ARTICLES

Neglected Treasures: Linking Historical Cartography with Environmental Changes in Java, Indonesia

Martin C. Lukas
Sustainability Research Center (artec) / University of Bremen / Bremen / Germany

ABSTRACT

The historical cartographic material of insular Southeast Asia provides significant potential for research into historical environmental changes. Yet most of this potential has not been realized. This article explores the historical cartography of the Segara Anakan lagoon region on Java's south coast in the context of a shoreline change analysis. It shows how historical cartography supports the analysis of environmental changes and vice versa. Thoroughly exploring the cartographic history of the target region helps to maximize the temporal scale and resolution of analysis; provides insight into the gradual development and replication, but also the ignorance, of cartographic knowledge; and supports an appraisal of the maps' reliability, all of which help to avoid analytical pitfalls. Complementing a quantitative analysis of more recent, relatively accurate cartographic material with a qualitative analysis of very early, less accurate maps and map-makers' records allows the temporal scale of historical environmental research to be extended further into the past. At the same time, it exposes the limits and pitfalls of historical cartographic analyses of environmental change. The author's analysis of the early maps of the Segara Anakan lagoon shows how information from complete but relatively inaccurate maps was repeatedly reproduced by map makers for about a century, while information from more accurate but incomplete maps was consistently ignored.

Keywords: Segara Anakan lagoon, historical cartography, map history, map production and replication, map accuracy, sea charts, historical environmental change, environmental history, shoreline reconstruction

RÉSUMÉ

Les documents cartographiques historiques des îles de l'Asie du Sud-Est recèlent un important potentiel de recherche dans les changements environnementaux historiques. Pourtant, pour l'essentiel, ce potentiel n'a pas été mis à profit. Les auteurs explorent dans cet article la cartographie historique de la région du lagon de Segara Anakan sur la côte sud de Java, dans le contexte d'une analyse des changements de la ligne de côte. L'auteur illustre de quelle façon la cartographie historique appuie l'analyse des changements environnementaux et inversement. Une exploration approfondie de l'histoire cartographique de la région cible aide à maximiser l'échelle temporelle et la résolution de l'analyse, offre un éclairage sur le développement et la réplication graduels, mais également sur l'ignorance de la connaissance cartographique et appuie une évaluation de la fiabilité des cartes, le tout aidant à éviter les écueils analytiques. Compléter une analyse quantitative d'un matériel cartographique plus récent et relativement précis par une analyse qualitative de cartes très anciennes et moins précises et des dossiers des cartographes permet d'étendre l'horizon temporel de la recherche environnementale historique encore plus loin dans le passé. L'analyse des premières cartes du lagon de Segara Anakan laisse voir dans quelle mesure l'information tirée de cartes complètes mais relativement inexactes a été produite à répétition pendant environ un siècle, tandis que l'information provenant de cartes plus précises mais incomplètes a été constamment ignorée.

Mots clés : Lagon Segara Anakan, cartographie historique, histoire des cartes, production et reproduction de cartes, exactitude des cartes, cartes marines, changement dans l'environnement historique, histoire de l'environnement, reconstruction des lignes de côte

Introduction

Nearly half a century ago, Koeman (1968) and Harley (1968) remarked that historical cartography had focused on carto-bibliography and map-makers' biographies, while the value of the historical evidence contained in the maps themselves 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

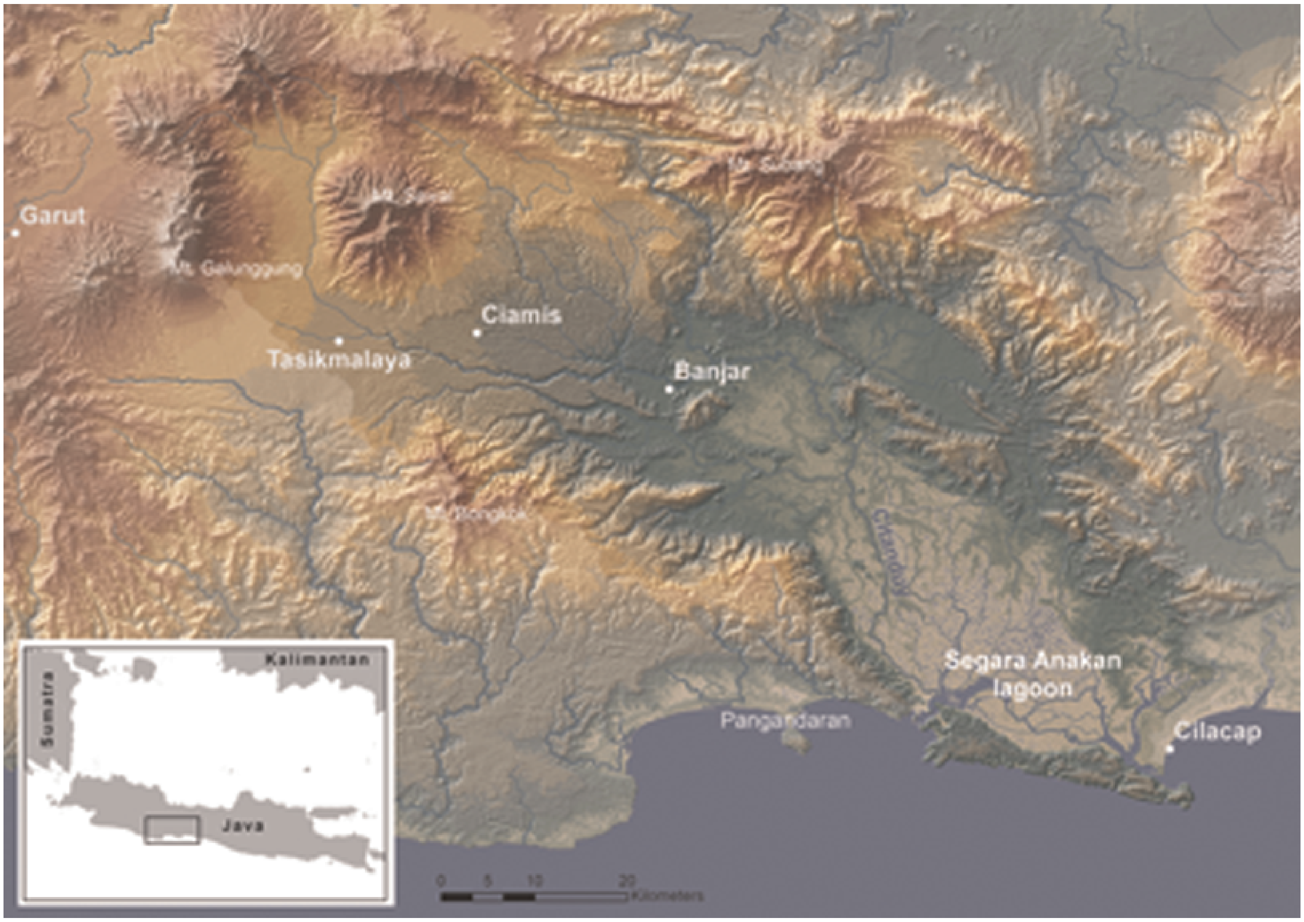

Figure 1. Location of the Segara Anakan lagoon and its catchment area on the south coast of Java. (For colour versions of all figures in this article, see http://dx.doi.org/10.3138/CART.2891.)

have been used to analyse a broad range of environmental phenomena, including coastal features (Crowell, Leatherman, and Buckley 1991; Jabaloy-Sánchez 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 a few cartographers had devoted attention to the historical maps of this region until recently. One of them is Schilder (1976, 1978, 1981), whose meticulous research into the cartographic history of the Netherlands East Indies deserves special appreciation. His and some other cartographers' research culminated in the publication of several brilliant atlases with facsimile reproductions of and background information about a large number of historical maps (Knaap and others 2007; Roever and Brommer 2008; Schilder and others 2006; Schilder and Kok 2010; Suárez 1999; van Diessen and Ormeling 2003). These atlases together with the map collections of, among others, the Royal Tropical Institute (Koninklijk Instituut voor de Tropen, KIT) in Amsterdam and the Netherlands National Archives provide an outstanding basis for research into historical environmental changes in insular Southeast Asia.

However, only a 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 the 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; and 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 article. The Segara Anakan lagoon has undergone profound social-ecological transformations. As a result of riverine sediment input, its water surface area has shrunk to one-fourth of its previous extent within the past century and a half. 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; Purba 1991; White, Martosubroto, and Sadorra 1989; 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 (Lukas 2015). This has contributed to the limited effectiveness of long-term interventions aimed at halting sedimentation (see, e.g., Schweithelm 1989). Knowledge of the longer-term dynamics and drivers of sedimentation is very limited. Data on river sediment loads cover only the past 30 years and are not reliable, and previous shoreline change analyses cover the twentieth 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 2015).

To analyse the dynamics of lagoon 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 it 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 rest of the article presents an attempt to extend the time scale of this quantitative analysis further into the past through a qualitative analysis of sea charts from the late seventeenth and early eighteenth centuries. This demonstrates the utility of analysing map-makers' records and defines the limits and illustrates some potential pitfalls of historical cartographic inquiry into environmental changes. It also shows how engagement with historical maps in reconstructing environmental changes contributes to historical cartography. The case presented reveals how topographic information from complete, though relatively inaccurate maps is repeatedly reproduced, while information from more accurate but incomplete maps is consistently ignored. It also shows that the maps valued as the most accurate and complete of their time as a whole can contain sections with information copied from some of the least accurate earlier maps.

Historical-Cartographic Analysis of Environmental Changes: Limits, Pitfalls, and Approaches

Historical maps have great potential for analyses of 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 geo-rectification and quantitative analysis. Yet a qualitative analysis of them, 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 before the production of more accurate maps.

Yet most cartographic analyses of historical environmental changes have been confined to the periods covered by maps that are sufficiently accurate for geo-rectification 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 those of Forbes and others (2004), on shoreline responses to storms in the Gulf of St Lawrence from the mid-eighteenth 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, intervening 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 gathering background information about map-makers and map-making processes and compiling 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 as high a temporal resolution as possible. Also, 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 sixteenth and eighteenth centuries (Pedley 2005; Smith 1986). Borrowing information from previous maps and combining it 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 outdated. The depiction of California as an island on various maps in the seventeenth and eighteenth centuries is a good example of map-makers consistently borrowing information from earlier, less accurate sources, despite having better information available (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 the *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, which regards each map "as part of an evolutionary sequence [...] through which [...] mutual indebtedness and innovation are established" (Harley 1968, 65) helps to reveal the chains of borrowing and to assess the maps' reliability, both of which are crucial in cartographically reconstructing environmental changes.

Errors in previous shoreline reconstructions of the Segara Anakan lagoon illustrate the pitfalls caused by insufficient attention to map-making processes and the copying of information. For example, Hadisumarno (1964, 1979) ignored the fact that the topographic maps produced by the US 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 5 m (1900–1940) to 54 m (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 reflected the situation in 1940 were based on surveys conducted in the 1920s. The same error appears in the shoreline change maps subsequently included in various project plans and reports (ASEAN / US CRMP, DGF 1992; Engineering Consultants, Inc. 1994; PRC-Engineering Consultants, Inc. 1987; Soewondho 1984). This error could easily have been avoided by paying attention to the documentation on the map sheets. In the case of earlier maps, in contrast, the borrowing of information is mostly not acknowledged and can be revealed only by a comparative analysis of the entire sequence of maps and an 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 maximizing 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 maximizing the temporal resolution of analysis and helps to evaluate the maps' reliability, reveal the borrowing of information between map-makers, and hence 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 not only forms the basis for the shoreline change analysis in the subsequent section but also provides insight into the gradual development and replication of, as well as ignorance about, cartographic knowledge. The review of this underutilized material and its sources is also hoped to 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 maximize, I gathered more than 50 maps and map series produced between the sixteenth and twentieth centuries from various libraries and archives worldwide. The following chronological account along with Table 1 focuses 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 sixteenth century provided the first known cartographic records (see Schilder and others 2006; Schwartzberg 1994; Thomaz 1995). The earliest preserved charts roughly sketching Java as an island were drawn by the Portuguese between 1513 and 1519 (see Suárez 1999; Thomaz 1995). While the topographic knowledge of Java's north coast improved slightly during the following decades, its south coast remained largely unknown to Europeans. Following the sighting of Australia in the 1530s, Java was even believed to be part of Australia. This is reflected in various

Table 1. Chronological overview of the historical maps of Java's south coast and the Segara Anakan lagoon*

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 and Reinéis	1513–1519			Various libraries; see Thomaz 1995	Earliest known charts roughly sketching Java as an island	Not suitable
Insul Indi orientalis	Jodocus Hondius	1600–1612		Approx. 1:16,000,000	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
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

Table 1. (continued)

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
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's 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's 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
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 contain a complete outline of the Segara Anakan lagoon, with increasing accuracy over time	For qualitative analysis only

Table 1. (continued)

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
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	Suitable for quantitative analysis	
Topographic map of Java, Residency Banjoemas (Map Sheets III, IV and VIII, VII)	TDNI, land tax survey brigades	1901–1904	1897–1901	1:100,000	KIT	Suitable for quantitative analysis	
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	1925–1929 (1942), reprints 1938–1942	1924–1926 (1940–1941)	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, US Army	1939–1944	Mainly 1920s	1:50,000	Indonesian National Library	Reproduction based on previous topographic map series	Note the time gap between the years of data collection and map production to ensure chronometric accuracy
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 in 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 map scale

* Of more than 50 historical maps and map series gathered, the table mainly lists those that contributed additional topographic information to previously existing maps.
KIT = Koninklijk Instituut voor de Tropen (Royal Tropical Institute); TDNI = Topografische Dienst in Nederlandsch-Indië; TNI = Tentara Nasional Indonesia.

Portuguese charts drawn between 1535 and 1561 in which the southern part of Java is 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 1595–1597 ascertained that Java was an island (Schilder and Kok 2010; Suárez 1999). This is reflected in various maps drawn thereafter, including the map of Java by John van Linschoten from 1598 (contained in the collections of the KIT) and the map of the East Indian Archipelago by Jodocus Hondius from 1606 (contained in the National Library of Australia). Both maps illustrate the immense gap between the topographic knowledge of Java's north coast 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 nineteenth 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 Dutch United East India Company (Vereenigde Oostindische Compagnie, VOC), which governed the relations between Java and the Netherlands (Knaap and others 2007; Schilder and others 2006). From 1864 this task was taken over by the Topographical Service in the Netherlands East Indies (Topografische Dienst in Nederlandsch-Indië, TDNI).

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 contain historical maps of Indonesia. The digitization 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)[1] along with the account of VOC manuscript charts by Schilder and Kok (2010) have tremendously enhanced access to this material and to related background information.

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 CENTURIES)

Whereas the sea routes through the Sunda Strait and along Java's north coast had already been charted fairly accurately in the early seventeenth century, Java's inaccessible and economically unimportant south coast was not systematically mapped before the 1690s (Knaap and others 2007; Schilder 1978). Until then, 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.[2]

Since Governor-General van Riebeeck was not satisfied with Coops's 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's (1911) book. While in drawing the outlines of the bays west and east of Nusakambangan, van Petten seems to have borrowed extensively from Coops's maps, he clearly drew the eastern part of the Segara Anakan lagoon more accurately than Coops had (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.

The subsequent voyage by Paulusz in 1739 was assigned the task of taking depth soundings in the Segara Anakan

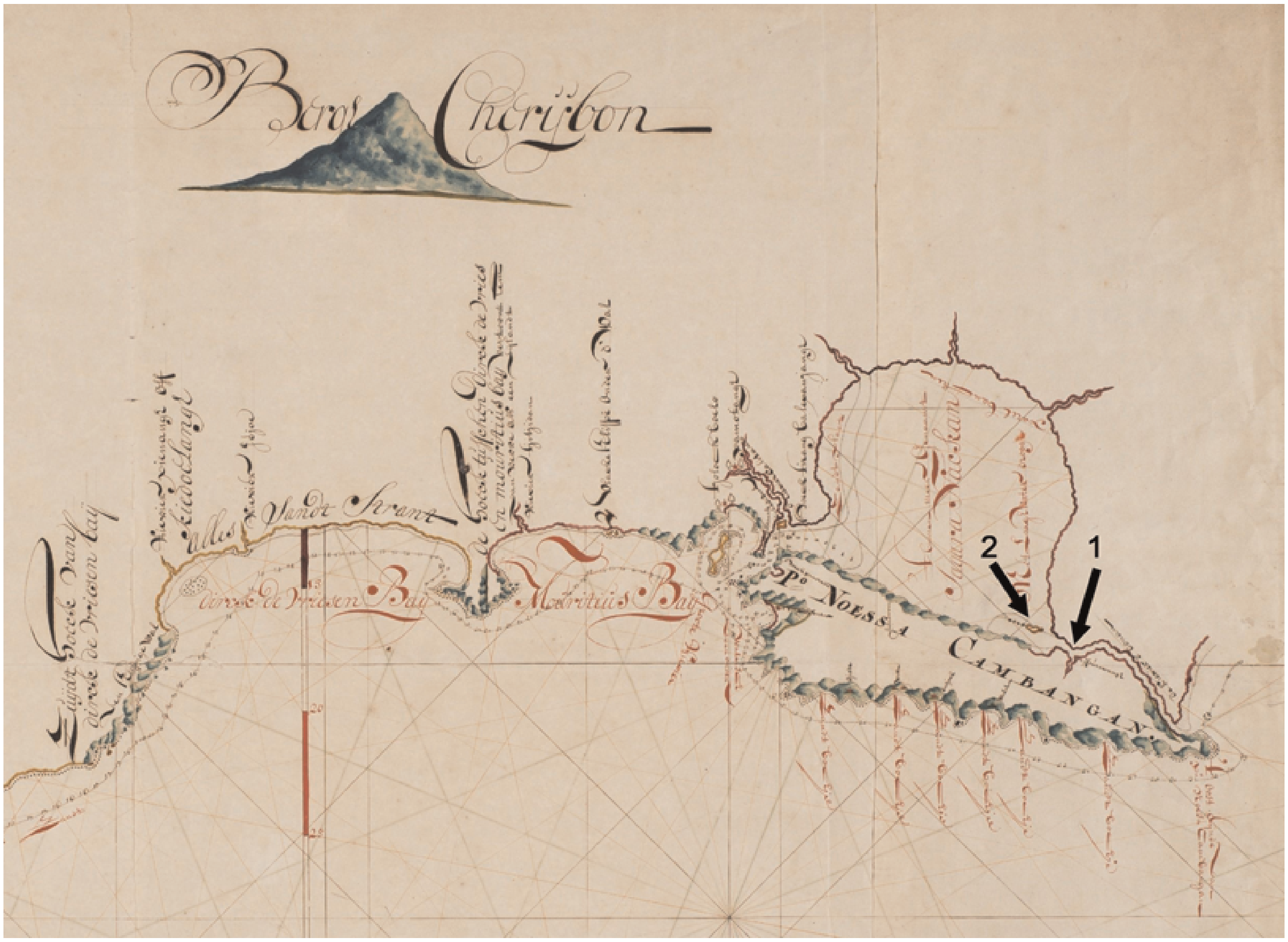

Figure 2. This section of the manuscript sea chart drawn by Cornelius Coops in 1698 represents the earliest known map of the Segara Anakan lagoon; retrieved from the Netherlands National Archives. The arrows illustrate the discussion of Coops's and van Petten's travel routes in the text.

lagoon region (Schilder 1978, 1981). However, the chart drawn by Paulusz did not contribute any additional topographic information for 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 entered the lagoon. Therefore, the lagoon's outline in his map is completely based on Coops's map. Schilder (1981, 104) valued Paulusz's 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's 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's map. However, the additional, more detailed and more accurate information contained in van Petten's map was neither taken up by Paulusz nor incorporated into any maps produced and published thereafter until the early nineteenth century.

That Paulusz and other map-makers and publishers thereafter consistently copied from Coops's 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.[3] That is, subsequent map-makers relied on Coops's 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), the map drawn by Francois Valentyn in 1725–1727 (contained in the Netherlands National Archives), and a map drawn by Ekeberg in 1774 (contained in the Kriksarkivet Stockholm; see also Arne 1959). Ekeberg produced this map a few years before conducting his own surveys,

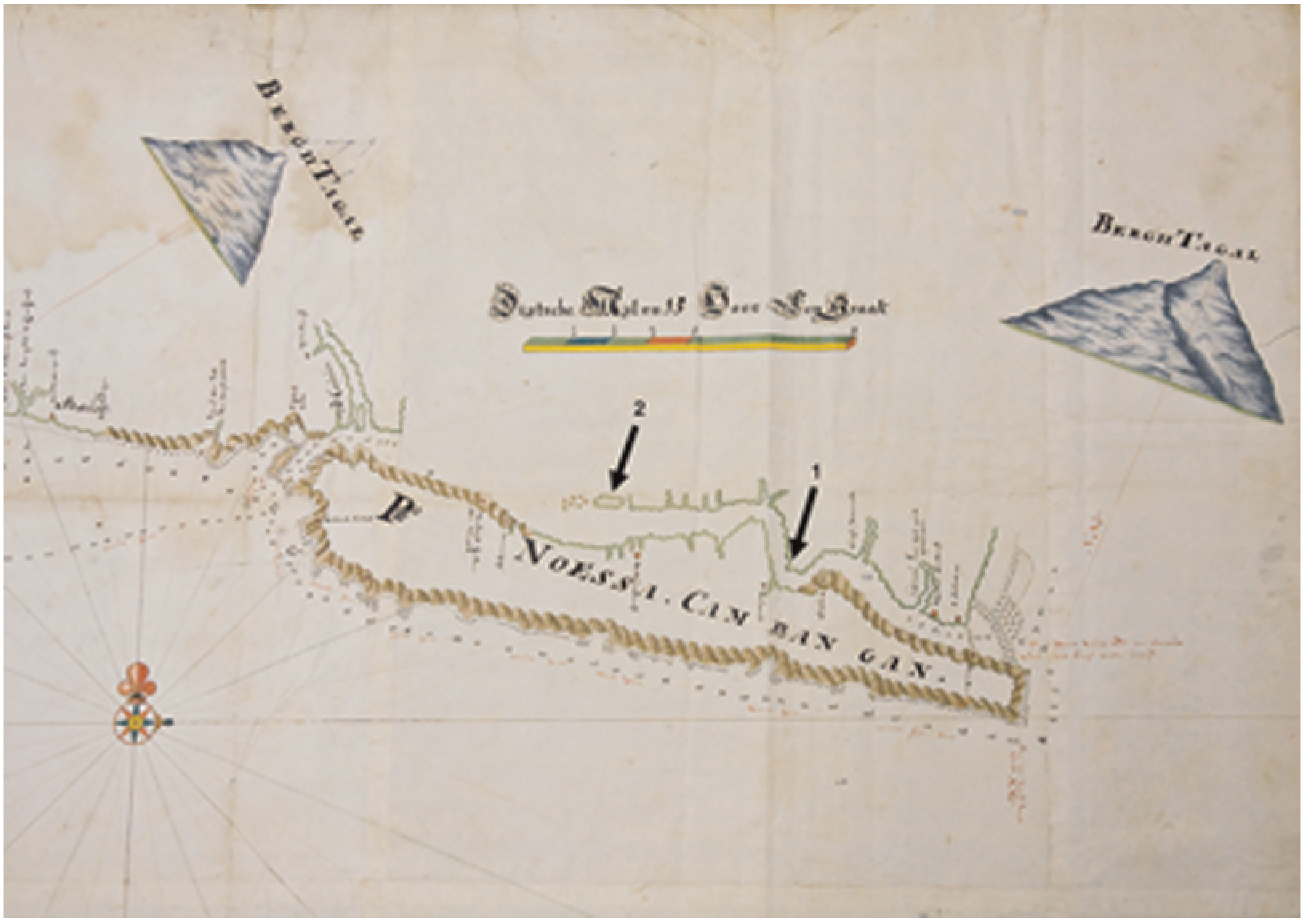

Figure 3. Section of the manuscript sea chart drawn by Albert van Petten in 1711; retrieved from the Netherlands National Archives. The arrows illustrate the discussion of Coops's and van Petten's travel routes in the text.

largely based on Paulusz's chart (Arne 1959). This is clearly reflected in his outline of the Segara Anakan lagoon, which is thus also based on Coops's 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's map from 1698, while the more detailed and more accurate knowledge contained in van Petten's map was consistently ignored.

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 nineteenth century. The maps produced during this period were merely enriched with topographic information on 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 several 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 unfortunately did 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.[4] These maps and the connections between Ekeberg and Dalrymple have to my knowledge not yet been explored by cartographers.

SYSTEMATIC TOPOGRAPHIC SURVEYS (NINETEENTH AND EARLY TWENTIETH CENTURIES)

The first large-scale mapping of Java was begun under the Dutch in the 1790s and pushed forward during the English Interregnum in 1811–1816 (Knaap and others 2007). The resulting topographic map series of the Priangan Regency from 1813 to 1815 comprises one of the two earliest maps depicting the entire Segara Anakan lagoon (Figure 5) with an accuracy that allows for geo-rectification without resulting in a distorted image. These maps were obviously not published immediately (see Olivier 1829), but the 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.

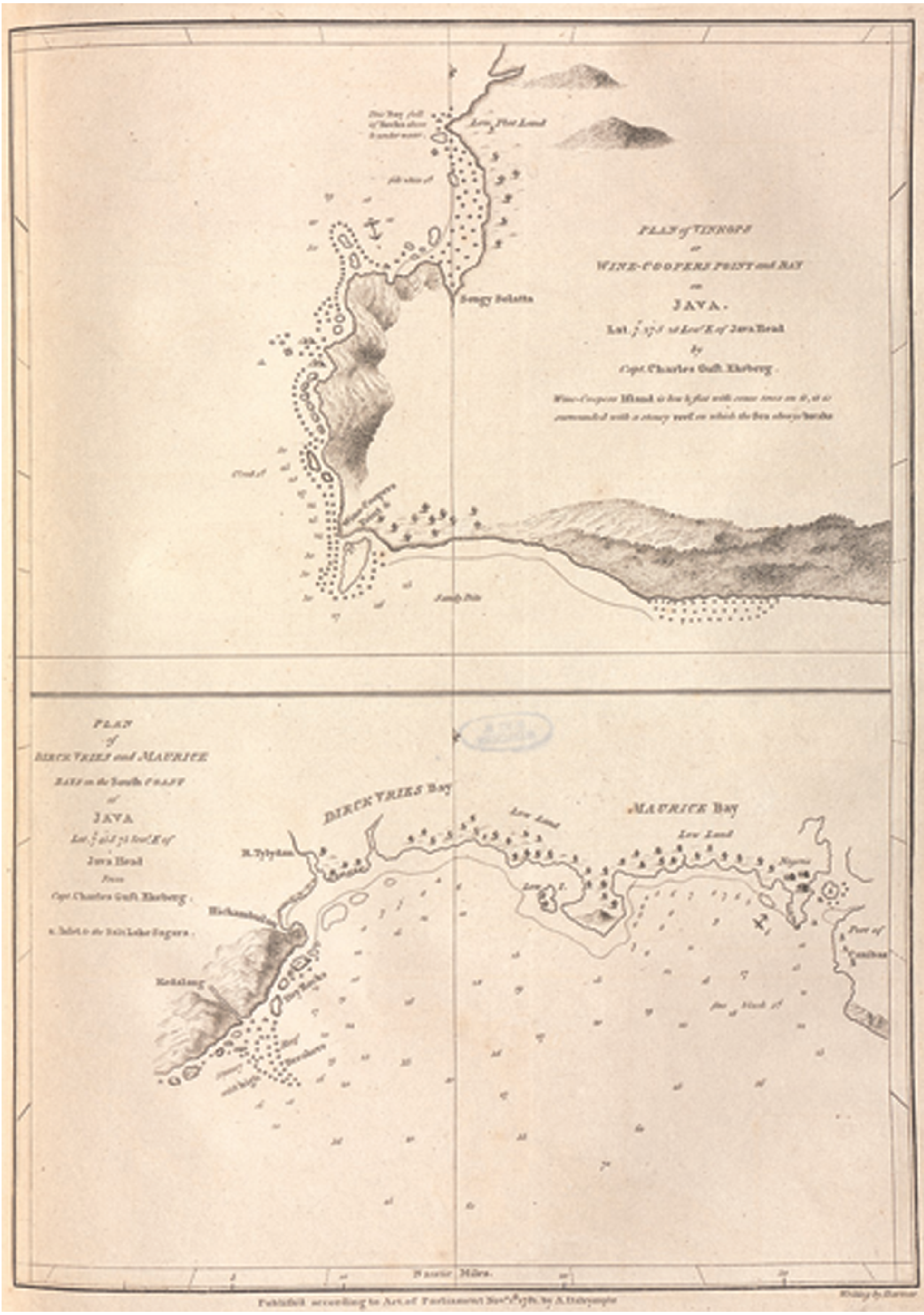

Figure 4. The map drawn by Carl Gustav Ekeberg in the early 1780s clearly depicts the bays east and west of the Segara Anakan lagoon more accurately than any of the earlier maps. However, Ekeberg did not map the Segara Anakan lagoon. Retrieved from the Bayerische Staatsbibliothek.

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.

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 hydrographic observations along the coasts of Java and other islands from 1808 to 1811 (Gommans and van Diessen 2010). His map represents the earliest documentation of water depths within the lagoon. However, his bathymetric data are confined to the main fairways and hence do not allow for a three-dimensional reconstruction of the lagoon's water body. The same applies to the shoreline and bathymetric surveys of the lagoon's outlets conducted during the English Interregnum[5] as well as a shoreline and bathymetric map of the eastern outlet,[6] the production of which (in 1848–1857) was certainly related to the construction of the nearby port of Cilacap. Both drawings are extremely detailed but cover only the lagoon's outlets.

Between 1849 and 1882/1886, a complete topographic mapping, including the first triangulation, of the whole of Java was carried out (Schuitenvoerder 1920; van Diessen and Ormeling 2003). The resulting residency maps, at a scale of 1:100,000, are clearly more detailed than all previous topographic maps. The residency map of Banjoemaas, produced in 1857–1860, contains a detailed outline of the Segara Anakan lagoon (see Figure 7). It is the earliest map that I found to be 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 1924–1926, while one sheet, covering the western outlet, is based on surveys conducted

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

in 1940/1941. Since no shoreline aggradation occurred in this area (at least, not within the lagoon), this map sheet could be used for the quantitative shoreline reconstruction along with the other map sheets.[7]

NO UPDATES FOR DECADES (1920S–1960S): LIMITS TO THE TEMPORAL RESOLUTION 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 from 1924/1926 to the 1960s clearly limits the temporal resolution of cartographic inquiry 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 US Army Chief of Engineers during World War II (Java and 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, was neglected by Hadisumarno (1964, 1979) and others. Also, the maps printed by the Japanese during their occupation of Java in 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 US 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 in 1955 at a scale of 1:250,000 (contained in the National Library of Australia), contains updated topographic information. However, since the information was updated only for parts of the lagoon, and owing to its small scale, this map cannot be used for reconstructing historical shorelines, and its qualitative analysis also does 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, and military and other organizations 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

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

theatre during retreat or thereafter. The aerial photographs recorded by the Dutch reconnaissance pilot Majoor van Breemen, which are contained in the Netherlands Institute of Military History, include images of the eastern part of the lagoon but not of the western part that was affected by sedimentation. My various attempts to get access to the material from aerial surveys that were likely conducted by the Indonesian Army Topographic Service in 1946 were not successful.

SATELLITE IMAGES: A NEW ERA OF MAPPING (1960S ONWARD)

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 US 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 nineteenth century, not to mention the manuscript sea charts from the seventeenth and eighteenth centuries.

Cartographic Reconstruction of Historical Shoreline Changes

QUANTITATIVE ANALYSIS OF THE MATERIAL FROM THE NINETEENTH AND TWENTIETH CENTURIES

Following a quantitative assessment of the planimetric accuracies of the historical maps listed in Table 1, the maps from the mid-nineteenth century onward, the Corona image, and several more recent satellite images were overlaid, 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 given by

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 and VIII, VII; retrieved from the KIT.

Lukas (2014a). Figure 10 depicts the results: a rapid decline in the lagoon's water surface area, which accelerated between 1857/1860 and the 1980s.

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 (Lukas 2015) 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 apply fully 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 are restricted by the cartographic material available, limiting the results' interpretability. My exploration of the cartographic history of the region, briefly sketched in the above section, helped to maximize the temporal scale and resolution of the quantitative analysis and to avoid pitfalls related to the borrowing of information. The maps from the early nineteenth 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

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 the KIT.

nineteenth century to more rapid aggradation thereafter. This development can be linked to dynamics in the lagoon's watershed, which are related, for example, to coffee cultivation, timber extraction, commercial estate development, 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 2014b, 2015). Since some of these dynamics began before the mid-nineteenth century, an extended analytical time scale of the historical cartographic shoreline change analysis is desirable. This could also ascertain whether the nineteenth 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 from the 1920s to the 1960s could, by increasing the temporal resolution of analysis, further support the linking of the aggradation process with various watershed dynamics during this period. The following two sections explore possibilities for extending the temporal scale and resolution of the shoreline change reconstruction by qualitative map analysis.

Towards an Increased Temporal Resolution of the Shoreline Change Reconstruction

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 1920s–1960s (see Table 1). 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 owing to the very small

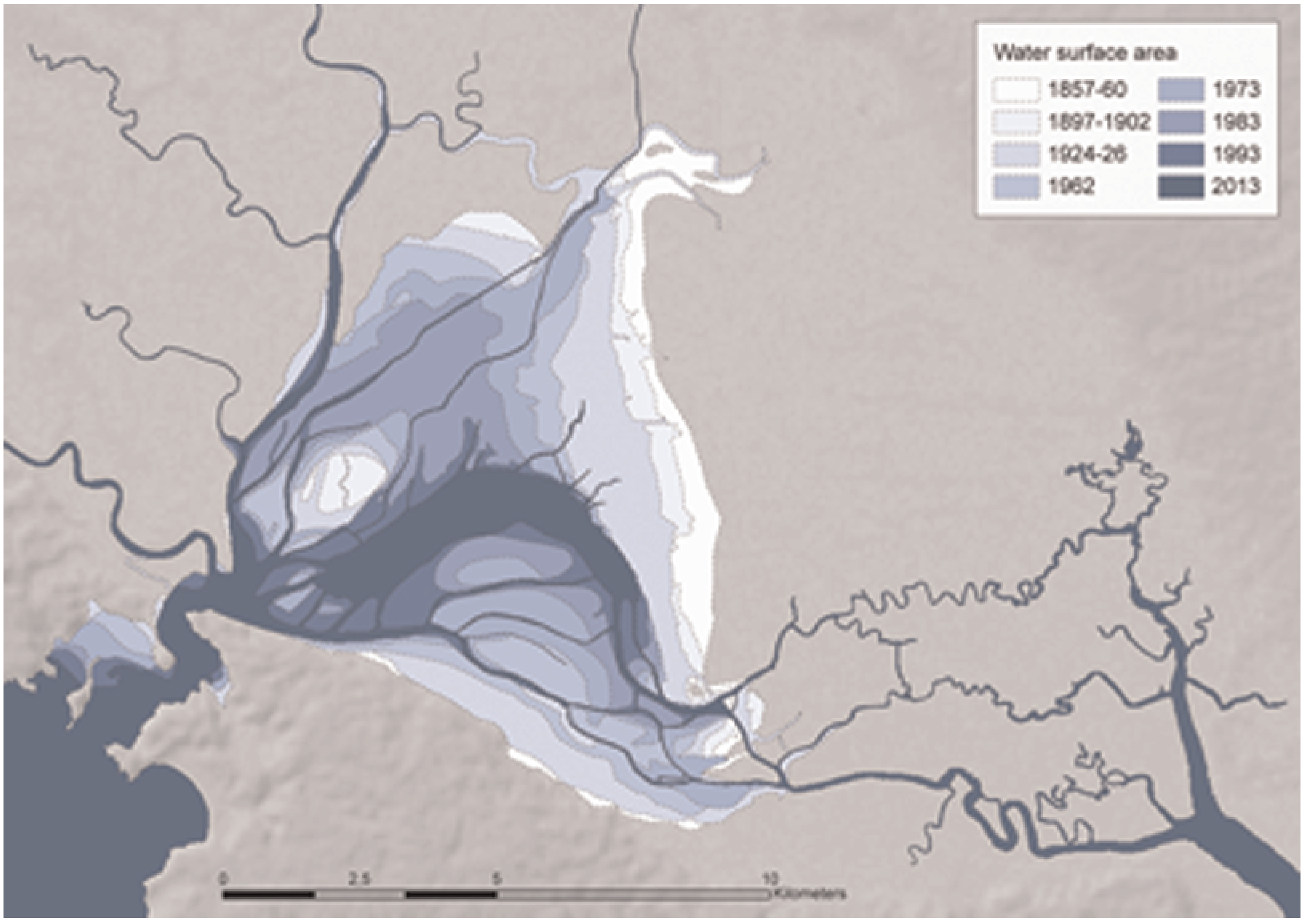

Figure 10. Change in the water surface area of the Segara Anakan lagoon 1857/1860–2013, based on the quantitatively analysable historical maps listed in Table 1 (1857–1860, 1897–1901, 1924–1926) and a series of satellite images (1960s onward). Base map: SRTM (shuttle radar topography mission), available from the US Geological Survey.

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 clearly gives a 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 article 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), that is, 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's 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's 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 1809/1815 (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's 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 4.5 km between 1698 and 1857/1860. This would (surprisingly) correspond to higher annual aggradation rates than during the following period from 1857/1860 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) and 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 1809/1815 (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's 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 spent 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 11 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 geo-rectify this chart, based on the topographic map from 1901/1904 and using eight control points, and received a fairly accurate overlay and an RMSE of 793 m at map scale in case of a first-order polynomial transformation and of 592 m in case of a second-order polynomial transformation.[8]

In contrast, it is barely possible for Coops's chart to be geo-rectified. Using eight control points, geo-rectification results in a twisted image and an RMSE of 1511 km and 728 m for first- and second-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 2.5 km 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, that is, that he actually passed through the eastern channel. This is certainly the reason he did not map the entire channel with as much detail and accuracy as van Petten did. He might instead have depicted the eastern part of the channel 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's maps and the analysis of Coops's 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 he did not visit, partly based on guesstimates, van Petten depicted only the sections that he actually mapped. The information from Coops's 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 unfortunately did 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's 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, my analysis might have relied on Coops's chart, which in fact I identified first, or on Paulusz's chart, which is considered the best sea chart of Java's south coast up to the beginning of the nineteenth century (Schilder 1981). Without van Petten's chart, if relying only on Coops's chart, our perspective on the possible longer-term development of lagoon sedimentation before the early nineteenth century would be unrealistic, or at least clearly more uncertain. Relying only on Paulusz's 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's view of the lagoon in 1698. Furthermore, one and the same historical map (i.e., Paulusz's map from 1739) might be valued as a 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 great potential of the historical cartographic material of insular Southeast Asia for exploring historical environmental changes has remained largely untouched until today. The digitization 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 deliver location-specific information from only 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 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, along with longer periods without cartographic surveys, limit the temporal scale and resolution of analysis. A thorough exploration of the cartographic history of the study area, that is, 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 maximize 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 avoiding 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 article, the availability of quantitatively analysable maps from the mid-nineteenth century onward allowed the depiction of 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.

Not only does exploring cartographic histories support 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 article, it offered insight into the production, replication, and gradual development of, but also ignorance about, 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 a representation of the most accurate and complete cartographic knowledge of their time as a whole can contain sections that only represent information copied from the less accurate of the earlier existing maps.

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

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Author Information

Martin C. Lukas is a member of the Sustainability Research Center (artec), University of Bremen, Enrique-Schmidt-Str. 7, 28359 Bremen, Germany. E-mail: martin.lukas@uni-bremen.de. The article builds on research carried out when he was affiliated with the Leibniz Center for Tropical Marine Ecology Bremen GmbH (ZMT), Fahrenheitstraße 6, 28359 Bremen, Germany.

Notes

1. The *Comprehensive Atlas of the Dutch United East India Company* comprises seven volumes. The entire atlas series greatly supports cartographically based historical research in the regions covered: volume 1: *Atlas Isaak de Graaf/Atlas Amsterdam*, covering all the VOC's settlements and territorial possessions in Asia and Africa between 1691 and 1704; volume 2: *Java and Madura*; volume 3: *Malay Archipelago and Oceania*; volume 4: *Ceylon*; volume 5: *Africa*; volume 6: *India, Persia and Arabian Peninsula*; and volume 7: *East Asia, Burma to Japan*.
2. See the maps contained in the Netherlands National Archives and the reproductions in Schilder and others 2006 and in Knaap and others 2007.
3. Special thanks to Ferjan Ormeling.
4. One sheet comprises the following two maps: (1) Plan of Vinkops or Wine-Coopers Point and Bay on Java and (2) Plan of Dirck Vries and Maurice Bays on the South Coast of Java, both by Ekeberg, which were published according to an Act of Parliament on 1 November 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, which were published according to an Act of Parliament on 17 February 1782 by A. Dalrymple.
5. 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.
6. *Het zeegat en de reede van Tjilatjap*, trigonometrisch opgenomen door den [trigonometrical survey by] Liutenant ter zee J. Groll, Uitgave Batavia, 1857, contained in the Netherlands National Archives.
7. The six map sheets, retrieved from the KIT and used for the quantitative shoreline change analysis, are reprints of the original maps. These reprints were produced between 1938 and 1942.
8. The RMSE (root mean square error) represents the residual error after transformation, i.e., the differences between the position of the control points after geo-rectification 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 can be assumed to mainly reflect the planimetric accuracy of the map (see Lukas 2014a).

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