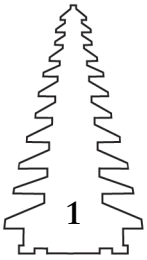
COPYRIGHT NOTICE:

J. Stephen Lansing: Perfect Order

is published by Princeton University Press and copyrighted, © 2006, by Princeton University Press. All rights reserved. No part of this book may be reproduced in any form by any electronic or mechanical means (including photocopying, recording, or information storage and retrieval) without permission in writing from the publisher, except for reading and browsing via the World Wide Web. Users are not permitted to mount this file on any network servers.

Follow links for Class Use and other Permissions. For more information send email to: permissions@pupress.princeton.edu



1

Introduction

> The transition from *myth* to *reason* remains a problem even for those who recognize that myth too contains reason.
>
> —Marcel Detienne, *The Masters of Truth in Archaic Greece*

When anthropologists try to evoke an exotic non-Western society like that of Bali, the result may look like a dance of marionettes. Customarily we begin by highlighting the unusual, the strange symbols and beliefs that are most unlike our own. Through the alchemy of our own words we imprint these symbols on our subjects' minds, and then they are made to dance. This approach can sometimes be fruitful: the celebrated French theater director Antonin Artaud wrote that he drew much of his inspiration from Balinese performances that he witnessed at the Paris World's Fair in 1937, and saw no need to complicate his first impressions by further study. But if we are interested in a less superficial encounter there is an alternative. Suppose, in a playful spirit, we turn the question around and ask what Western social science might look like from a "magical" Balinese perspective?

Picture a scene in a *griya*, the residence of a Balinese high priest. Inside a walled stone courtyard, he sits engrossed in transcribing a fourteenth-century manuscript borrowed from a colleague, surrounded by the paraphernalia of his daily rituals: silver bowls and bells, jars filled with holy water, and woven baskets filled with flower petals used to make offerings. To become a high priest, he has undergone years of apprenticeship to a senior Brahmin priest, reading and discussing the ancient literature of Hindu and Buddhist philosophy. When the mentor believes that the student is ready, a funeral ceremony is performed in which the student symbolically undergoes his own death, cutting his ties to ordinary human life so that he can concentrate on the cultivation of his mind. But not all of his studies are directed toward personal enlightenment; the apprentice

also learns how to perform rituals for the benefit of the community. I have had many conversations over the years with these "twiceborn" priests, hoping to gain insights into Balinese ideas about the sorts of questions that interest social scientists. Not infrequently they ask me to reciprocate. Like them, I have had to undergo a long apprenticeship in an intellectual tradition, Western social theory, that explores many of the same topics they have studied. In the past these conversations sometimes became uncomfortable for me: should I admit that I regard much of their belief system as mere magic, with no foundation in reality? But as my knowledge of Balinese philosophical literature grew, I realized that my first impressions were superficial, and I began to see ways to keep the conversation alive.

The concept of magic is important for Western science, which often sees itself as engaged in a centuries-old battle against superstition. From this perspective, magic is the antithesis of rational thought. This opposition is particularly important for the social sciences. In a recent book (*Sources of the Self: The Making of the Modern Identity*), philosopher Charles Taylor argues that in the Western world, the loss of a magical worldview was the essential precondition for the appearance of the modern sense of the self: "The decline of the world-view underlying magic was the obverse of the rise of the new sense of freedom and self-possession. From the viewpoint of this new sense of self, the world of magic seems to entail a thralldom, an imprisoning of the self in uncanny external forces, even a ravishing or loss of self."[1] According to Taylor, the need for a specifically *social* science comes from our recognition that the human mind is not fully rational, because it is constrained by being embodied and by living in the world. The task of social science is to make us cognizant of such constraints and, by so doing, help us to gain mastery over them.

Yet most of this would seem very familiar to a Balinese schooled in the disciplines of *Saivasiddhanta* and Buddhist philosophy. Both of these philosophical traditions have flourished for more than a millennium in Bali. They emphasize the liberation of the mind through awareness of the constraints imposed on it by the fact of being embodied in the material world. The real differences between the perspectives of Western social

[1] Charles Taylor, *Sources of The Self: The Making of the Modern Identity*, Cambridge, Mass.: Harvard University Press, 1989: 192. Similar arguments are developed by Keith Thomas in *Religion and the Decline of Magic*. Other historians have underscored the ways in which magic and alchemy were intertwined with science in early modern Europe, for example in Isaac Newton's keen interest in the mathematical basis of astrology. But this approach only serves to heighten the significance of the decline of magic as a prerequisite for the rise of science and modernity, except for those historians who challenge the distinction between early modern science and magic.

scientists and Balinese priests are not a simple matter of superstition versus science. Instead they reflect profoundly different ideas about the nature of society. Social science is comparative; it assumes that the world is a human creation and that social institutions are malleable. Comparisons, either between different societies or the same society in different historical periods, show how different social outcomes are produced. This idea was first articulated in Europe in the eighteenth century. "Civilization," for example, is derived from a French word that was first used in the plural form for the comparison of different societies in 1819.[2] But for a Balinese priest, the idea of a comparative social theory begins with a false premise. Balinese Brahmanical ideas of society are founded on the concept of caste. In a caste system, every person inherits his or her caste status at birth, and differences between castes are taken to be facts about the world, not about history. So for a Brahmin scholar, the basic framework of the social world is a given, and the idea of a comparative sociology seems merely odd.

But the conversation need not end there. After all, the social scientist's preferred method of comparison is at best indirect. Balinese literature is full of stories about different societies, which are studied for their insights into the workings of the social world. Why do some kingdoms—or some individuals—prosper while others do not? Why do conflicts arise, what makes them intensify, and how are they successfully resolved? The answers must lie in the actions of the people, and according to Balinese ideas, ultimately those actions are driven by people's sense of themselves. A great deal of Balinese philosophical literature, and much serious art including drama, painting, and poetry, explores the relationship between levels of mental development and behavior in the world. Thus the shape of an eye in a traditional Balinese drawing or painting expresses the level of emotional self-mastery of its owner. From the priest's perspective, a comparison between societies is like the beginning of a historical chronicle, a mere setting of the stage. The place to focus one's analytical powers—the heart of the matter—is in the ways the main characters display their shifting levels of consciousness and engagement with the world.

The Western social theory I studied is preoccupied with a different story: the emergence of modern society, the coming into being of a new kind of person. That is the story Taylor tells, but it is as old as social science itself, and has roots in a Christian worldview. The modern West is unique, according to this view, because only in the modern world is the

[2] Formerly "civilization" was a technical legal term, referrring to the conversion of a criminal prosecution into a civil matter. See Philippe Beneton, *Histoire des mots: Culture et Civilization*, Paris: Presses de la Fondation Nationale des Sciences Politiques, 1975.

self free to discover its own nature. Premodern societies see society as part of the natural order of the cosmos. The achievement of Western science has been to strip away superstition, to reveal that society is our own creation, not that of the gods. What Taylor calls "inwardness," the modern sense of the self as an autonomous agent and a historical being, is bound up in this recognition. Social science is thus a form of self-knowledge, as historical events are mined to discover the stages of the emergence of modern selfhood. In the European tradition of Hegel, Marx, and Weber, these stages are correlated with the development of democratic social institutions. Hegel's argument, which laid the foundation for nineteenth-century European social theory, is that social institutions reflect a society's level of maturity and self-awareness. It follows that genuine self-knowledge is available only to members of modern societies. Indeed, this tradition makes modern Western social scientists into uniquely privileged observers.

But a Balinese Brahmin priest also regards himself as a uniquely privileged observer, and for quite similar reasons. Like the social scientist, he lays claim to theoretical knowledge about human nature that is abstracted from observations of the world. Still, from the perspective of the social scientist, the priest's views and his own are not on an equal footing, because the Brahmin's views are contained within the horizons of his "premodern" worldview. This idea was perhaps most fully articulated by the French anthropologist Louis Dumont, author of a celebrated book on the caste system in South Asia (*Homo Hierarchicus*) and another on the modern West (*Homo Aequalis*). Dumont does not question the advanced historical vantage point of the West, or the "premodern" limitations of the Brahmanical worldview. But he argues that it is worth paying close attention to the East, because the caste system offers a chance to glimpse a universal aspect of human society, the principle of hierarchy, in a pure form unalloyed by modern ideas about equality. *Homo hierarchicus* still exists in the modern West, according to Dumont, but we have trouble recognizing him precisely because our ideology celebrates his downfall. Yet "caste has something to teach us about ourselves: . . . the castes teach us a fundamental social principle, hierarchy. We, in our modern society, have adopted the principle contrary to it, but it is not without value for understanding the nature, limits and conditions of realization of the moral and political egalitarianism to which we are attached."[3]

So for Dumont hierarchy is to the East what equality is to the West, the fundamental principle on which society is organized. The proposition could hardly be clearer. But is it true? A concern with hierarchy is certainly part of the outlook on life of a "twice-born" Balinese Brahmin

[3] Louis Dumont, *Homo Hierarchicus* (2nd ed.), Paris: Gallimard, 1979: 2.

priest. The farmers who visit him to ask for his assistance must speak to him in a language register called "High Balinese," filled with honorific terms, and he is supposed to respond to them in the unflattering vocabulary of Low Balinese. In this way, hierarchy is built into the fabric of daily life and the Balinese language. But if asked whether the concept of *Homo aequalis* is strange and unfamiliar to him, a priest might point out that the same farmers are obligated, as members of their village communities, to attend monthly assemblies where the community's affairs are decided by means of extended discussion followed by democratic vote. In those assemblies, every speaker must use the self-deprecating high register of the Balinese language, thus affirming both the personal dignity and the jural equality of his fellow villagers. Failure to use this register is understood to signify disrespect for the community, and is subject to formal sanctions. Farmers also belong to organizations devoted to the management of rice terraces for which we must use the Balinese word *subak*, because no equivalent term exists in English. Subaks are egalitarian organizations that are empowered to manage the rice terraces and irrigation systems on which the prosperity of the village depends, and they too have frequent meetings that are governed by the same strict democratic etiquette. Between them, the village and subak assemblies govern most aspects of a farmer's social, economic, and spiritual life. Thus the average Balinese farmer undoubtedly has more experience of direct democratic assemblies than the average Frenchman. These Balinese democratic institutions are not recent innovations; there are references to subaks and to village assemblies in thousand-year-old inscriptions.

Anomalous cases can be useful. Social science has long been fascinated by the Balinese, who have supplied some of the most colorful footnotes for our textbooks. But for the reasons we have just considered, it has proven difficult to get them safely tucked into their proper position in the "premodern" rear guard. The more we understand about Balinese society, the more the Balinese people seem to be marching off in both directions at once, adding new embellishments to their ancient rituals of status while also devoting themselves to the perfection of formal systems of self-governance. I am not the first anthropologist to take note of this paradox: Hildred and Clifford Geertz famously observed that "in Bali, *homo aequalis* and *homo hierarchicus* are engaged in war without end." Clifford Geertz also shares my skepticism about the application of standard social science models to Balinese society. "It is fatally easy," he writes, "to fit the Balinese state to one or another of these familiar models, or to all of them at once. . . . Yet to reduce [it] to such tired commonplaces, the worn coin of European ideological debate, is to allow most of what is most interesting about it to escape from view. Whatever intelligence it may have to offer us about the nature of politics, it can

hardly be that big fish eat little fish, or that the rags of virtue mask the engines of privilege."[4]

• • •

I would probably have lacked the courage to begin with this rather extravagant introduction had I not witnessed a series of social and environmental crises on Bali whose origins lie in precisely this problem, the failure of a Western social science preoccupied with modernity to adequately encompass the Balinese world. It is worth remembering that topics such as modernity, which appear as theoretical issues in academic classrooms, take on enormous practical significance in those parts of the world, such as Bali, where social scientists have given themselves the mission of promoting "modernization." As John Maynard Keynes wrote in the conclusion to his *General Theory* (1935), when madmen in authority hear voices in the air, they are likely to be listening to some academic scribbler of a few years back. Today, the path from academic scribbles to large-scale social engineering projects is nowhere shorter than in what is called the "developing world," where each new Five Year Plan must reflect the latest ideas about how to accelerate modernization.

Over the past forty years the Balinese have had much to do with Five Year Plans. The experience seems to have bred a profound ambivalence, particularly among the civil servants who are responsible for their actual implementation. On the one hand, Five Year Plans are seen as a good thing; they signify that the governance of the nation has passed from the hands of Western imperialists back to the Indonesians themselves. But in a paradoxical way, the Five Year Plans have actually intensified the involvement of Western advisers in policies related to rural development, compared with the role of the colonial civil services in the past. The explanation for this paradox is that colonial officials had limited practical goals, such as increasing agricultural production, and soon convinced themselves that the management of the rice paddies could be safely left in the competent hands of Balinese farmers. In contrast, the goals of the postcolonial Five Year Plans involved nothing less than wholesale social transformation, the comprehensive modernization of the countryside.

With the advent of the Five Year Plans, in the late 1960s a network of new institutions designed to achieve fundamental changes in the management of agriculture began to appear in Balinese villages. Farmers were urged to follow the advice of the agricultural extension service as a matter of patriotism, as their contribution to national development. It was

[4] Clifford Geertz, *Negara: The Theatre State in Nineteenth-Century Bali*, Princeton, N.J.: Princeton University Press, 1980: 123.

foreseen by the architects of the modernization plans that the new methods would come into conflict with preexisting local ideas; indeed they were intended to do so. The planners and consultants were prepared to believe that the farmers of Bali were already practicing effective techniques for managing irrigation and growing rice. But however successful such systems might be from a practical perspective, they were not designed to accomplish the broader goals of modernization. Five Year Plans were seen as an extension of the nationalist agenda: why should social and economic change be haphazard, when it could be intelligently guided?

With a long history of rice cultivation and a functioning infrastructure of roads, schools, and government offices, Bali was an obvious choice for field-testing and implementation of the modernization drive in Indonesia. Existing programs to boost rice production were augmented, and were embedded within a larger framework designed to accelerate the spread of capitalism and the adoption of new technology. I began to observe the results of these policies in 1971, when as an undergraduate I spent five months living in a Balinese village. Some farmers were already having second thoughts about the modernization drive, although they told me that they had initially been willing participants. When I returned a few years later, the resistance of the farmers was increasing, but so was the scale of the modernization program. While the new technologies were often ill suited to Balinese conditions, any reluctance to adopt them was taken as a sign of backwardness or even a lack of patriotism. It did not help that the "traditional" Balinese systems of agricultural management were inextricably linked to the Balinese religion. To plant native Balinese rice instead of the hybrid "Green Revolution" varieties endorsed by the extension service was to place oneself in opposition to the whole agenda of forward-looking nationalism and modernization.

The strength of sentiments on both sides of this issue was brought home to me when I attempted to alert foreign consultants in charge of the modernization programs to practical problems that the farmers were encountering as these plans were implemented. By the mid-1970s, harvests were failing in some regions as a consequence of explosions in the populations of rice pests and chaos in irrigation scheduling. Expensive new irrigation machinery installed in the weirs and canals at the behest of the consultants was being torn out by the farmers as soon as they felt that it was safe to do so. The explanation for these problems, I suggested, was that the traditional Balinese system of water management had simply gone unnoticed by the consultants. This system had been extensively studied by scholars during the colonial era, but their descriptions were mostly published in obscure Dutch academic journals, and so were easily overlooked. Moreover, traditional Balinese techniques for water control

and terrace management are based on principles nearly opposite to those of the top-down control structures favored by the planners. The Balinese manage things from the bottom up, by means of nested hierarchies of water temples that cooperate in setting irrigation schedules. To a planner trained in the social sciences, management by water temples looks like an arcane relic from the premodern era. But to an ecologist, the bottom-up system of control has some obvious advantages. Rice paddies are artificial aquatic ecosystems, and by adjusting the flow of water farmers can exert control over many ecological processes in their fields. For example, it is possible to reduce rice pests (rodents, insects, and diseases) by synchronizing fallow periods in large contiguous blocks of rice terraces. After harvest, the fields are flooded, depriving pests of their habitat and thus causing their numbers to dwindle. This method depends on a smoothly functioning, cooperative system of water management, physically embodied in proportional irrigation dividers, which make it possible to tell at a glance how much water is flowing into each canal and so verify that the division is in accordance with the agreed-on schedule.

Modernization plans called for the replacement of these proportional dividers with devices called "Romijn gates," which use gears and screws to adjust the height of sliding metal gates inserted across the entrances to canals. The use of such devices makes it impossible to determine how much water is being diverted: a gate that is submerged to half the depth of a canal does not divert half the flow, because the velocity of the water is affected by the obstruction caused by the gate itself. The only way to accurately estimate the proportion of the flow diverted by a Romijn gate is with a calibrated gauge and a table. These were not supplied to the farmers, although $55 million was spent to install Romijn gates in Balinese irrigation canals, and to rebuild some weirs and primary canals.

The farmers coped with the Romijn gates by simply removing them or raising them out of the water and leaving them to rust. This naturally upset the consultants when they eventually became aware of it. "Everybody can criticize and damage a project," a senior official complained, "but only few people can overcome those difficult problems and make the project viable."[5] Still, problems like this were not unexpected, and were viewed as merely practical difficulties in the transition to modern agricultural practices. Meanwhile, the modernization drive continued. In

[5] Letter to the Vice President (Projects) from Director, IRDD, 2 October 1984, Asian Development Bank. Professor Lucas Horst comments on the consequences of this error by the irrigation engineers in *The Dilemma of Water Division: Considerations and Criteria for Irrigation System Design*, Colombo: International Irrigation Management Institute, 1998.

a program called "Massive Guidance," an agricultural credit system was developed to promote the use of chemical pesticides and fertilizers. Dozens of warehouse complexes were built in rural Bali in order to make seeds and agrochemicals (bundled into "technology packets") available to the farmers on credit. The cost of the technology packets was recouped by deducting it from the farmers' profits when they returned to the warehouses to sell their harvests.

At first, "Massive Guidance" appeared to be a success. Farmers easily fell into a routine of purchasing "technology packets" and selling their crops for cash, which could be used to purchase consumer goods such as motorcyles. But it turned out that there were hidden environmental costs. Rice pests soon acquired resistance to pesticides. The agricultural service responded by prescribing more pesticides. Within a few years resistant pests such as the brown leafhopper were devastating rice crops, in some areas consuming the entire harvest. While the extension service turned to aerial pesticide-spraying campaigns, the farmers found a more effective solution by returning to the old system of coordinated region-wide fallow periods, organized by water temples. Pesticide usage declined, but meanwhile it was becoming apparent that the technology packets were triggering another major environmental crisis. The fertilizer contained in these packets included phosphate and potassium, minerals that are naturally abundant in the volcanic soil of Bali. Monsoon rains falling on the island leach these nutrients from the soil, and irrigation canals continuously transport them to the rice paddies. The result is a very efficient hydroponic system of fertilization, which in the past enabled the farmers to grow crops in the same fields for centuries without harming the land. But this natural system of fertilization was ignored by the designers of the "technology packets." A few years ago my colleagues and I began to measure nutrient concentrations in the paddies and irrigation canals, before and after fertilization. We found that most of the superfluous fertilizer flows out of the paddies and back into the rivers. By the time the rivers reach the sea, they contain very high levels of nitrogen and phosphate, which pollute the coastal zone. Many coral reefs located near the mouths of these rivers are dead or dying, blanketed with algal growths triggered by the excess nitrogen.

Altogether, the cumulative impact of modernization schemes such as Romijn gates and technology packets has been devastating to the ecology of the rice terraces, and to the social institutions that the Balinese have traditionally used to manage them. Yet these "environmental" and social problems are still not perceived by planners as serious issues. "Massive Guidance" is only incidentally about farming; its purpose is to promote the modernization of the countryside, and so questions like the effects of agrochemicals on the environment are seen as peripheral, while the

breakdown of traditional systems of management may actually be viewed as a good thing. The task that the planners have set themselves is to graft modernization programs onto whatever happens to be growing in the hinterlands. Oil palm plantations or copper mines could accomplish the same ends, if the island were endowed with different resources. Simply put, if "technology packets" lead to blighted reefs, it is the price of progress. It seems that the economist Keynes was right: "the ideas of economists and political philosophers, both when they are right and when they are wrong, are more powerful than is commonly understood. Indeed the world is ruled by little else."

Over the past few decades I have had many conversations with planners and consultants about their projects in Bali. Whenever possible I have seized the opportunity to invite them to visit a water temple and talk with the farmers directly. This never worked out quite as I had hoped: the consultants were usually delighted to make these trips, but they had to be scheduled so as not to conflict with the planner's real work, which always took place in hotels and government offices. Gradually I came to understand that the consultants saw their job as energizing the civil service. The views of the farmers, and indeed all the particularities of the Balinese case, are largely irrelevant to this task. When I returned the consultants to their hotels, the image that often came to mind was that of a team of specialists vigorously treating a patient for what might prove to be the wrong disease. Why, I wondered, do the consultants believe that the details don't matter?

In retrospect the answer seems embarrassingly obvious. From the perspective of conventional Western social science, the details of how "traditional" societies like Bali are organized really don't matter. The great social theorists from Marx to Durkheim, Weber, and Parsons were unanimous in their view of "traditional society" as an uncomplicated world held together by the bonds of kinship. One finds this view articulated today by the leading contemporary European social theorist, Jürgen Habermas. In his major work, *The Theory of Communicative Action*, Habermas explains that in traditional societies "the system of kinship relations forms something like a total institution."[6] According to Habermas, the central problem for the social theorist is to comprehend the patterns of change by which this simple world has been transformed. "Traditional" societies are merely the baseline from which modernity began to emerge, while fully modern societies are theaters of continual change. Consequently, the task for practicing social scientists in a place

[6] Jürgen Habermas, *The Theory of Communicative Action*, vol. 2, translated by Thomas McCarthy, Boston: Beacon Press, 1981: 157.

like Bali is to work with the agents of change, the modernizing civil service.

This perspective also creates a division of academic labor in the social sciences, reserving the study of "traditional" societies for anthropologists. It is in keeping with this division of labor that we anthropologists should spend our time tranquilly in the villages talking to farmers about topics like magic and kinship while other social scientists are busy helping the civil service invent the future. Still, as the anthropologist Marshall Sahlins observed a few years ago, it would be rather pathetic if anthropology never discovered anything that might complicate this view: "a hundred years of thought and fieldwork, all that mental and physical discomfort, would have been largely for nothing—an immense detour into the uncharted hinterlands of mankind that merely brought us back to the starting point."[7] My intention here, as the reader will have gathered, is to complicate this picture. I ask the reader's indulgence for beginning this book with so much indecorous hand-waving to signal its broader messages. My excuse is that otherwise it is likely to become the written equivalent of those field trips for the consultants, just another anthropological entertainment.

• • •

This book began with a question posed by a colleague. In 1992 I gave a lecture at the Santa Fe Institute, a recently created research center devoted to the study of "complex systems." My talk focused on a simulation model that my colleague James Kremer and I had created to investigate the ecological role of water temples. I need to explain a little about how this model came to be built; if the reader will bear with me, the relevance will soon become clear.

Kremer is a marine scientist, a systems ecologist, and a fellow surfer. One day on a California beach I told him the story of the water temples, and of my struggles to convince the consultants that the temples played a vital role in the ecology of the rice terraces. I asked Jim if a simulation model, like the ones he uses to study coastal ecology, might help to clarify the issue. It was not hard to persuade him to come to Bali to take a look. Jim quickly saw that a model of a single water temple would not be very useful. The whole point about water temples is that they interact. Bali is a steep volcanic island, and the rivers and streams are short and fast. Irrigation systems begin high up on the volcanoes, and follow one after another at short intervals all the way to the seacoast. The amount

[7] Marshall Sahlins, *Culture and Practical Reason*, Chicago: University of Chicago Press, 1976: 2.

of water each subak gets depends less on rainfall than on how much water is used by its upstream neighbors. Water temples provide a venue for the farmers to plan their irrigation schedules so as to avoid shortages when the paddies need to be flooded. If pests are a problem, they can synchronize harvests and flood a block of terraces so that there is nothing for the pests to eat. Decisions about water taken by each subak thus inevitably affect its neighbors, altering both the availability of water and potential levels of pest infestations.

Jim proposed that we build a simulation model to capture all of these processes for an entire watershed. Having recently spent the best part of a year studying just one subak, the idea of trying to model nearly two hundred of them at once struck me as rather ambitious. But as Jim pointed out, the question is not whether flooding can control pests, but rather whether the entire collection of temples in a watershed can strike an optimal balance between water sharing and pest control.

We set to work plotting the location of all 172 subaks lying between the Oos and Petanu rivers in central Bali. We mapped the rivers and irrigation systems, and gathered data on rainfall, river flows, irrigation schedules, water uptake by crops such as rice and vegetables, and the population dynamics of the major rice pests. With these data Jim constructed a simulation model (Figure 1). At the beginning of each year the artificial subaks in the model are given a schedule of crops to plant for the next twelve months, which defines their irrigation needs. Then, based on historic rainfall data, we simulate rainfall, river flow, crop growth, and pest damage. The model keeps track of harvest data and also shows where water shortages or pest damage occur. It is possible to simulate differences in rainfall patterns or the growth of different kinds of crops, including both native Balinese rice and the new rice promoted by the Green Revolution planners. We tested the model by simulating conditions for two cropping seasons, and compared its predictions with real data on harvest yields for about half the subaks. The model did surprisingly well, accurately predicting most of the variation in yields between subaks. Once we knew that the model's predictions were meaningful, we used it to compare different scenarios of water management. In the Green Revolution scenario, every subak tries to plant rice as often as possible and ignores the water temples. This produces large crop losses from pest outbreaks and water shortages, much like those that were happening in the real world. In contrast, the "water temple" scenario generates the best harvests by minimizing pests and water shortages.

Back at the Santa Fe Institute, I concluded this story on a triumphant note: consultants to the Asian Development Bank charged with evaluating their irrigation development project in Bali had written a new report

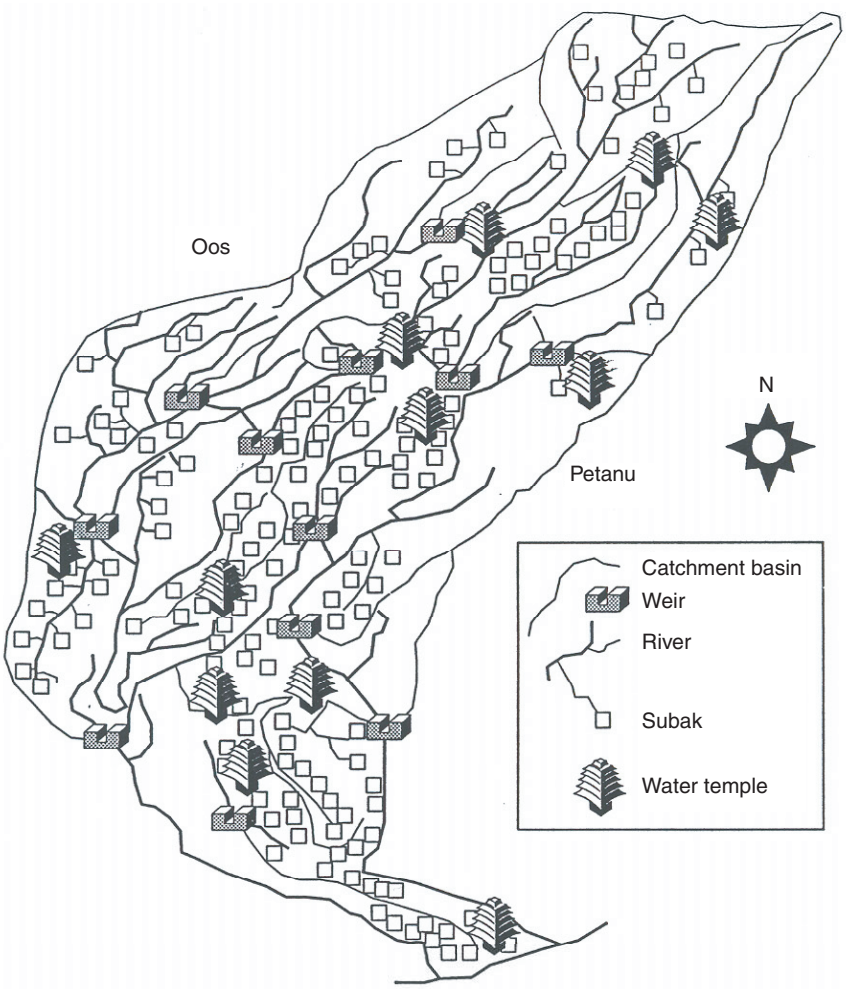


Figure 1. The original Bali model.
This map shows the approximate locations of catchment basins, irrigation systems, and 172 subaks located in the watersheds of the Oos and Petanu rivers in central Bali. Map is not to scale.

acknowledging our conclusions. There would be no further opposition to management by water temples. When I finished my lecture, a researcher named Walter Fontana asked a question, the one that prompted this book: could the water temple networks self-organize? At first I did not understand what he meant by this. Walter explained that if he understood me

correctly, Kremer and I had programmed the water temple system into our model, and shown that it had a functional role. This was not terribly surprising. After all, the farmers had had centuries to experiment with their irrigation systems and find the right scale of coordination. But what kind of solution had they found? Was there a need for a Great Designer or an Occasional Tinkerer to get the whole watershed organized? Or could the temple network emerge spontaneously, as one subak after another came into existence and plugged in to the irrigation systems? As a problem solver, how well could the temple networks do? Should we expect 10 percent of the subaks to be victims of water shortages at any given time because of the way the temple network interacts with the physical hydrology? Thirty percent? Two percent? Would it matter if the physical layout of the rivers were different? Or the locations of the temples?

Answers to most of these questions could only be sought if we could answer Walter's first large question: could the water temple networks self-organize? In other words, if we let the artificial subaks in our model learn a little about their worlds and make their own decisions about cooperation, would something resembling a water temple network emerge? It turned out that this idea was relatively easy to implement in our computer model. We created the simplest rule we could think of to allow the subaks to learn from experience. At the end of a year of planting and harvesting, each artificial subak compares its aggregate harvests with those of its four closest neighbors. If any of them did better, copy their behavior. Otherwise, make no changes. After every subak has made its decision, simulate another year and compare the next round of harvests. The first time we ran the program with this simple learning algorithm, we expected chaos. It seemed likely that the subaks would keep flipping back and forth, copying first one neighbor and then another as local conditions changed. But instead, within a decade the subaks organized themselves into cooperative networks that closely resembled the real ones.[8]

This discovery prompted a new question. Were the temple networks a solution, or a device for finding solutions? In other words, had the subaks solved a problem, or built themselves a problem solver? In some ways, the networks looked like a problem solver. For example, if we fiddled with the environmental conditions in the simulation—for example,

[8] In subsequent experiments we found that varying the environmental conditions—for example, by changing the rainfall patterns—led to slightly different network configurations. But as long as rice could grow in our artificial fields, adaptive networks always emerged.

by reducing rainfall—the networks would adapt by adjusting the patterns of synchronized cropping among the subaks. For this system to work in the real world, the subaks would need to be able to rapidly alter the scale at which they cooperated with their neighbors. While we were thinking about this question and experimenting with the model, Fontana and other researchers at the Santa Fe Institute were asking more basic questions about the nature of networks, which turned out to be relevant. There is an interesting distinction between networks created by engineers, such as the wiring system of a car or an airplane, and those that evolve, such as immune systems. An airplane's control system is designed to keep the plane flying by solving many specific problems. Each type of plane has its own wiring system; the network that controls a Boeing 727 would not work on an Airbus, and making changes in midair would not be a good idea. Immune systems are different, not only because they are produced by natural selection, but also because they must be able to cope with a much larger range of problems. They cannot specialize in defeating a single type of virus; instead they must have the ability to adapt to whole classes of possible invaders. Consequently, natural selection does not focus on optimizing one solution, but rather on improving the features of the system that enable it to learn and adapt. If real water temple networks were not created by a Great Designer, but rather came into existence by a process of trial and error like those modeled in our computer simulations, then they might be more like immune systems than the wiring of an aircraft. A self-organizing water temple network would need to be able to cope with many fluctuating environmental variables. Hence there would be rewards for temples that could function as efficient nodes or components in networks.

The analogy with self-organizing networks like immune systems had a further implication. Water temples are physically located at or near the main components of the irrigation systems. Most of the time they stand empty. Thus one can think of them as a sort of map of the hydrology of the watershed: the lakes, rivers, dams, canals, and blocks of terraces. This map acquires functionality when groups of farmers decide where to position themselves on it and exert control. The ability to shift the scale at which synchronized irrigation occurs is what gives temple networks their ability to manage the ecology. With that ability, the temple networks become flexible problem solvers.

Whether or not this was how things actually worked in the real world, it was an interesting idea. In the model world, or as they say in Santa Fe, *in silico*, the functionality of the temple networks is based on their capacity for dynamic behavior. The faster they can react by reconfiguring themselves into different patterns, the better they do at managing the

ecology.[9] This was a model for an intrinsically dynamic social institution. The capacity of water temple networks to solve problems at the global (watershed) scale could emerge from decisions taken at local scales. The success of the temple networks would depend on their ability to gather and respond to information from local environments. But most critically it would depend on cooperation. Farmers would have to be willing to cooperate with different-size groups in sharing their most precious resource, water. But if they could manage to sustain such cooperation, the simulations showed that something rather magical could occur. If each local group of farmers acts in its own interests and responds to purely local conditions, all the groups benefit as a solution for the entire watershed emerges. In the simulations, subaks begin by experimentally cooperating with their closest neighbors. Patches of cooperation appear and grow, adjusting their borders and irrigation schedules until the entire watershed is connected. The system grows from the bottom up, and rapidly adapts until globally optimal patterns of behavior emerge. Once the networks are in place, from year to year they can cope with changes in local environmental conditions.

The sheer inevitability of the appearance of networks in the model world naturally led us to wonder about the real world. We imagined a historical scenario for Bali that might have begun with the appearance of a few small irrigation systems. As irrigation expanded, these systems would have come into contact with their neighbors and begun to interact. The ability to vary the scale of water control in response to changing conditions would have been the key to success. If water temples began to function like nodes in a network, then an efficient and adaptable system of control could have emerged with no need for centralized planning. The real world was bound to be a lot messier than our computer simulations, but this scenario gave us a place to begin.

So about a year after the lecture at the Santa Fe Institute, with support from the National Science Foundation Kremer and I were able to return to Bali to take a fresh look at water temples. By then the question of the

[9] An illustration may help to clarify this point. Imagine a jigsaw puzzle of a watershed with perhaps hundred subaks, where each color signifies a cropping plan for the year: yellow might mean "plant a particular rice variety the week of February 15, and a different rice variety the week of July 20." Groups of subaks up and down the river choose this plan, while others adopt different plans, symbolized by different colors. The result, for the whole watershed, is a patchwork of colors. An enormous variety of different-size and different-color patches is possible, but nearly all of them would lead to widespread water shortages and pest outbreaks. Very few patterns will produce the abundant harvests for whole watersheds that the farmers actually enjoy. And the scale and color of the patches for optimal solutions will vary from year to year as environmental conditions change, or new irrigation systems come into existence.

functional role of water temples had become rather urgent at the Ministry of Agriculture research centers in Bali. We began to collaborate with members of their research staff. One question soon led to another, and before long we were joined by colleagues from other disciplines, from archaeology to computer science. This book describes the questions that we asked and the answers that we found.

• • •

Our first question was whether the conceptual model of self-organizing temple networks bore any resemblance to the actual history of irrigation development in Bali. There is a decades-old controversy among historians and anthropologists about the management of Balinese irrigation systems in the past. Were they entirely controlled by the subaks, and therefore decentralized? Or did the rajahs exert some form of centralized control? The fact that such a straightforward question could be debated for so long suggests that neither of these alternatives is entirely correct, and our model suggested a third alternative. But the model was based on contemporary data; whether it might illuminate the past would depend on the answers to several historical questions. For example, when did irrigation begin in Bali? How was it organized in the ancient kingdoms? When did subaks and water temples appear, and what was the scope of their authority?

We approached these questions from two directions. First, we reevaluated what is already known about the archaeology of water control, not only in Bali but also in neighboring agrarian kingdoms. Second, we undertook our own archaeological studies at the site of an ancient water temple and irrigation system. Chapter 2 describes our results, and suggests a historical explanation for the origins of the subaks and water temples. The argument turns on a point-by-point comparison of the history of water control in Bali with parallel developments on the neighboring island of Java. I have tried to make this comparison interesting for readers who are not archaeologists, but despite my best efforts it is not hard to get lost in the details. Readers who are not particularly interested in the historical origins of the subaks and water temples may prefer to read the summary at the end of the chapter and continue on to chapter 3.

In chapter 3, we return to the question of the ecological effects of water temple networks, and the basis for cooperation among the farmers. Kremer's model of 172 subaks in the Oos and Petanu watersheds was designed to capture the effects of temple networks at a gross scale. Clearly, the next step was to see whether its predictions were borne out in the actual management of the rice terraces. We decided to study fourteen subaks that form the congregation of one large water temple, the

Masceti Pamos Apuh, which is located in the same region as our archaeological excavations. By putting one small network of subaks and water temples under the microscope, we hoped to discover whether these networks really function as problem solvers. This chapter draws on some ideas from systems ecology and game theory, but they are discussed at a level that assumes no prior knowledge of these fields.

Chapter 4 continues the analysis of the fourteen subaks of Masceti Pamos Apuh. The emphasis shifts from ecology to the governance of the subaks. We pursue Karl Marx's fundamental question: who benefits? Does *Homo hierarchicus* really disappear in subak meetings, or does he merely put on some form of disguise? How do these self-governing bodies cope with conflicts and failures?

Chapter 5 continues the analysis of *Homo aequalis* in the subaks, but looks at the question from a Balinese perspective. Subaks devote a great deal of their time and resources to religious activities in the water temples. How are we to understand the relationship between these religious activities—the cult of water temples—and the functional role of the subaks and temple networks? This chapter follows our attempts to comprehend the deeper meaning of these rituals and beliefs, especially those that relate to the democracy of the subaks.

Chapter 6 focuses on Bali's supreme water temple, located on the rim of the central volcano overlooking a crater lake. This temple has the power to alter the decisions of the subaks, and it is governed by priests who are endowed with much greater spiritual authority than ordinary water temple priests. The very existence of such a temple appears to contradict the idea of water temple networks as decentralized, self-governing institutions. Fieldwork was aimed at resolving this puzzle. The results helped clarify not only the role of this temple but the deeper meaning of the water temple cult.

Chapter 7 concludes with a summary of what we learned from this series of investigations, and some reflections on the implications. To help orient the reader, I will foreshadow some of these conclusions here. The water temples of Bali went mostly unnoticed until the Green Revolution in agricultural interfered with their role in the management of rice terrace ecology. But even after their functional role became apparent, they proved to be difficult to comprehend from within the horizons of Western social science. Water temple networks depend on unprecedented levels of cooperation among farmers; they actively manage the ecology of the rice terraces at the scale of whole watersheds, and they appear to be organized as dynamical networks. Moreover, a great deal of what goes on in them falls into the Western category of "religion" or even "magic." But from the perspective of Balinese farmers, these "magical" ideas and practices provide indispensible tools for governing the subaks, the rice

paddies, and their own inner worlds. Water temple rituals draw on Hindu and Buddhist traditions of thought to create the preconditions for a robust system of self-governance. The wedding of these ideas with the managerial capacity of temple networks provides powerful tools for communities to impose an imagined order on the world. However, the farmers' recognition that such tools exist is coupled with an awareness of the ease with which they can fail. A certain kind of self-mastery, and awareness of interdependencies, is understood to be a prerequisite for governing both the social and natural worlds. These Balinese ideas about selfhood contrast with the celebration of the emergence of the autonomous subject in Western social thought. (A darker vision, perhaps most cogently expressed by the scholars of the Frankfurt School, associates the triumph of the unitary subject with rise of totalitarian rationality. But these two versions of the story of the emergence of the subject, which seem to us so far apart, draw similar connections between objective economic conditions and the subjective awareness of individuals.) The world of the water temples, I suggest, has different lessons to impart.