is located about 2.5km west of the western end of the eastern channel, where both van Petten (see Arrow 2 in Figure 3) and Coops (see Arrow 2 in Figure 2) demarcated an island. Coops did not mention in his report that he ever went further east, i.e. that he did actually pass through the eastern channel. This is certainly the reason that he did not map the entire channel as detailed and accurately as van Petten did. He might instead have depicted the eastern part of the channel

[11] The RMSE (Root Mean Square Error) represents the residual error after transformation, i.e. the differences between the position of the control points after georectification and their actual geographical location. In addition to small methodological inaccuracies related to scanning resolution, the selection of control points and possible, but negligible, geodetic inaccuracies, the RMSE can be assumed to mainly reflect the planimetric accuracy of the map (see Lukas under review).

as far as he went in from the eastern outlet and later the western part of the channel up to the island, while leaving out some 4.5 km in between (the eastern channel section between Arrows 1 and 2 in Figure 3), hence making it difficult to estimate the relative proportions of the lagoon's open water surface area and the length of the eastern channel. This comparison between van Petten's and Coops' maps and the analysis of Coops' records also suggest that Coops did likely not visit the north-eastern portion of the lagoon's open water surface area, but depicted its boundaries based on estimation.

While Coops depicted the entire lagoon including the sections that he did not visit, partly based on guesstimate, van Petten only depicted the sections that he did actually map. The information from Coops' map was repeatedly replicated for more than 100 years, while the cartographic knowledge contained in van Petten's map was ignored.

Since both Coops and van Petten did unfortunately not explore the northern portion of the lagoon, the additional insights we gain from these early charts with regard to the longer term development of lagoon sedimentation are limited. However, the analysis of this early cartographic material together with the processes of its production has (1) defined the limits of historical-cartographic analysis in this particular region; (2) demonstrated an approach to extend the temporal scale of historical-cartographic analysis as far back as possible by adding a qualitative analysis of earlier, less accurate maps to the quantitative analysis of more recent material; (3) illustrated how consideration of the map-makers' written records can help to evaluate the reliability of their charts; and (4) shown that aggradation rates in the eighteenth century were obviously by far not as high as Coops' chart on its own would suggest.

The qualitative analysis of these early manuscript charts also demonstrates potential pitfalls of interpreting historical cartographic material. Without a thorough exploration of the regional cartographic history, the analysis might have relied on Coops' chart, which in fact was identified first, or on Paulusz' chart, which is considered the best sea chart of Java's south coast up to the beginning of the 19th century (Schilder 1981). Without van Petten's chart and only relying on Coops' chart, our perspective of the possible longer-term development of lagoon sedimentation prior to the early 19th century would be unrealistic, or at least clearly more uncertain. Relying only on Paulusz' chart would have had a similar effect and in addition would have resulted in the wrong assumption that his map represents his view of the lagoon's outline in 1739, whereas in fact it represents Coops' view of the lagoon in 1698. Furthermore, one and the same historical map (i.e. Paulusz' map from 1739) might be valued as representation of the most accurate and complete cartographic knowledge of its time as a whole or for a particular area, while for (other) particular areas, it might be less accurate and/or detailed than other maps or simply represent cartographic knowledge copied from earlier maps.

Conclusion

The large potential that the historical cartographic material of insular Southeast Asia provides for exploring historical environmental changes remains largely untouched until today. The digitisation of archival material and some cartographers' meticulous research into the cartographic history of the region provide an outstanding basis for applied historical cartographic research. Historical maps represent a highly valuable source of historical spatial information. Other sources of such information often do not exist, are place-based (e.g. records of particular locations, archaeological artefacts), or are rather unfeasible to be analysed with a spatial coverage and resolution similar to that provided by maps (e.g. sediment archives). The latter applies to the case of the shrinking lagoon presented here. Analysis of sediment cores can realistically only deliver location-specific information from a few sites, which could later be used to support or question the results of the cartographic analysis presented here and to extend the temporal scale of analysis to cover a larger geological time span.

Notwithstanding the large potential of historical cartographic material and the value and uniqueness of the information it contains, particular limitations and potential pitfalls deserve consideration in cartographically exploring historical environmental changes. The limited availability and accuracy particularly of early cartographic material and longer periods without cartographic surveys limit the temporal scale and resolution of analysis. A thorough exploration of the cartographic history of the study area, i.e. the gathering of a complete account of historical maps and related background information about the producers and the production of these maps, not only helps to maximise the temporal resolution and scale of analysis, but also supports selection of the most suitable material, avoids reliance on comparably less accurate maps, exposes the borrowing of information between explorers and map-makers, and generally helps to evaluate the maps' reliability, and hence contributes to avoid potential pitfalls.

In reconstructing environmental histories, the periods with increasing anthropogenic influence are often particularly important to depict. In this context, the relative timings of the periods of enhanced mapping and of intensifying human impact on the environment considerably determine the fruitfulness of historical cartographic research. In the case presented in this paper, the availability of quantitatively analysable maps from the mid-19th century onwards allowed to depict a major transition phase from lower to higher shoreline aggradation rates. Longer-term data could provide additional insight. However, the qualitative interpretation of earlier, less accurate sea charts contributed only limited additional (longer-term) historical environmental information. Yet, it illustrated the limits and some pitfalls of historical cartographic inquiry and demonstrated how consideration of map-makers' records can support the evaluation of map reliability.

Exploring cartographic histories not only supports the analysis of past environmental changes, but vice versa, the intensive engagement with historical maps in trying to reconstruct environmental changes also contributes to historical cartography. In the case presented in this paper, it revealed insight into the production, replication and gradual development, but also the ignorance of regional cartographic knowledge. The exploration of the historical cartographic material of the Segara Anakan lagoon region has shown how explorers and map-makers borrowed cartographic information from one another. An interesting insight in this context is that topographic information from complete, though comparably inaccurate charts was repeatedly reproduced for decades or even a century, while information from more accurate but incomplete maps was consistently ignored. Furthermore, specific historical maps valued as representation of the most accurate and complete cartographic knowledge of their time as a whole, can comprise sections that only represent information copied from the less accurate of the earlier maps existing.

In addition to sharing historical lagoon shoreline information, which supports further research into the environmental history of the Segara Anakan lagoon region, and to providing additional insights into the cartographic history of this area, the example of applied historical cartographic research presented shall encourage the utilisation of the highly valuable but underutilised cartographic material of Java and other parts of Southeast Asia.

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Research Paper 3

Lukas, M.C. Widening the Scope: Exploring the Drivers of Coastal Sedimentation in Java, Indonesia.

Status: under review (Regional Environmental Change)

Research Paper 3

Lukas, M.C. Widening the Scope: Exploring the Drivers of Coastal Sedimentation in Java, Indonesia.

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Abstrak (Abstract, translated into Indonesian)

Proses daerah aliran sungai dan dampaknya pada pesisir dipengaruhi oleh berbagai faktor alam dan sosial yang berkaitan. Informasi tentang faktor dan proses ini sering kali terbatas. Akibatnya, bidang ini menjadi rentan terhadap politisasi dengan adanya debat, penelitian, dan intervensi yang terbatas pada sejumlah kecil pemicu masalah-masalah tersebut. Perdebatan tentang penyebab beban sedimen sungai dan sedimentasi pesisir yang tinggi di Jawa selama beberapa dekade berfokus hanya pada pertanian tadah hujan pada lahan pribadi milik petani, sedangkan pemicu lainnya diabaikan. Hal ini telah melemahkan efektivitas manajemen daerah aliran sungai. Makalah ini menghubungkan sedimentasi Laguna Segara Anakan di pantai selatan Jawa dengan karakteristik lanskap di masa lampau dan masa kini serta transformasi di daerah tangkapan airnya. Tiga perempat bagian laguna tersebut telah dipenuhi lumpur sejak pertengahan abad ke-19. Pemicu keadaan ini lebih beragam daripada yang diasumsikan secara umum hingga saat ini. Selain pertanian tadah hujan pada lahan pribadi petani, pemicunya mencakup penanaman kopi, penambangan kayu, pengembangan perkebunan, dan migrasi masuk pada akhir abad ke-19 dan awal abad ke-20; erosi di hutan negara dan lahan perkebunan yang dipersengketakan; praktik manajemen hutan negara; lereng buatan untuk memperluas lahan pertanian (ngaguguntur); pertanian di zona riparian; erosi dari jalan raya, jalan setapak, dan permukiman; modifikasi kanal sungai dan dataran banjir; dan erupsi vulkanik. Maka, pilihan dan harapan akan adanya tanggapan sosial yang ditujukan untuk mengurangi beban sedimen sungai dan sedimentasi pantai perlu dipertimbangkan kembali dan debat serta agenda penelitian terkait harus diperluas.

Kata Kunci

Sumber sedimen; hasil sedimen; erosi tanah; sejarah lingkungan; manajemen daerah aliran sungai; Laguna Segara Anakan

Widening the scope: Exploring the drivers of coastal sedimentation in Java, Indonesia

Martin C. Lukas[1]

Abstract

Watershed processes and their linkages with coastal zones tend to be marked by high levels of complexity, uncertainty and limited knowledge. This makes the field prone to politicisations with debates, research and interventions being confined to a few selected drivers of particular issues. Debates on the causes of high river sediment loads and coastal sedimentation in Java have for decades focussed on upland agricultural practices, while other drivers have been neglected. This has undermined the effectiveness of longstanding watershed management efforts and raised unrealistic expectations. This paper links an analysis of the historical dynamics of shoreline aggradation in the Segara Anakan lagoon on Java's south coast with a record of landscape transformations in its catchment area. It thereby explores a large range of drivers of accelerated lagoon sedimentation that have been neglected to date. The findings stress that both the choice and expectations of societal responses aimed at reducing river sediment loads and coastal sedimentation need to be reconsidered and that related political debates and research agendas must be broadened. High river sediment loads and coastal sedimentation have to be seen as a result of not only present characteristics of particular sections of the landscape, i.e. upland agricultural plots, but of a whole record of historical landscape modifications throughout the entire catchment area.

Keywords

Watershed-coastal-zone-interactions, watershed management, historical environmental change, land use and land cover change, forest management, Segara Anakan lagoon.

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1 Introduction

Watershed-coastal zone interactions are marked by complexity, high levels of uncertainty, and limited concrete knowledge. This makes the field prone to politicisations, with debates, research and political action focussing on selected issues and causal factors while neglecting others. This can undermine the effectiveness of management efforts and lay the ground for unrealistic expectations.

Watershed management in Java is a prime example illustrating these issues. The island constitutes a global hotspot of riverine sediment transport to the oceans (Lvovich et al. 1991; Walling and Webb 1996b). River sediment loads are naturally high due to tectonic activity, high relief intensity and high-intensity monsoon rainfalls. The interaction of this dynamic environment with profound anthropogenic modifications results in high erosion and sedimentation rates (cf. Lavigne and Gunnell 2006). Hence, upland erosion and the sedimentation of reservoirs, irrigation schemes and coastal ecosystems downstream have repeatedly been targeted in the frame of watershed management programmes since the 1970s. These programmes mainly focussed on terracing of rainfed agricultural land and tree planting. Despite substantial national and international funds invested, the effects of these efforts on river sediment loads are largely unknown and regarded as limited (see e.g. Diemont et al. 1991; Schweithelm 1988). This has been attributed to shortcomings in the design and implementation of the programmes with overly standardised approaches, the promotion of only one type of terraces regardless of varying soil, landscape and social conditions, the neglect of additional soil conservation measures, the poor maintenance of field terraces, land tenants' limited scope to invest into soil conservation, and national price guarantees for cassava (ADB 2006; Huszar and Cochrane 1990; Purwanto 1999; USAID 1984; USAID 1985).

More fundamentally, this paper argues that the one-sided focus of debates, research and interventions on contemporary upland farmers' private plots and the neglect of other drivers of sedimentation has a priori limited the effectiveness of watershed management. Building on several years of research in the catchment of the Segara Anakan lagoon (SAL), one of the long-standing priority areas for watershed management in Java, the paper explores a broad range of drivers of erosion and sedimentation that have been neglected to date.

The SAL, a shallow coastal lagoon on Java's south coast, has rapidly shrunk due to riverine sediment input. Political interventions aimed at halting lagoon sedimentation included dredging, building of river diversions and watershed conservation (see ADB 1996; ADB 2006; ECI 1994; Tim Koordinasi Wilayah 1989; USAID 1984; USAID 1985). Driven by the political interest in this area, the uniqueness of the lagoon and the high magnitude of change, the ecological and social conditions and transformations in the lagoon have repeatedly been the subject of research over the past decades (e.g. Ardli and Wolff 2009; Bird et al. 1982; Dudley 2000; Hinrichs et al. 2009; Holtermann et al. 2009; Jennerjahn et al. 2009; Jennerjahn and Yuwono 2009; Nordhaus et al. 2009; Olive 1997; Reichel et al. 2009; White et al. 1989; Yuwono et al. 2007).

In contrast, the lagoon's catchment area and hence the drivers of lagoon sedimentation have barely been subject to any research. No watershed-wide analysis of the various sediment sources, the underlying causes and related sediment transport dynamics has ever been undertaken. Instead, in the absence of concrete evidence, lagoon sedimentation, as a matter of course, has commonly been linked to 'population pressure' and 'poor', 'destructive', or 'unsustainable' farming practices in the uplands. This focus on upland agriculture has been related to disciplinary boundaries, with on-site erosion measured by agronomists and sediment yields measured by river engineers (Bruijnzeel 2004), but is also linked to hegemonic socio-political framings (Lukas and Flitner under review). The discursive establishment of upland farmers' private plots as the single most important sediment source provided a clear cut narrative for political intervention and rendered inquiries into the other causes of high river sediment loads 'unnecessary'.

Knowledge of the temporal dynamics and drivers of riverine sediment transport does not exist for the SAL region and is scarce for the whole of Java. Historical time series of river sediment loads are unreliable or do not exist (PRC-ECI 1987; Seckler 1987). Knowledge of the drivers and their relative contributions is lacking, with the exception of a few small sub-catchments, including the upper Konto catchment in East Java (Nibbering and Graaff 1998; Rijsdijk 2005; Rijsdijk et al. 2007a; Rijsdijk et al. 2007b) and the Cikumutuk catchment in West Java (Purwanto 1999; van Dijk 2002). Following years of implementing upland conservation measures in the catchment of the SAL, an assessment of the USAID-funded Citanduy II Project revealed that "[l]ittle has been learned about the sources of erosion. […] [T]here is much opinion but little fact" (USAID 1985:9). This has barely changed since then. The project's watershed planning consultant presumed "that a thorough sediment study of the Citanduy Basin would reveal that privately-owned upland farms [the main target of the project] contribute a small part of the sediment load of the Citanduy River" and that "[s]edimentation can only be reduced if its sources are identified and sediment delivery processes understood." (Schweithelm 1988:6).

This paper contributes knowledge on both the historical dynamics and drivers of sedimentation in the SAL. It links a historical-cartographic analysis of lagoon shoreline aggradation with landscape characteristics and transformations in its catchment area. The findings show that putting all the blame for lagoon sedimentation on contemporary upland farmers' rainfed agricultural plots is too simplistic as it neglects numerous other sediment sources and their underlying causes. The paper broadens the debate on erosion and sedimentation in Java and calls for a reconsideration of related research priorities and societal responses. In addition, given that limited knowledge constrains watershed management worldwide (cf. Walling and Fang 2003) and that related debates are often confined to selected issues, causes and responses, the approach presented, which links physical processes and societal dynamics and incorporates the historical dimension in critically reconsidering established 'truths', may inspire inquiries into watershed-related processes elsewhere.

2 Materials and methods

2.1 Study area

The SAL, which is protected from the ocean by the island of Nusa Kambangan, forms the estuary of the Citanduy, Cibeureum and Cikonde Rivers. Its catchment area comprises about 450,000ha (Figure 1). It is dominated by volcanic mountains in its uppermost (north-western) part, sedimentary mountain ranges in its northern-eastern and southern parts, and a partly plain, partly hilly central river basin. The major types of land use/cover comprise irrigated (rice field) agriculture, rainfed agriculture, small holder (mixed) forests, settlements with house gardens, and state forests. The region's tropical monsoon climate is marked by high-intensity, occasionally prolonged periods of rainfall particularly between November and April. Average annual rainfall is 3,000-3,500mm

(Weatherbase 2014). The area is divided into three districts: Tasikmalaya and Ciamis in the province of West-Java, and Cilacap in the province of Central Java.

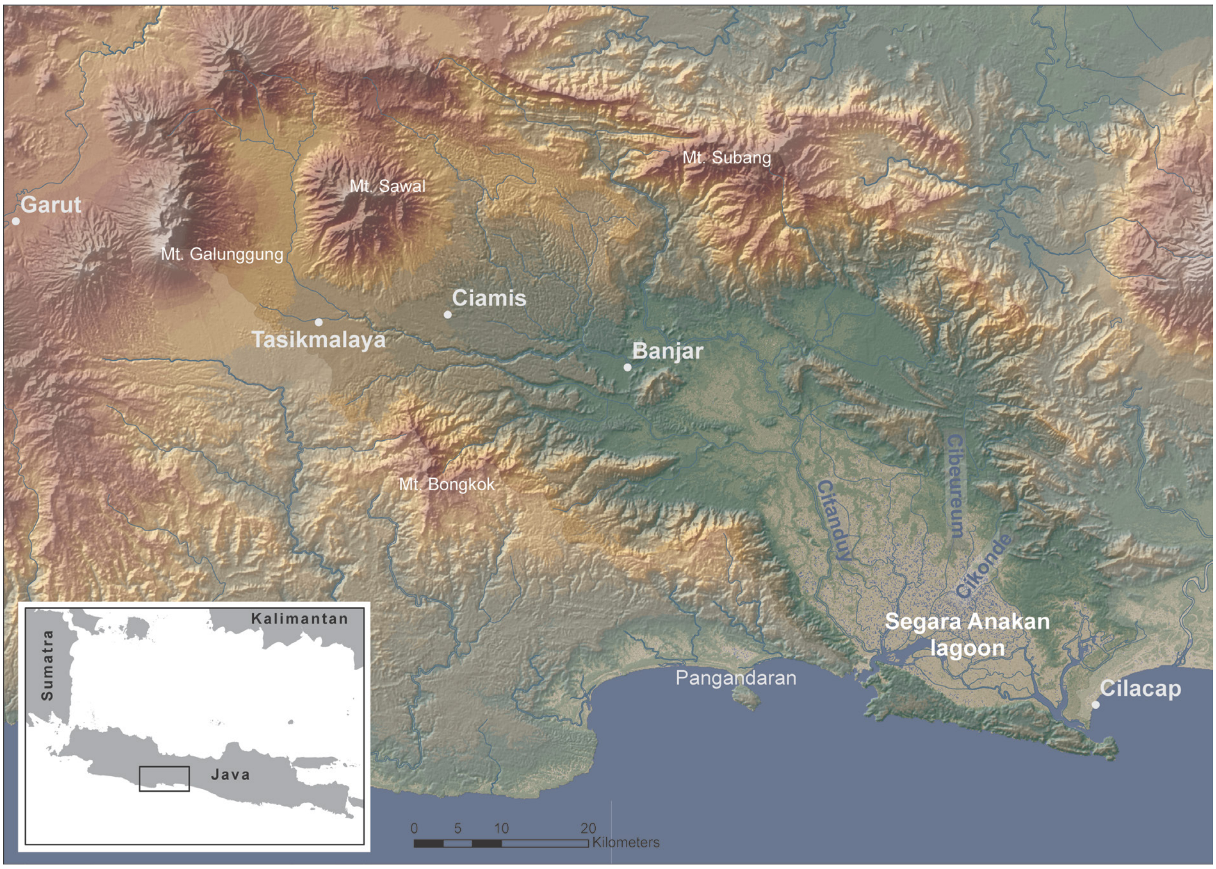

Fig 1 Location of the Segara Anakan lagoon and its catchment area on the south coast of Java.

2.2 Research scope

Debates on the causes of lagoon sedimentation have focussed on contemporary rainfed agricultural plots, i.e. one of various sediment sources in a contemporary snapshot. Other sites and sediment sources, the historical dimension and related societal drivers have been neglected. This research therefore aimed at widening the view to the whole record of historical and contemporary landscape characteristics and modifications in the entire watershed, including related societal dynamics.

The availability of historical maps and records confined the research to the period from the mid-19th century onwards. This period covers a major transition phase from a mainly nature-dominated to a mainly human-dominated landscape, which supports an appraisal of the various drivers of change (cf. Messerli et al. 2000). It is the period that Cooke (1992) referred to as the 'recent past' that is often neglected in favour of studies on either long-term or contemporary environmental dynamics. Knowledge of both lagoon sedimentation and watershed dynamics over this period is very limited. Data on riverine sediment loads goes back to the 1980s only and is inconsistent (PRC-ECI 1987). Previous shoreline change analyses covered the twentieth century only and were biased (see Lukas 2014a), and the explanatory value of two sediment analyses (Dewi et al. 1979; Kastanja 2001) with regard to the temporal dynamics and causes of sedimentation is limited.

2.3 Methods

Based on historical maps and satellite images (Table 1), the change in the water surface area of the SAL was reconstructed for the period 1857/60-2013. A comprehensive discussion of the historical maps, their production and accuracy is contained in Lukas (2014a); Lukas (under review). The maps and satellite images were scanned, if not acquired in digital form, and georectified using ArcGIS. Based on the maps and images, the historical lagoon shorelines were hand-outlined and historical water surface areas determined. Incorporating the georectification and a digitisation-operator error, an areal error was determined as a measure of the results' reliability (Table 1).

Table 1: Reconstruction of historical water surface areas of the Segara Anakan lagoon: Material, calculation and results

Data source	Date of data acquisition	Map scale / resolution	Lagoon water surface area (ha)	RMSE of georectification at real world scale* (Δx in m)	Digitisation-operator error*** (Δd in m)	Uncertainty of shoreline position ($\Delta y_l\ in\ m$) $\Delta y_l = \sqrt{\Delta x^2 + \Delta d^2}$	Perimeter of water surface area **** (l in m)	Areal error***** ($\Delta y_a\ in\ ha$) $\Delta y_a = \Delta y_l * l$
Topographische Kaart van de Residentie Banjoemaas (Map Sheets I and II); under the direction of the Kolonel Direktur der Genie W.C. von Schierbrand by the Kapitein der Infanterie W. Beijerink; 1860	1857-1860	1:100,000	8,579.5	127.0*	35.0	131.7	70,573	929.4
Topographical map of Java, Residency Banjoemas (Map Sheets III, IV en VIII, and VII); TDNI, Land tax survey brigades; 1901-04	1897-1901	1:100,000	7,993.9	46.0*	35.0	57.8	74,543	430.9
Topographical map of Java, Middle (and West), Map Sheets 42/XLI D, 43/XLI C, 43/XLI D, 42/XLII B, 43/XLII A, 43/XLI D); TDNI, Land tax revision brigades; 1925-29, 1938-42	1924-26	1:50,000	7,494.4	27.3*	17.5	32.4	84,864	275.0
Corona, FTV-1126, Mission No. 9034	17.05.1962	140m	5,795.1	14.1*	37.0	39.6	74,088	293.4
Landsat MSS	01.08.1973	79m	5,020.1	6.0**	21.0	21.8	95,804	208.9
Landsat MSS	25.04.1978	79m	4,589.0	6.0**	21.0	21.8	102,276	223.0
Landsat MSS	21.06.1983	79m	3,933.3	6.0**	21.0	21.8	87,346	190.4

Data source	Date of data acquisition	Map scale / resolution	Lagoon water surface area (ha)	RMSE of georectification at real world scale* (Δx in m)	Digitisation-operator error*** (Δd *in* m)	Uncertainty of shoreline position (Δy_l *in m*) $\Delta y_l = \sqrt{\Delta x^2 + \Delta d^2}$	Perimeter of water surface area **** (l in m)	Areal error***** (Δy_a *in ha*) $\Delta y_a = \Delta y_l * l$
Landsat TM	23.05.1993	30m	2,798.0	6.0**	8.0	10.0	110,735	110.7
Landsat TM	29.05.1998	30m	2,525.8	6.0**	8.0	10.0	106,048	106.0
Landsat TM	19.01.2003	30m	2,244.7	6.0**	8.0	10.0	131,077	131.1
SPOT 2, 20mC	13.07.2007	20m	2,231.3	6.0**	5.0	7.8	134,740	105.1
Landsat ETM+	13.03.2013	30m	2,181.5	6.0**	8.0	10.0	127,584	127.6

* In case of the historical maps and the Corona image, the RMSE mainly reflects the median planimetric error.

** Georectification of all satellite images resulted in RMSEs below 6m. To simplify, a common worst-case value of 6.0m is used for all satellite images.

*** In case of the historical maps, digitisation and operator errors are estimated at 0.25mm at map scale each (following Crowell et al. 1991); resulting in a combined digitisation-operator error of 0.35mm at map scale ($= \sqrt{0{,}25mm^2 + 0{,}25mm^2}$). In case of the aerial photographs and satellite images, estimates of the positional accuracy of the shorelines detected are based on M.-Muslim et al. (2007), who determined shoreline prediction accuracies depending on the spatial resolution of the satellite images of 3.16-4.25m in case of a resolution of 16m and 5.73-8.67m in case of a resolution of 32m. Based on these results and assuming a near proportional relationship between resolution and positional accuracies determined, positional accuracies of 8m in case of the Landsat TM and ETM+ images (30m spatial resolution), 5m in the case of the SPOT2 image (20m spatial resolution), 21m in the case of the Landsat MSS images (79m spatial resolution) and of 37m in case of the Corona image from 1962 (140m spatial resolution) are used.

**** Perimeter of all shoreline sections in the western part of the lagoon, not including the eastern channel network, which has not been affected by shoreline change. Since various shoreline sections also within the western part of the lagoon were not affected by aggradation, but have been included in the calculation of the perimeter, the areal resolution error clearly overestimates the actual extend of uncertainty of the results.

***** cf. Salerno et al. (2008).

The discussion of the drivers of lagoon sedimentation in the following section combines results of several years of research on watershed management and environmental dynamics in the region with information from documents and literature. It incorporates findings from an analysis of satellite images and historical maps and from interviews with representatives of governmental and non-governmental organisations, the state forest corporation, village governments, farmers, and other village residents. Information from different strains of literature is incorporated in exploring watershed transformations in the 19th and early 20th century and to integrate findings from research on soil erosion in other parts of Java.

3 Results and discussion

3.1 Temporal dynamics of lagoon sedimentation

The results of my historical-cartographic reconstruction of shoreline aggradation, provided in Table 1, Figures 2 and 3[2] and Online Resource 1, depict a dramatic decline of the SAL's water surface area from almost 9,000ha to slightly more than 2,000ha over the past 1.5 centuries. This process accelerated between 1857/60 and the 1980/90s and slowed down thereafter. The increasing lagoon aggradation rates conform to the accelerated growth of river deltas on Java's north coast between 1857/1922 and 1922/1946 (Hollerwöger 1964).

[2] The areal errors provided in Table 1 and depicted in Figure 3 clearly overestimate the actual extent of uncertainty of the results, since the perimeter used for its calculation includes various shoreline sections that have not been affected by aggradation.

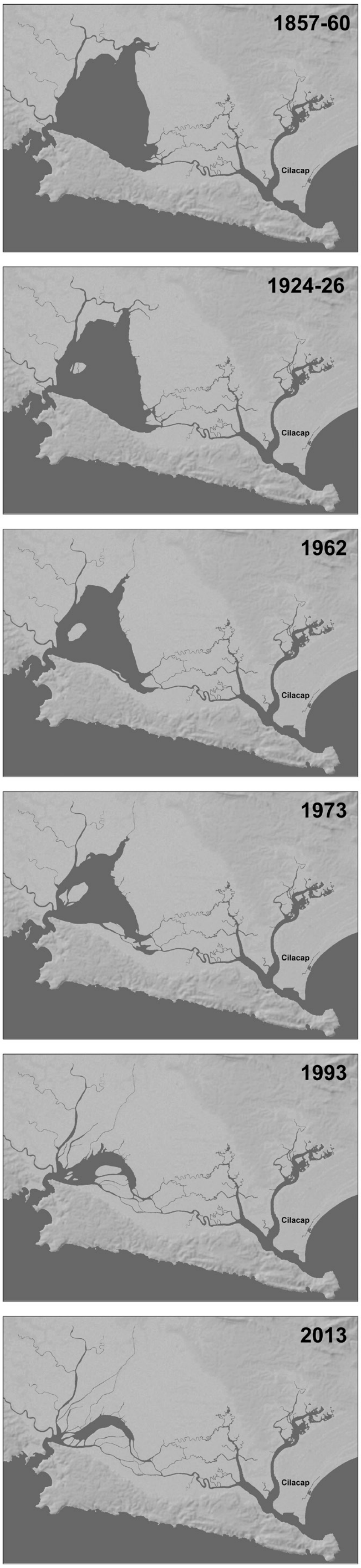

Fig 2 Map series illustrating the change in the water surface area of the Segara Anakan lagoon over time. Base map: SRTM (Shuttle Radar Topography Mission), available from the U.S. Geological Survey. The reconstructed shorelines are based on the maps and satellite images listed in Table 1. Higher resolution images and an animation-like illustration of shoreline aggradation over time are contained in Online Resource 1.

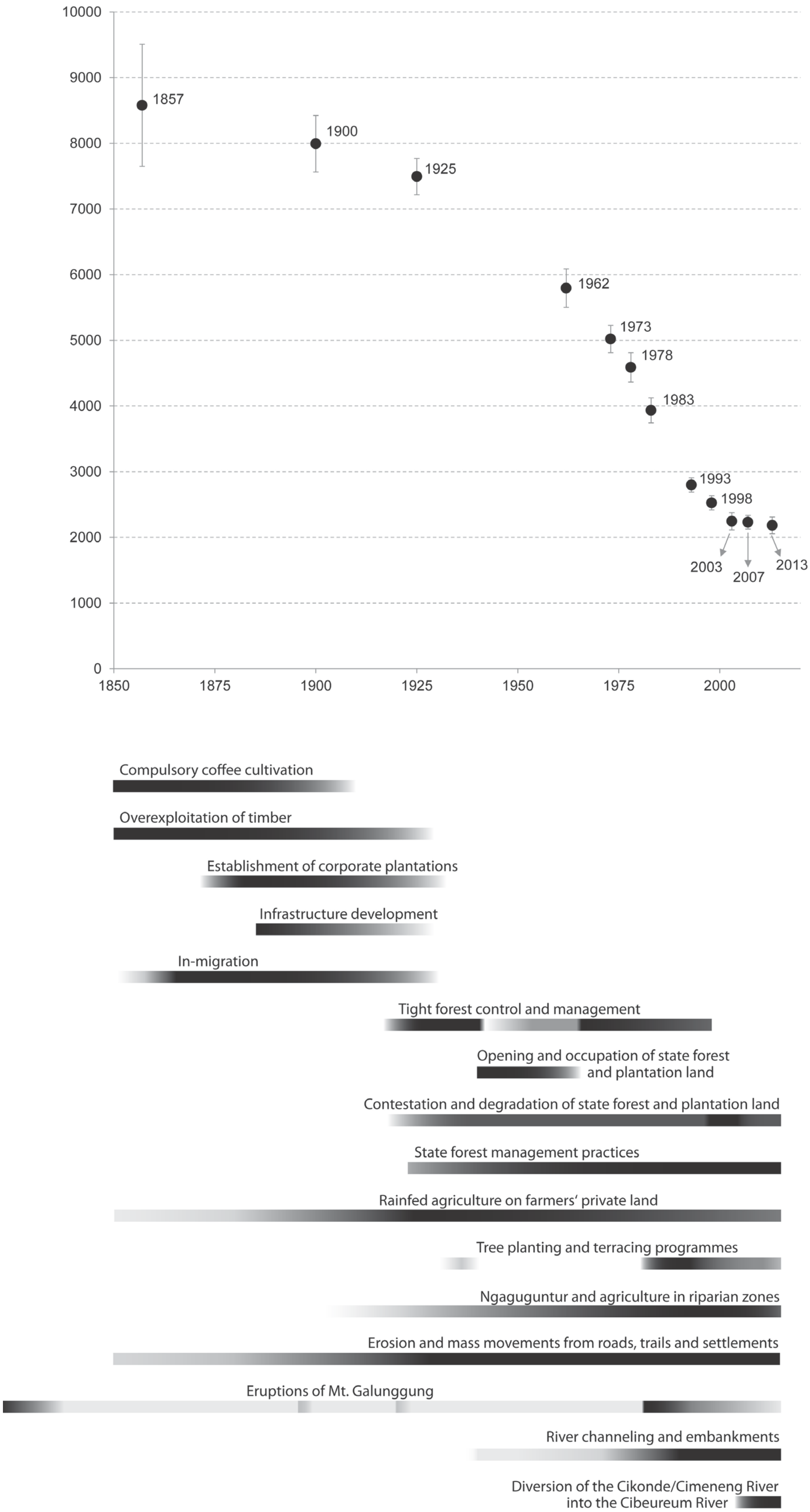

Fig 3 Change in the water surface area of the Segara Anakan lagoon over time between 1857/60 and 2013 combined with a record of landscape transformations in its catchment area.

The declining aggradation rates since the early 2000s are mainly related to the dredging of 9.3million m³ of sediments from a lagoon area of 512ha in 2002/05 (see ADB 2006). In addition, the Cimeneng/Cikonde River was diverted into the Cibeureum River in 2002/03 in order to redirect its sediment load to the western part of the lagoon, from where a larger portion of it is transported out into the ocean. It is not known whether the declining aggradation rates since the early 2000s were only caused by dredging or whether they also reflect any effects of the river diversion. They might also reflect a gradual increase in the proportion of riverine sediments that is not deposited in the lagoon but carried out into the ocean as the water body shrinks. At some stage the currents, caused by tides and freshwater input, will likely prevent further aggradation of the remaining water body.

The results presented in Figures 2/3 certainly cover the most important period, since they document a transition from comparatively low to high aggradation rates. Looking further back could provide additional insights, but is not possible given the limited accuracy of earlier maps. However, my analysis of elevation data suggests that the lagoon's maximum water surface area during the mid-Holocene sea level maximum 4,200 years ago might have been up to 4-5 times larger than that of 1857/60 (Online Resource 2). Since then, the lagoon must have continuously shrunk due to falling sea levels and sedimentation.

Before the following section links the shoreline change analysis with transformations in the lagoon's catchment area, the limitation of the analysis shall be discussed: The two-dimensional picture of shoreline aggradation can neither be directly translated into sediment volumes deposited in the lagoon nor into amounts of riverine sediment input. The first would require historical bathymetric data with a high spatial resolution, which does not exist. The second cannot be estimated for the past due to the temporally changing proportion of riverine sediments that are deposited in the lagoon and not transported out into the ocean. Despite these limitations, it can be assumed that the change in the lagoon's water surface area presented in Figures 2 and 3 provides a rough picture of the temporal dynamics of riverine sediment input, albeit not with proportionality.

3.2 Drivers of lagoon sedimentation

The following sections explore the various drivers of accelerated lagoon sedimentation. Figure 3 links these drivers in the form of a time sequence with the shrinking of the lagoon's water surface area.

3.2.1 Large-scale transformations in the catchment area between the mid-19th century and the 1920s

The most profound environmental transformations in the catchment of the SAL and throughout Java took place between the mid-19th century and the 1920s (cf. Smiet 1990). The large-scale conversions of natural forests during this period, triggered by coercive coffee cultivation, excessive timber extraction, plantation development, infrastructure development, and in-migration undoubtedly raised erosion rates and accelerated lagoon sedimentation.

The conversion of Java's natural forests into other land uses was relatively slow and gradual and was concentrated in the lowlands until the early 19th century (Smiet 1990). Until then, the mountainous areas in the southern part of West Java (the former Priangan Regency) and the adjacent parts of Central Java, including most of the catchment area of the SAL, were clearly less affected by anthropogenic impacts than many other parts of the island. The area was marked by low population densities, large forest areas and shifting cultivation (cf. Geertz 1971).

Compulsory coffee cultivation had the earliest profound and, in contrast to already existing shifting cultivation, a lasting impact on land cover and erosion rates in the area. Coffee cultivation, which had been introduced by the Dutch East India Company in the early 18th century (Fasseur and Elson 1992), was seen as the major driver of deforestation and soil degradation in the late 19th century (see Schaik 1986). Coffee was the major export crop from the Netherlands East Indies for decades and the principle source of profit for the Regents and the Dutch (Kano 2008; Kumar 1997). The uplands of Priangan became the main centre of coffee cultivation, with 56-65% of the population assigned to compulsory cultivation in 1840-1850 (Kultuurverslagen, quoted in Fasseur and Elson 1992). Under the Preangerstelsel, coffee was cultivated in 'coffee gardens' where, in contrast to the 'forest gardens' elsewhere, the original forest was completely cleared before planting, or the coffee was planted on abandoned swidden fields. This resulted in soil degradation and erosion (Schaik 1986). Once the coffee trees were old and the soils degraded, the deteriorated land was often transferred to peasants who used it for cultivating annual crops, while new land, including on steep slopes, was opened up for new coffee gardens (Schaik 1986, also see Nibbering 1988) . The pressure posed by the coercive cultivation regime made peasants move to other locations in the uplands (Palmer 1959), where they opened up new land. The coffee regime hence raised erosion rates, particularly during the 19th century, by the practices of coffee cultivation, by promoting rainfed agriculture on steep slopes, and by triggering migration to more remote areas.

Between the mid-19th century and the 1920s, ***timber extraction*** also resulted in deforestation and forest degradation and hence rising erosion rates in the region. While the teak forests in other parts of Java had already been overexploited during the 18th century (Boomgaard 1988), timber extraction by the Dutch remained relatively limited in most parts of the SAL region as in most uplands of Java until the mid-19th century, but rapidly increased thereafter (Dienst van het Boschwezen 1905, 1907, quoted in van Goor et al. 1982). In response to dwindling timber supplies, state-led forest management was established for the teak forests from the mid-19th century, while the still rising demand for timber was increasingly met by exploitation of the non-teak forests. Timber demand for ship building, infrastructure, houses, furniture, export, and the processing of export crops, particularly sugar, rose massively during the 19th century (Boomgaard 1988).

Starting from the 1860s, the ***construction and operation of railways*** all over Java additionally contributed to deforestation by increasing timber and fuelwood demand and by providing access to remote areas (cf. Boomgaard 1988). This particularly applies to the SAL region. A railway line from Jakarta/Bandung across the entire catchment area via Tasikmalya, Ciamis and Banjar to Yogyakarta was opened by 1894 (AGS 1945). Its construction created erosion-prone slope cuts, facilitated in-migration and the establishment of corporate plantations, and provided scope for the production and transport of export crops and the establishment of cassava flour mills, thereby promoting erosion-prone rainfed agriculture with cassava cultivation (cf. van Doorn and Hendrix 1983).

From the 1870s onwards, additional forest areas were cleared for the ***establishment of corporate plantations***. The Agrarian Law of 1870 declared all unoccupied land as government land, which could be leased out to entrepreneurs. This led to a gold rush like surge of estate development for the production of export crops in the late 19th and early 20th century. My analysis of the lists and maps of historical plantations contained in Knaap et al. (2007) revealed that a total of at least 25,000ha or about 5.4% of the catchment area of the SAL was converted into plantations. The replacement of forests by estate crops, mostly rubber, likely raised erosion rates, at least temporarily.

The demand of labourers for the plantations contributed to ***large-scale in-migration*** into this sparsely populated area. Also feudal duties, coercive export crop cultivation and forced labour in the lowlands triggered in-migration, since it made people flee to the uplands, where they opened up new land for their subsistence (see Boomgaard and van Zanden 1990; Raffles 1817). In addition, the abolishment of the Kultuurstelsel, which had limited peasants' mobility and thereby confined the growing population to existing arable land, contributed to a "spatial outburst" of people, directed towards the uplands (Palte 1989:42). The new roads and railways facilitated this. Hence, large numbers of people moved into the lagoon's catchment area between the 1860s and 1920s. The population of Priangan increased 24-fold between 1815 and 1930 (Widjoyo 1970). This undoubtedly accelerated the conversion of natural forests into (mostly more-erosion prone) types of land cover. In contrast to the teak forests, the conversion of 'junglewood' forests, "from the destruction of which nobody suffers" (Decree from 1777, quoted in Boomgaard 1988:61) was largely unrestricted until 1884 and in practice continued until the early 20th century (Boomgaard 1988; Smiet 1990).

Deforestation rates peaked in the late 19th and early 20th century (Smiet 1990). Between 1898 and 1936, the area of non-teak forests in Java declined from 4 to 1.8million ha (see Smiet 1990). The factors explored above not only reduced natural forest cover, but made land increasingly scarce. Thus, shifting cultivation in the uplands was gradually abandoned and replaced by wet rice cultivation in valley floors and rainfed agriculture and mixed forest gardens on hill land (see Palte 1989). While wet rice cultivation and mixed forests are considered as the most soil conserving cropping systems in the wet tropics, ***rainfed agriculture*** on hill land is prone to soil erosion and nutrient depletion (see Scholz 1998). In the whole of Java, the area under rainfed agriculture rose by 177% between 1883 and 1913 (Palte 1989). This trend continued during the following 1.5 decades, triggered by food shortages and rising prices for agricultural products due to harvest failures and the war (Boomgaard and van Zanden 1990). In Priangan, the rainfed area subject to Land Rent increased by 25% between 1907 and 1922 (see Boomgaard and van Zanden 1990).

Deforestation, dwindling timber supplies, soil degradation on former coffee plantations in Priangan (see Coster 1936), the rising dependency of lowland agriculture on steady water flows which were believed to be threatened by deforestation, and the linking of flood events with upland reclamation sparked calls for forest preservation in the late 19th century. These demands became increasingly vigorous in the 1910s/1920s (Anonymous 1922; Anonymous 1924; de Haan 1936; Oosterling 1927; Steup 1927). In the context of controversial debates over the forests' hydrological functions (see Roessel 1927; Steup 1927), observations and experiments were conducted to assess the relationships between vegetation, erosion and stream flows (Coster 1938; Gonggrijp 1941). Though their results were later judged by de Haan (1948) as being of limited value, forest cover was generally deemed as the most important means of watershed protection. To sustain timber production and steady water flows and to combat soil degradation, the colonial government ***strengthened and tightened forest management and conservation***. Forest land was mapped and delimited and peasants' forest uses increasingly criminalised (Peluso 1992). The forest areas were also expanded between 1915 and 1940, particularly in the eastern Priangan, which comprises parts of the catchment of the SAL (Dienst van het Boschwezen 1916, 1925, quoted in Boomgaard 1988; van Goor et al. 1982). Also in the other parts of the catchment, state forest land was expanded. For example, my case studies revealed that the government bought village land for conservation purposes near Kawunganten north of the SAL in the 1920s. In particular former coffee gardens, which no longer had economic value after production had declined at the end of the 19th century due to pests, soil degradation and decreasing prices and which had then partly been used by farmers for cultivating annual crops (Schaik 1986), were incorporated into the state forest domain (Galudra and Sirait 2006; Kerbert 1916; Zwart 1932). In 1937 all remaining non-teak forests in Java became legally protected (Smiet 1990).

Combined with the developments described above, the forest management and protection policies contributed to an increasing scarcity of land. Consequently, the era of large-scale migration to the uplands ended in the 1920s. By the 1930s, almost the entire land area of Java was divided between small holder land, corporate estate land, and state forest land (see Palte 1989).

3.2.2 Opening and occupation of state forest and plantation land in the 1940-50s

Following the major settlement and land clearing phase in Java's uplands described above, the period of the Japanese occupation (1942-45) and the early years of independence demarcated the next phase of larger-scale land conversions, though not comparable to those seen during the previous period (cf. Palte 1989). The absence of forest and plantation management and control during this period, the need to maximise food production, and the high demand for castor oil and timber for the Japanese army resulted in widespread state-initiated and spontaneous conversions of forests and plantations into rainfed agricultural land, leading to soil erosion (see e.g. Nibbering 1988; Palte 1989). An estimated 18% of the pre-war forest land of Java was destroyed between 1942 and 1950, leaving only 17% of the total land area forested (Prakoso 1954).

3.2.3 Contestations of state forest and plantation land

Since their demarcation in the 19th and early 20th century until today, state forests and plantations have been contested by peasants (see Peluso 1992 for a historical account). The state forests alone constitute almost one fourth of the land area of Java, which is remarkable given the island's extremely high rural population densities. These forests have been degraded due to timber and fuel wood thefts, burning, grazing, and cultivation by peasants throughout the 20th century (see e.g. Nibbering 1988; Peluso 1992; Smiet 1990). By 1940 one third of the protected forests of Java were deforested or degraded (Smiet 1990). Despite repressive forest management, including armed policing, during Suharto's New Order era from the mid-1960s until 1997, forest degradation remained a major issue throughout Java. For example, in the upper Konto watershed, the proportion of degraded forest land rose from 20% in 1934 to at least 41% in 1985 (Nibbering and Graaff 1998).

Degradation of state forest and plantation land peaked between 1997 and the early 2000s, when vast areas were plundered and partly occupied during the political turmoil following the fall of Suharto. Local residents, together with people from nearby towns who provided chain saws and trucks, and partly spearheaded by influential individuals, sometimes from the forest administration itself, used the opportunity of the political transition to plunder state forests and plantations. My case studies showed that large parts of the population in the forest margin areas participated in and gained from these processes. The plundering and occupations as part of the political transition led to lasting alterations of established patterns of forest access and control, but also resulted in large-scale forest and soil degradation. For the whole of Java, it was estimated that almost one third of the state forest land was left without forest cover (Ardana et al. 2009, quoted in Peluso 2011).

My research on land use/cover change and its drivers in the SAL region showed that state forests and plantations constituted substantial portions of the critical, erosion-prone land. Future land use and hence the erosion potential of these areas depend on the outcomes of partly ongoing struggles over resource access and control. Some of the land has been reforested by the state forest corporation. Some of it is managed through 'community forestry', whereby local residents receive part of the revenue and are responsible for safeguarding the trees, while the state forest corporation retains control over the land and remains in charge of all major management decisions. The performance of these programmes with regard to tree cover and observable patterns of soil erosion was mixed at the time of field research. The programmes' top-town character, the lack of a sense of ownership and responsibility for forests under the domain of the state forest corporation on the part of peasants, and the challenge of building more trustful relationships between peasants and the corporation, whose transformation from a fairly repressive power apparatus requires time, are major obstacles, constraining the performance of the programmes, socially, economically as well as with regard to soil conservation. Finally, some of the deforested areas remained as treeless, highly erosion-prone sites, cultivated with annual crops by peasants who claimed ownership over the land for historical reasons. Most of these claims are rooted in displacements of peasants or entire villages in the wake of a series of political insurgencies and counter-insurgencies in the 1950s-60s or in illegitimate expansions of former Dutch plantations when they were transferred into Indonesian ownership (also see Lukas 2014b). As long as these land conflicts are not resolved, the peasants use the land for cultivation but hesitate to invest in soil conservation. That is, erosion on these lands is the direct outcome of ongoing, historically rooted struggles over land.

3.2.4 State forest management practices

Rigid control and tight management of the state forests has been the core thrust of watershed protection in Java since the 1920s. It is hence no surprise that watershed management is under the responsibility of the Ministry of Forestry and the state forest corporation, whose sovereignty of interpretation over matters of watershed protection has barely been challenged. The entanglement of state forest and watershed management – institutionally, economically and in terms of political power – has effectively prevented the state forest corporation's own management practices from being debated in the frame of watershed management discourses (Lukas and Flitner under review). In fact, the one-age-cohort teak and pine plantations that constitute most of the state forests in the catchment of the SAL and the corporation's timber harvesting methods deserve critical appraisal.

The ***monocultures of one-age-cohort-teak-plantations*** on easily erodible sedimentary soils in the eastern and southern areas of the catchment partly exhibit high erosion rates. In case of low litter and ground vegetation densities, the large-leaved teak trees led to higher levels of splash erosion than in the open field due to the higher kinetic energy of the throughfall (cf. Calder 2005; Miura et al. 2002; Sidle et al. 2006; Vis 1986). In addition, the shedding of leaves during the dry season results in exposed soils or understorey vegetation at the onset of the rainy season, resulting in erosion. In fact, the few existing studies in Java's teak plantations (Widjajani et al. 2011; Wolterson 1979) indicate similar erosion rates as measured on rainfed agricultural land by Rijsdijk (2005). Though the results from different sites and researchers cannot be compared directly, they underline my observations in the catchment of the SAL. Based on similar observations, Schweithelm (1988:39), the watershed consultant of the Citanduy II project and one of the very few experts who have raised concerns over state forest management practices in Java, pointedly noted that “even-aged teak plantations are one of the worst land uses possible from a watershed management perspective.”

My analysis of satellite images, land use mapping and interviews showed that ***rotational clear cuts*** are the common timber harvesting method of the state forest corporation throughout the lagoon’s catchment. I observed that during clear cuts, not only the trees and potentially existing understory vegetation were cut, but also the tree stumps and roots were removed, resulting in the entire plot being dug up leaving the exposed mineral soil vulnerable to erosion during the next heavy rainfall event. I found such plots on very steep slopes, sometimes in direct proximity to streams, which results in high sediment delivery ratios. Only very few authors have parenthetically remarked the effects of timber harvesting methods on erosion and riverine sediment loads in Java. Lavigne and Gunnell (2006, Figure 7) provided visual documentation of numerous substantially sized landslides on mountainous state forest land near Cilacap following a large clear cut.

My observations and accounts of local residents also suggest that the ***one-age-cohort-pine-plantations*** might raise the risk of landslides. The state forest corporation has expanded and continues to expand the area under pine. Eight of the 20 forest districts of Java are to be developed as ‘pine areas’, since the forest corporation aims at increasing pine raisin production and since pine forests are not prone to timber thefts. Residents of a number of villages in the area around Karangpucang north of the SAL noted independently that landslides occurred particularly frequently in pine forests. They explained the occurrence of several long landslides on steep slopes after prolonged rainfall with the combination of saturated soils and the large weight of the thick canopies of the densely planted pine trees. These landslides damaged houses, killed people, and prompted the resettlement of an entire hamlet (the hamlet of Golongmasi in the village of Bantarmangu). This issue has not yet been the subject of scientific inquiry. Knowledge on the effects of land cover on landslide erosion is lacking for the whole of Southeast Asia, and landslide erosion is generally barely captured in erosion and sediment yield studies due to the studies’ limited temporal and spatial scopes (Sidle et al. 2006). Residents of pine forest margin villages also complained about reduced dry season water flows undermining their rice production following the upslope conversion of teak or other forest types to pine forests. Their observations suggest that the water uptake of dense pine forests reduces dry season stream flows not only in comparison to grassland (see Bruijnzeel 2004) but also in comparison to other forest types.

While state forest lands have been framed as the epitome of watershed protection for about a century, the peasants’ mixed forests, which cover substantial portions of the slopy land in the lagoon’s catchment and throughout Java, have barely been acknowledged in debates over watershed management. Many of these often very dense, diverse and multi-layered small holder forests, which are usually harvested by selective logging, provide better watershed protection than the forest corporation’s rotationally clear cut monocultures of teak.

3.2.5 Rainfed agriculture

Though this paper critiques the one-sided focus of debates on upland farmers’ private plots and the neglect of other sediment sources, the substantial contribution of rainfed agricultural land to river sediment loads cannot be denied. Soil erosion on slopy rain-fed agricultural land in Java has received much attention in watershed conservation programmes for decades and has been subject of research (e.g. Donner 1987; Palte 1989; Purwanto 1999; van Dijk 2002).

Rainfed agriculture on both terraced and non-terraced land in Java is marked by comparatively high erosion rates. For example, in the Konto watershed, rainfed agricultural land comprised only 15% of the area, but contributed 45% of the total river sediment load (Rijsdijk 2005). Also in the Cikumutuk catchment, bench-terraced rainfed agricultural land, and in fact mainly the bench terraces themselves, constituted the areas with the highest erosion rates along with settlements, trails and roads (van Dijk 2002; van Dijk and Bruijnzeel 2005). It should be noted, however, that this area constitutes a hotspot of steep, erosion-prone rainfed agricultural land without a variety of other land cover types, such as non-degraded, degraded, or occasionally clear cut mono-culture forests or dense small holder mixed forests. That is, site selection and research scope limit the range of possible results thereby contributing to the confinement of debates to upland farmers' private plots. The findings are undoubtedly highly relevant with regard to land use and soil conservation options and policies for rainfed agricultural land, but they cannot be up-scaled to provide the sole explanation of the high down-stream sediment yields of larger rivers, like the Citanduy.

The first bench terracing programmes were undertaken in the 1930s, but discontinued during World War II and the first years after independence (see Purwanto 1999). Since the 1970s the catchment of the SAL has been one of the priority areas for watershed conservation in Java. It is hence no surprise that, as my land cover mapping throughout the area showed, most upland agricultural land privately owned by farmers is terraced. However, terracing alone, if not combined with other soil conservation measures, such as mulching, denser vegetation or reduced tillage, might not effectively reduce soil erosion (see Purwanto 1999; Schweithelm 1988; Sidle et al. 2006; van Dijk 2002; van Dijk et al. 2004). This is particularly true for the areas with sedimentary soils. In these parts of the catchment, surface erosion is observably comparatively high under most land cover types. The terracing programmes showed little effect in these areas (Schweithelm 1988). Returning crop residues to the soil in the form of mulch or compost, as commonly practiced in organic agriculture, instead of burning them, which is common throughout Java, would certainly reduce surface erosion. Recent initiatives to promote organic agriculture in Java are encouraging in this respect.

My research also showed that the decade-long regreening programmes did contribute to increasing tree cover on farmers' private lands in some locations. However, the more significant increase in tree cover during the past decade was mostly attributed to factors other than the government's regreening programmes. They included the increasing profitability of tree cultivation, alternative incomes easing a shift from annual to perennial crops, and new bottom-up oriented incentives provided by governmental and non-governmental organisations (also see Lukas 2013). Some previously bare slopes covered by my case studies had repeatedly been targeted by regreening programmes without much success, but are now covered with mixed forests.

To sum up, rainfed agricultural land undoubtedly constitutes a major cause of high river sediment loads and lagoon sedimentation. Though the effects of the terracing and tree planting programmes have been regarded as limited, these efforts have not been without achievements. However, the effects of the programmes and the recent increase in tree cover on farmers' private lands on downstream sediment loads and their potential linkage with the declining lagoon aggradation rates depicted in Figure 3 are unknown. In fact, knowledge of the impacts of watershed conservation or other watershed modifications on downstream sediment yields, the time lags of such impacts, and the related effects of scale is limited not only in Java but worldwide (see Bruijnzeel 2004; Sidle et al. 2006; Walling and Collins 2008; Walling and Fang 2003).

3.2.6 Ngaguguntur and agriculture in riparian zones

Also practices related to irrigated agriculture considerably contribute to high river sediment loads. In many parts of the lagoon's catchment, farmers have over decades enlarged the area of irrigated fields in the valley floors by digging back the foot of the hill slopes. The excavated soil is usually shovelled directly into channels and streams. This practice is called 'ngaguguntur', a Sundanese term referring to "all activities where running water in a man-made canal is used to remove and transport any surplus of soil" (Diemont et al. 1991:219). Whereas in case of surface erosion some of the sediments are usually stored on the slope or at slope toes before they might enter the river network with time lags of decades or centuries, ngaguguntur puts the entire amount of material directly and immediately into the river network. That is, different from most other sediment sources, the sediment delivery ratio in case of ngaguguntur reaches 100%.

Very few authors have paid attention to this. Diemont et al. (1991) linked ngaguguntur to the extraordinary high sediment loads of the Cimunutur, a tributary of the Citanduy River. In addition, Purwanto (1999) documented one ngaguguntur in the Cikumutuk catchment. It comprised 785m³ of excavated soil (≈707tons assuming a bulk density of 900kg/m³) and contributed significantly to the total river sediment load.

Ngaguguntur is common in the Sundanese as well as the Javanese parts of the lagoon's catchment area. In some villages covered by my research, tens of thousands of square metres of hilly land were converted into plain irrigated agricultural land in this way. The example of the expansion of the irrigated area by about 25,000m² through ngaguguntur in one sub-village at the Raja River, a tributary of the Cikawung and Citanduy Rivers, shall illustrate the magnitude of riverine sediments contributed by ngaguguntur. Assuming an area of 25,000m² and an average excavation depth of only 5m results in 125,000m³ or 112,000tons of sediments (assuming a bulk density of 900kg/m³ as in Purwanto 1999). This corresponds to approximately 1-2% of the annual sediment load of the Citanduy River, which has been estimated at 5-10million tons (PRC-ECI 1987). This amount of sediments was not put into the river within one year but over a period of a few decades. However, considering an estimated number of at least several hundred, perhaps even a thousand other sites with similar landscape modifications in the catchment area, the contribution of ngaguguntur to total river sediment loads is substantial. Following ngaguguntur, mass-movements from the considerably steepened slope toes often contribute additional sediments over decades.

Also agriculture in riparian zones, which is widespread throughout the lagoon's catchment, contributes to high river sediment loads, whereby sediment delivery ratios can be as high as in case of ngaguguntur. Soil eroded from rainfed agricultural fields on river banks during rainfall or flood events directly enters the river. In addition, collapsing river banks due to both rainfed and irrigated agriculture in riparian zones can be observed along many river sections in the area. In line with this observation, Rijsdijk et al. (2007a) found that the collapse of rice field terraces in the riparian zone significantly contributed to the sediment loads of the Konto River.

3.2.7 Roads, trails and settlements

The increase in the area covered by settlements, roads and trails in the second half of the 19th and throughout the 20th century has very likely contributed considerably to the increasing sedimentation rates depicted in Figure 3.

The substantial contribution of rural roads, trails and settlements to river sediment loads has recently been acknowledged and quantified at a few locations in Java and elsewhere. For example, Rijsdijk et al. (2007b) found that although roads, trails and settlements together comprised only 5% of the total area of the upper Konto watershed, they contributed nearly 40% of the total sediment yield. Purwanto (1999) measured similarly high erosion rates on settlement plots in the Cikumutuk catchment. Thus, due attention needs to be paid to roads, trails and settlements in assessing the causes of high river sediment loads and in designing related watershed management strategies.

While neither contemporary nor historical data on the areas covered by roads and trails exists, settlement areas can be estimated based on topographic maps. For this purpose, scanned topographic maps from the 1920s[3] were compared with the most recent topographic maps[4]. Using the classification tools in ArcGIS, the settlement areas were extracted from each of the digitised map sheets, converted into shape files, simplified and manually corrected, and their total sizes calculated. The results reveal that the total settlement area in the lagoon's catchment more than doubled between 1924-26 and the 1990s to about 600km² or 13% of the catchment area[5].

However, since many settlements comprise soil conserving multi-storeyed house gardens (cf. Scholz 2000), only a portion of the total settlement area is to be regarded as erosion-prone land. Assuming that only half of the total settlement area (i.e. 6-7% of the catchment area) is erosion-prone, considering my observation of partly severe erosion from roads and trails, and taking into account the findings of Rijsdijk et al. (2007b), it is likely that roads, trails and settlements contribute between one third and half of the total amount of riverine sediments entering the lagoon. However, after four decades of investments into watershed conservation, the first small-scale pilot initiatives to reduce erosion within settlements were begun only recently.

3.2.8 Volcanic eruptions

In addition to the various anthropogenic drivers, a series of eruptions of Mount Galunggung, the only active volcano in the lagoon's catchment, has contributed to accelerated lagoon sedimentation. Following 1,000 or even 4,000 years of dormancy, the volcano erupted in 1822, 1894, 1918, 1982/83, and 1984 (GVP 2014).

Rivers affected by volcanic eruptions exhibit the highest sediment yields worldwide (Lavigne 2004; Milliman and Syvitski 1992; Walling and Webb 1996b). The kinds, magnitudes and temporal patterns of the effects of volcanic eruptions on the hydrology of river basins have been documented in various parts of the world (see Hayes et al. 2002; Kuenzi et al. 1979; Lavigne 2004; Major et al. 2000). Volcanic eruptions supply easily erodible ash and detritus to hill slopes and channels, and deposit tephra and destroy the vegetation in large areas, both of which reduces soil infiltration and increases

[3] Topographical map of Java, Middle (and West), TDNI, Land tax revision brigades; 1:50,000, reprints from 1938-42, 23 map sheets, Netherlands Royal Tropical Institute (KIT), Indonesian National Library.

[4] Peta Rupabumi', produced by the Badan Koordinasi Survey dan Pemetaan Nasional (BAKOSURTANAL) in 1997-98, based on surveys carried out in 1993-94, 1:25,000, 41 map sheets.

[5] The comparison of the areas derived from the different sets of maps is slightly biased due to the different map scales and different approaches of depicting dispersed (groups of) houses outside of the main settlements as point or areal phenomena. Visual comparison of the maps suggests that the potential bias introduced as a result of different map scales is relatively small in relation to the magnitude of change detected. Since the recent topographic maps, in contrast to the historical ones, depict dispersed (groups of) houses outside of the main settlements as point phenomena, the total settlement area calculated for the 1990s likely underestimates the actual area covered by settlements.

surface runoff and erosion (Hayes et al. 2002; Major et al. 2000). This, together with pyroclastic flows and lahars and the redevelopment of drainage networks on thick debris layers, can raise river sediment yields by several hundred orders of magnitude during the first 2-3 years after the eruption and keep them high for decades (ibid.).

The most explosive eruptions of Mount Galunggung occurred in 1822 and 1982/83 with total tephra volumes of >1billion m³ and >370million m³ respectively. The eruption of 1822 was one of the world's most explosive ones of the 19th and 20th centuries (see Kohno et al. 1999; Wilson 1999). Documentation of this early eruption is scarce. However, the extremely large amount of tephra ejected and a qualitative description of its impacts by Junghuhn (1854) suggest that it substantially accelerated lagoon sedimentation. Unfortunately, the shoreline change analysis presented in Figure 3 could not cover this period due to the lack of sufficiently accurate maps. Also the sediment analysis by Kastanja (2001), though it indicates an increased influx of volcanic material, does not allow for any estimate of the relative contribution of this and the other eruptions to lagoon sedimentation. However, Junghuhn (1854) described the effects of the 1822 eruption as follows:

> "[…]enormous amounts of mud, with dead bodies of humans and animals and smashed trees, were floated to the sea via the two major rivers of the region, the Tji-Wulan and Tji-Tandui. Particularly the Tji-Tandui carried tremendous amounts of material into the sea, namely to the inland sea "Segara Anakan" […], which hence became much narrower and shallower within a few days […]. Several years before this event, a sea ship still sailed from Banteng Mati through the Kindersee [Segara Anakan] to Tjilatjap. Now the narrow channel between Java and Nusa Kambangan is only navigable for rowing boats and at some places the mud is already stirred up by the boats" (translated from Junghuhn 1854:98-99).

More detailed information exists about the eruption of 1982/83. Of the total tephra volume of >370million m³, about 68million m³ was deposited in the catchment of the Citanduy (Wirosoemarto et al. 1989). This amount of tephra (ca. 88million tons, assuming a dry bulk density of 1,300kg/m³, following Bernard 2013) exceeds the estimated total annual sediment input into the SAL (ca. 5-10million tons, see PRC-ECI 1987) by a factor of 9-18. Which proportion of this material was transported into the lagoon within what time span is unknown. It was estimated that the eruption raised the sediment load of the lower Citanduy River by one order of magnitude during the year succeeding the eruption (RMI/PRC/ECI 1986, quoted in Schweithelm 1988). While the ash deposited in large parts of the catchment at depths between 1cm around Ciamis and >25cm close to the volcano (Katili and Sudradjat 1984; Sudradjat and Tilling 1984) certainly raised sediment delivery to the stream network for a comparatively short period, the material deposited on the slopes of the volcano and in the streams draining them as well as the destruction of vegetation certainly increased sediment delivery to the Citanduy for at least several years. Some of this material reached the lagoon with a time lag of a few years. Stevens (1994) found that the river bed of the lower Citanduy aggradated for a few years following the eruption until 1986/89. It likely took at least a similar time span until most of the material temporarily deposited in the river bed reached the lagoon. Hence, the eruption of 1984/85 raised annual sediment delivery to the lagoon for several years until the mid-1990s and contributed to the maximum in siltation rates during this period depicted in Figure 3.

3.2.9 River and floodplain modifications

In addition to the drivers described in the above sections, river straightening and embankments and the conversion of the seasonally inundated floodplains of the lower river basin into agricultural land have considerably accelerated lagoon sedimentation. Having been straightened and embanked, the Citanduy and Cikonde Rivers no longer deposit substantial portions of their sediment loads in the alluvial swamp lands upstream from the lagoon during storm water flows. Instead, the entire sediment load, which is especially high during storm water flows, is transported into the lagoon directly and with a reduced time lag.

Historical maps from 1857-60 and 1900/1901 show the lower Citanduy River meandering through swamp forests for almost its entire length (Online Resource 3, Figure a). Barely any settlements existed along the river banks. This changed between 1900 and the late 1920s. A revised topographic map sheet from 1929 documents a tremendous increase in settlement areas along the river and the conversion of some of the swamp forests into irrigated rice land (Online Resource 3, Figure b). However, apart from one or two small meander cut-offs, the river course remained the same between 1857-60 and 1929.

This changed in the second half of the 1930s, when levees were constructed and the river channel was shortened to reduce flood risk. At least 13 human-made meander cut-offs together with a few natural cut-offs reduced the length of the lower Citanduy from 51 to 38km (PRC-ECI 1975). Levee construction was continued in the mid-20th century, when villages on the opposing shores of the river engaged in “dike wars”, competing with each other in building higher dikes (Schweithelm 1989:14).

River and flood plain modifications were pushed forward on a larger scale in the 1970s as part of the USAID-financed Citanduy I project. An additional 20 meanders were removed, and more swamp land was converted into irrigated rice land (Tim Koordinasi Wilayah 1989). In addition, the Nusawuluh floodway was constructed to divert peak floods of the Citanduy River to the east into the Cibeureum River (see PRC-ECI 1987). As a result, some of the sediment load of the Citanduy is redirected into the northern part of the SAL. Of these redirected sediments a larger proportion is permanently deposited in the lagoon instead of being transported out into the ocean as would be the case if the sediments entered the lagoon via the Citanduy, whose estuary is close to the western outlet. The floodway carries flows 10-15 times per year for a duration of 1-10 days (PRC-ECI 1987). Given that these peak floods contribute a large proportion of the annual sediment load (for example, in 1984/85 two large floods contributed 20% of the annual sediment load of the Citanduy, PRC-ECI 1987), the Nusawuluh floodway has considerably contributed to accelerated lagoon sedimentation since the 1970s.

Levee construction and agricultural reclamation continued in the 1980s as part of the ADB-funded Lower Citanduy Irrigation Project. By the 1990s, the lower Citanduy River was substantially shortened, completely embanked and lined with settlements for almost its entire length (see Online Resource 3, Figure c). Also the Cikonde and Cimeneng Rivers were leveed and straightened in the 1980s (see Online Resource 4). This resulted in a large increase in sediment input to the northern part of the lagoon, from where only a comparably small portion is transported out into the ocean.

While most documents and debates have focussed on upland agriculture as major sediment source, a few project reports acknowledged the contribution of the river regulations to increased lagoon sedimentation as “profound” (PRC-ECI 1987-11), an unanticipated side effect of the Citanduy I and II projects which “decision makers had not fully appreciated” (Tim Koordinasi Wilayah 1989:vii). The river and floodplain modifications have magnified and will continue to magnify the impacts of all other drivers of lagoon sedimentation that have been explored in the above sections.

4 Conclusion

Three fourths of the water surface area of the Segara Anakan lagoon has silted up since 1857/60. This process accelerated between the mid-19th century and the late 1980s. The time-sequential linking of these temporal dynamics of lagoon aggradation with various watershed characteristics and modifications has shown that accelerated lagoon sedimentation is the result of a much broader range of drivers than commonly narrated in political and scientific debates. These drivers include compulsory coffee cultivation in the 18th and particularly 19th century, excessive timber extraction between the mid-19th century and the 1920s, infrastructure developments particularly in the late 19th and early 20th century, the establishment of plantations and in-migration between the 1870s and 1920s, the opening of forest and plantation land in the 1940s/1950s, the contestation and degradation of state forest and plantation land throughout the 20th century, state forest management practices, rainfed agriculture on farmers' private land, ngaguguntur and agriculture in riparian zones, erosion and mass-movements from roads, trails and settlements, and a series of volcanic eruptions. In addition, river channel and floodplain modifications have contributed to accelerated lagoon sedimentation and have multiplied the effects of all other drivers.

Although the effects of these drivers have not been quantified (this remains a major challenge in any larger river catchment worldwide), the synopsis of the various watershed modifications presented in this paper provides a more complete picture of the causes of lagoon sedimentation than has been drawn in the frame of long-standing watershed management debates and in any related written documentation. It suggests that both the choice and expectations of societal responses need to be reconsidered. Taking into account the entire range of historical and contemporary watershed transformations and characteristics, the possible contribution of soil conservation on farmers' private lands to reducing lagoon sedimentation, while desirable for the sake of sustaining soil productivity, is a priori limited. Reducing the pace of lagoon aggradation to levels seen in the mid-19th century by watershed conservation is unfeasible. Regarding lagoon sedimentation not only as a threat, but as a transformation that on its own alters but does not necessarily destroy the ecosystem and local livelihood opportunities seems to be a good starting point for further debates on societal responses.

The case of the Segara Anakan lagoon illustrates the large breadth of aspects and drivers that need to be considered in exploring watershed dynamics and their interactions with coastal zones. It also shows that societal debates, research and political action can be confined to very few issues and causal factors for decades while neglecting a large range of other drivers. Such one-sided discourses restrict the range of societal responses considered in allegedly trying to tackle particular issues. This results in unrealistic expectations about and limits the effectiveness of the societal responses chosen. In such contexts, societal debates need to be broadened by open-ended research that regards contemporary phenomena and processes as a result of not only the present characteristics of particular sections of the landscape (e.g. contemporary upland farmers' private plots), but of the whole record of past and contemporary landscape characteristics and modifications in the entire watershed, including their underlying causes. An interdisciplinary historical approach, linking physical processes and related societal dynamics in a time sequence, and the combination of various pieces of information (e.g. from different strains of literature, historical cartographic inquiry, remote sensing, intimate knowledge of the entire catchment area, and knowledge of socio-political dynamics) facilitates such open-ended research. It contributes to an improved overall understanding of the dynamics and drivers of environmental change and thereby challenges simplistic narratives and contributes to a more informed basis for discussions on appropriate societal responses.

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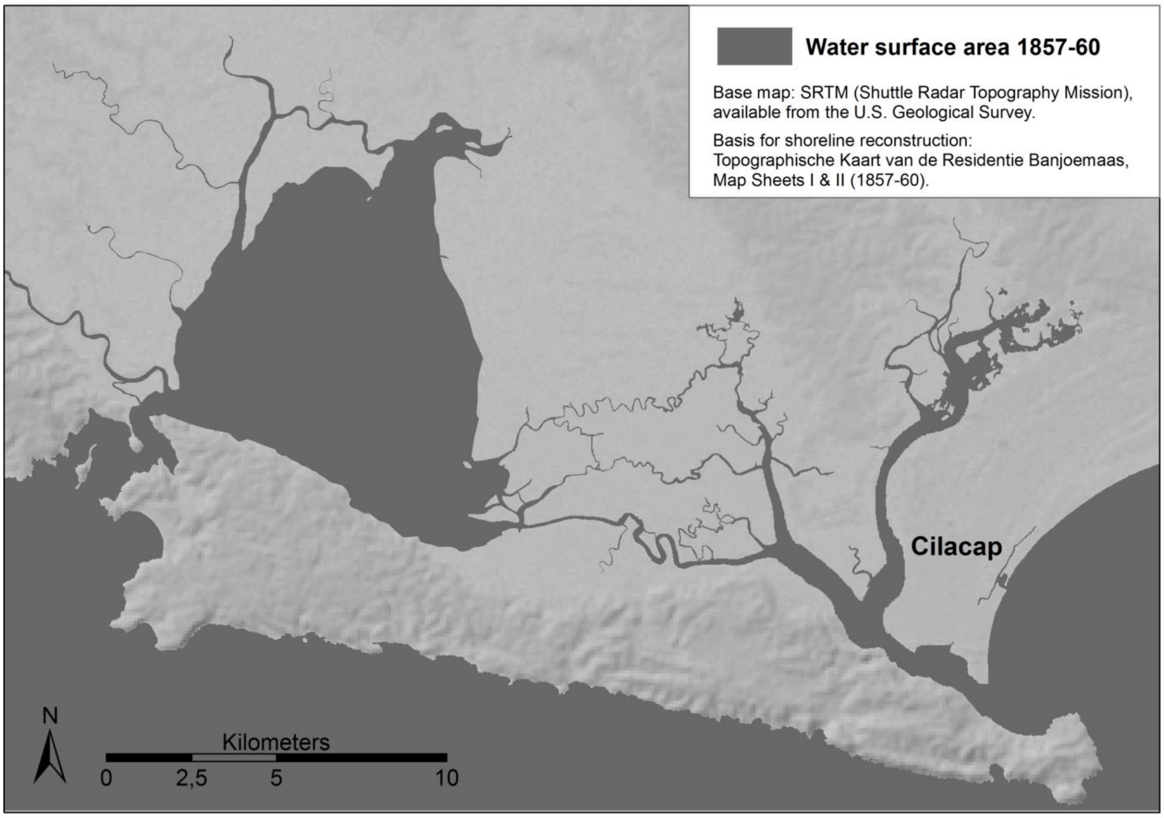
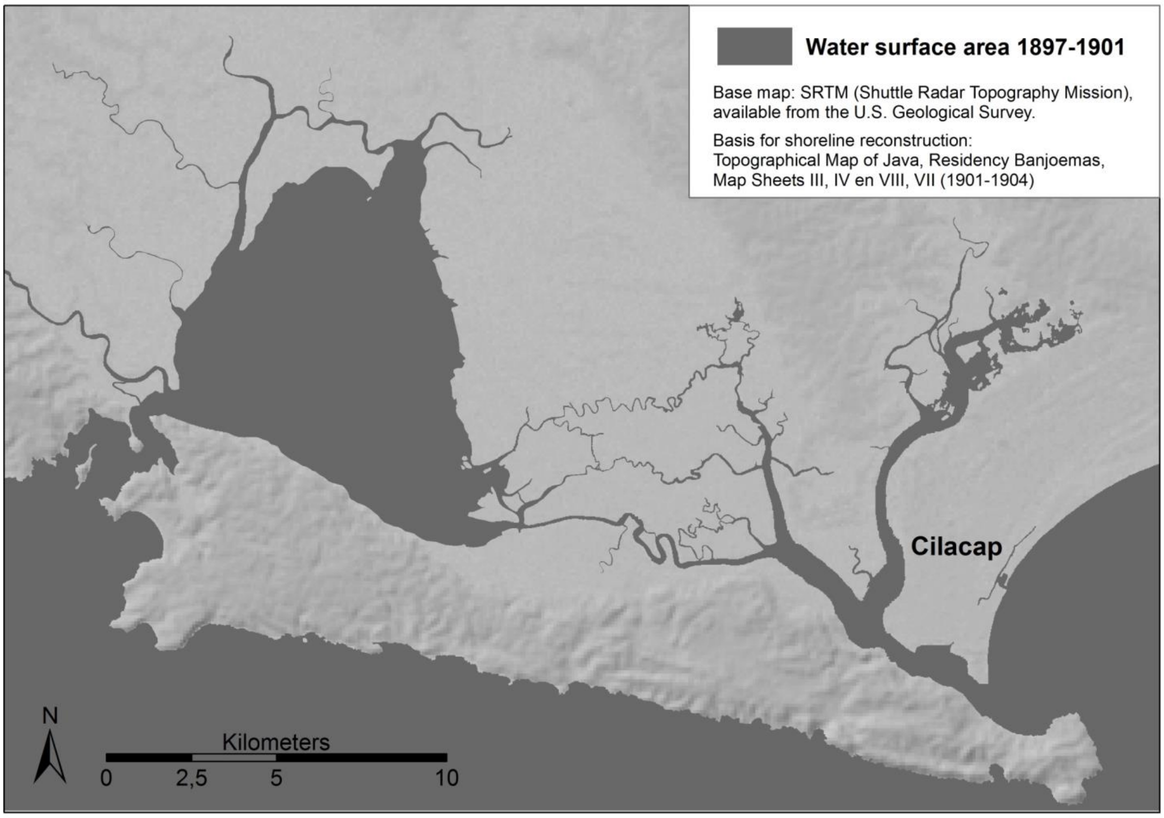
Online Resource 1 [see electronic file]

Map series illustrating the change in the water surface area of the Segara Anakan lagoon over time. Base map: SRTM (Shuttle Radar Topography Mission), available from the U.S. Geological Survey. The reconstructed shorelines are based on the maps and satellite images listed in Table 1.




Water surface area 1897-1901
Base map: SRTM (Shuttle Radar Topography Mission), available from the U.S. Geological Survey.
Basis for shoreline reconstruction:
Topographical Map of Java, Residency Banjoemas, Map Sheets III, IV en VIII, VII (1901-1904)
Cilacap
N
Kilometers
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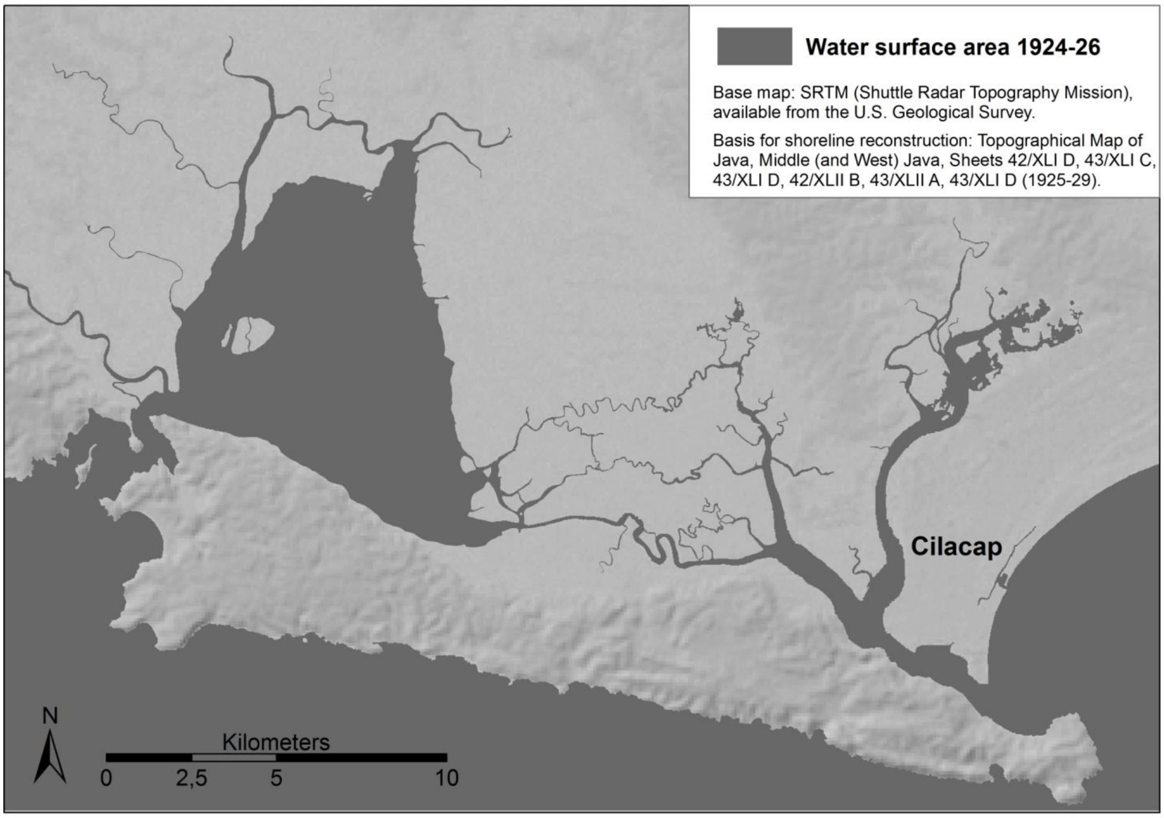
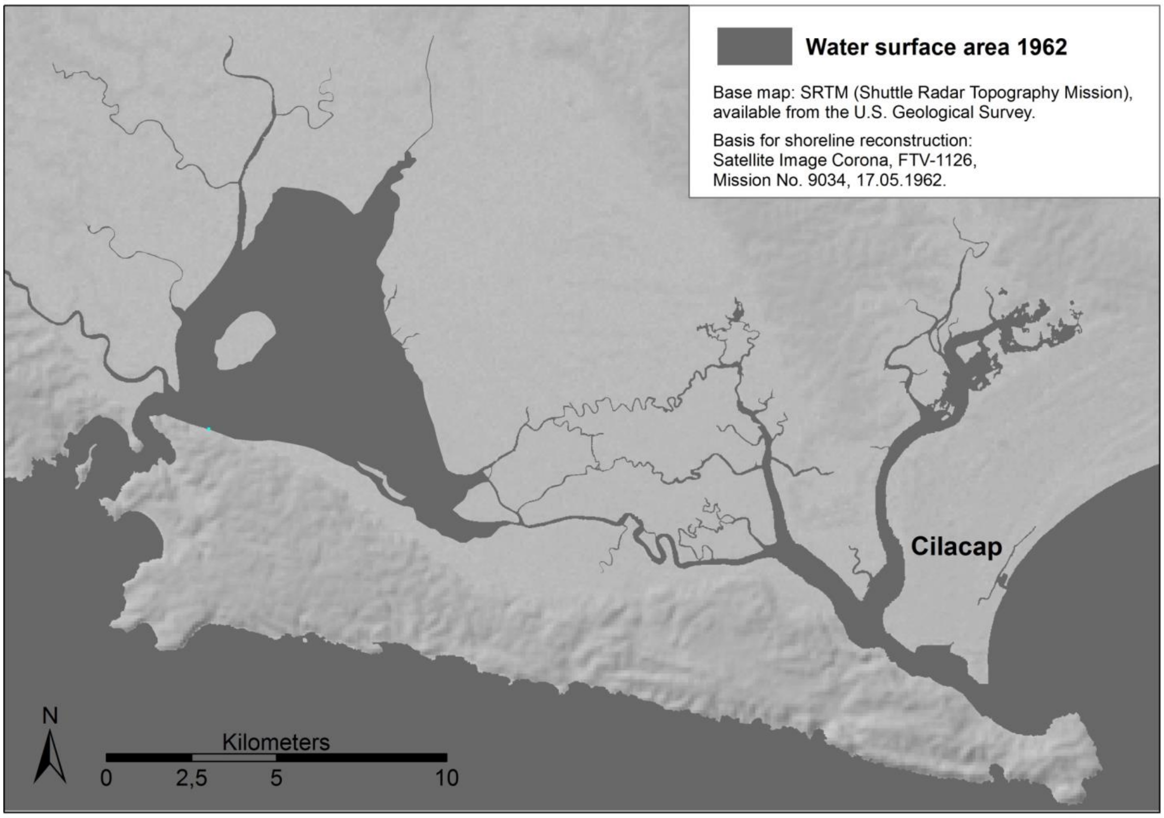
2,5
5
10


Water surface area 1924-26
Base map: SRTM (Shuttle Radar Topography Mission), available from the U.S. Geological Survey.
Basis for shoreline reconstruction: Topographical Map of Java, Middle (and West) Java, Sheets 42/XLI D, 43/XLI C, 43/XLI D, 42/XLII B, 43/XLII A, 43/XLI D (1925-29).
Cilacap
N
Kilometers
0
2,5
5
10


Water surface area 1962
Base map: SRTM (Shuttle Radar Topography Mission), available from the U.S. Geological Survey.
Basis for shoreline reconstruction:
Satellite Image Corona, FTV-1126,
Mission No. 9034, 17.05.1962.
Cilacap
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Kilometers
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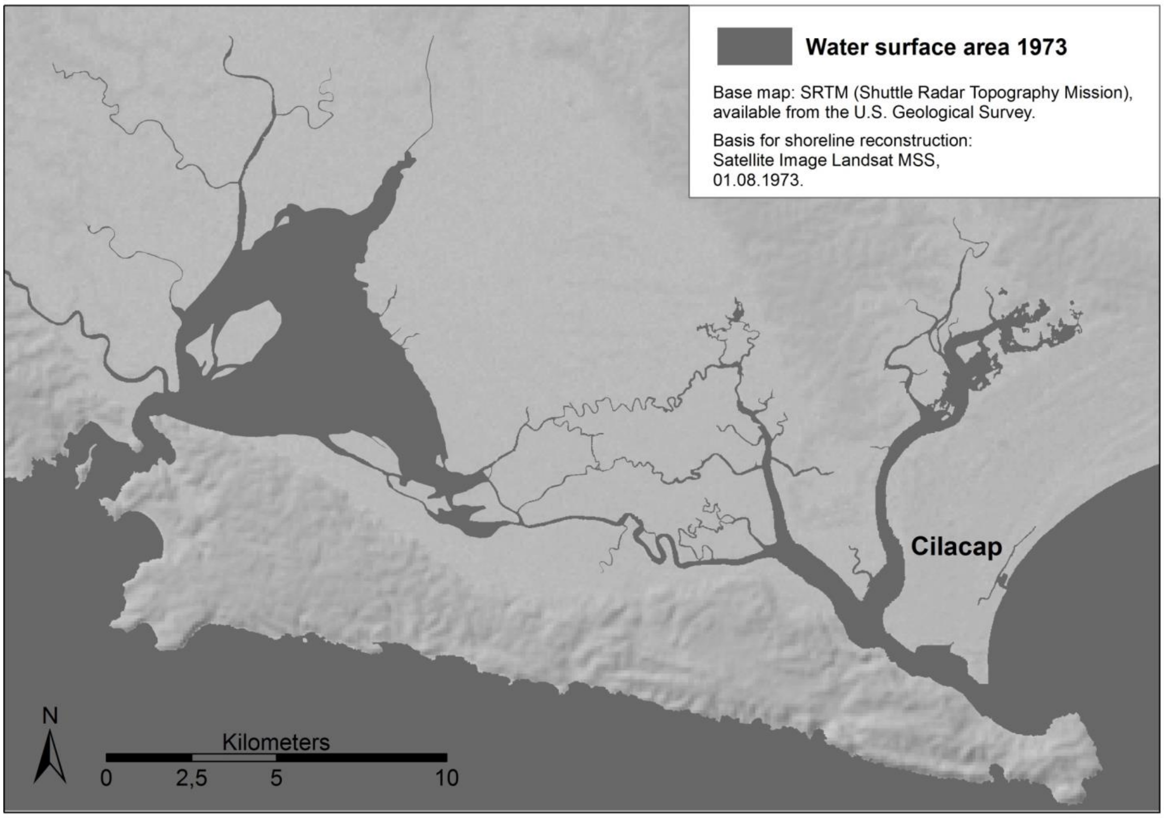
Water surface area 1973
Base map: SRTM (Shuttle Radar Topography Mission), available from the U.S. Geological Survey.
Basis for shoreline reconstruction:
Satellite Image Landsat MSS,
01.08.1973.
Cilacap
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Kilometers
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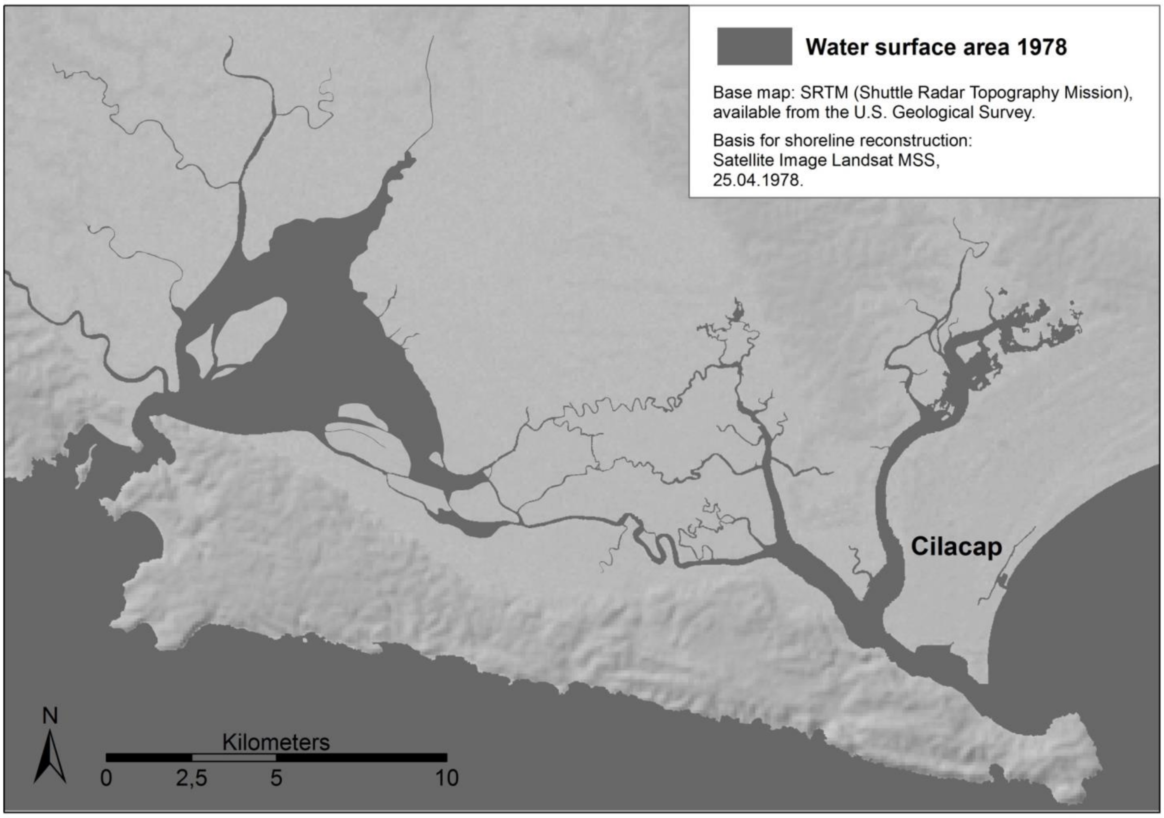
Water surface area 1978
Base map: SRTM (Shuttle Radar Topography Mission), available from the U.S. Geological Survey.
Basis for shoreline reconstruction:
Satellite Image Landsat MSS,
25.04.1978.
Cilacap
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Kilometers
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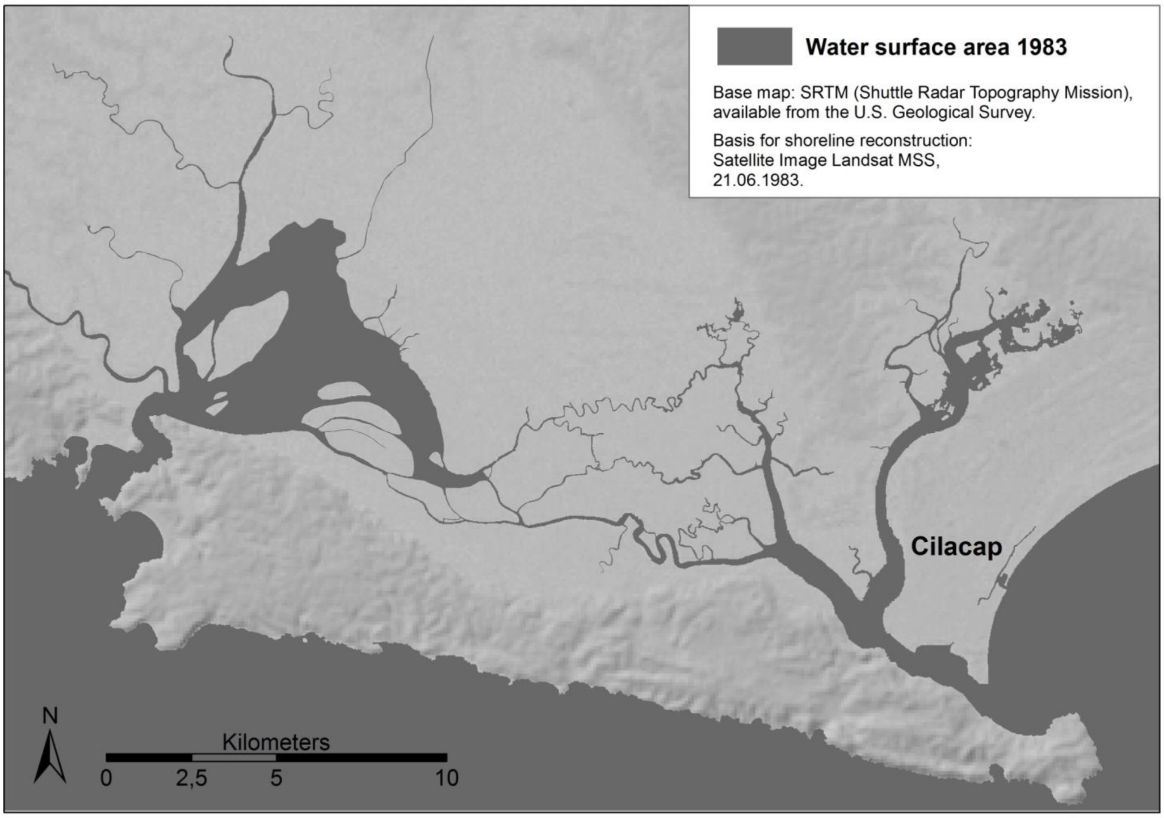
Water surface area 1983
Base map: SRTM (Shuttle Radar Topography Mission), available from the U.S. Geological Survey.
Basis for shoreline reconstruction:
Satellite Image Landsat MSS,
21.06.1983.
Cilacap
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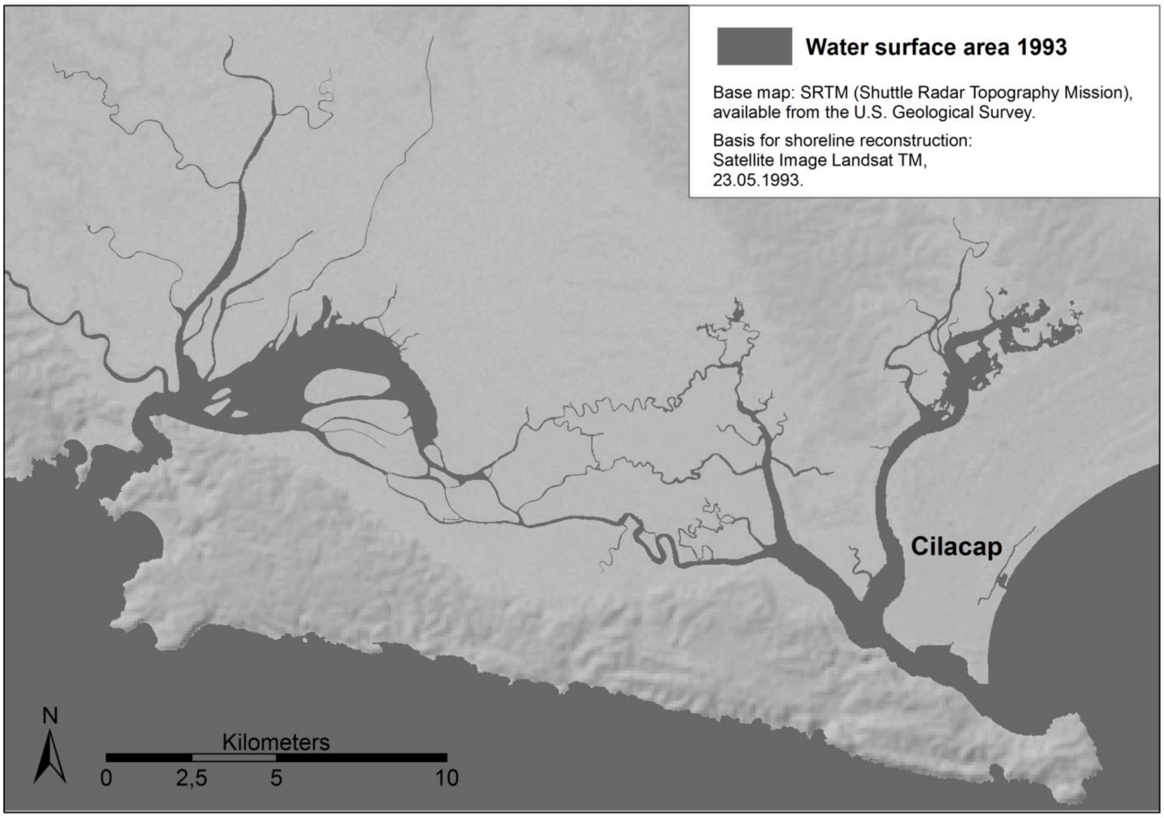
Kilometers
0 2,5 5 10


Water surface area 1993
Base map: SRTM (Shuttle Radar Topography Mission), available from the U.S. Geological Survey.
Basis for shoreline reconstruction:
Satellite Image Landsat TM,
23.05.1993.
Cilacap
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Kilometers
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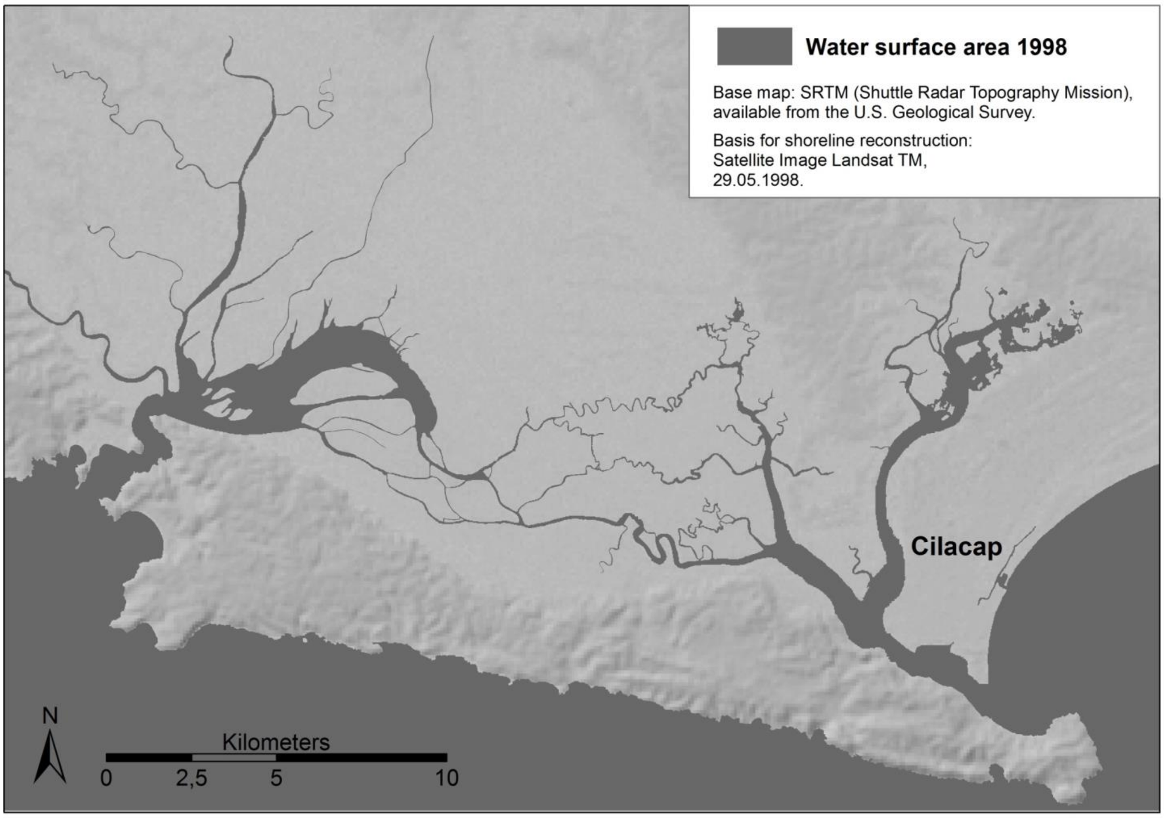
Water surface area 1998
Base map: SRTM (Shuttle Radar Topography Mission), available from the U.S. Geological Survey.
Basis for shoreline reconstruction:
Satellite Image Landsat TM,
29.05.1998.
Cilacap
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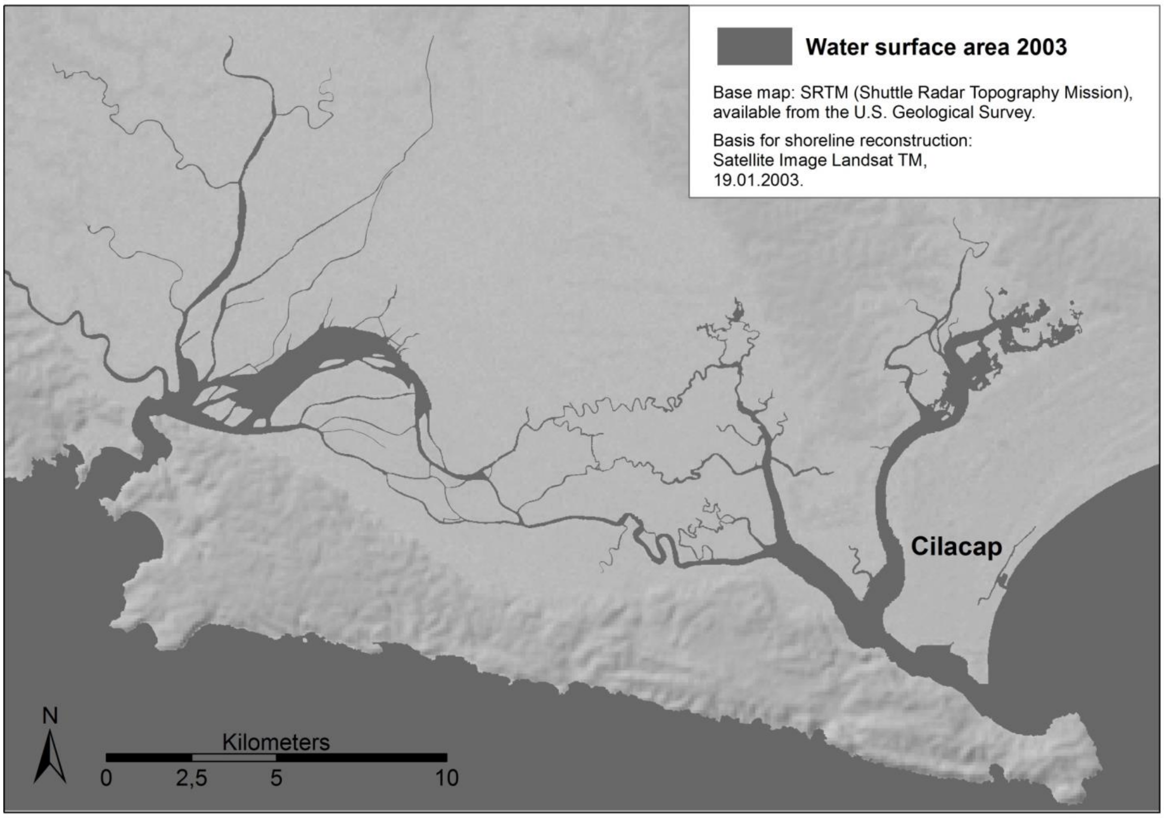
Kilometers
0 2,5 5 10


Water surface area 2003
Base map: SRTM (Shuttle Radar Topography Mission), available from the U.S. Geological Survey.
Basis for shoreline reconstruction:
Satellite Image Landsat TM,
19.01.2003.
Cilacap
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Kilometers
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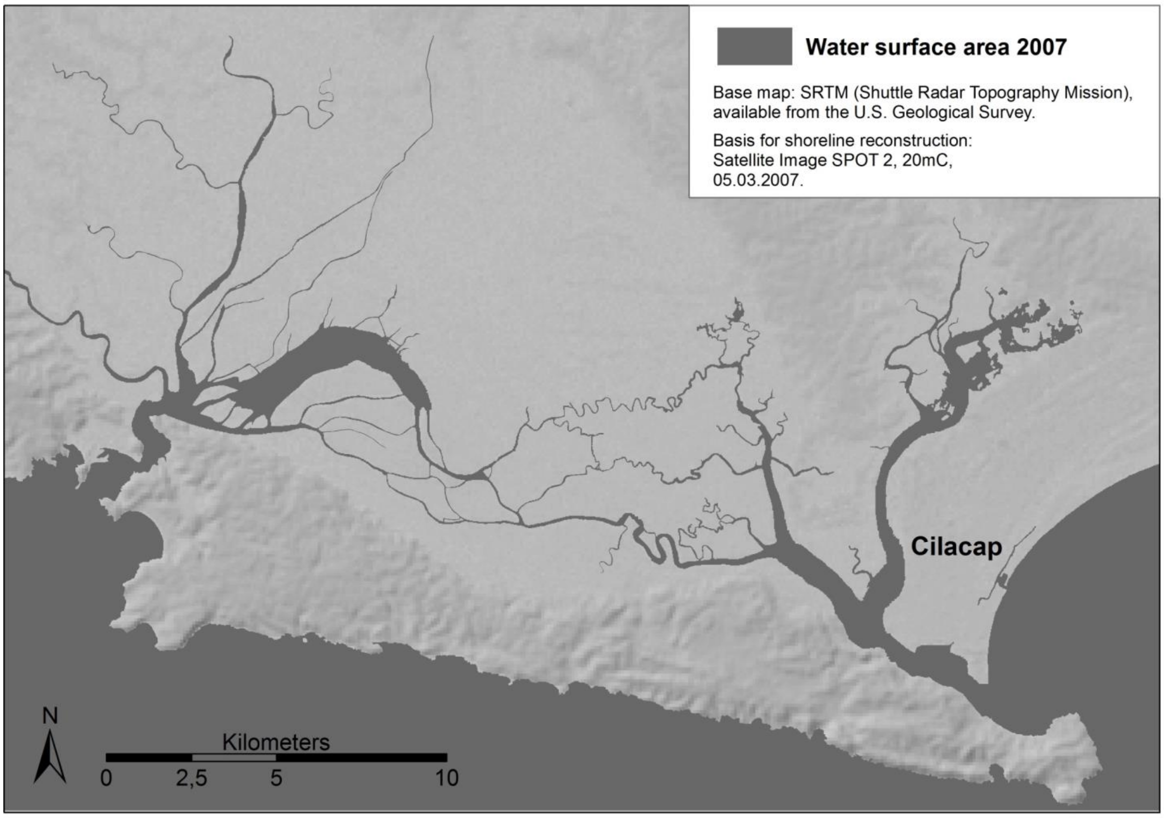
Water surface area 2007
Base map: SRTM (Shuttle Radar Topography Mission), available from the U.S. Geological Survey.
Basis for shoreline reconstruction:
Satellite Image SPOT 2, 20mC,
05.03.2007.
Cilacap
N
Kilometers
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2,5
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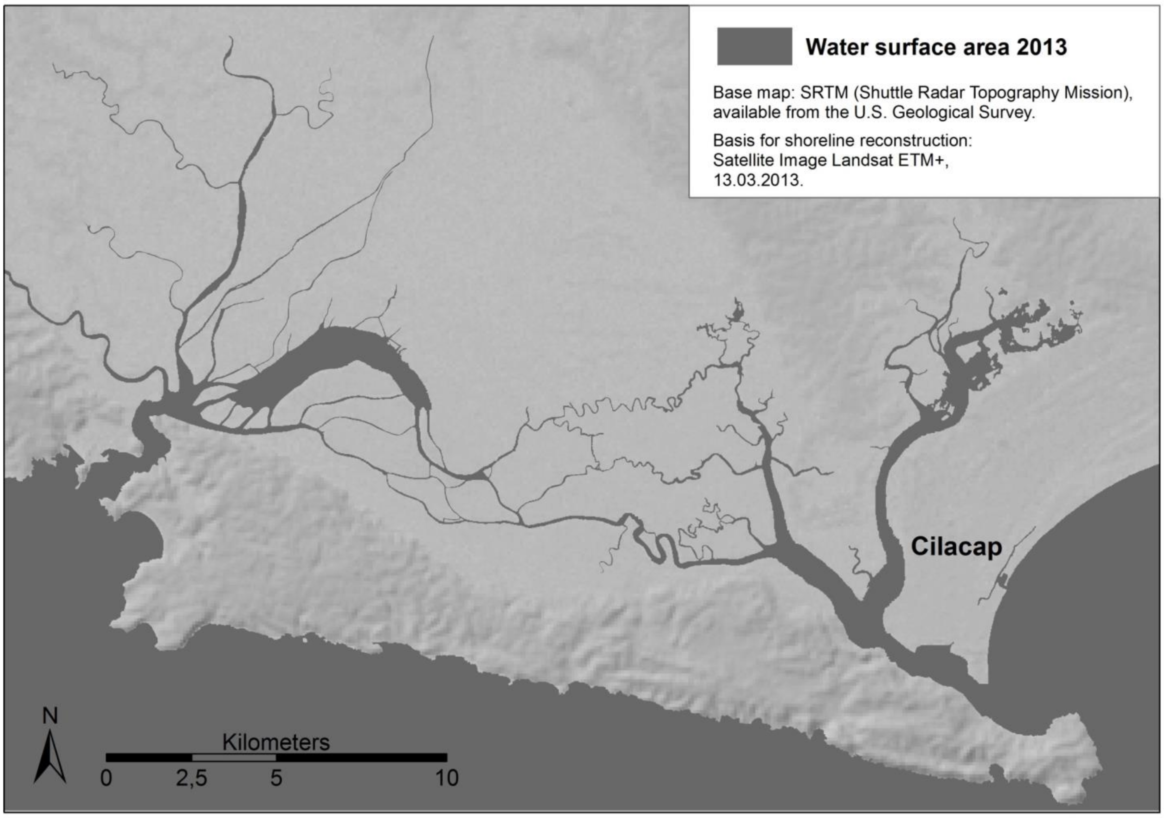
Water surface area 2013
Base map: SRTM (Shuttle Radar Topography Mission), available from the U.S. Geological Survey.
Basis for shoreline reconstruction: Satellite Image Landsat ETM+, 13.03.2013.
Cilacap
N
Kilometers
0
2,5
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Online Resource 2: Longer-term history of lagoon sedimentation

Figures 2 and 3 depict the dynamics of lagoon siltation since the mid-19th century, based on historical cartographic material and satellite images. An expanded analytical time scale of this analysis could provide additional insights with regard to the following questions: Does the nineteenth century really represent the end of a long period with low aggradation rates, or was it preceded by other periods with higher aggradation rates? What had been the maximum historical extent of the lagoon before it started to shrink?

The formation of the lagoon and its sedimentation had already been observed and attributed to various causes by a number of authors in the nineteenth and early twentieth century (see, for example, Junghuhn 1854, Cabaton 1911). More detailed hypotheses regarding the formation of the lagoon were later put forward by Schaafsma (1926), Pannekoek (1949), and Hadisumarno (1964), all of them describing the interaction of land subsidence, transgression and denudation processes in different ways. Hadisumarno (1964) illustrated the possible location of the former Citanduy estuary before 'regression' as being some 10-12km upstream from today's estuary by drawing a contour line at the current altitude of 8m above sea level. According to the most plausible hypothesis, the lagoon was mainly formed by post-glacial sea level rise (PRC-ECI 1987). It has been estimated that sea levels in Southeast Asia rose from 116m below present levels during the Pleistocene about 21,000 years ago to a maximum of 5m above present levels about 4,200 years ago (Sathiamurthy, and Voris 2006). During this mid-Holocene sea level maximum, the Segara Anakan lagoon must have reached its maximum extent. Due to falling sea levels thereafter and due to the effect of continuous sedimentation the lagoon must have shrunk since then – a process that is still going on.

The temporal dynamics of this process are largely unknown. Based on their analysis of a sediment core from the eastern part of the lagoon, Dewi, Mueller and Auliaherliaty (1979:7) concluded that "recent sedimentation is considerably higher than average sedimentation during the past 30,000 years." However, since the area where the sediment core was taken had possibly been disconnected from the Citanduy River until the end of the Pleistocene, i.e. before the lagoon was likely formed, these findings have to be regarded with caution.

Knowledge of the lagoon's maximum post-glacial extent could help us to view the sedimentation dynamics of the past 1.5 centuries in the context of longer-term developments. Based on remotely sensed elevation data[6] and neglecting the possibility of major vertical tectonic movements over the past 4,000 years and the terrain-raising effect of sediment accumulation, the figure below provides a basis for hypothetically visualising the lagoon's maximum post-glacial extent. The map depicts an area with present altitudes of up to 5m above sea level surrounding the current lagoon. To the northeast and to the southwest, this area is clearly demarcated by hilly terrain. To the northwest, the demarcation of a hypothetical former lagoon shoreline is rather difficult due to the lack of a clear terrain step and since the elevation data in this area is influenced by the linear patterns of areas with tree cover and buildings. Despite substantial uncertainty, it is not unrealistic to hypothesise on the basis of this data a water surface area about 4-5 times as big as that of 1857/60 as maximum post-glacial extent. An analysis of sediment cores from sites selected on the basis of the areas depicted in Figure 4 might provide related evidence.

[6] Special thanks to Michael Flitner

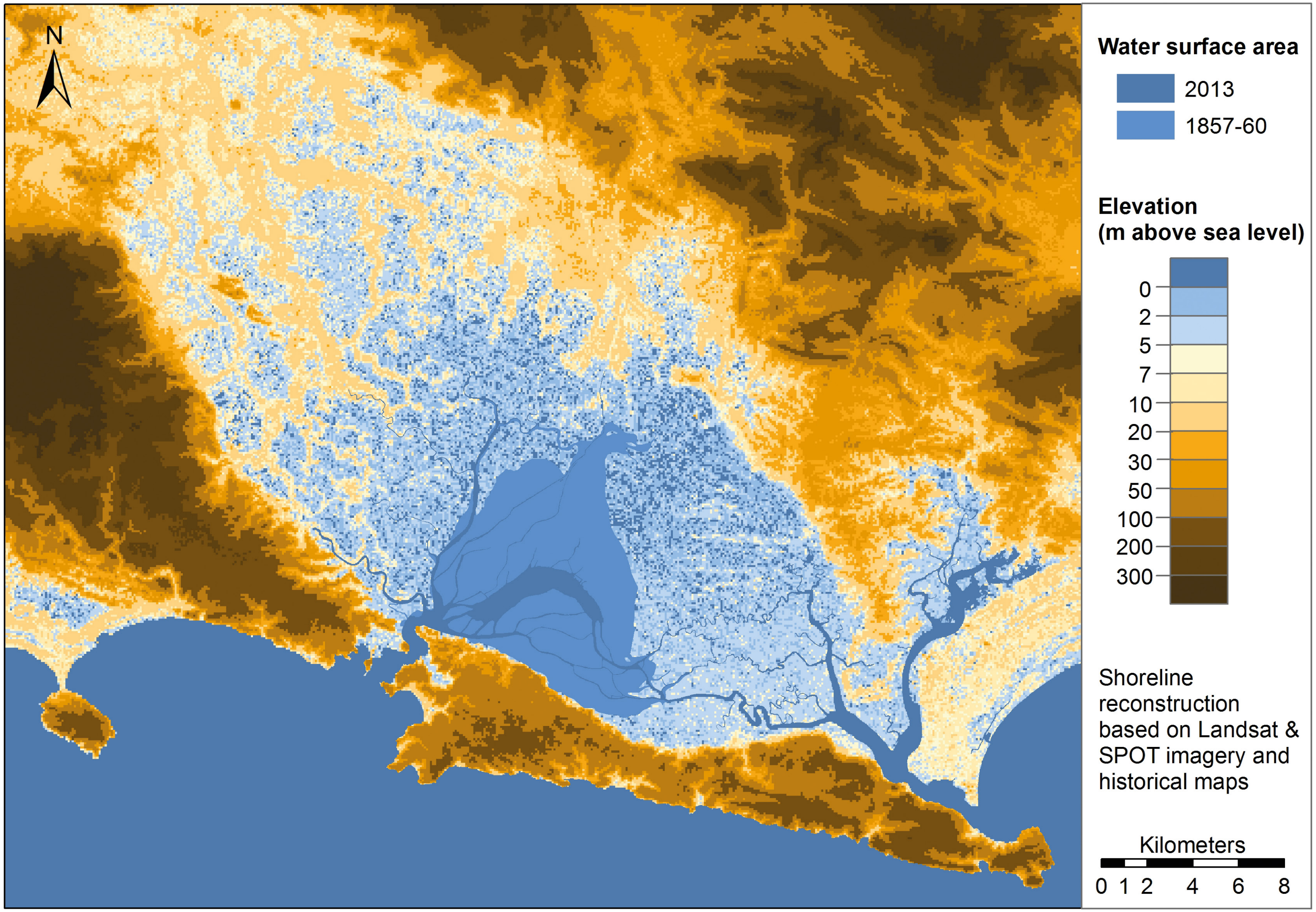

Figure: Hypothetical visualisation of the Segara Anakan lagoon’s maximum post-glacial extent based on remotely sensed elevation data (SRTM).

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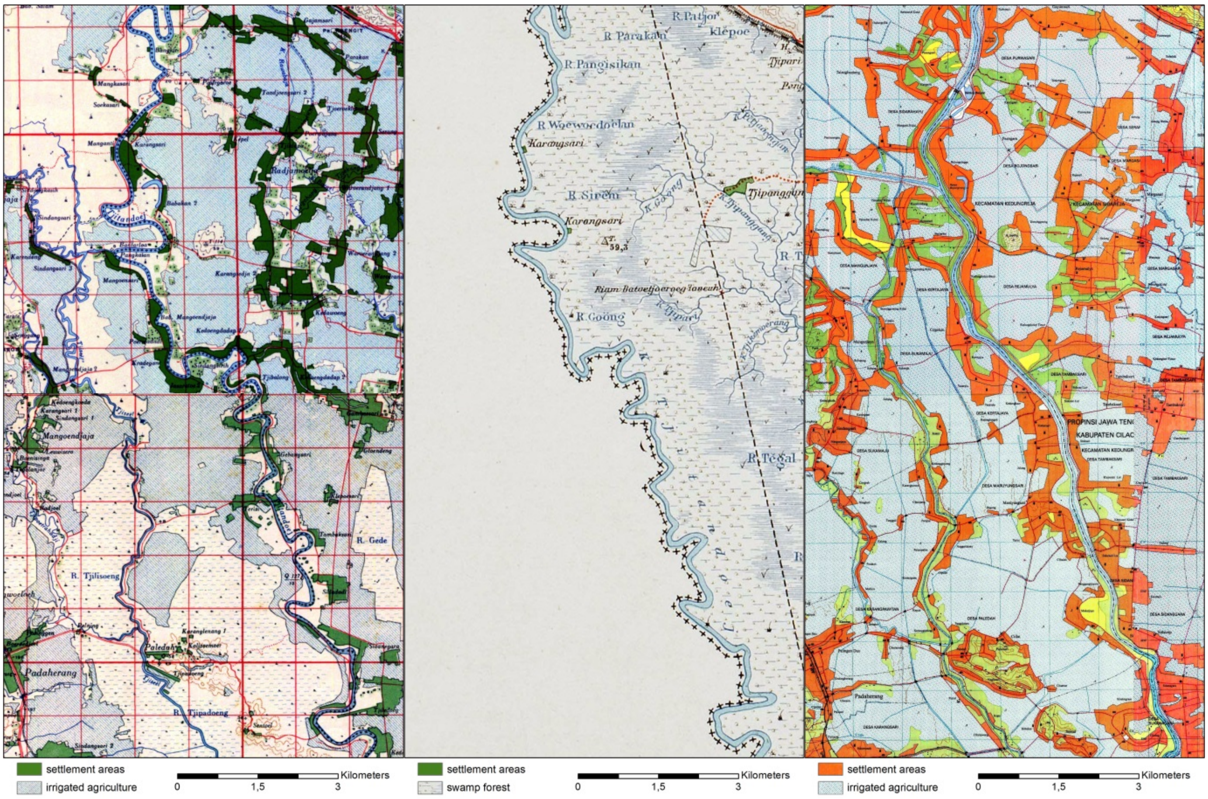
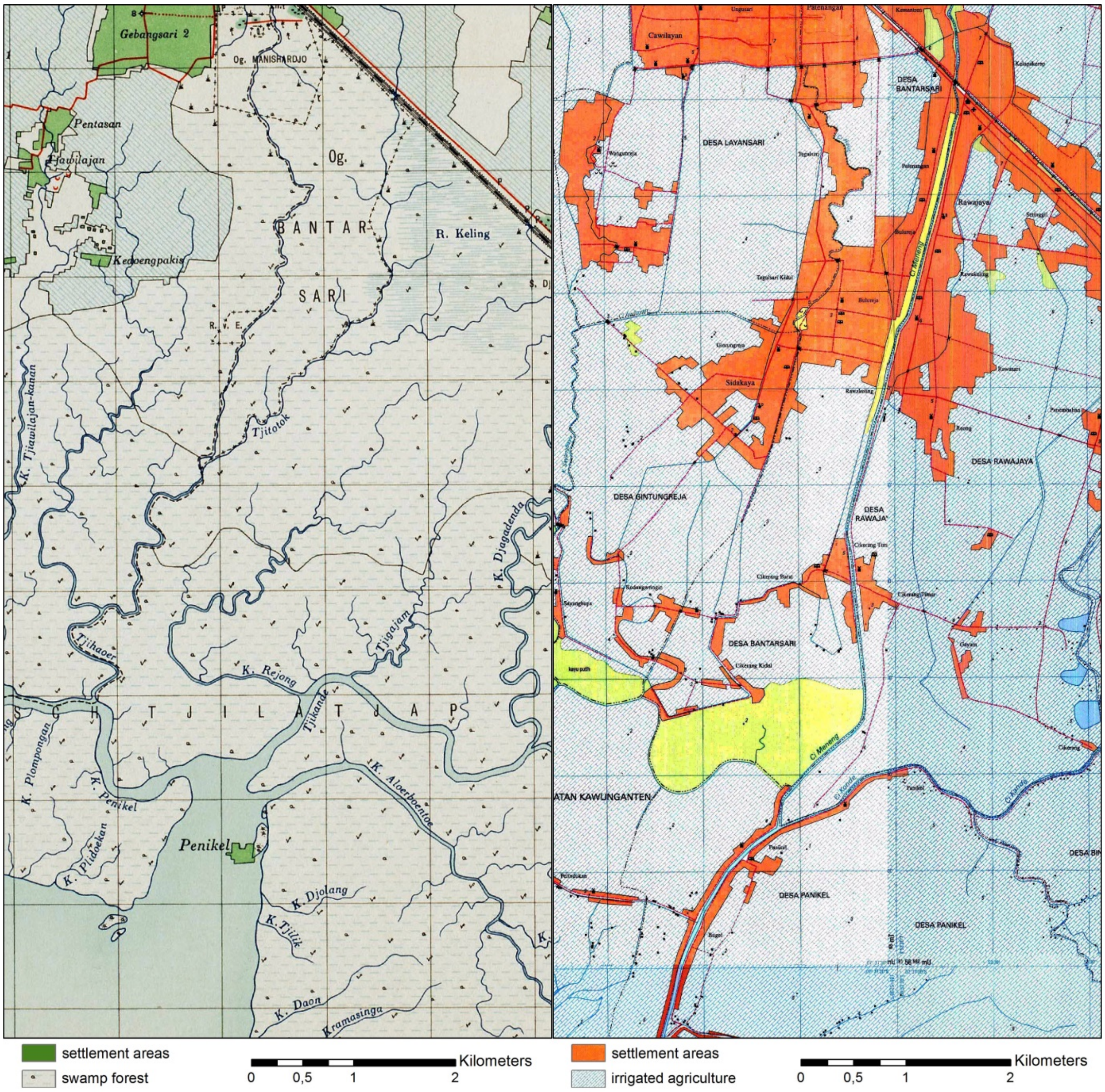
Online Resource 3 [see electronic file]

The series of topographic maps from 1900/1901, 1929 and 1998 depicts the transformation of the Citanduy from a river meandering through swamp forests to a straightened river lined with settlements and agricultural land along almost its entire length. Figure a: Topographic map of Java, Residency Banjoemas, Map Sheet III, TDNI, Land tax survey brigades; 1900/1901, 1:100,000, retrieved from Netherlands Royal Tropical Institute (KIT). Figure b: Topographic map of Java, Middle (and West) Java (Map sheet 42 / XLI D), TDNI, Land tax revision brigades, 1929, 1:50,000, retrieved from Netherlands Royal Tropical Institute (KIT). Figure c: Peta Rupabumi, produced by the Badan Koordinasi Survey dan Pemetaan Nasional (BAKOSURTANAL), 1999-2001, based on surveys carried out in 1998, Map sheets 1308-234, 1308-243, 1308-512, 1308-521, scale 1:25,000.



Online Resource 4 [see electronic file]

A comparison of a historical topographic map representing the situation in 1928 with a more recent topographic map illustrates the transformation of the Cikonde and Cimeneng from meandering rivers lined by swamp forests into straight, embanked channels lined by settlements and irrigated rice land. Figure a: Topographic map of "Midden-Java" (Map sheet 43 / XLI C, Kawoenganten), Topografische Dienst, Batavia 1928, printed 1939, 1:50,000, retrieved from Netherlands Royal Tropical Institute (KIT). Figure b: Peta Rupabumi, produced by the Badan Koordinasi Survey dan Pemetaan Nasional (BAKOSURTANAL), 2001, based on surveys carried out in 1998, Map sheet 1308-244, scale 1:25,000.



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Abstrak (Abstract, translated into Indonesian)

Degradasi lahan telah menjadi masalah politik utama di Pulau Jawa selama beberapa dekade. Secara umum, penyebabnya dibingkai oleh narasi yang berfokus pada praktik penanaman yang tidak bertahan lama yang dilakukan petani. Makalah ini menghubungkan degradasi lahan dengan perjuangan untuk menguasai sumber daya alam di Jawa Tengah. Makalah ini menyajikan studi kasus yang merupakan bagian dari proyek penelitian yang menggabungkan pengindraan jauh dan ekologi politik untuk mendalami perubahan pemanfaatan/tutupan lahan dan pemicunya di daerah tangkapan air Laguna Segara Anakan. Konflik lahan yang mengakar di masa lalu telah mengubah lahan menjadi medan tempur politis, dengan erosi tanah yang merupakan hasil langsung dari perjuangan politis. Dimulai dari analisis tentang perubahan lingkungan menggunakan gambar satelit dan peta historis, penelitian ini mendalami sejarah pemindahan paksa dalam kerangka serangkaian pemberontakan dan perlawanan politik balik yang brutal pada tahun 1950/1960an. Dalam perjuangan untuk meraih kekuasaan politik secara nasional ini, keseluruhan desa dimusnahkan, dan lahan petani diambil alih oleh negara. Sejarah politis ini 'terukir' dalam lanskap masa kini. Lahan yang dipersengketakan terdiri dari sejumlah lokasi yang paling rentan terhadap erosi di keseluruhan daerah tangkapan air laguna. Lanskap erosi tersebut adalah lanskap konflik dan merupakan simbol kekerasan dan ketidakadilan masa lampau. Sejalan dengan penelitian kami di bagian lain daerah tangkapan sungai, studi kasus yang disajikan di sini mempertanyakan wacana politik yang dominan tentang sifat degradasi dataran tinggi di Pulau Jawa. Penelitian ini memberikan wawasan tentang fragmen yang tidak terselesaikan dan kurang dieksplorasi dalam sejarah Indonesia dan mendesak adanya penggabungan ilmu perubahan pemanfaatan lahan dan ekologi politik (secara historis).

Kata Kunci

Ekologi politik secara historis, Pemanfaatan lahan dan perubahan tutupan lahan (Land use and land cover change/LUCC), Erosi tanah, Manajemen hutan dan daerah aliran sungai, Konflik lahan, Indonesia

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Eroding battlefields: Land degradation in Java reconsidered

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ABSTRACT

Land degradation has been a major political issue in Java for decades. Its causes have generally been framed by narratives focussing on farmers' unsustainable cultivation practices. This paper causally links land degradation with struggles over natural resources in Central Java. It presents a case study that was part of a research project combining remote sensing and political ecology to explore land use/cover change and its drivers in the catchment of the Segara Anakan lagoon. Historically rooted land conflicts have turned the land into a political battlefield, with soil erosion being the direct outcome of the political struggles. Starting from an analysis of environmental changes using satellite images and historical maps, the research explored a history of violent displacements in the frame of a series of brutal insurgencies and counterinsurgencies in the 1950/60s. In these struggles over national political power, entire villages were erased, and peasants' land was appropriated by the state. This political history is 'inscribed' in today's landscape. The contested land comprises some of the most erosion-prone sites in the entire catchment of the lagoon. The landscape of erosion is a landscape of conflict and a symbol of historical violence and injustice. In line with our research in other parts of the catchment, the case study presented here challenges dominant political discourses about the nature of upland degradation in Java. It provides insight into still unresolved and underexplored chapters of Indonesian history and presents a strong plea for combining land use change science and (historical) political ecology.
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Introduction

Since Blaikie and Brookfield's calls to explore the political-economic forces that shape resource use decisions and land use patterns (Blaikie, 1985; Blaikie and Brookfield, 1987), political ecologists have greatly contributed to a better understanding of the nature of land degradation. Linking environmental conditions and changes with political, social and economic structures, power relations, and patterns of resource access and control, they have questioned partly long-standing narratives about the causes of land and other kinds of environmental degradation (see, for example, Batterbury et al., 1997; Brookfield, 1999; Forsyth, 1996; Forsyth and Walker, 2008; Ives and Messerli, 1989; Klein, 2002; Leach and Mearns, 1994; Preston et al., 1997). In many cases, they have challenged neo-Malthusian explanations, focussing on population pressure, and the one-sided blaming of farmers' cultivation practices for environmental degradation as simplistic political narratives or 'environmental orthodoxies' (Forsyth, 2003, Leach and Mearns, 1994).

In Java, one of the global hotspots of erosion and sedimentation, simplistic narratives continue to dominate societal discourses about upland degradation, river water flows and coastal sedimentation. After decades of political interventions aimed at reducing soil erosion in the island's uplands, and more than a quarter century after Blaikie and Brookfield's (1987) 'Land Degradation and Society', population densities and upland farmers' allegedly unsustainable cultivation practices (cf. Sutadipradja and Hardjowitjitro, 1984) still dominate related discussions in state authorities and universities. These narratives are linked to neo-Malthusian environmental discourses and political interests. By distracting attention from exploring other causal factors of upland degradation and coastal sedimentation, i.e. by narrowing research agendas, these framings have been self-perpetuating. Also the lack of intersection between scientific communities, such as soil and land use change scientists and political ecologists, has contributed to the persistence of the misleading narratives.

In this context, research building on methods from different disciplines can be particularly fruitful. The case study presented here was part of a larger research endeavour that combined remote sensing, land use/cover mapping and historical cartography with social-scientific inquiry to explore land use and land cover changes (LUCC) and their drivers in the catchment area of the Segara Anakan lagoon, which is situated on Java's south coast. The case

[1] The article builds on research that the author carried out when he was affiliated with the Leibniz Center for Tropical Marine Ecology Bremen GmbH (ZMT), Fahrenheitstraße 6, 28359 Bremen, Germany.

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study establishes clear and direct causal links between struggles over natural resources and land degradation. It challenges established narratives about the drivers of upland degradation and makes a strong case for a historical political ecology (cf. Davis, 2009). Departing from an analysis of LUCC, the research unravelled historically rooted struggles over land that have literally turned it into a political battlefield, with soil erosion being the outcome of the political struggle. Bare, erosion prone slopes are the immediate result of ongoing struggles over land. Documenting the intricate historical roots of the land conflict, the research provides insight into local dynamics of the unresolved and little documented violent history of Indonesia in the 1950/60s. A series of insurgencies and counter-insurgencies related to the Dar'ul Islam rebellion and the anti-communist massacres during these two decades not only produced political forests cleared of people (cf. Peluso and Vandergeest, 2011, Vandergeest and Peluso, 2011), but in the long run created conflicts resulting in erosion-prone slopes cleared of trees. Following a brief review of related literature and an outline of the methodological approach used, the paper reveals the landscape of erosion as a landscape of conflict and a symbol of unresolved historical violence and injustice.

Soil erosion in Java's uplands: fragmented knowledge

Java, partly as a result of natural processes, exhibits some of the highest erosion and sediment yields worldwide (Walling and Webb, 1996) and has for decades been a hotspot of political interventions aimed at reducing soil erosion. The expansion of certain forms of agriculture has undoubtedly contributed to massively increased erosion rates in parts of the island (Dijk et al., 2004, Donner, 1987, Nibbering and Graaff, 1998, Palte, 1989, Purwanto, 1999). One of the most prominent examples is the highly profitable but ecologically destructive potato cultivation on the Dieng Plateau (cf. Lavigne and Gunnell, 2006, Rudiarto and Doppler, 2013). However, in other parts of Java, one-sided blaming of farmers' cultivation practices is not substantiated by empirical evidence. It has rather distracted attention from numerous other drivers of accelerated erosion and sedimentation (cf. Diemont et al., 1991, Schweithelm, 1989), and is partly a political strategy that has for many decades served as justification for the exclusive management of state forest territories by the state forest company and for keeping people out of these forests (cf. Galudra and Sirait, 2006, Lukas, 2013, Peluso, 1992).

The widespread neglect of contested state forest territories and of the roles of socio-political structures and processes, including questions of resource access and control, in soil and LUCC studies has contributed to the persistence of these narratives. In line with the framing of upland degradation as a result of population pressure and unsustainable farming practices, and partly embedded in related political interventions, most research on soil degradation and mitigation strategies in Java has focussed on farmers' agricultural plots (e.g. Dijk et al., 2004, Palte, 1989, Purwanto, 1999), while excluding disputed state forests from analysis (for an exception see Savitri, 2006); and LUCC studies may include demographic dynamics as explanatory variable but exclude land tenure (e.g. Verburg et al., 1999). Outstanding in terms of linking LUCC analysis and societal dynamics is the research conducted by Lavigne and Gunnell (2006), which focussed on Java's montane forests and volcanoes. But the scope of the few LUC(C)[2] analyses that have been conducted in the catchment area of the Segara Anakan lagoon (Astisiasari, 2008, Prasetyo, 2004), one of Java's hotspots of soil conservation efforts, was confined to remote sensing techniques without adequate ground truthing and did not include any empirical analysis of the causes of land use and land cover patterns and changes.

Struggles over resources 'inscribed' in physical landscapes – linking land use change science and political ecology

In addition to politically confined research foci, lack of intersection between scientific communities, such as soil and LUC(C) scientists and political ecologists, may contribute to the persistence of environmental narratives (cf. Turner, 2003). Though LUC(C) science and political ecology share much common ground (Turner and Robbins, 2008) and have been fruitfully combined in other parts of the world (e.g. Elliott and Campbell, 2002, McCusker and Ramudzuli, 2007), their problem framings and analytical approaches may differ considerably (Turner and Robbins, 2008). While LUC(C) and soil science may not (sufficiently) incorporate aspects like (historical) socio-political developments (McCusker and Ramudzuli, 2007) or questions of resource access and control, political ecology may sometimes not pay much attention to LUC(C) and other bio-physical environmental conditions and dynamics (Walker, 2005, Zimmerer and Bassett, 2003). Different from LUC(C) science, which usually aims at systematically assessing area-wide LUC(C) and their immediate and (mainly theory-based) distal causes, political ecologists typically select cases "as informed by theory that stresses the role of distal or exogenous processes that usually operate to disadvantage local land managers and are often captured in social conflict and land or resource degradation" (Turner and Robbins, 2008:303).

The effects of such processes, or more broadly of any societal structures and dynamics, on physical landscapes can be seen as 'inscriptions'. Shedding light on the effects of power relations on the environment, Bryant and Bailey (1997:43) noted that the shaping of natural resource uses by powerful actors is often visibly 'inscribed' in the environment, for example, in the form of plantations or dams, while the patterns of resistance of the less powerful "are often more difficult to discern". The forms of such resistance may include 'illegal' exploitation of resources (Bryant and Bailey, 1997), which has been a widespread phenomenon in Indonesia's state forests for decades (Nibbering, 1988, Peluso, 1992); uprooting of plantation trees (see Gerber, 2010); or forest clearance in national parks (Bryant and Bailey, 1997:43). Some of the forest fires in Madagascar resulting from poorer farmers burning out of frustration about richer farmers' tree plantings which establish legal claims over land (Kull, 2002, 2004) can be seen as 'inscriptions' of struggles over resources in the physical landscape. Examples of such 'inscriptions' of resistance are also found in Peluso's (1992) in-depth study of struggles over forest land and trees in Java from colonial times until the 1980s and in Bryant's (1997) political ecology of forestry in Burma. The 'inscriptions' of struggles over resources, or more broadly of societal structures and dynamics, in physical landscapes are forming the intersection of LUC(C) science and political ecology.

Choosing an analysis of LUC(C) as the starting point of the research and then exploring the drivers of the observed changes using political ecology informed social-scientific inquiry contributes to soil and LUC(C) science by providing knowledge on and directing attention to the (often neglected) roles of socio-political structures and processes. At the same time, it integrates bio-physical conditions and dynamics into political ecology. The often limited engagement of political ecology scholarship with actual environmental conditions and dynamics has been critically noted and discussed by a number of authors (Nygren and Rikoon, 2008, Vayda and Walters, 1999, Walker, 2005, Zimmerer and Bassett, 2003). If we see, with Paulson et al. (2004:17) "[p]olitical ecology's

[2] The abbreviation LUC(C) refers to both land use and land cover (LUC) and land use and land cover change (LUCC).

originality and ambition [to] arise from its efforts to link social and physical sciences to address environmental changes, conflicts, and problems", the (re-)integration of bio-physical conditions and changes into political ecological inquiry seems highly desirable. One effective approach to this end is to choose bio-physical conditions or changes as the starting point of inquiry and then construct "causal histories of interrelated social and biophysical events" without rigid a priori assumptions (Walters and Vayda, 2009:534, outlining the concept of 'event ecology'), though keeping in mind core political ecology questions, and applying them where relevant. The case study presented here was part of a research project that followed this approach, with an area-wide analysis of LUCC as the starting point of inquiry. In this way, physical environmental conditions and changes, i.e. LUCC and degradation, could directly be linked to struggles over the access to and control of land.

Research methods

The case study presented here was part of a larger research endeavour covering the entire catchment area of the Segara Anakan lagoon. This shallow coastal lagoon (see Fig. 1) has been heavily impacted by riverine sediment input (Lukas, Submitted for publication, White et al., 1989, Yuwono et al., 2007). Its catchment area has thus become a hotspot of political interventions aimed at tackling upland degradation, though with limited results. Against this backdrop, our research explored the dynamics and drivers of LUCC and land degradation throughout the catchment area. This research combined remote sensing, historical cartography and land use/cover mapping with social-scientific research methods.

In a first step, areas with LUCC were identified, based on visual interpretation of satellite images and the results of land use/cover mapping. For this purpose, a series of satellite images (Landsat MSS, TM, ETM and SPOT) taken between 1976/78 and 2007/2011 was acquired and georeferenced based on recent topographic maps. GPS-facilitated land use/cover mapping was carried out throughout the entire catchment area of the lagoon. False colour composites generated from the green, red and near infrared bands of the satellite images, the results of the land use/cover mapping (GPS tracks, photographs, and notes), and the topographic maps were overlayed, using ArcGIS. Flickering between images, differences particularly in tone, texture, patterns and shapes were identified and combined with the results of the land use/cover mapping and the intimate knowledge of the area (cf. Campbell and Wynne, 2011, Lillesand et al., 2008). In this way, a total of 297 LUCC areas were identified and delineated throughout the catchment area. These LUCC areas were overlayed onto topographic maps (scale 1:25,000), partitioned into map sheets and used in printed form during the social-scientific case studies conducted thereafter.

These case studies, which were mainly aimed at analysing the dynamics and drivers of LUCC, covered 60 of the 297 LUCC areas identified. In selecting case studies, the aim was to cover different parts of the catchment area, some of the hotspots of LUCC and erosion-prone land, and a wide variety of different cases. To further expand the temporal scale of analysis, historical topographic maps from the early 20th century were acquired for the case study areas, scanned, georeferenced and overlayed with the contemporary topographic maps and the satellite images. The case studies comprised transect walks and semi-structured interviews with representatives of district and sub-district governmental organisations, the state forest corporation, NGOs, and village administrations as well as with community groups, farmers, elderly people, and other village residents. An inductive approach was taken, with interviews mainly comprising broad, open-ended questions, especially during the first part. At the same time, the results of the satellite image processing (the LUCC maps) were, usually during the last part of the interviews, incorporated into the discussion. In this way, the combination of LUCC science and (historical) political ecology, or more broadly of remote sensing and social-scientific inquiry, provided scope not only for directly linking information about physical environmental changes and related social dynamics but also for constant cross-validation and cross-fertilisation. Many of the socio-political drivers and events would not have been uncovered without the area-wide analysis of LUCC, and vice versa, certain physical changes would perhaps not have been revealed

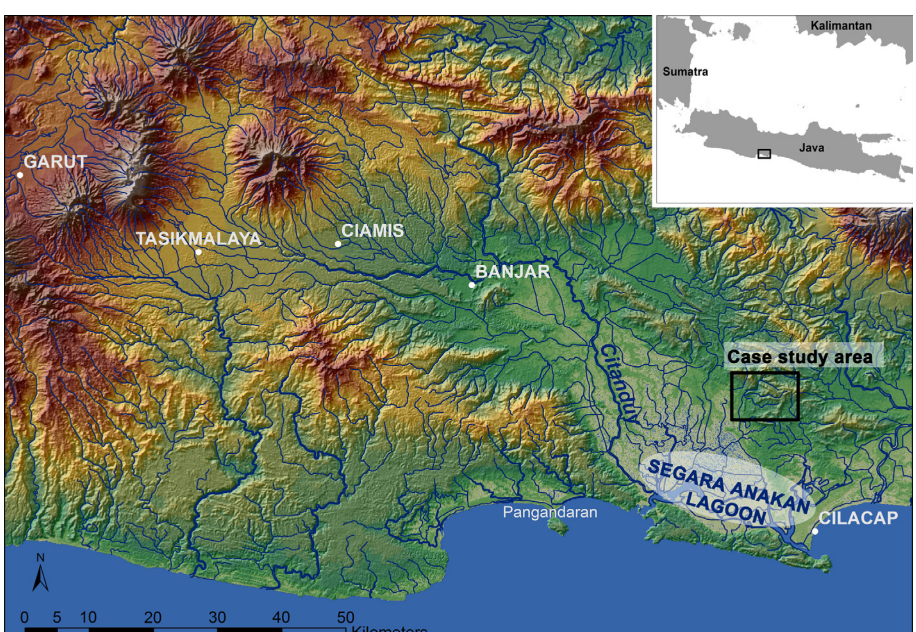

Fig. 1. Following an analysis of land use and land cover change (LUCC) in the entire catchment area of the Segara Anakan lagoon using satellite images, case studies focussing on the drivers of LUCC were carried out in various parts of the catchment area. The area of the case study presented in this paper is located north of the Segara Anakan lagoon.

without the social-scientific inquiry. Without the analysis of satellite images, most of the insightful cases of environmental degradation directly resulting from (historically rooted) struggles over resources would not have been uncovered. Taken together, many of these cases challenge common assumptions about upland degradation in Java.

The following is an in-depth account of one of the case studies with a particularly intricate history. Departing from the analysis of satellite images and land cover mapping, the research that comprised 20 interviews, a number of group discussions, and two extensive transect walks explored the causes of LUCC and degradation, which were of a socio-political nature. Step-by-step, this approach disclosed a history of violent displacements in the frame of a series of insurgencies and counterinsurgencies that were part of struggles over national political power and that have barely been documented to date.

A landscape of displacement, repression, rebellion, and erosion

Starting point of the research: LUCC and erosion

Based on the satellite images and land cover mapping, a hilly area north of the village of Binangun (see Fig. 2, LUCC area A), Sub-district Kawunganten, District Cilacap was identified as one of the most erosion-prone sites within the catchment of the Segara Anakan lagoon. This site is situated only 15 km north of the lagoon, within the catchment of the Cikonde River, a tributary of the Cimeneng River, which drains into the lagoon. The widely treeless, partly very steep slopes of this site were mainly cultivated with annual crops, like cassava and maize. Without much tree cover and without field terraces (Fig. 3), large parts of this hill area were heavily affected by soil erosion, which was clearly indicated by the exposed roots of annual crops and thick layers of recently deposited sediments in the adjacent streams. Deforestation in the hills surrounding Binangun was linked by a number of respondents to the increased frequency of flooding observed during recent years.

The indication of deforestation during the past decade detected in the satellite images, together with a short field visit indicating that villagers cultivated annual crops on steep slopes without any means of soil conservation, could have led to the misleading conclusion that it simply is, as suggested by established discourses, upland farmers' unsustainable farming practices that are the root cause of soil erosion. However, combining analysis of satellite images with inductive, open-ended social-scientific inquiry provided a contrasting, much more complex and more insightful counter-narrative.

Since it constituted some of the most-erosion prone land within a major regional hotspot of LUCC, I selected the site for a case study, which I conducted in 2011. Based on the case study results, the erosion-prone hill site is not simply to be seen as an example of upland farmers' unsustainable cultivation practices, but as a battlefield of historically rooted conflicts over land, with soil erosion being a result of these conflicts.

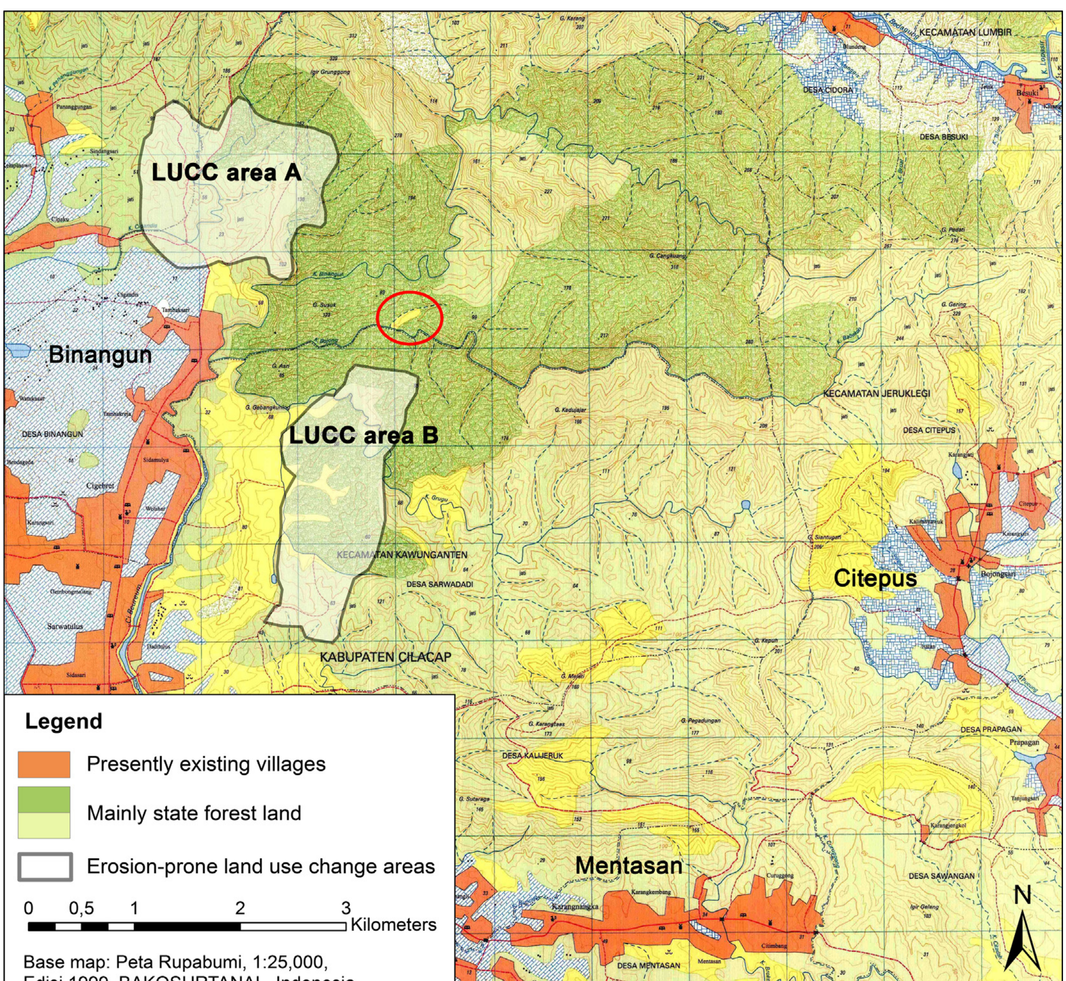

Fig. 2. Based on satellite image analysis and land cover mapping, a hilly area north of the village of Binangun was identified as one of the most erosion-prone sites within the catchment area of the Segara Anakan lagoon (LUCC area A). A second erosion prone land use change area east of Binangun (LUCC area B) shares a similar history.

Fig. 3. Cassava cultivation on partly very steep slopes without field terraces results in high levels of erosion. The photo was taken in LUCC area A. Though farmers have planted a few trees in some parts of the area, they hesitate to invest in additional soil conservation measures as long as the land remains disputed.

Departing from a brief retrospective glance at land use and village patterns around Binangun in late colonial times, the following sections shed light on partly violent displacements of people in the 1950/60s and related contemporary struggles over land, which are the immediate cause for soil erosion.

Looking back: disappeared villages and expanded state forest territories

Recounting memories from their childhood and narratives of their parents, elderly people of Binangun described the 1920s and 1930s as a time when the population was small and land abundant, with individual farmers owning between 2 and 20 ha of land. The valley floors were used for wet rice cultivation, and the hill slopes comprised coffee gardens and mixed forests with fruit and timber trees. In addition to the present village of Binangun, which is situated in a wide valley floor (see Fig. 2), there were numerous smaller villages within the hill land east and northeast of Binangun. Contemporary topographical maps depict this entire area as state forest land without any sign of presently or formerly existing villages (see Fig. 2). Prompted by my respondents' accounts, I found precise evidence of the formerly existing villages in a historical map, representing the situation around 1925/26 (see Fig. 4). These villages have since disappeared, and the entire area has become state forest territory (see Fig. 2).

A first piece of village land became state forest as early as 1924, when the Dutch administration purchased an area of comprising the upper reaches of the mountains east of Groenggang, a sub-village of Bringkeng, for conservation purposes. This purchase was part of broader forest conservation efforts in Java (see Galudra and Sirait, 2006, Kerbert, 1916, Zwart, 1928). Legal evidence of this purchase, which did not affect residential areas, exists, and the tenure status of the purchased land is not disputed today. This area is located northeast of the erosion-prone hill site. It is presently partly planted with teak.

Brutal times and first violent displacement

Present conflicts and soil erosion are rooted in the political dynamics of the 1950s and 1960s. In the early 1950s, the mountainous areas east of Binangun became a base of the Dar'ul Islam, an Islamist movement aiming at the new independent Republic of Indonesia becoming an Islamic rather than a secular state. The formation, ideology, strategies and organisational dynamics of the Dar'ul Islam have been explored in-depth by Horikoshi (1975), Jackson (1980), van Dijk (1981), and Dengel (1986). However, none of their maps and lists of locations include the region of the sub-districts Kawunganten and Jeruklegi that my case study shows to be another former base of Dar'ul Islam rebels. Also comparatively little knowledge exists about the local violent dynamics in rural and particularly forest areas that Dar'ul Islam rebels used as hideouts and about the resulting spatial patterns of migrations of rural populations. Peluso (1992) provided some insight into the relations between villagers, Dar'ul Islam rebels and the Indonesian National Army (TNI), with the former being caught in the violent encounters between the latter two. She also shed light on forest destructions by TNI forces aimed at destroying the rebels' hideouts.

Elder residents whom I interviewed in Binangun and other villages nearby described the Dar'ul Islam encounter in their area as a traumatic period. The rebels were based in the forest areas between Binangun, Mentasan and Citepus (see Fig. 2). They asked villagers for food and tried to recruit them. Those who refused were shot. My respondents described in detail how the rebels plundered and burnt houses, 'slaughtered' people and cut their bodies into pieces. Also some of the village board members of Bringkeng were killed. The first residents, feeling highly insecure, started leaving the area as early as 1951, secretly at night leaving behind all their belongings and cattle. Their dwellings provided additional bases for the Dar'ul Islam rebels. Later, refugee camps were set up in Sarwadadi, Cilacap and other places, and villagers were, partly by force, evacuated by state authorities and the TNI. The TNI fought against the Dar'ul Islam rebels. Since the rebels had recruited villagers and partly lived side by side with them, it was difficult for TNI forces to distinguish between rebels and ordinary people. Therefore villagers were consequently evacuated. By the mid-1950s, all residents who had not been killed or recruited by the rebels had left the area.

People sent into the swamp forest

The TNI, together with state authorities, including the district administration and village heads, decided then to move the displaced residents permanently to a safe place. They designed a land swap. Accordingly, parts of the village of Binangun as well as the entire villages of Grugu, Bringkeng and Babakan (see Fig. 4) were to be moved into an area just north of the Segara Anakan lagoon. This area had been state forest territory before. It was to be given to the people in exchange for their previous village land, which was beleaguered by Dar'ul Islam rebels and which was to become part of the state forest territory.

What at first glance appears as a humanitarian act, turned out to be a bad deal for the residents of the evacuated villages. The new land they were to receive was supposed to be the same size as their former village land. However, the quality of the land and its suitability for agriculture was very different. A number of respondents described the land provided as unfertile swamp land with high levels of salinity. Parts of the land were still covered with swamp forest. This land was difficult to reclaim and was flooded waist-deep for several months every year. The peasants did not receive any support in reclaiming the land, but, as one respondent noted, "[...] were just sent to this swamp area."

The displaced had no choice but to accept what was offered. Some of them reportedly did not even know about the agreement. Others were made to sign agreements. Since the swamp land was very difficult to reclaim and to cultivate, and given that the displaced people were in a desperate situation, forced to live from hand to mouth after having lost everything, many of them had no choice but to sell the piece of swamp land received in return for minimal payments or even only for some food. Out of hundreds

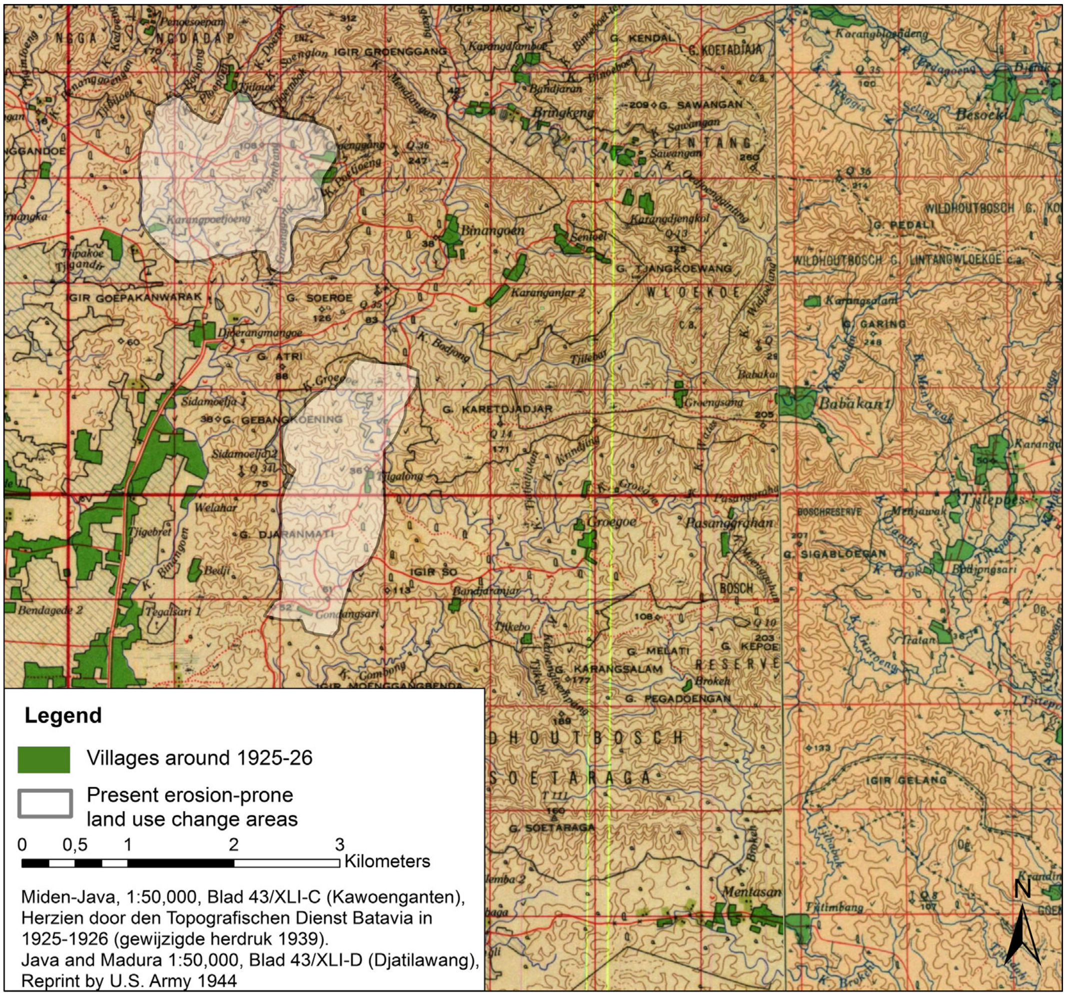

Fig. 4. Until the 1950s, numerous smaller villages and sub-villages were located in the hill land east and northeast of Binangun, as evidenced by historical maps produced in the 1920s.

of residents of the former village of Bringkeng, only the village head, the village secretary, two traditional healers, and an additional ten residents actually moved to what was to be set up as the new village 'Bringkeng Baru' ('New Bringkeng') in the swamp land. The large majority of the displaced, however, either had no other option than to cheaply sell off their part of the swamp land immediately or did not even receive any land. The latter was due to the fact that (1) some of the land reportedly had already been cultivated by other farmers since the Japanese occupation 1942–45, and (2) the total area provided in the swamp land was, contrary to the initial agreement, smaller than the previous village land. Some of the displaced people were told by their village head that they could not get any land, since the area was too small.

First return of the displaced

Consequently, those who ended empty-handed moved back home as soon as the security situation allowed. In 1961, just before the national leader of the Dar'ul Islam, Kartosuwirjo, was captured, the Dar'ul Islam rebels between Binangun, Mentasan and Citepus were brought under control. The last 15 rebels surrendered, and a military and police base remained at the former villages of Grugu and Bringkeng only until 1962. Many of the displaced villagers, including the village secretary of Bringkeng, moved back home, started rebuilding their houses, which had all been destroyed, and cultivated their former land.

However, legally they were not allowed to return, since according to the land swap agreement their land had become state forest territory. In other words, peasants were faced with the choice of either being landless or illegally returning back home. These circumstances made some of them become politically engaged and join the Barisan Tani Indonesia (BTI), the Peasants Front of Indonesia, which was associated with the Communist Party of Indonesia (PKI), and which called for land reform (cf. Peluso et al., 2008). Reflecting on the initiation and consequences of the land swap agreement, a village representative of Bringkeng Baru noted: "Some people didn't get any new land. They thus retuned to Old Bringkeng, and the land swap issue turned from a security problem [referring to the Dar'ul Islam] into a political problem [referring to the status of illegality and the PKI]."

Second violent displacement: "Your land or your life"

The profound change in the political landscape of Indonesia in 1965 brought about a second violent displacement of those who had returned to their former villages. The killing of six army generals in Jakarta on 30th September 1965, which military heads claimed to be an attempted coup by the PKI against the state, served as a starting point and justification for the formation of an authoritarian, militarised state and an anti-communist purge, which became one of the largest massacres of the 20th century, with an estimated half a million killings (Cribb, 1990, 2001).

All those who had returned to their former villages were labelled PKI members in 1965. They were forced to leave, and their houses were burnt down. People were faced with the choice of losing "their land or their lives", as one village representative succinctly stated. Many people were killed or put into prison and tortured.

One respondent, a father of six young children, was imprisoned on nearby Nusa Kambangan Island for ten years, where he "had to study suffering". Together with tens of thousands of other prisoners, he was forced to work. Apart from being forced to clear entire slopes of extremely deep-rooted, sharp alang-alang grass (*Imperata cylindrica*) by hand and from working in quarries, his labour contributed to the building of the roads between Jeruklegi, Wangon and Lumbir, of a tennis court for the staff of a military camp, and of a military chief's private house. He was also engaged as a household servant for another military chief. His wife had no choice but to get divorced and re-married to a military officer. After ten years he was released from prison. In his release report it reads that he could not be convicted with certainty of having been a PKI member. He still had to report to police and military offices regularly for two years, and his registration card contains an entry labelling him as political opponent, denied of many rights and freedoms. He lives in poverty today and depends on food and money from his neighbours and children. This is only one of many tragic life histories that shall illustrate the repression and violence and the deeply engrained historical injustices that must be considered in trying to understand contemporary land conflicts and resulting soil erosion.

Village land transformed into state forest land, an era of repression

The displacements of 1965 were consistent and permanent. The villages between Binangun, Mentasan and Citepus vanished from the face of the earth (Fig. 5). Almost the entire area immediately started to be managed by P.N. Perhutani, the state forest corporation. The area was delineated, partitioned into forest divisions and incorporated into the forest administrative system of Perhutani. It was immediately planted with teak.

Only one small piece of land in the midst of the new state forest territory remained in the hands of its former owner. I had identified it in the satellite images, since its land cover differed, and even topographical maps correctly delineate it as private land (see Fig. 2, red circle). This land belonged to a forest guard in the 1950s and 1960s, who, due to his personal connections, was free to choose not to give up his land.

The other peasants had to give way to the expansion of the state forest territory. During the New Order regime that General Suharto started to establish in 1965 and that remained in power until 1998, the displaced had no chance to claim the land they lost, no chance to secure justice. Relations between the villagers and the state and its forest corporation were marked by repression, anxiety and hatred, as the following statements made during a discussion with peasants and a village representative aptly summarise:

> "During the entire New Order regime the people were afraid to take any trees from Perhutani land not to mention to claim any land ownership."

> "During the New Order Regime you should be in line with the state bureaucracy, and if you were not, there were three choices: You were declared an obstacle to development, a member of the Dar'ul Islam, or a PKI member. The last option was the most common one."

> "I was afraid to complain. They would have labelled me as communist and killed me."

> "Perhutani is like a child of the government. Whenever there were problems between Perhutani and the people, the government intervened. People just had to develop hatred against Perhutani over time."

Peasants' access to the long-standing as well as the new state forest territories was strictly limited. As common all over Java, they were allowed to cultivate annual crops between newly planted trees for the first few years after planting (a system known as tumpangsari, see Peluso, 1992), but for the related permits peasants of Binangun had to make informal payment into the private pockets of the forest guards and forest labour foremen (mantri and mandor). Despite the state forest corporation's policing efforts, villagers continued to exploit resources from state forests, and in line with the tenure status of the land, they did so carelessly, which resulted in forest degradation in many parts of Java (Nibbering, 1988, Peluso, 1992).

Summing up: Insurgencies and counterinsurgencies and the territorialisation of productive forest resources by the state

The case presented here provides a concrete and particularly insightful piece of empirical evidence of the links that Vandergeest and Peluso sketched between political insurgencies, counterinsurgencies and the consolidation of postcolonial states and political forests in Southeast Asia (Peluso and Vandergeest, 2011, Vandergeest and Peluso, 2011). In this case, as described above and further discussed below, a series of partly brutal insurgencies and counterinsurgencies provided an opportunity for, served to justify or was part of the expansion of state forest territory at the expense of village land.

The first displacements were, in the beginning, related to the Dar'ul Islam insurgency. People, who feared for their lives, fled on their own initiative. Later, these displacements culminated in state-led evacuations as part of and to support an effective counterinsurgency of the TNI against the Dar'ul Islam rebels.

These first displacements in the 1950s would have been only temporary had state authorities not designed a land swap. The Dar'ul Islam insurgency and the need for an effective counterinsurgency required, or perhaps rather provided a good opportunity for, the land swap. Clearly disentangling the different motivations that led to the initiation of the land swap during this chaotic time is rather challenging in retrospect. However, based on a number of considerations and statements from my respondents, it appears that the land swap might not have been primarily driven by humanitarian concerns, but to a substantial extent by the interest of the state and its forest administration to depopulate a politically fragile area, to territorialise economically productive forest land in the hills and to provide in exchange a piece of what must have been regarded as economically unproductive swamp (forest) land. These considerations and statements shall briefly be summarised in the following.

Asked about the government's main motivation for the land swap, a village representative explained that "the area had become a base of the Dar'ul Islam. They plundered and burnt houses and slaughtered people, who were afraid and fled. The government and Perhutani used the situation to resettle people. The government wanted the area to become Perhutani land." Asked why the then-village head of Bringkeng had signed a land swap agreement which was obviously disadvantageous for the villagers, a current village representative explained that "all state authorities, including the district and sub-district heads, formed a strong alliance that was hated by the people. And the village head was pressured under the condition of not having any village land in the 1950s. New land, wherever, was urgently needed. So he might not have had any other choice." Since the land provided in the swamp area was

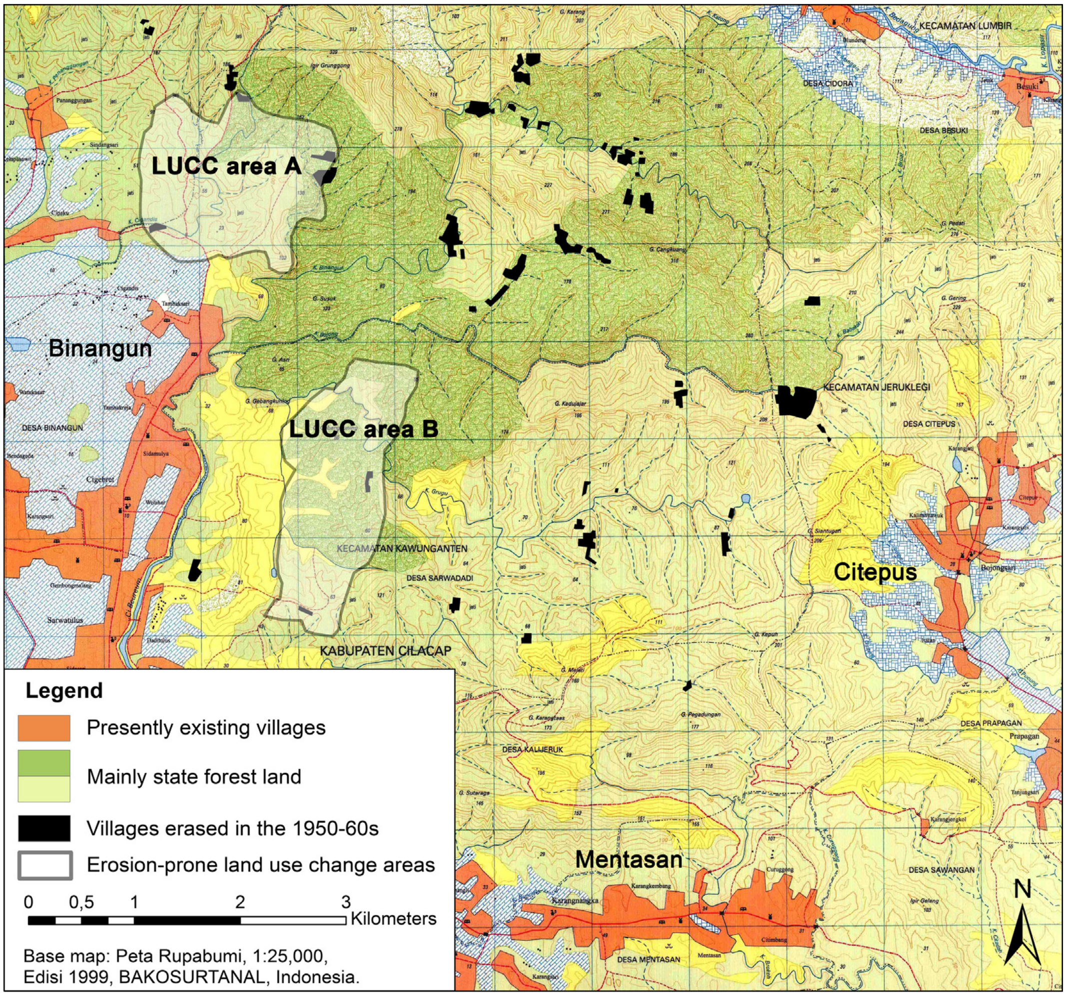

Fig. 5. The villages located in the hill land east and northeast of Binangun vanished from the face of the earth in the 1950–1960s, and the land became part of the state forest territory. This map of the disappeared villages is based on an overlay of a contemporary topographical map (Fig. 2) with a historical map representing the situation in the 1920s (Fig. 4).

smaller than the original village land, in 1963 the village head asked for additional land to fulfil the agreement. However, as the same respondent explained: "There was no chance for that. Government structures were extremely hierarchical, and the Bupati [head of the district] was still part of the royal family at that time. It was a feudalistic society. He was far above the people. His face was not allowed to be seen by the people and the village heads. It was completely covered with cloth." Given the different land sizes and land qualities and the way of implementation, the land swap was obviously not fair on paper and even more unfair in practice, but was pushed by repressive state authorities.

Those who returned home to their land in the early 1960s were considered illegal. This status triggered political resistance and made some of the allegedly illegal peasants to link with networks associated with the PKI. This insurgency of peasants against the territorialisation of their land by the state and its forest administration was brutally struck down in the frame of the anti-communist military-led counterinsurgency of 1965/66. The portrayal of the killing of six army generals in Jakarta as a violent act of the PKI against the state and the labelling and criminalisation of all those who had returned to their land as PKI members served as justification for a counterinsurgency, for the violent displacement of the returnees, hence clearing the way for territorialising their land.

This territorialisation (cf. Peluso and Vandergeest, 2001, Vandergeest and Peluso, 1995), which was inextricably linked with a series of two insurgencies and counterinsurgencies, involved violent displacements; the delineation of former village land and its partition into forest divisions, rendering village borders irrelevant; the incorporation of the land into the administrative system of the state forest corporation; and restriction of peoples' access to the land and its resources, which was enforced by armed forest police. The immediate planting of teak in the new state forest territory underlines the state's interest in the area's productive resources. Teak was (and still is) economically the far most important species for the state forest corporation. The Department of Forestry aimed at doubling teak exports, which had already increased 2.5-fold between 1965 and 1968 (Direktorat Djenderal Kehutanan, 1969), "for the development of [the] national economy and [the] prosperity of the people" (Department of Forestry, 1966). The swamp forest, given to the villagers in exchange, was not suitable for growing teak.

Also ideas and aims within the forest administration about watershed conservation supported the land swap. One respondent, who had been working for the state forest administration in the 1950s, explained that the new land provided to the peasants was well suitable for farming, whereas their former hill land was most suitable for forest. He subsequently highlighted the hydrological functions of forest cover on the hill land.

To sum up, the land between Binangun, Mentasan and Citepus had in the 1950s and 1960s become a battlefield of violent struggles over political power. All three of the major political forces that fought for national political power within the newly independent Republic of Indonesia, namely the Dar'ul Islam, communist groups (PKI) and the Military (TNI), and the violent confrontations between these forces, profoundly reshaped the landscape in this region, disrupted social life, brutally erased entire villages and many people, and provided scope for and was inextricably linked with the territorialisation of village land as state forest. The previous land use mosaic of scattered villages, agricultural land and mixed forests was transformed into production forests, comprising one-age-cohort teak and pine plantations, managed by the state forest corporation. These forest plantations and occasional clear cuts dominated the scene until the mid-1990s, as can be seen from the satellite images analysed. While the hill land was transformed into a state forest plantation, the 'relocation' of the villages initiated the gradual transformation of substantial mangrove and swamp forest areas in the northern part of the Segara Anakan lagoon region into rice fields and settlements (Fig. 6-1 and 6-2).

Political forests turned into erosion-prone battlefields

While the villages in the hill land vanished from the face of the earth, they continued to exist on historical maps and in the memories of the displaced and their descendants. The fall of the Suharto regime in 1997/98 provided the historical chance for the displaced as well as for large parts of the entire population to (re-)gain access to the state forests, or the 'political forests' which Peluso and Vandergeest (2001:762) defined as "lands states declare as forests". About half of the state forests in the area around Binangun were cut down within a few years. Almost every family from the villages surrounding the state forest, as well as outsiders from the nearby regions and towns participated and benefited. Illegal logging became a big business, involving loggers, porters, truck businesses and traders. The forests around Binangun had been ready for harvest, and Perhutani had already built roads and bridges within the forests to prepare the harvest and transport of timber. This provided perfect conditions for the illegal loggers. About ten trucks loaded with timber passed through Binangun every day. Even truckloads of security personal that arrived in the beginning were not able to, were afraid to or got paid to not interfere. The house of a Perhutani officer who aimed at enforcing state forest law and order was attacked. 'Illegal' logging went on until most trees were cut down. Around the mid-2000s, some areas were reforested by Perhutani, while other areas remained occupied by peasants, who not only harvested trees, but claimed land ownership for historical reasons.

Second return of the displaced

The hill area north of the village of Binangun that I had identified in the satellite images and based on land cover mapping as a major erosion prone site (see Fig. 2, LUCC area A), is one of the state forest areas claimed by peasants. The same applies to a larger area east of Binangun (see Fig. 2, LUCC area B). Until the early 1950s, the hill site north of Binangun (LUCC area A) had been part of the former village of Bringkeng. The hill site east of Binangun (LUCC area B) had been part of the former village of Grugu. Those who were displaced from Bringkeng and Grugu in the 1950/60s or their descendants and other villagers claim ownership over this land. Their claims are based on the fact that (1) the swamp land received in the 1950/60s was smaller than their original village land, and (2) most residents of the former villages did not sign and even did not get to know about the land swap agreement. In the case of Bringkeng, the villagers were to receive only 434.8 ha of swamp land in exchange for their 614.8 ha of fertile hill land. Therefore the peasants claim ownership over an area of 180 ha. In the case of Grugu, the peasants claim an area of about 200 ha.

The land areas claimed almost perfectly match spatially with the areas that I had identified as erosion-prone land based on the satellite images and land cover mapping. The conflict between peasants and the state forest corporation has literally turned this land into an erosion-prone battlefield. The land was cleared of its forest and has been cultivated by hundreds of peasants since then. In line with the disputed land ownership status, limiting the peasants' planning horizon, they have mainly grown annual crops. Growing these crops on steep slopes without field terraces and tree cover has resulted in high levels of erosion. This landscape of erosion is an 'inscription' of the ongoing, historically rooted struggle over land.

A group of farmers took the lead in fighting for land rights. They set up a first dwelling at the foot of the hill, which serves as a temporary residence and base camp of a farmers' committee, which they established as representation of the peasants cultivating and claiming land.

"It's like war with Perhutani"

At the time of field research in 2011, the conflict between the peasants and the state forest corporation over the land had been ongoing for a decade. This conflict has involved various formal and informal processes, and modes of indirect and direct confrontation. Reflecting on the course of the conflict and the current situation, one respondent noted: "It's like war with Perhutani."

Perhutani, with support from the police, tried to move the peasants off the land, "but hundreds of people were brave enough to stay" (a village representative). The peasants approached the head of Perhutani's forest district office. Since their hand-drawn maps were not accepted as evidence, they managed to organise a precise cadastral map of the former villages of Bringkeng and Grugu dated 1937 from the Military Topographic Service. The claimed land as depicted in this cadastral map almost perfectly overlays with the state forest land currently cultivated by peasants as depicted in the satellite image.

Perhutani reportedly regards the land swap of the 1950s as accurate, referring to a second purchase of 170 ha of village land by the Dutch administration in 1934. However, evidence of this alleged second purchase does obviously not exist. On the contrary, the cadastral map of 1937 depicts the corresponding area as village land, and according to elderly people, maps and border markers of Bringkeng did not change between 1925 and the 1950s. The villagers engaged two lawyers and staged two demonstrations in the district town of Cilacap.

In the early 2000s, Perhutani and representatives from the subdistrict administration offered an agreement, allowing peasants to cultivate the disputed land for 25 years, followed by a re-evaluation. At the same time, the agreement declared the disputed land as state forest land, hence reinforcing the ownership status quo. Many peasants were not aware of the latter and assumed they were granted ownership rights. The agreement also laid the foundation for the establishment of community forestry (PHBM: Pengelolaan Hutan Bersama Masyarakat). In the frame of PHPM schemes, which have been initiated throughout Java since the early 2000s, Perhutani continues to control the selection, planting and management of trees, while local residents have temporarily limited cultivation rights (tumpangsari), are responsible for safeguarding the trees and receive a share of the revenue. PHBM, as Singer (2009:133) aptly summarised, "can either be viewed as a break with the past as local populations can benefit directly from the income from the forest, or perceived as yet another way of buying local people out of their legitimate rights to the forest." Based on the latter viewpoint, Maryudi (2012) explored PHBM as a strategy of the state to regain control over the forests.

In the case of the land dispute investigated here, tricking peasants into a PHBM scheme, hence granting them limited access and

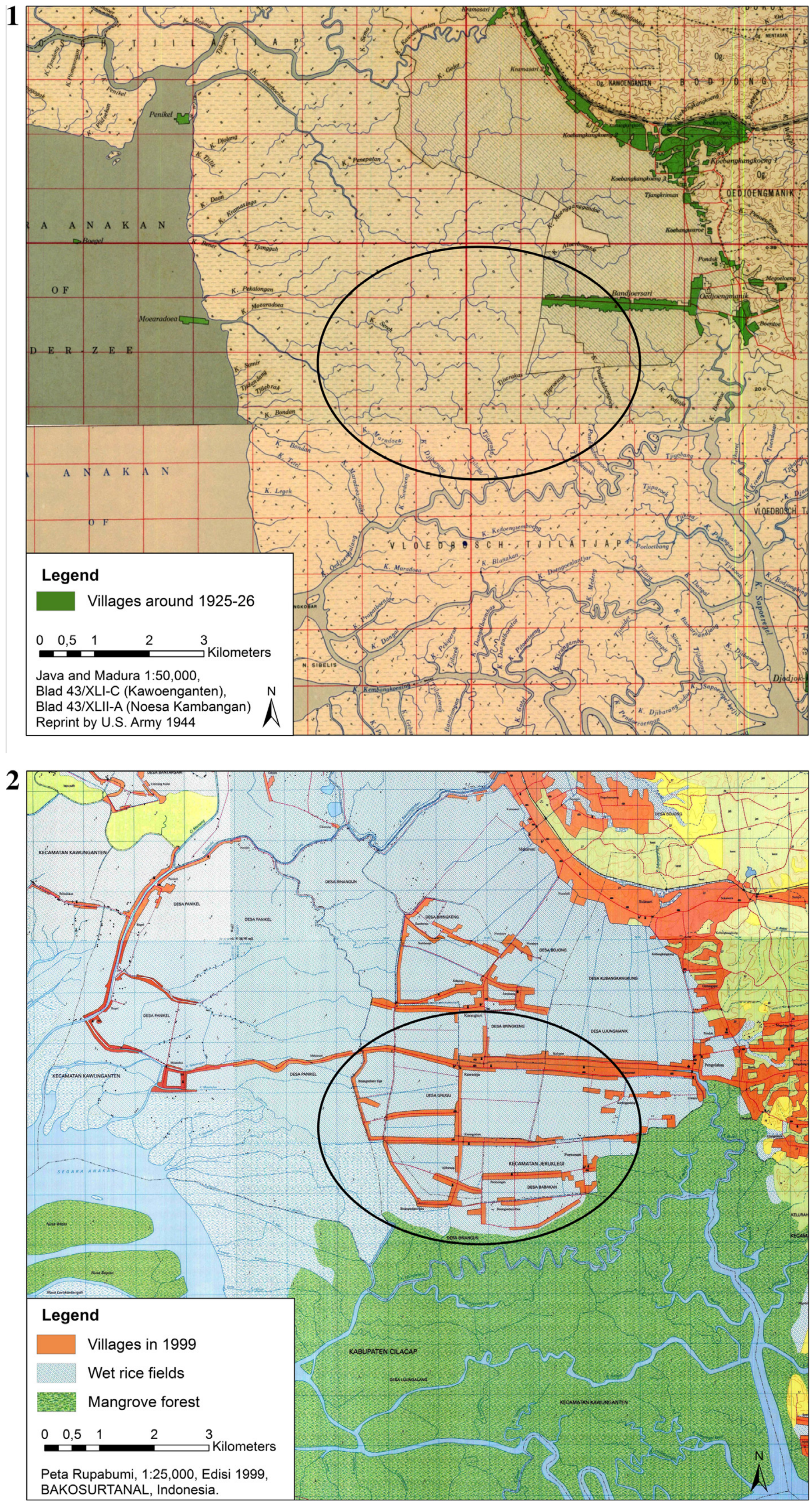

Fig. 6. (6-1 and 6-2) The historical topographical map of the north-eastern section of the Segara Anakan lagoon depicts expansive mangrove and swamp forest areas. The 'relocation' of the villages Grugu, Bringkeng and Babakan and parts of the village of Binangun initiated the transformation of large parts of this mangrove and swamp forest into rice fields and settlements. Though most residents from the 'disappeared' villages reportedly did not receive any new land, the new villages of Bringkeng, Grugu and Babakan, and the sub-villages Binangunbaru 1–3 have grown over time. Thus, the former mangrove and swamp forests have been replaced by villages and wet rice fields.

control over the land, undoubtedly appears as a strategy to regain control over the disputed land and to maintain the land ownership status quo. The peasants did not know for years what PHPM was until Perhutani started planting trees on the disputed land in 2008/2009. Upset about seeing Perhutani planting trees on 'their' land and regarding the tree planting as a strategy of Perhutani to re-territorialise 'their' land, the peasants pulled out the newly planted seedlings. This led Perhutani to engage the police, which resulted in tense encounters on the conflict land, involving a knife threat.

This open confrontation generated political attention up to the national level. The case was discussed in the national parliament in 2009, and the Ministry of Forestry recommended a survey of the historical village land. The survey was supposed to be carried out by a team formed by Perhutani. The peasants fear that they have to bear the costs, and at the time of the research in 2011, they were disappointed that nothing had happened yet. One respondent shared his concern that the process might intentionally be delayed until the last eye witnesses have died.

Tensions and confrontations on the ground between Perhutani and peasants have been going on in the meantime. Peasants are upset about Perhutani staff walking around on 'their' land and setting border markers. At the end of a discussion, a group of peasants confided in me that they had been afraid of talking to me in the beginning, because sometimes spies arrived and interrogated them without letting them know that they worked on behalf of Perhutani. One respondent added: "We are in trauma."

Erosion-prone battlefields

Having shed light on the history of two violent displacements, the territorialisation of former village land by the state and its forest corporation, and the dynamics of the resulting contemporary land conflicts, we return to the starting point of the case study: the issue of soil erosion in the catchment area of the Segara Anakan lagoon. Together with the research we have conducted in other parts of the watershed, the case presented here illustratively shows that blaming upland farmers' unsustainable farming practices for being the single-most important cause of soil erosion and lagoon sedimentation is a misleading, far too simplistic political narrative.

During the past years, the disputed, partly very steep land has been cultivated by peasants mainly with annual crops, which, due to the lack of field terraces or tree cover, has resulted in high levels of erosion. However, these cultivation practices are not peasants' preferred way of farming, but a result of the smouldering land conflict. Without having been asked and without knowing that LUCC and soil erosion were my points of departure for this research, a group of peasants explained that they would usually plant tree crops on such land, intercropped with annuals only during the first years, but that they had to postpone such investments until the tenure status of the land is clarified.

The representatives of the farmers' committee are aware of the relation between upland degradation and flooding and sedimentation. In fact, the committee comprises one person responsible for soil conservation. The farmers already have plans for investments into land terracing and irrigation. This will, as they explained, not only limit erosion, but reduce nutrient washout and increase yields. To some extent, the committee's commitment to soil conservation might be a political strategy to counter political discourses about farmers' allegedly unsustainable farming practices that commonly serve as arguments to keep them out of the 'state forest land'. As aptly formulated by Peluso et al. (2008), "[t]he landscapes of occupation must appear sustainably managed". In fact, some farmers have already planted some trees in the steeper portions of the slope (Fig. 3) and have converted a small area at the foot of the hill slope into terraced rice fields. Terraced rice fields and (mainly mixed) forests dominate large parts of the privately owned land in the lagoon's catchment area, and there has been a general trend of shifting from annual to tree crops in many parts of Java over the past years.

However, as long as the land conflict is not settled, the peasants will not further invest into field terraces, irrigation schemes and trees, at least not on a large scale. They demonstrate their claim over the land by cultivating it with annual crops. The state forest corporation on its part demonstrated its claim over the land by planting trees. Countering this territorialisation strategy, the peasants pulled the seedlings out. In other words, the bare, erosion-prone hill slopes have to be seen as battlefields of historically rooted conflicts over land, with erosion being a direct outcome of these conflicts. Without a satisfactory and just resolution of these conflicts, taking into account the history of violent and unfair displacements, the land will likely continue to be prone to erosion.

Power dynamics and conflicts at the grassroots level and the formation of a 'land mafia'

The story about the erosion-prone conflict land does not end here. It would be too superficial without shedding light on problematic strategies, power dynamics and conflicts at the grassroots level, which have started to impede the political and legal processes that could potentially lead to a resolution of the land conflict and hence to reduced soil erosion. Asked whether he was optimistic that the peasants would finally receive land rights, an insider noted that they had "made a big mistake". Details of these dynamics were rather difficult to grasp, since they had created lines of conflict within the village. The information presented in the following was confirmed by and cross-checked with a number of respondents and hence likely provides a correct albeit not complete picture.

The partition of the claimed and occupied state forest land between peasants is an intricate task. Since the land is occupied illegally, its partition among peasants is an informal process at the grassroots level. Many of those who were displaced in the 1950/60s have passed away, and documents of historical individual land tenure barely exist. It is hence difficult to determine who had owned which part of the previous village land. So who should receive how much land? According to a village representative of Bringkeng, a village forum had compiled a list of residents who had lived in the original village before 1951, and it was planned that both the former land owners and former landless were to 'receive' a piece of land.

However, in practice, representatives of the farmers' committee, which was set up as a representation and action group of those who claimed land and which itself consisted of farmers, started selling cultivation rights. Starting from around 2006, everybody who wanted to cultivate and claim part of the disputed land had to pay for their informal right to cultivate. One villager noted that (parts of) the farmers' committee had turned into a 'land mafia' ('mafia tanah'). This 'land mafia' forced peasants to pay by threatening them to pull out their crops and noting that they would otherwise lose their cultivation right. Afraid of losing their cultivation right, reportedly almost all, i.e. hundreds of peasants, paid IDR 19–25 million (approximately € 1.500–2.000) each for 'their' plot. Informal cultivation rights for comparatively large areas up to 10 ha were reportedly also bought by outsiders from neighbouring regions, who had no relation to the original village of Bringkeng. Some of those who purchased informal cultivation rights assumed they were buying the land, while others were aware that they only bought the 'right to claim the land' hoping to become the formal owners of the land after the resolution of the conflict with Perhutani. The informal cultivation rights have even been resold, often at higher prices. In addition to informally selling cultivation rights for land that formally still belongs to the state, representatives of the farmers' committee collected money for travel costs and legal processes from the other peasants. The informal sale of cultivation rights by the farmers' committee resembles to some extent the former practices of the forest guards and forest labour foremen, who collected informal payments from the villagers who wanted to receive temporary cultivation rights in the frame of tumpangsari.

Some village residents who critically observed the formation and practices of the 'land mafia' encouraged those who were required to pay to report the case to the village head. However, most buyers were afraid and did not admit their payment. The village board tried to get more information, and the head of the PHBM community forestry farmers' group reported the issue to the Perhutani forest district administration. At the time of the case study, the issue was under examination, and both the farmers' committee members and the peasants who allegedly paid had not confessed.

The informal sale of cultivation rights for disputed state forest land has contributed to, or is perhaps even used for, the discrediting of those who fight for land rights by a group of village representatives of Binangun who are cautious about or even in opposition to the peasants' land claim, who, in other words, tend to be on the side of Perhutani. One of them is the head of the PHPM community forestry farmers' group. He had worked for Perhutani as a forest guard previously and had obviously been installed by Perhutani to represent and enforce the state forest corporation's interests within the community. The persistence of such 'fragments' of the former repressive power apparatus in community forestry schemes has been explored in Lukas (2013). Also a representative of the village board of Binangun opposed the peasants' land claim. He expressed his positive views on Perhutani's PHBM policy and noted that in his opinion, "the land is actually not conflict land, because it had already been swapped in the 1950s".

Summary and outlook

One of the most erosion-prone hillsides within the catchment area of the Segara Anakan lagoon can be understood as an 'inscription' of historically rooted conflicts over land, with erosion being the direct outcome of these conflicts. The conflicts are rooted in a series of insurgencies and counterinsurgencies in the 1950/60s, which were inextricably linked to the struggles of the three major political forces, namely the Dar'ul Islam, Communist groups and the Military, over national political power within the newly independent Republic of Indonesia. Displacements of people in the wake of the brutal Dar'ul Islam insurgency and the state military's counterinsurgency in the 1950s provided an opportunity for the expansion of state forest territory at the expense of village land. A state-initiated land swap provided infertile swamp land to some of the displaced peasants in exchange for their fertile hill land and left the majority of them landless. Those who returned were violently evicted from the land in the mid-1960s within the scope of the 'anti-communist' massacres that were part of the formation of Suharto's repressive military regime. Their land was henceforth managed by the state forest corporation and converted into teak and pine plantations. The fall of the Suharto regime in the late 1990s provided scope for a new insurgency. The displaced returned and began to fight for their land, to fight for justice. Ongoing struggles and confrontations between the peasants and the state forest corporation have since then transformed the land into an erosion-prone battlefield. In other words, soil erosion is to be seen as a material flux running off the battlefields of political conflicts over resources. This landscape of erosion is a landscape of conflict and a symbol of unresolved historical violence and injustice. A fair resolution of the land conflict, establishing historical justice as far as this is still possible at this late stage, is obviously the most important prerequisite for a more sustainable, soil conserving management of the land.

However, over the course of the conflict, a group of peasants who took a lead in fighting for land titles established itself as a new dominator, exerting power over the other peasants and requiring them to buy 'informal cultivation rights' or 'rights to claim' the state forest land. With the formation of this 'land mafia' and with outsiders buying 'cultivation rights', the struggle over the land being a struggle for historical justice for the displaced has been diluted. Though these dynamics at the grassroots level deserve critical attention and need to be addressed, they should not distract from the need for a fair resolution of the historically rooted land conflict between those who were violently displaced including their descendants and the state with its forest corporation, which appropriated their land. The further course of the land conflict is the main factor determining future land use and potential levels of erosion.

Conclusion

In line with our research in other parts of the catchment area, the case of the disappeared villages presented in this article shows that the blaming of upland farmers' unsustainable farming practices for being the single most important cause of soil erosion and lagoon sedimentation is a one-sided, misleading political narrative. Instead, some of the most erosion-prone land areas have to be regarded as battlefields of historically rooted conflicts between peasants and the state and its forest corporation or between peasants and plantation companies over land. In these conflicts, the simplistic narratives about peasants' unsustainable farming practices have served as justification for keeping them away from the state forest territories.

The case of the disappeared villages presented here is a powerful example of the importance of taking into account social-political histories and their shaping of contemporary struggles and dynamics in trying to understand present land use patterns and the causes of soil erosion. Research linking LUC(C) science and (historical) political ecology can be particularly fruitful in this context. An area-wide LUCC analysis served as the basis for the identification of political ecology case studies. Hence, observed physical environmental changes served as the starting point of the political ecology research, and not political networks or theoretical considerations that may have an inbuilt preference for cases where exogenous forces and political struggles disadvantage local land users. Political ecology contributes to LUCC and soil degradation science by analysing (historical) social-political dynamics and struggles that are major causes of LUCC and soil erosion. Ignoring these dynamics and struggles in analysing the causes of soil erosion in Java does not just provide a superficial understanding of the situation but necessarily results in misleading conclusions.

The case study presented here clearly establishes direct causal links between political struggles over the access to and control of land and soil erosion. Historically rooted land conflicts have transformed the land into an erosion-prone battlefield, with soil erosion being the outcome. Unresolved socio-political pasts, marked by violence, problematic power relations, injustice, repression and upheaval, and a history of conflicts over resources, all of which are core issues of political ecology research, are inextricably and causally linked with environmental degradation.

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Research Paper 5

Lukas, M.C. Tenure contestation: An Important Cause of Land Cover Change.

Status: under review (Annals of the American Association of Geographers)

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Abstrak (Abstract, translated into Indonesian)

Hubungan antara kepastian kepemilikan lahan dan perubahan pemanfaatan lahan dan tutupan lahan (land use and land cover change/LUCC) telah menjadi fokus meningkatnya minat penelitian. Penelitian ini menunjukkan peran penting ke(tidak)pastian kepemilikan lahan sebagai determinan LUCC dan masih terbatasnya pengetahuan tentang pengaruh dan hubungan sebab-akibatnya. Saya berargumen bahwa kita harus memisahkan berbagai jenis ketidakpastikan kepemilikan lahan dan menilai hubungannya dengan LUCC secara terpisah. Makalah ini berfokus pada sengketa kepemilikan tanah sebagai suatu jenis ketidakpastian kepemilikan lahan. Ketidakpastian kepemilikan lahan adalah penyebab yang penting namun kurang didalami dari LUCC. Ketidakpastian tersebut mencakup dinamika yang berbeda dari ketidakpastian dalam situasi ketidakpastian kepemilikan lahan lainnya. Dinamika ini terdiri dari tindakan strategis sengketa, seperti pengosongan dan pembakaran hutan, penanaman pohon, penanaman tanaman, atau pencabutan bibit. LUCC adalah alat dan hasil dari tindakan strategis tersebut. Pandangan tentang 'ketidakpastian kepemilikan lahan', yang sebagian besar dikonseptualisasikan sebagai ketidakpastian tentang apakah hak kepemilikan lahan yang ada ditegakkan atau tidak, tidak merangkum dinamika ini secara memadai. Penelitian justru harus menginvestigasi proses perjuangan untuk memperoleh hak tersebut. Hal ini memerlukan analisis terperinci tentang keadaan lokal dan pendekatan berorientasi proses yang memperhitungkan lintasan historis dan menguraikan interaksi strategis secara dinamis. Aspek-aspek ini digambarkan dengan kasus empiris dari Pulau Jawa, Indonesia, di mana LUCC adalah bagian tak terpisahkan dari sengketa kepemilikan tanah yanng berlangsung sejak lama. Sengketa ini telah mengubah hutan atau perkebunan menjadi lanskap tanpa pohon yang luas, yang dalam gambar satelit menyerupai 'bekas luka'. Setelah penyelesaian konflik kepemilikan lahan, sejumlah lanskap yang dipersengketakan ini dikonversi menjadi mosaik sawah yang berteras dan kebun campuran atau kembali menjadi perkebunan.

Kata Kunci

Ketidakpastian lahan, konflik lahan, perubahan pemanfaatan lahan, ekologi politik, Jawa, Indonesia.

Tenure contestation: An important cause of land cover change

Martin C. Lukas[1]

Abstract

The links between tenure security and land use and land cover change (LUCC) have been the focus of increasing research interest. This research reflects the important role of tenure (in)security as a determinant of LUCC and the still limited knowledge of the effects and causal links. I argue that we must disaggregate the different types of tenure insecurity and assess their links with LUCC separately. This paper focusses on tenure contestation as one type of tenure insecurity. Tenure contestations are an important but underexplored cause of LUCC. They involve dynamics that differ from those in other situations of tenure insecurity. These dynamics comprise strategic acts of contestation, such as forest clearing and burning, tree planting, crop cultivation, or the uprooting of seedlings. LUCC is the means and outcome of such strategic acts. Notions of 'tenure insecurity', mostly conceptualised as uncertainty whether existing tenure rights are upheld, do not sufficiently grasp these dynamics. Research rather needs to investigate the processes of struggle over such rights. This requires detailed analyses of local circumstances and process-oriented approaches that take into account historical trajectories and dynamically unfolding strategic interactions. These aspects are illustrated with empirical cases from Java, Indonesia, where LUCC is an integral part of historically rooted tenure contestations. These contestations have turned forests or plantations into widely treeless landscapes, which resemble 'scars' in satellite images. Following the resolution of tenure conflicts, some of these landscapes of contestation were converted into mosaics of terraced rice fields and mixed forests or back into plantations.

Keywords

Tenure insecurity, land conflicts, land use change, political ecology, Java, Indonesia

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1 Introduction

Since land use and land cover change (LUCC) was recognised as an important dimension of global environmental change in the mid-1990s (see Geist and Lambin, 2001), the understanding of its drivers has been considerably advanced. Much of the scholarship moved away from simplified assumption-based models and reliance on a few related macro-indicators, like population density, towards a more realistic, empirically grounded understanding that takes into account the complexity of the site-specific, interwoven, multi-scalar processes and drivers of LUCC (see Lambin et al., 2003; Lambin et al., 2001). The Land Use and Land Cover Change Project (see Lambin et al., 1999; Turner et al., 1995) played an important role in this process. It promoted the linking of broader scale assessments of land cover changes with case studies that provide explanatory insight into the trajectories and drivers of these dynamics (Lambin et al., 1999; Turner et al., 1995). Previously, such links had barely been established, due to the methodological difficulties of integrating the diversity and complexity of local circumstances and related qualitative information into broader-scale assessments. The latter hence remained based on selected macro variables (e.g. Verburg et al., 1999). A number of meta-analyses that synthesised findings from a large number of site-specific case studies have since considerably improved our understanding of the wide range and the different roles of the various causes of LUCC (Geist and Lambin, 2001, 2002; Magliocca et al., 2015; Rudel et al., 2009; Rudel, 2005, 2008).

One of the critical factors influencing LUC(C)[2] that had long been rather underrepresented in much of the LUCC scholarship is tenure. The widespread lack of reliable area-wide data on the manifold forms of tenure makes it difficult to incorporate into broader-scale LUCC analyses. Long-standing debates on the links between tenure and resource utilisation are mainly rooted in economic scholarship and have largely focussed on the dichotomy between private and common-pool resources, without establishing a general conclusion as to which is more likely to contribute to sustainable resource management (see Bonilla-Moheno et al., 2013). The past few years have witnessed an increasing research interest on the links between tenure and LUC(C) (e.g. Araujo et al., 2009; Bonilla-Moheno et al., 2013; Buntaine et al., 2014; D’Antona et al., 2006; DiGiano et al., 2013; Farley et al., 2012; Paneque-Gálvez et al., 2013; Vergara-Asenjo and Potvin, 2014; Wannasai and Shrestha, 2008). Latin American frontier regions have been a particular focus of these studies. This research reflects both the critical role of tenure with regard to LUC(C) and the still limited generalizable knowledge on the various causal links. Recent meta-analyses have shown that no particular type of land tenure, neither common nor private property nor any other form of tenure per se guarantees sustainable land uses or promotes tree cover, but that the linkages between tenure and LUC(C) considerably vary depending on the local contexts (see e.g. Bowler et al., 2010; Robinson et al., 2014). There is a need to better and more systematically understand these different kinds of linkages.

[2] LUC(C) refers to both land use and land cover (LUC) and land use and land cover change (LUCC).

Particularly, the varied links between tenure (in)security and LUC(C) have not been well covered by empirical research until recently. Consequently, comparative meta-analyses have been constrained by the limited number of studies available, the limited explicit engagement of these studies with tenure (in)security, the heterogeneity in research approaches, and selection biases (see Robinson et al., 2014). I argue that in order to further our understanding of the varied links between tenure insecurity and LUC(C), we need to disaggregate the different types of tenure insecurity and assess their effects separately in qualitative case studies as well as in meta-analyses and quantitative broader-scale studies. The term 'tenure insecurity' has been used to characterise a diverse range of situations. Conflating these different situations in one category prevents us from systematically examining the links of each of these situations with LUC(C) and contributes to meta-analyses yielding mixed results without or with only few generalizable patterns. One of the situations of tenure insecurity that have a profound impact on LUC(C), but that has barely been explicitly and systematically analysed is tenure contestations. I argue that the dynamics of tenure contestation should be disentangled from other types of tenure insecurity and their links with LUC(C) be assessed separately.

The following section reviews literature on the effects of tenure insecurity and tenure contestations on LUC(C) and argues for the disentanglement of the latter from the former. The remaining part of the paper explores tenure contestations as a major driver of LUCC on the Indonesian Island of Java.

2 Tenure insecurity, tenure contestations and LUCC

Robinson et al. (2014) highlighted the need to consistently distinguish between tenure form and tenure security and defined the latter as "the assurance that land-based property rights will be upheld by society". Tenure form and tenure security are not consistently correlated, and any form of land tenure can be subject of tenure insecurity (Robinson et al., 2014).

The meta-analyses by Rudel et al. (2009) and Geist and Lambin (2001) showed that tenure insecurity was one of the globally important drivers of LUCC and that its role had increasingly been recognised over time. It has also been shown that it is not necessarily the legal status of the land, but the feeling of tenure security that is significant for farmers' land-use and investment decisions (Kusters et al., 2007; Wannasai and Shrestha, 2008).

Overall, the literature shows that the effects of tenure insecurity on LUC(C) are ambiguous. Tenure insecurity has been linked conceptually and, in some cases, also empirically to deforestation, reduced tree cover, shorter harvest rotations, no or limited replanting, low investment and unsustainable land uses (see e.g. Araujo et al., 2009; Barbier and Burgess, 2001; Deacon, 1999; Mendelsohn, 1994, 1995). Accordingly, tenure insecurity, understood as the risk of eviction, reduces the value of permanent crops and hence raises the likelihood that land users choose short-term, often rather unsustainable types of land uses (Mendelsohn, 1994, 1995). However, secure tenure and the provision thereof through, for example, land titling is not necessarily a sufficient determinant for sustainable land uses, increased tree cover or reduced deforestation (Acheson, 2000; Buntaine et al., 2014). Insecure tenure can also have the opposite effect: Instead of promoting deforestation and cultivation of annual crops, it can inhibit investment into converting forest to agricultural land and thereby promote forest preservation (Angelsen, 2007). In such contexts, the expectation of being granted secure tenure can boost deforestation (Angelsen, 2007). Conversely, in other contexts, tree planting serves as a strategy to enhance tenure security (Otsuka et al., 1997).

A comprehensive meta-analysis of the links between the form and security of land tenure and tropical forest cover change has been published by Robinson et al. (2014). Based on a review of 36 publications that documented 118 cases linking tenure and forest cover change, the authors found that protected areas were associated with positive forest outcomes and public (unmanaged public frontier or open access) land with negative forest outcomes, and that tenure security, regardless of the form of tenure, was associated with less deforestation. However, the limited number of studies available for review and the heterogeneity and limited direct engagement of these studies with tenure insecurity, as well as potential publication biases, limited the strength of these conclusions (Robinson et al., 2014).

I argue that, in addition to consistently distinguishing between tenure form and security, we should also disaggregate the different types of tenure insecurity. The term 'tenure insecurity' can refer, for example, to pioneer settlers in frontier regions who strategically clear forest to receive officially recognised land rights (e.g. Alston et al., 2000); to forest preservation or to timber mining and subsequent land abandonment in the absence of the expectation of recognised tenure rights (see e.g. Angelsen, 2007; Barbier and Burgess, 2001); to communal lands where farmers strategically plant trees to enhance personal tenure security (Otsuka et al., 1997); to squatters cultivating public or private land under the risk of eviction; to the risk of expropriation faced by the owners of established land holdings; to temporally limited leaseholds inhibiting longer-term investments (e.g. Damnyag et al., 2012); or to unclear boundary delineations (see Geist and Lambin, 2001). The term is also used to refer to ongoing tenure contestations where different actors claim rights over the same resource and engage in strategic actions to demonstrate and assert these claims (e.g. Araujo et al., 2009). Depending on the nature of the situation and contextual factors, the causal links between what is broadly termed 'tenure insecurity' and LUC(C) vary greatly. I therefore argue that conflating these various kinds of situations under the term 'tenure (in)security' prevents us from revealing the varied causal links. For example, conflating strategic land clearing in the context of tenure contestation with the land use decisions of the owners of established land holdings under the risk of expropriation can obstruct systematic analyses of the effects of each of these situations. Thus I argue that, in order to further our understanding of these causal links, we should disentangle the different situations (the different types) of 'tenure insecurity' and assess their links with LUC(C) separately. This paper does so for one type of tenure insecurity: it explores the links between tenure contestation and LUCC.

Tenure contestations have barely been explicitly explored as a driver of LUCC, and situations of tenure contestation are not well represented in common understandings about ‘tenure insecurity’. Most studies have referred to tenure insecurity as the probability of eviction or the risk of losing tenure rights without compensation and have explored how this affects individual land use decisions. Only a few scholars have explicitly paid attention to the roles of strategies and tactics in the context of tenure insecurity and how these affect land cover. For example, Angelsen (2007:22) distinguished a second aspect of tenure insecurity that can affect land use: the actions of land users to influence tenure insecurity, “including how land rights are acquired in the first place”. Also Geist and Lambin (2001:9) listed “race for property rights” and “[t]itling, legalisation” as underlying causes of LUCC, separate from “land tenure insecurity”. The land users’ actions to influence tenure insecurity, i.e. to strengthen their claims over land, can take the form of both deforestation (Fearnside, 2001) and reforestation (Kull, 2013; Wannasai and Shrestha, 2008).

However, overall, the role of tenure contestation and the related strategic actions and interactions between different actors as a driver of LUCC remain underexplored. This is related to the limited integration of in-depth analyses of diverse local circumstances and broader societal dynamics with spatial LUCC analyses in the past (see introduction). It also results from conflating tenure contestations under the term ‘tenure insecurity’. The latter has tended to be conceived of as a static condition, and economic theory presumes land uses in these contexts to be the outcome of profit-maximisation strategies. These conceptions tend to neglect temporal trajectories and the roles of social dynamics that unfold as part of ongoing tenure contestations, including strategic and tactical actions. Such actions can include, for example, the burning of forest stands, the felling of trees or the pulling out of tree seedlings planted by competing actors. Hence, in trying to understand the links between tenure contestations and LUCC, it is necessary to conceptualise the situation not only in terms of *the upholding of existing tenure rights*, but to analyse *the processes of struggle over such rights*.

Examples of the effects of such struggles on LUC(C) are contained in Dennis et al. (2005), who identified intentional burning by various actors in the context of tenure or land-use disputes as a major cause of forest fires in Borneo and Sumatra; in Kull (2002, 2004), who found that poorer farmers burnt richer farmers’ tree plantings out of frustration over related tenure claims; and in Peluso’s (1992) historical account of struggles over forest resources in Java.

A number of studies from the Brazilian Amazon constitute the major empirical research contribution explicitly focussing on the links between tenure contestation and LUCC. In this region, land reform policies promoted violent competition over land and raised the incentives of both land owners and squatters to strategically deforest in order to demonstrate their productive land use and thereby assert their legal tenure claims (Aldrich et al., 2011; Alston et al., 2000; Araujo et al., 2009; Fearnside, 2001). These tenure contestations raised deforestation rates above the level that would likely have occurred in the absence of the strategic competitive clearing. Araujo et al. (2009) distinguished between (a) deforestation resulting as an effect of expropriation risk through land reform policies on farmers' land use decisions and (b) deforestation resulting from strategic interactions between land owners and squatters in competitive land claim processes. The latter is further explored in Aldrich et al. (2011). The authors' detailed documentation of a conflict over a largeholding in Pará, combined with a regional-scale regression analysis, is one of the best documented accounts of tenure contestations accelerating deforestation. The authors showed that "contentious social interactions aimed at land possession" caused deforestation in excess to "agronomic deforestation undertaken to plant crops or pasture as an economic activity" (p.109). They noted that the complexity of multiple agents and competing land claims had not been well reflected in research on LUCC in Amazônia, which had tended to conceptualise LUCC as an outcome of "disaggregate decision makers responding autonomously to market signals and institutional incentives" (p. 120). The authors hence called for land change science to pay more attention to 'contentious land change', "which is the result of social processes as opposed to the isolated behaviours of individual agents" (p. 109).

These studies indicate that tenure contestation is an important cause of LUCC, and that the circumstances and dynamics driving LUCC in case of tenure contestation differ from those in other types of tenure insecurity. This must be reflected in the selection of research approaches. They must support detailed analyses of local circumstances, of related societal dynamics and particularly of the contentious roles and the strategic and tactical[3] interactions of various actors in ongoing social struggles. My research in Java has shown that it is also crucial to take into account the historical trajectories that have led to and that shape the dynamics of present tenure contestations. Not paying sufficient attention to these aspects easily results in wrong conclusions. The remaining part of the paper illustrates and expands these considerations with results of my research on LUCC in Java.

3 Tenure contestations and LUCC in Java, Indonesia

The amount of research focussing on LUCC and its drivers in Java has to date been rather limited. A few studies have analysed the expansion of urban and industrial land uses and related declines in the area under irrigated rice field agriculture (Dimyati et al., 1996; Firman, 1997, 2000; Yunus and Harini, 2005). Lavigne and Gunnell (2006) analysed LUCC on the upper slopes of some of the island's volcanoes. Their research constitutes one of the few studies in non-urban environments of Java that closely linked an analysis of LUCC with

[3] A clear-cut distinction between strategies and tactics (see Perramond 2007) proved rather unfeasible and unnecessary in the case studies presented in this paper. The paper therefore mainly uses the terms 'strategy' and 'strategic' in referring to strategic-tactical acts.

related social dynamics and driving forces. Most other studies on LUC(C) have been desk-based and confined to remote sensing, often with no or only limited ground truthing and without any empirical analysis of the drivers of LUCC, at best using a few selected macro-level indicators to support existing narratives (Astisiasari, 2008; Kurniawan and Krol, 2014; Prasetyo, 2004).

Desk-based analyses of LUCC that only rely on remote sensing and statistical data without thorough field research carry the risk of contributing to overly simplified, political narratives about the drivers of LUCC. Such studies tend to contribute no or barely any new insight into the range of drivers. Instead, the physical changes analysed are often framed by the authors or readers in the context of pre-existing narratives. In cases where the drivers of LUCC are the subject of the analysis, the selection of related statistics and macro-level indicators tends to be based on such narratives and is limited by the data available. For example, the desk-based simulation of LUCC for the whole of Java by Verburg et al. (1999) was based on a set of selected macro-level indicators, not including tenure. The lack of reliable area-wide data on land tenure and widespread tenure contestations, resulting in differing de jure and de facto tenure, indeed make it difficult to incorporate tenure form and security in such a macro-level analysis. In this way, potentially important causes of LUCC are a priori excluded from the inquiry. The study also equated forest cover with the area officially designated as state forest, assuming that forests are protected and hence no forest cover change occurs. In doing this the study a priori excluded major areas and drivers (including contested forest areas) from the inquiry.

The general lack of research, the desk-based nature of most studies without (thorough) field research, and the lacking integration of broader-scale analyses with site-specific, empirical in-depth studies account for the limited understanding of the drivers of LUCC in Java and have left a large space for political framings and simplified assumptions or ‘myths’ (cf. Lambin et al., 2001) to dominate debates on the drivers of LUCC. In this context, the role of tenure contestations, one of the most important drivers of LUCC in Java, has been neglected.

3.1 Methodological approach

The case studies presented below were conducted in the frame of a research project that analysed LUCC and its drivers in the catchment area of the Segara Anakan lagoon, which forms the estuary of the Citanduy, Cimeneng, Cikonde and a number of smaller rivers (Figure 1). This research linked land change science and political ecology (see Aldrich et al., 2011; Brannstrom and Vadjunec, 2013; Lukas, 2014; Turner and Robbins, 2008) – a combination that proved particularly fruitful for analysing the links between tenure contestations and LUCC. The research combined an analysis of satellite images and historical maps with land use/cover mapping and social-scientific inquiry.

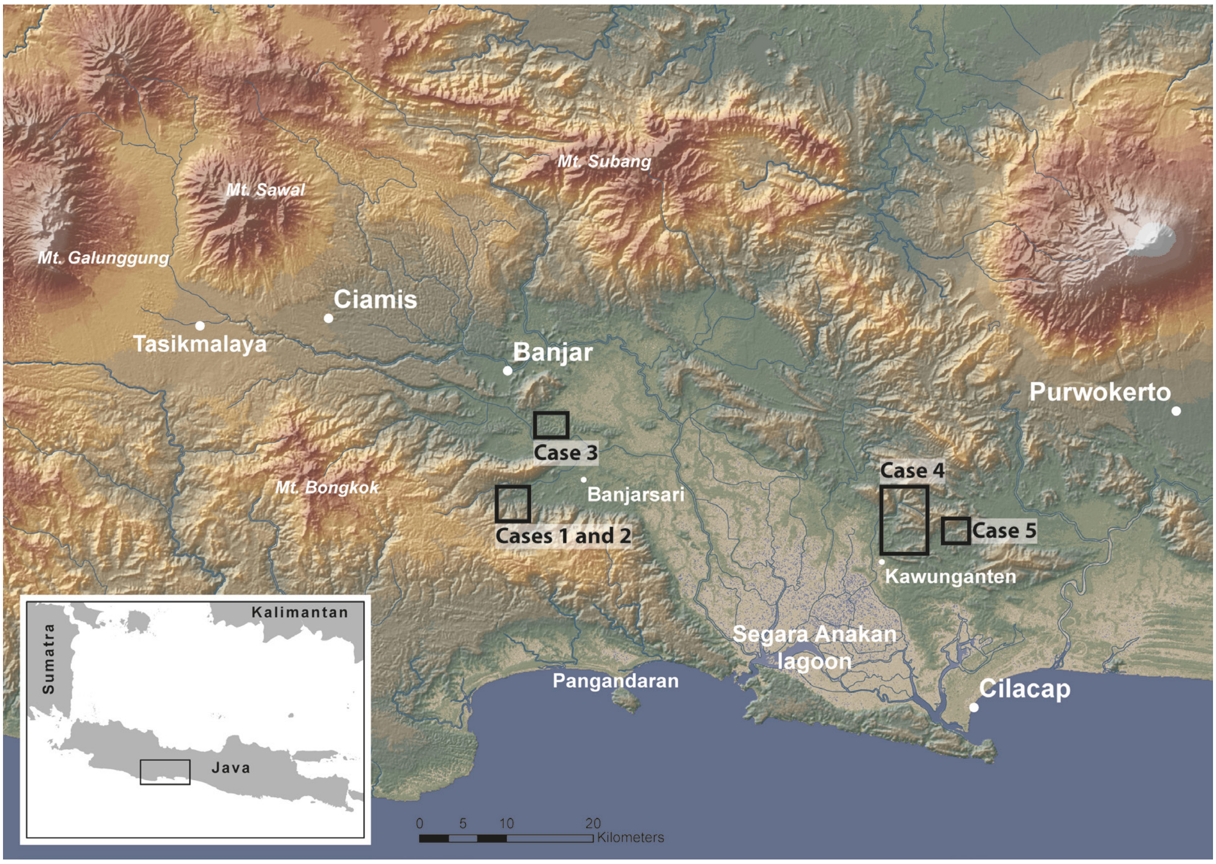

Figure 1: Locations of the case study areas

Based on visual analysis of a series of satellite images (Landsat MSS, TM, ETM; SPOT) taken between 1976 and 2011 and land use/cover mapping throughout the entire catchment area, a total of 297 LUCC areas were identified. Sixty of these areas were subsequently covered by case studies that aimed at analysing the dynamics and drivers of LUCC. These case studies covered different parts of the catchment area, some of the major hotspots of LUCC and erosion-prone land, and a wide variety of different dynamics. They comprised transect walks and semi-structured interviews with representatives of district and sub-district governmental organisations, the state forest corporation, NGOs, and village administrations as well as with community groups, farmers, elderly people, and other village residents. The interviews took an inductive approach, particularly in their first part. During the course of the interviews, the results of the satellite image processing (maps visualising the LUCC) were then incorporated into the discussion. In this way, each of the physical LUCC detected was directly linked with the drivers of these changes and related social dynamics. This approach also allowed for cross-validation and cross-fertilisation between remote sensing and social-scientific inquiry. Since an area-wide remote-sensing-based LUCC analysis and not particular social dynamics, such as known cases of tenure contestation, served as the starting point of the research, the range of the LUCC drivers revealed can be assumed to be widely unaffected by selection biases. Robinson et al. (2014) noted such selection or publication biases as a limitation of their meta-analysis.

3.2 Deforested landscapes of contestation

In a substantial number of the areas covered by the case studies, tenure contestations were identified as the main cause of LUCC. Some of these contested areas belonged to the most erosion-prone lands within the study region. Notions of tenure insecurity understood as the risk of eviction would not sufficiently grasp the dynamics that caused the LUCC on these lands. Instead, the historical trajectories that led to the situation of tenure contestation and the strategic interactions of the conflicting actors proved crucial in understanding the nature of the LUCC.

The cases of tenure contestation presented in the following sections share similar historical roots. Many of them go back to displacements of peasants or entire villages in the 1950-60s. These displacements were related to one or a combination of the following developments during the first two decades following Indonesia’s independence: (a) the renewal of licences for and the expansion of former Dutch plantation territories when they were transferred into Indonesian ownership; (b) the Dar’ul Islam insurgency, which aimed at Indonesia becoming an Islamic state and which took the form of a guerrilla war (Dengel, 1986; Horikoshi, 1975; Jackson, 1980; van Dijk, 1981); and (c) the subsequent formation of President Suharto’s authoritarian, militarised New Order regime from 1965. The latter involved an anti-communist purge, which became one of the largest massacres of the 20th century (see Cribb, 1990; Cribb, 2001). It entailed new displacements and suppressed any voices tentatively aimed at questioning the legitimacy of the displacements and of established patterns of access to and control over land and natural resources. The fall of the Suharto Regime in the late 1990s provided scope for open contestations over the land. These contestations are one of the major drivers of LUCC in the region. The accounts of the cases presented in the following sections combine the results of the remote sensing analysis with the information obtained in the frame of the various interviews conducted in the respective areas.

3.2.1 Case 1: Banjaranyar / Cigayam

One of the LUCC areas identified based on the satellite images is located south of Banjar in the sub-district of Banjarsari (see Figure 1). It spans an area of about 350ha between the northern banks of the Ci Putrahaji River, a tributary of the Ciseel River, and the villages of Banjaranyar and Cigayam (Figure 2). Some years ago, this hilly land appeared in satellite images like a scar on the landscape. Its low vegetation cover clearly delimited it from the surrounding, more vegetated area (Figure 2). Parts of this land were covered with scattered rubber trees and imperata grass; other parts comprised mainly non-terraced fields used for annual crop cultivation; and a few plots were newly planted with trees. The factors determining this peculiar land cover pattern can only be understood by exploring the history of LUCC, which is a history of tenure contestation.

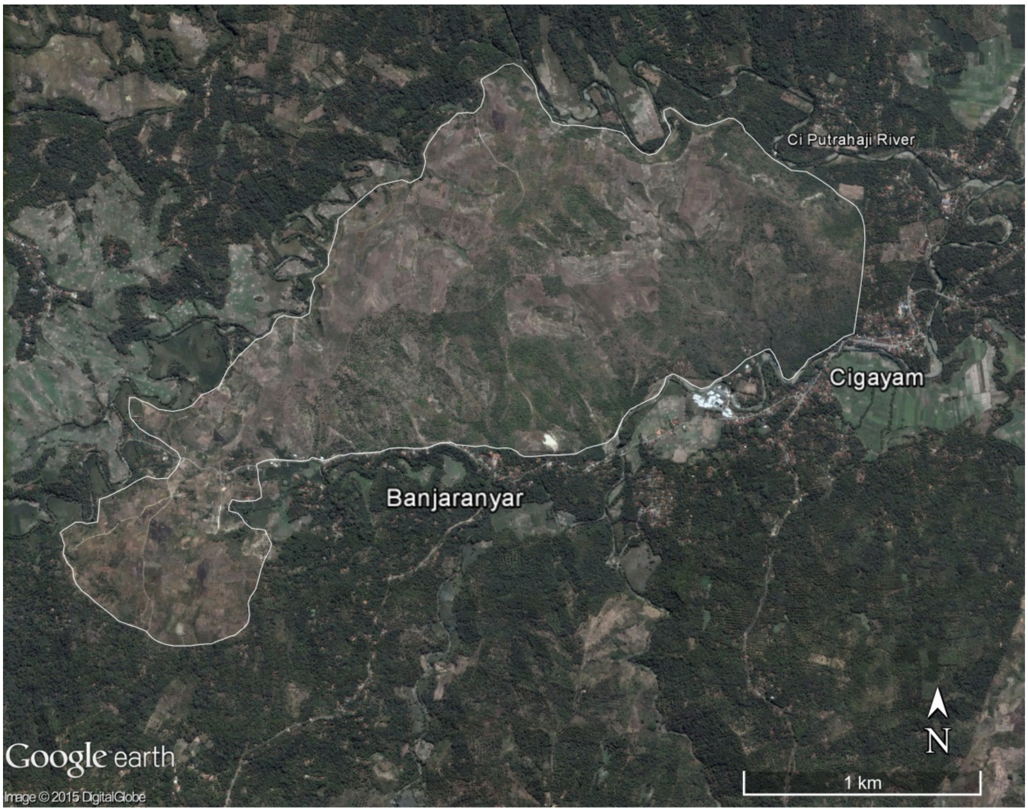

Figure 2: The contested plantation land at Banjaranyar/Cigayam is clearly visible in satellite images as area with low vegetation cover. Peasants have cut and burnt the rubber stand to assert their land claim. Satellite image: 3. September 2006.

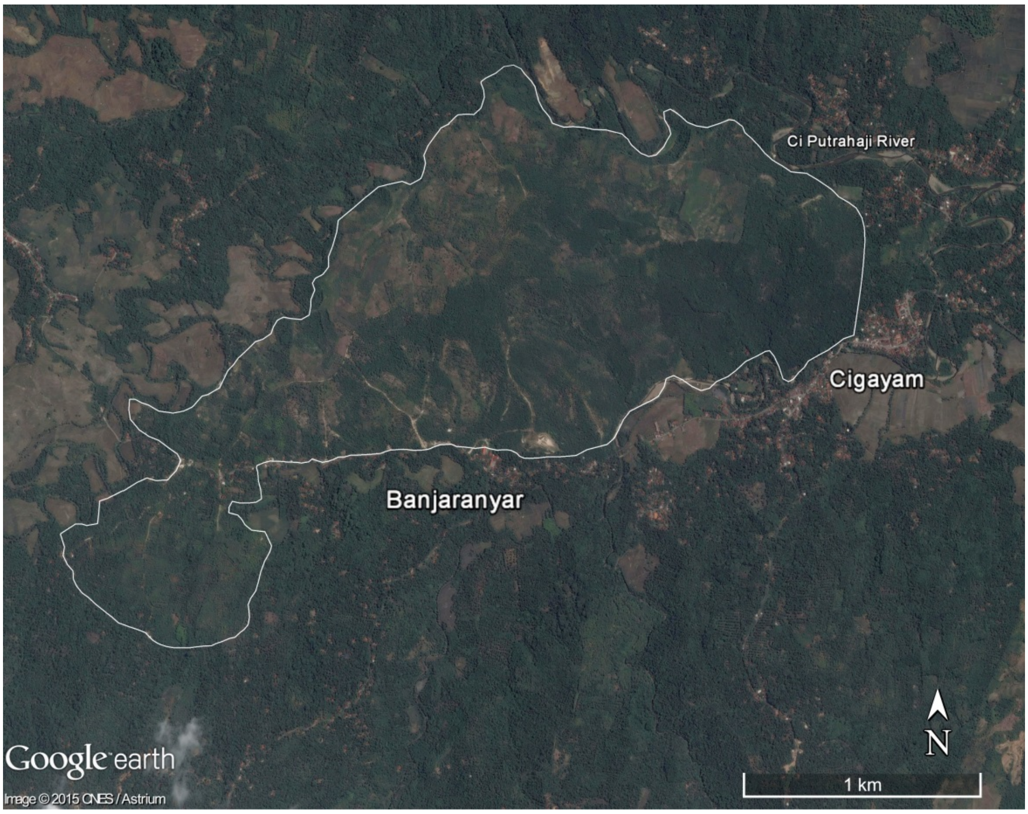

Figure 3: Increasing tree cover following the partial resolution of the land conflict. Satellite image: 10. January 2015.

In 1897, during colonial times, this land was granted to a Dutch plantation company. Following the Agrarian Law of 1870 which declared all unoccupied land as government land which could be leased out to entrepreneurs, there was a gold rush like surge of estate development for export crop production in the late 19th and early 20th century all over Java. The company received a 25-year leasehold and converted most of the land into a rubber plantation; its south-western part was planted with fruit trees. Though the leasehold expired in 1922, residents recount that the company continued using the land until 1942, when the Dutch owners of the plantation left the area in the wake of the Japanese occupation of Java.

During the subsequent period of political struggles for national independence and following Dutch military operations on Java, the local community wanted to gain control over the plantation land. Since the trees and the plantation infrastructure had been set up and owned by the Dutch, the local residents destroyed it in order to demonstrate their claim. They cut and burnt down most of the plantation, planted the land with annual crops and built about 40 houses. In the mid-1950s, during the Dar'ul Islam insurgency, refugees from other parts of Central and West-Java moved into the area and also settled on the former plantation land.

A few years later, the son in law of the village head seized this land to re-establish a plantation. To receive a long-term use right from the national government for the land, he required the consent of the local community. The latter agreed that an area of 60ha that was still covered with rubber trees could be granted to him and managed as a plantation. However, he mislead the community and managed to receive a long-term use right for the entire area of 349ha, on which he started to establish a plantation under the name Karet Nasional Cigayam (later renamed P.T. Mulia Asli). Local residents submitted a legal case to the district court in 1963. However, the case was not processed before General Suharto took over national political power in 1965. The peasants claiming and still cultivating the plantation land were evicted by the police on the initiative of the plantation owner. They were labelled members of the Indonesian communist party (PKI) and imprisoned for periods between several days and many years. The court case was not processed further.

Over the course of the eviction, the plantation area was also expanded to the north beyond its former legal boundaries at the cost of peasants' land. When some of the displaced returned around 1967, an informal agreement was made, allowing them to cultivate sections of the land against payment of leaseholds in the form of working days plus one third of their harvest. As part of a military-organised rice cultivation programme, which involved political prisoners (alleged PKI members) as workers, large parts of the land were planted with rubber, intercropped with rice. The farmers had to pay 60% of their rice harvest to the regional military unit.

By the early 1970s most of the land was converted into a rubber plantation. Only its south-western part remained fallow and was then occupied by peasants. From 1973, this part of the land was leased by a family member of the plantation owner, who set up a cassava factory and leased the land out to cassava farmers. In the other areas, some of the rubber stands were renewed in the 1980s and 1990s, after the company's land use right was extended by the national authorities.

In the late 1990s and early 2000s, most of the rubber stands were cut and burnt down as a result of recurring contestations over the land. Following the fall of Suharto's New Order Regime and in the wake of the political reformation, the peasants occupied parts of the land. As an expression of their land claim ("to show that the land is ours", Interview with a village representative, April 2011), they cut and burnt the rubber stands and planted annual crops. The plantation company in turn planted rubber to solidify its land claim. To sum up, the opponents in this land conflict used planting, felling and burning as strategies to assert their claims. Planting and felling and the resulting land cover pattern were hence not simply a result of land users' production aims under conditions of insecure tenure, but were part of the strategic interactions of opponents in their struggle over contested land.

Notwithstanding attempts of the company and the police to evict the occupants and a few arrests, the peasants, supported by the Sundanese Peasant Union (Serikat Petani Pasundan, SPP), managed to hinder the company from planting new rubber trees in parts of the land. They blockaded part of the land, filed a lawsuit over an area of 150ha, and protested in front of the district parliament. As a result, they were granted temporary land use rights in 2005. Two years later, 380 peasants received formal land certificates for the western-most portion of the plantation - an area of 69.5ha. This was part of the national land reform programme. Upon the granting of land certificates, many peasants immediately started planting (more) trees on their plots.

The history of tenure contestation is clearly imprinted in the land cover pattern shown on satellite images from 2006 (Figure 3). At this time, peasants' private land in the wider area surrounding the contested land was marked by terraced wet rice fields and dense, multi-storeyed mixed forests – a landscape with low erosion potential. In contrast, the landscape of contestation was a landscape with clearly less tree cover. The northern parts of the former plantation, which were still contested, were widely treeless and cultivated by peasants with annual crops. The southern and eastern parts of the plantation were covered with the scattered rubber trees that had survived the peasants' strategic clearing. Further modifications of this land cover pattern that had been shaped by strategic acts of *contestation* were impeded by the persisting situation of *tenure insecurity*. In the still contested northern parts of the area, peasants barely planted any trees, but continued cultivating the land with annual crops. The plantation company on its part refrained from replanting its rubber stands. In contrast, the 69.5ha of land in the western portion of the former plantation, for which peasants had already received cultivation rights and for which they were to receive certificates, started to be transformed. In 2006, it comprised a mosaic of newly terraced rice fields, plots with newly planted trees, and still non-terraced erosion-prone lands cultivated with annual crops.

By 2015, tree cover has clearly increased. Large parts of the land for which peasants had received land certificates are already covered with trees. In a few years, land cover in this area will certainly no longer be distinct from the surrounding pattern of terraced wet rice fields and dense, multi-storeyed mixed forests. The plantation company has also replanted large parts of its rubber stands in the southern and eastern portions of the land. Hence, the visibility of the history of tenure contestation as a widely treeless scar in the landscape is fading (Figure 3).

3.2.2 Case 2: Cigayam

A similar development could be observed on a more than 700ha large land area nearby that extends from Cigayam to the south. Satellite images from 2006 depict this area as a second treeless scar on the landscape. This land had also been used by a Dutch plantation company until the late 1940s. It was then cultivated alternately with rubber, sweet cassava, and albizia by various Indonesian plantation companies, one of which was owned by family members of President Suharto. At times, the land was occupied by peasants and used for annual crop cultivation. In 1997, the land was transferred to Perhutani, the state forest corporation, as part of a land swap and started to be planted with teak. Shortly thereafter, in the wake of the political reformation, the land was occupied and claimed by peasants. It was strategically cleared and planted with annual crops. This landscape of contestation was clearly visible as a treeless scar in satellite images of 2006 (Figure 4). Since then, it has started to be transformed into a mosaic of terraced wet rice fields and mixed forests, resembling the soil conserving land cover pattern of peasants' private land in the surrounding area (Figure 5). Facilitated by the SPP, the contested land has been subdivided and distributed to farmers. Struggles for land certificates were still ongoing at the time of field research. Nevertheless, many peasants had already started planting trees and building field terraces. This was to some extent a strategy to counter arguments targeting their land use and occupation as environmentally harmful.

Figure 4: Section of the contested plantation land at Cigayam: The cleared land has been subdivided among peasants, is used for cultivation of annual crops and has started to be planted with trees. Satellite image: 3. September 2006.

Figure 5: The land is being transformed into a mosaic of terraced wet rice fields and mixed forests. Satellite image: 10. January 2015.

3.2.4 Case 3: Kutawaringin

The third case presents a dense rubber plantation that was turned into a bare landscape of contestation and later converted back into a rubber plantation. As in the cases presented above this plantation, which is located in the village of Kutawaringin close to the Ciseel River about 10km southeast of Banjar (see Figure 1), was established in the late 19th century. In the 1950s it was transferred into Indonesian ownership and henceforth managed by P.T. Perkebunan Nusantara 8/13, a state-owned plantation company. Villagers recount that in 1955, the plantation area was extended to the east at the cost of peasants' land. In 1983, eight peasants formed a group aimed at getting their land back. A resulting consultation between the provincial parliament, the police, the court, and the plantation company came to nothing. The peasants were told that there had been a land swap, but village residents could not remember that they or their parents had received any land in exchange.

In the wake of the political reformation in the late 1990s peasants released their anger and completely cut and burnt down the rubber stands in an area of 243ha and planted some of this hill land with annual crops (Figure 6). A lawsuit handled by the district level court ended with the decision that the peasants were to be given an area of 106ha plus financial compensation for not having been able to cultivate this land between 1955 and 1997. Following this decision, the peasants continued cultivating the 106ha of the cleared land area in the east that had been granted to them, while the remaining westernmost portion of 137ha of the cleared land was replanted with rubber by the plantation company. However, the plantation company filed an appeal to the provincial court and won the case. A subsequent appeal by the peasants to the Supreme Court failed due to insufficient evidence of their historical land ownership. The entire area was therefore to be managed by the plantation company again.

In 2011, the eastern portion of the land was still cultivated by peasants. However, more than half of them were not the peasants who had originally cleared and claimed the land in the late 1990s, but were outsiders who had informally been sold cultivation rights by the original occupiers.

A recent satellite image from 2014 shows that the entire area has recently been replanted with rubber. The bare landscape of occupation and contestation is hence being converted back into a rubber plantation (Figure 7). As in the cases above, the land cover change from dense rubber stands into a treeless landscape planted with annual crops was the direct result of historically rooted tenure contestations. The dramatic clearing and burning of the rubber stands by the peasants on an area larger than they or their ancestors claimed to have owned before, was a strategic act to express and assert their land claim and an expression of their retained anger over the disappropriation of their land in the past.

Figure 6: Cleared landscape of contestation: Peasants have cut and burnt the rubber stands on the contested plantation land and cultivate part of the land with annual crops to assert

Figure 7: The cleared landscape of contestation is converted back into a rubber plantation. The western part of the land is already covered with dense rubber stands. In the eastern part, the mosaic of land parcels cultivated with annual crops by peasants (see Figure 6) has recently been replanted with rubber. Satellite image: 9. June 2014.

3.2.5 Case 4: Disappeared villages near Kawunganten

A number of other cases of LUCC caused by tenure contestations are rooted in a particularly intricate history with violent displacements of entire villages in the 1950s and 1960s. Some of the rural and forest areas throughout the study region became a base of Dar'ul Islam rebels in the 1950s. The rebels led a guerrilla war, plundered villages, and recruited, threatened and killed residents. This, together with counterattacks by the Indonesian National Army, resulted in large numbers of people leaving their villages or being evacuated. In the hills north of Kawunganten near Cilacap about 40 hamlets were vacated in this way. After the surrender of the rebels in 1962/63, many residents, who had not received any land in the frame of alleged land swaps, returned to their villages and started rebuilding their houses and cultivating their land. However, just after General Suharto took over national political power in 1965, the peasants were forced to leave their villages again. Those who refused were labelled PKI members. Corresponding signs were placed at their houses overnight to intimidate them and make them leave. Those who still refused to leave were killed or imprisoned.

Their villages were razed to the ground, and the area was incorporated into the state forest domain and henceforth managed by Perhutani, the state forest company. When the displaced peasants of the three hamlets that had existed north of the present village of Kubangkangkung asked their village head about the tenure status of their former land in 1972, they were harshly told that it was too dangerous to discuss this issue with the higher level authorities and that if they did, they could all be labelled PKI members and disappeared.

Finally, in the wake of the political reformation in the late 1990s, the displaced (or their descendants) of some of the vanished hamlets returned, cut down the forest and planted annual crops. A detailed historical account of these dynamics is contained in Lukas (2014). This case study of a contested land area north of the village of Binangun shows how the history of violent displacements and political repression and the resulting tenure contestations have turned the land into an erosion-prone 'political battlefield'. The conversion of the teak forest into a widely treeless landscape cultivated with annual crops on non-terraced slopes is a direct outcome of the historically rooted land contestations. The clearing of the forest and the planting of annual crops in the late 1990s was a strategic act of the peasants to express their land claim. Also the planting of trees by the state forest corporation during the following years and the pulling out of these trees by the peasants were strategic acts of conflicting actors aiming at expressing and asserting their land claims.

The LUCC in this area can hence only be understood by exploring the dynamics of *tenure contestation*, their historical roots and the related strategic interactions of the conflicting actors. However, the particular way of how farmers continue cultivating the contested land, i.e. the persistence of the present land use/cover pattern, can also be related to the enduring situation of *tenure insecurity*: The peasants hesitate to invest into building field terraces and irrigation schemes and into planting trees on a larger scale as long as the land remains contested.

3.2.6 Case 5: Sawangan

Another case of LUCC caused by historically rooted tenure contestations was revealed near the village of Sawangan about 15km north of Cilacap (see Figure 1). In this case, more than 100ha of tree-covered hill land were turned into a treeless landscape of contestation.

In the early 20th century, this land comprised the remote hamlet of Karangiengkol and was used by peasants. In 1937, as recalled by the eldest residents interviewed, these peasants moved about 2km to the southeast, where a road had been built and where they founded the village of Sawangan. Their former land at Karangiengkol was then used by a Dutch plantation company for rubber cultivation. As recalled by elderly residents, the company wanted to acquire the land, but could not do so since the peasants refused to sell their village land. However, based on a mutual agreement with the peasants, the company was allowed to use the land; the peasants did not have to pay land tax anymore and benefitted from employment opportunities.

During the Japanese occupation of Java in 1942-45, the peasants cut down the rubber stands and sold the trees as fire wood to the railway company. In the wake of the Dar'ul Islam insurgency in the 1950s, their village of Sawangan was burnt down and vacated. After they returned to Sawangan in 1963, the peasants also started cultivating some of the land at Karangiengkol. However, later on, the state authorities granted a long-term leasehold for this land to a plantation company, which was linked to an agricultural research institute. The cocoa plantation which was established served both for generating revenue and as an experimental farm. During the New Order regime, the peasants, deprived of any benefits, could only express their anger by critical polemic amongst them.

In the wake of the political reformation in the late 1990s, they cut down almost the entire cocoa stand and started cultivating the land with annual crops to demonstrate their claim. At the same time, they thinned and cleared substantial parts of the expansive state forest territory that surrounds their village in all directions. In this context, a staff member of Perhutani, the state forest company, shot a village resident, which in turn provoked attacks against Perhutani staff. This incidence resulted in heated political debates. The village head emphasised that "people don't need money, rice or any other social welfare programmes, but land to sustain their livelihood themselves." (Interview with a village representative, February 2011), and one of the candidates in the district governorial elections promised land to the people. Following his election, he committed to the redistribution of the contested land at Karangiengkol to the village residents.

Around 2008, a large part of the total land area of 113ha was divided among about 850 families, who received land certificates. During the following years, tree cover clearly increased on this land (Figures 8a and 8b, Supplementary Material 1). In 2011, about half of the plots were planted with trees, while the other half continued to be cultivated with annual crops. The farmers and village representatives interviewed expected that the entire area would be covered with trees in the near future. A satellite image from September 2014 shows that large parts of the former treeless, erosion-prone landscape of contestation have been transformed into a mosaic of terraced rice fields, newly planted mixed forests and agroforestry systems (Figure 9). However, a few non-terraced erosion-prone plots remain.

As in the cases presented above, the LUCC that occurred in the late 1990s and early 2000s were the direct result of historically rooted *tenure contestations*, whereas the recent transformation of most of the cleared, erosion-prone contested land into a mosaic of terraced rice fields and mixed forests can be related to the newly established situation of *tenure security*.

Figures 8a and 8b: Former contested land at Karangiengkol north of Sawangan: Following the provision of land certificates, the cleared landscape of contestation is being transformed into a mosaic of terraced rice fields, newly planted mixed forests and agroforestry systems. A few non-terraced erosion-prone plots remain. Photo 8a: 30. May 2008; Photo 8b: 4. February 2011.

Figure 9: Satellite image of the western part of the former contested land at Karangiengkol north of Sawangan: The cleared landscape of contestation is being transformed into a mosaic of terraced rice fields, newly planted mixed forests and agroforestry systems. A few non-terraced erosion-prone plots remain. Satellite image: 3. September 2014.

3.2.7 Tenure contestations: a widespread phenomenon

The five cases of tenure contestation presented in the above sub-sections are representative of a large number of similar cases throughout the study region and the whole of Java. Tenure contestations are widespread and are a major cause of LUCC.

My research revealed a similar case at Mount Sawal in the district of Ciamis, where residents of a former tin mining village were also displaced in the wake of the Dar'ul Islam insurgency and whose land was later incorporated into the state forest domain. Their contestation of this land since the late 1990s has, similar to the cases presented above, resulted in the conversion of forest into farmland.

In a number of other cases, tenure is contested for similar historical reasons, but land claims have not (yet) been expressed by land conversions and lawsuits. This applies, for example, to the case of the three vanished hamlets north of Kubangkangkung. When some of those displaced from these hamlets in the 1950/60s asked Perhutani about the tenure status of their former land in 2003, they were told that the land had been sold to Perhutani by their village head in the 1950s. Since they had not received any compensation, they started preparing a lawsuit. However, the person taking the lead was said to have turned the process into a business for his own private benefit and had collected a large sum of money from those who wanted to join the struggle for land rights. This resulted in discontent and thwarted the entire undertaking. Also in the village of Karangreja in the district of Cipari there is discontent over three unresolved cases of land disappropriations in the 1950/60s. Similar to the cases above, these disappropriations go back to the extension of plantations, dubious land swaps and displacements during the Dar'ul Islam insurgency. In the 1980s, a formal inquiry by two village representatives about the tenure status of the former peasants' land that had been incorporated into a military-run plantation ended with one of the village representatives and his son disappearing forever and the second village representative subsequently withdrawing the inquiry out of fear. Later in the 1980s and continuing until 2011, a swindler made peasants believe that he would take a lead in struggling for the land to be returned. This resident of a neighbouring village deceived the peasants and made them repeatedly pay large sums of money to him. It remains to be seen whether these and many other latent tenure contestations will at some stage also result in open conflict and LUCC.

4 Discussion and conclusion

Tenure contestations are a major cause of LUCC, but have rarely been systematically explored as such. The limited engagement of LUCC scholarship with tenure contestations can be attributed to scholars long-standing focus on remote sensing, macro-indicators and broader-scale models; emphasis on the individual decision making of isolated actors (cf. Aldrich et al., 2011); the lack of reliable, area-wide data on tenure; as well as the analytical conflation of situations of tenure contestation with other situations of tenure insecurity.

The case of Java illustrates how lacking attention to the specific local dynamics and drivers of LUCC, including related historical trajectories, and the continuous neglect of the roles of tenure left large space for assumptions and political discourses to dominate the discussions on the drivers of LUCC. These discourses have mainly focussed on population growth and farmers' cultivation practices. My research has shown that these assumptions are too simplistic and that tenure contestations are a major, though widely neglected, cause of LUCC and land degradation.

The links between tenure contestations and LUCC hence deserve more political and scholarly attention. The necessary engagement with these links requires case study approaches, because reliable, area-wide data on tenure is lacking, and de jure and de facto tenure of contested lands often differs. Synthesising findings from a number of case studies can then lead to general, broader-scale conclusions.

The literature review and the case studies presented in this paper suggest that in addition to systematically distinguishing between tenure form and tenure (in)security (Robinson et al., 2014), we should also attempt to disaggregate the different types of tenure insecurity as far as possible and assess their specific links with LUCC separately. Tenure contestation is one type of tenure insecurity. The specific dynamics driving LUCC in case of tenure contestation differ from those in other situations of tenure insecurity. These dynamics comprise strategic acts of contestation used by conflicting actors to express and assert their claims. Also historically based feelings of anger and distrust, historical experiences of social domination and repression and lacking mechanisms of conflict resolution can influence the course and magnitude of such acts. In the cases presented in this paper, these strategic acts included the clearing and burning of forests and plantations and the planting of annual crops by peasants, the planting of trees by peasants to counter arguments targeting their land use and occupation as environmentally harmful, the planting of trees by plantation companies and the state forest corporation to assert their land claims, and the uprooting of these trees by peasants. Merely framing these cases as (static) situations of tenure insecurity understood as the risk of eviction and analysing its effects on individual land use decisions assuming profit maximisation would not sufficiently grasp these strategic interactions that are so crucial in trying to understand the causes of LUCC and of current land uses. Framing tenure contestations as situations of a lack of tenure security, understood as the uncertainty that existing tenure rights are upheld by society, also carries the risk of a partial analysis and raises critical questions about *whose* tenure rights are to be upheld. Instead, analysing the driving forces of LUCC in case of tenure contestations requires a process-oriented approach that takes into account the dynamically unfolding relations between and the strategic interactions of the conflicting actors and the historical trajectories that have led to and that shape the dynamics of tenure contestation.

The case studies presented demonstrate that neglecting historical trajectories can easily result in misleading conclusions. Depending on the time scale and depth of analysis, the cases of LUCC presented in this paper could be related to different drivers. Based on a superficial, snapshot-like look at the present situation or the situation in the early 2000s, the prevailing land use patterns could erroneously be attributed to peasants' limited knowledge of more sustainable farming practices. They could also be understood as illegal squatting of state forest and plantation land and misleadingly framed as being a result of 'population pressure' – a commonly held argument on the densely populated island of Java. Framing some of the LUCC of the past few years in terms of tenure (in)security, which refers to the upholding of existing tenure rights, and analysing its effects on the land use decisions of assumingly profit-maximising individual farmers would yield additional insights, particularly with regard to the effects of a resolution of the tenure contestations on land use. However, to gain a more complete and more realistic understanding of the causes of the LUCC observed, it is necessary to conceptualise the situation not only in terms of *the upholding of existing tenure rights*, but to analyse *the processes of struggle over such rights*. It requires taking into account the historical trajectories of tenure changes and contestation, related socio-political developments, and the emerging roles of and interactions between actors. It then appears that the LUCC are an integral part of historically rooted land contestations. They are the direct result of and a strategy in contentions over political histories of disappropriation. Forest logging and burning and the planting of crops or trees are the competing actors' strategic political acts of contestation. The outcomes of these acts of contestation are visible as LUCC in satellite images.

The identification of LUCC in satellite images was the starting point of the research and led to the uncovering of the cases of tenure contestation presented here. Though in some of these cases occasional tree planting was observed as a strategic act of contestation, the tenure contestations generally transformed forests or plantations into widely treeless landscapes. In the satellite images, some of these landscapes of contestation appeared like 'scars' surrounded by areas with more vegetation cover. Following the resolution of the tenure conflicts, some of these widely treeless landscapes are being converted either into mosaics of peasants' terraced rice fields and mixed forests or back into densely planted (rubber) plantations.

The recent or future LUCC induced by a resolution of the tenure contestations can be framed by notions of tenure (in)security. The granting of land certificates, and the expectation thereof, influenced peasants' land uses. Some of the cases presented provide limited support to the finding of Kusters et al. (2007) and Wannasai and Shrestha (2008) that it is not necessarily the legal status of the land but the feeling of tenure security that already affects farmers' land use decisions: In case of the two contested areas near Banjaranyar, the farmers already began planting some trees after the SPP had started to support their struggle for formal land rights. However, the peasants' feeling or expectation of tenure security alone does not sufficiently explain these early tree plantings: In this and in the other cases, the planting of the first few trees and the building of the first few field terraces by the farmers prior to the granting of land certificates was to some extent also a strategic act to improve their prospects in the land contest, because the common argument that farmers' cultivation practices run counter to soil and watershed conservation aims could discredit their struggle for land rights. However, in general, tree planting and land terracing remained limited in all cases until the farmers were granted land certificates and were considerably advanced thereafter. Despite the latter, the resolution of land contestations and secure tenure are a crucial, but not necessarily a sufficient determinant for soil conserving land uses. While much of the farmers' private land in the study region comprises soil-conserving terraced rice fields and dense, multi-storeyed mixed forests, also erosion-prone plots with annual crops on slopy land exist, although their proportion is declining.

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Supplementary material [see electronic file]

Supplementary Material 1: Contested land at Karangiengkol north of Sawangan

Land cover change caused by tenure contestation: Peasants have cut down the cocoa stand of a former plantation and cultivated the land with annual crops to demonstrate their land claim. Following the provision of land certificates, they started planting trees and building field terraces. Photo: Martin C. Lukas, 30. May 2008.

Supplementary Material 1: Contested land at Karangiengkol north of Sawangan

Following the provision of land certificates, large parts of the cleared landscape of contestation are being transformed into a mosaic of terraced rice fields, newly planted mixed forests and agroforestry systems. A few non-terraced erosion-prone plots remain. Photo: Martin C. Lukas, 4. February 2011.

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Research Paper 6

Lukas, M.C. Watershed conservation in Java, Indonesia: Trapped in a tenure dichotomy.

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Abstrak (Abstract, translated into Indonesian)

Berbagai upaya telah dilakukan selama beberapa dekade untuk melawan degradasi daerah aliran sungai dan lahan di Pulau Jawa. Namun, banyak daerah aliran sungai dan lahan tetap terdegradasi. Makalah ini menunjukkan rumitnya hubungan pengelolaan daerah aliran sungai dengan dikotomi antara lahan hutan negara dan lahan pribadi petani, serta upaya untuk mempertahankan dikotomi itu, yang mengacaukan hasil upaya pengelolaan daerah aliran sungai tersebutterhadap lingkungan. Di sejumlah lahan hutan negara, tutupan pohon menurun dan degradasi meningkat sejak akhir tahun 1990an sebagai akibat dari sengketa sumber daya hutan antara petani dan perusahaan hutan negara. Sebaliknya, di lahan pribadi petani, tutupan pohon meningkat pada periode yang sama, dan konservasi tanah semakin baik. Upaya konservasi tanah dan daerah aliran sungai terus berfokus di lahan pribadi petani, sedangkan tingkat degradasi di hutan negara bergantung pada kemajuan sengketa antara perusahaan hutan negara dan petani. Sengketa ini dimediasi melalui program hutan rakyat. Kinerja program ini dalam membangun kepercayaan dan rasa memiliki di pihak petani tetap terbatas. Hal ini terlihat dari tutupan pohon terbatas dan penanaman tanaman dengan konservasi tanah yang rendah, yang mengakibatkan erosi. Makalah ini menganalisis penyimpangan kecenderungan tutupan lahan dan tingkat degradasi di lahan hutan negara dan lahan pribadi petani, penyebab, dan keterkaitannya. Makalah ini kemudian mengungkapkan perangkap yang merusak lingkungan pada sistem konservasi daerah aliran sungai dalam dikotomi rezim kepemilikan lahan serta membuka perdebatan tentang kemungkinan solusi. Perdebatan tersebut harus menghubungkan tujuan dan strategi perlindungan daerah aliran sungai dengan pengaturan (ulang¬) pola akses dan kendali hutan.

Kata Kunci

Hutan rakyat, pengelolaan hutan, tata kelola hutan, kepemilikan lahan, kepemilihan hutan, perubahan penggunaan lahan, perubahan tutupan lahan, degradasi lahan, pengelolaan daerah aliran sungai, Pulau Jawa, Indonesia

Watershed conservation in Java, Indonesia: Trapped in a tenure dichotomy

Martin C. Lukas[1]

Abstract

Substantial effort has been invested over the past decades to combat land and watershed degradation in Java. Yet, many lands and watersheds remain degraded. This paper shows that the entanglement of watershed management with the dichotomy between state forest land and peasants' private land and with struggles to uphold this dichotomy undermines the environmental outcomes of watershed management efforts. On many state forest lands, tree cover has declined and degradation increased since the late 1990s as a result of struggles between peasants and the state forest corporation over forest resources and their control. Conversely, on peasants' private lands, tree cover has increased over the same period, and soil conservation has improved. While soil and watershed conservation efforts continue to focus on peasants' private lands, the levels of degradation in state forests depend on the course of the struggles between the state forest corporation and peasants. These struggles are mediated by community forestry programmes. Their performance in building trust and a sense of ownership on the side of the peasants remains limited. This is reflected in scattered tree cover and crop cultivation with limited soil conservation, resulting in erosion. The paper analyses the diverging trends of land cover and degradation levels on state forest lands and on farmers' private lands, their causes and their linkages. It then exposes the environmentally detrimental entrapment of the watershed conservation regime in the dichotomy of the tenure regime and opens a debate over possible solutions. Such a debate must link watershed protection aims and strategies with future (re-)arrangements of the patterns of forest access and control.

Keywords

Community forestry, land degradation, watershed management, forest management, Indonesia

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1 Introduction

Land degradation in the uplands of the Indonesian island of Java has long been a subject of concern and of nationally and internationally funded political interventions and research. The negative effects of deforestation, agricultural expansion and soil erosion in the uplands and their impacts on water flows and irrigation schemes downstream were already debated in the early 20th century (see e.g. Coster 1936, Coster 1938, de Haan 1936a, 1936b, Oosterling 1927, Zwart 1928). From early on, these debates were linked with calls for the expansion and professional management of state forest territories (see e.g. Kerbert 1916, Zwart 1928, 1932). The state forests and their professional management by the state forest corporation have been regarded as the foundation and epitome of watershed protection up to the present (also see Galudra & Sirait 2006). This perspective shapes watershed management-related debates and political action. It is also reflected in the subordination of the watershed management agency under the Ministry of Forestry and in statistics that equate forest cover with the state forest territory (e.g. BPS 2015, Departemen Kehutanan 2002, Ministry of Forestry 2014, Verburg et al. 1999) without accounting for the forests on peasants' private lands which in fact cover substantial parts of the island.

While the management of the state forests has been completely entrusted to the state forest corporation, watershed protection efforts and related research have mainly targeted peasants' private lands over the past decades. Based on the assumption that upland peasants' rainfed agricultural plots constitute the single-most important source of riverine sediments and that upland agriculture exacerbates the seasonality of stream flows, substantial national and international funds have been invested into tree planting and soil conservation programmes, targeting farmers' private lands. The expansion of rainfed agriculture on slopy land since the late 19th century has undeniably raised erosion rates and reduced soil fertility in parts of the island (see e.g. Barbier 1990, Donner 1987, Magrath & Arens 1989, Nibbering & Graaff 1998, Palte 1989, Purwanto 1999, Repetto 1986, Rudiarto & Doppler 2013, van Dijk et al. 2004). Increasing tree cover and/or promoting other soil conservation measures on farmers' private lands are hence undoubtedly desirable and necessary.

However, the sole focus of debates, political action and research on upland farmers' private plots has long distracted attention from exploring and addressing the whole range of sediment sources (see also Diemont et al. 1991, Lukas 2015, Schweithelm 1988, 1989). For example, the roles of roads, trails and settlement areas as important sources of riverine sediments have been analysed only relatively recently (see e.g. Rijsdijk 2005, Rijsdijk et al. 2007a, Rijsdijk et al. 2007b).

Also, state forest territories deserve more attention in debates over watershed protection. The high erosion rates in some of the one-age cohort teak plantations, which dominate many state forest lands, have been largely excluded from political debates, though they have been acknowledged or analysed by a few scholars (e.g. Carson 1989, Widjajani et al. 2011, Wolterson 1979). In addition, soil erosion caused by rotational clear cuts, the state forest corporation's standard harvesting method all over Java, has to my knowledge not been the subject of any debate or inquiry. More importantly, struggles over the access to and control of state forests are a major cause of land degradation. The exclusive management of the state forest territories by the state forest corporation was met with resistance and challenged by peasants throughout the 20th century (see Peluso 1992 for a comprehensive account), resulting in degradation (see e.g. Nibbering 1988). Following the fall of General Suharto's New Order regime in 1997/98, large tracts of the state forests were cut down by the population. Many of these areas have since remained in a state of degradation. These degraded forest lands constitute one of the most important sediment sources. Yet, this issue has barely been debated openly in the context of watershed protection.

This paper shows that the entanglement of the watershed protection regime with the division into state forest lands and peasants' private lands undermines its effectiveness with regard to environmental outcomes. Watershed protection has historically been marked by two approaches: (1) professional management of the state forest territories by the state forest corporation and minimisation of degradation resulting from illegal use of resources by peasants, and (2) increasing tree cover and reducing soil erosion on peasants' private lands. The second is intended to contribute to the first through improving rural livelihoods and reducing the need for peasants to enter state forest land. However, the failure of the first has, together with other factors, contributed to the recent success of the second. While tree cover on state forest land was drastically reduced in the late 1990s and early 2000s and has remained relatively low in some of these areas, tree cover on farmers' private lands has in many areas increased since the early 2000s.

Following a brief outline of the research context and methods, the next two sections explore these diverging developments, their causes and related challenges separately for state forest lands and farmers' private lands. The final section links these developments, exposes the environmentally detrimental entrapment of the watershed conservation regime in the dichotomy of the tenure regime, and explores related challenges and future perspectives.

2 Research context and methods

The research presented in this paper is part of a larger research endeavour that explored watershed characteristics and transformations with a particular focus on land use and land cover change (LUCC) and its drivers as well as watershed and forest governance in the catchment area of the Segara Anakan lagoon. This shallow coastal lagoon on the south coast of Java (see Figure 1) has rapidly shrunk due to riverine sediment input (see Lukas 2014a), which has contributed to profound social-ecological transformations (see e.g. Ardli & Wolff 2009, Olive 1997, Purba 1991, White et al. 1989, Yuwono et al. 2007). These transformations, together with longer-standing political interests and previous interventions in the region have provided the rationale for particularly strong watershed conservation efforts in the lagoon's catchment area (see Lukas & Flitner 2015). The following sections present results of my catchment-wide analysis of LUCC, based on a visual analysis of a series of satellite images and land use and land cover mapping, and social-scientific case studies that explored the drivers of these changes. These case studies aimed at covering different parts of the catchment area, some of the hotspots of LUCC and a range of different dynamics. They comprised land use / cover mapping and transect walks and interviews with village representatives, farmers, elderly people and other village residents as well as with representatives of district-level governmental organisations, non-governmental organisations (NGOs), and the state forest corporation.

3 State forest land

Many of the LUCC areas that I detected throughout the catchment area of the Segara Anakan lagoon are situated within state forest territories. State forest territories also comprise a major proportion of the erosion-prone land within the catchment area. They are visibly one of the most relevant sediment sources contributing to high river sediment loads. Besides rotational clear cuts, which are the common management practice of the state forest corporation, struggles over the access to and control of state forest land and trees are the major cause of LUCC and land degradation in these territories. Following a history of exclusive and repressive management of these territories by the state forest company, many state forest lands were deforested by the people during the political reformation following the fall of the Suharto regime in 1997/98. Reduced tree cover and the cultivation of annual crops result in erosion in some of these areas. Community forestry schemes are the main strategy to resolve conflicts between the state forest company and the people, to combat illegal logging and to establish a socially, economically and environmentally more sustainable forest management regime. Their success remains to be seen.

The following sections explore these issues based on the empirical results of a number of my LUCC case studies. The findings of the individual case studies related to state forest largely support each other. The following account mainly combines results from case studies conducted in the areas surrounding the villages of Sawangan (sub-district Jeruklegi), Binangun (sub-district Kawunganten) and Kertajaya (sub-district Gandrungmangu), all located approximately 10-20km north of the Segara Anakan lagoon within the district of Cilacap and the province of Central Java (Figure 1).

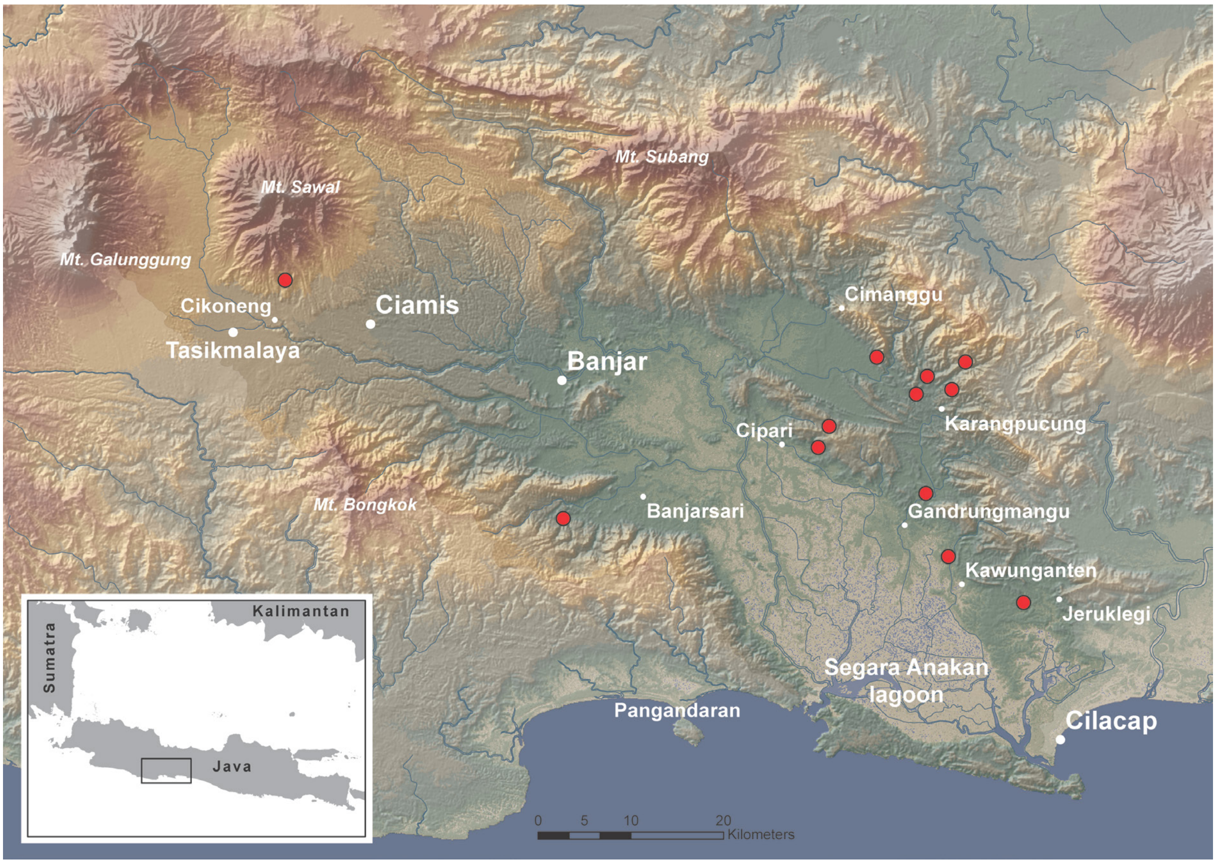

Figure 1: Location of the study area (red points mark the locations of the case study villages)

3.1 Historical background: repressive forest management

Most of the contemporary state forest land in the case study areas, as in most of Java, was demarcated as such by the colonial forest administration (see Peluso 1992 for a comprehensive historical account). Between the 1940s and 1965, some of these territories were temporarily cleared and used by peasants for crop cultivation. The eldest of my interview respondents remembered that during the Japanese occupation from 1942 until 1945, peasants cleared and used large tracts of the state forest territories surrounding their villages. This was encouraged by the Japanese occupying forces to meet increasing timber demands and to raise rice production (as was also described by Satō 1994). During the early years of national independence which followed, many of these lands were reforested. For example, the state forest land around the village of Sawangan was planted with teak in 1948. In the late 1950s and early 1960s, some of the state forest territories were cleared again and used by peasants for crop cultivation. This was encouraged by land reform movements, which were connected to the Communist Party of Indonesia (PKI, Partai Komunis Indonesia). They promised village residents ownership of state forest land.

This situation abruptly changed in 1965 when General Suharto took over national political power. The state forests were henceforth strictly and exclusively managed by the state forest company. The degree to which the residents of forest margin villages were excluded from using resources from the state forests varied between localities, and was dependent on the forest guards and their relations with village residents. Some of my respondents recounted that they were allowed to collect firewood for free; some respondents remembered that they had to pay informal 'fees' to the forest guards; while others noted that they were not allowed to take any firewood at all. Extracting timber was not allowed anywhere, but thefts occurred and caused forest degradation in some localities, though on a relatively small scale.

Among the villages covered by my case studies, the tension between residents and the forest company and its guards was most severe in Sawangan. The village is entirely surrounded by state forest territory. Elderly residents recounted that in the 1960s the comparably small number of residents were still able to more or less sustain their living based on the village land between these state forest territories and their additional crop cultivation on state forest land during the first years after the planting of new trees. This intercropping between the newly planted trees (*tumpangsari*) was allowed and was part of official forest management plans. Yet, sometimes the peasants had to pay informal 'fees' to the forest guards to be allowed to cultivate crops in the frame of *tumpangsari*. As the village grew larger and the areas that could be used for *tumpangsari* were increasingly limited due to the long rotation period of teak, the residents of Sawangan found it more and more difficult to sustain their living. This contributed to increasing tensions between the residents and the forest company. The residents were afraid of the forest guards, and sometimes people were arrested for minor thefts. In Sawangan, the people were afraid of taking even small branches. One of my respondents recounted how, when he was a child, he and his friends sometimes climbed trees and broke branches and then quickly ran away when the forest guards appeared. The regularly occurring minor thefts did not considerably reduce tree cover in this area, as was reported from other parts of Java (Nibbering 1988, Nibbering & Graaff 1998). This abruptly changed in 1997/98.

3.2 State forest territories turned into degrading lands

Following the fall of President Suharto's New Order Regime in 1997-98, many state forests throughout the catchment area of the Segara Anakan lagoon were plundered. Most families from the forest margin villages, as well as people from nearby towns like Wangon and Purwokerto, and also individuals who worked as staff members of governmental organisations, the state forest corporation, the police, and the military, participated. Depending on their skills, resources and networks, these different actors engaged in felling, processing and transporting the timber, provided trucks and chainsaws, traded or processed the timber, or provided protection from law enforcement efforts. The latter was often ensured by individuals who worked for the state forest corporation, the police and the military. Some of my respondents described the networks between the various actors involved in illegal logging as a 'mafia' (Rosyadi et al. 2005 also described illegal logging networks as a 'mafia'). Forest guards or police brigades who were tasked to intervene were unable to stop the plunder, were afraid themselves, were sometimes attacked, or were paid off. Yet, violent encounters occurred. For example, a village resident of Sawangan was shot by a forest guard.

A large proportion of the people of some of the forest margin villages participated in the plundering. One respondent noted that "Everybody here is actually a thief" (Interview, 8. February 2011). Talking about the motivations behind village residents' participation in the plundering of the state forests, some of my respondents noted that the people wanted to get the timber which they had not been allowed to access before, that they wanted to make money, but that they also wanted to demonstrate their power. One village resident of Sawangen noted that "Perhutani [the state forest corporation] had been perceived as a superpower before 1997 and appeared very weak thereafter" (Interview, 3. February 2011). A resident of Kertajaya said that "The people wanted to show that they have the power now" (Interview, 25. November 2009).

The plundering of the state forests peaked between 1999 and 2004. A representative of the sub-district administration of Jeruklegi estimated that about half of the state forests of the sub-district were cut down. His estimate corresponds with the changes that I identified in the satellite images. In some state forest areas, logging went on until no tree was left, '*sampai habis'* (Indonesian expression for 'until nothing is left') as many respondents stated. One village resident noted that even firewood became scarce as a result. The valuable teak trees were the main target of the loggers. In contrast, the pine forests, which were particularly widespread in the uppermost parts of the catchment area, in the districts of Ciamis and Tasikmalaya, were largely spared.

The logging of the state forests not only provided many people with quick income and the possibility to acquire new teak furniture. It also altered the power relations between the state forest corporation and village residents, and left behind critical erosion-prone land. Without being asked, a number of residents of Sawangan stated that they had observed reduced dry season water flows in streams and noted that their wells were increasingly short of water during the dry season. They also observed that the river bed was raised due to increased sediment input. They regarded these changes as being a result of logging and crop cultivation in the state forest territories. Residents of Binangun also attributed more frequent flooding to the degradation of the state forest land. Residents of Kertajaya mentioned a number of landslides following the plundering of state forests. The same was observed by residents in the sub-district of Banjarsari in West-Java. A representative of the forest and agricultural extension office of the sub-district of Kawunganten, who had intimate knowledge of the area, rated state forest land as the most significant source of riverine sediments. Whether and when this will change depends on the course of the ongoing struggles over new modes of forest governance, i.e. new forms of access to and control over forest resources and on the further development of relations between the state forest corporation and forest margin village residents. The performance of community forestry programmes, which have been established for many state forests in the catchment area of the Segara Anakan lagoon and all over Java to tackle these conflicts, deserves particular attention in this context.

3.3 Towards new modes of forest governance

Since the large-scale forest plundering between 1999 and 2004, some state forest lands have been claimed by peasants who demand land ownership rights, arguing that they or their ancestors had been illegitimately displaced from these lands in the 1950-60s (Lukas 2014b). On most other state forest lands attempts have been made at reforestation. The state forest corporation followed two major strategies to reforest, regain control and combat timber thefts: (1) replacing teak by pine forests, which are less prone to timber thefts, and (2) establishing community forestry programmes. The planting of pine seems to effectively halt illegal logging, but has been met with criticism in some forest margin villages, since pine forests reduce stream water flows and hence threaten wet rice cultivation (see Lukas 2015). Most state forest territories covered by the case studies presented here have been replanted with teak, sengon (Albizia chinensis) and other timber species and are covered by community forestry programmes (PHBM, *Pengelolaan Hutan Bersama Masyarakat*).

3.3.1 Establishment and formal regulations of the community forestry programmes

The official goals of the community forestry programmes are to protect state forests and to enhance human welfare in forest margin villages. Different conclusions have been drawn as to the extent that PHBM programmes have induced a shift from the previous top-down oriented forest management regime towards more participatory bottom-up approaches. While Rosyadi et al. (2005) described cases where groups of village residents together with NGOs actively shaped the process of PHBM design and implementation, Maryudi (2012) described the programmes as a top-down oriented instrument of the state forest corporation to regain control over the state forests.

In the villages covered by my case studies, the state forest corporation initiated the establishment of PHBM programmes. Information meetings (*sosialisasi*) and consultations started around 2003. The logged-over forest areas were surveyed, and management plans were drawn up. All village residents could register to become members of a community forestry group (LMDH, *Lembaga Masyarakat Desa Hutan*). These groups were to select a representative (*Ketua LMDH*), who is responsible for facilitating the groups, overseeing implementation of activities and communication between the state forest corporation and the groups, and for monitoring programme performance and compliance. It proved difficult to gain detailed insight into the specific procedure of how the group representatives were determined and which role the state forest corporation and village residents played in this process. However, it was obvious that in some cases former staff members of the state forest corporation were selected as group representatives since they took the initiative in facilitating the process and due to the experiences and contacts they had from working with the forest corporation. This was viewed critically by some residents in one of the case study areas.

A contract between the state forest corporation and the LMDH regulates the rights and responsibilities of and the revenue sharing between the different parties. In the villages covered by my case studies the first contracts were signed in 2005. Additional state forest areas were incorporated into the programme until 2009. The entire state forest territory that administratively belongs to the village of Sawangan is now covered by PHBM. About half of the families of Sawangan are members of the LMDH. Also, most of the partly heavily deforested and degraded state forest territory west of Kertajaya is covered by a PHBM programme, in which about 300 peasants from Kertajaya participate.

The selection of the tree species to be planted in the PHBM areas and the management plans and harvest times continue to be under the responsibility of the state forest corporation, although representatives of the latter stated that the concerns of the communities are taken into account. The state forest corporation provides the tree seedlings. The LMDH farmers plant these trees, are responsible for safeguarding them, and receive a share of the revenue when the trees are harvested. In addition, they can cultivate annual crops of their choice, fruit trees, coffee, cocoa, or forage grass under the tree canopy and collect firewood. In both Sawangan and Kertajaya, each peasant has these rights for an area of 0.25ha within the state forest territory. The entire harvest from annual crops, coffee, cocoa and fruit trees belongs to the LMDH farmers. The revenue of the timber trees is shared between the state forest corporation, the LMDH farmers, and the villages. There are different revenue sharing schemes, depending on the tree species and the LMDH groups.

In the case of sengon (Albizia chinensis) in Sawangan, the state forest corporation receives 45% of the revenue; the individual LMDH farmers receive 35%; and the village community as a whole receives the remaining 20% (Figure 2). The latter shall contribute to community development and can be used, for example, to improve village schools, to buy school books or to provide education grants, to organise training for farmers, to set up village nurseries, or to establish mushroom cultivation as an additional source of income. In the case of teak, the state forest corporation receives a larger share of the total revenue (Figure 3). This was explained by the fact that the teak stands had already been planted by the state forest corporation prior to the establishment of PHBM.

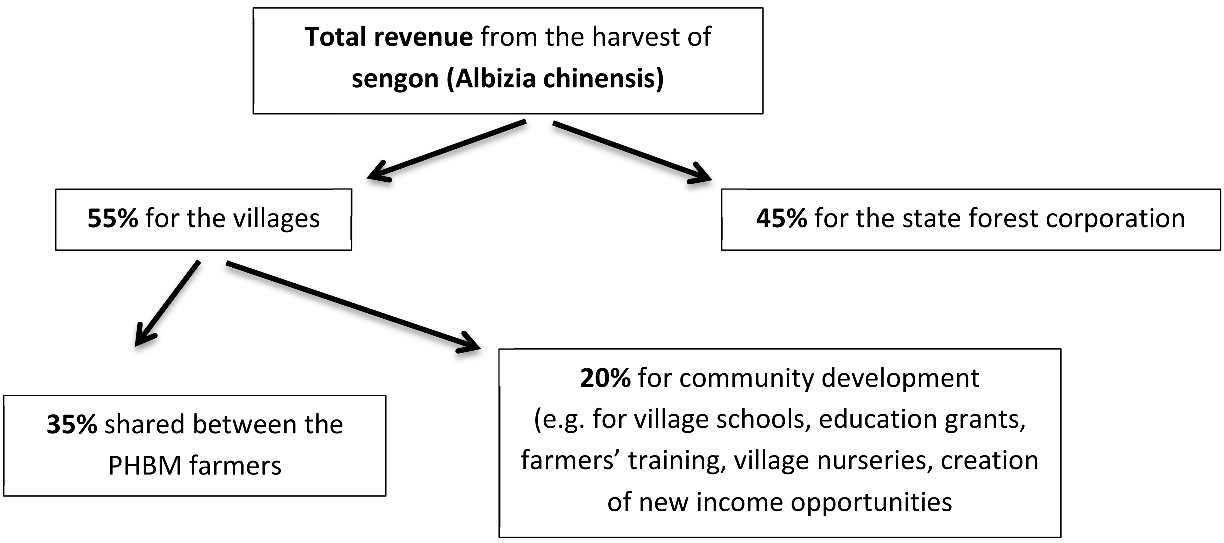

Figure 2: PHBM revenue sharing scheme in the case of sengon (Albizia chinensis) in the village of Sawangan.

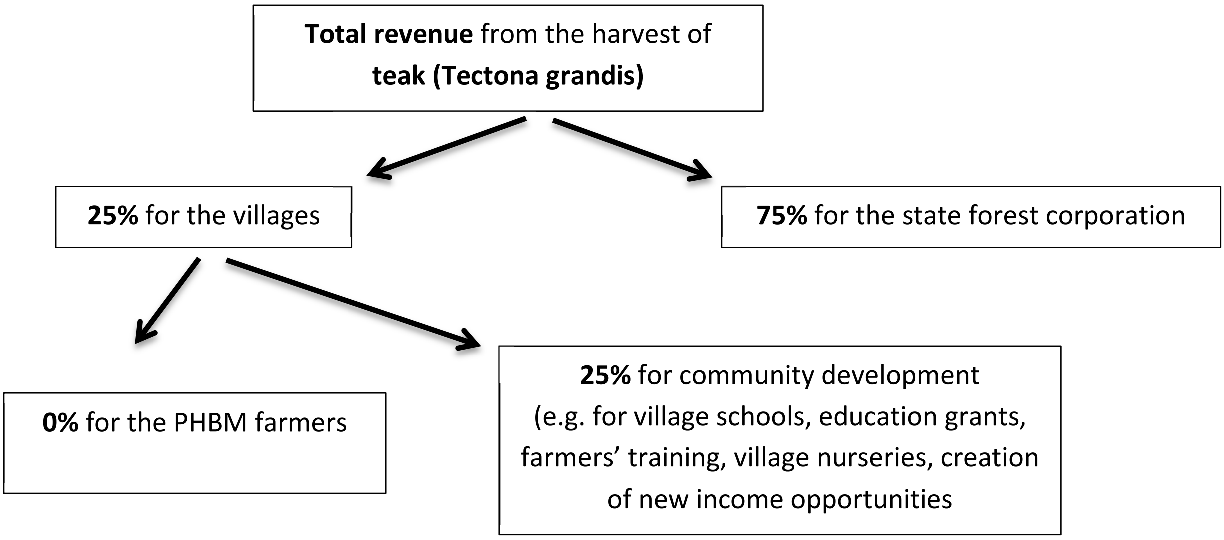

Figure 3: PHBM revenue sharing scheme in the case of teak (Tectona grandis) in the village of Sawangan.

Depending on the tree species and the revenue sharing scheme, the LMDH farmers and the state forest corporation have different responsibilities for tending the trees. In the case of sengon, the LMDH farmers of Sawangan are responsible for tending (such as thinning and pruning). In the case of teak, the state forest corporation pays the LMDH farmers for carrying out particular tending activities. Like the revenue sharing schemes, these responsibilities also differ between villages.

To raise the incentive for the communities to safeguard the trees and hence to combat illegal logging, the state forest corporation makes the revenue sharing dependent upon the preservation of the trees. If, for example, in the case of sengon 55% of the trees have been logged illegally, the state forest corporation receives its regular share of 45% (i.e. in this case the entire harvest), while the LMDH farmers and the community receive no share of the revenue from the timber harvest. The representatives of the community forestry groups (*Ketua* LMDH) are responsible for monitoring the planting and the maintenance of the forest stands and, if necessary, for taking measures to combat illegal logging. They are the “watchdogs”, as one village representative aptly noted. From time to time, the forest stands are also monitored by the state forest corporation’s forest guards. Prior to the establishment of PHBM, forest protection had been completely under the responsibility of these forest guards and the forest police. With PHBM, this responsibility has been devolved to the LMDH farmers and their representatives.

Overall, the LMDH farmers and village representatives rated the establishment of the PHBM programmes as a positive development. The programmes provide the opportunity to legally use state forest territory for crop and forage grass cultivation, to collect fuelwood, to receive a share of the revenue from the trees and funds for community development. However, some PHMB farmers and their representatives also expressed concern that it would still take a long time until the trees are harvested and revenues shared (especially in the case of teak) and that they had to carry most of the effort of and the entire risk related to the guarding of the trees. This remains a major challenge, as the following two sections explore.

3.3.2 (Need for) altered relations between the state forest corporation and communities

These new modes of forest governance with shared responsibilities and shared profits require altered relations between the state forest corporation and the residents of forest margin villages. The transformation of the forest corporation from a top-down, repressive power apparatus that defends the state forests through the force of arms into an entity that successfully manages state forest lands in collaboration with village residents requires time, as does the building of trust between the forest corporation and village residents. The political reformation and the large-scale plundering of the state forests in the late 1990s and early 2000s abruptly altered power relations and left behind critical erosion-prone land. The building of trustful relations and the transformation towards more sustainable modes of forest management require more time.

The relations between the state forest corporation and village boards and residents have undoubtedly improved. The residents and representatives of the villages covered by my case studies explained that prior to 1997 there was barely any communication between the state forest corporation and the villages, and if there was, it took the form of confrontation. This has started to change. As a village representative noted, “Perhutani is friendlier to the community now, and the punishment of illegal loggers is less violent” (Interview, 23.11.2009). Prior to political reformation, village communities were practically irrelevant for the management of the state forests. The spatial units of the state forest administrative system do not conform to the spatial units of the administrative system of villages and districts. Village boundaries within the state forest territories were thus irrelevant. Forest management plans were set up for different units across a number of villages, and the space of operation of forest guards as well as the employment of forest labourers was entirely independent of the administrative boundaries of the villages. In contrast, the PHBM programmes have rendered village communities and village boundaries relevant. The LMDH groups are formed at the village level, and hence forest management, benefit sharing schemes and monitoring are organised village-wise. This partial spatial re-organisation of forest governance contributes to and is part of the strengthening of the role of village communities.

Notwithstanding these changes, many residents and representatives of village boards and NGOs described communication and collaboration with the state forest corporation as being more difficult than with other state organisations. The forest corporation was often described as a state within the state; as a part of the former authoritarian state regime that has seen less reforms and that is still more top-down oriented and more intransparent than other parts of the state administrative system. My own experiences in conducting my field research confirm these views. Notwithstanding some exceptions, representatives of the state forest corporation often avoided sharing information and opinions during interviews. Researchers, NGO members or peasants are commonly ‘ping-ponged’ back and forth between different administrative centres of the corporation. My observations of meetings between representatives of the state forest corporation and village residents also suggest that the building of more trustful relations and communication patterns would be supported if the power divide still felt by both of these parties could be reduced.

Apart from the need to combat illegal logging, the state forest corporation’s aspiration to receive certification by the Forest Stewardship Council (FSC) has certainly contributed to its efforts to improve its relations with the residents of forest margin villages and to improve the performance of the PHBM programmes. Two forest management units were to receive FSC certification in 2008.

However, shortly before the certification was granted, a staff member of the state forest corporation shot a village resident. This incidence delayed the granting of FSC certification by several years.

By largely devolving the task of forest monitoring and guarding to the LMDH groups and by associating its former forest police with the regular state police forces, the state forest corporation has largely shed its previous responsibility for control and enforcement. Yet, fractions of its former power apparatus continue to exist in the frame of the community forestry programmes. Besides the LMDH groups, the PHBM programmes comprise a 'communication forum', whose members include the sub-district-level police and military forces. Also, staff of the former forest police, which are now associated with the regular police forces, continue to be paid by the state forest corporation. These networks of power might contradict the building of trustful relations with forest margin residents within the community forestry schemes.

Similarly, corruption within the PHBM programmes certainly undermines the building of trustful relations. One Ketua LMDH noted that he was supposed to receive a regular payment from the state forest corporation as compensation for his effort in facilitating the PHBM groups, in monitoring the planting and tending of trees and in guarding the forests, but that he had never received his payment. He was convinced that his payment was diverted into the pockets of staff members of the state forest corporation. The same Ketua LMDH decided then to collect informal payments from the LMDH farmers. He asked them for a payment of 25kg of rice per 1 bau of state forest land that the farmers cultivated. He noted that the farmers were used to paying informal fees to the forest guards in order to receive cultivation rights; that it had been common previously to give gifts to the staff members of the forest corporation as a 'Thank you'. Thus, not only fractions of the old power apparatus, but also corruption lives on in the community forestry schemes, potentially undermining the building of trustful relations, which certainly is an important foundation for the sustainability of the schemes.

3.3.3 Environmental sustainability: The major challenge of the community forestry programmes

With regard to environmental sustainability, the performance of the PHBM programmes is still unsatisfactory to date. The programmes have undoubtedly contributed to reducing illegal logging. This was confirmed by various respondents. One Ketua LMDH noted that "Without PHBM the forest would not be safe" (Interview, 5. February 2011). However, a number of respondents also pointed out that timber thefts were limited simply because there were barely any larger trees remaining on the land, and that timber thefts might occur on a larger scale again once the currently small trees have grown. It was also reported that some of the teak trees which were small at the time of the large-scale plundering in the late 1990s and early 2000s and which would have now been 10-20 years old, had disappeared, and that smaller trees were already being felled and used as fuelwood. In the case of teak planted prior to the establishment of PHBM, the small share of revenue dedicated to the community (see Figure 3) might not provide enough incentive to the farmers to refrain from felling trees. Many PHBM farmers also aim at increasing the area for crop cultivation at the cost of tree cover. This results in comparably high levels of soil erosion, since in contrast to most of the farmers' private lands, the state forest land that is used for crop cultivation is not terraced. To enhance the conditions for the cultivation of annual crops, revenue from which they do not have to share with the state forest corporation, the farmers uproot tree seedlings or cut some of the small trees which are viewed as belonging to the state forest corporation (Figure 4). These practices are clearly not only related to some of the farmers' need for regular annual incomes from annual crop cultivation. These practices are also rooted in the historically grown habitual distrust and confrontation between peasants and the state forest corporation. For example, a number of PHBM farmers expressed their scepticism as to whether they will truly receive any share of the revenue from the timber trees. Given this distrust and the lacking sense of ownership for the trees some farmers aim at limiting tree cover and refrain from protecting the trees when using the land for animal grazing. Consequently, the environmental sustainability of the PHBM programmes not only depends on the rights, regulations and revenue sharing schemes formally defined in the contracts, but also on the further development of trust, communication patterns and power relations.

Figure 4: Reduced tree cover on state forest land (Photo: M.C. Lukas, February 2011)

To raise the PHMB farmers' sense of ownership, increase tree cover, and reduce environmental degradation, a new scheme complementing the existing PHBM contract was planned for introduction in Sawangan at the time of field research. The PHBM farmers would be allowed and encouraged to plant additional trees themselves of their own choice in between the existing trees. In this way, the 'primary' tree species whose selection, management and harvest time is largely under the responsibility of the state forest corporation, would be complemented by a 'secondary' layer of trees, which might comprise a variety of species, such as fruit trees, coffee, teak, and sengon, and whose selection, management and harvest would be the responsibility of the PHBM farmers. Revenue sharing from the 'secondary' trees was planned as follows: 45% for the PHBM farmers, 20% for the community, and 35% for the state forest corporation. This scheme can be seen as a next step towards potential further devolution of state forest management to the communities: the state forest corporation largely confines its role to providing the land and receiving a share of the revenue, while the peasants themselves select and manage the trees.

Whether this new scheme will contribute to increased tree cover and reduced erosion potential remains to be seen. To date many PHBM farmers refrain from planting their own trees on state forest land even under the new scheme, since they do not have any sense of ownership of the land, their plots are not clearly demarcated and protected and they therefore fear that their trees and the fruits will not be safe.

The community forestry programmes have reduced, although not stopped, illegal logging on state forest territories. They give the residents of forest margin villages the possibility to use state forest land for crop cultivation, thereby enhancing their income and food security. The programmes also involve residents to varying degrees in the different aspects of tree management and protection, and provide them with a share of the revenue. Yet, the programmes have not (yet) succeeded in establishing trustful relations between the actors and in creating a sufficient sense of ownership of the land, the trees, and of forest management affairs on the side of the peasants. As a result, many state forest territories continue to be marked by high levels of soil erosion. The combination of scattered tree cover and crop cultivation without or with only limited soil conservation measures makes state forest territories in some areas a more important source of riverine sediments than farmers' private lands. While erosion in state forest territories is left to the course and outcome of struggles between the state forest corporation and peasants, erosion on peasants' private lands has been directly addressed by watershed protection programmes for decades. Contrary to state forest land, tree cover on farmers' private lands has been increasing since the early 2000s. The following section explores these developments on peasants' private lands, before the final section returns to the state forest lands and explores the environmentally detrimental entrapment of watershed protection efforts in the dichotomy between state forest lands and farmers' private lands.

4 Farmers' private land

Besides state forest territories, farmers' private lands undoubtedly comprise a major proportion of the erosion-prone land and a major source of riverine sediments in the catchment area of the Segara Anakan lagoon, as in many other parts of Java. However, in contrast to many state forest lands where tree cover was drastically reduced in the late 1990s and early 2000s and has remained relatively low in some of these areas, tree cover on farmers' private lands has in many areas increased since the early 2000s, reversing a longer-term trend of declining tree-cover. My analysis of satellite images going back to the 1970s generally showed relatively limited LUCC on farmers' private lands until the late 1990s. In a few areas, tree cover declined during this period. Since the early 2000s, however, tree cover on farmers' private lands has tended to increase. The following sections briefly explore these dynamics and their drivers, based on the empirical results of a number of case studies conducted in the catchment area. These case studies covered the following villages (see Figure 1): Surusunda, Ciporus, Bengbulang and Ciruyung (sub-district Karangpucung), Bantarmangu (sub-district Cimanggu), Karangreja and Segaralangu (sub-district Cipari), Banjaranyar (sub-district Banjarsari), Darmacaang (sub-district Cikoneng), Sawangan (sub-district Jeruklegi), and Kertajaya (sub-district Gandrungmangu).

My analysis of physical land cover changes was confined by the availability of satellite images to the period from the 1970s onwards. In the frame of the case studies, I could gather information about longer-term developments of LUCC prior to the 1970s, based on the accounts of elderly village residents. The next section briefly sheds light on these longer-term developments and the prevailing kinds of land use/cover on farmers' private lands.

4.1 Soil conserving forests and erosion-prone rainfed agricultural land

In many of my case studies, elderly village residents, referring to the lands outside the state forest territories, described a trend of declining forest and grassland areas and expanding agricultural land until the 1970s. In a few cases this trend continued until the 1980s and early 1990s.

The expansion of agricultural land in many of Java's uplands gained momentum and was particularly rapid in the second half of the 19th and in the early 20th century (Smiet 1990). The accounts of LUCC obtained in the frame of my case studies that reach the furthest back cover the early 20th century. Based on historical records and accounts of their parents, village residents and village representatives of Karangreja explained that individual in-migration of peasants from the lowlands, including from areas around Purworejo and Yogyakarta, led to reduced forest cover and the expansion of agriculture between around 1900 and the 1920s. These migrants, according to my respondents, were searching for land and wanted to escape the tax system imposed by the Dutch administration. This conforms with the dynamics in other parts of Java (see e.g. Palte 1989, Chapter 3).

More detailed accounts of LUCC obtained in the frame of my case studies cover the period from the 1950s onwards. Elderly residents recounted that in the 1950s and 1960s there was more forest around their villages than today, that there were fewer houses, and that there were still (more) wild animals, like monkeys, living in the area. A few residents also remembered that besides forests, also bush and grassland (grassland dominated by *alang-alang* = Imperata cylindrica) were more expansive at this time. Until the 1970s, and in a few areas also until the 1980s and early 1990s, the land under permanent agriculture expanded at the cost of forest, bush and grassland in many parts of the catchment area. Tree cover declined in many areas. In the cases where these developments continued until the early 1990s (e.g. in Karangreja, Segaralangu and Bantarmangu), I could detect these land cover changes in the satellite images. My respondents related these LUCC to the increasing population as a result of both natural population growth and in-migration from the lowlands. Statistical data confirms these demographic changes.

Yet, in many parts of the catchment, expansive areas with mixed forests remain. These forests are used and managed by peasants. They often comprise a diverse range of fruit and timber trees, are dense and multi-storeyed, and are usually managed by selective logging only (see Figures 5-7 for examples). Many of these forests are hence more soil-conserving than some of the one-age-cohort teak plantations that dominate many state forest territories and that are rotationally clear cut, also on steep slopes, which results in high levels of soil erosion (also see Lukas 2015). Also with regard to their species diversity, these forests are clearly more valuable than the monocultural state forests. Yet, these peasants' forests are usually not incorporated in the forest cover statistics of Java, which instead only account for state forest territories (e.g. BPS 2015, Departemen Kehutanan 2002, Ministry of Forestry 2014, Verburg et al. 1999), and their role with regard to watershed conservation has barely been acknowledged in watershed management debates.

In contrast to the large areas dominated by irrigated agriculture and the peasants' mixed forests (see Figures 5-7 for examples), permanent rainfed agriculture on slopy land tends to be marked by relatively high levels of erosion (see Figures 8-9 for examples). Its expansion at the cost of forest, bush and grassland until the 1970s (and in some areas until the early 1990s) has undoubtedly raised overall erosion rates. This was generally agreed upon by all respondents. In all areas covered by my case studies, attempts to address this issue were conducted within frame of mainly state-initiated tree planting and terracing programmes from the late 1970s and early 1980s onwards. The next section briefly sheds light on these programmes.

Figures 5-7: Much of the farmers' private lands in the catchment area of the Segara Anakan lagoon are dominated by irrigated rice fields and (often dense, multi-storeyed) mixed forests. These two types of land use are soil-conserving. (Photos: M.C. Lukas, December 2010 and May 2011)

Figures 8-9: Some of the farmers' private lands in the catchment area of the Segara Anakan lagoon comprise rainfed agricultural fields, some of which exhibit high levels of soil erosion. These areas have been targeted by field terracing and tree planting programmes. [Upper photo: The teak and pine plantations on the upper slope are part of the state forest territory, managed by the state forest corporation.] (Photos: M.C. Lukas, November 2009 and April 2011)

4.2 Tree planting programmes: Large efforts, but limited effects until the early 2000s

Programmes aimed at increasing tree cover on farmers' private lands were implemented throughout the catchment area of the Segara Anakan lagoon between the late 1970s and the time of my field research. My case studies provided insight into more than 20 different programmes. Rather than describing these programmes in detail, this section provides a brief overview of the major agencies involved, the activities carried out and the effects.

Most programmes were implemented under the Ministry of Forestry and its subordinated authorities, including the watershed management agencies. A few programmes were run in cooperation with the Ministry of Agriculture and the Ministry of Welfare. Many of my case study areas were also covered by the USAID-funded Citanduy and Citanduy II projects (Tim Koordinasi Wilayah 1989, USAID 1985) and the ADB-funded Segara Anakan Conservation and Development Project (ADB 2006, ECI 1994). Some initiatives were implemented by or in collaboration with government-owned companies (including the state forest corporation) or, more recently, with private companies (plantation and furniture companies) and NGOs.

Some of the programmes encouraged and supported farmers in terracing their agricultural land. In the 1980s, a number of model farms were established to develop and promote terracing techniques and to promote tree planting. Most programmes provided tree seedlings to the farmers, sometimes combined with fertiliser, training and funds to cover the labour costs. As an additional incentive to foster initiatives at the village level, competitions were held in the frame of some of the programmes. Also women's groups and schools were engaged in tree planting programmes. National tree planting days have been held to raise public attention and foster additional efforts.

Until the early 2000s, the effects of the various tree planting programmes were relatively limited. This was generally agreed upon by respondents across all case studies, and my analysis of the satellite images confirms this. This limited effectiveness was related by my respondents to top-down approaches in programme design and implementation as well as to farmers' limited awareness of the economic potential of trees and their reluctance to shift from annual to perennial crops, thereby taking the risk of reduced regular incomes. Referring to farmers' limited awareness of the economic potential of trees, the head of a farmers' group in Surusunda, where a model farm had been established in the 1980s, noted that "the farmers were very difficult to convince" (Interview, 24. April 2010). The top-down character and limited flexibility of many programmes contributed to the limited effectiveness (this was also noted by Purwanto 1999, Chapters 3, 4, 11, USAID 1984, 1985). It implied that the farmers were often not free to choose the tree species they wanted to plant. For example, when seedlings of fruit trees, like coconut, mango, rambutan or cashew, were distributed, the farmers in some areas were reluctant to plant them on their agricultural land since the fruit were often taken by other people and by animals. Instead, they planted a few of the trees in their house gardens. As many house gardens were already quite densely planted with trees, the effects of these programmes on tree cover remained limited.

4.3 Increasing tree cover since the early 2000s

Since the early 2000s, tree cover on peasants' private lands has increased in many parts of the catchment area. Many peasants have started to plant more timber trees, like sengon and teak, but also rubber, coffee, and cocoa. They plant more trees on their own initiative, but also the effectiveness of tree planting programmes has clearly increased. Some of the slopes in my case study areas that had repeatedly been targeted by regreening programmes for two and a half decades with very limited effects are now covered with trees.

My case studies revealed various factors that have contributed to this recent trend of increasing tree cover on peasants' private lands. Many respondents noted that the peasants had become increasingly aware of the economic potential of tree planting. It was noted that the regreening programmes that had been run previously had step-by-step contributed to farmers' awareness of the economic benefits of tree planting and of the need for soil conservation. Some respondents pointed out that the example of a few farmers who had planted larger numbers of trees in the 1980s and 1990s and reaped the first benefits in the early 2000s inspired other farmers to follow. Also, rising timber prices have played a central role. They have made cultivation of timber trees economically clearly more beneficial. It was also noted by a number of respondents that many peasants had realised that their soils were increasingly degraded after years or decades of cassava cultivation, with high levels of erosion and declining soil fertility.

Also, the presence or absence of local marketing opportunities is linked with tree cover on farmers' lands. For example, in Surusunda and Bengbulang, the presence of a number of cassava factories not only reflects but has promoted farmers' preference for cassava as the major crop. This has rendered tree planting programmes particularly ineffective. In Surusunda, the closure of the cassava factory due to its non-compliance with the environmental standards for sewage disposal prompted farmers to reduce cassava cultivation and to plant more trees. Conversely, the increasing presence of local wood processing factories was said to promote farmers' planting trees. In this way, the trend towards increasing tree cover and the growth of corresponding marketing opportunities is self-perpetuating. Also, additional off-farm employments of farmers or their family members have reduced the reliance on the annual income from crop cultivation, hence facilitating a shift from annual to perennial crops.

These various factors have considerably raised farmers' interest in planting trees, and this in turn has contributed to the improved effectiveness of recent tree planting programmes. However, recent changes in the design and implementation of the programmes have also contributed to higher levels of effectiveness. Bottom-up approaches promote initiative and a sense of ownership at the local level and ensure that the choice of species and the entire process is more tailored to farmers' preferences. For example, the 'Karet Rakyat' programme that is run by the Ministries of Forestry and Agriculture to promote rubber cultivation encourages farmers to organise themselves into groups, to negotiate with the suppliers of seedlings, to make planting, marketing and budget plans (with support from agricultural and forestry extension officers) and to submit funding proposals to the sub-district authorities. If approved, the programme covers one third of the investments costs, while the remaining part is covered by the farmers themselves. The 'Kebun Bibit Rakyat' programme that has been run by the watershed management agency under the Ministry of Forestry since 2009-10 to promote village nurseries follows a similar approach. Both programmes were viewed positively by staff members of sub-district authorities, village representatives and farmers alike.

In addition to government-run programmes, collaborations between private sector organisations and peasants, usually facilitated by village representatives and / or NGOs, have also fostered tree planting over the past few years. In one case, a plantation company provides rubber seedlings, fertiliser and training to farmers and later buys their harvest. In another, a pulp and paper company provides jabon (Anthocephalus cadamba) seedlings and fertiliser; the revenue is shared between the farmers, the entire village community and the company. In a third case, an NGO (*Bumi Hijau Lestari*), in collaboration with international furniture companies, agricultural scientists and village representatives, provides a range of seedlings, fertiliser and training to farmers and offers without obligation to buy their timber harvest later on. This initiative aims at certification via the Forest Steward Council (FSC).

5 Linkages between state forest land and farmers' private land

In analysing the causes of LUCC and in exploring the challenges and perspectives of watershed management in Java, state forest land and farmers' private land must not be looked at in isolation. This is important for three reasons. First, some of the land use and land cover patterns and changes on farmers' private land and on state forest land are linked with each other. Second, land and watershed management strategies have been and are still considerably shaped by struggles over the upholding of the tenure dichotomy between state forest land and farmers' private land. And third, comparing land use and land cover patterns and their ecological characteristics on state forest and farmers' private land opens new perspectives that appear important to consider in debates over the further development of land, forest and watershed governance. The following three sections explore these aspects.

5.1 Spatial shift of crop cultivation

While tree cover in many tracts of the state forest territory was massively reduced in the late 1990s and early 2000s and has remained relatively low in many areas, tree cover on many of the peasants' private lands has markedly increased. A large range of factors contributing to increased tree cover on peasants' private lands have been explored above. In addition to these factors, the possibility to cultivate crops on state forest territories in the frame of the community forestry schemes has encouraged peasants to plant more trees on their private lands. In this way, scattered tree cover and crop cultivation in state forest territories is causally linked with increasing tree cover on farmers' private lands. Although this causal relationship is not the single-most important determining factor of land cover patterns and changes throughout the watershed, it is relevant in some areas and hence deserves attention. The following account of land cover changes around the village of Kertajaya illustrates this.

The hillslope north of the sub-village of Igirtugel Utara in the village of Kertajaya (see Figure 10) – all farmers' private land – was largely empty of trees, partly covered with grassland and cultivated with annual crops throughout the second half of the 20th century, from the 1950s until the early 2000s. Though the village was repeatedly targeted by regreening programmes, tree cover did not markedly increase during this period. This started to change in the early 2000s. Peasants' increased interest in tree planting, combined with the continued support provided by regreening programmes, has led to markedly increased tree cover. Most plots on the hillslope are covered with trees now. For its success in increasing tree cover on farmers' private land, the village was the winner at the district-level and runner up in the province-level competition of the National Programme for Forest and Land Rehabilitation (GNRHL, Gerakan Nasional Rehabilitasi Hutan dan Lahan), a long-standing regreening programme run under the Ministry of Forestry by the watershed protection agencies. Besides the generally increased interest of the peasants in planting more trees (as explored above), my case study revealed that the possibility to cultivate annual crops on the state forest land west of the village (see Figure 10) contributed to them planting more trees on their private land. While tree cover on the peasants' private land has markedly increased, the state forest, which was plundered in the late 1990s and early 2000s, continues to be degraded, with scattered tree cover and high levels of surface erosion. The satellite image in Figure 10 clearly shows the contrast between peasants' private land, comprising a mix of irrigated rice fields and villages with dense house gardens in the valley floor and the largely reforested hill to the east, and the degraded state forest to the west.

Figure 10: While tree cover on peasants' private land (the hill land to the east) has increased, the state forest land (the hill land to the west) is degraded. The valley floors surrounding these two hills mainly comprised of terraced wet rice fields.

If the peasants were pressured to use state forest land for crop cultivation as a result of the tree planting programmes targeting their private lands, this spatial shift of crop cultivation along with its environmental effects could be framed as 'leakage'. However, conversely, the opportunity to use state forest territory for crop cultivation facilitates some peasants to plant more trees on their private lands. It also appears that the environmental effects of annual crop cultivation in state forest territories, where no or only limited soil conservation measures are applied, tend to be more detrimental than on farmers' private lands due to the peasants' limited sense of ownership. Peasants cultivate annual crops in state forest territories with a rather limited planning horizon, while they apply soil conservation measures and plant trees on their private land. The latter is also supported by the regreening programmes and the agricultural extension services, whose responsibility does not cover the state forest territory.

5.2 The tenure-related dichotomy of watershed management: A major challenge

As shown above, land use and land cover patterns and changes and the spatial patterns of critical erosion prone-land are considerably affected by struggles over forest tenure. At the same time, (struggles over the upholding of) the tenure dichotomy between state forest land and farmers' private land also considerably shapes the institutional set up and the strategies of land and watershed management. This in fact undermines the overall effectiveness of these strategies with regard to environmental outcomes.

It has been shown above that the community forestry programmes have contributed to combatting the large-scale plundering of state forests that occurred in the late 1990s and early 2000s. These programmes can be seen as a strategy of the state forest corporation to regain control over the state forests (also see Maryudi 2012). At the same time they provide peasants the possibility to legally use state forest land for crop cultivation, to be involved in forest management and protection, and to receive a share of the revenue from the timber trees. Yet, the lack of trust between the actors involved and the lack of success of the programmes in creating a sense of ownership of the land, the trees and of forest management affairs on the side of the peasants undermine the sustainability and the environmental performance of the programmes. The lack of trust and ownership are reflected in scattered tree cover, crop cultivation with limited or no soil conservation measures and erosion, causing some of the state forest territories to be hotspots of soil erosion. Tackling this issue is of utmost importance for more sustainable forest management and watershed protection. At the same time, it is a highly political issue, directly connected to struggles over the access to and control of forest resources.

However, the spatial responsibility of watershed, soil conservation and agricultural extension authorities ends at the border of the state forest territory. The levels of erosion therein depend on the course of the struggles between the state forest corporation and peasants over the control of the land and the trees and the levels of trust between these actors. Representatives of watershed authorities and of agricultural extension services, when directed to the fact that some state forest territories constituted a hotspot of soil erosion, admitted this and their inability to directly intervene in these areas posed a contradiction to their aim of reducing soil erosion and river sediment loads. Asked whether he had any possibility to influence the ways of management and cultivation in state forest territories, a representative of a district agricultural and forestry extension office whose work also aims at watershed protection, after pondering for a moment about how to respond to this question that hit a core issue of his work and that is a politically sensitive topic, admitted that ***this*** was ***the major*** difficulty. He further explained that this was difficult because these territories were under the responsibility of the state forest corporation and hence beyond the sphere of his influence and that "it would be against people" (Interview, 7. February 2011); it would be against people cultivating crops in state forest territories. He noted that the community forestry programmes reduced illegal logging and improved incomes and food security, but that they were problematic with regard to erosion and watershed protection.

In this way, the spatial confinement of the watershed, soil conservation and agricultural extension authorities' responsibilities to areas outside the state forest territories not only undermines the overall effectiveness of their programmes with regard to environmental outcomes. Some of the programmes themselves also pursue the goal of upholding the dichotomy between state forest and land and farmers' private lands. The programmes run by watershed authorities and the agricultural and forestry extension services target farmers' private lands. In addition to reducing erosion levels on these lands, these programmes also aim at increasing incomes and thereby reducing the interest of peasants to cultivate state forest territories. The representative of the district agricultural and forestry extension office quoted above explained that he aimed at reducing peasants' interest in cultivating state forest areas by encouraging and facilitating them to increase income from their own private land. The state forest corporation itself also runs various programmes aimed at facilitating farmers in using their own private land more intensively and in creating alternative sources of income. Representatives of the state forest corporation openly stated that these programmes pursued the dual goal of improving soil conservation and of improving rural livelihoods and thereby reducing the 'pressure' posed by residents of forest margin villages on the state forest land.

The programmes in fact certainly contribute to both of these goals to some extent. Yet, vice versa, the possibility of annual crop cultivation on state forest land also contributes to the effectiveness of the tree planting programmes on farmers' private lands. A few respondents even noted that additional tree planting programmes were not necessary, since the private land of those farmers interested in trees was already afforested. In contrast, the state forest territories surrounding these villages were partly deprived of trees and in a state of degradation.

5.3 Conclusion and outlook

Both some of the state forest lands and some of the farmers' private lands comprise erosion-prone slopes and constitute a major source of riverine sediments. The erosion potential on some of the farmers' private lands has been reduced as a result of various interwoven factors, including economic factors, peasants' generally increased interest in perennial crops, and regreening and watershed management programmes, the effectiveness of which has improved in the recent past. In contrast, the erosion potential on some of the state forest lands has markedly increased.

Watershed protection-related debates and programmes have focussed on farmers' private lands, while the professional management of state forest territories by the state forest corporation has been regarded as the epitome of watershed protection. However, in fact the one-age cohort teak plantations and rotational clear-cuts make some state forest territories more erosion-prone than some of the peasants' dense, multi-storeyed mixed forests. More importantly, struggles between the state forest corporation and peasants over forest access and control have turned many state forests into degrading lands. The erosion potential on these lands depends on the course of these struggles and on the performance of the community forestry programmes, which are an integral part thereof. The various tree planting and other watershed management programmes targeting farmers' private lands not only aim at soil conservation but also pursue the political goal of influencing the struggles between the state forest corporation and peasants by encouraging the latter to refrain from using state forest land. In other words, the programmes aim at upholding the tenure status quo. However, conversely, peasants' crop cultivation on state forest lands has in some cases contributed to the success of the tree planting programmes by reducing the necessity for peasants to cultivate annual crops on their private lands. More importantly, the spatial confinement of the programmes and of the institutional responsibility of the various state agencies assigned with environmental protection, soil conservation and agricultural extension to peasants' private lands leaves some of the most erosion-prone areas within the catchment (those within state forest territories) unaddressed. Hence, the dichotomy between state forest lands and peasants' private lands, the corresponding division of institutional responsibilities, and struggles over maintenance of this dichotomy are linked with and undermine the effectiveness of watershed conservation efforts.

These findings suggest that watershed protection could be enhanced if related debates and action not only targeted peasants' private lands, but also directly engaged with the management of the state forest lands. This engagement should cover both the state forest corporation's management practices and the community forestry programmes, or more broadly: the relations between peasants and the state forest corporation. It requires an open debate linking watershed protection aims and strategies with the further (re-)arrangement of the patterns of forest access and control.

Such a debate could benefit from comparing land use and land cover patterns and their ecological characteristics on state forest and on peasants' private lands. Some of the dense, multi-storeyed, only selectively logged peasants' forests could serve as good examples for the development of environmentally more sustainable modes of forest management in the contemporary state forest territories. Confronted with the issue of erosion caused by the state forest corporation's rotational clear cuts, a representative of a district agricultural and forestry extension office noted that this was an issue, that it takes 10-20 years after replanting until the forest fulfils its hydrological function again, and that selective logging should be the principle. However, these issues have barely been debated, and a number of respondents noted that communication between the state forest corporation and the various state agencies assigned with environmental protection, soil conservation and agricultural extension was very limited.

The views of different actors over the direction of further (re-)arrangements of the patterns of forest access and control are vastly diverging. While many representatives of the state forest corporation and of governmental organisations regard an approach that encourages peasants to refrain from using resources from state forest lands as the only logical and possible solution, representatives of some NGOs suggest the need for land reform, partitioning state forest lands among peasants. The first group of actors in turn rejects this option, arguing (1) that the land historically belongs to the state and its forest corporation, (2) that some of the land – if it was transferred to peasants – would be permanently converted into cropland, hence reducing the forest area and undermining watershed protection goals, and (3) that many of the poorest of the peasants would sell their land and would thus not be able to use any resources from the (former) state forest land anymore.

Community forestry is a middle way between these two opposing views. Whether the approach of the PHBM community forestry programmes will succeed in reconciling struggles over forest access and control and whether they will result in land uses that conform to watershed protection goals remains to be seen. The further development of the relations between the state forest corporation and peasants plays a major role in this context. A further devolution of forest management to the peasants might enhance their sense of ownership, which, as my case studies suggest, is a major prerequisite for more sustainable management of the community forestry areas. The planned refinement of the PHBM programme in Sawangan, enabling peasants to themselves plant additional 'secondary' trees of their own choice to fill the gaps between the 'primary' tree species determined by the state forest corporation is a step in this direction. In the best case, this and further refinements of the programmes could perhaps transform some of the former one-species, one-age cohort tree plantations, which dominated the state forest territories until the late 1990s and many of which are presently in a state of degradation, into mixed, multi-storeyed forests resembling some of the farmers' private mixed forests. Environmentally and perhaps also in terms of overall productivity, this would be advantageous and could serve as a vision in debates over watershed and forest management.

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Research Paper 7

Lukas, M.C. and M. Flitner. Scalar fixes of Environmental Management in Java, Indonesia.

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Scalar fixes of environmental management in Java, Indonesia

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Abstract

Recent work in cultural and political ecology has seen renewed interest in the spatial lexicon. The classical geographical concepts of space and place-making have been complemented by a growing body of work on networks, sites, assemblages and mobilities. At the same time, longstanding debates around scale have reached new heights in the context of environmental issues. This paper engages with work that explores the emergence and fixing of specific scales in struggles over such issues. Using the example of the Segara Anakan lagoon and its watershed on the island of Java, we explore the shifting modes of environmental management in the area and show how political framings of environmental matters and ongoing struggles over resources are linked to specific regimes of regulation and intervention on one side and on observation and knowledge production on the other. The conjuncture of these regimes can be understood as the production of scalar fixes that were critical in establishing and maintaining specific patterns of environmental management and resource control in the region throughout the twentieth century. In sketching the related conflicts and their different phases, we offer a conceptual approach how interpretive framings are functional in stabilizing power asymmetries by linking the production of environmental knowledge to processes of regulation and intervention.

Keywords:

Scale, watershed management, historical political ecology, Citanduy, Segara Anakan lagoon.

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1 Introduction

The influence of narratives and myths or, more broadly, interpretive framings of environmental matters has been acknowledged in large parts of the cultural and political ecology literature over the past two decades. Whether only to reduce complexity of social-ecological problems or to favour particular outcomes of related conflicts, interpretations and valuations are part and parcel of the societal relationships with nature. Our knowledge about both nature and society is situated, sometimes uncertain, and always incomplete. Accordingly, interpretations and framings of environmental problems tend to be actor specific and necessarily change over time. Yet they may persist for years or decades and heavily influence political discourse and action in certain fields over extended periods. Such framings can have complex, multiple origins and contain different types of knowledge, including scientific knowledge. At the same time, they can limit the type and scope of further knowledge production and hence obstruct consideration of alternative explanations, as we will illustrate with our empirical case. That is, interpretive framings translate between social-ecological processes including management interventions on the one hand and the production of knowledge on the other. This process often involves the production of scale and is, in the words of Rangan and Kull (2009:41) "what makes ecology political".

One of the fields of environmental governance that is often discussed in terms of scale and uncertain knowledge is watershed management. Water-based processes can unfold over large areas connecting places far apart from each other, and the drivers of these processes may operate beyond the boundaries of watersheds. Related management approaches are not just constrained by lack of reliable knowledge; they are typically confronted with fragmented interests and polities, rendering the popular approach of 'integrated management' and according policy prescriptions ambitious or even naïve (Blomquist and Schlager, 2005). In line with such arguments, several authors have called for specific attention to issues of scale in watershed management, often referring to bio-physical and social processes as well as scalar politics (e.g. Molle, 2007; Norman et al., 2012; Swyngedouw, 2013; Venot et al., 2011).

Hence research in watershed contexts has become a fruitful ground for the development and refinement of scale concepts. Vice versa, the analysis of struggles over watershed management can benefit from insights into the conceptual debate on scale and scalar politics. Our article aims to contribute to both ends. Engaging with the ongoing scale debate, we examine political struggles over resources and environmental management in the catchment area of the Segara Anakan lagoon in Java, Indonesia. This shallow, mangrove-fringed coastal lagoon is shrinking rapidly due to silting up by riverine sediments. Various interventions in the lagoon and its hinterland over the last decades have focussed on river basin development and later on lagoon and upland conservation. Taking a political ecology perspective, we critically explore the unfolding of spatially shifting management interventions in the lagoon-watershed region along with related ways of knowledge production, and how these processes are bound together in socio-political framings.

In the following section, we briefly summarize some main lines of recent work on scale and scalar politics to define our points of departure. We will thereby, inspired by Rangan and Kull (2009), develop a heuristics of scalar politics with three main dimensions, namely (1) observation and knowledge production on the one hand, (2) social-ecological processes including practices and interventions on the other, and (3) interpretive framings that translate between and shape the first two dimensions. We see the articulation of these three dimensions as crucial in explaining the formation and persistence of semi-stable arrangements that can be understood as scalar fixes. In the third part of the paper, we elaborate on our understanding in exploring the empirical case of the Segara Anakan lagoon and its catchment area. We focus our account on critically developing the two consecutive scalar fixes that prevailed in the second half of the 20th century. In the final section we draw the methodological conclusion from our case and define an avenue for further research regarding the temporal dimension of scalar fixes.

2 Scales, framings and scalar fixes

It is nearly a decade that Marston et al. (2005:422) have called to "expurgate scale from the geographic vocabulary" in favour of a "flat ontology". Yet the concepts of scale and scalar politics continue to be debated, and political ecology seems to be a particularly fruitful field of related discussions in recent years. There is neither a need nor the place here for a broader review of the scale debate with its ramifications and heterogeneous positions. With regard to political ecology, Neumann has given a broad overview in which he clarifies some of the main lines of thought and key theoretical distinctions, not without regretting "a continuing problem with the conflation of terminology and concepts, so that even in the political ecology of scale literature, scale, level, site, network and assemblage are not clearly distinguished" (Neumann, 2009:404).

This is reason enough to briefly sketch our main tenets. With large parts of the literature we share the view that scale should neither be understood as an "external fact awaiting discovery" (Delaney and Leitner, 1997:94) nor as levels of socio-political organisation. Instead it is conceived of as an outcome of contingent socio-political processes and thus as open for contestation. We agree with Moore (2008:213) that scale research should focus on the processes "through which specific scalar configurations solidify in consciousness and practice, and the effects these developments have upon social, political and cultural relations". Social actors can influence scalar configurations in a strategic manner in order to pursue particular political or economic outcomes or to legitimise certain activities (Bolin et al., 2008; Brown and Purcell, 2005; Kurtz, 2003; Smith, 1992; Towers, 2000). Along these lines, we can define the politics of scale for our purposes with Zulu (2009:688) as referring to processes in which "different actors construct, modify and contest the spatial extent, content, and resolution of information and decisions", if we understand the latter term to comprise ensuing social action. This definition, however, still leaves open at least two important questions: firstly, in which way the actors exert influence on those processes of scale making, and secondly, how it is possible that such processes can have quite stable outcomes over longer periods of time, despite their constructedness and modifiability.

To deal with the first question, we engage with the work of Rangan and Kull (2009) who proposed a three-pronged approach for analysing issues of scale in political ecology contexts. Building on Lefebvrian concepts, they see scale as "produced by three moments of action" which they call the "operational, observational and interpretative moments in the production of scale" (p. 35-37). The operational moment or operational scale is then understood as equivalent to or produced through patterns of interaction of both social activity and biophysical processes; spatial practice that can be "reflected in distinctive sozialized ecologies or landscapes" (p. 35-38). The observational scale, in contrast, is produced in the process of defining the limits of what is observed, of measuring, controlling, and planning. “Governments, policy-makers, scientists and social researchers produce observational scale by focusing on particular social groups or biophysical entities, delimiting the spatio-temporal extent of their activities or movements, determining the resolution of the data for analysing their behaviour and specifying the disposition […] of the entities or phenomena chosen for surveillance, control, or study” (Rangan and Kull, 2009:38). Contrary to the authors, we do not deem it useful or necessary to equate these two types of scales with the ontological and the epistemological moment of scale production. Rather we want to highlight in this context that both types do relate to material phenomena and processes in manifold ways. Thus, they do have geographical referents and may relate to one or more geographical scales in the traditional meaning of the term.

The third, interpretive or “translational” moment, is “crucial […] because it provides the means by which spatiotemporal difference and change is articulated, challenged or defended by using an order or range of values and sensibilities as the context for interpretation” (Rangan and Kull, 2009:35). Put more simply, the interpretive moment is the realm of framings. Interpretive framings can be any type of environmental narratives in a broader sense. And once more, specific spatial-temporal units or political levels can be an integral part of such framings. Other authors have made similar arguments. For example, Towers (2000) developed the idea of “scales of meaning” focussing on the framing of arguments in political discourses, complementing the processes of regulation (cf. Flitner, 2007). Further Kurtz (2003:894) developed the concept of “scale frames” as “the discursive practices that construct meaningful (and actionable) linkages between the scale at which a social problem is experienced and the scale(s) at which it could be politically addressed or resolved.”

As stated in our introduction, the idea that interpretive framings are highly important in the constitution of environmental issues, that is: in their becoming political, has gained a lot of support over recent years, and it is also an explicit starting point of our own research. Yet we see a problem in conceptualising such frames as an own type of scale or quasi-independent scalar practice. Rangan and Kull (2009:40) described the interpretive moment as “distinct from operational and observational scale in that it is produced as a normative hierarchy or ordered range of values that serve as the context and means by which ‘truth-making’ occurs”; interpretive scale is used to “extrapolate and translate across and between observational and operational scales”. More explicitly than the authors, we argue that processes of meaning-making are of central importance in shaping the moments of both observation and operation. Accordingly, we stress that observational scale not only depends “on knowing operational scale” (Rangan and Kull, 2009:39) but on political framings. Scientific endeavours, political interventions or everyday practices may be imbued with symbols, models and storylines. They all entail processes of meaning-making and, in a Foucauldian perspective, they can be understood as constitutive part of discourses. Such discourses or discursive frames may or may not have references to geographical scale in the traditional sense; they often contain spatial metaphors, but do not necessarily have extension, place, hierarchical ordering or other characteristics that suggest specific links to the spatial lexicon. For these two reasons, we do not treat processes of framing as a separate “interpretive scale”. Instead, we find it preferable to talk about interpretive framings that can concern and affect both observational and operational scales.

Based on this revision of Rangan and Kull (2009) and our empirical example, we propose a heuristics of scalar environmental politics comprising interpretive framings and the scales of observation and intervention (Figure 1). Accordingly, interpretive framings of social-ecological processes both shape the scales of observation used to explore these processes and constitute or justify particular modes and scales of practices and intervention aimed at altering these processes. Such practices and interventions may, for example, comprise upland conservation measures. They shape and are in fact part of social-ecological processes. And although interpretive framings may be considerably influenced by specific actors, they will in most cases also be linked to scientific facts and other pieces of knowledge regarding the complex social-ecological issues at stake. The selection of particular observational scales in line with interpretive framings thereby contributes to the solidification of the latter through intentionally or unintentionally including or excluding certain social-ecological phenomena and processes.

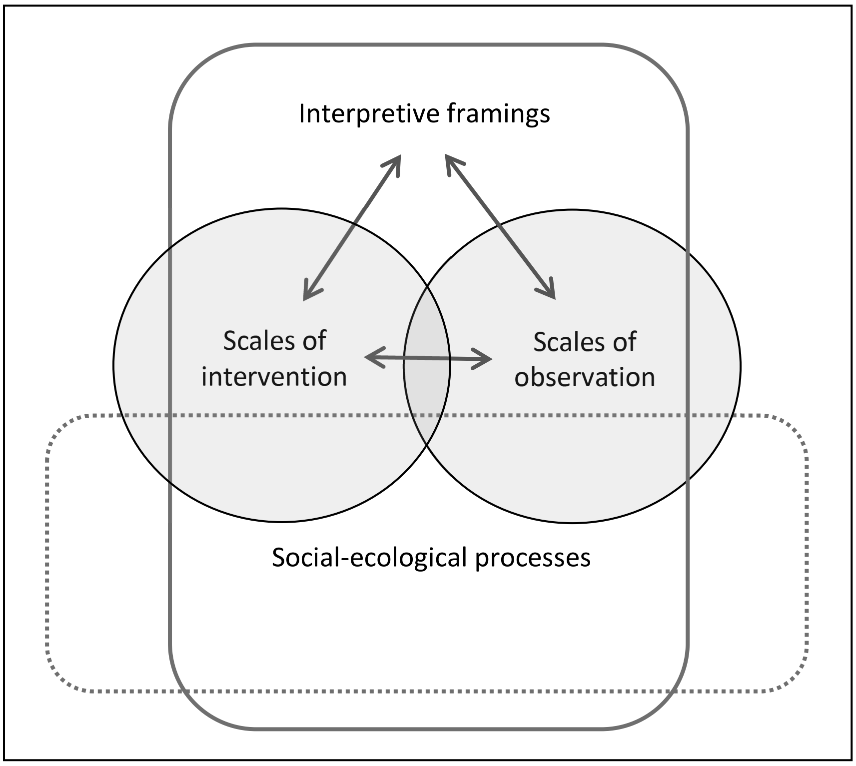

Figure 1: Heuristics of scalar environmental politics

This link between interpretive framings and the scales of observation is one important starting point to deal with the second question raised above: how interpretive framings and processes of scale making can have quite stable outcomes that persist over longer periods of time. The more effectively observational scales are confined by interpretive framings, the longer such framings may persist and legitimize particular modes and scales of political action. We refer to such semi-stable configurations of particular interpretive framings of environmental issues along with related scales of observation and intervention as 'scalar fixes'.

The term 'scalar fix' has been introduced to geographical debates to explain temporal fixity and change in the scalar organisation of capitalist production and capital circulation (e.g. Brenner, 1998). Building on this literature, Cohen and Bakker (2014) recently elaborated the notion of an "eco-scalar fix", defining it as "the process of rescaling and reorganizing governance […] and thereby displacing conflicts and crises, often through the construction of (purportedly 'natural') ecological scales, which simultaneously depoliticize and repoliticize governance" (p. 132). While we share this interest in the strategic construction of 'social-ecological scales', our empirical case will show how politically driven interpretive framings of environmental issues can just as well lead to a complete disregard of scales that seem quite 'natural' as units of observation and intervention in social-ecological processes. In other words, a scalar fix in environmental matters does not necessarily imply any naturalizing of social and political objects such as units of governance.

In line with these arguments and our three-dimensional heuristics of scalar politics we use the term 'scalar fix' to refer to semi-stable configurations of particular interpretive framings of social-ecological processes and related scales of observation and intervention. We hereby use the term 'fix' in both its connotations: referring to stability and problem solving (cf. McCann, 2003:162). It is the processes of establishment, articulation and solidification of the different scales that are in the centre of our interest in this paper, and the role of interpretive framings in this regard. In a similar vein, Sievanen et al. (2013) described such framings of observation and intervention as "scalar narratives":

> "Scalar narratives associate places, spaces, and processes at particular social, institutional, and geographical scales to explain events, attract attention and funding, and in the process, shift social relations by enrolling and excluding different forms of knowledge, spaces, and groups of people." Sievanen et al. (2013:208)

Scalar narratives or interpretive framings thus can be the starting point for the formation of particular scalar configurations and, as we will show, their confining of the scales of observation can play a crucial role in the solidification of such configurations as scalar fixes. Accordingly, the scales of observation may themselves be contested and play a critical role in challenging established, sometimes one-sided, interpretive framings and related modes and scales of political intervention.

In the following section we hope to corroborate our claims with our empirical example. We will explore the scalar reconfigurations of watershed and lagoon management in a historical perspective and critically explore two consecutive scalar fixes that have dominated related discourses, research and interventions over the past decades.

3 Scalar politics of environmental management in Java

As set forth in the introduction, struggles over watershed management are particularly prone to issues of scale. The island of Java provides prime examples to illustrate this. The magnitude of human impact on an environment that is already highly dynamic in geomorphological terms and the islands' reputation as one of the most densely populated areas in the world pushed Java into the spotlight of Malthusian prophecies of disaster even before environmental concerns found their way into the global political mainstream. Deforestation, soil degradation, erosion, and sedimentation, all classical watershed problems, became issues to be addressed in the frame of environmental management initiatives. Only a few of these initiatives have produced desirable, sustainable outcomes.

Using the example of the Segara Anakan lagoon and its catchment area we illustrate how simplistic narratives have constrained the effectiveness of management initiatives and how these even ran counter to their stated purpose. To provide a background, we first sketch what has been framed as major environmental issue in this region since the 1980s. Since then, conservation of the Segara

Anakan lagoon has dominated environmental management related discourses and action. This shallow coastal lagoon forms the estuary of the Citanduy River and a few smaller rivers to the east (Figure 2). The lagoon comprises the largest remaining expanse of mangrove forest in the south coast of Java. With its variety of habitats, its high biological diversity and its function as a major nursery ground for ocean shrimp it has not only been regarded as ecologically highly valuable, but forms the economic backbone for many people in the adjoining villages of Kampung Laut (see e.g. Dudley, 2000; Olive, 1997; White et al., 1989; Yuwono et al., 2007). Riverine sediment input, mainly from the Citanduy, but also from the Cikonde and Cibeureum Rivers, has drastically reduced the size of the lagoon's water surface area from more than 8,000ha in the mid-19th century to slightly more than 2,000ha at present (Lukas, under review). Sedimentation is said to have contributed to overfishing and mangrove degradation, which in turn undermines the economic viability of fishing, once the dominant livelihood strategy in Kampung Laut (Dudley, 2000; Olive, 1997; Sudjastani, 1982).

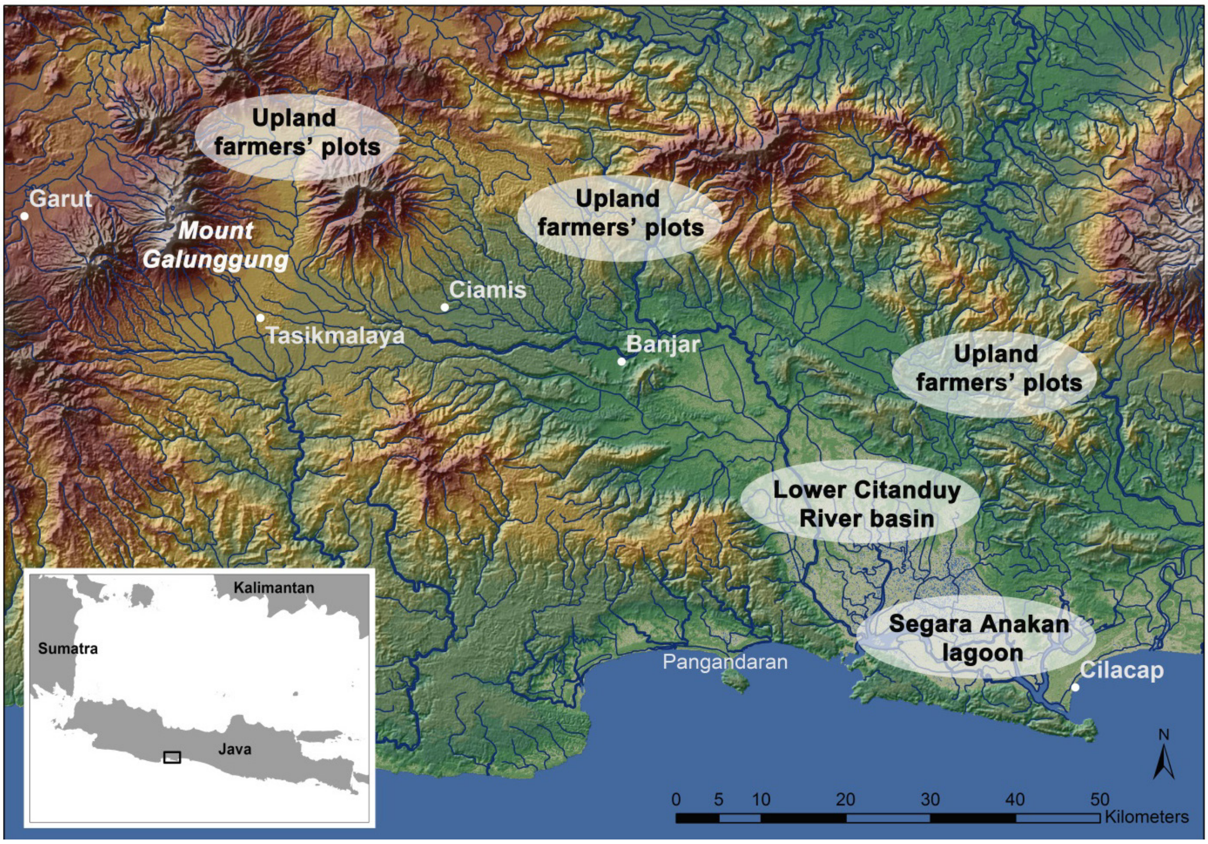

Figure 2: Map of the Segara Anakan lagoon and its catchment area with the major scales of environmental management-related intervention

Since the 1980s, the critical conjuncture of dwindling marine resources, increasing exploitation and ecological destruction has attracted a lot of political interest nationally and internationally, turning the lagoon into a hotspot of research and political interventions. The framing of lagoon sedimentation as a problem that needs to be addressed and that is mainly caused by unsustainable farming practices in the uplands has provided the political rationale for particularly extensive upland conservation efforts in the lagoon's catchment area. Proposed interventions have included the construction of river diversions to reduce riverine sediment input, lagoon dredging, and upland conservation. Whereas the construction of river diversions did partly not materialise for political reasons, and dredging obviously had only temporary effects, the upland conservation measures appear not to be appropriately tailored to the alleged goal of reducing sedimentation, and their effects remain uncertain, but seem to be limited (see e.g. Schweithelm, 1989).

Combining knowledge about social-ecological changes in the region, a review of management interventions and related political processes, and insights from our own research in the region over the past years[3], we critically explore in the following sections the links between interpretive framings of environmental matters and related scales of observation and intervention. The first constellation or 'scalar fix', which dominated in the 1960s and 1970s, is based on the framing of lagoon sedimentation as a desirable process, creating additional land for agricultural reclamation. The second 'scalar fix', which developed in the late 1970s and is still relevant at present, is based on the framing of lagoon sedimentation as an anthropogenic threat, mainly driven by unsustainable upland agriculture.

3.1 Scalar fix 1: River basin development

Looking at the contemporary main-stream framing of environmental matters in the lagoon-watershed region and the related substantial political and scholarly efforts devoted to the lagoon over the past three decades, one can easily presume that the area was prioritised for watershed management in the 1980s for the sake of lagoon conservation. In fact, however, the Segara Anakan lagoon was only valued as potential area for agricultural reclamation since at least the 1940s. Corresponding development plans, put forward in 1948, 1971 and 1975, proposed river engineering measures aiming at accelerating lagoon sedimentation and / or draining of the lagoon for agricultural reclamation of its 'unproductive' swamp and brackish water areas (for a summary , see PRC-ECI, 1987). Although these plans to reclaim the entire lagoon did not materialise, the lower Citanduy river basin became the scale of implementation of agricultural development projects of national and international political importance from the late 1960s onwards.

At that time, the river basin was invested with political meanings that were shaped at scales far beyond the watershed and that were related to various national and international political dynamics and interests. The post-World War II struggle between world political systems, the international emergence of river basin development as a preferred modernisation strategy, the national government's imperative to consolidate state power and counter political instability and insurgencies; and finally national commitments to achieve rice self-sufficiency: These factors all contributed to raising interest in the Citanduy river basin and turned it into a scale of intervention for one of the first large U.S.-Indonesian development projects. The 'Citanduy Project', funded by the US Agency for International Development (USAID) and the Asian Development Bank (ADB) marked the beginning of a series of large development interventions in the area.

In the 1960s, parts of Southeast Asia had become political and military battlefields in the fight for a communist versus capitalist world order, a fight in which Indonesia played an important role. After the country's communist movements had been purged in one of the bloodiest massacres in

[3] Our own research combines remote sensing and historical cartography with social-scientific research methods, focussing on land use and land cover changes and environmental governance in Central and West Java (Lukas 2013, 2014).

Southeast Asia's history in 1965-66 (see Cribb, 1990, 2001), Suharto's anti-communist New Order regime paved the way for a broader U.S.-Indonesian economic partnership, providing an opportunity for the United States to promote the western liberal model of modernisation and expand its influence in the region. The United States' engagement in Indonesia was first constrained by its reluctance to support an authoritarian, nepotistic, and pervasively corrupt military regime that seemed to provide limited perspectives for democratic development (Simpson, 2008). However, Indonesia's economic decay, its regime's high expectations of U.S. assistance and, perhaps most importantly, the course of the Vietnam War created the political moment for a massive turnaround:

> *"The worse things got in Vietnam, the more President Johnson wanted to invest in Indonesia's success, just as administration officials, the press, and Congress wanted to see Indonesia as a validation of the American stance in Indochina."* (Simpson, 2008:241)

Indonesia was to become a symbol of non-military, development oriented engagement of the U.S. in Southeast Asia. In collaboration with the IMF, the World Bank, the ADB, and private investors, they aimed at paving the way for Indonesia's modernisation, unavoidably military-led modernisation (Simpson, 2008) which would probably not lead the country to the path of democracy but at least create political stability by reducing poverty and social unrest.

By that time, river basin development had become a favoured modernisation strategy. Partly based on the political rhetoric surrounding the allegedly great success of the giant Tennessee River Valley engineering project in the 1930s, U.S. overseas assistance and diplomacy had generally contributed to a massive worldwide surge in river development initiatives between the 1940s and 1960s (Ekbladh, 2002; Molle, 2009).[4]

These intertwined national and international processes, apparently produced the idea of initiating a river basin development project in Indonesia with financial support from USAID. The selection of the Citanduy river basin for this endeavour had clear political motivations: The attention of the national government to this part of Java "was initially prompted by political instability in the area, into the early 1970's, as a result of Darul Islam activity" (USAID, 1985:5). The Citanduy region had been one of the national strongholds of the Dar'ul Islam, a radical Islamic movement that fought for Indonesia to become an Islamic State between the late 1940s and 1960s (see Dengel, 1986; Jackson, 1980; van Dijk, 1981). The followers of Dar'ul Islam were "deeply wary of the Suharto regime's commitment to what they viewed as a secular path to modernisation" and consequently "[m]any army leaders still feared the potential power of political Islam and a revival of movements like Darul Islam […]" (Simpson, 2008:254-255).

In the hills just northeast of the project's designated target area, the Dar'ul Islam insurgency and the state's counter insurgency had displaced the entire population from a number of villages, which prompted the state to design a land swap and to incorporate the former village land into the state

[4] That this strategy was to materialise in Indonesia was to some extent a result of U.S. President L. B. Johnson's personal commitment to river development. During his visit to the Commission overseeing the US-funded Mekong River development project, Johnson is quoted declaring: "I am a river man. All my life I have been interested in rivers and their development." (Press Release ECAFE/88, 17 May 1961, Memo, Ortiz-Tinoco, nd, Vietnam Country File, National Security File, Box 202, LBJL; quoted in Ekbladh [2002]). A few years later Johnson added: "'We should take some of our ambitious plans which haven't been working in other countries, […] and put them into action in Indonesia'" (Simpson 2008:241).

forest territory (Lukas, 2014). The deal left many villagers landless, triggered conflicts and made villagers join communist movements (ibid.). The latter were also strong in the region before being crushed in the wake of Suharto's seizure of national political power in 1965/66. The river basin development approach as a state dominated large-scale intervention was obviously in line with the national government's strong interest to bring the Dar'ul Islam and the communist movements in the Citanduy region under control or prevent their resurgence and to consolidate state control in this politically fragile area. Moreover, given the manifold disruptions in the area with large numbers of people fleeing the countryside, a project focussing on agricultural development must have seemed a perfect strategy for economic recovery. It was also in line with the New Order regime's firm commitment to achieve national self-sufficiency in rice production with a 'Green Revolution'.

Hence various political dynamics and interests advanced the transformation of parts of the lower river basin from seasonally inundated swamp land into a 'rice bowl', starting with the ADB and USAID financed 'Citanduy Project' in 1969. Parts of the target area north and northwest of the lagoon, which comprised one of the largest swamp areas in Java, had been barely populated by humans before, and when Teijsmann (1855:216-17) travelled through the area by boat a century earlier, he described the vegetation along the river bank as so dense that it was impossible to pass through without using a machete. Agricultural reclamation of this area had already begun before World War II, was continued during the Japanese occupation (Satō, 1994, 2006), and was now to be considerably advanced and completed by flood control measures and irrigation schemes (PRC-ECI, 1975; Tim Koordinasi Wilayah, 1989).

To sum up (see Table 1), various national and international political developments and interests led to the choosing of the lower Citanduy river basin as the scale of intervention of one of the first larger internationally funded development projects in Indonesia. In line with the political interests and the prevailing development paradigm at that time, the swamp lands of the lower river basin along with the Segara Anakan lagoon and its mangroves were framed as potential for agricultural development and modernisation, and lagoon sedimentation was framed as a desirable process. The scales of observation that became relevant in this context comprised, among others, the space of South-East Asia as a political frontline, the area of political insurgencies by Dar'ul Islam and communist movements; and national rice production with a particular focus on the irrigation systems in Java. The broader interpretive framing that connected and stabilised these parts contained the spatial metaphors Tennessee River valley, Vietnam, the Mekong river basin as well as the paradigm of agricultural modernisation internationally propagated as the 'Green Revolution'.

Table 1: Scalar fixes of environmental management in in the region of the Segara Anakan lagoon and its catchment area

Scalar fix	**River Basin Development**	**Lagoon and upland conservation**
High time	1960s/70s	Since 1980s
Key scalar narrative	Unproductive swamp land is to be converted into a 'rice bowl'; lagoon siltation is a desirable process	Further loss of the lagoon can and should be stopped; 'unsustainable upland agriculture' is the main driver of siltation
Political context	Vietnam War Non-military, development oriented engagement of U.S.A. in SE Asia National government's interest to consolidate state power and counter political insurgencies	Emerging environmentalism and greening of aid State forestry as part of cleptocratic rule Entanglement of state forest and watershed management
Scales of intervention	Lower Citanduy river basin (waterworks, irrigation channels, settlements)	Upland farmers' plots (tree planting and terracing) Segara Anakan lagoon (dredging, river diversions, investor-based aquaculture development)
Scales of observation	Area of political insurgencies (Dar'ul Islam, communist groups) Population growth and migration National rice production	Lower river basin (flooding, dry season water shortages, sedimentation) Segara Anakan lagoon ('hotspot' of research) Upland farmers' plots ('unsustainable farming practices')
Broad interpretive framings	Example of Tennessee River Valley project Authoritarian development 'Green Revolution'	'Himalayan degradation' Watershed management 'Sustainable development'

3.2 Scalar fix 2: Lagoon and upland conservation

The framing of social-ecological processes in the area and, with them, the scales of observation and intervention underwent a radical shift in the late 1970s and early 1980s (cf. Table 1). At that time, lagoon sedimentation started to be seen as a threat, and hence political attention gradually shifted from the lower river basin to the lagoon and to the uplands, both of which became the major scales of intervention. The formation of this new scalar fix was related to (1) hydrological issues in the newly reclaimed agricultural areas of the lower river basin and (2) emerging global environmental discourses. Both fitted together and provided the rationale for new kinds of interventions. In addition and perhaps most importantly, the formation of this new scalar fix and its persistence over several decades is related to politically confined scales of observation and the politics of state control over forest territories.

Shifting framings, shifting scales of observation and intervention

In line with emerging global environmental discourses and related shifts in development paradigms and the greening of aid, the Indonesian government strengthened environmental conservation policies. These broader political changes shaped the way in which landscapes and environmental processes were framed and provided opportunities for new interventions which were to 'solve' problems that partly arose from the previous interventions in the lower river basin.

The identification of upland degradation and lagoon sedimentation as threats and the initiation of related upland and lagoon conservation measures was in line with international environmental agendas, but also seen as a logical consequence of hydrological issues in the lower river basin. Upland degradation was identified as a threat to the newly established 'rice bowl' in the lower river basin, since it was perceived to cause seasonal flooding, dry season water shortages, and sedimentation of irrigation channels (see PRC-ECI, 1975; PRC-ECI, 1987). This framing of hydrological issues in the lower river basin as being a result of upland degradation provided a first political imperative for upland interventions. That is, intervention shifted into the uplands, and the lower river basin – previously the major scale of intervention – became part of the interpretive framing to justify this shift in attention.

Over the course of the project, also lagoon sedimentation was identified as a threat to the newly reclaimed agricultural areas, because it impaired drainage of the irrigation network (see PRC-ECI, 1987). At the same time and in line with emerging global environmental discourses, the lagoon was 'discovered' as a highly valuable ecosystem and a major nursery ground for ocean shrimp (see, e.g. Bird et al., 1982). Consequently, irrigation projects in the lower river basin (via the problem of drainage), international environmental discourses, and offshore fisheries combined in a new scalar narrative that pushed the lagoon into the spotlight of political attention and provided the imperative for its conservation. As a consequence, sedimentation was suddenly seen as a threat – a menace to the irrigation schemes in the lower river basin, for the lagoon's biodiversity and also for the peasants of Kampung Laut, who were now all of a sudden portrayed as victims of environmental 'disruption'. Consequently, the lagoon which was to be preserved became the major scale of observation within the watershed and an important scale of intervention, too. Just as the lower river basin had become a symbol for national agricultural development and modernisation, the lagoon was now to become a symbol of environmental conservation.

As a result, environmental and social changes in the Segara Anakan lagoon have repeatedly been subject of research projects until presently, and development interventions, most notably the ADB-funded 'Segara Anakan Conservation and Management Project', aimed at environmental conservation and improving livelihoods. However, the achievements of three decades of research and interventions appear to be rather limited. Engineering measures to reduce riverine sediment input (river diversions) and lagoon dredging only partly materialised, led to social conflicts and had negative or only temporary effects. The establishment of shrimp ponds as an alternative livelihood option hardly benefitted local peasants whose portrayal as victims had served as a rationale for the intervention (Reichel, 2007). The ponds were hence plundered and are largely abandoned. Project reports and research results related to the Segara Anakan lagoon fill entire book shelves by now, but the basic issues persist. They include, for example, poverty and exclusion, mangrove degradation, limited success of replanting, and, not the focus of much research and debate to date, struggles over resources.

The lagoon not only became a major scale of observation and intervention, but also gradually superseded the lower river basin's function in legitimizing the upland interventions. The framing of lagoon sedimentation as a threat to the ecosystem and to local residents, which required upland conservation, including agricultural extension to poor upland farmers, perfectly befitted environmental and development paradigms. This politicisation of upland agriculture moved the upland farmers, who had so far received little attention under the New Order regime, into the centre of agricultural development efforts.

Following feasibility studies and first pilot projects between 1976 and 1980, the USAID-funded 'Citanduy II' project was implemented between 1981 and 1988. It supplemented the upland conservation and regreening programmes that were carried out by the Ministry of Forestry (MoF) also in other parts of Java and continued until recently. The focal scale of intervention was upland farmers' private plots, and the approach was to encourage and assist them in terracing their land and increasing tree cover. Interestingly, despite the fact that the lower river basin and the lagoon were often referred to in the official rationale for Citanduy II, a supposedly 'integrated' watershed project, "integration […] had not occurred at all […] [and] mission interest and attention has been so dominated by the upland element that the lowlands and the watershed concept are forgotten; 'watershed' has come to be synonymous with upland catchment areas rather than the original concept of all that lies between geographic divides including lowlands" (USAID, 1985).

The success of continued reclamation of the lower river basin was perceived to depend on upland conservation efforts, and these, based on the perspective of those concerned with lowland agricultural reclamation and lagoon conservation, had failed to raise farmers' awareness for issues of erosion (ADB, 1996b) and were generally "improperly carried out" (ADB, 2006:8). Despite the fact that the upland interventions had obviously increased the portion of upland dryfields being terraced, they in fact seem to have failed to reduce downstream sediment yields (Diemont et al., 1991; Purwanto, 1999; Schweithelm, 1988). This has been attributed to various reasons, including procedural shortcomings and site-insensitive delivery of one-type-fits-all upland agricultural packages (Purwanto, 1999; USAID, 1985). In other cases, as our own research has shown, farmers were made to adopt a variety of tree crops over time which they were told provided great economic opportunities, but which finally failed causing farmers to return to annual crops. And while extension workers at the local level were to convince farmers to alter their cropping patterns in favour of perennial crops, national level policies seeking alternative exports to oil in fact constrained these efforts by encouraging cassava cultivation through prize guarantees (Huszar and Cochrane, 1990; USAID, 1984).

Interpretive framings confining and being reinforced by the scales of observation

Looking beyond the effectiveness of the conservation measures on farmers' private plots and widening our view to the entire catchment area directs attention to the critical role of the scales of observation in the formation and solidification of the new scalar fix. Tellingly, most research on soil degradation and related mitigation strategies in Java since the 1980s has focussed on the scale of upland farmers' agricultural plots (e.g. Dijk et al., 2004; Palte, 1989; Purwanto, 1999). That is, the scales of observation remained within the scope of the dominant interpretive framings leading to a 'problem closure' as described by Hajer (2000). Once upland farmers' plots were discursively established as major cause of seasonal lowland flooding and lagoon sedimentation and became the preferred scale of intervention, observation was confined to the same scale, i.e. the upland farmers' plots. Such observation would inevitably confirm the existence of erosion and the suitability of the chosen scales of intervention. In this way, the links between interpretive framings and the scales of observation and intervention play an important role in the consolidation and persistence of particular scalar fixes of environmental politics.

Hydrological issues in the lower river basin and lagoon sedimentation provided the main rationale for interventions in parts of the watershed. Yet strikingly, the whole watershed never became an important scale of observation. That is, there has barely been any systematic, open-ended, watershed-wide research on the various potential drivers of lagoon sedimentation, let alone on the links between upland agriculture and lowland flooding, seasonal water shortages and sedimentation. After years of implementing upland conservation measures which were meant to reduce sedimentation and flooding, an assessment of the 'Citanduy II' project had to reveal that "[l]ittle has been learned about the sources of erosion. […] [T]here is much opinion but little fact" (USAID, 1985:9). This has barely changed since then.

In the absence of concrete empirical evidence, the drivers of lagoon sedimentation were 'established' by interpretive framings. Untested narratives became, to use Klein's (2002:191) apt formulation, 'institutionalised as facts', guiding research and interventions. Our review of literature and project documents revealed that while no watershed-wide research on the sources of erosion, its drivers and related sediment transport dynamics had been undertaken, many sources mainly claimed 'poor', 'destructive', or 'unsustainable' farming practices in the uplands as major causes of lagoon sedimentation. Our interviews with representatives of governmental organisations at various levels as well as discussions with staff members of universities largely confirmed these views.

These narratives seem just another formulation of the 'Himalayan Degradation' hypothesis (see Forsyth, 1996; Ives and Messerli, 1989), where marginalised upland farmers were blamed for all the ills downstream. But then we have to ask further: Why were observational scales not adjusted to encompass other dimensions of the social-ecological processes? How is it possible that the one-sided blaming of upland peasants' farming practices continues to this day while other obvious drivers of lagoon siltation are hardly mentioned, let alone examined?

Among the factors that have been systematically neglected in most accounts and in most research so far are anthropogenic as well as natural ones. Anthropogenic sources of erosion include road batters and earth trails, settlements, state forest management practices which involve clear cutting also on steep slopes, lowland agriculture extending right onto the river banks, and *ngaguguntur*, a common practice aiming at increasing the size of irrigated fields in river valleys by digging back the foot of hill slopes and shovelling the excavated soil directly into channels and streams. In some villages covered by our research, thousands of square metres of hilly land were converted into irrigated fields in this way, causing tens of thousands of cubic meters of soil entering tributaries of the Citanduy River. Natural factors may also have played a substantial role, in particular the increased volcanic activity. Mount Galunggung, the only active volcano in the upper Citanduy watershed, had been dormant for more than 4,000 years, but since 1822 has erupted five times. Rivers affected by volcanic eruptions are generally known to exhibit the highest recorded sediment yields worldwide, with yields remaining high for decades following an eruption (Hayes et al., 2002; Lavigne, 2004; Major et al., 2000; Walling and Webb, 1996). And in fact, a number of naturalists of the 19th century, among others including Junghuhn (1854), described sedimentation of the Segara Anakan lagoon as a natural process, which was considerably accelerated by eruptions of Mount Galunggung.

These natural and anthropogenic drivers have hardly entered the debate, since the scales of observation were – in line with the interpretive framings – confined to upland farmers' private plots. Similarly, the adverse and irreversible effect of the conversion of the lower river basin from swamp land into a 'rice bowl' has received only limited attention. Some project documents clearly acknowledge that besides providing livelihood opportunities for many farmers, agricultural reclamation has considerably accelerated lagoon sedimentation (ADB, 1996a; PRC-ECI, 1987). But this causal link did not fit in the socio-political framing, could not serve as an imperative for political action, and may not have been politically opportune. It would only have distracted from the newly consolidated clear-cut upland-lagoon discourse that was to serve as a basis for upland rehabilitation projects for decades.

Scalar fix as hegemonic discourse: The role forest lands

According to our research, the 'problem closure' regarding watershed management is mainly related to long-standing conflicts around state forest management, entailing struggles over the access to forest land.

Some of these conflicts have their roots in the Dutch colonial system with its forced coffee cultivation, large-scale timber extraction and estate development (Fasseur and Elson, 1992; Schaik, 1986). The related processes tremendously altered land cover and led to irreversibly increased erosion rates and accelerated lagoon sedimentation from the mid-19th century onwards. Large-scale deforestation, the growing dependency of lowland agriculture, particularly the colonial sugar industry, on steady water flows for irrigation and the observation of serious erosion on former coffee and neglected tea plantations in the Priangan (Anonymous, 1922; Coster, 1936) raised general concerns over the negative hydrological impacts of soil degradation and sparked calls for forest preservation in the first decades of the 20th century (see e.g. de Haan, 1936). These calls were based on the assumption of forests generally functioning like a sponge, balancing stream flows over time. Although this rather simple conception remains contested ever since (see, e.g. Bruijnzeel, 2004; Calder and Aylward, 2006; Roessel, 1927), the framing of forests as a basis for watershed conservation has served as a rationale and justification for their exclusive management by the state and its forest corporation until today (cf. Galudra and Sirait, 2006). That is, the assumed negative impacts of upland degradation on lowland agriculture and the related role of forest cover to sustain hydrological services gave land appropriation and exclusive forest management by the state and its entangled entrepreneurs a new, additional meaning that was conforming to the state's interest in the forests' productive resources.

The latter provided another important rationale for the rigorous management, expansion and control of forest land by the state: large-scale timber extraction had undermined the sustainability of the forests' production base. Timber was not only an important export commodity, but urgently needed for the building of railways and the processing of export crops, like sugar, coffee and tobacco, hence was an important basis for colonial exploitation. Therefore, timber extraction was to be sustained and increased by scientific forest management. Forest land was gradually mapped and delimited, and traditional forest uses by local peasants were increasingly outlawed (for a detailed account, see Peluso, 1992). The former coffee gardens which were economically no longer meaningful for the Dutch were partly incorporated into the state forest domain (Galudra and Sirait, 2006; Kerbert, 1916; Zwart, 1932).

Following political post-independence struggles and calls for land reform, the New Order Regime (1965-1997) was marked by renewed expansion and strict enforcement of the state's control over forest and plantation land. The claiming of nearly a quarter of Java's land area as state forest territory, not including estate land, and its coercive management led to a situation characterised by Peluso (1992) as 'Rich forests, poor people'. Peasants who had very limited rights to the forests and were excluded from related management decisions put enormous pressure on forest land. Despite heavy policing efforts, they continued to exploit resources from the state forests and, given the tenure status of the land, they did so carelessly, which resulted in forest degradation in many parts of Java (see, for example, Nibbering, 1988; Peluso, 1992). Faced with "social economic pressure on the forest [that] increases each year" (Bratamihardja, 1992: 96), the state forest corporation launched first 'social forestry' programmes in the 1980s. In addition, the corporation was "trying to neutralize pressure keep[ing] in mind environment[al] conservation", for example, by supporting forest margin peasants to "improve their environment and the productivity of their own land" (Bratamihardja, 1992: 96). In other words, farmers' private plots became a privileged scale of intervention in order to better defend the state's claim over forest lands. The state forest corporation follows this approach until today. It runs programmes encouraging forest margin people to plant more trees on their private lands and supporting them in adopting alternative livelihood strategies – hence creating alternatives to using resources from the state forest territory, and thereby defending the forest land tenure status quo.

While the forest lands managed by the state forest corporation have been framed as a crucial, non-contestable foundation of watershed conservation, peasants' private plots became the major scale of intervention in the frame of the various watershed management programmes and projects. These interventions, including the various tree planting programmes and the 'Citanduy II' project, were implemented under the responsibility of the MoF, which, after it had split from the Ministry of Agriculture in 1983, became one of the most powerful ministries. Watershed management (with regard to off-stream issues and land cover) has since been under the MoF which together with the state forest corporation has framed watershed management. Pushing farmers' private plots into the centre of watershed management discourses is in line with Malthusian or 'Himalayan' degradation discourses and donors' priorities, and provides a clear-cut political imperative for tree planting programmes that serve another important purpose: reducing pressure on state forest land. In this way, the establishment and consolidation of the second scalar fix of environmental management with its scalar focus of observation and intervention on upland farmers' plots is effectively linked to the hegemonic state discourse about maintaining control over the forests' productive resources. The entanglement of state forest and watershed management has also effectively prevented the state forest corporation's own management practices, which contribute to upland erosion (clear cutting) and dry season water shortages (dense pine monocultures) from being debated in the frame of watershed management discourses.

Ironically, the historically rooted struggles over forest and plantation land have not only contributed to the formation and consolidation of the second scalar fix, but have themselves been a major cause of upland degradation. Contested state forest and plantation land comprises some of the most erosion-prone lands within the watershed of the Segara Anakan lagoon (see Lukas, 2014). And interestingly, since the late 1990s these struggles have entailed contestations of this scalar fix and challenged the hegemonic role of state forestry. In particular, peasants and land reform movements now frame questions of just access to land at a larger time scale, taking the struggles of the 1950s and 1960s into account (ibid.). In doing so, they lay claim to the former role of the forestry administration by portraying peasants occupying state forest land as "sustainable managers of fragile upland environments" (Peluso et al., 2008: 398). Thus with a broader shift in political power and the state forest administration with its private extensions in a crisis of legitimacy, the scalar fix that has dominated watershed management for three decades seems to loosen its grip.

4 Conclusion

The case of the Segara Anakan lagoon and its catchment area provides a prime example illustrating the establishment of scalar fixes of environmental management in the context of particular political constellations and interests. It also highlights the persistence of particular scalar fixes over longer periods of time, and their tendency, using the words of Sievanen et al. (2013:214), to "discursively sidelin[e] and even mask[…] contentious issues". Both the watershed and the lagoon have been profoundly transformed by natural processes and a multitude of socio-political dynamics, and both have been invested with meanings changing over time, at the same time implying and resulting from particular scales of observation and intervention.

One important insight from this empirical case is the crucial role and political character of observational scales. It comes as no surprise that the key agents of interventions tend to choose scales of observation that do not challenge their objectives. It is more disturbing to see that few scientists were able or willing to challenge the confinements that came along with the dominant interpretive framings. They have largely focussed on particular scales (such as farmers' contemporary private plots) in line with hegemonic framings, thus affirming the established patterns of intervention. As a consequence, interventions in the uplands that aimed at reducing lagoon sedimentation, seasonal water shortages and flooding were based on unrealistic expectations and ignored various other causal factors which did not fit into the strategic interpretive framings and preferred modes of intervention.

In this context, it is important to our understanding of scalar fixes that they are not simply disposable or at the discretion of particular actors. In contrast to Cohen and Bakker's (2014) approach to eco-scalar fixes, we also do not narrow the focus on the state, or on the political-administrative system as a quasi-autonomous actor in a well-defined jurisdictional space. The processes and empirical case we are concerned with are less clear-cut and more polymorphous; they involve actors on diverse political levels reaching beyond the nation state, and they form part of social struggles that belie functionalist readings where ready-made scales are being deployed by the powerful. With Sievanen et al. (2013:213) we do not see "the simple replacement of one scalar configuration with another fully formed one", but rather "provisionally stabilized outcomes of scaling and rescaling processes".

The empirical case presented also directs attention to the role of the temporal aspect of scales in the shaping and consolidation of particular interpretive framings. For example, the framing of seasonal flooding of the newly established irrigation schemes in the lower river basin as being a result of unsustainable upland agriculture is based on a short-term observation that does not cover the period prior to the conversion of the seasonally inundated swamp forests into agricultural land. Another example is the framing of lagoon sedimentation as an outcome of unsustainable upland agriculture. This interpretive frame minimizes earlier social-ecological processes, in particular, transformations during colonial times (e.g. deforestation through large-scale timber extraction, erosion on coffee plantations) and interventions in the 1960/70s (river channelling and embankment), and it largely excludes these processes from debate and analysis. That is, there also exists a politics of temporal confinements regarding observation and knowledge production as well as regarding interventions. Only few authors have explicitly dealt with temporal issues in the scale debate so far, describing a politics of temporal scale (McCann, 2003) or pointing to future obligations (Bolin et al., 2008) and the recurrent character of rescaling processes over time (Brown and Purcell, 2005). Social-ecological change seems to require such a time-sensitive perspective due to the very processes it is concerned with.

The perspective of scalar fixes urges us to see the scales of observation not as boundaries of our research, but as subjects of critical inquiry. Investigating the intricate relationship between interpretive framings and the scales of observation and intervention, including not only their spatial and hierarchical but also their temporal characteristics, can help to gain a better understanding of the political struggles over environmental management, including the ambivalent role of scientific research. The persistence of certain explanations has been the focus of this paper and the starting point of our theoretical interest. The current political struggles over land and forest resources in Java demonstrate how even such interpretive framings can be challenged successfully that seemed unchangeable for decades.

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Chapter 6
Political Transformation and Watershed Governance in Java: Actors and Interests

Martin Christian Lukas

6.1 Introduction

This chapter analyses transitions in watershed and forest governance in Java. It focuses on the reorganisation of political structures, changing actor constellations and the emergence of new management approaches. These transitions have been part of broader political transformations in Indonesia and reflect learning effects from experiences with previous management approaches, shifts in broader political and scientific discourses as well as developments on international scales. This chapter will particularly shed light on changes in the interplay of various actors, their interests and power relations and their discursive constructions of environmental issues and relate these changes to the emergence of new management approaches. It describes a transition from a pronounced state-led, centralistic, hierarchical style of government, claiming sovereignty of interpretation over environmental issues and being largely based on command-and-control structures, to more dynamic and vertically

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This chapter builds on empirical work that was carried out by the author between 2008 and 2011 when he was affiliated with the Leibniz Center for Tropical Marine Ecology Bremen (ZMT). The research was part of the bilateral Indonesian-German research programme SPICE II (Science for the Protection of Indonesian Coastal Marine Ecosystems), sponsored by the German Federal Ministry of Education and Research, the Indonesian Ministry of Marine Affairs and Fisheries (DKP) and the Ministry for Research and Technology (RISTEK). The author was also supported by the Bremen International Graduate School for Marine Sciences (GLOMAR), which is funded by the German Research Foundation (DFG) within the frame of the Excellence Initiative by the German federal and state governments to promote science and research at German universities. The author is grateful to Suci Ramdania, Hesti Maharini, Syarifah Aini Dalimunthe, Choiriatun Nur Annisa and Rendy Enggar Suwandi for their field research assistance and to Michael Flitner, Jonas Hein and Heiko Garrelts for their review of the paper and their suggestions.

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more fragmented, network-like forms of governance with an increasing involvement of non-state actors, new actor coalitions and a more diverse range of management approaches and initiatives.

The emerging new modes of governance can be characterised by their much ‘flatter’, more horizontal structures, for which different authors have used terms like ‘networked’ or ‘nodal governance’ (Parker 2007; Burries et al. 2005). However, these terms have to be specified in the context of Indonesian watershed governance. Despite revolutionary political transformations in the country and visible progress in many areas, simplistic, one-sided sociopolitical discourses have persisted in some realms, and some of the previously most powerful actors continue to dominate political processes and decision-making in the fields of natural resources use and environmental conservation. This is in line with one of the main arguments developed by Flitner and Görg (2008) that contrary to the intuitive implication of governance ‘networks’ describing trends towards less hierarchical, more participatory regimes, dominant centres of power and influence often continue to exist. Yet they are not situated in well-defined hierarchical levels as before but less visibly embedded in complex networks which may at the same time be more dynamic, with changing temporary constellations or ‘nodes of power’.

Yet political rights and possibilities to exert influence of those who were previously excluded, repressed or at best seen as passive recipients or implementers of watershed interventions, have tremendously improved. Following their powerful, and at the same time environmentally disastrous, rebellion in the frame of a nationwide political upheaval in the late 1990s, they now have more freedoms to push their interests, to struggle for their rights, to set up networks and form alliances with new actors, supporting them in questioning established sociopolitical discourses and setting up new management approaches that are locally rooted but influenced by actors from various scales. Like previous political transformations during the twentieth century, the political transitions since 1997 have exacerbated environmental problems. But at the same time, they have provided the scope for developments towards new, socially and ecologically more sustainable modes of watershed governance.

6.1.1 Watershed Governance in Java: Long-Standing Investments, Long-Standing Challenges

The volcanic island of Java, by nature already a highly dynamic environment, has been rapidly transformed by human activities. The rapidly increasing magnitude of human impact and the islands’ reputation as one of the most densely populated areas in the world pushed Java into the spotlight of Malthusian prophecies of severe environmental and human disaster even long before environmental concerns found their way into the global scientific and sociopolitical mainstream (see, e.g., Geertz 1964). Particularly deforestation, soil degradation, erosion, sedimentation and flooding, all classical watershed problems, became issues to be addressed in the frame of environmental management initiatives.

Concerns over the possible negative hydrological impacts of soil degradation were already raised in the late nineteenth and early twentieth century. Accelerated deforestation in many parts of the island after the mid-nineteenth century, the observation of serious erosion on former coffee and neglected tea plantations in the Priangan, the southern part of West Java, and the growing dependency of lowland agriculture, particularly the colonial sugar industry, on steady water flows for irrigation sparked calls for forest preservation (Oosterling 1927; de Haan 1936) and provided a rationale for the spatial extension and strict management of state forest territories by the Dutch administration.

Following the worldwide surge in river basin development initiatives as a favoured modernisation strategy between the 1940s and 1960s (Ekbladh 2002; Molle 2009), river basin development became a matter of national importance in Indonesia in the late 1960s. With support from international development organisations, a first series of river basin development projects was implemented in some of Java's major river basins, including Solo, Brantas and Citanduy. Watersheds were delineated as planning units nationwide, and watershed management authorities were set up. In 1969, the government established river basin development authorities directly under the Ministry of Public Works in a number of Java's major river basins, including the Citanduy, Citarum and Solo rivers. Starting in the 1970s, political interest gradually turned from agricultural reclamation, irrigation systems and flood protection in the lower river basins to upland conservation. Since then, substantial resources have been allocated for upland conservation measures in Java, both in the frame of donor-funded development projects and in the frame of the continuous national regreening programmes, which have focused on tree planting and terracing of agricultural land. Yet many watersheds in Java continue to be considered as degraded (Interviews April 2008, January 2010).

Research and interventions have mainly focused on optimising small holder farming systems and improving peasants' livelihoods (ADB 1996, 2006; Purwanto 1999; Tim Koordinasi Wilayah 1989; USAID 1985). But this can neither sufficiently explain nor address some of the most important issues and challenges related to upland degradation. My analysis of land use and land cover change and its drivers in the catchment areas of the Citanduy, Cimeneng and Cikonde rivers has shown that state forest areas rather than small holders' private plots seem to comprise the major hotspots of critical, erosion-prone land and that the long-lasting investments into upland conservation, which focused on small holders' private land, have had only limited effects. To understand the underlying causes of this situation and to assess the achievements, chances and challenges related to recent transitions towards new modes of watershed governance, it is important to look at the historically grounded interplay between the various actors, their interests, their power relations, their discursive constructions of environmental issues and their roles in designing and implementing management interventions.

This will be illustrated in the following sections, based on empirical findings of recent research on land use and land cover change and forest and watershed governance in the catchment area of the Segara Anakan lagoon, the estuary of the Citanduy, Cimeneng and Cikonde rivers. Section 6.2 will shed light on some of the major characteristics and patterns of forest and watershed governance during Indonesia's New Order Regime between 1965 and 1997. Section 6.3 will briefly describe the revolutionary, partly chaotic dynamics with regard to forest management following the fall of the New Order Regime between 1997 and 2001. The fourth and main section will explore transitions towards new modes of forest and watershed governance since then. It describes an increasingly open political arena providing opportunities for new or newly empowered actors to frame alternative discourses, to develop alternative management approaches and to challenge long-standing power relations. It further illustrates transformations of parts of the previously centralistic, hierarchical state apparatus into elements of more flexible networks encompassing various state and non-state actors and exposes the pervasive persistence of long-standing nodes of repressive power as major, albeit not easily visible obstacle to sustainable resources governance. The conclusion will reconsider the analysed developments towards new modes of governance, conceptualising them as transitions in the frame of a gradual shift from traditional hierarchical forms of government to networked or nodal governance.

6.2 Watershed and Forest Governance During the New Order Regime 1965–1997: Coercive, Non-participatory Approaches

6.2.1 'A Strong Alliance That Was Hated by the People'

Between 1965 and 1997, forest and watershed management like most other spheres of public life in Indonesia were dominated by a repressive, centralistic, hierarchical nation state. President Suharto's New Order Regime, which particularly during its first two decades was pervasively dominated by the military, was marked by forcibly coordinated command-and-control structures with state institutions on all levels being politically brought into line. The national government, the central locus of decision-making, with its hierarchical, top-down oriented administrative system and its enterprises claimed absolute political sovereignty, which was secured by police and military forces. Accordingly, the state with its sectoral authorities particularly under the Ministries of Agriculture, Forestry and Public Works and its province, district and sub-district administrations as well as its state corporations widely claimed sovereignty of interpretation over watershed and forestry issues and dominated related management approaches. Governance of natural resources, particularly forest resources, was closely entangled with the state's interest in natural resource exploitation.

But also international donor organisations, such as USAID, World Bank and Asian Development Bank (ADB), with their external experts as well as Indonesian scientists substantially contributed to watershed management and the formation of related discourses. However, their spheres of influence were rather limited to the fields of converging interest, where joint collaboration with the Indonesian government was sought by the participating parties, albeit for different reasons. For example, the US-led international surge of river basin development as a preferred modernisation strategy (Ekbladh 2002; Molle 2009) was perfectly in line with the goal of Indonesia's New Order Regime to achieve rice self-sufficiency and to consolidate state control. Hence, river basin development projects marked the beginning of a broader US-Indonesian economic partnership in the late 1960s, which provided the USA the opportunity to promote the western liberal model of modernisation after Suharto's military coup and the subsequent crush of Indonesia's communist movements in one of the bloodiest massacres in Southeast Asian history (Simpson 2008). The USAID-funded Citanduy I Project was one of the first large river basin development projects implemented. It focused on agricultural reclamation of the lower river basin, irrigation schemes and flood control measures. The selection of the Citanduy basin as implementation site was partly related to previous violent conflicts between the state and radical Islamic and 'communist' movements in that area. The river basin development approach as a state-dominated, large-scale intervention was certainly in line with the national government's strong interest to bring these movements under control or respectively prevent their resurgence and to establish or consolidate state control in this politically fragile area.

Aside from the fields of converging interest, the influence of international donor organisations, external experts and Indonesian scientists on management approaches was rather limited. The knowledge, data and recommendations they contributed were usually widely tailored to management approaches and planned interventions that had already been outlined before. Alternative interpretations and critical arguments were at best occasionally raised by a number of foreign researchers. Intransparent administrative structures and procedures were not only a machinery of corruption but could easily slow down unwanted initiatives. For example, the establishment of the socio-economic research unit that was integral part of the Citanduy II project design but apparently, and possibly for political reasons, not sought by the government was effectively hindered by administrative formalities (USAID 1984).

Notwithstanding the substantial achievements of some of the interventions, including the conversion of the lower Citanduy basin into a fertile rice bowl, problematic power and decision-making structures had partly detrimental effects. Besides the national government, provincial- and district-level authorities were in different ways involved in decision-making. But for communities, there was no scope for participation, and residents of the area in retrospect often subsume all state authorities on the various levels from the national government down to the subdistrict and partly even the village level as 'a strong alliance that was hated by the people but was better not defied' (Interviews, February 2011). The people were mainly recipients, implementers or targets of management approaches and had very limited possibilities to participate in decision-making.

This constellation of actors and power and the resulting non-participatory, partly coercive management approaches and simplistic, one-sided political discourses had detrimental environmental effects and undermined the effectiveness of management interventions. This will be illustrated in the following two sections, which will exemplarily shed light on coercive forest management and upland conservation measures.

6.2.2 Coercive Forest Management and Forest Degradation

Management of Java's state forest areas, which account for no less than about one quarter of the surface area of this extremely densely populated island, was and still is assigned to the state forest corporation. During the New Order Regime, the state forest corporation was one of the most dreaded organisations within the 'strong alliance that was hated by the people but was better not defied' (Interviews, February 2011).

The state forest corporation has been one of the most relevant actors in watershed governance on Java but has often not received adequate attention in this context. Its forest management practices, its relations with forest margin people, its discursive power and its particular position within institutional arrangements have greatly affected both physical watershed processes and watershed management during the past decades.

Forest areas had been declared as state domain and had been mapped and delimited under the Dutch colonial administration in the second half of the nineteenth century and further extended thereafter. They had been managed in increasingly repressive ways with forest margin people facing severe restrictions of their traditional access to forest resources (Peluso 1992). The state forest corporation, the successor of the 'colonial forest empire', further strengthened the system of coercive power during the New Order Regime. A strong forest police, in case of need supported by the military, secured the state forests from peasants. Fatal shots on villagers were not uncommon.

The political rationale for this coercive forest management approach was rooted in two claims, complementing each other: the state's and its forest corporation's interest in exploiting the forests' productive resources and the argument that watershed conservation required professional forest management. The latter could thrive on the concerns about soil degradation that had already been raised in the late nineteenth and early twentieth century and that were further underpinned in the context of forest devastation during the Japanese occupation between 1942 and 1945, when peasants were encouraged to encroach state forest and plantation land to use it for food crop cultivation – partly officially with leaseholds and partly in-officially (Interviews, February 2011). The rise of environmentalism in Indonesia after the mid-1970s (Cribb 1988) provided additional ground for asserting the state's sovereignty over forest resources. The clear-cut narrative that forests should be managed by professionals for the sake of optimising production and watershed conservation, while peasants would not be able to manage forestland sustainably, entwined the state's and its forest corporation's interest in production and control over forestland (Peluso 1992; Interviews, April 2008, April 2011).

In reality, the approach of coercive management neither allowed optimised production nor was it a successful watershed conservation strategy. State forests remained contested, and even substantial efforts and repressive methods for guarding them could not entirely prevent peasants, who had been deprived of their traditional access to forest resources, from 'illegally' using them. This 'illegal' exploitation not surprisingly was inefficient and destructive, since people, if they took the risk and bypassed forest guards, tended to regard state forests as de facto open access resource, which could recklessly be exploited without paying attention to questions of resource sustainability and optimised production (Nibbering 1988). This resulted in forest and hence watershed degradation and comparably low levels of productivity (ibid., Peluso 1992; Singer 2009). It was not before the late 1970s and early 1980s that increasing hindsight into the failure of coercive forest management and the influx of ideas from the international level paved the way for the implementation of first social forestry programmes, albeit on a small scale and with limited success (Simon et al. 1992; Singer 2009).

However, in the context of watershed management initiatives, including national regreening programmes and donor-funded watershed management projects, degradation within state forest territories never received adequate attention. Professional forest management by the state forest corporation was commonly seen as synonymous with sustainable forests and watershed conservation. Hence, management of state forest territories and their protection from the people for the sake of production and watershed protection were entrusted to the corporation. While forest management by the corporation was discursively framed as epitome of sustainability, the historical roots of the seemingly irreconcilable, ecologically detrimental tensions between the corporation and peasants were never addressed. Also the corporation's own management practices, which have always involved regular large-scale clear cuts, including at steep slopes in close proximity to streams, have never been questioned in the context of watershed conservation, even though these practices obviously cause substantial erosion. The power of the discourse which portrayed forest management by the corporation as a means for sustainable forest and watershed management effectively prevented the emergence of any contrary views.

The persistent contradiction between the political pursuit of watershed conservation and related long-lasting efforts on the one hand and the failure to adequately discuss and address widespread degradation in state forest territories and its causes on the other hand can only sufficiently be explained with historically grounded tensions between the state forest corporation and peasants, the state's interest in the control over and exploitation of forest resources and related institutional arrangements. The latter granted the forest corporation the sole responsibility over state forest territories, while the spatial responsibility of watershed management authorities at both the scale of the watershed and the various administrative levels ended at the border to the state forest. Furthermore, the basin-wide watershed management authorities responsible for upland conservation were established under the responsibility of the Ministry of Forestry, which in turn has close ties with the state forest corporation.

6.2.3 Upland Conservation: Simplistic Political Discourses and Top-Down Approaches

While degradation within state forest territories was not adequately addressed, substantial resources were directed into upland conservation measures targeting small holders' private land all over Java. One hotspot of upland conservation efforts was the catchment area of the mangrove-fringed Segara Anakan lagoon. In this region, upland degradation was seen not only as a cause for the sedimentation of irrigation channels, seasonal flooding and dry season water shortages in the newly established ‘rice bowl areas’ of the lower river basin but also as a threat to the unique ecosystem of the estuarine Segara Anakan lagoon and the livelihoods of its residents (White et al. 1989; Olive 1997; Yuwono et al. 2007).

The causes of these problems were mainly attributed to the population in the upper catchment area with governmental organisations and experts pointing to population pressure, poverty and unsustainable upland farming as major issues. This framing of erosion and sedimentation processes as an environmental crisis caused by poor upland farmers provided a clear-cut narrative for the joint interest of international donor organisations, the Indonesian government, the forest administration and the state forest corporation to take collaborative action. Supporting poor upland peasants in terracing their land and encouraging them to plant more trees would contribute to reducing poverty, to inducing development in economically marginalised upland areas and to environmental conservation (ADB 1996, 2006; Tim Koordinasi Wilayah 1989; USAID 1985). These were shared interests of the government and international donor organisations and were in line with international environmental and development discourses. Enhancing the livelihoods of forest margin people and encouraging them to plant ‘their own’ trees also befitted the interest of the forest administration and the state forest corporation since it might help to reduce the pressure on state forestland. This coalition of actors with converging interests set a ‘machinery of discourse and management interventions’ in motion that has dominated watershed governance till today. Upland farmers’ private plots were discursively framed as major source of erosion; experts set up experimental and demonstration farms and developed agricultural extension packages; tree planting programmes were initiated, and farmers received training and seedlings. Departing from first pilot projects in the frame of the Citanduy I project in the late 1970s, these activities have been carried out for decades in the catchment area of the Segara Anakan lagoon and all over Java both in the frame of development projects, funded, among others, by USAID and ADB, and in the frame of the national conservation and regreening programmes (ADB 2006; USAID 1984; Interviews, May 2008–May 2011).

In both cases, planning and implementation were mainly under the responsibility of the Ministry of Forestry, which, after it had split from the Ministry of Agriculture in 1983, became one of the most powerful ministries. This constellation helps to explain why watershed conservation became synonymous with the enforcement of professional state forest management by the state forest corporation and with terracing and tree planting programmes on farmers’ private land, with the latter along the way potentially supporting the first.

That this ‘machinery of discourse and management interventions’ has barely been challenged for decades has to do with the dominance of a repressive, centralistic state with forcibly coordinated command-and-control structures and with development experts and Indonesian scientists being engaged as part of the machinery to contribute to the preparation and implementation of predefined interventions rather than to critically question them. It has to do with long-lasting simplistic assumptions regarding the role of professionally managed production forests for watershed conservation in Java and with internationally circulating, though questionable, discourses about the destructive hydrological impacts of marginalised upland farmers' cultivation practices in other parts of the world (see Ives and Messerli 1989; Forsyth 1996; Forsyth and Walker 2008). Ecological discourses, once formed and appropriated by a powerful actor coalition in line with their political interests, can serve as normative foundations for political action and effectively confine boundaries of knowledge production or render critical scientific inquiry seemingly unnecessary – a phenomenon conceptualised by Hajer (2000) as 'problem closure'.

More participatory approaches to forest and watershed management would likely have provided opportunities for discussing, investigating and addressing various other causes of lowland and lagoon sedimentation, including the state forest corporation's management practices, the underlying sociopolitical causes of forest degradation, considerable historical land use changes in the nineteenth and early twentieth century that were triggered by colonial exploitation, the digging out of slope toes by farmers to expand their wet rice fields and, last but not least, a series of volcanic eruptions within the past two centuries. This would likely have resulted in management approaches addressing watershed issues more effectively and efficiently since the entire range of drivers, partly including the historical courses of their development, would have been addressed according to their actual relevance.

More participatory approaches would also certainly have enhanced the effectiveness of the long-lasting investments in the frame of the conservation and regreening programmes. These were later judged to have failed to raise farmers' awareness for issues of erosion (ADB 1996) and were generally 'improperly carried out' (ADB 2006: 8). Despite the fact that the upland interventions obviously considerably increased the portion of upland dryfields being terraced, they in fact seem to have failed to reduce downstream sediment yields (Diemont et al. 1991; Purwanto 1999). This has been attributed to various reasons, including, among others, procedural shortcomings and site-insensitive delivery of one-type-fits-all upland agricultural packages (USAID 1985; Purwanto 1999). These problems can mainly be ascribed to non-participatory, mechanical approaches, inflexible top-down oriented decision-making structures and rigid regulations. The types of terraces farmers could construct were too restricted and partly locally not adapted, and the time slots for completing the work were inflexible. Not the farmers or communities but state authorities in collaboration with state-run nurseries decided which trees farmers could plant at what time (Interviews, November 2009–May 2011). Exertion of pressure and authority was reportedly not uncommon. In some cases, farmers were made to adopt a variety of different tree crops over time which they were told provided great economic opportunities but which finally failed, partly causing farmers to return to annual crops. For instance, the promotion of clove trees and subsequently declining clove prices, both related to business interests of the President Suharto's family, caused farmers to experience economic losses (Interviews, November 2009, February 2011).

The upland conservation and regreening programmes have raised the proportion of terraced agricultural land and substantially increased tree cover in selected sites. However, their overall contribution to watershed conservation has remained very limited as measured in terms of effort invested over decades.

6.3 Political Upheaval and Environmental Crisis

The revolutionary political upheaval in Indonesia that started in 1997 and involved the fall of Suharto's New Order Regime triggered environmentally disastrous developments but, at the same time, provided scope for the emergence of new, possibly more sustainable modes of watershed and forest governance. Environmental destruction was not only a result of chaotic upheaval and lawlessness, but itself has to be seen as an integral part of the rebellions against the state and its forest corporation, against their hegemonial ecological discourses, against coercive forest management and against decade-long repression and injustice. The environmental destructions and the subsequent and still ongoing rearrangements and renegotiations of political structures, of the configuration of actors, their levels of power, their political room for manoeuvre and their strategies have provided opportunities for *or* utterly necessitated the search for new management approaches.

The nationwide turmoil after 1997 provided opportunity for or was rather partially driven by large-scale upheavals of peasants, questioning established patterns of access to and control over forestland. The linking of local peasants' struggles with the emergence of national-level revolutionary forces brought land reform movements, which had been widely eradicated in 1965 and which could persist only as underground movements thereafter, back into the political arena (Peluso et al. 2008). After years of repressive modes of state forest management, a powerful countermovement of villagers spearheaded by influential individuals, partly including staff members of the forest corporation itself, used the opportunity of social tumult during the political transition after 1997 to plunder the state forests and therewith challenge consolidated power structures and get access to and control over resources they had been deprived of for decades or centuries. Peasants' re-appropriation of forestland, or what is commonly referred to as 'illegal logging', abruptly and forcibly shifted the control over forest resources from the state forest corporation to the people, altered the power relations between peasants and the forest corporation, and left behind critical, erosion-prone land. It needs to be remarked that illegal logging was not only driven by 'formerly repressed peasants' but was partly coordinated and accelerated by influential, wealthy individuals from towns or other regions, who provided chainsaws, trucks and safeguard and used the opportunity of political upheaval for their personal gain (Interviews, November 2009, February–May 2011). However, village residents in different parts of the catchment area of the Segara Anakan lagoon stressed that everybody participated and that illegal logging and occupation had not only been driven by personal economic hardships or the prospect of economic gain but that it had been a strategy 'to demonstrate who had the power' (ibid.). The devastated state forests are to be seen as a product or manifestation of decades of repressive government, coercive forest management and injustice.

The roots of these injustices partly go back to the late nineteenth and early twentieth century when the state forest areas were demarcated by the colonial forest administration and traditional uses started to be increasingly discriminated (Peluso 1992). In other cases, concrete land conflicts between peasants and the state forest corporation go back to evacuations of entire villages in the 1950s in the wake of political unrest triggered by the Darul Islam, a radical Islamic movement fighting for Indonesia to become an Islamic state. Following dubious state-organised land swaps, which left many of the displaced people landless, the villagers who returned to their land were forcibly evacuated in 1965 to make way for the expansion of state forest territory (Interviews, February–May 2011). Other land conflicts go back to disappropriations of peasants' land by plantation companies (ibid.). In all cases, the alliance of state authorities, companies, police and military effectively oppressed the displaced until 1997, leaving no room for resistance. Since then, the displaced have returned, cleared the forest, occupied the land and struggled for land titles (ibid.). My case studies suggest that as long as these land conflicts are not resolved, the land remains prone to erosion since farmers tend not to invest into soil conservation measures without any long-term perspective.

Decades of repressive forest management, which allegedly aimed at watershed conservation but in fact had always been detrimental to conservation goals, have finally resulted in massive large-scale forest devastation and hence watershed degradation. Erosion, landslides and more severe floods at the scale of sub-watersheds since the late 1990s have been the obvious consequences.

6.4 Towards New Modes of Forest and Watershed Governance

This ecological devastation together with the political transformations in Indonesia since the late 1990s has opened windows of opportunity for transitions towards new, possibly more sustainable modes of watershed and forest governance. These still ongoing transitions are driven by or respectively involve major reformations of the overall political system, altered power relations and 'new' actors entering the political arena. But they also reflect a paradigm shift that is related to learning effects from experiences with previous watershed and forest governance approaches and to influences of political and scientific discourses and societal developments on larger (international) scales. There has clearly been a shift from non-participatory, state-dominated, top-down oriented repressive command-and-control approaches towards more decentralised, participatory, incentive-based approaches. And there are clear signs of developments towards a better balance between the state's and the corporate's claims of sovereignty over production and conservation on the one hand and the local populations' resource use rights and needs and an acknowledgement of their factual substantial contributions to watershed conservation on the other hand. However, many of the achievements made are the results of fierce political struggles, and the persistence of established political discourses and some of the 'old' dominant centres of repressive power continue to pose major challenges.

Long-standing power relations and patterns of conflicting interest combined with habitual ways of thinking and communicating and related courses of action continue to affect the scope and outcomes of forest and watershed management approaches. Continued forest and watershed degradation, albeit less devastating than in the late 1990s and early 2000s, is a visible sign of still ongoing political struggles for and conflicts over new modes of governance.

Based on a number of governance and management issues encountered in a series of case studies in the catchment area of the Segara Anakan lagoon between 2009 and 2011, this section explores both transitions and patterns of persistence in watershed and forest governance since the late 1990s and discusses related achievements and challenges.

6.4.1 'New' Actors and Actor Coalitions: New Discourses and Management Approaches

With the fall of Suharto's New Order Regime and the following democratisation and decentralisation of the political system, the state rendered its sole sovereignty of interpretation and decision-making, thereby providing room for various previously unheard, excluded or oppressed actors to contribute their views to sociopolitical discourses, to influence decision-making processes on, form networks and take coordinated action, and to struggle for their rights and push their interests. Peasants, who had previously mainly been seen as passive recipients or implementers of interventions, have now enhanced opportunities to participate in decision-making at the community level, to have their interests represented by village heads, who are not necessarily an extended arm of the central government, and to form farmers' groups that are not anymore coordinated and brought into line by the central government (Interviews, November 2009, February–May 2011).

Such farmers' groups with support from non-governmental organisations (NGOs), many of which are run by or linked with groups of university students, collaboratively struggle for rights over land that was disappropriated in the 1950s and 1960s, that is not properly managed by plantation companies, or whose tenure is renegotiable due to expiring long-term leaseholds. Corresponding legal processes drag on over many years, but in a few cases, farmers have in fact already received land titles (Interviews, November 2009, February–May 2011). Particularly interesting with regard to the formation of new modes of forest and watershed governance are the local management plans that farmers with support from the NGOs have set up for disputed land in some areas and that challenge the long-standing simplistic watershed discourses. For example, Serikat Petani Pasundan (SPP), a leading farmers' organisation in West Java (see Rachman 2004), has in the process of claiming former plantation land in one part of the catchment area developed spatial plans for this land, with land partitions for all families of the surrounding communities and conservation-oriented management rules (Interviews, April 2011). The latter assign steep slopes to conservation and mixed forests and valley floors to terraced wet rice fields. These locally based management plans replicate the soil-conserving land use pattern that has already prevailed on small holders' private land for decades and challenge the long-standing discourse that claims small holders' allegedly unsustainable cultivation practices as main cause of watershed degradation. In fact, in contrast to state forests, a large proportion of small holders' private land in the lagoon's catchment area with its combination of terraced wet rice fields and stratified mixed forests, managed by selective logging rather than clear cuts, could serve as a model for watershed conservation. Acknowledgement of these spatial realities is an important basis for more targeted interventions. Hence, dismantling the long-standing misleading discourses is an important contribution towards new, more participatory and more sustainable modes of watershed governance. Initiatives of new actor coalitions like the one described above contribute to that.

The transformation of a repressive, centralistic state, claiming sovereignty of interpretation, into a more open political arena with various previously unheard actors being able to form networks and build coalitions provides new opportunities for sustainable watershed governance. From political processes previously excluded villagers have built networks with NGOs and urban-based student activists. The bundling of different experiences, competences and spheres of influence in such networks gives the participating actors the power to effectively push their views and interests, to question established discourses and to develop alternative, more participatory and locally based management approaches. Their links with broader level organisations, such as the Consortium for Agrarian Reform (Konsorsium Pembaruan Agraria, KPA), allow them to exert political influence on the national level (Afiff et al. 2005). As new emerging nodes of power and influence, such networks expand into the spaces opened up by the fragmentation of a long-standing, state-dominated, hierarchically integrated power apparatus.

Other emerging nodes of influence involve in addition to NGOs private sector organisations and universities and span various levels, including the international. In one part of the lagoon's catchment area, Bumi Hijau Lestari, an Indonesian nonprofit foundation established by furniture manufacturers from all over the world, contributes to increase tree cover on farmers' private land. The initiative, which focuses on Central Java, is similar to the regreening programmes that were run by the state for decades, but leaves more flexibility to farmers. The latter can choose between various species, and the foundation then provides seedlings and fertiliser and in collaboration with the Bogor Agricultural University organises workshops to teach farmers how to produce their own organic fertiliser and how to take optimal care of the trees. The farmers can freely choose when to harvest their trees and where to sell them but are encouraged to use the foundation's funding partners as marketing channel. Asked for a comparison with the previous state-run regreening programmes, village heads and farmers highlighted the better quality of seedlings and training and the flexibility and transparency. They also felt to play a more active role throughout the entire process (Interviews, November 2009).

It appears that a foundation that links furniture manufacturers from all over the world, who, driven by the social and environmental awareness of their customers, want to demonstrate their corporate social responsibility, with farmers, village heads and a university runs an alternative regreening programme without any involvement of the state and obviously with better results than the previous state-run programmes. However, in spite of being well accepted and successful at the local level, the initiative does not explicitly target the basin-wide hotspots of watershed degradation. Driven by the mission to contribute to social and environmental sustainability at the localities of timber production, the initiative does not necessarily select the sites of intervention according to degradation levels. In this context, linkages between the new network and the long-standing state-run watershed management authorities – i.e., linkages between newly emerging and long-standing nodes – might possibly be promising. In such a constellation, the state authorities could facilitate the smoothly running programmes of the foundation by contributing expertise on the hotspots of watershed degradation.

6.4.2 'Old' Structures and Actors in Transition: New Approaches

Besides creating space for 'new' actors and actor coalitions to emerge as new nodes of influence and power in an increasingly open political arena, the national political transformations have also at least to some extent reshaped the previous centralistic, hierarchical, top-down oriented state apparatus into a more fragmented network. Ambitious efforts towards decentralisation involved major shifts of power and authority between all levels from the national to the village level, with district governments emerging as important nodes of power and influence and communities gaining more autonomy (Resosudarmo 2005).

These transformations provide a basis for district and sub-district authorities in charge of natural resource management to play a more central role as regional facilitators rather than implementers of top-down oriented programmes, thereby providing space to experiment with more participatory, incentive-based approaches. Such developments are supported by the Ministry of Forestry. Following a recent replacement of the head of the ministry's Directorate for Land Rehabilitation and Social Forestry (Direktorat Jenderal Rehabilitasi Lahan dan Perhutanan Sosial, RLPS), funding for the long-standing regreening programme, which has briefly been outlined in Sect. 6.2, was phased out. Partly in collaboration with the Ministry of Agriculture, funding is now provided for more participatory programmes, which are facilitated by the district-level authorities (Interviews, February–May 2011).

The concept of these programmes establishes communities as central loci of initiative, decision-making and action. For example, in the frame of a recently launched smallholder rubber programme (Karet Rakyat), the participating farmers not only decide how many trees they would like to plant in which areas at what time but are supposed to organise the entire process themselves. They are encouraged to establish farmers' groups, who develop plans for village nurseries and planting programmes and negotiate with suppliers of material. Extension personnel from the district and sub-district offices, who are responsible for agriculture, forestry and watershed conservation, facilitate these activities and provide support in finding appropriate marketing channels. Once the farmers' group has a thorough concept, it can apply for public funding via the district administration, which would then contribute one third of the total investment costs. The head of a district extension service in the lagoon's catchment area emphasised the importance of his role as facilitator in the process since this would, among others, help to prevent the formation of exploitative farmer-trader relations. In this context, he also planned to invite investors for building a rubber processing factory in the area, thereby offering the possibility for farmers to directly sell their produce to the factory without relying on traders (Interviews, February 2011).

The example of the Karet Rakyat programme and its comparison with the previous regreening programmes described in Sect. 6.2 impressively illustrates the changing roles of some state authorities from being decision-makers to being facilitators. In this case, a district authority, which had previously as part of a hierarchical command-and-control system been responsible for implementing the blueprints designed by the ministry at the local level, has now become a facilitator of village-based initiatives, providing expertise if needed, channelling funds from the ministry to the village to support these local initiatives and establishing links with the private sector. In other words, some of the fragments of the previous state-dominated, hierarchical structure have been transformed into a loose network encompassing farmers together with state and market actors. Where this works well, it can be a prime example for environmental governance that bridges dichotomies between state and market approaches and between conservation and development and that is mainly based on incentive rather than regulation and command-and-control. First experiences with the new approach in the lagoon's catchment area are encouraging; further developments need to be seen.

Clearly, the performance of such new approaches heavily depends on the persons involved. Throughout all levels of the state administration, new reform-oriented, innovative forces are competing with long-standing conservative structures that hold on to top-down oriented command-and-control approaches. The latter combined with intransparent, shady procedures can easily impede initiative and trust at the local level. Part of the government of the same district whose Karet Rakyat initiative has been outlined above was recently under investigation over diverting village development funds for their personal gain (Interviews, February 2011). But also local capacity plays an important role for paradigm shifts and new approaches to materialise in successful natural resource management. For example, lacking local capacity to understand formal contracts and initiate legal processes provides more powerful actors, such as the state forest corporation, room for manoeuvre thereby obstructing transitions towards more participatory approaches and makes villagers extremely vulnerable to exploitation by thugs, who pretend to support communities, but only collect large amounts of money before they disappear (Interviews, February 2011). Understandably, the villagers' historically rooted lack of trust in state authorities and their habitual strategy of passive resistance towards state-led interventions are important challenges for any initiative. Changes in mindsets and communication patterns on both sides – among representatives of state authorities and among the people – are perhaps as relevant as the concepts of new management approaches. Furthermore, developing appropriate local level decision-making structures and processes is a learning process that requires time and also heavily depends on the persons involved.

The latter aspect plays an important role also on higher levels. Single-state authorities, such as the Ministry of Forestry, can be conceived as networks comprising rather conservative and rather reform-oriented elements, each of them being part of broader networks spanning all scales from the local to the international. Aiming at promoting new governance and management approaches, such as market-based instruments, international donor organisations, such as the United Nations Development Programme (UNDP), attempt to connect with and support some of the (more innovative) elements within the ministry rather than trying to overturn the entire structure (Interviews, January 2010). International organisations, selected elements of the ministry, national NGOs and various regional and local actors in the project sites then appear as a network, developing and promoting new governance approaches.

These developments have been enabled by broader political transformations in Indonesia and have been influenced by both learning experiences and international paradigms. In case of the state-run regreening programmes, insight into the limited effectiveness of the previous command-and-control approaches has contributed to the development of new, more participatory, locally based approaches. In fact, the concept of the previous regreening programmes as such had already been incentive based, but the way of implementation gave the programmes the character of regulatory top-down interventions, which often were not in line with local needs and interests and therefore not particularly successful. Last but not least, the international paradigm shift towards participatory, incentive-based approaches, integrating NGOs, private actors and markets, obviously contributes to the formation of new modes of watershed and forest governance in Indonesia through interlinked networks and flows of information and ideas.

6.4.3 Persistent Nodes of Power: Between Repression and New Modes of Governance

The discussion of transformations towards new modes of watershed governance in the previous two subsections has focused on developments in conjunction with management approaches for small holders' private land while excluding the further development of the state forest areas, which have been exposed as major hotspots of degradation in Sects. 6.2 and 6.3. What has become of the environmentally destructive conflicts over forest resources between villagers and the state forest corporation? Have new modes of forest and watershed governance transformed the state forests from political battlefields into sustainably managed woodlands?

It appears that state forest areas continue to be a hotspot of degradation and that watershed discourses and related interventions, in spite of converse spatial realities and alternative framings by new actor coalitions that have been discussed in Sect. 4.1, generally continue to be focused on small holders' private land. The notions of 'unsustainable upland farming' and 'population pressure' as major watershed issues continue to be recited like mantras by both state authorities and experts. These discourses are obviously an effective legitimation for non-action with regard to degradation in state forest areas. In fact, long-standing institutional areas of responsibility continue to limit the scope of action of the state authorities assigned to watershed management. The responsibilities of watershed and province-level planning authorities as well as district-level administrations still widely end at the border to the state forest areas (Interviews, May 2008, January 2010, February 2011). Hence, the sustainability of state forest management widely depends on the outcomes of renegotiations between the forest corporation and peasants over resource access and control.

The major result of these renegotiations to date is community forestry programmes. In the frame of these programmes, the forest corporation grants peasants the right to use forestland for food crop production during the first years after trees have been replanted and later shares some proportion of the benefit from harvesting the trees with the communities. This benefit sharing is supposed to promote the communities' sense of ownership, thereby reducing the risk of illegal logging. In fact, the state forest corporation attempts to confer the responsibility of safeguarding the forest upon the communities (Interviews, February 2011). Compared with the situation prevailing until the late 1990s, the community forestry schemes appear as promising new modes of forest governance, which have replaced coercive, state-dominated approaches by participatory, community-based approaches.

However, in fact, the programmes are not yet particularly successful in many parts of the lagoon's catchment area (land use mapping and interviews, May 2008–May 2011). The underlying causes are related to the corporation's domination of the entire process and its remaining as central locus of decision-making. This together with historically grown tensions between the corporation and peasants, involving a pronounced lack of trust and habitually conflicting patterns of communication and action, clearly undermines the sustainability of the community forestry programmes. While the programmes pretend to be participatory bottom-up approaches, they are in reality based on standardised blueprint contracts designed by the forest corporation to be signed by the community, and the process of establishing the community forestry groups and related structures is dominated by the corporation rather than based on participatory processes. All decisions regarding the planting, management and harvesting of the trees are made by the corporation. Peasants have no possibility to participate in decision-making with regard to the choice of species and planting or harvesting times. For example, they have no chance to effectively communicate their concerns over the corporation's practice of vastly expanding the area planted with pine, which, according to peasants in many areas, undermines water supply for irrigation and causes landslides. Any collaboration between the corporation and peasants is considerably complicated by historically grown patterns of distrust and confrontation. Peasants, for historical reasons, deeply distrust the corporation and see it as a repressive apparatus, as an enemy. The corporation's staff members in turn often exhibit attitudes of predominance towards peasants, whom they often view as uneducated, 'backward', ignorant and unable to sustainably manage forest land.

Consequently, the community forestry programmes have not been very successful in generating a pronounced 'sense of ownership' over state forest territory among peasants. As result, the trees, which are to be considered as property of the corporation, are partly not well maintained; tree cover is reduced, and cultivation of annual crops is understandably not accompanied by soil conservation measures.

Taking a historical and actor-based perspective, it appears that the design of the community forestry programmes was perhaps not primarily driven by the sincere motivation to experiment with and implement new participatory, community-based modes of forest governance for the sake of environmental and social sustainability but was a strategy of the forest corporation to regain control over its territories and its trees. Following years of large-scale illegal logging in the early phase of the political transformation, the corporation had no choice but to make concessions to peasants. Means of obvious coercion, as regularly used before the political transformation, would not be legitimate anymore. Thus, granting peasants limited cultivation rights, and sharing benefits with them was the preferred strategy to regain control over territory and trees.

The mere existence of community forestry programmes as new, seemingly participatory modes of forest governance should not hide the fact – and the problems outlined above illustrate this to some extent – that the state forest corporation remains as a node of enormous power and influence, as a part of the former repressive state that has not been as thoroughly reformed as government bodies. Large parts of the forest corporation widely remain as a centralistic, hierarchical, top-down oriented, intransparent apparatus.

The commitment of the corporation's upper management to introduce reforms and its political rhetoric – last but not the least motivated by its long-standing determination to seek certification by the Forest Stewardship Council (FSC) – are encouraging, the more so as certification would create additional international pressure (Interviews, January 2010, February–May 2011). But at the same time, the political rhetoric may hide both the enormous challenges ahead and some highly problematic nodes of power and repression. For example, the collaboration between the forest corporation and peasants in the frame of the community programmes is not only – as described above – complicated by historically grown patterns of deep distrust and a pronounced imbalance of power between the two parties. But authorities of the forest corporation continue to maintain close relationships with police and military forces. In these networks, fractions of the former hierarchically integrated repressive alliance of all state authorities live on and continue to exert influence, control and pressure – less obvious than before since the power is not organised in well-defined hierarchal levels anymore but is less visibly embedded in more complex networks (cf. Flitner and Görg 2008). Disputes between the forest corporation and peasants are not directly dealt with by the corporation's own forest police anymore but by regular police forces. But close (personal) networks allow the corporation to promptly deploy the police. Peasants claiming state forestland for historical reasons and waiting for legal processes to proceed have fear whenever approached by an unknown person since they 'never know whether it is a spy acting on behalf of the state forest corporation or the police' (Interviews, February–May 2011). District-level representatives of the military are members of the communication forums within the community forestry programmes (ibid.). Not easily visible, such nodes of power substantially contribute to the outcomes of new forest and watershed governance approaches. Repression lives on in the midst of an increasingly open political arena that is being reshaped by political transformations and that provides scope for promising developments towards new modes of governance.

6.5 Conclusion

Analysing the interplay between actors, their interests, their power relations and their discursive constructions of environmental issues and the emergence of this interplay over time sheds new light on present modes of environmental governance. Understanding current management approaches as an outcome shaped by present political structures and the processes of their emergence, by long-standing struggles over political power, resource access and control and by sociopolitical discourses and problem-solving paradigms provides a context that helps to explore the underlying causes of their 'success' or 'failure'. This context opens up perspectives on the achievements of and future challenges embedded in newly emerging modes of governance, which would possibly remain hidden if one would adhere to the assumption that the various actors and approaches necessarily aim at solving environmental issues (cf. Mayntz 2001).

Current modes of watershed and forest governance in Java have to be seen, among others, as an outcome of the historically emerged interplay between long-standing struggles over the access to and control of forest resources, simplistic sociopolitical discourses regarding the causes of upland degradation, international development and environmental management paradigms and broader revolutionary political transformations in Indonesia. The latter have triggered environmentally disastrous developments by transforming many state forest areas into political battlefields but have also opened windows of opportunity for transitions towards new, possibly more sustainable modes of watershed and forest governance. These transitions involve shifts from non-participatory, state-dominated, top-down oriented repressive command-and-control approaches towards more decentralised, participatory, incentive-based approaches.

Building on Burries et al. (2005) and Flitner and Görg (2008), the analysed transitions can be conceived and conceptualised as gradual shift from a very hierarchical style of government to networked or nodal governance. They are characterised by an increasing fragmentation of the previous centralistic, top-down oriented state apparatus into a more fluid network of nodes of power and influence. While some fragments of the 'old' hierarchically integrated structure continue to persist as powerful nodes of repression, others are being transformed into nodes of innovation, linking with newly emerging networks and thereby advancing the transition. Exploring the connections between the previous 'old' structure, i.e., the vertically integrated alliance of repressive state authorities, and the present nodes of power and influence exposes some of the major barriers to innovation and illustrates that some elements of the 'new' modes of governance might be more infused with 'old' repressive elements than visible at first glance. In fluid, diffuse and partly informal networks, which may span not only a multitude of governmental and non-governmental organisations but also individual actors on various scales, the localities of power and influence are less obvious than in formal, well-defined hierarchical levels (cf. Flitner and Görg 2008).

Indonesia's political transformation since the late 1990s, involving democratisation and decentralisation, has created space in an increasingly open political arena for new actors and actor coalitions to emerge as new nodes of influence. In the context of watershed and forest governance, peasants' organisations and village heads together with NGOs, private sector organisations and universities form networks, bundling different experiences, competences and spheres of influence, and spanning various scales. Expanding into the spaces opened up by the fragmentation of the long-standing, state-dominated, forcibly coordinated power apparatus, these networks increasingly question established discourses and develop new, more participatory, locally based management approaches. Some 'fragments' of the state administration – and these can be both individuals or entire authorities – also experiment with, support or establish new, more participatory, locally based management approaches. Both the newly emerging networks and these 'innovative' reform-oriented 'fractions' of the state administration appear to be the promoters of new modes of governance. Linkages between both – i.e., constellations where state authorities link with community-level actors, NGOs and private sector organisations – appear to be particularly promising. If these newly established approaches work well over the long term, they could be prime examples of environmental governance that bridge dichotomies between state and market approaches and between conservation and development and that are based on different types of incentives rather than on coercion and command-and-control. However, other 'fragments' of the former repressive power apparatus – including large parts of the state forest corporation, which has close ties with the police and military – continue to persist as powerful nodes of influence. Within an increasingly open political arena that is being reshaped by political transformations, continued forest and watershed degradation is the visible sign of ongoing political struggles for and conflicts over new, more sustainable modes of governance.

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III. Appendix

Example of an interview guideline

Most questions to be used for both semi-structured interviews with the various participants and for focus group discussions

A. Changes in land use and land cover

1. Have you noticed any environmental changes in your area over the past years and decades? If so, what kind of changes? (*Note: Concept of 'environmental change' locally not existing – find proper way of describing its meaning*)

2. Have land use and land cover changed in this area over the past years and decades?
   - What kind of changes? When? Where? Driven by whom? What causes?

3. Do you view these changes as positive or negative and why?

4. What do you think could be effects of these changes? Who do you think could be affected in what way?

5. Have you noticed any change in tree cover (on farmland / forest land)?
   - What changes? When? Driven by whom & why?

6. Who owns, manages and uses which forest areas in this region?

B. Land use management

1. Have there been any initiatives / interventions / policies to manage land use in this area? If so: What kind? When? By whom? What resources/networks?

2. What do you think about these initiatives / interventions / policies? What effects did they have?

3. Are there any institutions regulating land use, including crop cultivation, tree planting, cultivation methods? If so, what kind of institution at which level?

4. Do you think land use (including agriculture and forestry) should be managed in a different way and if so in what way?

C. Erosion and sedimentation

1. Do you think soil degradation / soil erosion is an important problem in this area? If so, how do you think could the situation be improved? Are there any measures taken in this area to reduce soil erosion and if so what kind of measures and by whom?

2. Have you heard about sedimentation in the Segara Anakan lagoon? If so, what do you think are the causes?

3. Taking into account the problem of lagoon sedimentation, do you think it is necessary / possible to reduce soil erosion in this area? If so, how could it be achieved?

D. Personal information (peasants)

1. Have you always been living here and if not where did you live before and when and why did you move to this place?

2. What are your (family's) livelihood strategies?

3. How much and what kind of land do you cultivate? (house garden, sawah, tegalan, kebun, others)

4. Are you the owner of that land?

5. What crops/trees do you cultivate and has that changed over time? When? Why?

6. What are the three most important farm/forest related problems you face?

7. Do you have any problems with soil degradation / soil erosion on your land?

Declaration in accordance with § 6 (5) Promotionsordnung

Herewith, I declare that:

1. This doctoral dissertation is my own work. It was compiled without recourse to any unauthorised aids.
2. No materials or references other than those cited were used.
3. Due reference has been made to all works either quoted or used as the basis for ideas.
4. A software-based plagiarism assessment is permitted.

Bremen, 7. August 2015

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(Martin C. Lukas)