PHOTOS BY J. STEPHEN LANSING—UNIVERSITY OF SOUTHERN CALIFORNIA

Under the volcano: *The temple and the high priest (inset) of Bali's water religion*

TECHNOLOGY

The Electronic Goddess

Computerizing Bali's ancient irrigation rites

For the past 10 centuries or so, rice farmers on the island of Bali have taken great care not to offend Dewi Danu, the water goddess who dwells in the crater lake near the peak of the Batur volcano. Toward the end of each rainy season they send representatives to Ulun Danu Batur, the temple at the top of the mountain, to offer ducks, pigs, coins and coconuts in thanks for the water that sustains their terraced fields. Outsiders have long considered the rituals of Agama Tirtha, "the religion of holy water," an interesting but impractical way to grow crops. Indeed, development agencies have spent millions trying to improve on the ancient system. But according to two researchers at the University of Southern California, the outsiders have had it all wrong.

With the help of an ingenious computer program, anthropologist Stephen Lansing and ecologist James Kremer have shown that the Balinese ricegrowers are practicing state-of-the-art resource management. Besides placating the goddess, it turns out, the island's ancient rituals serve to coordinate the irrigation and planting schedules of hundreds of scattered villages. And as the new computer model makes clear, the result is one of the most stable and efficient farming systems on the planet.

Lansing suspected much of this long before he was able to prove it. When he started doing fieldwork in Bali, back in the early '70s, he discovered that the hundreds of village-size farming cooperatives, or *subaks*, that dot the island were linked through a network of temples extending all the way from the seacoast to the top of the volcano. If a subak wanted to tap a new spring, or divert water from a canal into its own fields, it would appeal to the Jero Gde, the high priest of the main water temple. Only after weighing the interests of the other farmers in the watershed would he offer a judgment.

The priests did more than divvy up water, though. Lansing learned that they were in fact ecological master planners, helping the subaks juggle their planting schedules to conserve water, preserve soil and control the spread of pests. To keep rats and insects from proliferating, groups of subaks would plant, irrigate and harvest simultaneously, then leave their fields fallow for a set period. And to ensure that water wasn't wasted during fallow periods, different groups would plant at different times. The system had apparently kept the soil rich enough in nutrients to produce several tons of the same crop every year for centuries, with no decline in yield.

New system: While Lansing explored the secrets of the old system, the Indonesian government and the Asian Development Bank were busy designing a new one. From 1978 to 1984 they spent $24 million introducing high-yielding rice strains and building bigger dams and canals in selected watersheds. Project officials told the peasants to keep their fields in constant production. Pesticides would take care of the rats and insects, they said, and fertilizers would preserve the soil.

The poisons proved quite effective at killing off the protein-rich fishes and eels that had always thrived in the paddies. The pests became resistant, though, and the rice crop soon dwindled. When Lansing suggested that the project's engineers could learn something from the local water priests, he got a letter from officials at the development bank, explaining that the priests don't "exercise any active role in irrigation-related activities."

That's when Lansing turned to his USC colleague James Kremer. An ecologist, Kremer was skilled at measuring the natural processes that converge in a rice field. It occurred to him that if he could simulate the crucial interactions on a computer screen, the project officials would be able to compare the old and new farming systems for themselves. So Kremer amassed historical data on such variables as rainfall, planting schedules and pest proliferation. Then, with help from Lansing and others, he designed a computer program that calculates the likely effect of a change in any one of these variables. All the user has to do is choose a scenario. The computer promptly churns out total crop volumes for the region and for each of the 173 subaks within it.

As priests and project officials played with the program, they quickly discovered that the most fruitful harvests grew out of the scenarios most closely resembling those the farmers had been following for more than a millennium. By the time the Asian Development Bank formally acknowledged that fact last spring, many of the peasants had already reverted to their traditional ways. But the new dams and canals are still in place, and all parties seem to agree that the computer model could make them far more useful.

In fact, officials at the bank recently asked Lansing and Kremer to suggest ways of incorporating their program into a permanent water-management system for the island. The two are working on modifications that will enable anyone—priest, peasant or foreign hydrologist—to use the program without prior training. Since the model expresses the insights of each group in terms the others can understand, the scientists figure it could provide the basis for a lasting alliance among them.

Some experts foresee applications for Lansing and Kremer's new model throughout the Third World. Development agencies too often miss out on vital local wisdom, says Walt Coward, director of Cornell University's International Agriculture program. Aided by tools like this one, they could avoid the costly mistake of fixing what isn't broken. The point, he says, is not that folkways never need fixing—they often do. It's that old and new aren't mutually exclusive. They can mix and merge, on the circuit boards of a computer.

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