Institutional Analysis of the Subak Irrigation System in Bali, Indonesia

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1 Part I: System Structure - Collective action

The rice paddies and irrigation system of this case is near Tihingan Village, in the, Klungkung district, 45 Km northeast of Denpasar on the Island of Bali, in Indonesia. The original case spans from 1957 to 1959. The data was extracted for a chapter by Geertz (1967) in a book about irrigation systems in South Asia (ed. Coward, 1980) and catalogues an action situation involving 455 rice farmers who are members of an organization called a *subak*, that regulates irrigation and planting cycles. Additional information found in Lansing (2007)

The key resources (natural infrastructure) in the system are the watershed and its associated ecology, which includes both land (private) and water (shared). The key resource relevant to the commons dilemma faced by the community is water for irrigation (common-pool). It should be noted that water dictates crop cycles, which are managed to mitigate pests, requiring coordination of crop fallowing techniques.

This case study is part of the original Common-Pool Resource (CPR) database. A summary of the original CPR coding conducted in the 1980s by Edella Schlager and Shui Yan Tang at Indiana University may be found here.

1.1 The Commons Dilemma

Potential over appropriation / poor coordination of appropriation

The water temples make decisions about cropping and irrigation patterns by taking into consideration the trade-off between two constraints: water sharing and pest control. If everyone plants and harvests at the same time, and a widespread fallow period may be required to reduce pest populations by depriving them of food and/or habitat. In addition, if everyone plants the same rice variety at the same time to coordinate their harvests and fallow periods, then irrigation demand cannot be staggered. Furthermore, cropping choices made by upstream farmers strongly affects the amount of water that reaches the weir in the dry season, upon which their downstream neighbors depend. Asymmetric water access has led to conflicts between headend and tailend farmers.

Potential under-provisioning of public infrastructure:
All farmers in the *subak* contribute to the maintenance of the hard infrastructure (field canals) both with labor for large projects and tax payment to fund *pesakeh* to carry out smaller projects. All users also contribute to the soft infrastructure (guarding against theft in harvest). There is no mention of under-provisioning of public infrastructure in the original case (pre-Green Revoltuion).

1.2 Biophysical Context (IAD)

Natural infrastructure (NI):

Water in Bali flows down deep river gorges from the top of a volcano in the center of the island to the sea, creating a serious of natural watersheds. In the absence of hard and soft human made infrastructure, villages at higher elevations may have access to a more consistent source of water. This causes an asymmetry from upstream to downstream in terms of water supply. Irrigation is dependent on both controlling the volume of water during the rainy season (November to April) and storing water in irrigation systems for provisioning during the dry season. The wet and dry cycles are important in maintaining biogeochemical cycles essential for good rice yields. Controlled changes in water levels create pulses that alter soil pH, release potassium (when draining) and phosphorus (when submerged), increases nitrogen fixation through algae, stabilizes soil temperature, and more. A delicate ecological balance is crucial to mitigating pests. Viruses, bacteria, grasshoppers, rats, and other pests can destroy rice crops. However, farmers can burn rice fields (losing nutrients) or flood fields to kill pests, which is only effective through coordinated action of all fields in a large area. If only one farmer attempts to control pests, it will be useless because pests can migrate from field to field. Collective action is required to keep pests at bay.

Hard human-made infrastructure:

Most Balinese irrigation systems begin at a weir (diversionary dam) across a river, which diverts part of the flow into a tunnel. The tunnel may emerge as much as a kilometer or more downstream, at a lower elevation, where the water is routed through a system of canals and aqueducts to the summit of a terraced hillside. In the regions where rice cultivation is oldest in Bali, irrigation systems can be extraordinarily complex, with a maze of tunnels and canals shunting water through blocks of rice terraces. The weir in the river that provides the water for the main canals is usually made of earth, logs, and stones, and may be easily washed away by flash floods. Therefore, these must be kept in good condition in order to regulate water to prevent flooding or water scarcity. The private infrastructure used for farming is not described in either Lansing (2007) or Geertz (1970).

1.3 Attributes of the Community (IAD)

Social Infrastructure

Each social activity (religious, farming, legal) has its own governance structure and set of rules. While these groups influence each other, they never fuse. In addition, each citizen may be a member of various *subak* groups, as well as one *bandjar* group. This criss-crossing of social relations across the countryside forms a complex web of relationships.

Subaks strictly follow rules set by the water temple, and farmers follow rules set by the *subak*. This compliance is due in part to effective monitoring systems, where the *pekaseh* of each *subak* can fine members. Social norms for compliance rely on a dense social network created by governance systems with overlapping members. Balinese share a common religion and village life revolving around ritual and festivals. Temples regulate both holy and secular life, and exists for specific *bandjar* and *subak,* with some festivals that unite members of both. The various festivals at each temple throughout the year is essential to developing social ties. Geertz calls it “the linchpin of the entire system” p 89 (1970).

Bandjar is a group of households that form a village. This social institution regulates public infrastructure such as the marketplace, roads, and paths. A person can belong to one *Bandjar*, but multiple *subak* if he (farmers are male) has ride paddies in multiple places. *Subaks* and *Bandjar* are separate in both membership and governance structure- yet rely on the infrastructure of each in order to function.

Human Infrastructure

There is no mention of formal education in the case studies. However, indications are that the human infrastructure in the system is incredibly high. The depth of river gorges and absence of reservoirs requires complex engineering and ingenuity to construct the correct series of tunnels, width of canals, placement of weirs, and more to regulate the water system with pure gravity. In addition, the ability of leaders in the water temples to successfully regulate pests by making correct cropping and fallowing decisions among the *subaks* requires in depth local knowledge, or *metis.*

1.4 Rules in Use (IAD)

The rules in use, ie. Soft human-made infrastructure, are provided by Geertz (1970) and Lansing (2007) (see system representation. Based on the study, the following specific rules are relevant for this case.

Position Rules: 5 elders (*klian*) for each *bandjar, and* one *klian* for each subak.
Few subaks are further divided into *tempek* (in *Subak* A there are four) and elect *tempek* leaders. 120 farmers in *subak* A are assigned to the role of *pekaseh.*

Bandjar : A village-level social institution (distinct from *subak* both in members and governance structure)

Jero Gde (described in Lansing 2007) is head of all 45 subaks in the region (the *pepasyan*)

Boundary Rules: A farmer must own a plot in a *subak* to be a member of that subak. Each citizen belongs to the *bandjar* where he or she lives.

Choice Rules: Farmers must pay taxes and obey *subak* regulations (to plant rice, vegetables, or lay field fallow). There are four sharecropping systems under which a tenant can receive ½, ⅓ or ¼ of the crop based on location and quality of land, crop type, source of seeds and cattle, etc. Three options to rent land are 1) *gade* system- tenants may rent land for cash 2) *plais* system- owners can place land for rent and find new tenants when they find a higher bidder and kick old tenants off 3) *melanjain*- tenants plants dry crop and receives half the harvest, but in addition must prepare the owner's field for rice planting but receives no share of the rice crop.

Aggregation Rules:
All types of *klian* are elected by members of the respective *bandjar, subak,* or *tempek* members. One vote for each member in each election.
Subak: Each *subak* elects a leader, or *klian*, who represents the local *subak* in inter*subak* governance, such that *subaks* that are in the same watershed coordinate at the level of a regional water temple. Each temple (which can hold 10-15 *subak*) meets once a year to determine planting and irrigation schedules. This coordination is regulated by *adat,* a code of customary law, to which all *subak* in the watershed adhere. For large tasks, like repairing a main dam, the whole *subak* may be mobilized.

Bandjar: Households in a village elect the members of the *bandjar.* The elders of *bandjar* are chosen by consensus and nominate their successors every 5 years.

Scope rules: There is not enough information to infer about scope rules.

Information Rules: *Subak klian* tell their members the crop type and cycle they will plant.

Payoff Rules: Each farmer pays a percentage fee (depends on *subak*) based on their *tenah* (total water supply, land area, rice seed demands, and rice production) to the *subak. Pekaseh* receive a portion of this for the maintenance and monitoring the hard human made infrastructure irrigation system. Farmers pay fines if they fail to comply with *subak* regulations. *Bandjar* members (heads of each family) must attend meetings every 35 days or pay a fine.

1.5 Summary

The history of irrigation in Bali is a complex governance network that has effectively regulated sustainable rice yield, reduced inequality, and minimized the effects of disturbances from pests, droughts and floods on livelihoods of the Balinese. Sophisticated public hard and soft infrastructures reduce variability from shock and coordinate asymmetries in water supply in the watershed. Major shocks to the system during the Green Revolution destroyed the soft human made infrastructure, with serious consequences (see Dynamic Analysis).

2 Part II. Dynamic Analysis - Robustness

This update extrapolates from research on changes in the *subak* irrigation system in Bali, Indonesia. Follow up to this case is provided by Lansing (2007) who wrote about a major shock and temporary suspension of the *subak* system and its implications during the Green Revolution in the 1980s. The system was reinstated in the 1990s, but suffers from new exogenous pressures of tourism and subsequent land use change. Additional information on the current state of the *subak* system is provided by documentation from UNESCO, SEI (Salamanca et al 2015) and Dharmiasih and Lansing (2014). Since a selection of 20 *subak* that “exemplified natural, religious, and cultural components” become a World Heritage in 2012, UNESCO provides annual reports on threats to the conservation of the subak system. In-text parentheses indicate corresponding links in the system representation (Robustness diagram) on the SES library.

2.1 Update on the Commons Dilemma

The Green Revolution temporarily suspended the *subak* system, which impacted the resource system by disrupting the balance of pests (Lansing 2007). The Indonesian government and Asian Development Bank installed policies to encourage farmers to achieve maximum rice yield production by grow rice continuously throughout the year and using chemical fertilizers. The *Jero Gde* and *subak* heads no longer dictated rice-cropping patterns, and this soft public infrastructure was replaced with hard made human infrastructure of high yield rice seeds, specialized fertilizers, pesticides. THis proved to be less robust than the combination of public infrastructure and soft human infrastructure in the Balinese *subak* system.

While control of irrigation and crop cycles returned to the *subak* in the 1990s, new threats to the commons come from tourism and land use development. UNESCO reports note that land is highly valued for tourism, and some *subak* heads sell their land to developers. The resulting deforestation may impact the hydrologic balance the irrigation system depends on (UNESCO 2015). (Dharmiasih and Lansing 2014) assert that the robstuness of this system hinges on the ability of UNESCO to support local governance and regulate tourism and land use. Salamanca et al (2015) speculate the *subaks* will only remain in Bali as a tourist attraction but not as a livelihood strategy for farmers. Conflicts about which *subak* receive tourism money and water for tourist infrastructure represents a new social dilemma. Since many farmers now use pesticides, the role of the *subak* in mediating crop schedule to balance ecology is now less of an issue.

2.2 Exogenous Drivers (social, political, economic, etc.)Shocks, Capacities, Vulnerabilities

...to and of the Resource (link 7 to R):

The Green Revolution imposed a fine on farmers for failing to crop rice two to three times a year, which destroyed ability of water temples to regulate crop fallow cycles and appropriate water. This caused pest outbreaks and chaos among farmers who no longer had reliable access to water in the dry season their *subak* previously provided (Lansing 2007). This decrease in soil fertility remains a problem to the present day (Salamanca et al 2015).

Returning control to the *subak* and designating their practices as part of a UNESCO cultural landscape has returned some ecological balance to the system. However, new pressures of increasing agricultural input prices, high land taxes, water scarcity, and increasing tourism demand cause some farmers to sell land for development (UNESCO 2015), compromising the hydrologic balance of the system. As water is increasingly allocated for tourism, less remains for the *subak* (Salamanca et al 2015). Biophysical changes across Bali indicate subsidence, groundwater level falling, and salt instruction (Cole 2012). This provides a vicious feedback cycle, because as water scarcity increases, pressures to sell and convert land are greater, and water supply becomes ever more variable.

...to and of the Public Infrastructure (link 7 to PI):

The value of the soft human infrastructure came to light during the Green Revolution, when water temples lost power to regulate cropping cycles. The hard human made infrastructure of the Green Revolution (specialized seeds and fertilizers) could not regulate pests and prevent rice harvest destruction. Lansing (2007) does not comment on the impacts of the Green Revolution on hard public infrastructure. While the Green Revolution initially destroyed soft public infrastructure, the Asian Development Bank later encouraged Indonesia to allow the *subaks* to resume control of water and cropping cycles in 1988, and soft public infrastructure of the *subak* system was partially restored.

Recent UNESCO documents note with high concern that conversion of land use may disrupt the hydrologic system. Deforestation in upper parts of the watershed could cause scarcity, which would make it difficult to reliably grow rice, or floods, which can destroy the irrigation infrastructure. UNESCO has recommended catchment management plans to regulate land use and require impact assessments for construction permits for tourism. A lack of coherent water policy means there is no soft infrastructure in place to regulate how water for tourist infrastructure that affect the hydrologic system. Farmers note that water directed toward tourism (e.g. hotels) is not monitored and *subaks* are concerned about increasing non-agricultural uses of water and impact of tourists hiking on delicate paddy bunds and sacred shrines, destroying the productive and symbolic function of rice cultivation (Salamanca et al 2015).

...to and of the Public Infrastructure Providers (link 8 to PIP):

The Green Revolution weakened the role of subak and temple heads, because they no longer regulated crops or water. Now, many farmers rely on agricultural extensionists from the Indonesian state, who only know how to give support for high yield rice varieties (*padi baru*) with short crop times and intensive input requirements. The local variety, *padi lokal,* is unfamiliar to these extension agents (Salamanca et al 2015).

The UNESCO world heritage site included *subak* heads in a governance assembly, but did not include the Gde (temple preist). UNESCO supports public infrastructure providers with capacity building efforts that teach *subak* leaders to read and create irrigation maps, allowing them to better articulate problems to government agencies. However, according to Salamanca et al (2015) some farmers feel uninvolved with the UNESCO process.

...to and of the Resource Users (link 8 to RU):

During the Green revolution, farmers had to pay fines for farming with their low yield rice varieties. Many farmers also converted to chemical fertilizers during this time. Organic fertilizer is expensive, and only becomes cheap to produce if enough farmers get involved, which is a challenge as more farmers exit the *subak* system. Expensive inputs, high land taxes, and water scarcity make it difficult to make a profit from rice cultivation. This causes farmers to sell land. In addition, youth are less interested in farming. Salamanca et al (2015) found that women feel the knowledge of rice farming and subak system should be taught in schools so the knowledge is not lost. Darmiahsih and Lansing (2014) note that 1000 hectares of rice are converted every year.

2.3 Robustness Summary

The *subak* system overcame one major external shock: The Green Revolution. The fact that *subak* system survived despite the introduction of new hard infrastructure and the temporary suspension of the authority of water regulation and crop cycles is remarkable (link 7 to PI). However, the legacy of the Green Revolution continues to impact the system. Knowledge of some traditional rice farming was lost, and government extensionists can only give support for high yield rice varieties that requires large expensive inputs (link 8 to resource users). However, new shocks of tourism and the difficulty of profit from rice farming increases land conversion, which in turn diminishes hydrologic robustness of the resource system (link 7 to resource). Efforts to include 20 *subak* in a World Heritage Site in 2012 has spurred new financial support and governance structures that may help mediate current problems, and provide a source of economic support in the form of tourism. However, concerns with the governance system, including failure to include temple priests, and efforts from the Indonesian government to take control, means continued conflicts in water allocation and conversion of rice paddies remain. Darmiahsih and Lansing (2014) note the UNESCO could remove Bali *Subak* from the World Heritage List if these conflicts remain unresolved. Finally- if the *subak* system is preserved due to tourism and its nature as an emblematic cultural heritage site but not due to its ability to support livelihoods of Indonesian farmers, does this transformation from farming to tourism represent fragility or robustness?

3 Case Contributors

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