Foreword to 2nd Edition of ***Priests & Programmers***

Steve Lansing began the work reported here, like many anthropologists before him, with the simple intention of exploring the intricate beauty of Balinese culture. Fortunately for those of us whose appreciation of cultural anthropology is more enthusiastic than professional, his curiosity led him to explore questions and deploy methods that reached beyond the boundaries of his native discipline. The result was an enormously rich study of how Bali's human institutions and environmental landscapes coevolved over the centuries to produce a complex adaptive system. That system proved to be sustainable in the face of volcanic eruptions, dynastic warfare, and colonial invasion. It took the well-intentioned but ultimately arrogant expertise of early Green Revolution reformers to push the system beyond its limits and into a mutually reinforcing downward spiral of ecological and social degradation. *Priests and Programmers* tells the story of how Lansing and his collaborators elucidated the interlinked geological, ecological, social, and religious processes that have shaped the Balinese landscape and, in so doing, became entrained in a process of social learning that helped the system to recover some of its previous resilience.

A wide range of scholars, students and development practitioners has come to know and benefit from Lansing's story, assisted not only by the lucid writing style on display in this most welcome new edition of *Priests and Programmers,* but also through an excellent film, an accessible simulation model, and a series of follow-up studies, all available through his web site (XXXXX). I am one grateful beneficiary of the diverse perspectives Lansing has brought to bear on human-environment interactions in Bali, having used them for more than a decade in teaching a course on Sustainable Development at Harvard University's John F. Kennedy School of Government. My course uses four detailed case-studies to explore how scholars, policy makers and local practitioners have interacted in efforts to promote increases in human well-being without degrading the environmental life-support systems on which further development depends. I have kept the Bali story in an otherwise-changing set of course cases over the years simply because it is the one that elicits the most learning in my students, and the one they best recall when I talk with them as alumnae. What makes Lansing's rendition of the Bali story such a pedagogical gold-mine?

First, the Bali story is a specific instance of the much more general case of sustainable use of natural resources to support human well-being in the developing world. Half of the world's people still live in rural communities. A billion or so of those people are poor, with livelihoods more or less directly tied to the continuing productivity of natural resources. Often, as in the Bali case, sophisticated local knowledge of those resource systems and their limits has enabled societies to do quite well in utilizing them sustainably over centuries or longer. Increasingly, however, such traditional use systems have come under pressure from efforts to accommodate more people, increase yields or respond to a globalizing economy. Distressingly often, the result has been catastrophic for both people and the resource systems they inhabit.

Lansing's work is especially valuable in illustrating the multiple forms that may be taken by the "local knowledge" that often turns out to be central to sustainable resource management. The individual villagers he interviewed in Bali clearly knew a great deal about planting rice, protecting it from pests, and building the irrigation systems that provided it with water. Some of this knowledge they could explain to him very articulately. Some was less explicit, consisting rather of the sort of "tacit" knowledge (or knowledge of practice) with which we all are familiar in our daily lives. Lansing's analysis, however, takes the reader far deeper into an understanding of the "local knowledge" that enabled sustainable human development of Bali's steep volcanic slopes. He shows that over the centuries, the value and thus the use of water had taken on not merely material but also spiritual significance for the Balinese. The religious structures, practices and calendar that revered water for its own sake had evolved in ways that also served effectively to regulate and coordinate the sharing of limited water resources among farmers across entire watersheds. The "local knowledge" guiding sustainability thus consisted of what individuals knew and knew how to do, plus the physical system of irrigation canals and water shrines that such peoples' ancestors had constructed over time, plus the enduring religious beliefs that strongly shaped both individual and social action. The elegant systems models of water use and agriculture on Bali created by Lansing and his colleagues clearly show that each of these sorts of "local knowledge" is crucial for the sustainable use of the system. Though the forms of relevant local knowledge would clearly be different for other resource systems, the general teaching value of Lansing's work is in its compelling illustration that local knowledge matters more than we think, that it is more multidimensional than most of us would imagine, and that it is embodied in forms and places that most of us would not suspect.

This leads to what I as teacher, researcher, and occasionally policy advisor have found most valuable in Lansing's work: his demonstration that to most of us, most of the time, most of the knowledge relevant to the sustainable management of resource systems may be simply invisible. Through careful archival work, for example, he shows that the Dutch colonial administrators – though more sensitive than most to the intricacies of water management – "saw" only the irrigation hardware of the Balinese and missed entirely the "soft" role of water temples and related religious practices in regulating the use of the hardware. Similarly, Lansing demonstrates that the Green Revolution agronomists – even the Balinese among them – saw the *tika* calendar as an historical irrelevance, missing its crucial role in setting fallow schedules that resulted in effective pest management. Perhaps most strikingly, he illustrates that well-meaning policy analysts -- raised in the modern science tradition -- were unable to see in religious leaders' generally accurate diagnoses of the crisis conditions of the 1980s anything more than superstition. The cumulative force of these cases of selective blindness sets up one of the most powerful teaching "moments" I have experienced, letting me ask my students (and myself) "What potentially relevant sources of knowledge are *you* overlooking in your present work on sustainable development?"

The stand-and-deliver power of this question is substantially enhanced by Lansing's own demonstration that it can, in fact, be frankly confronted and dealt with. In *Priests and Programmers,* but even more in the associated film *The goddess and the computer*, we see Lansing and his collaborators grappling with the challenge of learning to "see" human-environment interactions through multiple lenses. They go further still, wrestling with the even more perilous task of creating shared frames of reference from which different actors – priests, programmers, and bureaucrats alike -- can see, and understand, one another's views of the world. The use of computer models and graphics by the Lansing team to facilitate this essential "boundary spanning" role is as subtle and self-critical as any I have seen in a career of making and using models to inform resource policy.

This thoroughly delightful little book has long since become a classic in the emerging field of sustainability science. It elegantly illustrates the field's central tenet that complex human-environment systems can be more clearly understood and more effectively managed through the application of appropriate multi-disciplinary concepts, methods and models. It also reminds us of how important it is that those tools of the field be wielded by individuals who are not only careful scholars, but who also approach their work on the very real problems of sustainable development with appropriate empathy and humility. Its republication in this second edition is an occasion for celebrating the occasional ability of good people doing good scholarship to make the world a slightly better place.

William C. Clark
Harvey Brooks Professor of International Science, Public Policy and Human Development
John F. Kennedy School of Government
Harvard University
Cambridge MA 02138 USA

Preface to 2nd Edition of ***Priests & Programmers***

The readership that I anticipated when I began this book was the small community of anthropologists and other scholars interested in Indonesian cultures. The title I had in mind was "The Temple of the Crater Lake", because I thought the most interesting story was the discovery that one of Bali's major temples played a hitherto-unnoticed role in managing the ecology of the rice terraces. But the editors at Princeton persuaded me to adopt a different title, so as to emphasize the contrast between Balinese farming systems and the new methods introduced by Western consultants. This proved to be good advice: the new title helped to bring the book to the attention of a wider readership with different interests than the Bali specialists. The editor's invitation to write a preface for a new edition gives me an opportunity to address some of the questions that both groups of readers have raised.

Priests and Programmers tells the story of well-intentioned but ultimately disastrous attempts by planners to reorganize farming systems on the island of Bali. I did not set out to investigate this topic, instead I stumbled onto it while pursuing more conventional anthropological questions. Like other anthropologists and artists before me, in the 1970's I had become fascinated by Balinese ideas about time, music, literature and the theater, especially as they come to life in performances held in village temples. It seemed permissible to pursue these delightful topics because they were also very popular among the Balinese; this was a time when many Balinese were rediscovering the riches of their "traditional" culture.

It was in these luxurious circumstances that I began to take an interest in the temples connected with agriculture and the "Green Revolution." The agricultural rituals that take place in Balinese fields and water temples require each household to create gorgeous flower offerings to the gods, and the calendar itself is also a thing of beauty, with intriguing connections to ideas about music and the human life cycle. These were the topics that initially captivated me. But as I learned from the farmers, the timing of these agricultural rites was thrown off by the Green Revolution, which required them to plant new hybrid rice varieties as often as field conditions would permit. Some of the rituals of the "rice cult" could be rescheduled to fit the new accelerated timetable for Green Revolution rice. But others, like harvests, could not, because they were tied to the phases of the moon or other ritual calendars. Consequently, while the ancient stone temples were still regularly blanketed with flower offerings shaped into mandalic patterns, the timing of these rites no longer matched the growth of rice in the surrounding fields. And farmers wondered what the consequences might be.

A possible answer soon appeared, in the form of devastating outbreaks of rice pests and interruptions in the flow of irrigation water to the fields. Was there a link between these problems and the disruption of the temple calendars? *Priests and Programmers* opens with this question, which by the early 1980's was becoming a matter of acute concern for Balinese farmers and public works officials. But lurking behind this issue was an even more fundamental question:

Why wasn't the functional role of water temples a matter of common knowledge?

In 1984, as I note in the introduction to *Priests and Programmers,* the head of the irrigation division of Bali's Department of Public Works reported that "study of the role of large-scale coordination of irrigation by temples is urgently needed." How was it possible that the Balinese engineer in charge of irrigation for the island could ask such a question? Or the Dean of the faculty of agriculture at Bali's Udayana University? For that matter, if the temples really did play a functional role in water management and rice production, why was this not reported in the many studies of Balinese farming carried out by Dutch colonial researchers in the early years of the twentieth century?

I began to pursue these questions with the usual research methods of cultural anthropology: digging into the colonial archives and Balinese manuscripts; talking with farmers, extension agents and water temple priests; mapping irrigation systems and observing temple rituals. My starting point was Clifford Geertz' elegant analysis of the Balinese "rice cult", which showed how agricultural rituals were "symbolically linked to cultivation in a way that locks the pace of that cultivation into a firm, explicit rhythm."[1] This rhythm had been disturbed by the Green Revolution. But what exactly were the consequences? Were the effects limited to the domain of culture, or did they extend to the ecology of the rice paddies? This question led me to begin working with a systems ecologist, James Kremer, in 1983. Together we built a computer simulation model of irrigation at the watershed scale, which enabled us to mimic the patterns of coordination created by networks of water temples. Using the model, we could simulate the effects of the Green Revolution by depriving the temples of any functional role, and instructing the artificial farmers to plant rice as often as they could.

The results of these simulations closely resembled the actual patterns of pest outbreaks and water shortages that we observed in the fields. If all the fields within a sufficiently large area harvest at the same time, and the fields are subsequently flooded, rice pests are deprived of their habitat and their populations will decline. However, this technique requires all the farmers in the area to plant their crops at the same time. This requires a lot of water to flood the fields and turn them into ponds. If too many farmers try to do this at the same time, there will not be enough water for their downstream neighbors. Our simulations showed that the temple networks sustain good harvests by finding planting schedules that provide enough water for everyone, but also permit pest control by synchronized fallow periods for each block of terraces. Soon after the temples lost control of planting schedules, pest populations exploded. Indeed, one could think of the Green Revolution as a kind of experimental test of the functional role of water temple networks: remove them from control of irrigation schedules, and see what happens. This was not, of course, what the architects of the Green Revolution had in mind, and they were not particularly pleased to be shown simulations in which their policies drove down harvests by disrupting temple networks. But it did supply an answer to the question of why the functional role of water temples had escaped everyone's attention: before the Green Revolution, the very success of the temple networks in balancing water needs and sustaining good harvests made them nearly invisible.

[1] Clifford Geertz, Negara: The Theatre State in Nineteenth Century Bali. Princeton, N.J.: Princeton University Press, 1980, 82,

Are the water temples of Bali a unique case?

This question came up soon after Kremer and I began to publish our results. Perhaps the Maya or the ancient Khmer had invented something like the Balinese water temples? But in the end, the most interesting comparison we found was much closer to Bali. And it had nothing to do with irrigation, temples or rice.

In 1967, the year the Green Revolution began in most of Indonesia, another government program opened the forests of the Outer Islands to logging for export. Like the Green Revolution, this policy inadvertently set in motion an experimental test of the resilience of a tropical ecosystem. And like the Green Revolution, it produced immediate, spectacular results. By the early 1970's, logging exports were generating annual export earnings of over US$1.5 billion, eventually rising to as much as $6 billion.[2] As the Ministry of Forestry proclaimed in 1990,

> The logging industry is a champion of sorts. It opens up inaccessible areas to development; it employs people, it evolves whole communities; it supports related industries…It creates the necessary conditions for social and economic development. Without forest concessions most of the Outer Islands would still be underdeveloped.[3]

By the 1980's, in response to indications of forest degradation from logging, the Ministry began to promote industrial tree plantations for the pulp and paper industry, supported by interest-free loans from the "Reforestation Fund" and international investment. Along with reforestation, the government also encouraged the creation of palm oil plantations on logged land. Sawmills, logging roads and palm plantations proliferated in the 1990's, and exports of pulp, paper and palm oil boomed. In 2002, export taxes on raw logs were eliminated and Indonesian firms were permitted to sell logs to anyone. Plans for biodiversity conservation were based on selective logging and reforestation, and the creation of national parks.[4]

The dominant canopy tree family in Borneo and Sumatra is the *dipterocarpaceae*, which consists of ~267 tree species that make up over 85% of Indonesia's tree exports. The sustainability of the timber industry thus depends on the regenerative capacity of dipterocarp forests. In 1999, ecologist Lisa Curran and her colleagues reported the results of a comprehensive 14 year investigation of the ability of the dipterocarps to reproduce. Regrowth depends on the survival of sufficient quantities of seedlings. Many forest

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[2] "Over the past two decades, the volume of dipterocarp timber exports (in cubic meters) from Borneo (Kalimantan, Sarawak and Sabah) exceeded all tropical wood exports from tropical Africa and Latin America combine." Curran et al., Lowland Forest Loss in Protected Areas of Indonesian Borneo. Science 303 (2004):1000-1003.

[3] Situation and outlook for the forestry sector in Indonesia. Jakarta: Food and Agriculture Organization and Directorate General of Forest Utilization, Government of Indonesia, 1990.

[4] Paul K. Gellert, The Shifting Natures of "Development": Growth, Crisis and Recovery in Indonesia's Forests. World Development 33:8 (2005):1345-1364.

animals and birds are seed predators, so the trees are engaged in a continuous race to produce more seeds than the predators can consume. Curran found that long ago, the trees evolved essentially the same solution to the problem of controlling predation that was later discovered by the Balinese farmers: reproductive synchrony. Dipterocarp forests produce nearly all of their seeds and fruits within a very small window in time, in a phenomenon known to ecologists as "mast fruiting." For seed predators, this means that large quantities of dipterocarp fruits and seeds only become available in short irregular bursts that occur every 3-6 years, triggered by the El Nino Southern Oscillation (ENSO). ENSO is a global climatic cycle that causes an extreme reduction in rainfall in Borneo from June to September. The ENSO dry spell is used by the trees as a signal to initiate flowering and reproduction. Seed predators respond by synchronizing their own reproductive cycles to ENSO years, and by moving across the landscape, far from their usual ranges, to feed on dipterocarp seeds.

Over the past three decades, the harvesting of timber caused widespread fragmentation of what had formerly been a vast contiguous expanse of dipterocarp forest in Borneo, disrupting regional reproductive synchrony. Once synchrony was lost, small-scale local masts could not produce enough seedlings to escape being eaten by predators. Curran's extensive observations and field experiments led to a single conclusion: "Seed escape, and thus regeneration, only occurred in major mast events when all dipterocarp species across large areas participated."[5] The parallel with the Balinese case is exact. In the rice terraces of Bali, disruption of the synchronized planting schedules formerly organized by water temple networks led to crop failure, as migrating pests moved across the landscape consuming one harvest after the next. Similarly, in Borneo the mast synchrony of canopy trees depended on signals sent through the root system. When the forests became fragmented, it was no longer possible to overwhelm predators with a vast synchronized mast.

We now know that in both Bali and Borneo, large-scale reproductive synchrony emerged as a solution to the problem of controlling seed predators. But in both cases, this cyclical pattern was invisible to planners. In Bali, the farmers were able to respond in the nick of time and restore control to the temple networks. But the trees were not so fortunate. The latest research by Curran and her colleagues shows that the lowland forests of Indonesian Borneo have lost the capacity to regenerate, probably beyond hope of recovery. As a consequence, ENSO – formerly a great forest regenerator – has become a destructive regional phenomenon, triggering droughts and wildfires with increasing intensity. By the 1990's, much of Indonesian Borneo had been deforested, leaving logging debris in place of canopy trees. When ENSO arrived in 1998, forest fires raged across the island and four hundred million metric tons of carbon were released into the atmosphere. Even peat swamps caught fire, adding another two hundred million tons of carbon. (For comparison, the Kyoto target for reduction in carbon emission for the whole earth was five hundred million tons).[6]

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[5] L.M. Curran and M. Leighton, "Vertebrate Response to Spatiotemporal Variation in Seed Production of Mast-Fruiting Dipterocarpacae". *Ecological Monographs* 70:1, p.102.
[6] Curran estimates that by 2005, less than 35% of the lowland forests (<500 m a.s.l.) were still standing, most of them already degraded (*personal communication).*

Thus in both Borneo and Bali, synchronized growing cycles emerged as a solution to the problem of controlling predator populations in the winterless tropics, imposing a clockwork pattern on the life cycles of many species. At least in this respect, the water temple networks of Bali were not unique. Might other, similar systems exist elsewhere? If so, would they always be driven by the need for predator control? How much of the functional structure of the water temple networks was directly tied to the ecology of Bali or the biology of pests?

In 1998 we published a paper in the *Journal of Theoretical Biology* suggesting that phenomena like water temple networks or the Borneo forest clock could emerge spontaneously as global solutions to local problems.[7] We argued that this process- the emergence of self-regulating structures from the bottom up- was not tied to the specific ecology of Balinese rice terraces. But such systems would be likely to fade into the background as long as they were functioning normally. Our thinking on this question was influenced by the work of ecologists on the emergence of self-organized systems, and we used "Daisyworld", a thought experiment created by the chemist James Lovelock, to make our case.[8] Daisyworld had several advantages for us: the biology is as simple as Lovelock could make it; the model shows precisely how small-scale local adaptations can produce an emergent global structure; and it also shows why such global structures can easily fade from view, becoming noticeable only when the system as a whole has been pushed near its limits.

Lovelock's model is simple and interesting enough to be included here. Daisyworld is an imaginary planet orbiting a star like the Sun and at the same orbital distance as the Earth. The surface of Daisyworld is fertile earth sown uniformly with daisy seeds. The daisies vary in color, and daisies of similar color grow together in patches. As sunshine falls on Daisyworld, the model tracks changes in the growth rate of each variety of daisy, and changes in the amount of the planet's surface covered by different-colored daisies. The simplest version of this model contains only two varieties of daisies, white and black.

Black daisies absorb more heat than bare earth, while whites reflect sunshine. Clumps of same-colored daisies create a local microclimate for themselves, slightly warmer (if they are black) or cooler (if white) than the mean temperature of the planet. Both black and white daisies grow fastest and at the same rate when their local effective temperature (the temperature within their microclimate) is 22.5°C, and they respond identically, with a decline in growth rate, as the temperature deviates from this ideal. Consequently, at given average planetary temperature, black and white daisies experience different microclimates and therefore different growth rates.

If the daisies cover a sufficiently large area of the surface of Daisyworld, their color affects not only their own microclimate but also the albedo or reflectance of the planet as a whole. Like our own sun, the luminosity of Daisyworld's star is assumed to have gradually increased. A simulation of life on Daisyworld begins in the past with a cooler sun. This enables the black daisies to spread until they warm the planet. Later on,

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[7] J. Stephen Lansing, James N. Kremer and Barbara B. Smuts, "System-dependent selection, ecological feedback and the emergence of functional structure in ecosystems", Journal of Theoretical Biology **192**, 377-391.

[8] James E. Lovelock, A numerical model for biodiversity. *Phil. Trans. R. Soc. Lond.* ***B*** , **338** (1992), 365-373.

as the sun grows hotter, the white daisies grow faster than black ones, cooling the planet. So over the history of Daisyworld, the warming sun gradually changes the proportion of white and black daisies, creating the global phenomenon of temperature regulation: the planet's temperature is held near the optimum for the daisies, as shown in Fig. 1.

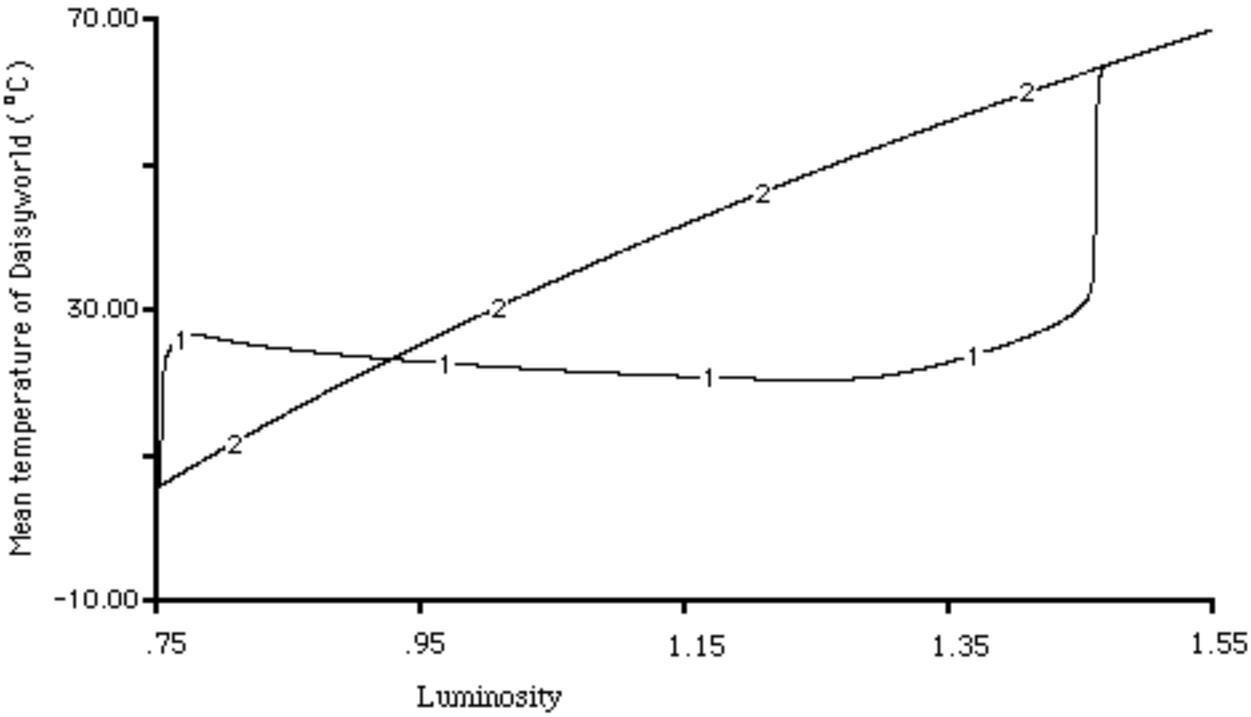

Figure 1: Results of a simulation of temperature regulation on Daisyworld. As the sun ages and it's luminosity increases from 0.75 to 1.5 times the present value (1.0), the temperature of a bare planet would steadily rise (2). In contrast, with daisies present, the temperature stabilizes close to 22.5° C (1).

Imagine that a team of astronauts and planners is sent to investigate Daisyworld. They would have plenty of time to study the only living things on the planet, and they would almost certainly conclude that the daisies had evolved to grow best at the normal temperature of the planet, 22.5° C. But this conclusion would invert the actual state of affairs. The daisies did not adapt to the temperature of the planet; instead they adapted the planet to suit themselves.[9] A Daisyworld without daisies would track the increase in the sun's luminance (line 2), rather than stabilizing near the ideal temperature for daisies (line 1). Only when the sun's luminosity becomes too hot for the daisies to control (~1.4) will the daisy's former role in temperature stabilization become apparent.

Lacking this understanding, planners hoping to exploit Daisyworld's economic potential as a flower supplier would fail to appreciate the possible consequences of different harvesting techniques. While selective flower harvests would cause small,

[9] Peter T. Saunders, Evolution without Natural Selection: Further Implications of the Daisyworld Parable. *J. Theor. Biol.* **166** (1994), 370.

probably unnoticeable tremors in planetary temperature, clear-cutting large contiguous patches of daisies would create momentary changes in the planet's albedo that could quickly become permanent, causing temperature regulation to fail and daisy populations to crash.

Daisyworld and the dipterocarp forests of Borneo are simpler systems than the water temple networks of Bali. While daisies and dipterocarps have only one parameter to manage (respectively, temperature and pests), the temple networks need to adjust the balance between water sharing and pest control at multiple sites in large, interdependent and interconnected irrigation systems. This is a much more complicated problem, which inevitably produces temporary winners and losers as environmental conditions fluctuate. But the very simplicity of Daisyworld's flowers and Borneo's trees may help to clarify the more subtle dynamics of the water temple networks.

What's happening now?

Priests and Programmers recounts the history of our attempts to convince planners of the functional importance of water temple networks. In the end we were successful: today, except for some farms located near urban settlements, where the temple system no longer functions, the control of cropping cycles has returned to the temple networks, and farmers are no longer urged to plant rice as fast as they can. Indeed, the agricultural extension service in Bali has become a strong advocate for the temple system. Pesticide use has also declined, as pest populations were brought under control by the system of regional fallow periods. But one key component of the Green Revolution package remains in place, causing needless ecological damage at a high cost to the farmers, and threatening the long-term productivity of the rice terraces.

Green Revolution plants are bred to make efficient use of chemical fertilizers. When the Green Revolution began in Indonesia, fertilizer production was expanded and farmers were instructed to purchase "technology packets" containing seeds, fertilizers and pesticides on credit.[10] The fertilizer contained in these packets included all of the nitrogen, potassium and phosphate needed by the plants. But phosphate and potassium are naturally abundant in the volcanic soil of Bali.[11] Monsoon rains falling on the island leach these minerals from the earth, and irrigation canals transport them to the rice paddies. This natural system of fertilization was ignored by the designers of the technology packets. Working with staff from the agricultural extension service and the soil science department of Udayana University, Kremer and I measured nutrient concentrations in the paddies and irrigation canals, before and after fertilization. We

[10] Frederick C. Roche , "The Technical and Price Efficiency of Fertilizer Use in Irrigated Rice Production", *Bull. Indo. Econ. Stud.* Vol 30 No 1, April 1994, pp. 59-83; James J. Fox, "Managing the Ecology of Rice Production in Indonesia", in Joan Hardjono, ed., Indonesia: Resources, Ecology and Environment. Oxford University Press, 1991:61-84.

[11] G.E. Wheller, R. Varne, J.D. Foden and M.J. Abbot, "Geochemistry of Quaternary Volcanism in the Sunda-Banda Arc, Indonesia, and Three-component Genesis of Island-Arc Basaltic Magmas", Jour. of Volcanology and Geothermal Research 32 (1987), 137-160.

found that most of the superfluous fertilizer flows out of the paddies and back into the rivers, accumulating to very high levels before reaching the coast.[12] Isotopic analysis of coral shows increases in nitrogen from fertilizer, and reefs located near agricultural drainages are often blanketed with destructive macroalgae.[13] One of our Balinese colleagues, Dr. Alit Artha Wiguna of the Ministry of Agriculture, carried out dissertation research on fertilizer use along an entire river in western Bali. He found that the cost of fertilizer for one hectare of rice in 2004 was approximately $101, of which $69.60 is superfluous (unused by the rice).[14] Moreover, soil fertility was much reduced in these paddies, compared to the paddies located in remote upstream locations that continued to plant native Balinese rice and rely on natural (organic) fertilizer. Artha Wiguna is now leading a campaign to reduce the use of chemical fertilizers, and return to traditional methods of organic farming. The alternative is to accept continuing needless damage to the terrestrial and marine ecology of Bali.

If such self-organizing processes are indeed common, why haven't we noticed them?

In the past two decades, ecologists have become interested in the ways that patterns can emerge from multiple processes occurring at different scales. In one of the most cited papers on this topic, Simon Levin observes that patterns are often generated by the collective behavior of smaller scale units, which "operate at different scales than those on which the patterns are observed."[15] Ecological journals are filled with examples of such processes, with a growing emphasis on global-scale phenomena such as climate change. But these ideas have been slow to spread to the social sciences. Karl Marx famously dismissed the peasants as a "sack of potatoes", and for most social scientists, it is still true that one piece of countryside looks much like the next. Even anthropologists are seldom inclined to search for the kinds of pattern-and-scale interactions that Levin describes. Consider, for example, anthropologist James Scott's *Seeing Like a State: How Certain Schemes to Improve the Human Condition have Failed*. This book begins with an analysis of the ecological disaster created by the beginning of "scientific forestry" in eighteenth century Germany. The replacement of natural forests with orderly rows of commercially valuable trees soon led to pest outbreaks and "forest death". Scott goes on to explore the appearance of new practices designed to improve the "legibility" of the countryside for state bureaucracies, such as cadastral surveys, surnames, censuses, and the promotion of procedures deemed to be scientific (objective, precise and universally valid) at the expense of local knowledge. Scott characterizes local communities as

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[12] J. S. Lansing et al., Volcanic Fertilization of Balinese Rice Paddies. Ecological Economics 38 (2001) 383–390.
[13] Guy S. Marion et al. Coral skeletal δ^{15} reveals isotopic traces of an agricultural revolution. Marine Pollution Bulletin 50:9 (Sept 2005):931-944.
[14] Wiguna, I.W.A.A. 2002. Kontribusi sisetm usahatani padi sawah terhadap pengkayaan hara nitrogen, forfor dan kalium aliran permukaan pada ekosistem subak di Bali. Doctoral dissertation, Environmental Sciences, Bogor Technical University, Indonesia.
[15] Simon A. Levin, The Problem of Pattern and Scale in Ecology. *Ecology* 73 (1992):1943-1967.

repositories of *metis*, a Greek term which he borrows from the Classical scholars Marcel Detienne and Jean-Pierre Vernant. As these authors show, *metis* was a favorite term for Greek poets; used to describe the craft, cunning or clever adaptability of heroes like Odysseus.[16] Scott uses *metis* to describe the knowledge and practices of local communities, and offers a spirited defense of *metis* as it is embodied in practices like shifting agriculture.

Metis, then, is ad hoc, local, ingenious and colorful. But it is not systematic, patterned, or emergent. One might easily view Balinese farming practices or water temples as particularly rich examples of *metis*; as treasuries of accumulated lore. Indeed, each community might be expected to have its own local stock of *metis.* This is precisely what I expected to find when I began my research on the water temples, and were it not for my collaboration with Dr. Kremer, it is probably all that I would have noticed. My point is not to critique Scott's book, which is after all focused on the behavior of states as instigators of development schemes. Instead I wish to emphasize how easy it can be, even for an anthropologist, to fail to recognize the kinds of multi-scale interactions that ecologists have trained themselves to see. *Priests and Programmers* describes how my colleagues and I gradually came to recognize the water temples as more than repositories of *metis.* But to borrow Scott's metaphor, our ability to see, to recognize emergent patterns in water temple networks, required a learning process. The temple networks came into view partly as a result of the Green Revolution, which exposed their ecological role, and partly through our expanding familiarity with the properties of complex adaptive systems like Daisyworld. Indeed, the enduring message of *Priests and Programmers* may be how easy it was to miss the significance of the temple networks- just as planners failed to appreciate the functional significance of the forest clock in Borneo.

[16] Marcel Detienne and Jean-Pierre Vernant, Cunning Intelligence in Greek Culture and Society. Atlantic Highlands, N.J.: Humanities Press, 1978.