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4 / The Goddess and the Green Revolution

INTRODUCTION

The village of Sukawati lies between two rivers, the Oos and the Petanu. Between the village and the sea, there is a large block of about five hundred hectares of rice terraces that keeps over a thousand Sukawati farmers busy, wet rice being the world's most labor-intensive crop. On the last little knoll before the beach, where the rice terraces end, there is a magnificent old temple called the Masceti Er Jeruk. I became interested in this temple during my fieldwork in Sukawati in 1975. But while I wanted to learn about the legendary history of the temple, the local farmers were more interested in talking about its current problems. I learned that in the old days the temple had set an irrigation schedule for all the rice terraces in its vicinity. But as a result of a new agricultural policy called the Green Revolution, the temple had lost control of the irrigation schedule, and everyone was planting rice as often as they could, without regard for the temple's irrigation schedules.

The term "Green Revolution" refers to the replacement of native rice with specially bred high-yielding varieties (HYVs), which require the use of chemical fertilizers and pesticides. The Green Revolution began in the laboratories of the International Rice Research Institute in the Philippines in the 1960s, and spread swiftly across Asia, gaining a firm foothold in Indonesia by the early 1970s. In Bali, the Green Revolution was accompanied by new government agricultural policies, which promoted continuous cropping of the new HYV rice in an effort to boost rice production. With a fast-growing population, government planners were eager to find new ways to increase agricultural yields, and farmers were encouraged to plant HYVs as often as possible. But in Bali, the immediate gains in rice yields soon began to be offset by water shortages and unprecedented outbreaks of rice pests and diseases. In Sukawati, the farmers were required to grow HYV rice continuously, which provided an uninterrupted source of food for all the local rice pests.

In 1979, I returned to Bali for two short trips connected with the making of a documentary film. I spent several weeks in Sukawati, and learned that the old temple had managed to regain control of the irrigation schedules. The farmers had decided that the policy of continuous rice cropping had failed to increase harvests, because it made the water supply too unpredictable and led to increasing losses from pests. But policy makers were still pushing the Green Revolution, and there was a political struggle going on between "conservative" farmers who preferred to return to the old

system of irrigation management by temples, and those who wanted to grow rice as often as possible.

In 1983 I returned with my family for a year to study the role of temples like Er Jeruk in the ecology of rice production. It seemed to me that there was an urgent need for a better understanding of how the traditional Balinese system worked, before it was too late. Some rice terraces in Bali are at least a thousand years old, and have produced one or two crops every year, year after year, century after century. In fact, rice terraces are the most ecologically stable and productive agricultural system ever invented, capable of supporting a large population indefinitely. Were modern development planners right to think that the water temples had outlived their usefulness?

We lived in a sort of bungalow in the rice paddies near the village of Kedewatan. The house belonged to the head of a *subak*, or farmer's association, named Wayan. Subaks are associations of farmers who share the water from a single source, like a spring or an irrigation canal. They have both practical and religious functions pertaining to water management and rice cultivation. Wayan's subak encompassed 133 hectares of terraces, owned by about double that number of farmers. The house we rented from Wayan was located not in the village but in the midst of his fields, making it easy to observe both rice-field rituals and farming activities. It was also conveniently located to observe seasonal changes in the insect population of the paddies: my wife's open-air kitchen always had a fair selection. Another good indicator of the pest populations in the rice paddies was the number of bats that turned up at sundown to catch airborne insects.

My research strategy was quite simple: I spent hours with Wayan, trying to observe every detail of what went on in his fields, asking endless questions about what I saw, and following him on his errands connected with both the "practical" and the "religious" aspects of rice production. In the evenings, my wife and I compared my observations with those of several other scholars: a German named Paul Wirz, who published a superb study of Balinese agriculture and the "rice cult" in 1927; the Dutch colonial administrators V. E. Korn, F. A. Lieftrinck, and Charles Grader; the more recent work of an American anthropologist, Clifford Geertz; and a thoughtful critique of Geertz's ideas by an English anthropologist, Mark Hobart. I mention the names of these scholars here because their work was the starting point for my project. The basic issue was the relationship between the practical role of the subak in rice-terrace ecology and the rituals of the "rice cult." As subak head, Wayan had to organize both activities for the members of his subak: the intricate series of rituals of the "rice cult," which were carried out in the fields and local temples; and the actual physical work in the paddies, from field preparation to harvest. Earlier, Clifford Geertz had proposed an elegant model of the relationship between these two tasks, showing that the timing of the ceremonies of the rice cult is "symbolically linked to cultivation in a way that locks the pace of that cultivation into a firm, explicit rhythm." The "water-opening ceremony," for example, actually marks the beginning of the irrigation schedule, just as the harvest ceremonies mark its end. The rituals of the rice cult thus provide a way for the farmers to time the flow of water and the phases of agricultural labor. In Bali, Geertz wrote, "a complex ecological order was both reflected in and shaped by an equally complex ritual order, which at once grew out of it and was imposed upon it."⁴⁹

But another anthropologist, Mark Hobart, found that the actual sequence of rituals is often badly synchronized with what is happening in the fields. He criticized Geertz for creating an idealized picture of the match between rituals and rice growth, and suggested that the real picture was far more complex.

Fortunately for me, the subak head I was working with became quite interested in this controversy. Wayan had already served as subak head for twenty-odd years, and was very knowledgeable about the workings of the subaks in his area. While he saw Geertz's point, he also believed that subak rituals served more important purposes than timekeeping. Wayan was also curious about the reasons for differences in the ritual cycles between subaks in different regions of Bali. We both suspected that they might be related to variations in ecological conditions. Wayan willingly agreed to visit other subaks with me, so we could compare the details of their ritual cycles with his. These journeys took us to many subaks and water temples, but the real turning point in the research came when I accompanied Wayan and a small delegation of farmers up to the Temple of the Crater Lake for an annual temple festival that draws together more than two hundred subaks.

I am going to begin the water temple story there, at the Temple of the Crater Lake, rather than with my first journeys with Wayan. It took quite a long time to make sense of the water temple system, and we don't have time here to retrace the whole story. Instead, by skipping ahead to the Temple and the Goddess of the Lake, we can begin this chapter in a more Balinese way, at the center of yet another "cosmological map."

THE GODDESS OF THE LAKE AND HER TEMPLE

From anywhere in central Bali, a farmer need only glance up to the clouds around Mount Batur to be reminded of the ultimate origin of the water flowing into his fields. In the crater of the volcano, at an elevation well above the height at which rice may be grown, there is an immense fresh-water lake, stretching over 4,240 acres.⁵⁰ The lake is regarded by the farmers and temple priests as the ultimate source of water for the rivers and springs that provide irrigation water for the whole of central Bali. Priests describe the mountain lake as a sacred mandala, or cosmic map of waters, fed by springs lying at each of the wind directions, high above the irrigated lands. The steam from the caldera of Mount Batur represents the zenith of the mandala, while the nadir is found in the depths of the lake. Each of the springs around the lake is regarded as the origin of waters for a particular hydrological region of central Bali.

The entire mandala of the lake forms the center of a much larger mandala, consisting of the island of Bali and the seas that surround it. Priests sometimes speak of the lake as a freshwater ocean, filled with life-giving water, which contrasts with the salt ocean that encircles it, far below. The lake is the home of one of the two supreme deities of Bali, the "Goddess of the Lake," Dewi Danu. Her relationship to the farmers of central Bali is succinctly defined in a manuscript kept in her temple:

"... because the Goddess makes the waters flow, those who do not follow her laws may not possess her rice terraces."⁵¹

According to legend, the goddess and her male counterpart, the God of Mount Agung, emerged from an erupting volcano in the year 231 (on our calendar). Together with other, lesser gods, they took possession of the land and waters of Bali. The goddess rules the lake and Mount Batur, the second-highest peak in Bali, while the god rules Mount Agung. As the male and female deities of the two highest mountains, they form a complementary pair, the supreme gods of the island. The male god of Mount Agung is worshipped at the temple of Besakih, high on Mount Agung, and is symbolically associated with the king of Klungkung, who claims supremacy over all other Balinese kings. But the Goddess of the Lake has no special relationship to any king or kingdom. Her principal congregation consists of several hundred subaks, which make annual pilgrimages to her mountain-top temple called Pura Ulun Danu Batur, the Temple of the Crater Lake.

When I began my research, the Temple of the Crater Lake's relationship to the subaks was not described in the literature on Balinese religion or water management. Yet the importance of the temple for the farmers can be detected in some of the earliest descriptions of Bali by foreign visitors. For example, in 1830 a missionary traveler was sent to Bali by the Singapore Christian Union to explore the prospects for "extending the benefits of Education and the knowledge of Christianity" to the Balinese. At that time, very little was known about Balinese culture. The missionary's report begins with a brief list of the principal Balinese courts, after which he turns his attention to the "riches of Bali":

Bali has several inland lakes or reservoirs of water situated near the tops of high mountains, several thousand feet above the level of the sea. These lakes all contain fresh water, whose rise and fall corresponds to the sea. Their depths are great, but irregular: in some parts bottom has been found at forty or fifty fathoms and in other parts it is said no bottom can be got at the depth of several hundred fathoms. Some of them are long, and others round, the largest about four miles across, and twelve in circumference; at any rate, they contain water enough to irrigate the inhabited parts of the island with little trouble and expense; and however much water is taken from them, they never seem to decrease. These lakes form the riches of Bali; in a country where there are no great rivers, and where the inhabitants have to depend for subsistence entirely on the irrigation of their rice fields, these lakes are indispensable, and without them it appears evident that so great a population could not be maintained. The scarcity of waters elsewhere is so great, and all the rivers so insignificant, that persons traveling in the dry season are obliged to carry water with them, but by means of these lakes the diligent husbandman is enabled to obtain water enough for all his wants, and consequently two crops of rice are taken annually . . . ⁵²

Interestingly, the missionary got his facts wrong, but in such a way as to confirm the myth. The lakes do not have tides, of course, nor do they have river outlets. But in temple rituals the crater lake is described as an ocean, a metaphysical idea that the missionary evidently took literally. It is also part of the mythology of the temple that the lakes are connected to the rivers by underground tunnels. The water in the lakes is thought to pour out continuously through these tunnels, yet "however much water is taken from them, they never seem to decrease." This belief in underground tunnels from the crater lakes as the source of irrigation waters was also mentioned in a report by a Dutch colonial officer in 1887:

There are temples by the shore of every lake in Bali, for it is believed that the streams are fed from the lakes by underground tributaries. Yearly pilgrimages must be made to these sanctuaries . . .⁵³

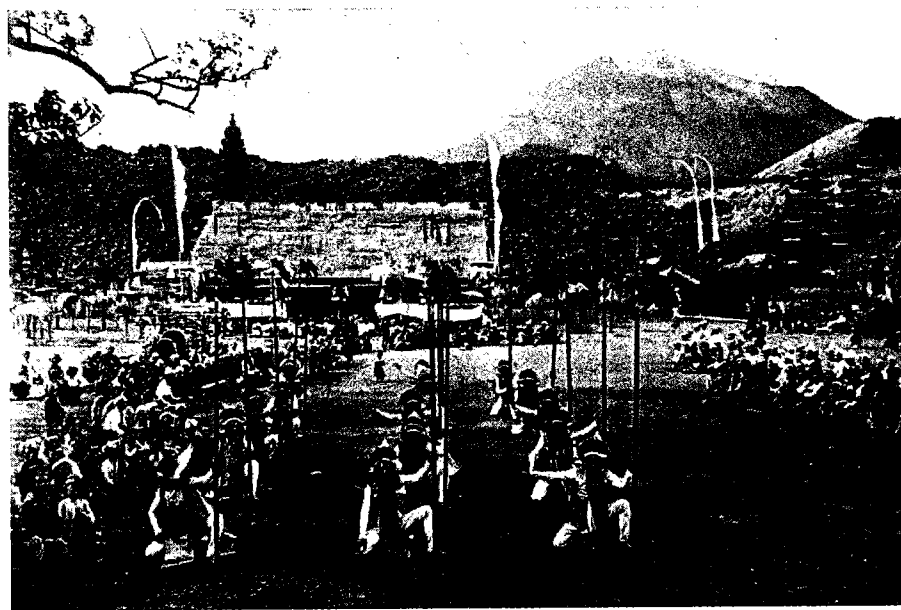
At the time of my fieldwork, a hundred years later, these yearly pilgrimages continued, as thousands of farmers brought offerings to the Goddess of the Lake in appreciation for her gift of water.

The temple used to be located down in the crater, between the still-active caldera and the lake. A volcanic eruption brought a towering river of lava to within a few feet of the temple's gate, as can be seen in a photograph taken a few years later. A Dutch architect who visited the temple in 1918 was amazed, writing that

The fame of holiness, coming from this temple, has risen after the last eruption of Batoer in 1905 even more by the miraculous way by which it was then saved from total destruction. The glowing lava stream was stopped just at the main entrance in an inexplicable way!⁵⁴

But in August 1926, the old temple was not so lucky. The Dutch officer in charge of the district reported what happened:

On the third of August 1926, at 1 A.M., Mount Batur began to erupt. Along the north-western slope a long crevice appeared with a lot of noise and thunder, from which fires and many lava fountains spewed forth. I was informed of this and went to Kintamani, and descended to the village of Batur. It was impossible to get an overview of the situation: the inhabitants were not worried, and trusted in the power and will of the gods, and in the temple which already once before had stopped the lava-stream. From above you



Baris Gde (warrior) dancers in front of the Temple of the Crater Lake (Pura Ulun Danu Batur) before the 1917 earthquake. Note the wall of lava that stopped just outside the gate. Archives of the KITLV, Leiden.

could see that the lava-stream was not moving towards the village. However, it seemed to me that the continuous eruptions would eventually fill the hollow in which the village was nestled. In the afternoon of the first day a new source of lava came into being at about 1,200 meters distance from the village. With the sound of a diesel engine, it regularly emitted large waves of blood-red glowing lava. A lava stream started to move towards the village . . .⁵⁵

The village and the temple were quickly abandoned, as the inhabitants raced for safety. A new temple was soon constructed on the rim of the crater, looking down on the great lake and the still-active caldera.

I first visited the temple in the company of Wayan and half a dozen farmers from his subak, in February 1984. We arrived in two small trucks and unloaded the subak's offerings: a live pig, half a truckload of coconuts, some live chickens, and many baskets of unhulled rice. These were hauled away to pens and storerooms behind the kitchens, while we were given a meal. I learned that unlike other Balinese temples, the Temple of the Crater Lake is always manned by a small staff of priests and elders, who are always available to welcome visitors (usually subaks experiencing problems with water shortages or rice pests). A few days later, I returned to the temple with a much larger delegation consisting of about forty people from Wayan's subak. They brought their own individual offerings to the goddess, which they placed before the altars in the inner sanctum of the temple. Priests guided them in prayers, sprinkled everyone with holy water from the lake, and presented the leaders of the subak with a bamboo tube filled with holy water. This water was taken home to the subak's main temple, there to be mixed with more holy water and distributed to every family to sprinkle on their fields. Meanwhile, the temple's ancient Great Orchestra (*Gong Gde*) played as dozens more subaks arrived. After making their offerings and receiving their holy water, most subaks exited via the kitchens, where all the farmers were given a cooked meal by the temple staff. The ingredients for these meals came from the temple's storerooms, from offerings like those Wayan's subak had brought up a few weeks earlier. With an active congregation of more than two hundred subaks, the temple is able to feed thousands of people during major festivals.

The Temple of the Crater Lake was clearly key to understanding the water temple system, and in the past ten years I have spent many months at the temple or on journeys with its priests. My vantage point on the subaks gradually shifted from my wife's kitchen overlooking Wayan's fields to the kitchens adjoining the temple's storerooms. This proved to be an ideal place to learn about how subaks handle problems or disputes. The temple kitchens are continuously manned on a regular schedule by teams of priests and elders. When a subak delegation arrives, they are first led into the kitchens, where they are offered food and drink, and given a chance to describe the reason for their visit to the temple. I could listen in, ask questions, and try to follow up the most interesting cases, often with the help of temple priests.

There are twenty-four permanent priests of the temple, who are chosen in childhood as lifelong servants of the goddess. This priesthood is organized in a hierarchy, and at its summit there is a single high priest who is believed to be the earthly representative of the Goddess of the Lake. This priest is called the *Jero Gde*. He is also known as *Sanglingan*, "Lightning-struck," because he is selected in childhood by a virgin priestess⁵⁶ of the temple, after the death of his predecessor. On these occasions, the priestess goes into trance to allow the Goddess of the Lake to possess her

voice and describe the boy whom she has chosen to become the new Jero Gde. From the moment of his selection until the day of his death, the Jero Gde is regarded as the earthly representative of the Goddess of the Lake. By day he offers sacrifices to her on behalf of the hundreds of subaks that make up the temple's principal congregation. By night, he may receive guidance from her in dreams. He is always dressed in white, the color of purity, and wears his hair long. Although he is of commoner caste, his permanent identification with the Goddess of the Lake sets him apart from all other Balinese priests.

It is true that other priests are sometimes believed to be possessed by a deity. For example, at the climax of the ritual for creating holy water, Brahmana high priests⁵⁷ are thought to incarnate the god Siwa. Similarly, trance mediums (*balian*) are regularly "possessed" by unseen spirits. But in these cases, when the ritual or trance is finished, the link between priests and deities is broken. In contrast, the magical identification of the Jero Gde with the Goddess of the Lake continues for his lifetime. In the case of the current Jero Gde, it is said that signs of his special relationship with the goddess were detected even before he was chosen. As he explained to me:

"... Before I was chosen, I had a feeling—a strangeness in myself. I mean, often when I went home, I was given a name alluding to the presence of a god."

Once, I asked him what it was like for an eleven-year-old boy to suddenly take on the responsibilities of a Jero Gde. His answer stressed the guiding role of the goddess:

"... the Deity chose me through the trance of the Virgin Priestess. Then I immediately went through the ceremonies of 'installation'—I was purified, to become the Jero Gde. At that time I was still eleven years old... But because I was selected by an imperial Deity (Ida Sasuunan), there were no problems. I simply went along, just as I do now. I had become the Jero Gde, even if I was still a child."

While ordinary Balinese priests are not identified in this way with deities, kings are. According to Balinese religious belief, the Goddess of the Lake and the God of Mount Agung share dominion over the island, a concept that is taken literally by the inhabitants of the mountains, who point to the side of the lake where the power of the goddess stops and the dominion of the god begins. In the time before the Dutch, when Bali was ruled by kings, the king of Bali was symbolically identified with the male God of Mount Agung and Besakih temple. But while the powers of the king of Bali derived from his descent, those of the Jero Gde originate in the logic of the water temple system. Unlike the king, who claimed symbolic dominion over the whole of Bali, the authority of the Jero Gde is strictly limited. As the living representative of the Goddess of the Lake, his powers extend to the Temple of the Crater Lake and the waters believed to originate from the lake. Essentially, he is a temple priest, but his relationship to the Goddess of the Lake gives him a special authority over irrigation water. As he himself remarked,

"... it is only the Goddess of the Lake who can properly give water. She already embodies, incarnates water, which she gives to her subaks, from the lake..."

But did the symbolic identification of the Jero Gde with his goddess endow him with real control over water rights? Or was his position purely symbolic? One afternoon I put this question to a subak head. This was his response:

SUBAK HEAD: It's like this. Everything that concerns the subaks is interconnected. The word is *anugraha* ("grant" or "gift"). So that—as with the fifteen subaks located at our Masceti temple—the flow from the spring has been calculated. It produces enough for so many hectares. Now if, for example, there was a request for more water, obviously the Jero Gde must lower his hand, give a decision. So it won't happen that those who have received the "grant"—from the Masceti temple and the Batur temple—don't get enough water. Because they have the right, from earlier times. Because these things are usually written in the records at the Temple of the Crater Lake.

This answer appeared to affirm the authority of the Jero Gde over the allocation of water rights. But I wondered whether the priest merely gave his blessing to whatever decision had been taken by the farmers. Had he ever refused a request for irrigation water?

SUBAK HEAD: Earlier, there was a request to open new terraces here—a request that went straight to the Temple of the Crater Lake. But, well, maybe because the Jero Gde was concerned about the people of my village, anyway he didn't give permission. If he had, there would have been a lot of twists and turns! So it was dropped. Up till now, it hasn't happened. The water can't be taken.

We, too, once had a desire to open new lands, convert some dry fields to rice terraces. We asked permission from the Temple of the Crater Lake, so that our water would be sufficient for the new terraces. But the Jero Gde declined.

LANSING: Where . . . ?

SUBAK HEAD: Just upstream from the Bayad weir, we wanted to use that water. There is a spring there; we wanted to use it. We weren't going to build a new weir on the river, just use that spring. But if we did, the Bayad weir would have been affected (i.e., there would be a reduction in the flow reaching the Bayad weir). So we had to abandon the idea.

LANSING: Where does the authority of the Jero Gde come from?

SUBAK HEAD: Belief . . . overflowing belief. Concerning Batur temple—really that is the center, the origin of waters, you see. At this moment, the Jero Gde holds all this in his hands. At the Temple of Lake Batur.

This answer was in accord with the image of the role of the Jero Gde and the mandala of waters described by the temple priests. Evidently, the subaks acknowledged the right of the Jero Gde to decide upon water allocations, in the name of the goddess. But to truly resolve the question of the extent of the temple's authority over water rights, I sought out cases that involved real disputes. I soon found a good one: a case in which a subak tore apart the dam belonging to their upstream neighbors.

A QUARREL BETWEEN SUBAKS

The village of Pengalu lies at high elevation, and began growing rice on irrigated terraces only ten years ago. Formerly they relied on rainfall to grow dry rice and vegetable crops. In 1986, the village sent a messenger to urgently request a visit from the Jero Gde. In response, the Jero Gde sent a temple messenger to inquire into the case. I spoke to the messenger, who described the problem as follows:

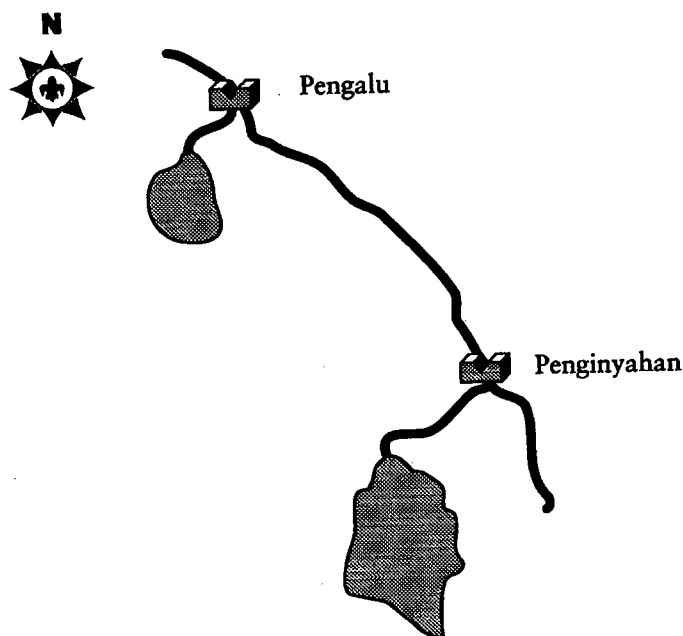


Figure 12 The amount of water available to Penginyahan is strongly affected by the release flow from Pengalu.

TEMPLE MESSENGER: It had to do with water. The source was a little to the north of the village of Pengalu, to the northwest. The water was taken by Pengalu, and brought down. Earlier, there was enough. But now, in the dry season, there wasn't enough for Penginyahan (the village immediately downstream from Pengalu). So this became a problem. The water for Pengalu—the new subak—was taken back by Penginyahan.

On the appointed date, I drove to the village with the Jero Gde and a delegation from the temple. By observing what he said and did, I hoped to be able to gauge the extent of his real powers over irrigation. We were accompanied by two temple messengers who are responsible for this region of central Bali, and two of the regular priests of the Temple of the Crater Lake.

When we arrived at the village of Pengalu, the entire subak was seated in their village meeting hall, awaiting our arrival. We were led to seats on an elevated platform, where four village leaders joined us facing the subak. I requested permission to tape the meeting, and the Jero Gde nodded his acknowledgment. Rather nervously, the village leaders agreed. After brief welcoming remarks, the head of the subak explained the problem:

SUBAK HEAD: . . . so we built a weir on the Telaga Genteg stream. The weir was built by the whole community. The idea was to raise the waters to irrigate terraces for the hamlets of Kerta and Mawang. . . . A little while ago, if I'm not mistaken, on the 21st and 22nd of January, our subak was demolished by subak Penginyahan. Why the people of Penginyahan

wrecked our weir,⁵⁸ we don't know. So since the 22nd of January, 1986, we of subak Pengalu haven't had water. No water at all enters subak Pengalu. There were about two hundred people from Penginyahan, led by the heads of their subak and village. The government—the police, *kabupaten* and *kecamatan*⁵⁹—have taken this in hand, but nothing has been done. So that you may know, Jero Gde, that this is how things are for subak Pengalu. Our subak is ten years old, we have harvested rice for ten years, and we have joined the congregation of the Temple of Batur. Now Penginyahan has engaged in destruction. So subak Pengalu up to now hasn't planted rice. Our fields are empty. . . .

JERO GDE: In these things, if we find a path the way we do in Bali, there is only one (way), which is the direction upstream, to the origins. Isn't it so? Who is the owner of these waters? In truth, when matters develop into a big confrontation, everyone's wishes are bad, then everything turns bad. And the effect is, the water is not used. Water that is needed. So it is. So this new problem, first I must take it up to the regent (*bupati*). Such things, every aspect must be taken up or they can't be concluded. Now apparently this forest area is only producing about a hundred liters of water, right?⁶⁰ If things don't work out, that water is definitely wasted. Lost, useless. My concern is, I don't promise, but let us together make strenuous efforts, force things into the very best path, then perhaps we can obtain the opportunity to fix this situation of ours, our dam at Pengalu. May the village easily receive this path, which is my decree, so that the path you've begun with the *bupati* can be followed to the end. Together!

After these remarks, the Jero Gde asked to visit the site of the damaged weir. The entire structure had been washed away, and the river was flowing freely in the direction of Penginyahan, a few kilometers downstream. After looking the situation over, the Jero Gde asked the subak to gather around him, and addressed them:

JERO GDE: I am ready to add to my former words. As I asked earlier, who owns these waters? Clearly it is only the Deities who prevent this spring from drying up, is it not so? What about downstream? Now you of Pengalu already have the right to use some of this water. And for those below (i.e., the Penginyahan irrigation system) there was no shortage, formerly? For Pengalu here, just how many hectares were in use before the dam was destroyed?

SUBAK HEAD: About thirty hectares.

JERO GDE: So now, my wishes are, remember the Goddess! Things are not good now, so the medicine must be applied quickly. As for me, I feel very sad. Together, then, let's begin.

THE COSMOLOGICAL ROLE OF WATER TEMPLES

The Temple of the Crater Lake sits high on the rim of the crater above Lake Batur. Symbolically, it is situated at the center of a mandala, or cosmic map, that encompasses the whole of the island of Bali. This cosmological map has a meaningful structure, based on the idea that the Goddess of the Lake brings life to the fields and villages by causing the rivers and springs to flow down the sides of the volcano. Wherever a group of farmers divert some of the waters of the goddess into their fields, they construct a temple or a shrine where they can show their gratitude with prayers and offerings. The larger temples also provide a place for farmers to meet and talk over practical problems, such as irrigation schedules. However, the practical

role of the water temples in ecosystem management makes sense only in the context of their "cosmological" meaning.

Each of the hundreds of small-scale irrigation systems along Balinese rivers begins with a spring or, more often, a weir (diversionary dam) in a river, which diverts all or part of the flow into an irrigation canal. Beside each weir or spring there is always a small shrine or temple, where the farmers who benefit from this particular flow of water can make offerings to the Goddess of the Lake and the "Deity of the Weir" (*Bhatara Empelan*), who are thought to make the waters flow into the canal.

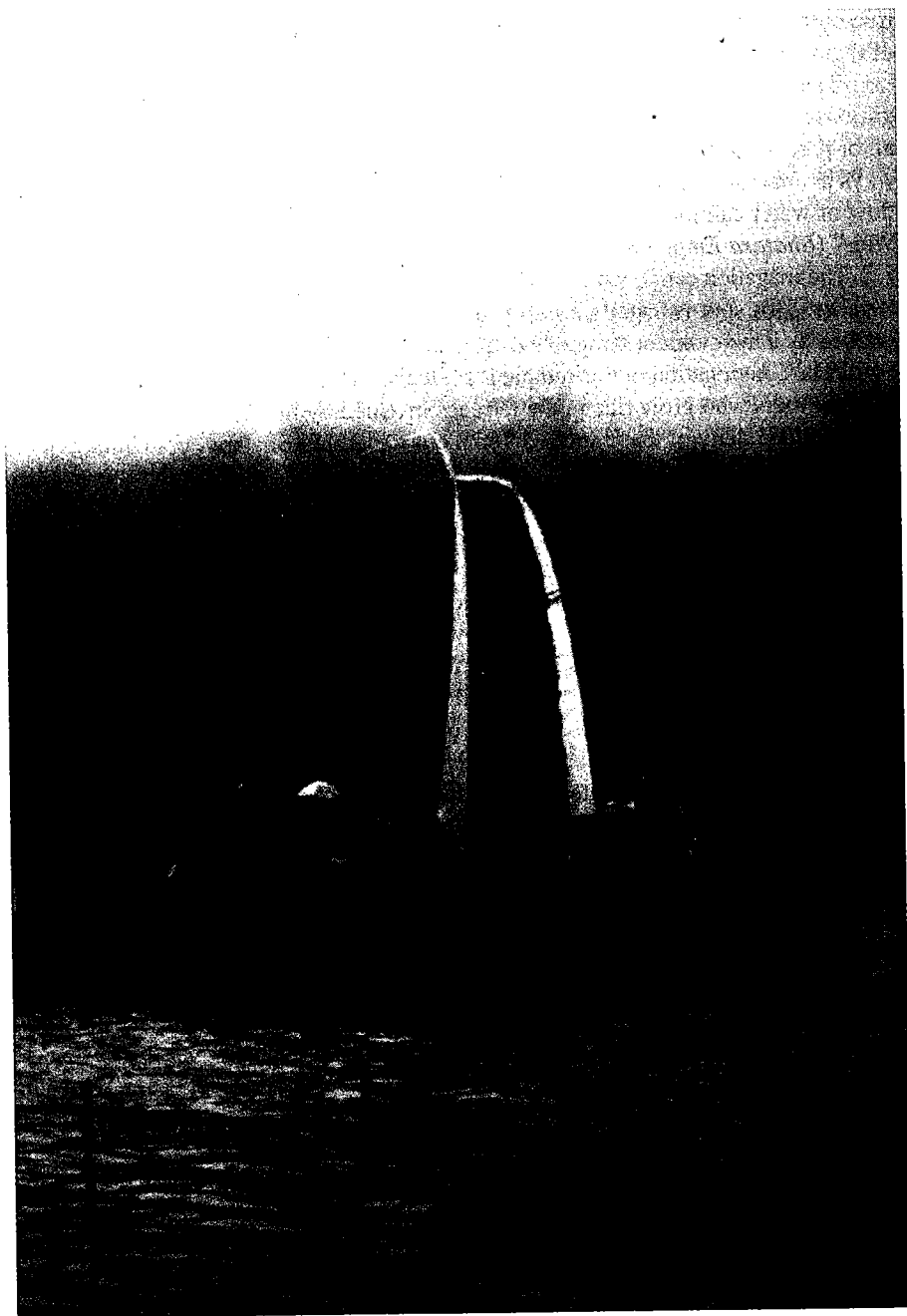
The irrigation canal, which takes off from the weir, eventually reaches a block of terraces. This spot is usually a kilometer or more downstream from the weir and is marked by a major water temple, the "Head of the Rice Terraces Temple" (Pura Ulun Swi). The congregation of this temple is the same as that of the weir shrine: it consists of all farmers who grow rice in the terraces irrigated by this particular canal system. The principal deity of the Ulun Swi Temple is called *Ida Bhatara Pura Ulun Swi*, the "Deity of the Ulun Swi Temple," whose influence extends to all of the terraces watered by the canal. The temple itself is simply a walled courtyard containing a shrine where farmers can make offerings to this deity. Additional shrines provide a place for offerings to other gods and goddesses such as the Deity of the Weir and the Goddess of the Temple of the Crater Lake. These offerings at the Ulun Swi temple acknowledge the dependency of farmers on the flow of waters into their terraces, which in turn depends upon the flow at the weir, and ultimately upon the flow in the river.

Other water temples and shrines follow a similar logic. All water temples are physically located at the upstream edge of whatever water system they purport to control. Chains of water temples articulate the hydro-logic of each irrigation system. Temples and shrines are situated in such a way as to exert influence over each of the major physical components of the terrace ecosystems, including lakes, springs, rivers, weirs, major canals, blocks of irrigated terraces, subaks, and individual fields. The temples link these physical features of the landscape to social units according to a simple logic of production: the congregation of each temple consists of the farmers who obtain water from the irrigation component "controlled" by the temple's god.

Looking at the system from the bottom up, each farmer has a small shrine (*bedugul*) located at the spot where irrigation water first enters his fields. This "upstream" corner of his fields is considered sacred; it is here that he makes offerings to the Rice Goddess incarnate in his crop. At harvest time, the rice that grows closest to the water inlet is used to create a sacred image of the Rice Goddess herself, which is not eaten but carried to the rice barn and given offerings.

Upstream from the farmer's field shrine, the next water temple is usually the subak temple, representing a block of irrigated terraces with a common water source. Several subaks make up the congregation of an Ulun Swi temple, associated with a large canal, and a weir or spring shrine. Several weirs' subaks typically form the congregation of a *Masceti*, a regional water temple. Finally, each spring, lake, and the headwaters of each river have shrines or temples. The largest water temple is farthest upstream: the Temple of the Crater Lake, associated with Lake Batur, which is considered to be the source of all irrigation waters within its river boundaries.⁶¹

There are also important temples located at the downstream terminus of irrigation systems, which are classified as *Masceti* regional water temples. Upstream and



A water temple located in Lake Bratan

downstream temples have very different functions, associated with two different symbolic properties of water. Upstream water is associated with the nourishing or life-giving effects of water, and is regarded as a gift from the Goddess of the Lake. In contrast, downstream water is cleansing water: water used to purify, to wash away pollution. It is not collected in sacred vessels, like upstream water, but left running in the rivers. Impurities such as the ashes from sacrifices are thrown directly into the rivers, which bear them to the sea. This is the basis of a powerful symbolic contrast: while the waters high above in the crater lake represent the mystery of water as life-giver, the waters of the sea are associated with the equally potent mysteries of dissolution and regeneration. "Downstream" *masceti* temples are located at the downstream edge of the last block of rice terraces irrigated by major rivers, along the sea coast. By the time they reach the sea, the rivers are considered to be brimming with impurities: the ashes of burnt sacrifices, the discharge from villages and fields. The sea dissolves them all, removing their human content as impurities, and returning them to a wild, elemental, natural state.

ECOLOGY OF THE RICE TERRACES

But what is the relationship between the symbolic logic of water temple rituals and the actual practical ecology of the rice terraces? To answer this question, we need to understand something about the ecology of rice paddies.

There is no question that the rice terraces of Bali are quite ancient. One of the earliest known writings in the Balinese language, a royal edict from the eighth century A.D., refers not only to rice harvests but to irrigation-tunnel builders.⁶² The oldest human settlements in Bali are concentrated in the best rice-growing areas, where it appears that some terraces have been under continuous cultivation for a millennium or more. Traditional rice paddies are unique in that they are able to produce large amounts of grain indefinitely, with no diminution in yields. By contrast, all other systems of irrigated agriculture are subject to a gradual decline in productivity as a consequence of salinization and loss of soil fertility.

As we have seen, most Balinese irrigation systems begin at a weir (diversionary dam) across a river, which diverts part of the flow into a tunnel. The tunnel may emerge as much as a kilometer or more downstream, at a lower elevation, where the water is routed through a system of canals and aqueducts to the summit of a terraced hillside. In the regions where rice cultivation is oldest in Bali, irrigation systems can be extraordinarily complex, with a maze of tunnels and canals shunting water through blocks of rice terraces. Since the volume of water in the rivers during the wet season can be ten times greater than the dry-season flow, the irrigation system has to cope with conditions ranging from a trickle to flash floods. Irrigation systems originating at different weirs are often interconnected, so that unused water from the tail end of one irrigation system may be shunted into a different block of terraces, or returned to a neighboring stream.

To appreciate the level of precision required for the system to work, it is necessary to understand something about the basic dynamics of the paddy ecosystem. In essence, the flow of water—the planned alternation of wet and dry phases—governs

the basic biochemical processes of the terrace ecosystem. There is a general theory in ecology that holds that ecosystems characterized by steady, unchanging nutrient flows tend to be less productive than systems in which there are nutrient cycles or "pulses."⁶³ Rice paddies are an excellent example of this principle. Controlled changes in water levels create "pulses" in several important biochemical cycles. The cycle of wet and dry phases alters soil pH; induces a cycle of aerobic and anaerobic conditions in the soil, which determines the activity of microorganisms; circulates mineral nutrients; fosters the growth of nitrogen-fixing algae; excludes weeds; stabilizes soil temperature; and, over the long term, governs the formation of a plough pan that prevents nutrients from being leached into the sub-soil. Potassium, for example, is needed for the growth of the rice and depends largely on drainage. Phosphorus is also essential. It is slowly leached from the volcanic rock and transported by the rivers and irrigation canals. For this reason, phosphorus levels may be increased more than tenfold by regularly flooding the fields.⁶⁴

The main crop produced is of course rice. But in addition, the paddy also produces important sources of animal protein such as eels, frogs, and fish. Even the dragonflies that gather over the rice to hunt insects are themselves hunted by little boys, who roast and eat them. Most paddies support a large population of ducks, which must also be carefully managed since they will damage young rice plants if left untended. After each harvest, flocks of ducks are driven from field to field, gleaning leftover grain and also eating some of the insects, like brown planthoppers, which would otherwise attack the next rice crop. Traditional harvesting techniques remove only the seed-bearing tassel, leaving the rest of the stalk to decompose in the water, returning most of its nutrients to the system. Depending upon the danger from



Rice terraces

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rice pests, after harvesting, the farmer may decide to dry the field and burn the stalks, thus killing most pests but losing some of the nutrients in the harvested plants. Alternatively, he may flood the field and allow the rice stalks to slowly decompose under water.

As a method of pest control, the effectiveness of drying or flooding the fields depends on cooperation among all of the farmers in a given block of terraces. It would be useless for a single farmer to try to reduce the pests on his own field without coordinating with his neighbors, since the pests would simply migrate from field to field. But if all of the fields in a large area are burned or flooded, pest populations can be sharply reduced. Both kinds of fallow periods—burnt fields or flooded—are effective techniques for reducing the population of rice pests, but both depend on synchronizing the harvest and subsequent fallow period over a sufficiently large area. How many hectares must be left fallow, and for how long, depends on the species characteristics of the rice pests. Major pests include rodents, insects, and bacterial and viral diseases.

Just as individual farmers manage their paddies by controlling the flow of water, so larger social groups control pest cycles by means of synchronized irrigation schedules. The role of water in the microecology of the paddy—creating resource pulses—is duplicated on a larger scale by irrigation cycles that control pest populations by flooding or draining large blocks of terraces.

A good example of the practical role of water temples is provided by the largest water temple in my old village of Sukawati, the masceti temple Er Jeruk. Here the role of the temple is described by the head of the village, who is also a farmer:

VILLAGE HEAD: The Pura Er Jeruk is the largest temple hereabouts, that is, the temple whose congregation includes all the farmers of the village of Sukawati. Now below this temple there are also smaller temples, which are special places of worship for the subaks—each subak has its own. There are fourteen of these temples, fourteen subaks, all of which meet together as one here. They meet at the Temple Er Jeruk. Every decision, every rule concerning planting seasons and so forth, is always discussed here. Then, after the meeting here, decisions are carried down to each subak. The subaks each call all their members together: "In accord with the meetings we held at the Temple Er Jeruk, we must fix our planting dates, beginning on day one through day ten." For example, first subak Sango plants, then subak Somi, beginning from day ten through day twenty. Thus it is arranged, in accordance with water and "Padewasan"—that is, the best times to plant. Because here time controls everything. If there are many rodents and we go ahead and plant rice, obviously we'll get a miserable harvest. So we organize things like this: when the rodent population is large, we see to it that we don't plant things they can eat, so that they will all die—I mean, actually, that their numbers will be greatly reduced, pretty quickly . . .

LANSING: Is there a fixed schedule of meetings?

VILLAGE HEAD: Once a year. Each new planting season, there is a meeting. If the planting schedule is not to be changed, there is no meeting. Of course, the ceremonies held here go on regardless; there are two temple festivals here, a one-day festival every six months, and a three-day festival every year . . . This place is the home of the spirits of those who have preceded us, who built this temple. I would call this temple the fortress of the farmers hereabouts.

All three groups plant rice at least once a year, in the rainy season. During the dry season, there is a rotational system. One group is guaranteed water for a second planting of rice, and one group plants a vegetable crop, receiving water once every five days. The third group will plant either rice or vegetables, depending on whether the amount of irrigation water is judged adequate for rice. By setting the cropping pattern and irrigation schedule, the *masceti* temple attempts to optimize water sharing, while establishing a widespread fallow period, so as to reduce pest infestations.

ECOLOGICAL CRISIS: THE GREEN REVOLUTION

In the mid-1970s, the advent of the Green Revolution in Bali put an end to the practical role of temples like Er Jeruk in the creation of cropping patterns. To the extent that planners took any notice at all of water temples, they were inclined to dismiss them as religious institutions that had no constructive role to play in the campaign to boost rice production. The result was an ecological crisis. To understand what happened, we need a brief overview of the Green Revolution in Bali.

The Green Revolution began in Asia at the International Rice Research Institute (IRRI) in the Philippines. In 1962, IRRI agronomists developed a new high-yielding variety of rice called IR-8, which matured in 125 days and produced 5,800 pounds of grain per acre on test plots. In the late 1960s, IR-8 and its successors reached Indonesia. At that time, Indonesia was forced to import nearly a million tons of rice per year from other nations to feed a growing population. The Indonesian government became an enthusiastic proponent of the Green Revolution, which promised to dramatically increase rice production. Since the IRRI rice was designed to be responsive to chemical fertilizers, it was necessary to provide farmers with access to fertilizers and pesticides, as well as the new seed stocks. In 1967, the Indonesian government invited a Swiss company, CIBA, to develop a system for furnishing these necessities to farmers. The new program was called BIMAS for *Bimbingan Massal*, or Massive Guidance. Despite initial failures of the BIMAS program to increase rice production, the government decided to invest heavily in a national program to achieve self-sufficiency in rice. This program was based on two components: government subsidies to reduce the cost of fertilizers and pesticides to the farmers, and extension of BIMAS (which the government took over in 1971) to all major rice-growing regions of Indonesia. In order to ensure that farmers would have access to the fertilizers and pesticides required to grow the new "miracle rice," a government banking system (the People's Bank) was empowered to provide credit to small farmers for the specific purpose of purchasing agrochemicals and farm machinery. Massive Guidance brought rapid results: by 1974, 48 percent of the terraces of south-central Bali were planted with the new rice; three years later the proportion had climbed to 70 percent.⁶⁵

Within a few years of the beginning of the Green Revolution, the government took two further steps that had a profound impact on the water temple system in Bali. The first was a shift in cropping patterns. IR-8 proved to be highly susceptible to an insect called the brown planthopper, which is estimated to have destroyed 2 million tons of rice in Indonesia in 1977. Rice scientists at IRRI came up with a new variety of rice, IR-36, which was resistant to the planthoppers and had the further advantage

of maturing very quickly.⁶⁶ In Bali, the use of IR-36 was strongly encouraged. Balinese farmers were forbidden to plant native varieties, which take much longer to mature, are less responsive to fertilizers, and produce less grain. Instead, double-cropping or triple-cropping of IR-36 (or other high-yielding rice varieties) was legally mandated. Farmers were instructed to abandon the traditional cropping patterns and to plant high-yielding varieties as often as possible.

The second step was taken as a result of a series of studies by foreign consultants on ways to improve the performance of Balinese irrigation systems. These studies culminated in the Bali Irrigation Project, a major engineering project launched in 1979 by the Asian Development Bank. The aims of the project were succinctly defined in their feasibility study:⁶⁷

The Bali Irrigation Project (B.I.P.) is the first large scale attempt in Bali island to improve the irrigation systems. Past interventions by the Department of Public Works have been limited to isolated improvements, with negligible external consequences. In contrast, the B.I.P. will intervene in 130 subaks (about 10 percent of the total Bali subaks), many sharing the water from the same river. The impact of the main improvements will concern:

- River water sharing and subak coordination
- New Operating & Maintenance rules
- Programmed cropping patterns
- Use of measurement systems
- Changes in cropping techniques
- Yield monitoring systems
- Taxes and water charges

In consequence the Subak may lose some of its traditional facets, especially part of its autonomy.

The principal emphasis of the project was the reconstruction of thirty-six weirs and associated irrigation works, at an estimated cost of about forty million dollars.⁶⁸ Since in most cases these "subak improvement schemes" were not designed to bring new land into cultivation, economic justification for the project was largely based on a mandated change to continuous rice cropping for as many subaks as possible. In the long run, according to project officials, this would generate a minimum of 80,000 tons of additional rice production each year, which could be sold for export and thus provide the \$1,300,000 per annum needed to repay the Bali Irrigation Project loan to the Asian Development Bank.⁶⁹ All of these estimates were later revised upward, as the project added an additional sixteen subak improvement schemes to the original plan.

As a later evaluation report on the project noted, "The introduction of the project coincided with the government's push for self-sufficiency in rice and the encouragement given to farmers to extend the substitution of short rotation varieties [of rice] for the traditional long duration varieties. . . . These factors temporarily led to the abandonment of the Balinese cropping calendar, traditionally the key to overall watershed and irrigation scheme management."⁷⁰ By the late 1970s, the mandated change to continuous rice cropping began to remove the temples from control of irrigation and cropping patterns. In the upper reaches of the rivers, where coordination of irrigation was essential during the dry season, farmers often refused to abandon the temple schedules. But farther downstream, the threat of legal penalties against

anyone failing to grow the new rice led to continuous cropping of Green Revolution rice. Religious rituals continued in the temples, but field rituals no longer matched the actual stages of rice growth. As soon as one crop was harvested, another was planted, and cropping cycles drifted apart. During the rainy season, no one was likely to run out of water. But during the dry season, the supply of irrigation water became unpredictable. Soon, district agricultural offices began to report "chaos in the water scheduling" and "explosions of pest populations," as in this 1985 report by the Department of Public Works of the Regency of Tabanan:

I. Background

Concerning the explosion of pests and diseases which recently attacked the rice crops, such as brown planthoppers, rodents, tungro virus, and other insects, in the Tabanan regency; and also with regard to the frequent problems which began to arise at about the same time concerning water sharing during the dry season, various groups are now urgently working to get on top of the problem. The result has been acknowledgment of the following factors which caused the explosion of pests and diseases:

1. In areas with sufficient irrigation water, farmers are now planting continuously throughout the year.

2. In areas with insufficient water, farmers are planting without a coordinated schedule.

In other words, the farmers/subaks have ceased to follow the centuries-old cyclical cropping patterns . . .

A similar report for the neighboring regency of Gianyar tells the same tale, beginning with the massive damage to crops caused by the brown planthopper in the late 1970s. As elsewhere in Bali, farmers in Gianyar were encouraged to plant the planthopper-resistant rice IR-36. But IR-36, while unpopular with planthoppers, fell an easy victim to a viral disease called tungro. As a result, the planthopper plague was quickly followed by an "explosion of the tungro virus":

The Explosion of the Tungro Virus

Tungro began to be a problem in Gianyar in 1980, and steadily increased until the explosion in 1983/84, destroying 421.15 hectares of rice completely, predominantly the variety IR 36 . . . A temporary remedy was found in the new rice variety PB 50. In one cropping season, tungro was reduced, but immediately afterward the new rice was afflicted by *Helminthosporium Oryzae* . . .

Following a, by now, familiar pattern, the new PB 50 rice proved vulnerable to two new diseases, as described in the Gianyar report:

The Explosion of *Helminthosporium* and Rice Blast

Problems with *Helminthosporium Oryzae* actually began in 1977/78 when five hectares were reported to be damaged. The explosion began in 1982/83 when 6007.95 hectares of paddy were afflicted . . .

Thus by the mid-1980s, Balinese farmers had become locked into a struggle to stay one step ahead of the next rice pest by planting the latest resistant variety of Green Revolution rice. Despite the cash profits from the new rice, many farmers were pressing for a return to irrigation scheduling by the water temples in order to bring down the pest populations. But to foreign consultants at the Bali Irrigation Project, the proposal to return control of irrigation to water temples was interpreted

as religious conservatism and resistance to change. The answer to pests was pesticide, not the prayers of priests. Or as one frustrated American irrigation engineer said to me, "These people don't need a high priest, they need a hydrologist!"

STUDYING THE ECOLOGICAL ROLE OF WATER TEMPLES

In the spring of 1987, I began a new phase of research on the ecological role of the water temples in collaboration with a systems ecologist, Dr. James Kremer. My year of fieldwork in Bali (1983-84) had convinced me that the primary role of water temples was in the maintenance of social relationships between productive units. The question that Kremer and I wished to address was: did these systems of social coordination have measurable effects on rice production? The Green Revolution approach assumed that agriculture was a purely technical process, and that production would be optimized if everyone planted high-yielding varieties of rice as often as they could. In contrast, Balinese temple priests and farmers argued that the water temples were necessary to coordinate cropping patterns, so that there would be enough irrigation water for everyone, and pests could be reduced by coordinated fallow periods. Kremer suggested that these alternatives could be scientifically evaluated in an ecological simulation analysis. Furthermore, such an analysis might yield deeper insights into the reasons for regional differences in the organization of water temple networks.

Our first idea was to investigate cases in which water temples had been removed from irrigation management. But we quickly concluded that it would be impossible to learn very much from such a study, since it would be difficult to directly associate events such as pest infestations with the absence of temple control. Moreover, a temple-by-temple comparison would not reveal the effects of higher-level systems of coordination between temples. The water resources available to any single temple are affected to some degree by the irrigation schedules of their neighbors upstream, and we hoped to be able to evaluate the effects of such cooperative arrangements in water management. In order to evaluate the significance of this coordination, we decided to model all of the irrigation systems that lie between two rivers in south-central Bali, the Oos and the Petanu.

Based on my earlier fieldwork, we knew that water temples make decisions about cropping patterns by taking into consideration the trade-off between two constraints: water sharing and pest control. As previously noted, if everyone plants at the same time, they will also harvest at the same time, and a widespread fallow period can reduce pest populations by depriving them of food and/or habitat. On the other hand, if everyone plants the same rice variety at the same time to keep down the pests, then irrigation demand cannot be staggered and there will be water shortages. Striking an optimal balance between these two constraints is not a simple matter, since the choices made by upstream farmers have implications for their downstream neighbors, and constraints such as the amount of water available for irrigation vary by location and by season.

Consider a simple model consisting of two subaks, one upstream and one downstream. Assume that the water supply is constant but inadequate to meet the needs of

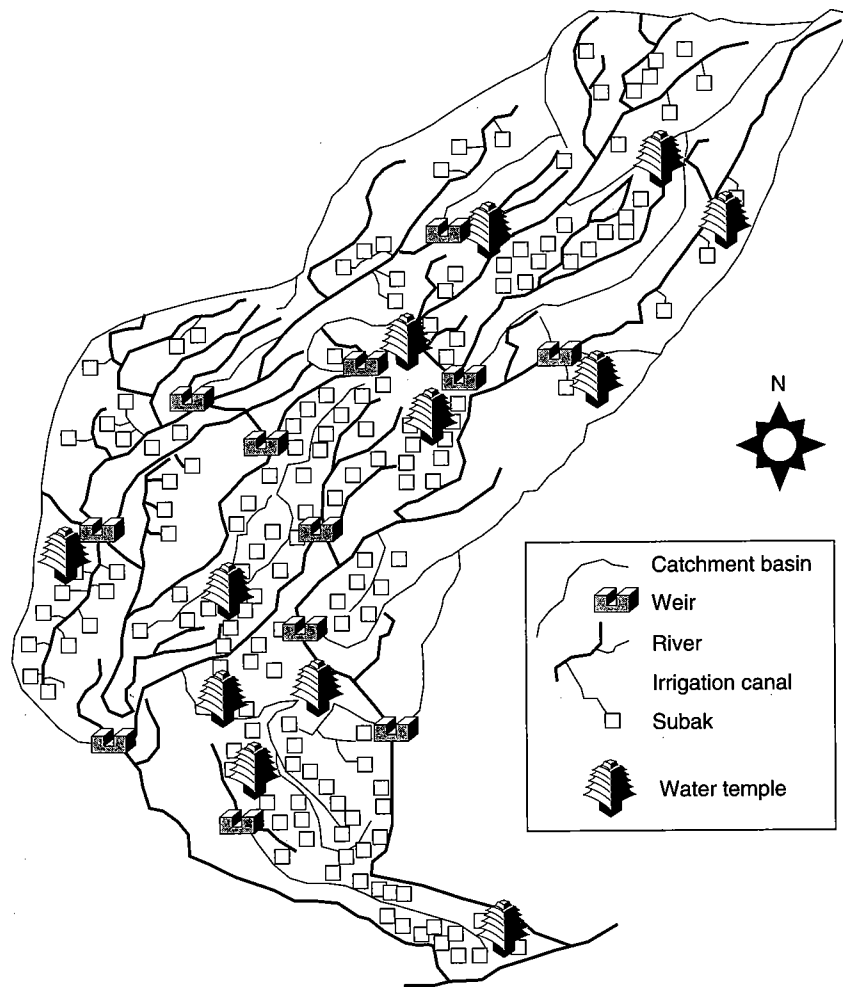
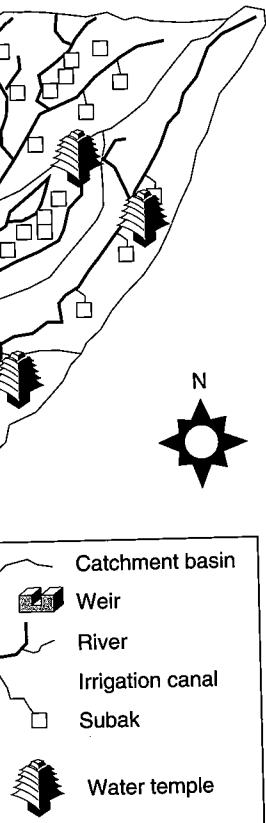


Figure 13 Computer model of irrigation along two Balinese rivers. This map (not to scale) shows the location of catchment basins, irrigation systems, and subaks along the Oos and Petanu rivers in south-central Bali.

both subaks at once, although sufficient if they stagger their planting schedules. Both subaks can suffer losses from the spread of rice pests.

Given these assumptions, we can immediately draw several conclusions: the upstream subak does not care about water scarcity, and so is free to choose any irrigation schedule. The downstream subak faces either water scarcity (under simultaneous cropping) or high pest damage (under staggered cropping) and will choose the lesser of two evils. If pest losses are high, both subaks will want to coordinate their planting schedule so that the pests will be reduced by a simultaneous fallow period. If pest losses are low, the upstream subak still wants to plant simultaneously to minimize pests, while the downstream subak prefers to stagger plantings so it will receive more water.



This map (not to scale) shows the location of the Oos and Petanu rivers in south-central Bali.

their planting schedules. Both

draw several conclusions: the farmer is free to choose any irrigation water scarcity (under simultaneous cropping) and will choose the fallow period that he will want to coordinate their planting with a simultaneous fallow period. The farmer will plant simultaneously to minimize stagger plantings so it will re-

This simple model yields a basic insight into the logic of the temple system. If we paid no attention to the relationship between fallow periods and pest populations, it would seem that the upstream subaks would lack any incentive to cooperate with their downstream neighbors. But if we take the role of pests into account, we can see that upstream subaks have much to gain by cooperation. Helping their downstream neighbors satisfy their water needs is likely to be in their own self-interest, since it will allow them to synchronize irrigation schedules and reduce losses from pests. The model has the surprising result that under certain conditions, increasing the pests can lead to higher average rice yields!⁷¹

The real world is a little more complicated: instead of two subaks, one upstream and one downstream, there are hundreds, and each one may influence ecological conditions for several neighbors. In order to gain an understanding of how these effects are transmitted, we built a computer model of all the subaks along two adjacent rivers in south central Bali. The purpose of the model was to evaluate the effects of social cooperation via temple networks on rice yields.

The watershed of the Oos and Petanu rivers includes approximately 6,136 hectares of rice terraces divided into 172 subaks. Based on topographical maps, we divided the watershed into 12 catchment basins and calculated the relationship between rainfall and stream flow for each of them. For each of the 172 subaks, we specified its location, area, the basin in which it is located, the dam from which it receives irrigation water, and the dam to which any excess water is returned. Given this geographical setting, the computer simulates the rainfall, river flow, irrigation demand, rice growth, and pest dynamics for all subaks on a month-by-month time scale. At the appropriate times, the harvest is adjusted for cumulative water stress and pest damage, yields are tallied, and the next crop cycle is begun.

The first use we made of this model was to compare the results of different types of social relations among subaks on harvest yields. It was possible to try multiple runs of the model, in which we kept all the biological variables the same but tried out different possible scales of social coordination:

- every subak is randomly assigned its own cropping pattern
- all the subaks follow the same cropping pattern
- half the subaks follow one pattern, and half plant a month later
- several other hypothetical patterns of coordination
- subaks plant in clusters based on the real patterns created by water temples

We were not really surprised to find that the last option (the water temple scale of coordination) produced the best harvests by finding the right balance between water sharing and pest control. But this result was important because it provided objective evidence that the water temples were playing a vital role in the ecology of the terraces.

But how well did our model reflect reality? To find out, I spent months working with a team of Balinese students to gather fresh data from our study area, so that we could test the harvests predicted by the model against real data. Figure 15 compares the model's predictions for each subak with real harvest data. There is a strong positive correlation. To make sure that these results were meaningful, we tried running the model with the same data (on crops planted, rainfall, etc.), but scrambled the

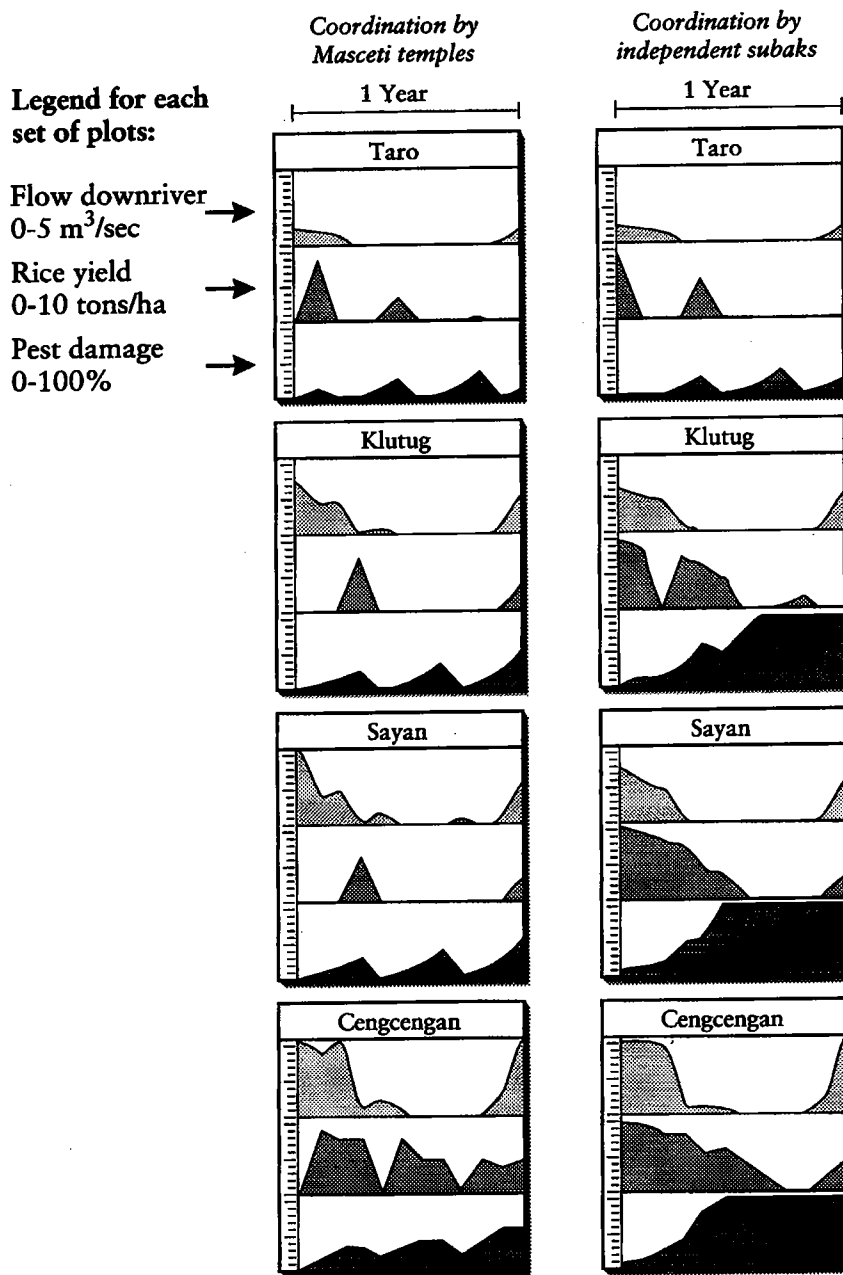


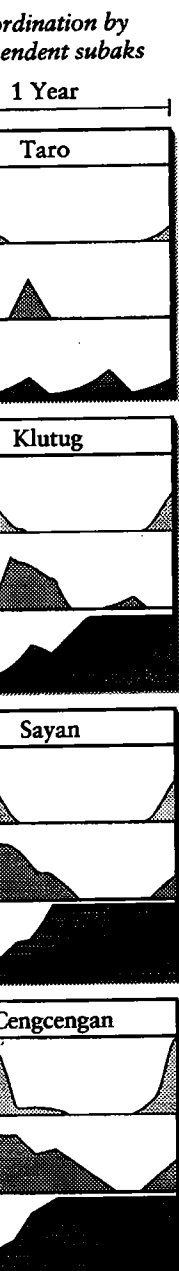
Figure 14 Comparison of yields with and without water temples. The computer model predicts simulated annual patterns for river flow, rice yield, and pest damage from the upper regions of the watershed (Taro) to the region nearest the sea (Cengcengan). Each of the three plots shows average results for the subaks in the area, over a twelve-month period (reading from left to right). The column on the left shows the effect of the coordination of planting schedules by large water temples (Masceti), while the column on the right shows the results of planting without temple coordination (in other words, each subak sets its own independent cropping pattern).

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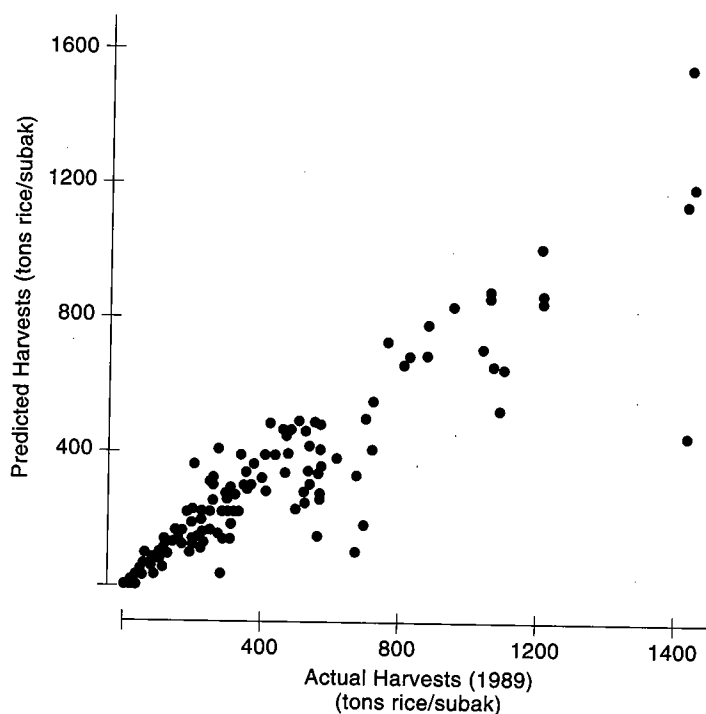


Figure 15 Comparison of model predictions with actual rice harvests by subak

planting dates. The correlation dropped to near zero, indicating that the synchronization of cropping patterns by the water temples is highly significant for harvest yields.

WATER TEMPLES AS A COMPLEX ADAPTIVE SYSTEM

In 1993, a new insight into the workings of the water temple system appeared from an unlikely source: complexity theory.⁷² Imagine that the water temples don't exist, but that all the known ecological changes along our two rivers are otherwise unchanged. As a new year begins, each of our 172 subaks plants rice or vegetables. At the end of the year, harvest yields are tallied. Now each subak checks to see whether any of its nearest neighbors got a better total yield. If so, they copy the cropping pattern of their most successful neighbor. After all the subaks have decided to either copy a neighbor or stick with their old cropping schedule, the computer simulates another year of growth. The process continues until all the subaks decide to stick with their current cropping pattern. What will happen?

I created this computer experiment because I wanted to see if I could figure out how the water temple system might have developed. Did someone have to design it, or could it come into existence spontaneously?

Figure 16 shows the distribution of cropping patterns for the first year in this experiment. Each symbol indicates a different cropping pattern; you can see that they

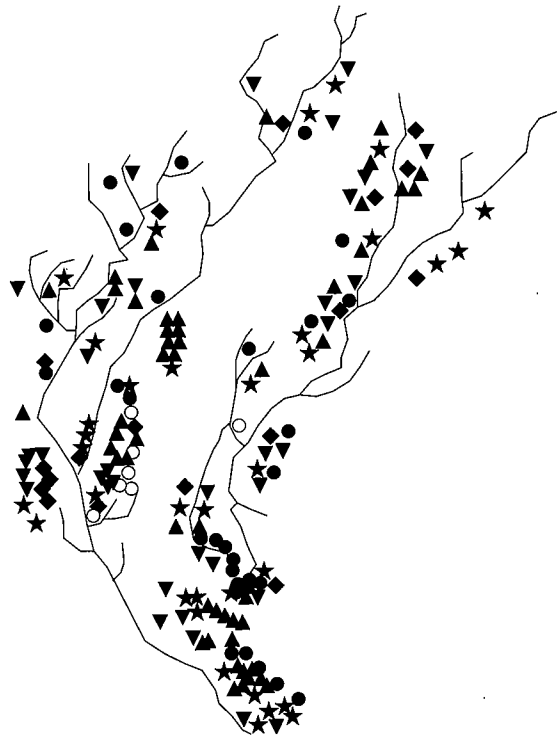


Figure 16 First run of a model of coadaptation. Each symbol indicates a different cropping pattern, randomly distributed among subaks in the Oos-Petanu watersheds. Average harvest was 4.9 tons of rice per hectare.

are pretty random. The average harvest for this run was 4.9 tons of rice per hectare. Figure 17 shows the pattern eight years later. See how the symbols have clustered in groups, representing local groups of subaks that are following the same schedule. The average harvest has almost doubled, to 8.57 tons. Now have a look at Figure 18, which shows the patterning created by the actual system of water temples. As you can see, the last two figures are nearly identical.

I was pretty excited when I ran this program for the first time and saw patterns that closely resembled water temple networks emerge out of randomness. Things got even more interesting as we ran more simulations, twiddling the dials on the physical and biological variables (rainfall, pest dispersal rates, etc.), and watched to see what happened. As long as we stayed within the bounds of biological possibility, the same phenomena occurred: in less than forty years, a complex structure of coordinated cropping patterns emerged, which bore a remarkable similarity to the actual pattern of water temple coordination along these rivers. And as the artificial temple networks formed, harvest yields steadily increased.

Once these artificial water networks form in the computer, they display another interesting property: the ability to recover quickly from perturbations like low rainfall or a new kind of pest. Such disturbances appear as a cascade of changes that propagate through one or more clusters of subaks, but the temple network quickly adjusts. Yields remain higher than if the temple system were to stop functioning (as it did during the Green Revolution), leaving every subak to set its own individual cropping pattern.



Figure 17 Last run of the model. Average harvest yields rose to 8.57 tons per hectare. Note the clusters of subaks following identical cropping patterns.

ons of rice per hectare. Symbols have clustered in the same schedule. Give a look at Figure 18, water temples. As you

time and saw patterns of randomness. Things got the dials on the physiological possibility, the complex structure of coordination-similarity to the actual as the artificial temple

er, they display another perturbations like low rain-cascade of changes that temple network quickly to stop functioning (as to set its own individual

These results had several implications, both practical and theoretical. The main practical implication was that, in the computer, the emergence of temple networks leads to higher average yields and improvements in sustainability (the ability to cope well with changes in the environment). It appears that the temple networks are intrinsically capable of doing a better job of management than either uncoordinated planting (the Green Revolution system of "every man for himself") or centralized governmental control.

On a theoretical level, the computer model gives us a new way to think about the development of complex, sophisticated systems of irrigation management like the water temples of Bali. Our models show that the structure of water temple networks could have developed through a process of trial-and-error adaptation by the farmers, rather than deliberate planning by royal engineers or other planners. In the future, we hope to be able to compare test this idea against real archaeological data to see if the actual historical development of water temple networks follows the logic of coadaptation we see in the computer model.⁷³

CONCLUSION: ARE THE WATER TEMPLES OBSOLETE?

Water temple networks are social creations, a social response to the problem of sustaining the rice terraces as productive ecosystems. The physical facts of interdependency in the irrigation systems and the need to create coordinated fallow periods for



Figure 18 The distribution of cropping patterns in the traditional system of water temple networks. Note the similarity to Figure 17.

pest control place a premium on cooperation. All farmers who share water from the same source must cooperate in construction, maintenance, water allocation, and the management of disputes. Water temples link the physical features of irrigation systems to the social world of the subaks according to a logic of production: the congregation of a temple consists of the farmers who obtain water from the irrigation component "controlled" by the temple's god. Inside each temple, along with the shrine to the temple's principal deity, there are additional shrines for other gods. Offerings to these gods provide a way for the temple congregation to acknowledge their relationships to other temples and the social and physical units they represent. Finally, our ecological models suggest that the networks of relationships created in this way play a vital role in the ecology of the rice terraces.

But the practical importance of this traditional system of resource management was not apparent to development planners. At first, the very existence of the temple networks was not recognized. Later plans for irrigation projects by international development agencies foresaw an end to the productive role of water temples "as an almost inevitable result of technical progress."⁷⁴ For this reason, Kremer and I felt that it was important to bring the results of our analyses to the attention of development planners, who were not always eager to hear from us. Irrigation specialists from the Ford Foundation kept advising us (and our Balinese colleagues) to focus on individual farmers or subaks, and forget about modeling water temples. But as time went on, we began to receive a more sympathetic audience. The final evaluation report for the Bali Irrigation Project reversed the planner's earlier skepticism towards water temples:

The substitution of the "high technology and bureaucratic" solution in the event proved counter-productive, and was the major factor behind the yield and cropped areas declines experienced between 1982 and 1985. . . . The cost of the lack of appreciation of the merits of the traditional regime has been high. Project experience highlights the fact that the irrigated rice terraces of Bali form a complex artificial ecosystem which has been recognized locally over centuries.⁷⁵

The report noted that erosion of the strength of the traditional vertical integration among water temples threatens "the long term sustainability of the irrigation systems."⁷⁶ It concluded with the observation that "no post-evaluated project of the Bank exhibits self-sustained and high performance comparable to Bali."⁷⁷

But perhaps the most satisfying result was the visit of the Project Evaluation Mission to the Temple of the Crater Lake, described in the language of officialdom:

The Project Evaluation Mission interviewed leaders of the high Water User Group at Batur who have been instrumental in the proper establishment of some 45 new subaks during the last ten years. Apart from providing the required spiritual background, they often provided technical advice, for example on spring development, canal and tunnel siting and building, and clarifying water allocation issues. In light of the minimal success of the Project Office to develop new irrigation areas, it is suggested that there would be benefit from seeking advice from them. At the least, it is considered that this exercise would be of assistance in bringing the two parallel water development and management institutions into closer contact and could have more far-reaching impacts.⁷⁸

At the time of this writing, official policy towards irrigation and water temples in Bali is in a state of flux. There is a continuing need to sustain high levels of rice production, and also to divert some flows formerly used for irrigation to urban uses. Nonetheless, for the first time, the water temples have achieved recognition by state irrigation bureaucracies, and for now the temples have regained informal control of cropping patterns in most of Bali.

NOTES

49. Geertz, *Negara*, 82.

50. *Statistical Yearbook of Bali 1986*, published by the Statistical Office of Bali Province, Jl. Raya Puputan Denpasar, Bali:8.

51. Rajapurana Ulun Danu Batur Vol. II:24 28.b.1, stenciled manuscript, library of the Bali Museum, Denpasar, Bali.

52. *Journal of a Tour along the Coast of Java and Bali & with a Short Account of the Island of Bali, Particularly of Bali Baliling*. Printed at the Mission Press of the Singapore Christian Union, Singapore, 1930, p. 24.

53. F.A. Lieftrink, "Rice Cultivation in Northern Bali," in J.L. Swellengrebel, ed., *Bali: Further Studies in Life, Thought and Ritual* (The Hague, 1969).

54. Stukken ajkomstig van P.A.J. Moojen (architect, kunstschilder), "Kultuurprobleme," stukken voornamelijk betreffende de restauratie van tempels op Bali, met platte gronden. Ca. 1930. 1 bundel. H 1169:17, KITLV, Leiden. P. 21, letter to His Excellency the Governor General of the Nederlands-Indies, 21 January 1919.

55. "Memorie van Overgave der onderafdeeling Kloengkoeng," door Controleur J.C.C. Haar, 27 May 1926-3 Feb. 1930, pp. 22-24 (Leiden: Archives of the Koninklijk Instituut voor Taal-, Land- en Volkenkunde).

56. The Balinese word that I have translated as "virgin priestess" is Jero Balian. There are two such priestesses at the temple, the elder (*duuran*) and younger (*alitan*). Each is herself chosen by a Jero Balian,

upon the death of her predecessor. Unlike the male priests of the temple, the virgin priestesses may not marry. They are the only priests of the temple who act as trance mediums (balian).

57. The Balinese term is *Pedanda siwa*. For a description of the role of Brahmana high priests in the preparation of holy water, see Christiaan Hooykaas, *Surya-Sevana: The Way to God of a Balinese Siva Priest* (Amsterdam: Verhandelingen K.N.A.W., nieuwe reeks, Deel 72/3, 1966).

58. A "weir" (*empelan*) is a diversionary dam in the river, which channels all or part of the flow into an irrigation canal. Almost always in Bali, this canal begins as a tunnel, since the rivers lie at the bottom of deep ravines.

59. Bali is divided for administrative purposes into eight administrative regions called kabupaten. At the head of each kabupaten is an official called the bupati, whose role with respect to his kabupaten is likened to that of the governor for the province of Bali. Each kabupaten is itself subdivided into half a dozen or so sub-districts called kecamatan. I have followed the usual practice of translating kabupaten as "regency."

60. Probably the Jero Gde meant that the flow from the spring amounted to about a hundred liters per minute, produced by the watershed area above the spring.

61. This is the typical pattern along the Oos and Petanu rivers, and more generally, in Bangli, Gianyar, and Badung. Elsewhere, there are other patterns of water temples that await investigation.

62. Roelof Goris, *Prasasti Bali I* (Bandung: N.V. Masa Baru, 1954), 55. The inscription is 002. B. betin A1:1b.4 (*undagi pangarung*).

63. Eugene Odum, *Basic Ecology* (New York: CBS College Publishing, 1983), 490-491.

64. Shoichi Yoshida, *Fundamentals of Rice Crop Science* (Manila: International Rice Research Institute, 1981), 147-151; Surajit K. DeDatta, *Principles and Practices of Rice Production* (New York: John Wiley & Sons, 1981), 297-298.

65. Laporan Statistik Pertanian ("Reports on Agricultural Statistics"), Dinas Pertanian Daerah Bali, Kantor Statistik Pulau Bali, Renon, Bali.

66. IRRI estimates an average growth of 105 days for IR-36, whereas the fastest-growing native Balinese varieties take about 135 days. However, as we will see, the rapid growth of high-yielding varieties of rice is not an unalloyed benefit, but a question of tradeoffs. Native Balinese rice takes longer to mature, and puts more of its energy into the whole plant rather than the seeds. Consequently, it is more resistant to disease and other stresses in its environment.

67. Anon., *Bali Irrigation Project Feasibility Study Part 2, Volume 5A (Subak Improvement Schemes)*. Manila: The Asian Development Bank, 1981. Consultant's report prepared by Electroconsult International, Milano, Italy, and Agricultural Development Corporation, Seoul, Korea, for the Directorate of Irrigation, Ministry of Public Works, Republic of Indonesia, January 1981.

68. *Ibid.*, pp. 1-7.

69. *Bali Irrigation Project Feasibility Study Part 2, Volume 5A (Subak Improvement Schemes)*, pp. 1-2. The economic evaluation described in this study assumes that the project will generate \$15,360,000 per year in increased rice production (pp. 1-8).

70. Project Performance Audit Report, Bali Irrigation Project in Indonesia. Asian Development Bank Post-Evaluation Office PE-241 L-352-INO (Manila, Philippines, May 1988), 47.

71. When crops are staggered, the aggregate yield falls due to pest damage to *both* fields, as opposed to simultaneous cropping in which there is water stress in only the downstream subak. But if the pest damage is low, the downstream subak may prefer staggered planting to minimize water stress. Higher pest levels provide an incentive to the downstream subak to prefer simultaneous cropping, even though this means somewhat higher losses from water stress. So there exists a theoretical range of pest levels such that increasing the amount of pest damage in the model can result in higher aggregate yields by compelling the downstream subak to switch to synchronized planting.

72. A good popular introduction to complexity theory is Roger Lewin's *Complexity: Life at the Edge of Chaos* (N.Y.: Macmillan, 1992). A general scientific introduction is provided by Stuart Kauffman, *The Origins of Order: Self-Organization and Selection in Evolution* (Oxford University Press, 1993).

73. See J.S. Lansing and J.N. Kremer, "Emergent Properties of Balinese Water Temple Networks: Coadaptation on a Rugged Fitness Landscape." *American Anthropologist* 95:1 (March 1993):97-114.

74. Project Performance Audit Report, Bali Irrigation Project in Indonesia. PE-241, L-352-INO, Restricted. May 1988: The Asian Development Bank, Manila, Philippines, 47.

75. Project Performance Audit Report, Bali Irrigation Project in Indonesia. PE-241, L-352-INO, Restricted. May 1988: The Asian Development Bank, Manila, Philippines, 48-50.

76. *Ibid.*, 47.

77. *Ibid.*, 50.

78. *Ibid.*