

## The Blind Spot in the Green Revolution: Temples, Terraces, and Rice Farmers of Bali

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Balinese rice terraces (Wikipedia.org)



rice terrace (commons.wikimedia.org)



Balinese water temple (Wikipedia.org)



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### PART 1: Green Revolution Policies in Bali – Problem or Solution?

During the 1960s, an agricultural revolution was underway: the Green Revolution. As a result of adopting modern agricultural practices, developing countries were witnessing spectacular increases in cereal crop yields. These practices included modern irrigation and crop management techniques, the use of synthetic chemical fertilizers and pesticides developed during this period, and most critically, the use of new crop varieties, called high-yielding crop varieties (HYVs).<sup>1</sup> Plant scientist Dr. Norman Borlaug, who is often referred to as the “father of the Green Revolution”, won a Nobel Peace Prize for his role in developing HYVs and is credited for saving millions of people from dying of starvation.

In Southeast Asia, the Green Revolution came in the form of a HYV of rice developed at the International Rice Research Institute in the Philippines during the 1960s. At that time, Indonesia was importing rice from other countries to meet their growing food demands, and the Indonesian government was eager to increase their self-sufficiency in rice production. Thus, by the 1970s, the Indonesian government was implementing new agricultural policies inspired by the Green Revolution, which promoted continuous cropping of the new HYV rice.

On the Indonesian island of Bali, rice farmers adopted these new practices, which included introducing new fertilizers and pesticides, building new weirs (dams) and irrigation structures to enable new, continuous cropping schedules, and replacing native rice with HYV rice. The institution of these government-mandated changes represented a major departure from the practices associated with the traditional Balinese system of wet rice cultivation.

Before the Green Revolution, farmers had followed a cropping calendar set by the Temple of the Crater Lake and local “subaks”, which are associations of farmers, rather than planting rice continuously. Subaks, canals, and

<sup>1</sup> <http://www.agbioworld.org/biotech-info/topics/borlaug/green-revolution.html>

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weirs sharing a single water source, and are governed by social practices and rituals centered around water temples,<sup>2</sup> which are temple structures built wherever water is diverted from water sources into irrigation canals. Remarkably, this system enabled Bali's rice terraces to produce grain for more than 1000 years with no decrease in yields, which is usually seen in other systems of irrigated agriculture.

Shortly after the Green Revolution agricultural policies were implemented, there was a dramatic increase in rice crop production. But after a brief period of productivity, rice yields plummeted as the result of severe water shortages and unprecedented pest and disease outbreaks. Disputes soon arose between those who blamed the Green Revolution policies for the problems and advocated a return to the traditional system of management by the water temples and those who thought that the new agricultural practices should be maintained.

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With your group, discuss the following:

1. Imagine that you are a Balinese rice farmer who is arguing for a return to traditional cultivation practices. What might some of your arguments be?
  2. Imagine that you are an Indonesian government official in charge of agricultural policies. What might your response to these farmers be?
  3. What sources of knowledge are likely to be valued by each of these groups?
  4. What kind of information or data might help inform the government official's decision of whether to continue the Green Revolution agricultural policies or to return to traditional practices?
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### **PART 2: Temples, Terraces, and Rice Farmers- A Socio-Environmental System**

Anthropologist Dr. Stephen Lansing, arrived in Bali in 1979 to study religious rituals of the traditional Balinese. During this time, he spoke with several rice farmers and learned about their problems with their rice harvests. As they described their troubles and the changes that followed implementation of the new Green Revolution policies, he began to wonder how their traditional system of rice cultivation worked. Perhaps the old system works better? To answer these questions, Lansing returned to Bali in 1983 to study the role of the Balinese water temples and subak system in rice farming. He began by collecting ethnographic data (qualitative data aimed at understanding cultural phenomena) from conversations with local rice farmers and temple priests<sup>3</sup>.

#### **The water-temple system**

Lansing learned by shadowing a subak leader that members of subaks engage in a series of rituals in the fields and at local temples called “water temples.” The subak leader organizes these rituals as well as the physical labor involved in cultivating rice, and water-temple priests set the irrigation schedules after consulting with farmers downstream during a ritual. Some anthropologists hypothesized that these rituals helped to coordinate the timing of the physical activities; for example, the “water-opening ceremony” marks the beginning of the irrigation period, and the “harvest ceremony” ends it. But looking at ritual sequences of different subaks, there was not always a strong synchronization with what was going on in the fields. And ritual sequences were different in different regions of Bali. What then is the connection, if any, between these rituals and the farming practices?

To understand this, Lansing needed to know how the water temple system worked. In Bali, there are five main terrace regions with hundreds of subaks and temples. After talking and visiting with several subaks and temples, he joined representatives from more than 200 subaks at the annual temple festival at the Supreme Water Temple of Pura Ulun Danu Batur (Mount Batur). The fresh-water crater lake in this volcano is regarded as the original water source for the more than 170 rivers and springs<sup>4</sup> that feed into the rice terraces and is home of Dewi Danu, the Goddess of the Lake. The Temple is symbolically placed at the center of a mandala, or cosmic map, for the island of Bali to represent the role that the Goddess is believed to have in controlling the flow of rivers and springs from the volcano. From Mount Batur, a complex network of temples and shrines radiates. Temples are built wherever waters from these rivers and spring are diverted by weirs (dams) into irrigation canals as a place to offer thanks and prayers to the Goddess. There are regional water temples, or Masceti, each representing a congregation of several subaks. Each subak, in turn, has its own, smaller temple representing all the irrigated terraces that share a single water source. A shrine is also built at the point where water from the irrigation canals enters an individual farmer’s terrace.

In addition to their roles as places for offerings and prayers and as gathering places for social functions, temples serve as meeting places where farmers meet periodically to coordinate their plantings with each other and

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<sup>3</sup> S. Lansing (1994) *The Balinese*. Cengage Learning

<sup>4</sup> T. Harford (July 13,2012) *The lessons that flow from Bali’s water temples*. Financial Times.

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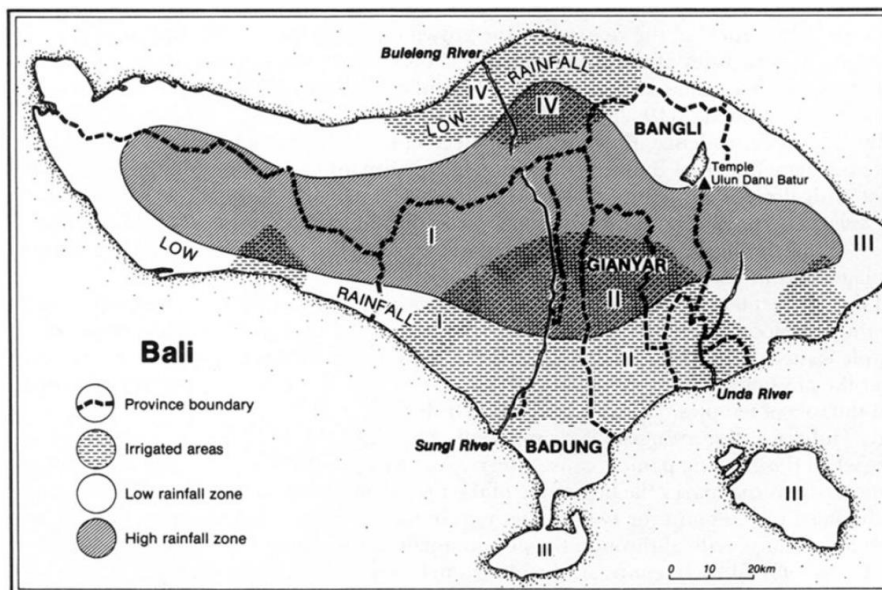


determine irrigation and cropping schedules. Temple priests also play a role in mediating disputes between subaks over water allocation; Jero Gde, the priest of the Supreme Water Temple at Mount Batur, is regarded as the earthly representative of the Goddess of the Lake and holds ultimate authority to decide upon water allocations in the name of the Goddess.

But how does this social system interact with the ecological system involved in rice production?

### The rice paddy ecosystem

Rice has been grown in Bali on terraced fields that cover the island's hillsides for thousands of years and is the staple of the Balinese diet. The water need to grow rice in Bali descends from the Crater Lake on Mount Batur, percolating through the porous volcanic soil and picking up minerals vital for rice growth, and is diverted from streams and rivers into irrigation canals. Despite the tropical lushness of Bali, the island has wet seasons and dry seasons, and this seasonality in rainfall makes irrigation water essential for growing rice, especially in the lowlands (Fig 2, below).



**Fig 1: Rainfall and irrigation patterns on Bali** (figure from Lansing, 1987). Note that only the central area of the island, which is higher in elevation, receives high levels of rainfall. Water flows from this central zone towards the coasts, flowing through irrigation canals to rice fields along the way.

Thus, at times, water is scarce and becomes a resource that needs to be shared and managed amongst neighboring farmers through coordinated irrigation and cropping schedules. As a result of these schedules,

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water levels in these rice terrace ecosystems fluctuate or pulse. This ebb and flow of water affects water chemistry and can introduce or remove minerals, nutrients, and sediments, as well as toxins and waste materials. Thus, irrigation patterns affect basic biogeochemical processes in the rice paddy ecosystem (i.e. soil pH levels, mineral cycles, anaerobic conditions in soil, soil microbe activity, growth of nitrogen-fixing algae, phosphorus levels, and formation of a hard layer of subsoil or clay that prevents nutrients from leaching out of the water and into the subsoil.)<sup>5</sup> The productivity of the rice paddies is likely affected by these pulses in water levels because wetland ecosystems that experience such cycles tend to be more productive than systems that are permanently flooded or drained.<sup>6</sup>

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STOP and Discuss:

1. Based on the description you just read, create a hierarchical diagram (flow chart or picture) of the rice ecosystem including the following parts: Mount Batur, rivers, streams, the Crater Lake, and rice terraces.
  2. Now, add the Balinese network of temples on this same diagram, including the following parts: weirs/dams, the Supreme Water Temple, Regional Temples (Masceti), Subak Temples, Shrines.
  3. How does the water temple system interact with the rice terrace ecosystem?
  4. Socio-environmental systems are tightly linked social and biophysical subsystems that mutually influence one another. Describe and/or diagram how the Bali rice cultivation system is an example of a socio-environmental system; include the parts of the system and indicate how they interact.
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<sup>5</sup> S. Lansing (1994) *The Balinese*. Cengage Learning

<sup>6</sup> <http://www.nature.com/scitable/knowledge/library/ecology-of-wetland-ecosystems-water-substrate-and-17059765>

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### PART 3: Water, Pests, and Neighbors

Another important component of rice cultivation is the management of pests, including insects, rodents, and bacterial and viral diseases. Two methods are typical for managing pests in rice terraces: 1) draining the fields and burning the stalks to kill the pests or 2) flooding the fields, and allowing the rice stalks to slowly decompose under water. These “fallow periods,” when pests are starved of food, reduce pest populations in the managed area.

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STOP and Discuss:

1. Think about pest management: what do you think might happen over the period of a few years under the following scenarios? Assume that Subaks A, B, C and D are all neighbors, and that there are no other subaks nearby.
    - a. Farmers in Subaks A and B follow the same cropping pattern, while their neighbors in Subak C and D follow a different cropping pattern such that they plant rice at different times than Subaks A and B.
    - b. Farmers in Subaks A, B, C, and D plant rice year round.
    - c. Farmers in Subaks A, B, C, and D all follow the same cropping patterns and leave their terraces fallow during the same time.
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As described earlier, irrigation water is critical for rice cultivation in Bali due to seasonal differences in rainfall. In this system, water comes from groundwater flows and from seasonal rivers and streams, and water flows from higher elevations down into the lowlands and out to the ocean. At the start of each new planting season, water demands are especially high as the dry fields must first be saturated with water. During these times and other periods when there is insufficient water to irrigate all the rice terraces in the system, the farmers who are downstream are most affected.

In 1998, a field survey was conducted in which farmers were asked, “Which is worse, pests or water shortages?” Data from ten subaks were collected. From each subak, a random sample of 15 farmers was chosen, 5 each from the up-stream, mid-stream, and down-stream sections of the subak.

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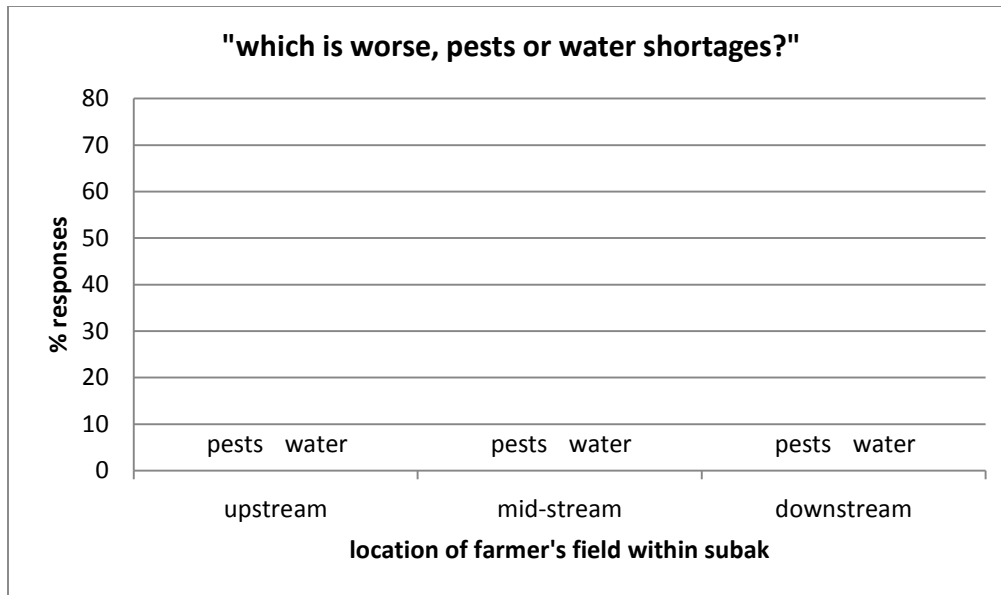
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STOP and discuss:

2. Predict what the survey responses might have been (focus on relative values of the responses):



**Fig. 2. Survey responses about major concerns of farmers stratified by field location (relative to water supply) within a given subak.**

3. Given what you now know about the Balinese way of cultivating rice, can you think of a hypothesis that might explain the problems the Bali rice farmers were encountering during the Green Revolution?

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### **PART 4: Testing a Hypothesis: Is the Water Temple System Necessary for Cultivating Rice?**

Steve Lansing saw trouble brewing. In the late 1970s, rice crops on Bali were failing as farmers were forced to continuously plant their rice fields despite using new, high-yield rice varieties. Meanwhile, arguments broke out about who would get the limited water. Balinese temple priests and farmers argued that the water temple system, which coordinates cropping and irrigation patterns, is necessary to ensure that there is enough water for everyone and that pests are controlled. Yet government planners dismissed these claims because they viewed the water temple system as filling only a religious role and the priests and farmers' concerns as resistance to change and modernity. Lansing thought the water temples played an important role in managing water and controlling pests, and started thinking about how could he could test this hypothesis?

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STOP and discuss:

1. What are some ways that this hypothesis might be tested? What kind of information could help inform the government planners' decisions about whether or not to continue the Green Revolution agricultural policies?

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To test the hypothesis that the coordinated cropping and irrigation patterns controlled by the water temple system are critical for allocating water and managing pests, Lansing decided to create a computer simulation model. He teamed up with James Kremer, an ecologist who built computer models to study how ecological systems change over time given different conditions.

With Lansing's input, Kremer built a simulation model that predicts rice yields as a function of cropping patterns and environmental conditions. This model would allow them to test whether the cropping patterns set by the water temples result in higher rice yields compared to other cropping patterns. To create such a model, he needed to incorporate several kinds of data related to rice farming.

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STOP and DISCUSS:

2. What kind of data might be important to obtain for this model?

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For this model, Kremer focused on the watershed of the Oos and Petanu rivers and the 172 subaks in this area. He then calculated the relationship between rainfall and stream flow for each of 12 catchment basins (see glossary) in the watershed, which is needed to predict water availability for growing rice. Then, he mapped the locations of the 172 subaks in this watershed and placed them within the network of rivers, streams, dams, and temples. The model also included the following variables, for which he added actual data: cropping patterns; size of subaks; which Masceti temple each subak belongs to; and, for the rice crops, the maximum yield, duration of crop planted before harvest, and sensitivity to pests; and for pests, growth rate when a specific crop is available and the rate and distances of dispersal. Based on these data, Kremer's computer model could then simulate rainfall, river flow, irrigation demand, rice growth, and pest dynamics for every subak on a monthly basis and calculate virtual rice yields.



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Once the simulation model was created, a critical question to examine was: does the model sufficiently capture the system's dynamics and accurately predict actual rice yields based on the set of conditions? To test the accuracy of the model, Kremer input actual monthly rainfall into the model and assigned each simulated subak the real cropping schedule that it followed in the field. Then, these results were compared with actual rice yields from each of the subaks during the same time period. Fig. 3, below, shows the results.

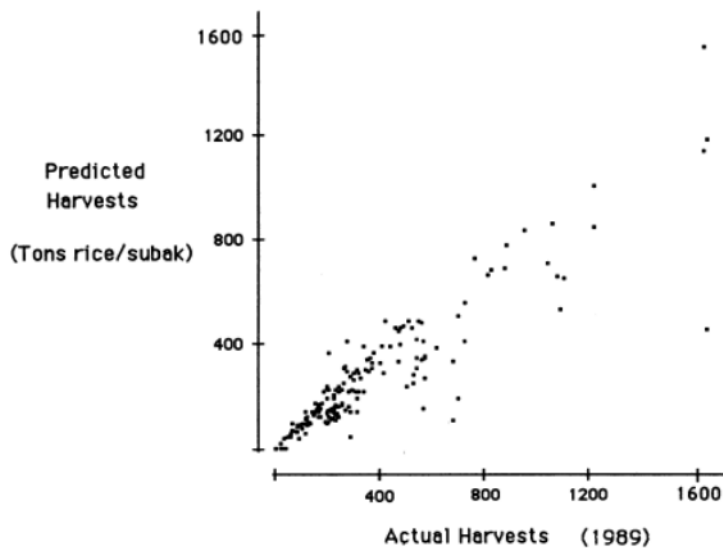


Fig 3: Predicted harvests, from the computer simulation, versus actual rice harvests (Lansing and Kremer, 1993)

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STOP and Discuss:

3. Based on the results in Fig. 3, do you think the model Lansing and Kremer built accurately predicts rice yields? In other words, does this model work as they intended?

4. If we assume the model does a very poor job of predicting actual rice harvests, would the results be different from what you see in Fig. 3? If so, how?

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The critical question that Lansing and Kremer wanted to ask with the computer model was: how do different levels of social coordination of cropping patterns affect harvest yields? These different levels of coordination included:

- each subak randomly determines its own cropping pattern (the pattern observed during the Green Revolution),
- all subaks follow the same cropping pattern,
- half the subaks plant with one pattern and the other half plant a month later, and
- subaks plant in clusters based on the real patterns created by water temple coordination.

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What level of coordination works best for managing cropping schedules? To investigate, Kremer ran the model several times with environmental factors held constant while the level of cropping coordination was varied.

Figure 4 below shows two diagrams representing simulation runs of the Lansing-Kremer model, one (diagram A) where each subak was randomly assigned a cropping pattern, and the other (diagram B) where clusters of subaks followed the same schedule as determined by the water temples. Each shape represents a particular cropping pattern, and subaks with similar shapes follow the same cropping schedule.

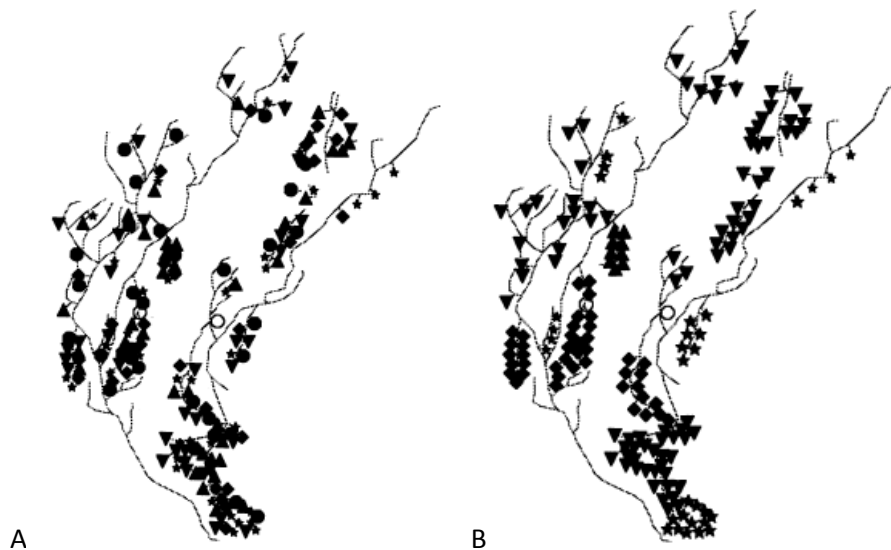


Figure 4 From Lansing and Kremer 1993:107-108

STOP and Discuss:

5. Draw a diagram similar to the two above that reflects a pattern where all subaks in the entire watershed follow the same cropping schedule. In the Lansing-Kremer model, this is the watershed level of coordination. Diagram A represents the subak level, and Diagram B represents the temple level.

6. Looking at the three diagrams, discuss how the coordination of cropping patterns might affect the two critical issues in Balinese rice cultivation: water availability and pest management. Use the chart below to summarize what you think might be the degree of severity (high, medium, low) of the two problems at each level of coordination.

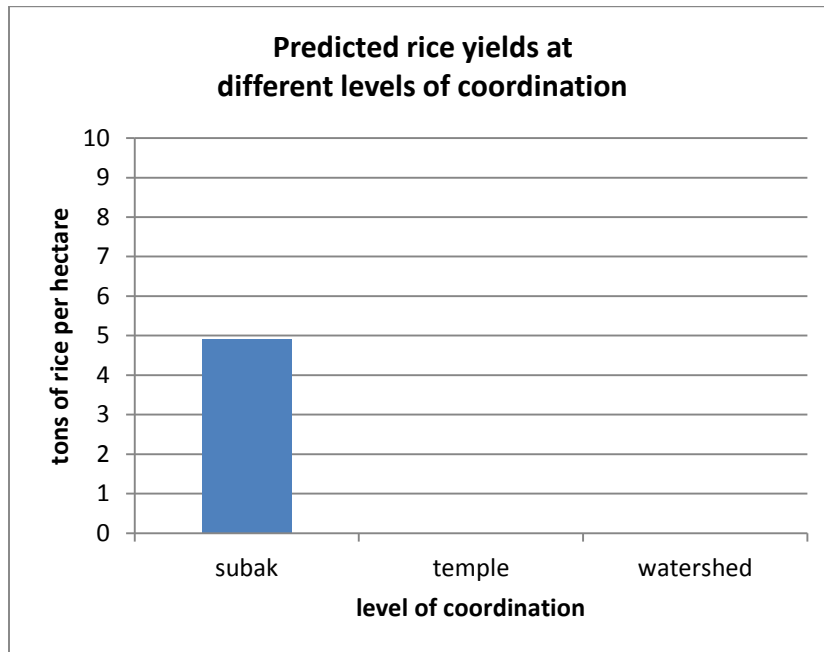
	subak level	temple level	watershed level
pest outbreaks			
water shortages			

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7. In the figure below, estimate what you think the approximate rice yields were for each level of coordination. What would be the relative rice yields for the temple and watershed levels? (The Lansing-Kremer model predicted a rice yield of 4.9 tons of rice per hectare under the subak level of coordination.)



8. Explain how the predicted rice yields of the Lansing-Kremer model supports or refutes Lansing's hypothesis about the role of water temples.

9. Revisit the diagram you created of the Bali rice cultivation system as a socio-environmental system and revise it given what you now know. Use a different color for your additions and revisions.

10. Returning to the first question you answered in this case study, what information can you now add to the arguments of the rice farmers discussed earlier? Imagine that you have a meeting with the Indonesian government officials in charge of agricultural policies to explain the new information that Lansing and Kremer found through their simulation model. What would you say?

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### Glossary

**complex adaptive system** – a system of diverse agents, such as farmers, that interact with their neighbors and adapt their behavior to their social and ecological environment. The relative success of these agents or their behaviors selects for those that do best in a given environment, allowing the system to evolve and to form complex-looking patterns

**productivity** – degree of food production; technically in ecology, production means the fixation of atmospheric carbon into plant biomass through the process of photosynthesis

**subak** – association of farmers who share the water from a single source, such as a stream or irrigation canal

**socio-environmental system**- Tightly linked social and biophysical subsystems that mutually influence one another. Example: human behaviors, decisions, and policies influence the status of ecosystems (e.g., water quality) that, in turn, influence human beings' quality of life and future decisions.

**terrace** – rice paddy that has been graded so its surface is level and can hold water

**water temple** – Balinese hindu temple that services a religious and water management function

**weir** – dam that redirects some of the water from a stream or a canal to a rice field

**catchment basin**– the area drained by a river and the streams and canals that branch off from that river

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