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Water and rice in early Java and Bali

Water-management and early rice cultivation in Southeast Asia

The management of water has deep historical roots in island Southeast Asia. The oldest manifestation of agricultural water management in the maritime region appears to have taken the form of modification of natural swamps. Archaeological data suggest that such managed swamp cultivation, possibly of indigenous strains of *taro* (*Colocasia esculentum*, Schott.), was under way in the New Guinea highlands by about 9000 years ago (Golson 1977). Similar management of swamps and wet areas for such crops has continued in all parts of the maritime Southeast Asia into the present. During the early historic period in maritime Southeast Asia, however, systems for the irrigation of seasonally or permanently dry land were overwhelmingly associated with the cultivation of the non-indigenous grain, rice (*Oryza sativa* L.).

Asian domesticated rice, on the basis of data available at present, is believed to have been developed from wild rices native to the mountainous region of the upper Irrawaddy, Mekong and Yangzi river systems. The earliest evidence of its intensive cultivation comes from the middle and lower reaches of the rivers just to the west, east and south of this mountainous origin area, in a band stretching from the Brahmaputra valley in northeastern India to the Yangzi valley in central China, on the southern edge of the millet belt. The oldest known site connected with intensive rice cultivation is that of Hemudu, on the fringes of Lake Taihu, near the mouth of the Yangzi River, from which very large quantities of rice have been recovered. At least 8000 years ago, the inhabitants of this and neighbouring settlements practiced what appears to have been 'receding-flood' cultivation of rice on a fairly substantial scale (Glover and Higham 1996). Under these receding-flood conditions it was possible to grow rice using the digging sticks and stone tools available to Neolithic farmers.

Rice was almost certainly brought to the islands of Southeast Asia by Austronesian-speaking peoples during the later Neolithic period (Bellwood 1997:110); the maritime Southeast Asian strain, recognized by some as *Oryza sativa* var. *javanica* (Chang 1976), appears to have been derived from the japoni-

ca strain that was first developed in central China (Oka 1988; Glover and Higham 1996). The paucity of archaeo-botanical data from island Southeast Asia has made reconstruction of the earliest phases of rice cultivation in the region difficult. However, there is archaeological evidence for the presence of rice in northwestern Borneo by about 4000 years ago (Glover and Higham 1996:426), and in Bali by at least 2000 years ago (Bellwood et al. 1992). Since the climate, the soil conditions and the latitude of Bali and Java favour rice cultivation to a far greater extent than do those of northern Borneo, it seems probable that rice was cultivated on the two islands at least as early as it was on Borneo.

The antiquity of irrigated rice cultivation in Java and Bali is less certain. Palynological data suggest that burn-offs associated with swidden cultivation of grains – possibly both rice and millets – began in western Indonesia between 5000 and 3000 years ago (Bellwood 1997:233). In much of the region, the pattern of settlement mobility established at this early stage appears to have persisted into historic times. However, in Java and Bali the transition to more permanent regimes of rice cultivation may have begun before the end of the Neolithic period. Indeed, on the margins of some lakes and along the lower courses of rivers, as in mainland Southeast Asia (Van Liere 1985), the earliest system of rice cultivation was probably ‘receding-flood’ cultivation. Under these conditions, stable settlements of modest size would have been possible. Palynological evidence suggests that if such regimes developed at an early stage in Java, they did so at moderate altitudes rather than in very low-lying areas (Sutikno 1989:8). This early phase of seasonally-flooded agriculture has, unfortunately, yet to be recovered archaeologically.

Flooding of areas other than seasonally inundated lake and river edges requires both a greater input of labour and metal tools, since such cultivation involves land clearance, the creation and maintenance both of bunded, terraced, ploughed and ‘bottomed’ fields, and of a system of dams and water conduits for distribution of water. Although no direct data are available at present concerning the methods or geographical distribution of rice cultivation in Java and Bali during the later prehistoric period, the presence of iron, buffalo and cattle by the beginning of the first millennium AD suggests that, as in mainland Southeast Asia during the same period, the conditions existed for bunded rice-field systems to have spread outwards from the lake and river margins. This does not, however, rule out dry-field rice as an important subsistence crop in mixed upland cultivation systems.

The earliest solid and detailed information concerning Javanese and Balinese rice-growing regimes is that found in historical sources. The most important of these sources are the several hundred surviving Old-Javanese and Old-Balinese language tax charters inscribed on stone or copper plates during the later first and early second millennia AD. These sources indicate that

by the ninth century AD, rice was not only the major subsistence crop on these islands, but it was also both a market commodity and the basis of state agricultural tax systems. These records further indicate that both dry and irrigated rice fields were already an established feature of the landscapes of the two islands at this time. The Javanese and Balinese of the period had already developed specific terms, not only for irrigated rice fields (*sawah* in Old Javanese, *huma* in Old Balinese), but also for dry or 'hill' rice fields (Old Javanese *gagā*, Old Balinese *parlak*), these latter distinguished from the dry fields planted with other crops (Old Javanese *tgā*, Old Balinese *mmal*). Although the same term (*pari*) was used for both wet-field and dry-field rice plants in the straw, Balinese charters and early Javanese literature distinguished the husked grains of the non-sticky types of rice grown in sawah fields (Old Javanese *wēas/bras*, Old Balinese *bras*) from the sticky rice grains (*lakētan*, *kētan*) – red, black and white – of most of the hill-rice crops.

The inscriptions further indicate that, on both islands, states had a particular interest in encouraging communities to shift away from swidden-based dry-field agriculture towards greater investment of time and effort in creating banded and irrigated wet-rice fields. This state-encouraged expansion of irrigation began to increase significantly in the early second millennium AD. By the eleventh century, as the expansion of wet-rice cultivation accelerated, the manner in which irrigation systems were managed on the two islands appears to have begun to diverge. These divergences reflected the differences in geography that shaped the religious and political economies of the two islands (Christie 1992).

The geographical contexts of irrigation

Both Java and Bali lie just below the equator, within the tropical maritime region. The mean annual rainfall of what were, in the past, the most densely populated portions of the islands – that is, central and east Java, and southern Bali – is moderate, and the climate of the region is monsoonal. The heaviest rains fall between November and February, and these portions of the two islands experience a dry season of a month or more between June and September. Although, in general, the climate grows progressively drier as one moves eastwards from central Java to southern Bali, the local patterns and volumes of rainfall differ more within each island than they do, on the whole, between these portions of the two islands – depending both upon where the islands lie in respect to the rain shadows cast by Australia and Borneo, and upon the placement of different sub-zones with respect to the sea and to major mountains.

Both Java and Bali lie within the so-called Pacific 'ring of fire'. Their landscapes are dominated and shaped by living and extinct volcanoes. These

mountains trap rain clouds, watering most generously their southern flanks. Since this effect is noticeable to a degree even outside of the rainy season, increases substantially the available surface water on these mountain slopes. The agriculturally important rivers of the islands, most of which flow southwards initially, rise from waters that percolate through into the spring lines encircling the volcanoes, providing year-round flows. Most of the rivers flowing out of the Perahu and Merapi-Merbabu massifs in central Java, and out of the central Balinese peaks, remain small, draining separately through sloping uplands towards the relatively narrow southern coastal strip, some converging near the coast.

The agricultural environment to the south of the volcanoes in central Java – generally the wettest portion of the region in question – is relatively stable, with moderate seasonal shifts, many small and medium-sized rivers fed by numerous volcanic springs, and relatively shallow inclines across much of the area. However, the two major rivers of Java – the Solo and Brantas – empty into the sea on the northeast coast of east Java. They rise, respectively, in the waters draining off the east side of Merapi and off Mount Lawu in central Java, and those draining the Malang highlands of east Java. They owe their length, direction of flow, and ultimate volume, to the limestone hills near Java's south coast, which block their immediate exit into the sea, deflecting them first northwards and then eastwards, collecting water from numerous smaller tributaries along the way. The large delta formed by the Brantas River near east Java's coast has long been of considerable agricultural importance, although the waters have not been as easy to harness as those of the smaller rivers of central and east Java's uplands.

Southern Bali's landscape, although similar in some ways to that of central Java, is much more dissected. The volcanoes are larger in respect to the island's size, so inclines in many areas are steeper, and the coastal strip narrower. Thus, areas that are both well watered and reasonably level are more restricted than on Java. In addition, the land through which much of the water flows is composed of deep layers of soft *lahar* (volcanic mud) ejecta. Over the millennia even small trickles of water have cut very deep and narrow ravines through the Balinese landscape. These ravines, which obstruct east-west movement, developed into political boundaries, first between communities and later between states.

Water is not the only gift of the volcanoes of Java and Bali. The active volcanoes of the two islands have played an additional role in agriculture: they produce large quantities of neutral-to-basic, mineral-rich volcanic *lahar* (volcanic mud) and *ladu* (volcanic ash) ejecta. These active Javanese and Balinese volcanoes, which produce mineral-rich ejecta regularly, but usually not violently, directly affect the fertility of land on their slopes, and indirectly – through the action of water – that of the land below them. The volcanoes themselves do

not directly fertilize, on any regular basis, the land surrounding the majority of known early occupation sites, which lie at some distance from the volcanic slopes, often on ground too high to be inundated naturally. In order to make use of the annual build-up of volcanic ejecta that is washed down the slopes of the volcanoes and into the rivers that rise on their flanks, the water that carries this silt needs to be captured, first in weirs, and then in channels connected to the fields. Such systems collect, and distribute to fields, both water and fertilizing silt. However, the creation and maintenance of these systems require regular and organized labour input. It is on this basis that the area around Mount Merapi in central Java, still supports one of the greatest densities of agricultural population in the world (Hugo et al. 1987:56).

The early states of Java proper and of Bali all developed in the shadows of living volcanoes. Because living volcanoes can be harnessed in order to enhance the productivity of the fields that surround them, farming populations – in the past as in the present – have clustered most densely around these mountains. However, settling in close proximity to living volcanoes is dangerous. The volcanoes that give life and fertility can also bring death and destruction. Thus volcanoes have occupied a central position in the indigenous religions of Java and Bali, first linked to the spirits of ancestors, then also with the imported Hindu god Śiva, whose nature and attributes might have been designed with volcanoes in mind. Religion, in turn, provided an important focus for the organization of the agricultural calendae. In the dissected landscape of southern Bali, in particular, religion tended to bridge the gap between the organizational capabilities of the somewhat fragmented political hierarchy and the cooperative and technological needs of farmers.

The archaeological evidence for the distribution of early farming settlements

Early farming settlements encircling the volcanoes of Java and Bali appear to have been located below the spring line, and away from the areas affected on a regular basis by potentially catastrophic *lahar* flows. Although profiles of early settlement layers at the site around Borobudur, which is located at some distance to the southwest of Mount Merapi in central Java, indicate several minor episodes of volcanic ash deposition during the period of occupation – each episode delivering layers of ash a few centimetres thick – such ash deposition was too infrequent and irregular to be relied upon for the purposes of enriching farmer's fields. The situation elsewhere in the region appears to have been similar. During the earliest phases of occupation of the region, swidden farming, dependent upon vegetation-ash fertilizing, must have been the norm.

In those areas of central Java that have been surveyed, the distribution of early historic remains seems to indicate that most early settlement was lo-

cated nearer to the mountains than the coasts, on gently sloping fluvio-volcanic plains between about 50 and 400 m above sea level (Mundardjito 1993; Sutikno 1989:9). Pollen samples from the site of Borobudur indicate that by the ninth century AD the region surrounding the monument was reasonably well settled, and that the landscape supported a mixture of grain fields, house gardens, palm groves and forest similar to that of recent centuries, although in somewhat different proportions (Nossin and Voûte 1986:858). Much of the land below 25 m appears at that time to have been under swamp-forest or constituted uncultivated flood plain (Sutikno 1989:7-8). Early farmers apparently chose, by preference, land with moderate ground-water potential, and possibly that surrounding lakes in the uplands; it seems, on the basis of present evidence, that low-lying wet areas were not the first parts of the landscape to be exploited by farming settlements for the planting of rice.

The earliest archaeological remains mapped in east Java are found in the Malang highlands and on the slopes of the surrounding major volcanic massif. There is less evidence for dense early farming settlement of the lowlands closer to the east coast. Harnessing the water in east Java's Brantas delta and lower Solo region required not only engineering skills, but also major inputs of labour. This lowland region became more important after the beginning of the tenth century AD.

Evidence from Bali suggests that developing patterns of settlement and agriculture were similar to those of central Java. The Tampaksiring-Pejeng region to the south of the volcanic massif – which falls within an altitudinal band similar to the preferred early settlement area in central Java, but with a steeper incline – was probably the most densely populated region by the mid first millennium AD.

The transition to irrigated rice cultivation

The size of populations in central and east Java, and in Bali, during the late first millennium AD cannot have been greater than a tiny fraction of the present population of the same regions. Farmers on the two islands, at the end of the first millennium, were thus not likely to have been straining the carrying capacity of the land, nor were they likely to have been under pressure to intensify crop production for purely subsistence reasons. Dry-field rice and other dry-land crops could adequately have fed the farming population of the region, even though growing population density may have made abandonment of wide-scale swidden farming necessary.

These three regions present differing opportunities for irrigation. The fewest obstacles are presented by the landscape of central Java. Here more than eighty percent of sites dating to the later first millennium AD lie within 500 m of at least one river (Mundardjito 1993:14). In the relatively under-populated

landscape of central Java during the first millennium, irrigation appears not to have called for elaborate artificial constructions or administration. If, as seems to have been the case, no more than one irrigated crop was grown annually, even simultaneous inundation of fields watered by the same rivers and streams would not necessarily have taxed the water sources. The rains alone should, in a normal year, have provided much of the water necessary, particularly if transplantation of seedlings was practiced.

Settlement distribution in east Java seems to have altered rather rapidly at the end of the first millennium AD. Most of the known first millennium sites, aside from the remains associated with old ports, are located in the uplands and on the slopes of the volcanic massif. Population build-up in the Brantas delta and lower Solo region appears to have begun rather suddenly after the beginning of the tenth century AD.

Two major factors seem to have acted simultaneously to drive this rapid growth of settlement in this lowland zone. One factor was catastrophic: it appears that the active volcano Merapi, at the heart of settlement in central Java, exploded violently late in 928 or early in 929 AD. Stratigraphic evidence suggests that heavy ash-fall was followed by a partial collapse of Merapi's cone, which sent a major valley-filling pyroclastic flow of *lahar* (hot volcanic mud) into lower-lying areas to the south and east (Newhall et al. 2000). The palace relocated itself near the coast in east Java, which had been annexed some decades earlier by the central Javanese state of Mataram. A large proportion of the surviving population of the region appears to have been resettled, under state direction, in the under-occupied lowlands of east Java, where the state focused upon building up the east Javanese agricultural base.

The other factor driving this growth in settlement in the east Javanese lowlands in general – and in the Brantas delta and Solo river-mouth region in particular – was trade. An Asian sea-trade boom that began early in the tenth century stimulated a rapid expansion of Java's exports to overseas partners. These exports included both east Java's own spices, dyestuffs and other agricultural products, and certain spices, aromatics and dyestuffs imported by the Javanese from eastern Indonesia. This international sea-trade boom had the knock-on effect of increasing east Java's exports of such agricultural products as rice, sugar and pulses, along with salt, to trading partners in its archipelago network.

Demand from the ports for agricultural exports was most easily met by farmers settled along the lower reaches of the two main rivers. Pioneering settlement of the region behind the ports appears to have been a major objective of the distribution of royal tax grants during the tenth and eleventh centuries. Some of these grants were explicitly made to encourage forest clearance and population build-up in order to make the river routes and roads in the region safer for trade. Other grants were made in order to provide for the

maintenance of major dams and flood barriers. The policy of using tax incentives to attract settlement into this region seems to have been successful, since by the fourteenth century the east Javanese lowlands supported the densest concentration of substantial settlements on the island.

During the same period, population build-up on the slopes of southern Bali presented somewhat different changes to would-be irrigators, and called for rather different relations between settlement and river.

Incentives for the conversion to irrigated rice agriculture

Conversion to wet-rice farming regimes was labour-intensive, even in areas where the local conditions made it easy. At the same time, although such intensification of agriculture was manifestly in the interest of the administrations of the early states of Java and Bali, there is no evidence that these states were ever in a position to enforce such changes in agrarian practice. Rulers did not own the land of their states by right of office. Nor could these states afford to provide tax incentives for the development of all wet-rice fields. Therefore, inducements must have operated powerfully enough at the community level to begin the process of conversion from dry-rice to wet-rice farming.

Three such inducements seem probable. The added fertility of fields delivered by irrigation waters that carry captured volcanic run-off must have been one major incentive. The increase in volume and predictability of rice crops must, at some point, have promised to offset the labour involved in setting up such a field and channel system. The other inducement was probably related to a combination of population increase, community ownership of territory and structural changes in patterns of land tenure within communities.

Javanese and Balinese communities of the late first millennium AD (*wanua* in Old Javanese and *banua* in Old Balinese) appear to have owned territories larger than the fields and other types of land under immediate cultivation or other use. This territory was probably originally that which each community controlled for swidden-farming purposes, including fields that were fallowed for a number of years. As the population of each community increased, the original communities appear to have undergone a process of fission, with daughter villages hiving off to create pioneering settlements on the margins of the old territory. However, by the end of the first millennium AD, this process had apparently proceeded as far as it could, without major restructuring of inter-settlement and settlement-state relations, in the heartlands of central Java and possibly southern Bali. This was not the case, however, in east Java, where the contents of inscriptions indicate that the pioneering process carried on into the eleventh century, and even later in some areas.

The contents of Javanese and Balinese inscriptions of the ninth to fifteenth century indicate that farming practices of the early occupants of the islands

had become complex. Types of farmed land listed in these charters included not only dry fields (including swidden), fallowed swidden land, house land (planted with trees and perennials), orchards and betel gardens, but also irrigated rice fields and such mono-crop fields as *taro* gardens and cotton fields. Other types of productive land included pasture, forest, marshes, riverbanks, caves and salterns. Of these all, however, it is clear from the inscriptions that irrigated rice fields were, by the ninth century, the most valuable in terms of sale-value, and the most valued by the state as tar-producing resources.

The epigraphic record suggests that, by the ninth century, communities in the heartlands of central Java and southern Bali had come under pressure to intensify farming within their boundaries. Given the fact that irrigation is only effective if a network of water channels is first built and then regularly maintained, any conversion to wet-rice farming is unlikely to have been undertaken by individual community members in isolation. Nor would such a conversion have been worthwhile for individuals under a land-tenure system appropriate for swidden farming, in which land is held communally, but worked individually on a rotation basis. Some change in land-tenure must have accompanied the shift, possibly based upon existing regulations concerning inherited ownership of structures built, and productive trees and perennials planted, by individual community members.

It is clear that by the time tax documents were issued on permanent materials in local languages – early in the ninth century in Java and late in the same century in Bali – not only did wet-rice fields exist in large enough numbers to provide much, if not most, of the agricultural tax income of the states that issued the charters, but these fields were individually owned, heritable, and alienable. Sale of land is mentioned in a number of ninth and tenth century Javanese inscriptions. Although most types of land within a community's territory were sold by the community council as a group, three types of land – house land (planted with trees and perennials), orchards and *sawah* (irrigated rice fields) – were sold by individuals. By the tenth century, *sawah* fields were those most often cited as having been pawned or leased. They formed the major capital holdings of farming families.

Chinese reports of the eleventh and twelfth centuries mention rice as the major crop of Java (Hirth and Rockhill 1966:77, 83). However, although short-season rice had been developed in Southeast Asia by the eleventh century (Ho Ping-Ti 1956-57), double cropping of rice is not mentioned in Java until the fifteenth century (Mills 1970:91), and even then only in the Brantas delta region. None of the Javanese or Balinese inscriptions written before the fifteenth century makes any reference to double cropping of rice. Yields from single annual rice crops were then, as they still were early in the nineteenth century, sufficient not only for subsistence purposes, but also to provide surpluses substantial enough to underwrite both the palaces, with their atten-

dant bureaucracies, and at times very large monumental building projects that stretched over decades.

Diverging approaches to the administration of irrigation

The three regions under discussion provided varying opportunities for state involvement in water management (on this topic, see also Hunt, Wolters in this volume). Farming communities in ninth-century central Java had existed in long-term proximity to an increasingly powerful court, which was underwriting the most substantial and costly monumental building campaign in the island's history, and which was at the same time sufficiently strong by the mid-ninth century to annex its major sister-state in east Java. Both undertakings required the control of substantial rice surpluses. At the same time, there was clear pressure to settle and open landscapes along the major trade routes linking south central Java to the ports of the north coast. In southern Bali, during the late ninth and tenth centuries, not only did farmers live in even closer proximity to their court, but they also encountered greater technical obstacles to irrigation that required high levels of inter-community cooperation, which might have invited state intervention. During the tenth century, the Brantas delta and Solo mouth region of east Java probably provided the greatest opportunity for royal involvement in water management, since in these lowlands pioneering occurred late, with royal encouragement, in areas where rivers were large and difficult to manage, and where there was pressure to produce surplus rice for export.

There were, thus, both opportunities and incentives in all three regions for some sort of state involvement in water management during the ninth and tenth centuries AD. The responses of the Javanese and Balinese states to these opportunities, as reflected in the epigraphic record, reveal a good deal about the political organization of those states.

Inscriptions provide both direct and indirect information concerning early water management in Java and Bali. Most of the surviving Old-Javanese and Old-Balinese language inscriptions are tax charters that record in some detail the economic underpinnings of the communities concerned and the levels and types of tax payments and labour duties extracted by the state. Since, by the ninth century, irrigated rice cultivation provided the largest single source of tax income, one might expect that the tax charters would devote a good deal of attention directly to irrigation. Yet that is not the case. Only a handful of charters mention specific waterworks of any kind, and most of these were apparently constructed for religious, rather than agricultural, reasons. However, although little direct mention is made of water management in the majority of charters, it is alluded to indirectly: in references to officials connected with water and to technicians specializing in water control, in references to minor

taxes connected with irrigated rice agriculture, and to tax breaks designed to encourage communities to expand the area of fields under irrigation.

Water management in early central and east Java

By far the most common reference to water control in Java and Bali is found in lists of officials. In ninth and early tenth century inscriptions from central Java, mention is made of several officials who appear to have had some connection with water: the *hulu air/er* (water official), the *air warangan* (water 'marriage' official), the *matamwak* (dike/balk official), the *air haji* (royal water official), and the *jukut air* ('water-greens' official). Significantly, these were all either community officials or religious officials.

Of these officials, the first three are found listed amongst community officers in charters issued during the ninth and early tenth centuries in central Java. These local officials are the only ones connected with water to be mentioned in charters during this period. Although, after that time, a reorganization of the contents of the inscriptions excluded such lists, there is no reason to doubt that community officials continued to fulfil similar roles until at least the fifteenth century. Community water officials were chosen from amongst the land-holding heads of household belonging to the community council. The most important, and the most frequently mentioned, of these community officials was the *hulu air* (irrigation official). The office was of moderate importance, in the same class as the *hulu wras* (rice official), the *hulu alas* (forest official), the *hulu buru* (hunting official), and the *hulu pkan* (market official). The number of *hulu air* within a single community appears to have depended upon the size of its farming population and the spatial distribution of its fields in relation to water sources. Up to eight *hulu air* have been recorded for a single community, all apparently of equal status (Jurungan 876 AD; Machi Suhadi and Soekarto 1986:2.7.3). The activities of the *hulu air* and the two other community water officials appear to have been undertaken at a very local level, their authority being limited to the community of which they were members. All, with the possible exception of the *air warangan*, appear to have been involved in the practicalities of water control and distribution.

Both the *air haji* and *jukut air*, mentioned in ninth and tenth century inscriptions, were connected more clearly with the state administration. Judging by the epithets attached to their names, however, they were lower-level officials. The *jukut air* is mentioned once, early in the tenth century, in the surviving record (Lintakan 919 AD; Boechari 1986:E 13 a-c), but the *air haji* is mentioned regularly, in inscriptions issued between the ninth and thirteenth centuries, in lists of minor royal tax collectors (*mangilala drabya haji*) who acted as small scale tax farmers. Both of these minor state officials appear, however, to have been religious officials rather than members of the lay administration. The

exact nature of their connection with water is uncertain, but the cult of holy water, which is central to modern Balinese religion, was already in existence in both Java and Bali by the ninth century, and was probably very old indeed on both islands.

Aside from the dam (*dawuhan*), possibly on the Opak River or one of its tributaries that was beneficiary of the Rumwiga charter of 904 AD (Machi Suhadi 1986), no other mention is made, in the surviving central Javanese charters of the ninth and early tenth centuries, of water management.

The situation in east Java was somewhat different. Because of changes made during the tenth century in the contents of charters – enlarging the clauses dealing with commerce at the expense of lists of local officials attending the ceremonies – fewer mentions are found in east Javanese inscriptions of officials connected with water. A small number of charters from east Java, dating to the thirteenth century and later, do however mention an official called the [*pang*] *hulu bañu* (water official) in connection with for instance, the Sarwadharma charter of 1269 AD (Pigeaud 1960, I:101) and the Trailokyapuri charter of the late fifteenth century paying the charges (literally ‘buying’ water) were religious establishments, and the collectors were members of the community from which the religious establishments received their water, these officials appear to have been the successors to the *hulu air* of the ninth and tenth centuries.

None the less, irrigation clearly was a matter of importance to early Javanese state administrations, at least to the extent that much of their tax revenue was derived from the production of rice under irrigation. Encouraging farmers to open wet-rice fields (*sawah*) had the beneficial effect of anchoring the population in place, allowing greater density of settlement, and making subjects easier to count and tax. It also made their harvests both more generous and more predictable. Rulers, in addition, recognized the importance of irrigated rice fields in settling and ‘domesticating’ certain key areas of countryside, where security was important for other reasons.

A number of grants issued during the later ninth and early tenth centuries, both in central and in east Java, were made explicitly in order to encourage conversion of forest and swidden land to wet-rice fields. Grants of this type were made largely on the fringes of settled territories, especially along major road and water connections between the interior and the coast. In central Java, between 872 and 882 AD, a series of at least ten tax grants was made to several temples in the region to the north of Magelang, along the main route to the north coast. In many cases, these grants – made at the behest of local apanage-holders, but given royal sanction – involved dry swidden land (*tgal*) or fallowed swidden land (*sukēt*), which was to be converted to wet-rice fields (Christie 1991:31; Boechari 1986: E5, E6, E7, E9, E10, E15, E18; Machi Suhadi and Soekarto 1986:2.7.1, 2.7.3, 2.7.4, 2.7.6). At the beginning of the tenth century, during a period of expansion and consolidation along the road to the

north, another such grant was issued in respect to forested land on the slopes of mounts Sumbing and Sundoro, for the stated purpose of protecting the high road road (Sarkar 1971:lxix).

During the same period, in east Java, similar grants were issued. The Balin-gawan charter of 891 AD (Sarkar 1971:lvii) concerns a grant made for the conversion of swidden land to wet rice fields along the route between the Malang uplands and the coast, the stated reason being the need to reduce the danger presented to travellers by the swidden fields along the road. Early in the tenth century a grant was made in the delta region, again concerning forest land to be converted into wet-rice fields, because the forest presented a danger to traders and coastal people (Barrett Jones 1984:181).

However, in none of the cases above did the rulers in central or east Java involve themselves directly in the process of land clearance or water control. They merely provided tax incentives for others to do so.

There are a few recorded cases in east Java of royal association, of a sort, with specific water works. These inscriptions fall into two groups. One group comprises a collection of charters from the uplands and mountains around Malang along with one from the Brantas delta region, which span a period from the early ninth century to the mid fourteenth century. The other group includes two charters from the lowland Brantas-delta and Solo-mouth region, both of which were issued during the reign of Airlangga in the eleventh century.

The upland inscriptions all relate to water temples associated with the mountain sources of certain rivers. The series of three linked inscriptions from Hariñjing (Callenfels 1934) concerns a dam (*mula dawuhan*) and channel (*dharmma kali*), both of which were constructed in 804 AD explicitly for religious reasons. The projects were carried out by a religious figure, in connection with his religious foundation, for which a royal tax grant was made. The ownership of the foundation, its associated water systems and lands, and its tax-free benefice status, were to devolve upon the descendants of this religious personage. Since his water works flooded land belonging to others, he provided land in replacement. The two later Hariñjing inscriptions deal with reconfirmations of the original benefice grant. Similarly, a sacred dam foundation (*sang hyang daw[u]hhan*) at Pamwatan was the focus of the Kĕtanan I charter of 904-905 AD (Sedyawati 1994:322).

The Air Kali inscription of 928-929 AD (Boechari 1986:95-7) also concerns a royal tax benefice set up to support a religious foundation, this one on the slopes of Mount Kawi to the west of Malang. It was connected with the offering of holy water (literally Śiva water). The Turuyan inscription that was issued a few months later in 929 AD, to the southeast of Malang, concerns the sacred dam of a water temple that was constructed on a small tributary of the upper Brantas River. The Wulig charter of 935 AD (Brandes 1913:xliv), deals with a grant made by a queen, involving the community councils of Wulig

and five other communities, for the upkeep of three dams (*dawuhan*), built on the slopes of Mount Welirang – apparently on the upper reaches of the River Bangsal – at Kahulunan, at Wuatan Wulas and at Wuatan Tamya. The dams mentioned in the Wulig charter were, like the water works of Hariñjing, connected with a water temple, in this case the Śaivite holy Amrita (Elixir of Life) temple. In all three of these inscriptions of the 920s-930s AD, the primary object of the water control project was religious.

The much later edict of Kusmala (Callenfels 1919) issued in 1350 in the same region, also concerns a Śaivite temple. Like the other mountain temples in the mountains of east Java, this pious construction was modest in size and, like a number of other such temples, it was undertaken by a person other than the ruler, who then approached the ruler to obtain benefice status for the supporting community. The subjects of all of these upland charters were water channels and dams built as part of water temples of the type that was common in the mountains of east Java. None of them relates directly to agricultural irrigation, and none implies direct royal involvement in water management.

Of the two eleventh-century charters from the Brantas delta region, one – the Cane charter issued in 1021 AD (Brandes 1913:lviii) – also relates to a water temple. This temple was already in existence when the ruler Airlangga granted additional tax-relief to the community of Cane. It is interesting to note that the community included pioneering settlements (*babad*).

The other inscription of this group – the benefice charter of Kamalagyan, issued in the delta region by the same king in 1037 AD (Brandes 1913:lx) – concerns the repair of a major dam (*dawuhan*) at Kamalagyan and a related dike (*tambak*) at Waringin Sapta. This document is unique in the surviving corpus of Old Javanese language inscriptions, in that it alone concerns a water control project that involved direct royal action. It is also the only case on record in which the primary purpose of the project was not religious, although the community involved had a connection with a local water temple named the Lake of Dharmma (*ranu ring dharmma*). The circumstances under which the project was carried out appear to have been unusual:

(7) ... The reason [for the the reductions] is that his majesty built the dike at Waringin Sapta on land belonging to residents of the community of Kamalagyan, (8) as an unselfish meritorious act, to improve the well-being of all communities located downstream: Lasun, Paliñjwan, Sijanatyēsan, Pañjiganting, Tālan, Daśapangkah [and] Pangkaja, including the benefices (*sīma*), the *kalang* religious groups, the *kalagyan* religious establishments, the *jumpu* communities, monasteries, religious halls, (9) ancestor temples, spirit sanctuaries [and] hermitages of ascetics, the foremost among those affected being the holy religious foundation at Surapura, called the Abode of Śiva.

These were all of the communities that had suffered from flooding [that washed out their wet-rice field bunds (*carik*), caused by the shift [in the course of] the great river (*bangawan*), [which] had broken through [the dike] at (10) Waringin

Sapta. This caused a shortfall in royal taxes [due to] the disappearance of their banded wet rice fields. Because of the difficulty experienced by the whole [local] populace, who tried repeatedly to [rebuild] the dike against the great river, (11) without meeting with success, his majesty took action by summoning all of the dependent members of the communities with skill in moving earth. His majesty ordered all [of those who were] at his command to undertake, as royal *corvée* duty, the building of [a replacement] dam.

The dam, now successfully completed (12) by his majesty, stands firm, permanently blocking the flow of the water, deflecting the current of that great river to the north. This has eased the minds of the boat-handlers [and] all heads of groups who carry merchandise from [the port of] Hujung Galuh, including (13) ship captains [and] merchants from other lands, all coming to Hujung Galuh.

The residents of the farming communities were all very happy that the floods covering their [area of] wet-rice fields – both current and planned – had been brought to an end through the meritorious (14) damming of the flow of the great river at Waringin Sapta by the king. That is why his majesty's dam was connected with the dike at Waringin Sapta.

At that time, his majesty was concerned that the dam might not be kept strong, (15) because some people might wish to destroy the meritorious structure, or, at the proper time, those who dwell there might neglect to guard it. Therefore [the edict was sent] to Kamalagyan, including its *kalagyan* religious foundation, designating the households in the vicinity of the dam at Waringin Sapta (16) as a benefice (*sīma*) of his majesty's dam, [established] for the maintenance in good order of the sacred dam. At the same time, royal taxes from Kamalagyan were reduced to 10 *suvarṇa* in gold ...

(18) ... The dam was built by his majesty in order to bring about prosperity in the world, and the revival of the well-being of all of the sacred religious foundations ... (19) ... The king ... visibly showers the world with the elixir of life (*amṛta*) ...

It is notable in this case that, although the ruler used his royal *corvée* rights to rebuild the dam, he did so only after the local populace, having failed in their attempt to make repairs, had approached him for aid. Following the rebuilding of the dam, the ruler, worried about provision for the long-term upkeep of the flood-prevention works, placed the dam under the supervision of a local religious establishment, consigning it to the care of designated households in the community closest to the dam, and funding its upkeep through the grant of a religious benefice. The civil engineering construction thus became a religious foundation.

Several points of interest arise from this inscription. The ruler apparently considered the circumstances unusual enough to call for an extended explanation in the text of the charter. The contents of the charter suggest that the ruler's involvement in even major water works was not automatic. Indeed, no reference is made to royal involvement in the building of the original dam. When the dam gave way, causing a regional disaster, the local communities had, in fact, exhausted their own resources before calling upon the king for

aid, suggesting that local solutions to such problems were the norm. However, it is also possible to infer from the text that these communities, although working together in their attempt to remedy the situation, had no local or regional, supra-community institution to organize them. In addition, it appears that, in connection with water works that affected more than one community, there was no institution – at either regional or state level – that could automatically be expected to maintain them. It was for this reason that the care of the dam was placed under the supervision of a religious community, and supported by a religious benefice. The ruler, in fact, presented his work as a religious act.

In sum, the inscriptions from both central and east Java suggest a remarkably low royal profile in respect to the pragmatic aspects of water management. Only one charter in the surviving corpus records direct royal involvement in the construction of a secular water-control project, and this dam was rebuilt in order to maintain the accustomed flow of the river rather than to create new access to water. The dam was subsequently converted into a religious site, joining the list of water temples already patronized by royalty.

Water management in early Bali

The situation in Bali differed from that in Jawa. By the end of the first millennium AD, intensive landscape alterations of the type associated with rice terracing had begun in the southern Bali (Scarborough et al. 2000:80). Mentions of professional irrigation-tunnel engineers (Old Balinese *undagi pangarung*) appear as early as 896 AD (Bebetin AI.II.b.4); Goris 1954:55). Tunnel excavation developed in response to the very dissected nature of the Balinese landscape, in which surface water was often located in ravines at some depth below the level of the adjacent fields. Tunnels allowed the Balinese to tap upstream sources, route the water through the ridges flanking the ravines, and use this water to irrigate slightly lower slopes on the other side. Successful tunnel excavation requires engineering expertise. The Old Balinese-language Bebetin AI inscription treats the tunnel engineer in the same manner as other high-level professional artisans – such as boat builders and stonemasons – who made a living by selling their services. It thus appears that not only were irrigation tunnels already being excavated by the late ninth century, but that there was enough such work available to support a class of professional specialists. Yet this Balinese professional class appears to have been linked neither to the courts nor to the community administrations.

The early Balinese royal courts do appear to have had a hand in some aspects of water management. The Manukaya charter, issued in 962 AD (Goris 1954: no. 205), refers to a royal order to repair a dam that had been damaged by floods. Although the primary purpose of the dam may have been to enclose a sacred bathing place, the present dam at this spot provides irrigation for over

200 hectares of wet-rice fields (Schoenfelder 2000:43). Charters of the eleventh century indicate that the palace did have it within its gift to grant those communities supporting religious foundations certain releases from customary law restrictions, including privileged access to water as in the Tengkulak A charter, issued in 1023 AD (Ardika and Beratha 1998:95):

(VI.a.3) ... The community council is permitted to extend [without fine] the main irrigation channels (*kali*) within their community territory, (4) across all sorts of land, to take water [from a shared source?] in order to fill their channels and weir (*dawuhan*), and to relocate channels supplying rice-fields ...

A few charters mention grants of tax relief upon the extension of community irrigation infrastructure in order to expand wet-rice production, but in these cases the tax involved was a tax on harvested rice rather than one levied directly upon the water or irrigation infrastructure. There is no evidence of the involvement, at this early period, of any class of official equivalent to the later *sedahan* (labour-mobilizing officials), noted in late pre-colonial documents by Schulte Nordholt (1996:58), who appear to have coordinated water allocation and collected *sawah* tax in some areas.

There appear also to have been no major irrigation taxes levied by the early Balinese courts. Two minor levies do appear very occasionally in inscriptions of the eleventh century and later in relation to water: the *pa-er* and the *rotting bañu*. The *pa-er* (water) tax, mentioned in the Banjar Sangguhan A charter of 1072 AD in connection with irrigated rice land in Bañu Rara that was linked to the *kasuwakan* (*subak* grouping; see below) of Rawas (Callenfels 1926:60), appears in connection with a number of other minor taxes levied upon such local enterprises as the snaring of animals. This tax is also mentioned in the Tengkulak A inscription of 1023 AD and the Klungkung A inscription of 1072 AD (Ardika 1994:26). The tax was too minor to provide evidence for any substantial interest of the court in irrigation.

The *rotting bañu* (water purchase compensation) provides even less evidence for major royal involvement in irrigation management. The contents of the Dawan charter of 1053 AD (Ardika and Beratha 1998:134-5) suggest that it was a private payment

(I.b.4) ... It was ordered by the king (*paduka raja*) that wet-rice fields (*sawah*) should be created from land that had formerly been forest in Tabaran. The measurement of the *sawah* to be created (5) was 2 *tembuku*, 74 *galéng*, 12 *pangdingding*, carrying an established royal corvée duty of 62 units in rotation, ... (6) the total [water depth?] being 8 *kilan* (span). This was bought/paid for by the king on behalf of the god *bhatara punta hyang Sinanghala*, to provide paraphernalia for Śaivite ritual, as an indication of the king's devotion. The *sawah* land was to be entrusted to the care of the community council, to be farmed on an annual basis. Each person who farms the *sawah* of the god must make (II.a.1) an annual water-payment (*rotting bañu*) to the representative of the god ...

The water payment made here appears to have been, not a royal tax, but a tenant's payment to a landlord who owned the land through right of purchase. An interesting aspect of this passage is the manner in which the wet-rice fields to be created were measured. The term *tembuku* (Modern Balinese *temuku*) refers to a dividing block for irrigation channels (see Geertz 1980:70); a *galěng* is an irrigation channel wall or dike; and a *pangdingding* is a lift-lock. While the Javanese of the eleventh century were measuring *sawah* land by square measure of area, the Balinese were already calculating the size of *sawah* in terms of the irrigation network and its water capacity.

Similar measurements appear in other inscriptions, most notably in an incomplete Balinese inscription, probably dating to the late-eleventh or twelfth century, that is deposited in the Museum Mpu Tantular in Surabaya (Machi Suhadi and Richadiana Kartakusuma 1996:12-3). This middle plate of a longer inscription bears part of a list of named areas of *sawah* and their measurements:

(XI/7.a.1) [2] *galěng*; in Sisihaji their labour duty (*butajinya*) [is] 11 *galěng* (irrigation channel [units?]) for 4 irrigation channels with lift-locks (*pangdingdingnya* 4 *galěng*); in Tupi their labour-duty [is] 7 *galěng* for [1] irrigation channel with lift-locks; in Manambihan their labour-duty [is] 10 *galěng* for 2 irrigation channels with lift-locks; (2) in Tngulan their labour-duty [is] 6 *galěng* for 2 irrigation channels with lift-locks; in Pindim their labour-duty [is] 6 *galěng* for 2 irrigation channels with lift-locks; in Tiri their labour-duty [is] 4 *galěng* for [1] irrigation channels with lift-locks of the (3) *sunghadi balusangan* type, with 4 *tambuku* (irrigation channel dividing blocks); *subak* in [...]: their labour-duty [is] 8 *galěng* for [1] irrigation channel dike with lift-locks; in Rapuhbis their labour-duty [is] 4 *galěng* for [1] irrigation channel with lift-locks; (4) in Tapabe their labour-duty is [4] *galěng* for [1] irrigation channel with lift-locks; the *subak ligundi* in Kung: their labour-duty [is] 2 *galěng* for [1] fenced irrigation channel (?*tada pangdingdingnya*) with lift-locks of the *sunghadi pada kundangan* type, with irrigation channel dividing block ...

Further types of irrigation channels with lift locks listed in this inscription include: *sunghadi manabe*, *sunghadi [bu]luhan* (upstream) *tngah air tambuku*, *jibulu*, *sunghadi saman air tambuku*, *sunghadi er tambuku*, *sunghadi balubungan*, *sunghadi maranda tambuku*, *sunghadi sada subak*. The list suggests a complex technology involving a variety of named types of water channels, lift-locks and dividing blocks, attuned to a carefully engineered landscape. This charter fragment also makes it clear that *subak* groupings played a role in the irrigation network.

The earliest surviving mentions of irrigation societies (*subak/suwak*), and of *subak* groupings (*kasubakan/kasuwakan*), in Balinese inscriptions appear in the eleventh century. By this time population build-up seems to have precipitated a restructuring both of the physical and of social landscape. The spatial distribution of Balinese irrigation tunnels – which by their nature cross community boundaries – made it impossible for irrigation to be handled at a purely com-

munity level, as seems normally to have been the case in Java. Balinese charters, written either in Old Balinese or in Old Javanese, make no mention of a recognizable community-level official equivalent to the Javanese *hulu air*, or later *hulu bañu*. Instead, by 1022 AD, when the Old-Javanese language Baturan inscription (Goris 1954, I:15-6, II:167-73, 200, no. 352; Soekarto 1986:60) was issued in Bali, an official called *makaser* (Modern Balinese *pakmek*), had begun to appear in connection with the distribution of water:

(V.b.4) ... In addition, (5) the community council of Baturan follows the *makaser* of Air Gajah (modern Goa Gajah), receiving from Pujung Ngaji [water] to a measure of 2 *kilan* (about 40 cm), [with] 10 *kilan* going to Air Gajah, [and] 8 *kilan* going to the *makaser* ...

In this case, it appears that the whole of the community of Baturan was linked to water distribution from Pujung Ngaji, under the direction of an official at Air Gajah.

Later in the same century the court was called upon to settle a dispute, recorded in the Er Rara inscription of 1072 AD (Soekarto 1986:34-5), over the distribution of water:

(I.a.1) ... That was the time of the handing down of the instruction of the youngest son of both the Goddess enshrined at Burwan (2) and the God enshrined at Bañuwka, to measure the wet-ricefields (*huma*) in Kadandan [and?] in Er Rara, in the *kasuwakan* of Rawas. The wet-rice fields were to be remeasured upstream, as of old, so that the measurement will stand (3) permanently. [The remeasured fields were]: in Tal, upstream from Pakudungan; in Poh Raya, upstream from Rapuh; in Tampuyak, upstream from Kaleburan, from Hanunang, [and] from Sabo; in Purut Tung, upstream from Rñu(4)mten; in Siring, upstream from Timbul, from Kurtu [and] from Poh; in Bunut, upstream from Jumpari; in Srihijit, upstream from Punaga; in Parlak, upstream from Burit Tabar; (5) in Parukpuk, upstream from Baru, from Calagi, from Dahyang [and] from Yanaker; in Kling, upstream from Suka Talun [and] from Sitem; in Tasik Tama, upstream from Tingkir; in Nali(6)nti, upstream from Er Bidik; in Kacicang, upstream from Er Kupa; in Juhet, upstream from Dawa; in Jeruk, upstream from Timbul Di(I.b.1)kit; in Galumpang upstream from Galagah; in Poh Dikit, upstream from Ligundi; in Titils, upstream from Samuraga; in Er Těngah upstream from Brigidi. (2) This was the whole number of upstream wet-rice fields in the *kasubakan* of Rawuas.

Fields in at least 27 named hamlets, belonging to 18 different communities, are listed in connection with the *kasuwakan* of Rawas. This *kasuwakan* or *ka-subakan* appears to have been large by comparison to modern Balinese *subak* groupings. Since the modern society includes in its membership all farmers sharing a single water source for irrigation, it crosses community boundaries. The same appears to have been the case in the past.

The charter of Udayapatya, issued in 1181 AD (Soekarto 1986:41-2) refers to 19 separate *kasuwakan* connected with the community:

(III.b.2) ... Not to be subject to [tax?] are the wet-rice fields (*sawah*) in the farming community (*thani*) of Udanapatya: in the *kasuwakan* [of] (3) Padang Aruna, in the *kasuwakan* of Dadap, in the *kasuwakan* of Den Rumah, in the *kasuwakan* of Parumahan, in the *kasuwakan* of Padang(4)ni, in the *kasuwakan* of Teger, in the *kasuwakan* of Air Batu, in the *kasuwakan* of Padang, in the *kasuwakan* of Kampinis, in the *kasuwakan* of Lod (5) Rumah; in the *kasuwakan* of Sak, in the *kasuwakan* of Burwan, in the *kasuwakan* of Pande, in the *kasuwakan* of Sawan, in the *kasuwakan* of Paryya(6)da, in the *kasuwakan* of Ankarpi, in the *kasuwakan* of Tatlu[.], in the *kasuwakan* of Air Malet, in the *kasuwakan* of Dapet. These are the wet-rice fields (IV. a.1) belonging to the council of Udanapatya, in their community territory. At that time the boundaries of the community were established: to the east the ravine (2) of Air Manis; to the south, Kala [...] connected with the community of Alang Batu; to the west, Ra(3)ningan, connected with the community of Sakaran; to the north, Buyung Hyang [and?] Tambang, connected with the community of Kdisan ...

Soekarto locates these *kasuwakan* names across the region stretching from Batur lake in the north to Gianyar in the south. The *kasuwakan* names differ from the communities named in the same document, and it remains unclear just how these *kasuwakan* groupings interlocked with the named communities. However, the number of *kasuwakan* involved suggests a local irrigation network of considerable complexity and more than one water source, used by a community spread over a somewhat awkward landscape.

The early use of the term *makaser* (chief) to designate the *subak* official in charge of allocating water – as in the Baturan charter of 1022 AD (Goris 1954:352.5b5) – rather than the term *klihan*, as at present, might suggest that the holder of the office had rather more power in the past. Otherwise, from the fragmentary evidence available, it appears that the eleventh-century Balinese *kasuwakan*, or *suwak* group, functioned in a manner similar to the modern *subak*. In addition, a strong link between religion and water, still central to Balinese watermanagement administration, is evident from the Balinese inscriptions. The *air haji*, a religious official known from Javanese inscriptions, appears in Bali, but only in Old-Javanese language inscriptions issued after 993 AD. From the contents of these charters, this figure appears to have been a Śaivite priest, as was apparently the *nayaka air* (water chief), who is mentioned at least once in Balinese charters, in Bangli Pura Kehon B, of the early eleventh century (Goris 1954:356.9). The mention made in the Trunyan A1 inscription, issued in 891 AD (Goris 1954:57), of an official called *ser danau*, apparently associated with the holy lake Batur, suggests that the hierarchy of water temples, to which modern *subak* societies are connected (Lansing 1991), may have begun to form as soon as the irrigation networks were established.

The modern Balinese *subak* tradition thus appears to have a historical depth of nearly a millennium. As noted above, it was first mentioned in inscrip-

tions of the eleventh century, apparently during a period of rapid population growth, which put pressure on the more easily accessible water sources. This forced communities into greater levels of cooperation, not only in creating and maintaining irrigation systems, but also in regulating the distribution of water (Schoenfelder 2000:41). The main difference between the situations in early Java and early Bali was the fact that the Balinese needed a supra-village institution to coordinate water sharing. The states appear not to have taken on this role. Instead, the Balinese invented the *subak*.

Conclusion

In neither early Balinese kingdoms nor those of early Java was the state centrally involved in irrigation. The driving factors for the development of irrigation systems appear, both in Java and in Bali, to have come from below rather than from above. In central Java and the uplands of east Java – with relatively under populated landscapes, gentle inclines and easily accessible surface water – farmers were never placed in the position of needing to create institutions to coordinate inter-community irrigation systems. The water used for irrigation by early farmers in these areas appears to have been sourced within areas controlled by their communities. Even in the delta region of east Java, communities seem not to have formed institutions outside of themselves to handle water control. There were never, pace Van Setten van der Meer (1979:42), any *subak* societies formed in early Java (Christie 1992).

However, the link between water and religion is a persistent thread that runs through Javanese and Balinese inscriptions – a link that is particularly noticeable in connection with engineered water works that needed long-term maintenance. The palaces of both islands appear to have linked themselves to water through their connection with the gods and ancestor spirits of the mountains that were the sources both of water and of fertility. But the practical organization of agricultural irrigation was handled, on both islands, at a lower level. It is at this level of pragmatic organization of water management that the differences in the practices of the two islands are clearly evident by the ninth century – differences which become more apparent as population growth and the demands of trade began to place increasing pressure upon the island landscapes by the eleventh century. These differences are still visible today.

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