Chapter 3

# Environment and Landscape of the Brantas River Basin

The chapter consists of three sections. The first explores the Javanese natural and cultural landscape, and therein I attempt to highlight the geographical conditions relating to Javanese agricultural practices in ancient times. I also provide a brief comparison with the geographical features of mainland Southeast Asia. In the second part of the chapter, I attempt to show the important role climate played in shaping both the natural and the human environment through an explanation of the climate change that occurred in ancient Java. The last section contains a description of the Brantas river basin and its role in the geopolitical development of the East Javanese states.

## 3.1. THE NATURAL AND CULTURAL LANDSCAPE OF JAVA

The island of Java is situated between latitude 5°15’ and 8°30’ south and between longitude 105° and 115°15’ east, stretches roughly 1,000 km from west to east, and has a total area of around 132,107 km$^2$. Java shares with the rest of the Indonesian archipelago a position between the Indian and the Pacific oceans and between the Asian and Australian land masses. The majority of Java consists of material from the Tertiary and Quarternary periods, although some very recent geological areas have been formed by folds, volcanic deposits, and sediments. Java is formed of two distinct parts, the northern and the southern part. The first is a geosynclinal lowland that stretches across the north of Java and is composed primarily of Tertiary developments modified by very young folds. The latter is a southern mountain range, an area of Quaternary volcanoes. This volcanic range stands on a Tertiary rock base and is interrupted by valleys and river basins that were formed by rivers cutting through the range or flowing down the mountainsides.[1]

The geographical conditions of Java are distinct from those of its neighbours in Southeast Asia, and especially those of the Southeast Asian mainland. Three main distinctive features are the causes of this difference: the existence of volcanoes, the river system, and the soil.

## Volcanoes

Java has a larger number of volcanoes than the southeast Asian mainland. There are about 90 active volcanoes in Southeast Asia, 19 of which are in the Philippines and the rest—71 volcanoes—are in Indonesia. Of these 71 volcanoes, 34 are currently active.[2] Java has the largest number of active volcanoes, with around 25.[3] These volcanoes have made a significant contribution to the geographical conditions of the island, either through changing its physical geomorphology or by shaping its anthropogeography. The Javanese volcanoes are one of the main factors that created the island's cultural landscape.

The history of volcanicity in Java has often been explored through the prism of catastrophe, but it has also benefitted the islands; for example, the soil of Java is extremely fertile. Volcanic activity has not only formed the distinctive Javanese landscape, it has also provided an enormous and widely-deposited volume of sediment for the majority of the island. When volcanoes explode, they produce material—in the form of both ash and pyroclastic flows—that create very fertile black soils with a high water-retention capacity. Such soils are very fertile and so are extensively cultivated.[4]

## Soil

The soils of Java and of the Southeast Asian mainland are very different, and that has led to distinctive geomorphological features in both areas. Most of the soil of

1 W. Donner, *Land Use and Environment in Indonesia* (London: The Institute of Asian Affairs, 1987). The detailed zones of Java can be seen in: H. Th. Verstappen, *Outline of the Geomorphology of Indonesia* (Enschede: International Institute for Aerospace Survey and Earth Sciences, 2000): 26-30.

2 H.Th. Verstappen, "Volcanic Islands", in: *The Physical Geography of Southeast Asia*, ed Avajit Gupta (Oxford: Oxford University Press, 2005): 143.

3 N. van Padang, *Catalogue of the Active Volcanoes of Indonesia* (Napoli: International Volcanological Association, 1951): 62.

4 A. Gupta, *Tropical Geomorphology* (New York: Cambridge University Press, 2011): 268; T. Whitten, Roehayat Emon and Suraya A. Afiff, *The Ecology of Java and Bali* (Hongkong: Periplus Editions, 1996): 95; Verstappen, "Volcanic Islands": 148; Donner, *Land Use and Environment in Indonesia*: 7-10.

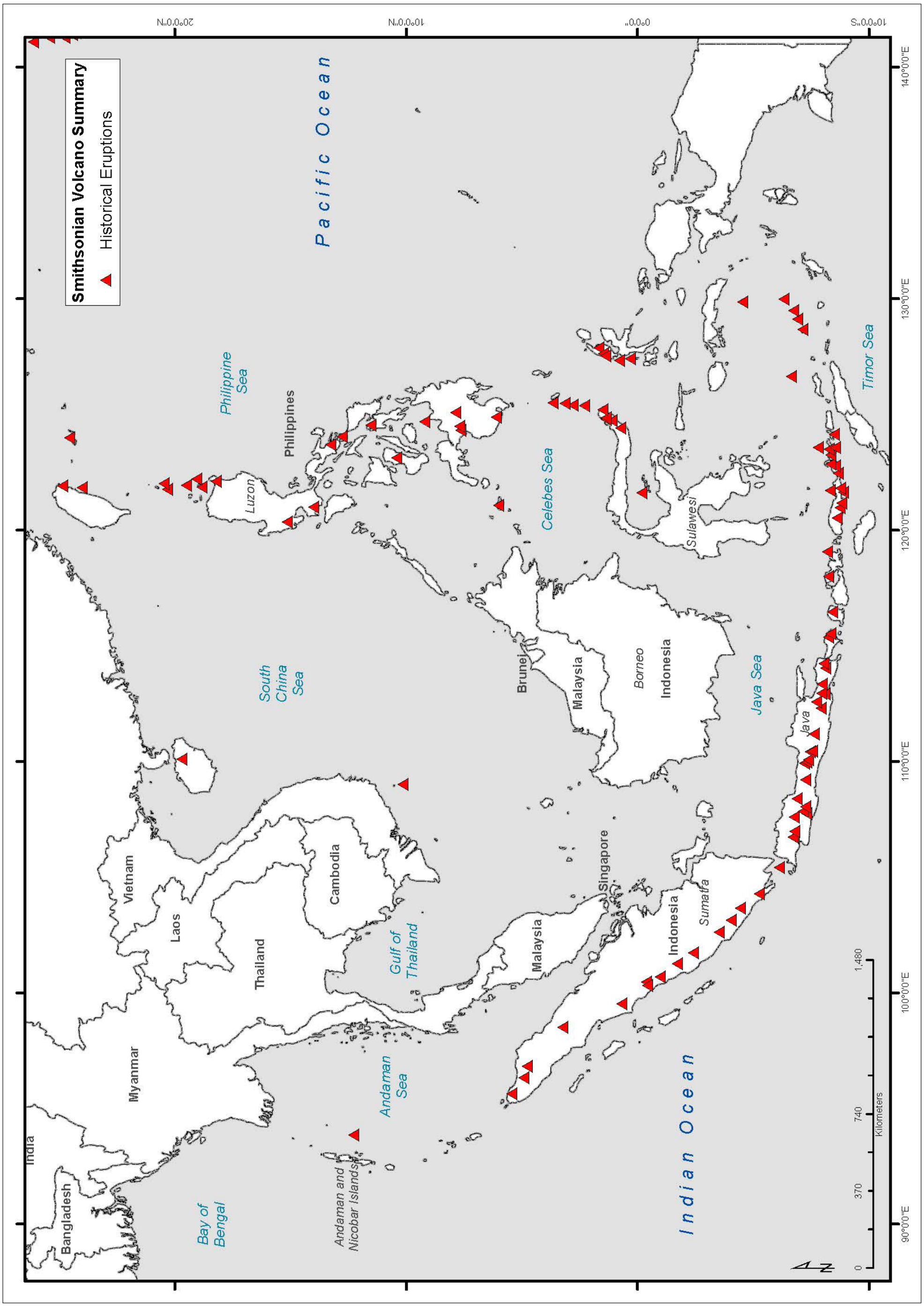


**Fig. 3.1.** Volcanoes in Southeast Asia. (Source: https://www.earthobservatory.sg/files/resources/files/Southeast%20Asia-Volcanoes%20map.pdf)

the Southeast Asian mainland is *acrisols* while Java is dominated by *andosols*.[5] The *andosols* consist of material produced by volcanic eruptions. They spread far around the area of the volcano and are then weathered by the humid tropics until, after several decades, the land is extremely fertile. The *andosols* form the dominant soil group in Java (as well as in West Sumatra and the Philippines) and have higher agricultural potential than *acrisols*. As such, it is more productive when cultivated than is the soil of the Southeast Asian mainland, especially if it is also irrigated. This means that Java is more productive as regards agricultural cultivation than anywhere on the Southeast Asian mainland. S. van Valkenberg[6] described the fertile land of Java in the following way:

> Notwithstanding the disastrous eruptions, the volcanoes must be considered a veritable gift of the gods. Their fertile ashes have, to a large extent, covered the Tertiary laterite and made of Java a real garden of the East.

Although, in general, Java is a very fertile land, sometimes there may be a short period of agricultural difficulties, usually caused by natural disasters such as dry climate, heavy rain, or earthquakes.

As in most tropical zones, though, the Javanese littoral was far from conducive for massive agricultural investment. In fact, as we have seen already, it was easiest to start agriculture in the semi-arid interiors and not on the coast, mainly because of its unhealthy conditions (e.g. malaria) as well as water management problems. In tropical areas high, year-round rainfall produces poor soils due to nutrient leaching, so that it is precisely those areas with a pronounced dry season, such as Central and East Java, that are the most fertile, although irrigation may be necessary in order to realize their full potential.

## Rivers

In addition to volcanoes and soils, the fertility of Java is also influenced by the Javanese river system. In their relationship with the material ejected by the volcanoes, rivers function as a means of transportation, as they carry the volcanic matter a large distance. They carry and deposit this sediment to places including valley floors, alluvial fans, along alluvial valleys, and at deltas.[7] The rivers of Java, such as the Bengawan Solo and the Brantas, carry volcanic sediment over a wide area, widening the area of extremely fertile land. In contrast, while the Southeast Asian mainland contains larger and longer rivers they do not disperse volcanic sediment as happens on Java.

5 R. Dudal, "Soils of Southeast Asia", in: *The Physical Geography of Southeast Asia, ed Avijit Gupta* (New York, Oxford University Press, 2005): 102.

6 S. van Valkenberg, "Java: The Economic Geography of a Tropical Island", *Geographical Review* 15/4 (1925): 569-570.

7 Gupta, *Tropical Geomorphology*: 129

Although there are a number of differences between the physical environments of Southeast Asia and Java, both regions share the importance of rice, the production of which has influenced political, economic, social, and cultural life both in the past and present. The history of agriculture in Southeast Asia has been dominated by the management of rice cultivation.

Regarding the history of agriculture over the whole of Southeast Asia, there is not sufficient historical and archaeological evidence to explain its development in the region, including within Java.[8] The origin of rice cultivation has been particularly subject to debate. There are many theories regarding where rice (*Oryza sativa*) originated and how it spread across Southeast Asia. However, on the basis of archaeobotanical data, many scholars now believe that rice spread across mainland Southeast Asia from southern China before the third millennium BC. Archaeological research in Sarawak and Sulawesi reveals that the introduction of rice cultivation into the islands of Southeast Asia occurred around 2,000 BC.[9] Yet, in the case of Java, a date for the beginning of rice cultivation has not been established. Bellwood assumes that rice was domesticated in Java in the first century CE.[10] So far, however, there is no archaeological or palaeobotanical evidence for this assumption. The earliest evidence comes from palynological evidence, inscriptions, temple reliefs, and the existence of rice chaff in bricks that dates back at least to the eighth century CE.[11]

However, many scholars discuss the development of rice only and ignore the importance of other staples in the development of agriculture in early Java, such as foxtail millet, Job's tears, taro, yams, and sago. Indeed, in some areas the inhabitants focus on a certain food staple, such as on the Ok mountain of central New Guinea, where taro is the staple (although they also cultivate other varieties of plant for food).[12] In mainland Southeast Asia, too, certain areas focus on specific types of agriculture; for example, the Mon, Khmer, and Cham prefer house-gardening, while the Burmese, Thai, and Vietnamese cultivate rice.[13] In the case of Java, rice cultivation

8 I.G. Glover, "The Late Prehistoric Period in Indonesia", in: *Early South East Asia. Essays in Archaeology, History and Historical Geography*, ed. R.B. Smith and W. Watson (New York: Oxford University Press, 1979): 167-184.

9 C. Doherty, Paul Beavitt, and Edmund Kumi, "Recent Observations of Rice Temper in Pottery from Niah and other Sites in Sarawak", *Bulletin of the Indo-Pacific Research Association* 150 (2000): 150; I. C. Glover, "Prehistoric Plant Remains from Southeast Asia, with Special Reference to Rice", *South Asian Archaeology* 1 (1977): 7-37.

10 P. Bellwood, *Prehistory of the Indo-Malaysian Archipelago* (Honolulu: University of Hawaii Press, 1977): 117.

11 J.W. Christie, "The Agricultural Economies of Early Java and Bali", in: *Smallholders and Stockbreeders. History of Foodcrop and Livestock Farming in Southeast Asia*, ed. Peter Boomgaard and David Henley (Leiden: KITLV Press, 2004): 47-48.

12 G.E.B. Morren Jr and David C. Hyndman, "The Taro Monoculture in Central New Guinea", *Human Ecology* 15/3 (1987): 301-315.

13 The Khmer developed wet-field rice agriculture extensively, especially, and gradually, in the Mekong Basin, yet most parts of Cambodia kept house-gardening. See: R. A.

and house-gardening probably existed side-by-side. Another example of a cultivated grain is foxtail millet, which was also farmed in ancient Java. A famous relief from the Borobudur temple shows sheaves of grain on a shoulder pole, which suggests that foxtail millet was a cultivated grain and a food staple for the Javanese.[14]

Regarding ancient Javanese cultivation systems, Jan Wisseman Christie assumed that swidden (slash-and-burn) agriculture was practiced by the Javanese.[15] Her assumption was based on the Srokodan inscription—a Balinese inscription from the ninth century CE—although the inscription itself does not specifically mention swidden agriculture happening in ancient Bali. She bases her assumption on her translation of *lmah sukĕt* as a fallow swidden land, but it is a mistranslation.[16] It is not relevant to discuss here the shifting cultivation types of Java. The land area of Java is not as large as is the case on the other main islands of Indonesia, such as Borneo, for example, neither is the forest denser. Despite having limited space to shift cultivation, Javanese cultivators do not have to move from one area to another because the lands are fertile enough to be used all the time; the volcanic ash and sediment mean it is permanently fertile. In addition, Pujoarinto and Cushing—who conducted research on pollen stratigraphic evidence of human activities at Dieng, in Central Java—found no evidence of the use of fire to clear the land because there were not significant levels of carbon within the sediment.[17]

The development of agriculture in ancient Java enters the historical record after the ninth century CE, as further archaeological and textual data suggest. According to Christie, wet rice cultivation was the main agricultural production method in Java, followed by various other farming systems based on the following productive types of land:

> dry or hill rice fields *(gagā, gagān);* dry or swidden fields *(tĕgal/parlak);* fallowed swidden land *(lmah sukĕt);* orchards or perennial gardens *(kbuan/ ngmal, mmal);* houseland with gardens *(pomahan); sirih* gardens *(pasĕrĕhan);* taro fields *(patalĕsan);* cotton fields *(pakapasan);* meadow or grass land *(dukut/ padang);* treeless, uncultivated land *(harahara);* forest *(alas);* marsh *(rĕnĕk);*

O'Connor, "Agricultural Change and Ethnic Succession in Southeast Asian States: A Case for Regional Anthropology", *The Journal of Asian Studies*, 54/4 (1995): 969-970, 972-973. See also: G.J.A. Terra, "Some Sociological Aspects of Agriculture in S. E. Asia", *Indonesië* 6/4 and 6/5 (1953): 297-316, 439-63.

14 Although there is debate regarding this relief (I b 41), and particularly whether it is rice or foxtail millet. See: D. Henley, "Rizification Revisited: Re-examining the Rise of Rice in Indonesia with Special Reference to Sulawesi", in: *Smallholders and Stockbreeders. History of Foodcrop and Livestock Farming in Southeast Asia*, ed. Peter Boomgaard and David Henley (Leiden: KITLV Press, 2004): 121-122.

15 Christie, "The Agricultural Economies of Early Java and Bali": 50-51.

16 See: R. Goris, *Inscripties voor Anak Wungçu* (Bandung: Masa Baru, 1954): 129-130.

17 Agus Pudjoarinto and Edward J Cushing, "Pollen-stratigraphic evidence of human activity at Dieng, Central Java", *Palaeogeography, Palaeoclimatology, Palaeoecology* 171/3 (2001): 329-340.

river banks/margins *(tpitpi);* rivers *(luah, kali, bangawan);* lakes, ponds *(ranu/ danu);* salterns *(lmah asinan* or *pawuyahan).*[18]

I have different interpretations for some of those Old Javanese words than does Christie. For instance, I prefer to interpret *gagā* as meaning a dry rice field, not always on a hill; *tĕgal* as a dry cultivated field, not a type of swidden cultivation; and *lmah sukĕt* as an uncultivated field. Despite these differences of interpretation regarding field types, for the period after the ninth century CE I agree with Christie that different types of agriculture were practised in ancient Java and that rice cultivation was one of the types of agriculture. The Javanese cultivated a wide variety of plants on different types of agricultural lands.[19] These included dry fields, irrigated lands, gardens, and even ponds and riverbanks.

Of all these different cultivation systems in ancient Java, the *sawah* was the most important agricultural activity, both for individuals and states. The development of wet-field rice cultivation in that region is believed to have been related to subsistence farming, to increased tax revenue, and to trade. In other words, some of the rice produced in Java was consumed by the Javanese households who grew it while the remainder was traded, thereby contributing to the state's income through taxes. As such, it was sensible for the Javanese rulers to support the people's attempts to create more wet rice fields. The increase in cultivated land resulted in many forests across Central Java being converted into agricultural land. For example, forests of teak, which had been introduced to Java around 200 CE and had become widespread across the island, were cleared for agriculture in the sixth century CE.[20] Moreover, from the ninth century CE, ancient Javanese inscriptions detail many more examples of the conversion of dry fields to wet rice fields, encouraged by the state.[21]

One consequence of the expansion of the wet rice fields and of the increased demand for rice as a commodity was that the state had to find a new strategy to accomplish it.[22] It seems likely that the relocation of the Javanese kingdom from

18 Christie, "The Agricultural Economies of Early Java and Bali": 50.

19 See for the various types of agricultural lands in Majapahit period: Ph. Soebroto, "Sektor Pertanian sebagai Penyangga Kehidupan Perekonomian Majapahit", in: *700 Tahun Majapahit. Suatu Bunga Rampai*, eds. Sartono Kartodirjo, et al. (Surabaya: Dinas Pariwisata Daerah Propinsi Tingkat I Jawa Timur, 1993): 152-176.

20 Franck Lavigne and Yanni Gunnell, "Land Cover Change and Abrupt Environmental Impacts on Javan Volcanoes, Indonesia: A Long-Term Perspective on Recent Events", *Reg Environ Change* 6 (2006): 94.

21 Christie, "The Agricultural Economies of Early Java and Bali": 55.

22 For paddy farming in ancient Java based on the relief evidences, see: Siswanto, "Potret-Potret Kearifan Lingkungan Masa Lalu dalam Relief dan Sastra Tertulis". In: *Majapahit. Batas Kota dan Jejak Kejayaan di Luar Kota*, ed. Inajati Adrisijanti (Yogyakarta: Penerbit Kepel Press, 2014): 60-67.

Central to East Java in the tenth century CE[23] was one of the strategies by which rice production and commerce were increased. By relocating the centre of the kingdom to East Java, close to the Brantas river and its tributaries, there were two benefits. First, water for irrigating the rice fields became more easily accessible than it had been in Central Java, which had no large river and tributaries comparable in size to the Brantas. Consequently, it was easy to create irrigation infrastructures for rice fields in East Java. Archaeological data from this region provides us with further evidence of irrigation infrastructure features—dams, canals, and tunnels—as do epigraphic records, which provide more indications than do the archaeological data and epigraphic records of Central Java. Secondly, as a commercial river, the Brantas connected the inland rice production centres with coastal trading centres.[24] As the East Javanese coastal trading posts became more prominent in Southeast Asia after the tenth or eleventh century CE, more and more rice was transported through the Brantas river routes from its hinterlands.

In conclusion, a comparison of the farming practices of the Southeast Asian mainland with those of Java demonstrates that differences in the natural environment caused people to create specific agricultural practices appropriate for their area. For example, the fertility of Javanese soil is more sustainable for agriculture than is that of mainland Southeast Asia due to the existence of volcanoes and of *andosols* in the former.

The growth of agriculture in Java does not follow Boserup's theory of population pressure, which states that increased population growth results in starvation which then motivates people to invent agricultural technologies and cultivation methods in order to increase food production.[25] The evidence from Java shows that Javanese agricultural growth was the result of the natural fertility of the land, increased economic factors (rice trading), and improved irrigation technology, especially as regards rice cultivation. As a result of both the benefits of its cultivation and encouragement from the Javanese rulers, rice became a favorite plant for cultivation in Java. Economic considerations also caused the rulers to shift the centre of the kingdom from Central to East Java—to the Brantas river basin—in order to produce more rice and have easier access to coastal ports, eventually enhancing their capability in irrigation technology, but the direct cause of the eastern shift were quite different and more dramatic.

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23 The problem of the movement of the Javanese Kingdom has been explored by Boechari; see: Boechari, "Some Considerations of the Problem of the shift of Mataram's Center of Government from Central to East Java in the 10th century A.D." (Jakarta: Proyek Pelita, Pembinaan Kepurbakalaan dan Peninggalan Nasional, Departemen P. & K. 1976).

24 Some ports in delta Brantas river were mentioned by Christie, in: J.W. Christie, "Javanese Markets and the Asian Sea Trade Boom of the Tenth to Thirteenth Centuries A.D.", *JESHO* (1998): 344-381.

25 See: E. Boserup, *The Condition of Agricultural Growth* (Chicago: Aldine, 1965).

## 3.2. CLIMATE CHANGE

While the previous section discussed the environment and agriculture of Java, in this part I will discuss the region's climate and how climate change influenced the socio-political development of the Javanese states. In other words, I want to explain to what extent climate change in the tenth to the sixteenth centuries impacted the development of the Javanese states. My assumption is that, to a certain degree, people who live in the changing environment will adapt to the climate or at least to climate conditions. At the state level, the changing environment and the inhabitants' adaptation to it help contribute to the growth of the state itself.

Lieberman is one scholar who has explored the relationship between climate change and the growth of states. His hypothesis is that the early development of Pagan, Angkor, and Dai Viet in mainland Southeast Asia was the result of stronger monsoons at the time of the medieval climate anomaly (*circa* 900/950-1250/1300 CE).[26] Unfortunately, he does not go into detail about the influence this had on the Javanese states, simply concluding that the increase in East Javanese agriculture was driven by the monsoons and weak El Niño during the period c. 820-1270 CE.[27]

Lieberman's statement raises a very interesting question when we look more closely at the Javanese states of that period. As noted above, in 929 the centre of the Javanese kingdom was moved from Central to East Java, from a relatively wet and fertile region to a drier area with less rain. Different theories regarding the reasons for this move to East Java have been proposed by various scholars, and many explanations have been advanced; these include religious reasons, warfare, economic considerations, natural disasters, and environmental factors, and these have been summarized by both Boechari[28] and Voûte.[29] Caesar Voûte, as well as giving a summary of the reasons for the shift, also put forward a hypothesis of his own: that it was triggered by continuous sedimentation along the north coast which resulted in the silting up of the Central Javanese trading ports. This resulted in an

26 V. Lieberman and Brendan Buckley, "The Impact of Climate on Southeast Asia, circa 950–1820: New Findings", *Modern Asian Studies* 46/5 (2012): 1049-1096. See also: V. Lieberman, *Strange Parallels: Southeast Asia in Global Context, c. 800-1830. Vol. 2: Mainland Mirrors: Europe, Japan, China, South Asia, and the Islands* (Cambridge: Cambridge University Press, 2009). Another scholar who also relates climate to the development of Southeast Asian states is Anthony Reid; see: Anthony Reid, *Southeast Asia in the Age of Commerce, 1450-1680. Volume 2. Expansion and Crisis* (New Haven: Yale University Press, 1993).

27 Lieberman, *Strange Parallels: Southeast Asia in Global Context, c. 800-1830. Vol. 2*: 792.

28 Boechari, "Some Considerations".

29 C. Voûte, "Religious, Cultural and Political Developments during the Hindu-Buddhist Period in Central and East Java-Relations with India and Srilangka- Human Actors and Geological Processes and Events", in: *Society and Culture of Southeast Asia Continues and Changes, ed. Lokesh Chandra* (New Delhi: International Academy of Indian Culture and Aditya Prakashan, 2000): 329-334.

economic disaster for the Central Javanese polity so it moved to East Java, where the harbors were still suitable for trading.[30] However, none of these theories considers the change in climate that occurred at that time as being a factor.

The question remains as to what the relationship was between the movement of Javanese states, on the one hand, and the climate, monsoon rains, and weak El Niño on the other. To answer this question, we must explore the connection between the climate, monsoons, and El Niño in Java at that time.

Regarding the difference in climate between Central and East Java, the map below shows the classification of climates on Java. The Köppen climate classification divides Java into three zones: Am (tropical monsoon), Aw (tropical wet and dry/ tropical savanna), and Cfa (humid subtropical). Most of East Java has an Aw climate, meaning it is drier than the rest of Java.[31] It has a pronounced dry season, with the driest period seeing less than 60 mm of precipitation over more than two months. As such, under normal conditions Central Java is more suited to growing agricultural crops, especially rice, than is East Java. Most of the Central Java region with its Am climate has an amount of rainfall in the wet months which can compensate for the lack of rainfall in the dry months. If there is too much rainfall, though, the quality of agricultural soil may degrade caused by nutrients leaching as in the case of Java's coastal areas.[32]

Java's climate correlates with the monsoon rains and with the El Niño Southern Oscillation (ENSO),[33] and both these factors determine whether rain will be abundant or scarce in any given period. On the basis of proxy evidence such as tree-ring records and coral evidence,[34] it seems that there was a high frequency of

30 *Ibid*.

31 Sutikno, "Kondisi Geografis Kraton Majapahit", in: *700 Tahun Majapahit. Suatu Bunga Rampai*, eds. Sartono Kartodirdjo, et al. (Surabaya: Dinas Pariwisata Daerah Propinsi Tingkat I Jawa Timur, 1993): 16-18.

32 The effect of too much rainfall on the soil quality can be seen in D. Henley, "Population, Economy and Environment in Island Southeast Asia: An Historical View with Special Reference to Northern Sulawesi", *Singapore Journal of Tropical Geography*, 23, 2, (2002): 171-174. See also: E.C.J. Mohr, "Climate and soil in the Netherlands Indies", *Bulletin of the Colonial Institute of Amsterdam*, 1 (1923): 245; E. C. J. Mohr and R. L. Pendleton, The soils of Equatorial Regions with Special Reference to the Netherlands East Indies (Michigan: J. W. Edwards, 1944): 114-117.

33 Grove and Chappell define it in the following way: "The phenomenon itself is a see-saw of atmospheric mass involving exchanges of air between eastern and western hemispheres centerd in tropical and subtropical latitudes, with centers of action over Indonesia and the tropical Pacific Ocean"; John Chappell and Richard H. Grove, "ENSO: A Brief Overview", in: *El Niño. History and Crisis*, ed. Richard H. Grove and John Chappell (Cambridge: The White House Press, 2000): 5.

34 D. Khider, *Paleoceanofraphy of the Indonesian Seas over the Past 25,000 Years* (Dissertation University of Southern California, 2011): 140-143; K. M. Cobb, et al., "El Niño/Southern Oscillation and Tropical Pacific Climate during the Last Millennium", Nature 424 (2003): 271-276.

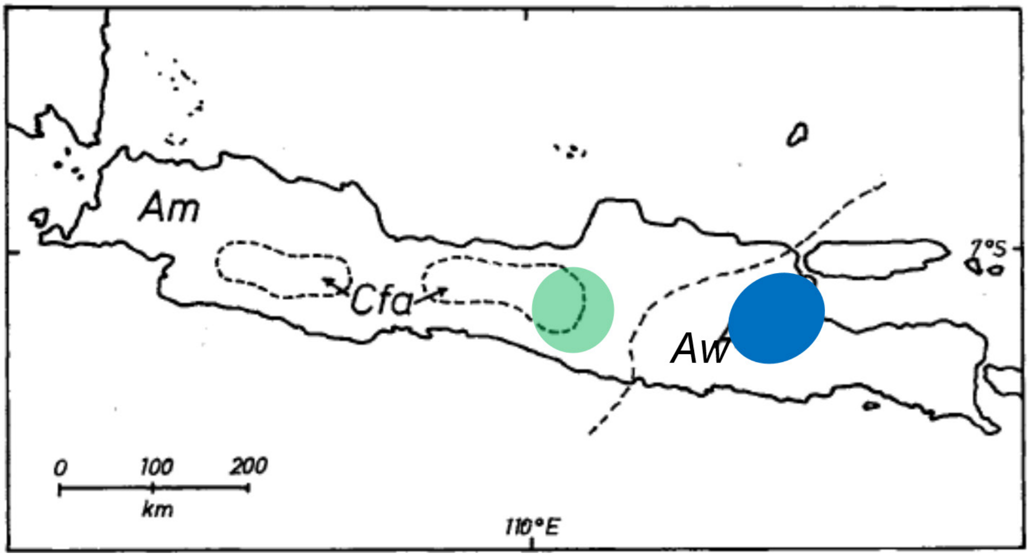


**Fig. 3.2.** Climate of Java and the centres of Javanese states

*Am* = Tropical climate, rainforest climate despite a short dry season (monsoon type)

*Aw* = Tropical climate, tropical savanna climate with a pronounced dry season

*Cfa* = Temperate rainy climate, wet in all seasons, with hot summers

= Centre of Central Javanese state

= Centre of East Javanese state

*Basemap: Meyers Grosser Weltatlas,* 1979, pp. 246-7.

Source: Wolf Doner. Land Use and Environment in Indonesia: 88, with a modification.

La Niña and relatively cool conditions in the years *c.* 900-1300 CE (the "Medieval Warm Period" or "Medieval Climate Anomaly"). Consequently, Java had higher than average rainfall during the Medieval Climate Anomaly. J.R. Rodysill agrees with this hypothesis and, based on her research on lake sediment deposits in East Java, states that there was more frequent flooding in East Java from 850 to 1350 CE as a consequence of high activity levels of both El Niño and La Niña during the Medieval Climate Anomaly.[35] Another study by B.L. Konecky *et al*. conducted on precipitation proxy reconstruction from Lake Lading, Java, from 850 CE to present, proves that rainfall has continually increased in Java over the past millennium. Indeed, there were drier periods occurred during 960–1090 CE, 1260–1300 CE, 1380–1450 CE, 1600–1690 CE, 1790–1800 CE, and 1840–1900 CE, but wetter conditions happened

35 J.R. Rodysill, et al., "ENSO-driven Flooding Events in East Java, Indonesia during the Past Millennium", *American Geophysical Union, Fall Meeting 2013*, see: http://adsabs.harvard.edu/abs/2013AGUFMOS34A.06R

in between.[36] It is interesting that at least from 850 to 960 CE a wetter climate occurred in Java just before the political power in the Central Java moved to the East Java.

I suggest that climate was a primary factor behind the shift of the Javanese kingdoms towards the eastern part of the Island. To support my hypothesis, I will explore both historical and archaeological records. First, archaeological evidence from Central Java contains indications of natural disasters caused by severe rainfall. This, in turn, caused pyroclastic sediments from mountain tops to cascade down the surrounding valleys in the form of rain-triggered volcanic mudflows (lahar flows[37]), events which are almost always caused by heavy rainfall. When the lahar flows occur soon after an eruption, they are hot lahar flows; if not—if they happen some time after an eruption—they are cold lahar flows. However, cold lahars are more hazardous than are hot lahars because they occur more frequently. F. Lavigne declares that the frequency of cold lahars depends on the characteristics of the rainfall and on the volume and grain size of the fresh pyroclastic deposits on the mountain.[38] In the case of the Merapi volcano, around the tenth century there were pyroclastic deposits that were the result of a 765-911 CE eruption[39] and which had become cold lahars in subsequent years. These cold lahars were transported down the valleys via rivers—there are at least 13 rivers on the slopes of the Merapi volcano—and many of the lahars travelled a long distance from the banks when the rivers overflowed as a result of a period of extreme rainfall.

During the Medieval Climate Anomaly, when there was increased rainfall in Java, more lahars would flow from the tops of the mountains down the mountainsides to the river basins, via valleys and rivers whose headwaters were in the mountains. As a result, many temples that lay in the regions around the volcanoes were buried by volcanic ash and sediments. Most of those in the vicinity of Merapi, for example, were struck by a volcanic mudflow at some point that buried or destroyed them;

36 B.L. Konecky et al., "Intensification of Southwestern Indonesian Rainfall over the Past Millennium", *Geophysical Research Letters*, 40 (2013): 386–391.

37 A lahar is defined by Lavigne as "a mixture of debris and water, other than streamflow, that flows from a volcano at relatively high speed. A lahar is usually an event, not as a deposit, which may be originated in several ways, from debris avalanches, through lake outburst or breaching, snowmelt by pyroclastic flows, which transform to aqueous flows, and through removal of pyroclastic debris by subsequent heavy rainstorms during an eruption." See: F. Lavigne and Jean-Claude Thouret, "Sediment transportation and deposition by rain-triggered lahars at Merapi Volcano, Central Java, Indonesia", *Geomorphology* 49 (2002): 45–69.

38 F. Lavigne, et al., "Lahars at Merapi Volcano, Central Java: An Overview", *Journal of Volcanology and Geothermal Research* 100 (2000): 423–456.

39 According to Andreastuti, this date is nearest to the time when the Central Javanese polity moved to East Java in the 10th century CE. See: S.D. Andreastuti, Chris Newhall, and Joko Dwiyanto, "Menelusuri Kebenaran Letusan Gunung Merapi 1006", *Jurnal Geologi Indonesia* 1/4 (2006): 204 and 207.

**Fig. 3.3.** Liyangan site, Temanggung, Central Java, an archaeological site which is buried by volcanic mudflow of Sindoro mountain. (Source: Left Photo from http://sains.kompas.com/read/2014/11/23/21135401/Situs.Liyangan.Sudah.Dihuni.Sejak.Abad.ke-6 and right photo by Dwi Pradnyawan)

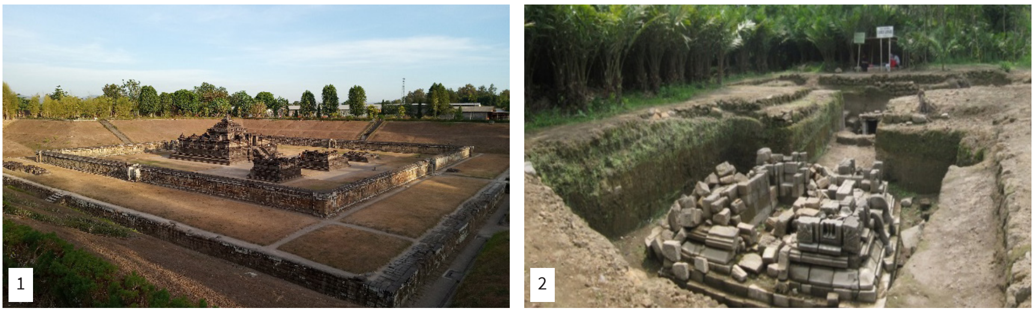


**Fig.3.4.** Sambisari (1) and Losari (2) temples, which are other examples of temples buried by alluvial sediments. Sambisari was found six metres below the surface. (Photos by Tjahjono Prasodjo)

Sambisari and Kedulan temples are two such examples. And Merapi was not the only volcano in Central Java that caused temples to be buried. Mt. Sindoro,[40] situated not far from Temanggung, also did so to Liyangan, which is a large archaeological compound dating from around the ninth century CE that was discovered in 2009 and contains evidence of a disaster caused by lahars, primarily from the Sindoro volcano. The site was covered by four to seven metres of volcanic deposits.

Secondly, another record—an Old Javanese epigraphic text dating from 907 CE, the Rukam inscription, found in 1975 in Petarangan village (Temanggung) on the

40 Mount Sindoro (Sundoro or Sendoro) is a statovolcano with a long history of large eruptions from prehistoric time; See: N.J.M. Taverne, "Vulkaanstudiën op Java", *Vulkanalogische Mededelingen No. 7*. ('s Gravenhage: Algemeene Landsdrukkerij, 1926): 40-45.

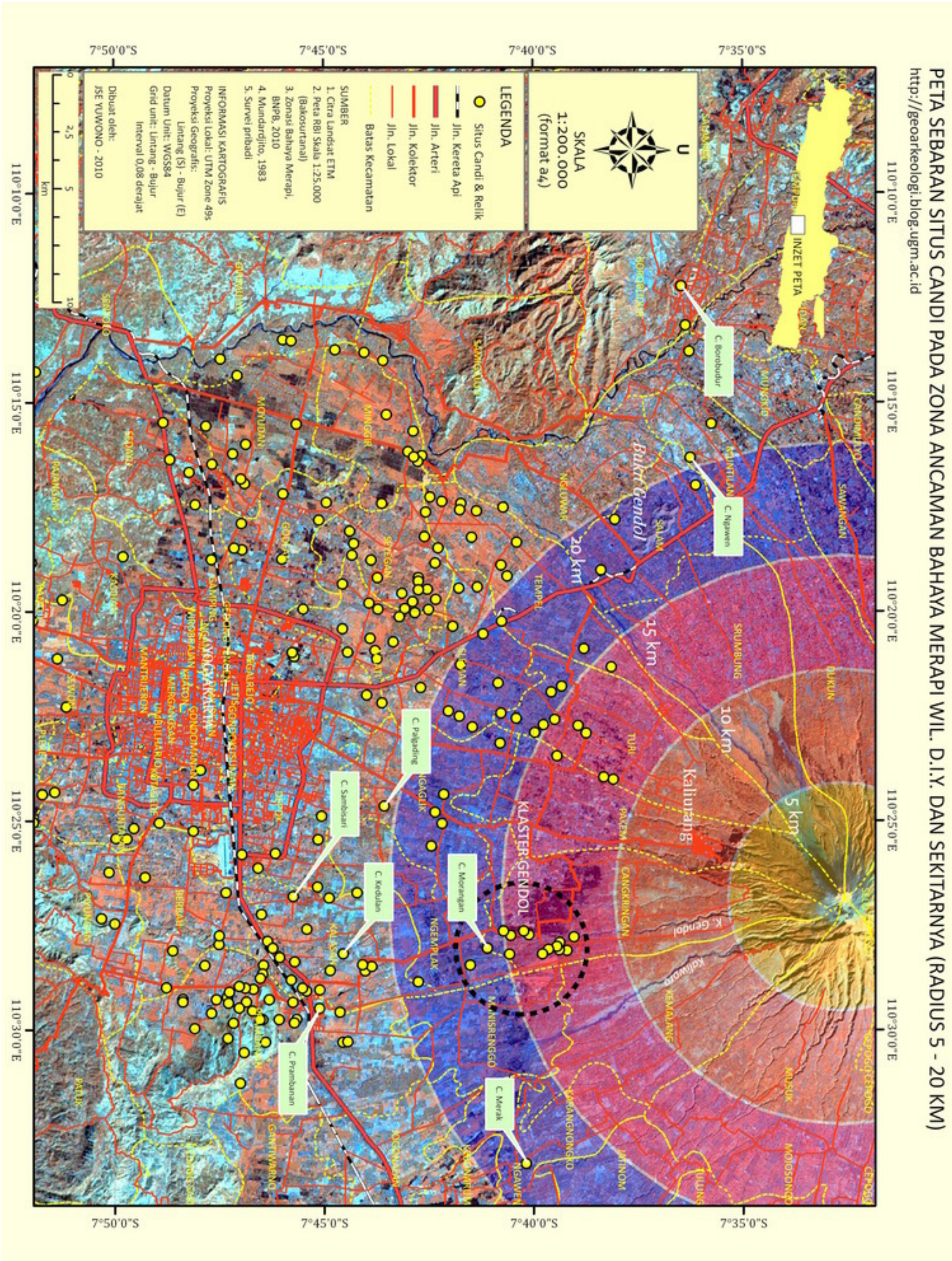


**Fig. 3.5.** Map of the distribution of archaeological sites, temples, and *in situ* artefacts on the western and southern slopes of Merapi volcano within the Merapi hazard zones. Yellow dots indicate the locations of archaeological sites, temples, and artefacts. Source: http://geoarkeologi.blog.ugm.ac.id/tag/jogja/

slopes of Mount Sumbing—contains information relating how Śrī Mahārāja Rake Watukura Dyaḥ Balituṅ, the king of the Central Javanese kingdom, gave the order to designate the village of Rukam as a *sīma* because it had been destroyed by *"guntur"*. I translate the term *guntur* as lahar flows, so the phrase "*saṅkā yan hilaṅ de niṅ guntur*" in the inscription means "because of the fact that it had been destroyed by lahar flows".[41] This differs from Titi Surti Nastiti's translation as "because it was destroyed by a volcanic eruption".[42] Her citation of the whole sentence is

1. *....tatkāla ājñā śrī mahārāja rake watukura dyaḥ balituṅ śrī dharmmodaya mahāśambhu miṅ*
2. *sor i mahāmantri śrī dakṣottama bāhubajra pratipakṣakṣaya kumonnakan ikanaṅ wanua i rukam wanua i dro saṅkā yan hilaṅ de niṅ guntur sīmān rakryān sañjīwana nini haji maṅasĕa i dharmma nira i limwuṅ muaṅ pagawa*
3. *yana kamulān*[43]

I translate it as:

1. ...at the time when the order of Śrī Mahārāja Rake Watukura Dyaḥ Balituṅ Śrī Dharmmodaya Mahāśambhu
2. was sent down to Mahāmantri Śrī Dakṣottama Bāhubajra Pratipakṣakṣaya to give an order regarding Rukam village, which is a village in the inner part of the palace; because of the fact that it had been destroyed by lahar flows, it should be converted into a *sīma* of Rakryān Sañjīwana, the grandmother of the king, as a tribute to the holy temple in Limwuṅ and should
3. be made a *kamulān* (a shrine for ancestor worship)

In addition, three inscriptions found near the Kedulan temple—the Panaṅgaran, Sumuṇḍul, and Tluron inscriptions—also relate a flood disaster. They state that a dam and a canal should have been built to prevent water flooding a dry-field and that construction was delayed for years as a result of various disasters. As the temples in which the inscriptions were found were buried by 8 metres of volcanic sediment, it is very possible that the inscriptions refer to a lahar flood, not just flooding by water. These four inscriptions together demonstrate that lahars occurred at that time, and

41 Lahar is an Indonesian term that internationally accepted as a geologigal term describes a rapidly flowing mixture of volcanic mud flows and water from a volcano. F. Lavigne et al.: "Lahars at Merapi Volcano, Central Java: An Overview", *Journal of Volcanology and Geothermal Research* 100 (2000): 423–424.

42 T.S. Nastiti, Dyah Wijaya Dewi, and Richadiana Kartakusuma, *Tiga Prasasti dari Masa Balitung* (Jakarta: Pusat Penelitian Arkeologi Nasional, 1982): 23. According to Zoetmulder, "*guntur*" also means "flood (with rocks and lava from a volcanic eruption)" instead of simply "volcanic eruption". See: P.J. Zoetmulder, *Old Javanese-English Dictionary. Part 1: A-O* ('s-Gravenhage: Nijhoff, 1982): 556.

43 Nastiti, Dyah Wijaya Dewi, and Richadiana Kartakusuma, *Tiga Prasasti dari Masa Balitung*: 23.

it is very likely that they were caused by heavy rainfall.

Thirdly, East Java's climate and environment is unlike that of Central Java. East Java does have some active volcanoes but not as many as Central Java, where the urban centres were surrounded by active volcanoes. In East Java, Kelud, Semeru, and Raung are the most active volcanoes, while Central Java has Slamet, Dieng, Sindoro, Sumbing, Merbabu, and Merapi.[44] Another characteristic of the volcanoes of Central Java is that they are found in a relatively small area; this is especially the case with Merapi and Merbabu, which are on two adjacent mountains, as are Sindoro and Sumbing. It is also possible to compare the volcanic eruptions on mountains in Central Java and East Java; for instance, Merapi and Kelud are both famous for their violent and often deadly eruptions, yet Merapi has almost always had repeated eruptions over a relatively long period of time whereas Kelud's eruptions are usually comparatively brief. Kelud produced less lava, bombs, and ash than Merapi which makes Merapi steeper than Kelud.[45] When a lengthy eruption, such as those of Merapi, occurs at a time of heavy rainfall, it often leads to a very dangerous long-term lahar disaster in the surrounding areas.[46] Unstable geological conditions caused by volcanic activity on Central Java around the ninth and tenth centuries have been highlighted by Christie, who has shown that epigraphic records support the notion of geological turbulence in that period.[47]

Although East Java is located in an Aw climate zone—meaning that the centre of the Javanese kingdom moved to a drier region when it relocated there—it moved into the Brantas river basin, meaning that the increased dryness was offset by the water that flowed into the basin, which could be accessed easily. Moreover, it survived in this new, drier area partly as a result of the increased rainfall that was a result of Medieval Climate Anomaly; however, even if there had only been average rainfall—or even a period of drought[48]—it was still more secure compared to the Central Java region.

After the periods of heavy rainfall of the Medieval Climate Anomaly, some

44 For each description of these mountains, see: van Padang, *Catalogue of the Active Volcanoes of Indonesia*: xiii, 102-104, 107-115, 118-128, 132-137, 141-145, 153-156.

45 E.C.J. Mohr, *The Soils of Equatorial Regions with Special Reference to the Netherlands East Indies* (Michigan: J. W. Edwards, 1944): 647.

46 Thouret and Lavigne show how the same hazards and risks are still faced by those living around Mount Merapi in Central Java today: J. Thouret and Franck Lavigne, "Hazards and Risks at Gunung Merapi, Central Java: A Case of Study", in: *The Physical Geography of Southeast Asia, ed Avajit Gupta* (Oxford: Oxford University Press, 2005): 275-299.

47 J.W. Christie, "Under the Volcano: Stabilizing the Early Javanese State in an Unstable Environment", in: *Environment, Trade and Society in Southeast Asia: A Longue Durée Perspective*, ed. David Henley and Henk Schulte Nordholt (Leiden: Brill, 2015): 46-61.

48 Based on paleolimnological records, Jessica R. Rodysill et al. find that there was a drought period in East Java in the period 930-1130. See: J.R. Rodysill, et al., "A Paleolimnological Record of Rainfall and Drought from East Java, Indonesia during the last 1,400 year" *J Paleolimnol* 47 (2012): 125–139.

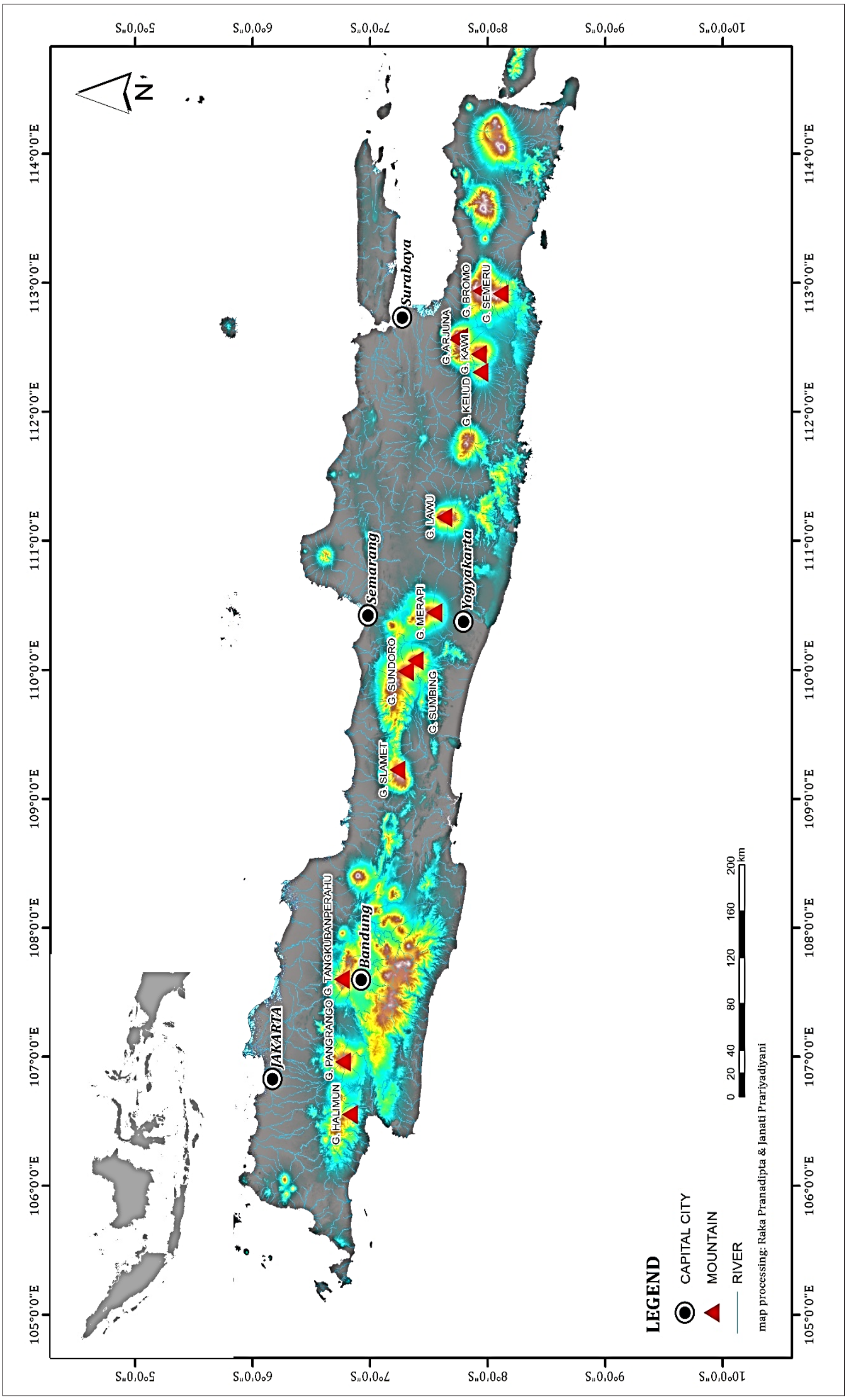


**Fig. 3.6.** The distribution of volcanoes on Java. (Map by Tjahjono Prasodjo)

parts of the world, including Southeast Asia, entered a much drier period, as the Southeast Asian climate was impacted by the Little Ice Age. This occurred from the early fourteenth to the mid-nineteenth century, after the Medieval Climate Anomaly. Whereas the Medieval Climate Anomaly had produced more rainfall, the Little Ice Age was marked by droughts, although their duration and intensity varied from place to place. That lengthy and recurring droughts occurred during the Little Ice Age in mainland Southeast Asia have been highlighted by various scholars, as have their influence on the region's states.[49] Even the period of transition from the Medieval Climate Anomaly to the Little Ice Age contributed to the crises faced by various Southeast Asia states. In the field of paleoclimatology, research into the relationship between climate and the development of states in Southeast Asia before the nineteenth century is still in its infancy. There is limited data and that which does exist is not always consistent.

Recently, some research has been conducted into the East Javanese paleoclimate, particularly on the basis of the paleolimnological records from three lakes in East Java.[50] The most important finding is that there were periods of drought at various points in East Javanese history. One of these pieces of research has discovered evidence of four droughts over the past 1,400 years, occurring in 930-1130, 1460–1640, 1790–1860, and 1985–2008 CE.[51] Another record, from Ranu Lamongan, shows two multi-decadal periods of drought: *c.* 1275–1325 CE and *c.* 1450–1650 CE.[52] Further research, by Rodysill *et al.*, demonstrates that the most severe drought happened around 1790 CE, ± 20 years.[53] On the basis of their research into the sediments of Lake Kalimpaa in central Sulawesi, Michael Wündsch *et al*. have explained that the periods of drought in East Java coincided with those in Sulawesi, although there are parts of their study that also highlight dissimilarities.[54] On the basis of an isotopic analysis of stalagmites from the Ciawitali cave, in West Java, Watanabe *et al*. have suggested that there were episodes of drier conditions

49 Lieberman and Brendan Buckley, "The Impact of Climate on Southeast Asia, circa 950–1820": 1073-1074.

50 Rodysill, et al., "A Paleolimnological Record of Rainfall and Drought from East Java, Indonesia During the Last 1,400 year": 125-139; Jessica R. Rodysill, et al., "A Severe Drought During the Last Millennium in East Java, Indonesia", *Quaternary Science Reviews* 80 (2013): 102-111.

51 Rodysill, et al., "A Paleolimnological Record of Rainfall and Drought from East Java, Indonesia During the Last 1,400 year": 137.

52 Shelley D. Crausbay, "A ca. 800-year Lithologic Record of Drought from Sub-Annually Laminated Lake Sediment, East Java", *Journal of Paleolimnology* 35 (2006): 641–659.

53 Rodysill, et al., "A Severe Drought during the Last Millennium in East Java, Indonesia": 109-110.

54 Michael Wündsch, et al., "ENSO and Monsoon Variability During the Past 1.5 kyr as reflected in sediments from Lake Kalimpaa, Central Sulawesi (Indonesia)", *The Holocene* (2014): 10-11.

around the years 1600, 1800, and 1990 CE, a hypothesis that agrees with lake sediment analysis.[55] However, the records are inconsistent, especially those which show there was a period of drought in 930-1130 CE in Java;[56] I assume this to be a "false" record, or at least one that should be critically reconsidered, because other research findings have suggested that it was, in fact, wetter in Java at that time.[57] Hence, periods of drought in either Java or East Java took place *c.* 1300 CE, *c.* 1450-1650 CE, *c.* 1790-1860 CE, and 1985-2008 CE. These were interspersed with wetter periods.

The Javanese droughts that occurred during the transition between the Medieval Climate Anomaly and the Little Ice Age correlated with similar events in mainland Southeast Asia. Buckley *et al.* have sought to explain the relationship between climate—especially long droughts combined with intense monsoons in Cambodia—and the eventual demise of the Khmer empire. Based on climatic evidence from a 750-year hydroclimate reconstruction on the basis of tropical southern Vietnamese tree rings, they argue that a decades-long drought would have decreased Khmer agricultural productivity while large-scale monsoons would have destroyed the water control infrastructure.[58] Lieberman and Buckley added further similar examples from Pagan and Dai Viet to confirm this idea.[59] Their conclusion highlights a correlation between a drought-driven climate and socio-economic vulnerabilities that could eventually create a situation in which the kingdoms in question could collapse.

The drier climate of East Java was both expected and planned for by farmers and by the state through the provision of irrigation infrastructure; in other words, the solution put forward for the drier climate was the construction of more waterworks. Evidence found in Old Javanese inscriptions regarding water infrastructure or water management is rare and most are from East Java rather than Central Java.[60] This pattern suggests that problems regarding water control were greater in East Java.

55 Y. Watanabe, et al., "Hydroclimate Reconstruction in Indonesia over the Last Centuries by Stalagmite Isotopic Analyses". *PAGES News*, Vol 20, No 2, December (2012): 74-75.

56 See: Rodysill, et al., "A Paleolimnological Record of Rainfall and Drought from East Java, Indonesia During the Last 1,400 year": 135.

57 Khider, Paleoceanofraphy of the Indonesian Seas over the Past 25,000 Years: 140-143; Cobb, et al., "El Niño/Southern Oscillation and Tropical Pacific Climate during the Last Millennium": 271-276. Also see: Rodysill, et al., "ENSO-driven Flooding Events in East Java, Indonesia during the Past Millennium".

58 B.M. Buckley, et al., "Climate as a Contributing Factor in the Demise of Angkor, Cambodia". *PNAS*, vol. 107, no. 15, April 13 (2010): 6749-6750.

59 Lieberman and Brendan Buckley, "The Impact of Climate on Southeast Asia, circa 950–1820": 1049-1096.

60 J.W. Christie, "Water from the Ancestors: Irrigation from Early Java and Bali", in: *The Gift of Water: Water Management, Cosmology and the States in Southeast Asia*, ed. Jonathan Rigg (London: School of Oriental and African Studies University of London, 1992): 17.

Archaeological features and artifacts from East Java relating to water management can be found all along the Brantas river valley, and include dams, water-tunnels, ponds, and river channels. As a result of facing larger water-management issues, it seems that the role of the East Javanese court was greater, if not in the water management system as a whole, at least in specific instances such as collecting agricultural taxes.

To sum up, both the physical environment itself and other environmental factors in Java played important roles in how ancient Javanese political authorities and societies responded and adapted to the environmental conditions. I also consider that the climate and climate change in ancient Java, and especially ancient East Java, had a profound influence on the socio-political dynamics of the states. Climate records, combined with historical and archaeological data, support the various explanations put forward by scholars about how these states and their inhabitants adapted to the changing environment and climate by simply improving water control technology and management or, as an extreme measure, by moving the state's centre.

## 3.3. THE BRANTAS RIVER BASIN

The basin is surrounded by Mount Bromo and Mount Semeru to the east, a series of low ridges to the south, Mount Wilis and its ridges to the west, and the Kedung low ridges and Madura Strait to the north. In the middle of the basin is the Arjuno mountain complex, which consists of Mount Arjuno, Mount Butak, and Mount Kelud. The Brantas river is 320 km in length, and its source is located in a village called Sumberbrantas, on the southern flank of Mount Arjuno. The basin covers nine regencies—Tulungagung, Trenggalek, Kediri, Nganjuk, Blitar, Malang, Mojokerto, Jombang, Sidoarjo—and five municipalities—Malang, Kediri, Blitar, Mojokerto, and Surabaya.[61]

The river flows in a clockwise, spiralling course from its source to the Madura Strait. The main branch of the river can be divided into three parts, or reaches. The first part, also known as the upper reach, starts at the spring, runs southward through the Malang Plateau, and, after about 20 kilometres, turns west. After this, the Brantas river is joined by a large number of tributaries which stream down from the southern slope of Mount Kelud. The slopes of this first reach are generally steeper than those of the second stretch, or the middle reach. The middle reach begins near Tulungagung, when the Brantas river turns northward, and it then flows north to north-west of Jombang, before flowing eastwards to Mojokerto. The lower reach of the Brantas river begins at Mojokerto, where it divides into two branches,

61 Anjali Bhat, Kikkeri Ramu, and Karin Kemper, "Institutional and Policy Analysis of River Basin Management. The Brantas River Basin, East Java, Indonesia". *World Bank Policy Research Working Paper* 3611 (May 2005): 8.


**Fig. 3.7.** Map of the Brantas river basin. (Source: Anjali Bhat, Kikkeri Ramu, and Karin Kemper, “Institutional and Policy Analysis of River Basin Management The Brantas River Basin, East Java, Indonesia”. *World Bank Policy Research Working Paper* 3611, May 2005)

Kali Mas and Porong. Both branches discharge into the Madura Strait, the Kali Mas river to the northeast of Surabaya, at Surabaya Strait, and the Porong river at Porong bay, south of Sidoarjo.[62]

As the geomorphology of the river basin is, to a large extent, characterised by volcanoes, the basin and the river itself are impacted by their existence. At the very least, the volcanoes both contribute to the fertility of the basin and play a role in silting up the river, riverbed aggravation, and reservoir sedimentation through their eruptions. The two active volcanoes in the basin are Mount Semeru and Mount Kelud, which at times produce volcanic ash and other material. The volcanic debris that is deposited on the mountain slopes is regularly taken, via rainwater runoff, into the Brantas river. Analysis of the Brantas river sediment shows that it mainly consists of tuffaceous sandstones, agglomerates, or volcanic conglomerates.[63]

The sedimentation that is a product of the volcanic material also plays a role in shaping the Brantas delta, which is the area between the Kali Mas and the Porong rivers. The delta was formed in the Mid-Pleistocene era, demonstrated by marine deposits being found as much as dozens of metres below the present-day sea level.[64] The ancient delta certainly did not have the same form as it does now, because the delta was almost entirely shaped during the last century, as is evident from old maps.[65] The question is, however, how far the delta has altered and developed between then and the present. Van Bemmelen estimates that, in the tenth century, the Brantas estuary was still fairly wide and formed a natural harbor, but now the Porong estuary is more than 40 km from the very end of the Brantas river.[66] On the basis of a list of ferry harbors along the Brantas river that was inscribed on a Trowulan inscription from 1358 CE and an old map of Residentie Soerabaia, Van Stein Callenfels and Van Vuuren suggest that the mouth of the Brantas or Porong was in Tulangan or Pamotan,[67] 30-20 km from the coastline today. On the other hand, Verbeek believes that, a thousand years ago, the coastline was essentially the same

62 R.D. Moetariyono, *Sediment Budget and Estuarine Circulation on The Brantas River Estuary East-Java, Indonesia* (Masters Thesis, Faculty of Engineering and Applied Science, Memorial University of Newfoundland, Canada, 1992): 5-17.

63 P. Hoekstra and Tiktanata, "Coastal Hydrodynamics, Geomorphology and Sedimentary Environments of Two Major Javanese River Deltas. Program and Preliminary Results from The Snellius-II Expedition (Indonesia)", *Journal of Southeast Asian Earth Sciences* 2/2 (1988): 102.

64 Sunarto, *Rekonstruksi Sejarah Geomorfologis Delta Brantas dalam Hubungannya dengan Situs Arkeologi Medowo Jawa Timur* (Yogyakarta: Fakultas Geografi UGM, 1990): 24.

65 Hoekstra and Tiktanata, "Coastal Hydrodynamics, Geomorphology and Sedimentary Environments of Two Major Javanese River Deltas": 104-105.

66 R.W. van Bemmelen, *The Geology of Indonesia---General Geology of lndonesia and Adjacent Archipelagoes*, Vol. 1A. (The Hague: Martinus Nijhoff, 1949): 30.

67 P.V. van Stein Callenfels and L. van Vuuren, "Bijdrage tot de Topographie van de Residentie Soerabaia in de 14de Eeuw", *Tijdschrift van het Koninklijk Nederlandsch Aardrijkskundig Genootschap* 41/1 (1924): 67-81.

as it is today, an assumption he makes on the basis of an archaeological survey of the Brantas river delta in which he found archaeological artifacts in both Kalang Anyar and Tulungan, only 3 km from the present coastline.[68] Most researchers believe that the delta is constantly evolving and that these morphological changes suggest a dynamic development along the whole river basin over time.

Like the majority of Indonesia, the Brantas basin has a tropical monsoon climate which is divided into two seasons: the rainy season, from November to April, and the dry season, from May to October. The changing of the seasons is influenced by the Southeast Asian monsoon wind pattern. In the rainy season, the wind blows from the South China Sea, bringing moist air with high levels of humidity, while the reverse is the case in the dry season, when the wind brings dry air from the Australian continent. Peak rainfall is from December to February, while June to August is the peak of the dry season, when rainfall drops to a minimum. As such, 80% of rainfall occurs in the rainy season and there is an average of 2,000 mm per year. Nevertheless, there is variability between the level of rainfall in the mountains and in the lowlands, as the latter sees less. The mountainous areas have significant rainfall, occasionally even having some in the dry season; the average rainfall in these mountainous areas is between 3,000 and 4,000 mm. The annual mean temperature in the Brantas river basin is between $24.2^0$ and $26.6^0$ celsius and the annual relative humidity ranges from 75% to 82%.[69]

The origins of the name of the river—which is the second largest and longest river in Java—is unknown. Although many authors wrote descriptions of the river in Old Javanese or Sundanese texts, they did not call it "the Brantas." In Old East Javanese inscriptions the river was named *Bangawan*, such as in the Kamalagyan inscription of 1037 CE;[70] today, this term is used to describe any river. Bujangga Manik, who wrote an account of his journey from Sunda to East Java in the fifteenth century, may have named the river Ci Ronabaya. He wrote about the Ronabaya river when he crossed it after passing through Blitar, on his return journey to Sunda, and Noorduyn[71] has suggested that "Ronabaya" refers to the Brantas. Babad Tanah Jawi, an Old Javanese source from the eighteenth century, calls the river Banawi Palabuhan or the Palabuhan river.[72] Hence, at least up to the that time the river

68 R.D.M. Verbeek, *Oudheden van Java: Lijst der Voornaamste Overblijfselen uit den Hindoetijd op Java, met Eene Oudheidkundige Kaart* ('s Hage: Nijhoff, 1891): 207.

69 E. Aldriana and Yudha Setiawan Djamila, "Spatio-Temporal Climatic Change of Rainfall in East Java Indonesia", *International Journal of Climatology* 28 (2008): 437.

70 See the transcription of the inscription in: J.L.A. Brandes, "Oud-Javaansche Oorkonden", Negalaten Transcripties van Wijlen Dr. J.L.A. Brandes, uitgegeven door Dr. N.J. Krom, *VBG* 60 (1913): 134-136.

71 J. Noorduyn, "Bujangga Maniks Journeys through Java: Topographical Data from an Old Sundanese Source", *BKI* 138/4 (1982): 425-426.

72 See: J. Noorduyn, "Further Topographical Notes on the Ferry Charter of 1358, with Appendices on Djipang and Bodjanegara", *TBG* 124/4 (1968): 469.

was not called the Brantas. It may be that the old sources referred to above call the river by a local name or that the river had many names given to it by the different peoples who lived near it. If that is the case then it may be that one reach of the river was called Brantas; this is likely to have been the first part of the river as the river's spring is at Sumber Brantas (Source of the Brantas) village in the sub-district of Bumiaji, in Batu, East Java. Perhaps, in the past, during the initial mapping of Java or East Java the cartographer took "Brantas" as a label to name the whole reach of the river.

The Brantas river was closely linked to the growth of East Javanese polities in the tenth to the sixteenth centuries. It is possible to see very clearly here the political role of the river, especially when the capitals of the East Javanese polities shifted from one location to another. This was the case as early as the time Pu Siṇḍok Śrī Īsānawikramma Dharmmotuṅgadewa (929-949 CE), the king of Java, moved his capital to East Java and proclaimed himself the founder of a new dynasty, the Īsāna,[73] while his kingdom used the name Matarām.[74] He built his new capital at Tamwlang,[75] now a village in Tambelang, but then moved it to Watugaluh, near the Brantas river in Jombang. In the year 1019 CE, a new king of Java ascended the throne. This was Airlaṅga (r. 1019-1045 CE), one of the most famous kings of early Java. During his reign, he subjugated many local polities and thereby unified the kingdoms in the area. However, at the end of it, he had to divide his kingdom into two—thereby creating the Jaṅgala and the Paṅjalu kingdoms—one for each of his two sons.[76] After around 60 years, the Kaḍiri kingdom emerged. The capital of this kingdom was centreed on Kediri, also in the Brantas basin, although it was in the upper part of the middle reach.[77]

After the fall of the Kaḍiri kingdom (*c.* 1222 CE) there emerged a new dynasty. This dynasty was that of Rājasa, also called Girīndra, and its kingdom was called the Siṅhasāri. This is very important because its capital was moved towards the upper reach of the Brantas river. The founder and first king of this dynasty was Ken Arok (1222-1227 CE), who unified Java by conquering neighbouring polities. According to the Nāgarakṛtāgama, he conquered both the Kaḍiri and the Jaṅgala kingdoms and once again unified East Java.[78] The most famous of the kings of Siṅhasāri was

73 The name of this dynasty is recorded in the Pucangan inscription, which was issued by Airlangga, see: H. Kern, "De Steen van den berg Penanggungan (Surabaya), thans in 't Indian Museum te Calcutta", *VG* 7 (1917): 83-114.

74 See the Paradah inscription and the Añjukladang inscription: Brandes, *Oud-Javaansche Oorkonden: Nagelaten Transcripties*: XLVIII and XLVI.

75 Poesponegoro and Nugroho Notosusanto, *Sejarah Nasional Indonesia III*: 158.

76 On this division, see: H. Kern, "De Sanskrit-inscriptie van het Mahākṣobhya-beeld te Simpang (stad Surabaya, 1211 çaka)", *VG* 7 (1917): 187-197; S. Robson, Deśawarṇana (Leiden: KITLV Press, 1995): LXVIII.

77 Poesponegoro and Nugroho Nootosusanto, *Sejarah Nasional Indonesia III*: 265.

78 S. Robson, *Deśawarṇana* XL: 1-5.

Kṛtanagara (1254-1292 CE), who was the first Javanese king to attempt to expand his power outside Java. In 1275 CE, he sent an expedition to Mālayu (western Sumatra) to make an alliance with the Mālayu in an attempt to counter Chinese supremacy in the Malacca Strait.[79] Besides Mālayu, other polities that were his imperium included Pahang (Malaysia), Gurun, Bakulapura, Sunda, and Madura and the rest of Java, while he also had a good political relationship with Campa. The Siṅhasāri polity declined in 1292 CE because of a rebellion by Jayakatwaṅ who was from Kaḍiri, and this was followed by large-scale political upheavals involving Jayakatwaṅ, Wirarāja, Wijaya (a son-in-law of Kṛtanagara), and the Mongols.[80] Wijaya succeeded in usurping power, becoming the first king of a new kingdom—Majapahit—which became extremely powerful until its eventual collapse in the first quarter of the sixteenth century. It is likely that the Majapahit capital moved several times, although the largest of them is believed to have been at Trowulan, a site located close to the Brantas river. From its beginnings until the last quarter of the fourteenth century, Majapahit rule saw great economic, political, and cultural achievements. However, the rest of the Majapahit period after king Hayam Wuruk was declining, especially as a result of the internal political struggles between various members of the ruling family.

Besides increased political developments, in this period East Java was characterised by increased development along the Bengawan Solo and the Brantas river basins. Following the movement of the Javanese kingdom's centre of power to East Java, water management greatly increased, and East Javanese inscriptions[81] provide more records related to the building of water control infrastructure. These inscriptions demonstrate that many dams and other irrigation works were built in the Brantas river basin at this time. These inscriptions highlight the double-edged nature of the river: it provides water for irrigation and for shipping but remains a constant threat due to the risk of flooding.[82]

As such, the hydrological infrastructure projects of ancient East Java included

79 J.G. de Casparis, "Sriwijaya and Malayu", *SPAFA Final Report: SEAMEO Project in Archaeology and Fine Arts, Consultative Workshop on Archaeological and Environmental Studies on Sriwijaya* (Jakarta, Padang, Prapat and Medan: Southeast Asian Ministers of Education Organization, 1985): 247-249.

80 On the Mongol invasion of Java, see: D.W. Bade, *Of Palm Wine, Women, and War: The Mongolian Naval Expedition to Java in the 13th Century* (Singapore: Institute of Southeast Asian Studies, 2013). See also: J. Gommans, "Java's Mongol Demon. Inscribing the Horse Archer into the Epic History of Majapahit", in: *HerStory. Historical Scholarship between South Asia and Europe. Festschrift in Honour of Gita Dharampal-Frick*, ed. Rafael Klöber and Manju Ludwig (Heidelberg: CrossAsia-eBooks, Heidelberg University Library, 2018): 243-252.

81 N.C. van Setten van der Meer, *Sawah Cultivation in Ancient Java: Aspects of Development during the Indo-Javanese Period, Fifth to fifteenth Century* (Canberra: Australian National Univesity Press, 1979).

82 F.H. van Naerssen, "De Brantas en Haar waterwerken in den Hindu Javaanschen tijd", *De Ingenieur* 35/7 (1938): A65.

damming rivers and building canals both to prevent flooding and to provide water for agriculture. As early as 804 CE, a canal was built in the upper reaches of the Brantas river by the elders and villagers of Culaṅgi; an inscription records that the canal was called the Hariñjing canal. Today, it is known as the Srinjing canal.[83] Another water control feature of the ancient Brantas river basin is mentioned in the Kamalagyan inscription, from 1037 CE.[84] This records a dam built upon the orders of King Airlaṅga both to prevent flooding of the surrounding areas where, in the past, the river had burst its banks and to help trading vessels reach Caṅgu, the hinterland royal-port.[85]

Indeed, hydrological infrastructure played a very important role in supporting economic life within East Java, and consequently the East Javanese polities would sometimes intervene when local problems could not be solved by the community itself. The scale and richness of irrigation features constructed during this period is demonstrated by the archaeological records of the Majapahit kingdom, as there are more than ten dams from the Majapahit period in the Brantas river basin,[86] while archaeological features in the ancient city of Trowulan demonstrate that there was an ancient East Javanese urban population near the Brantas river.[87] This city, located at the confluence of the Brantas river and some of its tributaries, has a large number of hydrological structures—including canals, reservoirs, and bathing places—which were part of the water control network system of the Brantas river basin. This will be explored further in Chapter 5.

Furthermore, in the past, the Brantas river played an important role as a means of transporting goods and people from the coast to the hinterlands and vice versa. The Trowulan inscription from 1358 CE describes places or villages along the river as being harbors, showing that it was possible to navigate the river as far as the vicinity of Kertosono from the Kali Mas and the Porong rivers. The ancient Nagarakṛtāgama text mentions Bubat, a village located on the Brantas river, as being a large commercial centre with many sizeable buildings that was populated

83 Sukabumi or Hariñjing inscription, see: P.V. van Stein Callenfels, “De Inscriptie van Soekaboemi”, *MKAW-L*, B 78 (1934). See also: F.H. van Naerssen and R.C. de Iongh, The Economic and Administrative History of Early Indonesia. Leiden: E.J. Brill, 1977): 57.

84 Brandes, *Oud-Javaansche Oorkonden*: 134-136.

85 Tjahjono Prasodjo, “Kemajuan Teknologi Masa Airlangga: Contoh Kasus Pembangunan Tambak atau Ḍawuhan dalam Prasasti Kamalagyan 1037 M.”, paper presented in a discussion “Airlangga sebagai Tokoh” in Jombang (2004): 5.

86 H. Maclaine Pont, “Eenige Oudheidkundige Gegevens Omtrent den Middeleeuwschen Bevloeiïngstoestand van de Zoogenaamde ‘Woeste Gronden van de Lieden van Trik’ voor Zoover Zij Wellicht van Belang zullen kunnen zijn voor eene Herziening van den Tegenwoordigen Toestand”. *OV* 1926, Bijlage G (1926): 100-129.

87 J.N. Miksic, "Water, Urbanization, and Disease in Early Indonesia", in: *Complex Polities in the Ancient Tropical World. Archaeological Papers of the American Anthropological Association*, No. 9, eds. Elizabeth A. Bacus and, Lisa J. Lucero (Arlington: American Anthropological Association, 1999): 175-180.

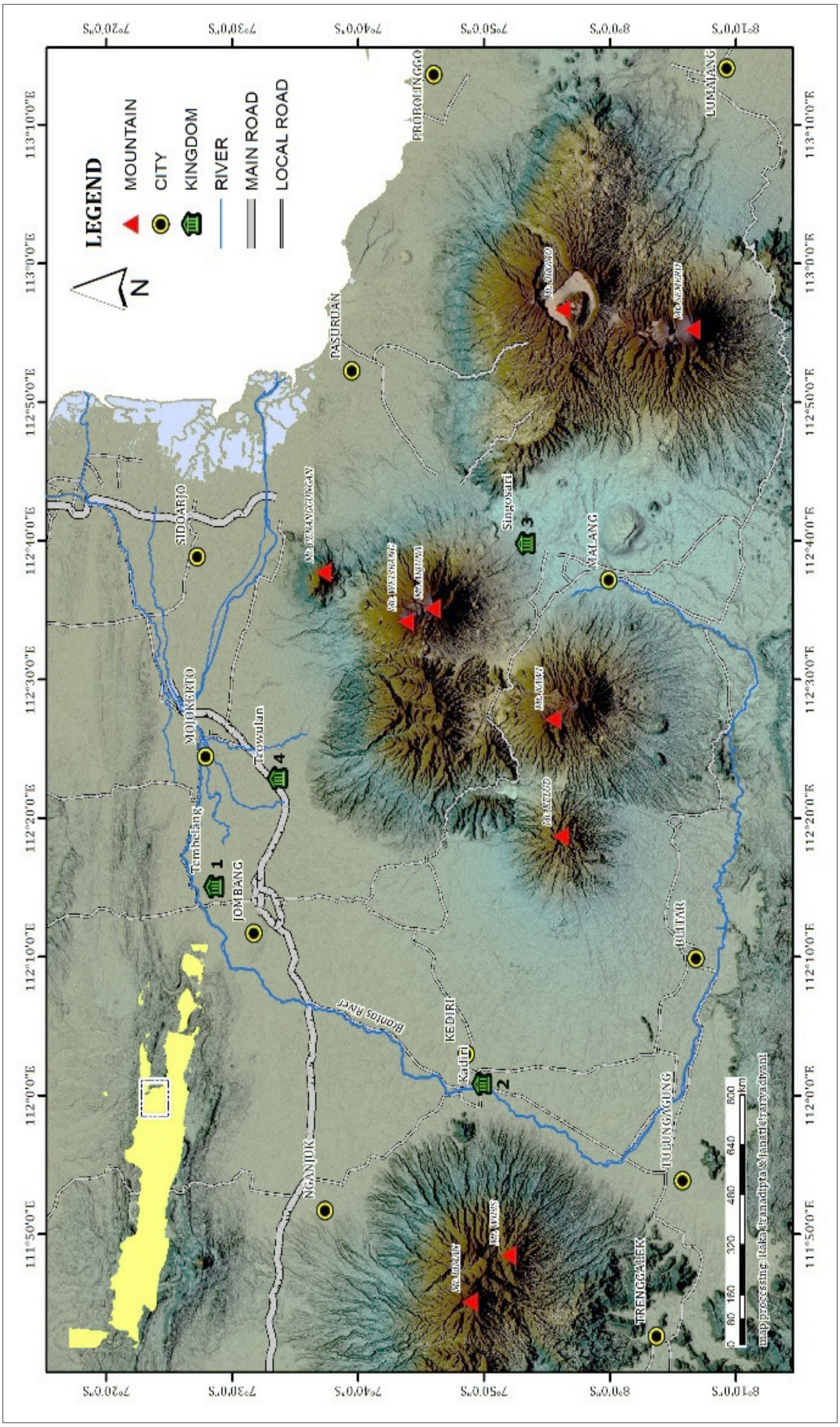


**Fig. 3.8.** Centers of East Javanese polities. 1.East-Java Mataram kingdom (929-1006 CE), 2. Kaḍiri kingdom (1117-1222 CE), 3. Singhasari kingdom (1222-1292 CE), 4. Majapahit kingdom (1293-1521 CE). (Map by Tjahjono Prasodjo)

by both local and foreign inhabitants. Due to the fact that the Brantas river was navigable, it facilitated communication between the people who lived along it, from the hinterland to the coast.

## 3.4. CONCLUSION

Comparing the situation of Central Java before the tenth century with that afterwards in East Java, the latter also faced environment problems but there was less instability than in Central Java. The largest disasters experienced were floods, the result of overflowing rivers caused by heavy rain or lahars. For instance, the capital of the Majapahit kingdom, Trowulan, was located in an area that is greatly influenced by various geological systems—including the volcanic system (Anjasmoro-Welirang-Penanggungan-Kelud) and the river system (Brangkal-Landean-Pikatan)—which led to flooding several times a year. On the other hand, the area was extremely fertile.

To sum up, the Brantas river basin has been a dynamic region since prehistoric times both in geographical terms and in how the inhabitants have dealt and coped with climate changes through water control infrastructure. The hydromorphology of the river has changed over time and is dependent on many aspects, from the structure and evolution of the surface of the basin to how humans have interacted with and sought to control the river. The hydrological systems of the Brantas river basin have evolved due to a variety of natural and anthropogenic influences, including changes in land and water use caused by human inhabitation, agriculture, climate change, modifications to water infrastructure, and water use. As such, this kind of hydromorphological response must be considered important when researching water management in the Brantas river basin.