Master's Thesis

Human and Structural Trade-offs in Sustainable Irrigation Management: Case Study of Karangasem, Bali and Kunisaki, Japan

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Certification Page

I, Matthew Scott Jansing (Student ID 51216604) hereby declare that the contents of this Master's Thesis are original and true, and have not been submitted at any other university or educational institution for the award of degree or diploma.

All the information derived from other published or unpublished sources has been cited and acknowledged appropriately.

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Abstract/Summary

Climate change poses a considerable threat to the availability of fresh water in the near future. One of the greatest water consuming activities is paddy rice irrigation. The Globally Important Agricultural Heritage Systems (GIAHS) program of the Food and Agricultural Organization (FAO) has identified several agricultural systems that it deems sustainable; including irrigation management as a determining criterion. Furthermore, GIAHS sites have characteristically high occurrences of group collaboration, highlighting the importance of social capital in facilitating said irrigation management. This study sought to quantify how different types and amounts of social capital could lead to sustainable ends; and moreover, how different water management styles could be defined as 'sustainable'. Following an extensive analysis of social capital and irrigation water-use in two GIAHS systems, Karangasem, Bali and Kunisaki, Japan, this study found that bonding and relational social capital mainly facilitates certain kinds of irrigation management under the umbrella term, "human solutions", which typically favor environmental sustainability. Meanwhile, Kunisaki depended more on "structural solutions" which favored economic sustainability. In order to better assist agricultural communities everywhere struggling with water-use problems, the identification of these types of social capital and their effect on overall sustainability can lend to informing decision-makers and stakeholders on how to achieve a better-balanced sustainable outcome for their farming operations.

Chapter 1: Introduction

1.1 Research Background

Less than 1% of the water on Earth is available for human-use and water used in agriculture accounts for 70% of this (FAO, 2007). Of that 70%, an estimated 60% is wasted because of inadequate irrigation systems, inefficient methods of water application, and the use of crops that do not fit the environment they are being grown in (WWF, 2018). Furthermore, because of increasing environmental and geopolitical pressures on Pacific island countries such as climate change, tropical storm anomalies, and demographic shifts, self-sufficiency via sustainable water management is projected to become especially important for communities in volcanic island landscapes in the near future (Duncan, 2011). Porous volcanic soil, prolonged periods of little rainfall, narrow rivers, and steep topography often make agriculture and irrigation water procurement in volcanic island landscapes especially difficult.

In an attempt to develop theory for sustainable irrigation management in such regions, this research compares two alleged examples of sustainable irrigation in Karangasem, Bali and Kunisaki, Japan. This study assumes that both of these agricultural communities are successful examples of sustainable irrigation management because of their international recognition as such; either by academic research or international organizations. Furthermore, their similar landscapes and crop choices but dissimilar socio-economic conditions and irrigation methods allow for the variables associated with management and social organization to be effectively analyzed as they are performed in similar environmental conditions affecting agricultural performance. Figure 1.1 shows a basic outline of the variables in each system that are relevant to this study.

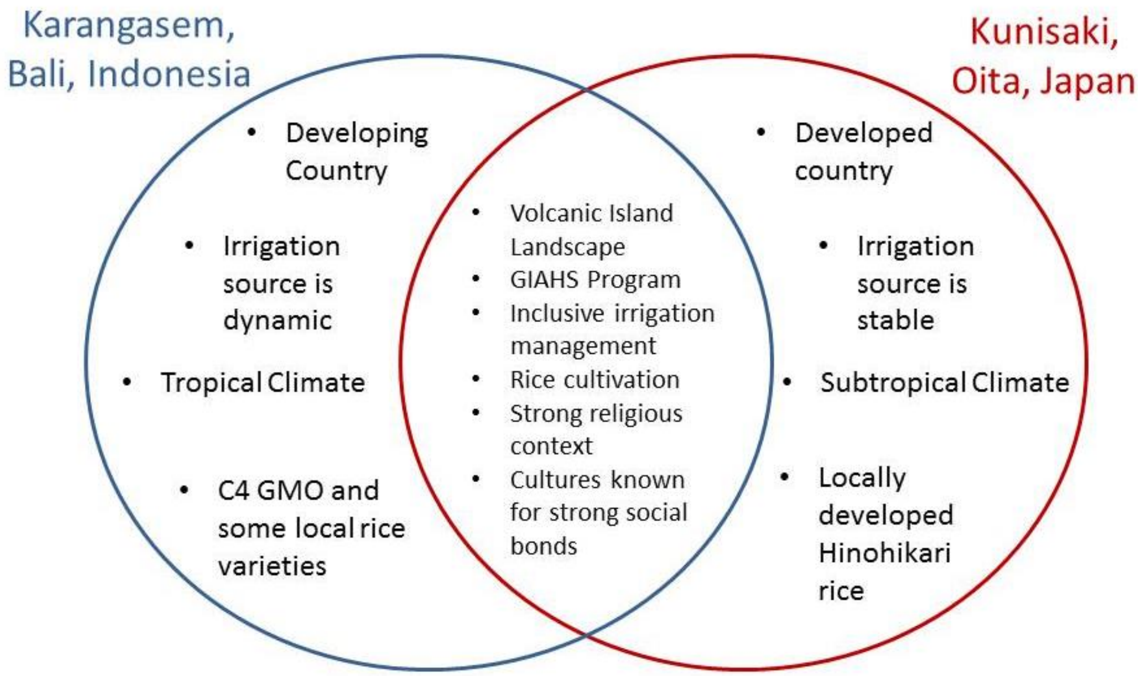


Figure 1.1: This chart lists the main characteristics of each system that were considered when case study locations were chosen for this research. The characteristics listed in the center serve to establish some common ground upon which the characteristics on the left and right can be effectively compared.

1.2 Bali and the Subak

Bali has been center-stage for socio-anthropological research since the 1970s and boasts a surplus of academic literature; most of which praises the success of its network of farmers' association s known as *subak* (Lansing, 1993; 2005; 2006; 2011). John Stephen Lansing, a major academic player in the field of Balinese studies, especially stresses the subak's success in contrast to Green Revolution agricultural methods which were introduced to Indonesia in the 1970s. The subak operates as a self-regulating, bottom-up water management organization that meets regularly to democratically decide irrigation schedules for all members in a watershed. The typical infrastructures used for irrigation amongst the subak are concrete or stone channels with weirs that deliver flowing water from mountain streams. The subak studied in this research, Subak Embukan, consists of 336 farmers with 12 branch leaders and 1 main leader, and the total cultivated area of their operations is 76 hectares.

All of the subak farmers' daily operations and the structure of the farming landscapes are the products of Balinese Hinduism. Subak water scheduling meetings are always held at so-called water temples or *beduguls*, and religious rituals are performed hand-in-hand with agriculture. Lansing argued that the subak's greatest achievement as a social organization is ensuring that downstream farmers get equal shares of water to upstream farmers through rice pest management via coordinated rice paddy flooding. Images 1.1 and 1.2 show the location and farming infrastructure of Ababi Village- the host community of Subak Embukan which was chosen to represent Karangasem Regency's subak in this research.

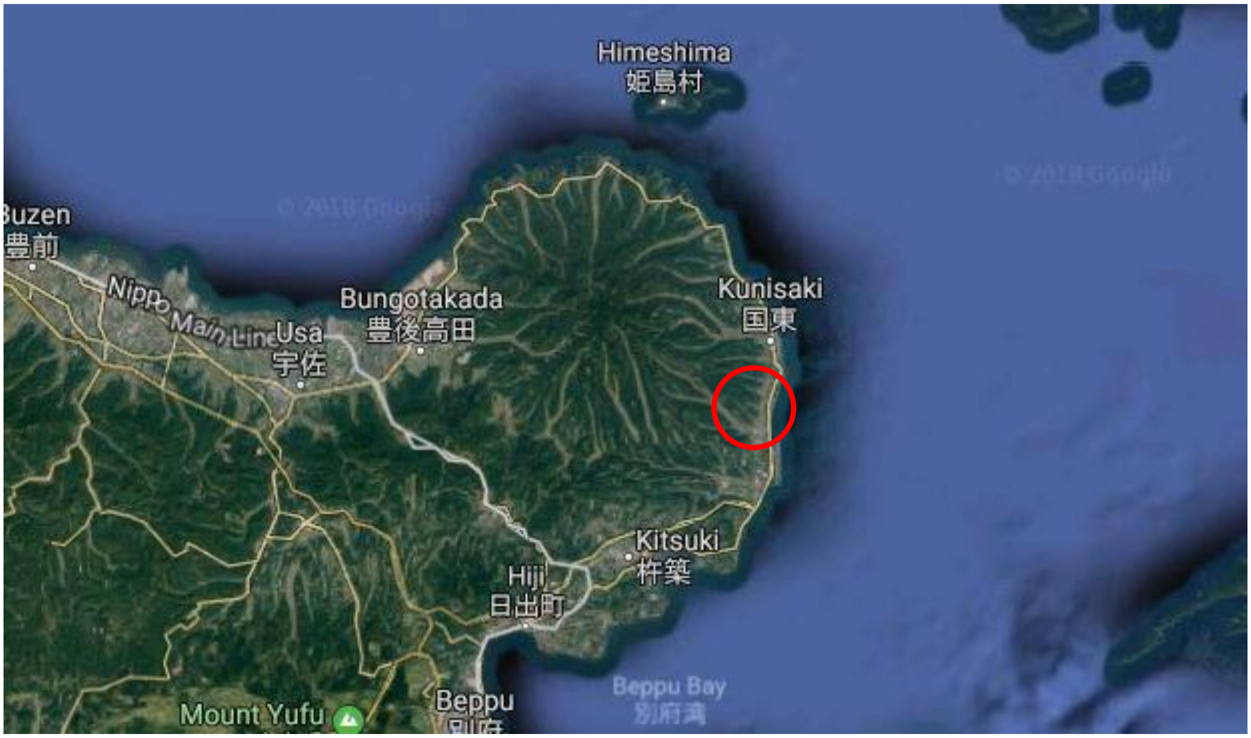
- **Image 1.1:** Location of Ababi Village, Karangasem Regency, Bali, Indonesia

Image 1.2: Canals and Rice Paddies in Ababi Village (2017*)*

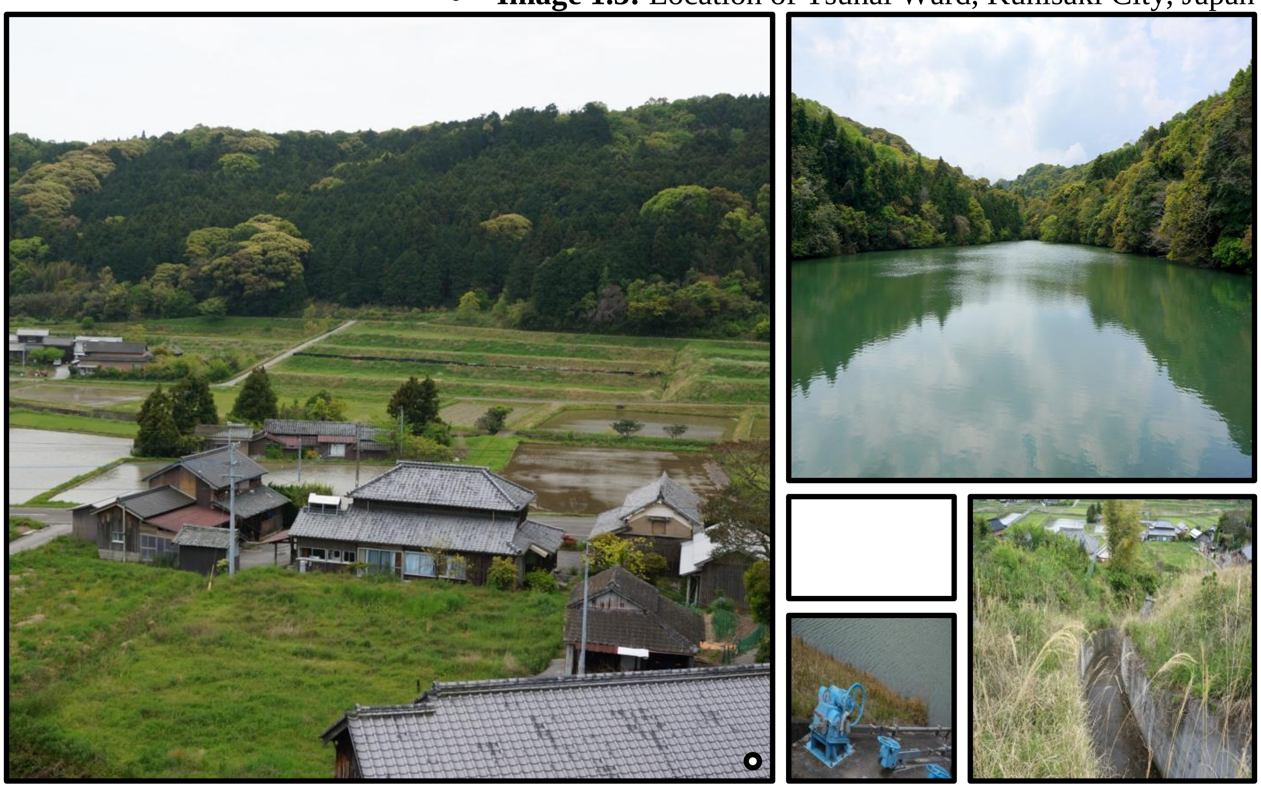
1.3 Kunisaki and the Tameike

Interestingly, Kunisaki, Japan has very little academic literature underpinning it, but was officially recognized as a Globally Important Agricultural Heritage System (GIAHS) in 2013. The GIAHS program is an initiative started by the Food and Agricultural Organization of the UN (FAO) in 2002 which aims to help preserve and develop culturally and sustainably significant agricultural heritage systems around the world. The designation process involves a comprehensive application followed by a formal review and a consequential inspection from an elected member of the GIAHS Scientific Advisory Board (FAO, 2017). This research, therefore, assumes the competency of this institution and pulls much of its supporting data from Kunisaki's official GIAHS application. Karangasem also applied for GIAHS status in 2015 and its application will be a large part of this study's background information, but its acceptance into the program is still tentative so more weight will be given to the academic research that supports it.

Kunisaki's irrigation system is comprised of a network of man-made ponds built into the mountain forests of Kunisaki peninsula. These ponds called *tameike* accumulate rainwater that can be transported to and from other ponds within a pond system. This is important because the region is claimed to only receive 1500mm of rainfall annually, compared to the national average of 1700mm (GIAHS Promotion Association of Kunisaki Peninsula Usa Area, 2013). With the ability to save and transport so much rainwater, Kunisaki's system is said to be incredibly water efficient, letting none go to waste. For each tameike in a system, there is one water manager known as an *ikemori*, and in the ward chosen in this research, there are 5 ikemori who serve a total of 11 farmers and 50 hectares of farmable land. These managers work together to efficiently deliver water based on the needs of these farmers in their community. Buddhism also has a very strong influence on the peninsula. Images 1.3 and 1.4 show the location of Tsunai Ward, the community chosen to represent Kunisaki in this research.



- **Image 1.3:** Location of Tsunai Ward, Kunisaki City, Japan



- **Image 1.4:** Tameike and Rice Paddies in Tsunai Ward (2017)

1.4 Research Objectives

The Globally Important Agricultural Heritage Systems program was initiated by the Food and Agriculture Organization in 2002 as a response to the "global trends that undermine family agriculture and traditional agricultural systems," (FAO, 2017). This alludes to issues such as aging farming populations, migration of young people to urban centers, and the rapid increase of corporate/industrial mass-production methods (Fuller et al. 2015; MAFF, 2016). In an attempt to conserve these traditional systems, the livelihoods contained within them, and their indigenous ecological knowledge, the FAO proposed a dynamic conservation approach where accepted sites become long-term members of the program and are supported and monitored as they continue to evolve (FAO, 2017). What is somewhat unclear, however, is how the FAO defines or classifies sustainable practices for each GIAHS site. As Japan is the only developed host country in the Asia-Pacific, how would the sustainability of traditional agricultural methods there compare to those in a developing country with very different socio-economic pressures? Furthermore, the GIAHS program puts specific emphasis on agricultural communities' "cultures, value systems, and social organizations" as a part of its main criteria, but what role does the technology and infrastructure used in a system play in sustainability? Understanding these questions would likely allow these communities and other communities worldwide to be better supported.

Taking these gaps in knowledge into account, this research aimed to analyze the social structure of each system to determine the role social capital and its effect in regards to sustainable irrigation management. Through this analysis, one main question and two additional supporting questions were analyzed:

- How does social capital contribute to the success or failure of sustainable irrigation management?

- How does the profile of social capital change over time as a community industrializes, and what effects on sustainability does it have?
- What plays a bigger role in successful water management, the social capital within the community or the structure of the irrigation system itself?

Social capital is defined as "networks of social relations characterized by norms of trust and reciprocity than can improve the efficiency of society by facilitating coordinated actions" (Lehtonen, 2004). It is commonly used to measure the relationships within a social system and will be the unit of measure to be compared to the level of sustainability for each system's irrigation management.

1.5 Significance of the Research

Academic research on Bali's subak has been extensive, but predominantly socio-anthropologically focused. A concrete, calculated appraisal of its overall sustainability has yet to be realized. Jha & Schoenfelder (2011) have also pointed out that current disputes in the field of subak research are the result of subak management differing based on their location, so diverse micro-level studies are needed to progress the field. Academic research focusing on water management in Kunisaki is virtually nonexistent, but based on its induction to the FAO's GIAHS program and subsequent publications, it can be said that it hosts a comparatively promising social landscape that is conducive for sustainable water management. Therefore, there are four main benefits provided by this study: (i) it can answer to the recent call for smaller case studies in the field of subak research, (ii) it can help pioneer foundational research on Kunisaki's emerging system, (iii) the social dimension, as the most theoretically underdeveloped of the three dimensions of sustainability, can be further understood, and (iv) the results can offer real world suggestions for future development in agricultural water management in volcanic island landscapes. By the very nature of these areas' topography, flat land conducive for agricultural cultivation and reliable water supplies are often scarce enough to create a real necessity for efficient and effective water management (Duncan, 2011).

Chapter 2: Literature Review

2.1 Sustainable Irrigation and Examples from GIAHS Program

A concrete definition of sustainable irrigation has yet to be developed, but some of the main contributing factors found in the literature are: having an appropriate and reliable water source with measures to reduce losses from transportation and soil (Chartzoulakis & Bertaki, 2015), protecting the upper watershed from pollution and erosion (Bhuiyan, 1993), preventing waterlogging and the buildup of salts in the soil (Singh, 2015; Wichelns & Qadir, 2015), and providing water to all members of the system in an equitable manner (Loof & Onta, 1994). In other words, sustainable irrigation 1) has a low negative impact on the environment, 2) uses water efficiently, 3) maintains water and soil quality, and 4) is properly managed so that it is fair and economically equitable to all users. Rice crops, however, are usually not significantly affected by waterlogging because as Nishiuchi et al. showed in their 2012 paper, *Mechanisms for coping with submergence and waterlogging in rice*, rice can be incredibly resilient to it. Most non-arid climates also do not typically have soil salinity problems because rainfall is usually frequent enough to diffuse the salts to normal levels.

Other GIAHS in the Asia-Pacific that irrigate rice have examples of successes and failures regarding the considerations for sustainable irrigation outlined above. The Ifugao Rice Terraces in the Northern Philippines, for example, have problems with erosion and landslides which deposit sediments in the rice terrace infrastructure during heavy rainfall. This is because of timber extraction, highlighting the need to protect the upper watershed. Biodiversity loss also occurs due to excessive fertilizer application and pig farming near the water sources, highlighting a need for zoning laws and regulation (Philippines Department of Environment and Natural Resources, 2008).

A successful example of sustainable irrigation methods comes from the Traditional Gudeuljang Irrigated Rice Terraces in Cheongsando, Korea. This community constructed their water transport structures underground, which both increases the area of land that can be used for rice production and minimizes water losses due to evaporation during transport. The mountains in Cheongsando are also left relatively underdeveloped which helps maintain the quality of the upper watershed (Wando County, Jeollanam-do Provincial Government Republic of Korea, 2013). These examples from the Philippines and Korea give an idea of how sustainable irrigation can manifest or fail to manifest in practice, and they provide a point of reference to see where the two communities studied in this research stand in comparison.

2.2 Bali and the Subak

A considerably large amount of research done in Bali is comprised of studies on tourism and the subak (Byczek, 2011; Cole, 2012; I Gusti Agung et al. 2015; Lanya et al. 2015; Law et al. 2016; Tajeddini et al. 2017). These two themes' importance is also evidenced in Karangasem's GIAHS proposal which sited rapid tourism development and agricultural land conversion as the main threats to the agricultural sector (Karangasem Regency Government, 2015). This interplay between agriculture and tourism development is critical because it highlights the interesting socio-political position the subak is currently in. The system itself is the result of centuries of traditional agrarian society bound together by Hinduism and animism/mountain worship, but now that Indonesia is industrializing and there are societal and economic changes brought on by globalization and mass tourism, the landscape is also changing, and the compatibility between the subak and these outside influences is being tested. Straub

(2011) found that tourism infrastructure and industries are already causing water shortages for some subak in southern Bali today. In Bali's history, there was never such competition for water resources as there is now, and this, combined with a rising population, is calling for the system to adapt or change.

The long, historical effectiveness of the subak until now, however, has certainly been well-documented by many scholars; especially one John Stephen Lansing who attributes its success to the unique religious landscape and strong bonds of trust and cooperation between farmers (Lansing, 1993; 2005; 2006; 2011). In his book *Perfect Order: Recognizing Complexity in Bali*, he specifically calls out the failure of Green Revolution farming methods when they were introduced to the subak system. Non-staggered water schedules and reliance on nonnative rice varieties created water shortages and enabled rice pest populations to multiply. Lansing described it as a classic case of the 'Tragedy of the Commons' (Hardin, 1968) where farmers disregarded their neighbors' water use and tried to optimize their own yields, resulting in exhausted water resources. The traditional subak system was argued to be more effective than Green Revolution methods because it maintained social equity, curbed pest growth, and optimized mean rice yields despite a shared water source. At the same time, however, with Indonesia's rapidly growing population, whether or not local Balinese rice yields can continue to sustain Bali in the future is uncertain (Lanya et al. 2015; World Bank, 2018). Jha & Schoenfelder (2011) also stated that with agriculture beginning to decline due to the younger generation choosing occupations in urban areas and other famers moving to commercial production, the community-based ties may be weakening, becoming less necessary, or both at the same time. That is not to say, however, the subak will become obsolete, but the nature of the way it functions may be changing to fit a changing social landscape.

Until now, the basis by which the subak has functioned has been its host religion, Hinduism, and more specifically, the concepts of Tri Hita Karana and Tri Mandala. Tri Hita Karana literally translates to "three causes of prosperity", which are man's relationship to man, man's relationship to God, and man's relationship to nature (Pitana, 2010). If these three things are kept balanced and harmonious, then the subak's water management is said to succeed. Tri Mandala refers to spatial use of the island of Bali using three zones: mountain, village, and environment. The mountains are reserved for the gods, the villages between the mountains are for mankind, and the outside edges of the island are for evil spirits. Combined, Tri Hita Karana and Tri Mandala dictate both the landscape of the subak irrigation system and how the people within the system are meant to behave (Karangasem Regency Government, 2015). As a result, mountains, such as Mt. Agung, are left underdeveloped and reserved for the gods; save for some temples and paths that connect to those temples. This can protect the water sources from drying up or being dirtied by the activities of man (Strauch & Almedom, 2011).

As one travels down the mountain and to the valleys, one will find the rice terraces and subak canals which deliver water to the terraces. This is the realm where man's relationship with fellow man and environment becomes important. Here is where Lansing described the cooperation game (based on Game Theory) that Balinese farmers play with nature which ensures that water users upstream and downstream receive their equal share of water. Typically, users upstream have first claim to water coming from the mountains and if they irrigate more land, they will get a larger yield as agriculture is an economy of scale. This would be problematic for downstream farmers who would be left with little to no water, resulting in a Tragedy of the Commons scenario. However, this does not occur because of the threat of rice pests. These pests' ability to reproduce is inhibited by staggered water use schedules, making it so that no large expanse of paddy is left dry at any given time. In this way, food and habitat is being denied to the pests. This dilemma between water and pest control gives the water users downstream leverage with the users upstream, because if they are not given water, rice pests will grow and negatively affect the entirety of the subak. Balancing these two flows of irrigation water and pest populations, according to Lansing, helps the subak farmers react to changes in their environment and achieve balance and water equity.

There also exists contention, however, over the origin of the subak system and differences in the amount of social cohesion depending on which subak is in question (Hauser-Schäublin, 2005; Jha & Schoenfelder, 2011; Nordholt, 2010). The main issue these scholars take with Lansing's conceptualization of the subak is that he only studied subak in the southern region and also downplayed the possible top-down influence of regional Balinese kings, as well as land reform and governmental changes brought about by the Dutch in the 19th and 20th centuries. They argued that the harmony of the subak members and the existence of downstream paddies could simply be the result of a king's mandate to expand production. History and geographical differences in social cohesion are important factors to consider for the purposes of this research, but they are also not the primary focus. The sustainability of the subak 's irrigation system in its present state is the main concern for this research as that is what is being considered for GIAHS designation, and it was what was measured in this study. Nevertheless, it is clear from the above sources that internal and external influences on the subak need to be carefully discriminated and considered as determining factors when studying the effectiveness and efficiency of irrigation management. Internal factors would be bonding and bridging social capital, religion, infrastructure, local climate and species, etc., and external factors would be linking social capital, past Balinese kings, Dutch colonization, mass tourism, industries, and the Indonesian government's development efforts.

2.3 Social Capital in the Subak

Scholars such as Jha (2004) have pointed out important considerations for measuring social capital in Bali such as the status of women, which in Balinese agriculture is reportedly low. This suggests a possible problem with bridging social capital deriving from traditions and cultural norms. Although women do participate in agriculture to a large degree, they rarely occupy positions of power within the subak and are expected to do gender specific jobs, such as ritual offerings. This was also found to be true in Lansing's book, but he took a less critical approach, stating that although women may have little power in irrigation management, their roles in religious and household affairs were quite strong.

MacRae and Arthawiguna (2011) have also described the considerable influence an individual can have in a subak system, despite their large size and tight social network. The study of two entrepreneurs growing and marketing organic produce within a subak network provided significant insight into the actual role of the subak as a managerial entity and in facilitating cooperative action. In short, these entrepreneurs' ideas and methods were initially rejected by the whole of the subak, but after their success was evident, people slowly began to adopt similar operations and participate; suggesting high social resilience, but not outright obstinacy. It seems the subak is not necessarily an agent of change or revolution itself, but a social facilitator grounded on the basis of fair water allocation. The subak's charter (or constitution as it were) known as *awig-awig* specifies rules based on water sharing and usage. Outside of water schedules, however, there is nothing specifying crop choices, marketing strategies, etc., leaving considerable room for regional peculiarities. This is why this study seeks to focus on a small geographic area so as to explore such possible cases of individual ingenuity.

2.4 Kunisaki and Satoyama Landscapes

Kunisaki has little research underpinning it other than more comprehensive reiterations of what was already outlined in its GIAHS proposal (Hayashi, 2014; Vafadari, 2013a & 2013b; Weiwei et al. 2014). These sources described the system's structure, the consequential nutrient cycling between the forests and tameike, and also the benefits of the system, such as the preservation of biodiversity and cultural livelihoods. Vafadari's paper (2013b) also covered the prospect of agro-tourism and briefly mentioned social capital saying that there is likely not enough leadership to utilize it for agro-tourism in most of the communities' present states. Overall, though, the main subject of interest for all the papers on Kunisaki is the novelty of the interlinked tameike system and forest management rather than communal networks like in Bali's case. Kunisaki's system was created in a similarly religious society where mountains were the sites of temples and frequented by practitioners of Buddhism or *Shuugendou* (修験道), but there are much fewer direct connections between this religious environment and the management of the tameike when stood next to the subak. There is also little concrete data in the current literature on the exact environmental impact of the tameike or the social networks that support them, which suggests that some frontier research will need to be conducted to gather sufficient background information to treat the case with the same accuracy as Karangasem's.

There is, however, data on landscapes similar to Kunisaki's in other regions of Japan. Kunisaki's system is considered to be an example of Japanese *satoyama* (里山) which literally refers to villages at the foot of a mountain. In a broader context, however, it refers to agrarian communities that live in harmony with their forested mountain environments, reaping social and economic benefits while providing environmental services (Indrawan et al. 2014; Katoh et al. 2009). Researches on these communities, although not specifically about Kunisaki, are numerous and provide some useful insights into how traditional Japanese agriculture and irrigation typically function.

What seems to be the most important point to contextualize the condition of these satoyama landscapes is that almost all of them are suffering from the aging and depopulation problem currently taking hold of Japan. The average age of a farmer in Japan was 66 in 2015, and Oita prefecture was slightly higher at 67 (MAFF, 2016). Moreover, younger generations tend to move to urban areas to seek employment, leaving no one to take the place of current farmers. Many of these landscapes are dotted with abandoned farmhouses and rice fields, so much that they are becoming a considerable burden on the government (Brasor & Tsubuku, 2016).

Several pieces of legislation were implemented in order to help these communities, including the 'New Policy for Food, Agriculture and Rural Areas Act' in 1992 and the 'Act on Promotion of Development of Infrastructures for Leisure Stay in Rural Areas' in 1994 which were introduced to improve the environmental quality of satoyama areas and help facilitate green tourism, respectively (Fukamachi, 2017). Along with these acts were the creation of numerous committees and organizations, both national and local, and promotions to help spread awareness of the value of satoyama landscapes. The Ministry of Agriculture Forestry and Fisheries (MAFF) even adopted the ‘Direct Payments for Hilly and Mountainous Areas’ policy, wherein farmers in these locations were given financial support to make up for the economic shortcomings of their environment (Ibid). Still, the depopulation trend is continuing in many satoyama communities (Indrawan et al. 2014).

This demographic shift has negative implications for both communities and the environment. If satoyama landscapes continue to dwindle and disappear, the indigenous knowledge built up from centuries of environmental management could be lost (GIAHS Promotion Association of Kunisaki Peninsula Usa Area, 2013). Along with that, because satoyama areas were previously maintained so well for so long, organisms that have depended on satoyama also might be negatively affected, such as the grey-faced buzzard or the Genji firefly (Katoh et al. 2009). Both of these species prefer semi-forested, semi-agrarian landscapes and have often benefitted from the activities of satoyama until recent decades; however, both have experienced drops in their populations due to habitat loss. Whether or not this is a drop below a naturally occurring population threshold or if the satoyama landscapes of yesterday artificially augmented the environment’s carrying capacity for these organisms is unknown, but according to the study done by Kadoya and Washitani (2011), maps of satoyama landscapes both in Japan and abroad are well-correlated to biodiversity maps. This was especially evident in contrast with regions like the Corn Belt in the US where monocultures are widespread. It would seem the diversity of crops grown and activities performed in satoyama landscapes lend to the natural processes of other organisms. Creating a landscape ‘mosaic’ is what keeps these regions balanced and sustainable (Takeuchi et al. 2016), but without people to maintain these mosaics and without economic backing to support their activities, their environmental benefits will be lost.

2.5 Social Capital in Satoyama Landscapes

When considering the social capital of satoyama landscapes, there should be a distinction made between the social capital of today and the social capital that supported these systems in the past. This is because of two things- the first being the demographic changes previously mentioned. Social capital is interdependent with human capital (Parts, 2003), and presently many of these areas lack adequate human capital, so what social capital there is to be found in a satoyama community today is likely not reflective of the social capital during the country's developing stages. The second reason one should recognize a difference between present day social capital and historical social capital is that it is likely that the orientation and scope of social capital has changed. According to a study by Kamiyama et al. (2016), the satoyama communities on the Noto Peninsula commonly share some of their agricultural products outside of the market, either for subsistence purposes or via social connections with family or friends. Many of the people involved in the receiving end of these transactions are from outside of the Noto Peninsula in larger urban centers like Tokyo. This was found to foster considerable social ties despite long distance. Indeed, it appears that Japan being a developed nation has created much more linking and bridging forms of social capital despite apparent drops in bonding social capital. This is facilitated both by citizens and their connectedness and government institutions (Takeuchi et al. 2016).

2.6 Summary of Both Cases

Both the subak in Karangasem and the tameike system in Kunisaki have their own unique socio-political climates within which they operate. Both systems are supported by the central government in some respect, but it appears there are a lot more initiatives within Japan's government and NGOs, whereas the Indonesian government appears to be mostly concerned with increasing yields as the bottom line; although, that is not to say it is indifferent to pursuing sustainable production or that there are not NGOs concerned with sustainable water management. The literature also emphasizes Bali's apparently strong bonding social capital which facilitates the success of the subak's water management, whereas Japan suffers from a lack of human capital and appears to rely more on the structure of satoyama itself rather than the social networks of the incumbent farmers.

The subak is also much more rooted in religion and tradition than the tameike system appears to be. This is not to say that there is no relevance to religion at all in Kunisaki's case, but the more important factors appear to come from the system structures themselves and the so-called 'landscape mosaics' which support biodiversity and sustained usage of natural resources. Thus, these two examples are ideal for exploring the second research question of this study.

What this study seeks to contribute to the growing literature on both systems is a formal, systematized measurement of both social capital and irrigation water use. A positive correlation between social capital and water use efficiency is only assumed by most studies. Lansing's book on the subak included figures on mean rice yields and total paddy area, but exactly how much water was used and in what way has yet to be explored. Furthermore, his study only covered subak in the southern region of the island, whereas this study on Karangasem will represent communities in the west. As for Kunisaki, there is no data on water usage in the literature. It is only assumed that the ability of the tameike to not only gather but also share and transport water leads to sustainable ends. This study seeks to determine the detailed relationship between irrigation water management and social capital and whether it does or does not lead to sustainable management; and if so, in what way can it be considered sustainable.

Chapter 3: Theoretical Framework

3.1 Social Capital and the Triple Bottom Line

This study utilizes the three commonly used pillars of sustainability to assess each community: environmental, economic, and social. The social dimension, however, is given more weight because although all three dimensions are important and interrelated, it is the most crucial when evaluating management strategies and the organizational patterns of human networks. The main indicator of success for this study is therefore the environmental, social, and economic sustainability of the two systems, and the main subjects of analysis are individual stakeholders and stakeholder organizations that make up the involved social capital.

Lehtonen (2004) defines social capital as “networks of social relations characterized by norms of trust and reciprocity than can improve the efficiency of society by facilitating coordinated actions”. This can include institutions such as farmers’ associations, religious groups, social groups, and NGOs; as well as their respective norms and values. Many scholars and the World Bank recognize social capital as being strongly correlated to sustainable development potentiality. Jonathan Isham et al. (2002) quantified this relationship by surveying World Bank funded potable water development projects in Sri Lanka and India. Based on the so-called ‘social capital index’, the more social capital found in these communities, the more likely it was that the community members participated in a project and the more likely it was that stakeholders expressed satisfaction in the project’s outcome. This study takes a similar approach under the assumption that social capital is positively correlated with the successful management of communal institutions. This study differs from previous ones, however, by focusing on sustainability as the indicator of success.

There are two main approaches to social capital, the Network Approach and the Social Structure Approach. The Network Approach focuses on ties between actors within a community based on three classifications: bonding, bridging, and linking. Bonding social capital is typically shared by family members, close friends, or people who have lived in the same community their whole lives. These ties are usually the strongest with a high degree of network closure, but can also have negative effects such as exclusion of outsiders or a lack of innovation (Álvarez & Romaní, 2017). Bridging social capital is usually shared between actors form different social groups divided by age, gender, occupation, etc. Ties created in this classification are usually weaker than those in bonding social capital, but can bring new ideas and innovation to a system. Finally, linking social capital is shared by actors divided by explicit institutional borders such as farmers and national government offices. These ties are usually quite weak like bridging social capital, but can also provide important benefits to a system, such as subsidies, education, promotions, and other types of support. Maps of all the major nodes within the social networks of each system are provided in figures 3.1 and 3.2 below.

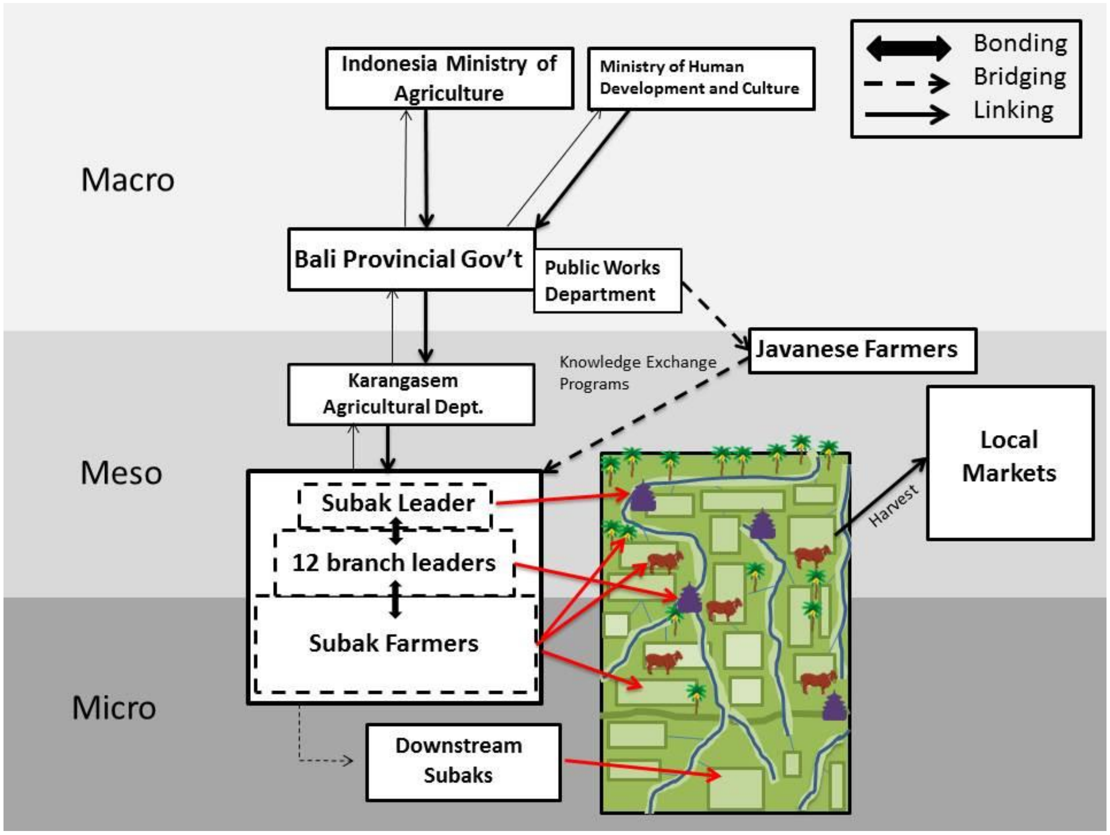


Figure 3.1: Network social capital in Ababi, Karangasem, Bali, Indonesia

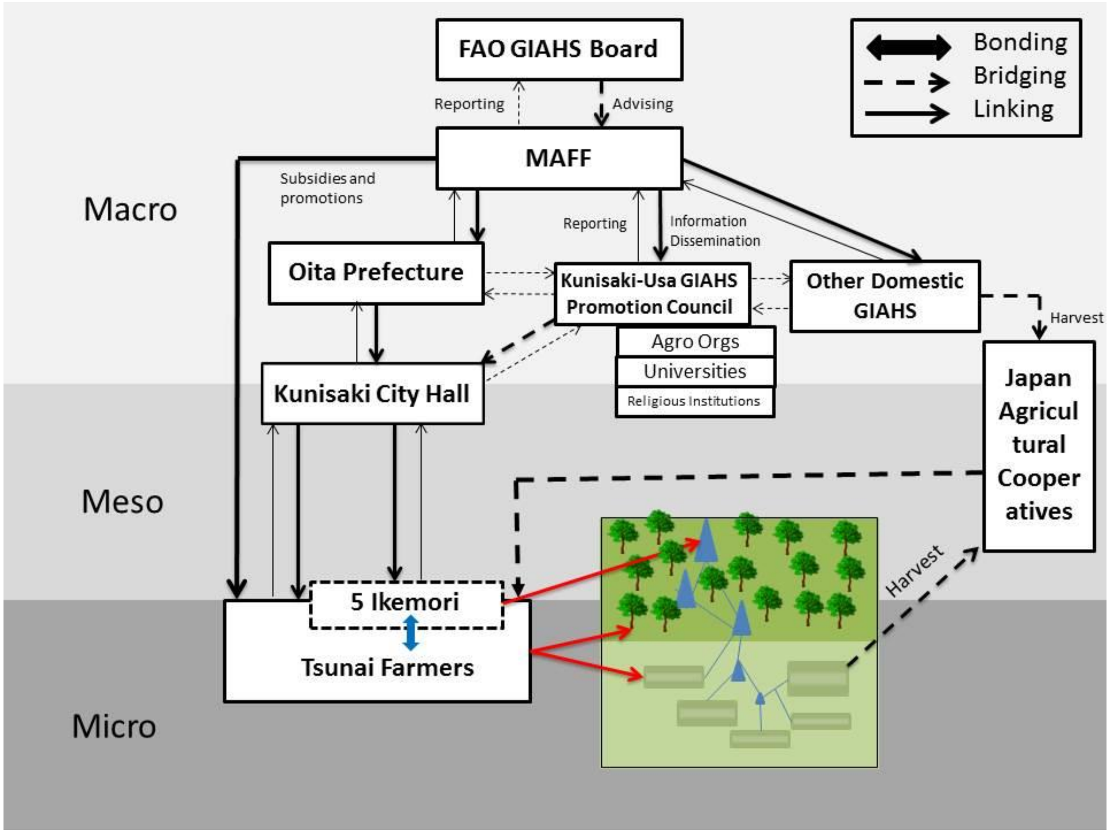


Figure 3.2: Network social capital in Tsunai, Kunisaki, Oita, Japan

In the Social Structure Approach, there are also three classifications of social capital: structural, cognitive, and relational (Claridge, 2004). Structural social capital looks into the culture and identity of a community and the nature of the institutions individuals are connected by. Cognitive social capital is measured by prevailing norms, attitudes, and values within a community; or more simply, what people think of their system. Relational social capital refers to the bonds of trust and reciprocity between individuals.

Table 3.1: Network and Social Structure Approaches broken down into their subcategories with descriptions and examples

Approach	Classification	Description	Example
Network Approach	Bonding	Connections **within** a social group or community; Horizontal ties between people of similar demographics	Family, friends, neighbors, members of a local association
	Bridging	Connections **between** social groups or communities; Horizontal or vertical ties between people from dissimilar demographics	People of dissimilar cultural background, economic status, gender, age, etc.
	Linking	Connections **between** social groups or communities where there is a significant hierarchy; Vertical ties between people from dissimilar demographics	Patron/Client, Government/Citizen, Teacher/Student
Social Structure Approach	Structural	Social system through which society operates and its typical procedures that facilitate group action	Laws, traditions, modes of government, religion
	Cognitive	Like norms, values, unspoken-rules, taboos, etc. which govern the actors within a social system	Language, culture, ceremonies, narratives
	Relational	Relationships between actors within a social system and the nature of said relationships	Trust, reciprocity, obligations

Both of these approaches can be used to provide useful insight into a community and both were adopted for this study because of the small scale of each system and the need to thoroughly analyze them. The Network Approach provides information on the different levels and hierarchies of the water management systems and draws a map of all the different actors involved, from the farmers all the way to national government agencies. The Social Structure Approach will allow a look into the qualities and characteristics of each community's social capital, rather than simply mapping them horizontally or vertically.

3.2 Adjusted Approach to Social Capital

The concept of social capital, however, is not without its criticisms in the academic community, so for the sake of accommodating some failures recognized in past studies, this study took a modified approach to social capital. One common criticism is that referring to resources (natural, economic, or social) as ‘capital’ only serves to perpetuate ‘economist’ or ‘productivist’ mindsets that sometimes takes true sustainability out of focus (Lehtonen, 2004). This is because the values of certain parts of the environment or society are sometimes abstract and conceptualizing them in monetary terms is inappropriate. Some also contest that the social dimension is a special case in relation to the other two dimensions because of how tightly integrated it is to them, so it cannot be effectively isolated and analyzed. Many also see social capital as being problematic because of the “difficulty if not impossibility to quantify most social phenomenon,” (Ibid). In other words, social capital can oversimplify the complex, subjective, and sometimes irrational relationships between societal actors.

Further still, Galvan (2007) points out that there are also forms of social capital that are undesirable and can actually hinder a community’s ability to cooperate effectively. His example was street gangs in Los Angeles. Technically gangs are social capital, but are an example of defectors who divide and compete with prevailing cooperative efforts. Galvan also took observations on a Senegalese NGO, the Association des Paysans de Tukar, and posited that it is often not social capital itself which is important, but environments that are conducive to social capital being created dynamically. His case study of the Senegalese NGO showed that its success was actually owed to a lack of social capital which allowed the organization to operate more independently from central authorities and later resurrect itself as a different NGO once the original one had run its course.

Nevertheless, social capital is still widely used to measure the social dimension of sustainable development and there has yet to be an alternative analytical framework created that better quantifies the effects of social phenomena. The possible failures of a social capital approach mentioned above were given consideration and several amendments were created to assist the accuracy of this study. First, not only did this study quantitatively measure the social capital present in Karangasem and Kunisaki, the nature and orientation of the social capital was also qualitatively measured via an anthropological approach. This means that the quality of the values, relationships, social norms, and circulated information facilitated by the systems' communal networks were analyzed in relation to their contributions or detriments to the success of the system. This includes group and individual behavior, as well as indigenous knowledge and newer information trends such as shifts to organic farming methods. In this way, social capital is still the basis for indicating success in the social dimension, but the quality of said social capital is prioritized to properly understand the detailed dynamics of how it is achieved. This detailed approach is especially appropriate because of the small geographic size of each system.

Additionally, in order to address the economic and environmental dimensions, the social dimension is analyzed as an affective agent that results in economic and environmental outcomes. Economic outcomes were measured by the farmers' ability to address risks, their business expenditures, and their relative job satisfaction. Environmental outcomes were measured by four criteria: Water Demand, Water Footprint, water quality, and managerial effectiveness. The Water Footprint is a calculation of the total green water, blue water, and grey water used to produce a certain amount of product, which was rice in this case. Green water is rainwater that falls directly onto the rice paddies, blue water is water supplied by irrigation, and grey water is the total water needed to dilute water that was polluted by fertilizers and pesticides to a safe level. This method produces a functional equivalent (i.e. m^3/t) which can be used to effectively compare the two systems' overall water efficiency (Chapagain and Hoekstra, 2011; Marano and Filippi, 2015).

Chapter 4: Methodology

4.1 Study Sites

Kunisaki lacks foundational literature, so it was necessary to spend more time accumulating primary information there than in Karangasem. The literature on Bali also points out that the basic theories for subak have already been fairly established, so newer studies need to be focused on local characteristics to maintain significance in the field (Jha & Schoenfelder, 2011). This is partly due to the recent attention brought to the power individuals have to influence these small-scale systems (MacRae, 2011). For this reason, during data collection in both areas, the research focused on a very small geographical location. For Kunisaki, it was the Tsunai ward. It is a small sliver of the peninsula with six tameike that was frequently cited in Kunisaki’s GIAHS proposal. For Karangasem, Ababi village was the subject area, which is a small community centered around the Tirta Gangga water palace mentioned in Karangasem’s GIAHS proposal. It is a fifteen minute drive northwest from Amlapura.

4.2 Research Design

This research is a comparative case study with an inductive approach where the main goal is to develop theory that can be further generalized for similar cases. In order to collect ample data and ensure triangulation of findings, a three-pronged approach was adopted, constituted by a macro level, a meso level, and a micro level. The order in which data was collected also followed these levels (starting with the macro level) in order to have previously collected data inform the questions asked in the next level. This reduced the redundancy of findings and allowed the final survey given at the micro level to be time-efficient and focused.

All interviews were conducted in the respondents' native languages and assisted by an interpreter. All survey questions were also translated by a native speaker.

4.3 Data Collection

At the macro level, semi-structured interviews with government officials involved in each of the irrigation communities were conducted. For Ababi, the deputy head of the Karangasem Office of Forestry and Plantations in Amlapura was interviewed. For Tsunai, it was the chief and two other representatives of the Agricultural Department in Kunisaki City Hall. Questions in these interviews concerned the following 5 criteria:

- Their offices' relationship with the water management system
- Agricultural organizations active in their jurisdiction
- Legalities and policies concerning the system
- Development and technology
- Environmental impact data

At the meso level, semi-structured interviews were conducted with the leaders of the irrigation management bodies themselves. In Ababi, it was the leader of Subak Embukan, and in Tsunai it was two of the five Ikemori, their treasurer/historian, and the Chairman of the Kunisaki-Usa GIAHS promotion council. Questions in these interviews concerned the following 5 criteria:

- Management strategies

- Duties of managers
- Trends in management
- Involved farmers and relationships
- Technology used in water transport

At the micro level, structured surveys were handed out to the farmers using the irrigation schemes being studied. In Ababi, there were twelve respondents; one from each of the twelve branches of Subak Embukan. In Tsunai, all eleven farmers operating in the ward were surveyed. The surveys contained around 67 questions divided into four sections: General Information (G), Water Use (W), Social Capital (S), and Economic Assessment (E). Respondents were informed of the purpose of the study as well as their right to choose not to answer any of the questions. The questions in the Water Use section were used to calculate the water demand and water footprint of each farmer's operations, as well as investigate the difference in farming style between individuals within a community. The Social Capital section was used to measure each community's approximate amount of social capital, based on the six different classifications of social capital: bonding, bridging, linking, structural, cognitive, and relational. Many questions were also dually purposed to measure other social phenomenon such as resilience to change, geographical distribution of social relationships, and others. The majority of questions employed the Likert Scale, meaning respondents could choose 'strongly disagree', 'disagree', 'neutral', 'agree' or 'strongly agree' in response to a given statement. These answers were then converted to a numerical scale from -2 to 2 so they could be averaged and compared. The answers were averaged instead of summed because some farmers elected not to answer.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
-2	-1	0	1	2

Although the answers were converted to numeric values, they do not represent a social capital 'unit' of any kind. Therefore, the scale is better thought of as a conservative measurement of the social capital 'intensity', rather than a concrete measurement. As cited in the theory chapter, it would be arbitrary to attempt such a measurement anyway.

The Economic Assessment section was to find out if farmers are able to support themselves based on their own opinions and also find what kinds of support they receive; either from the government or from other sources of income. It also measured farmers' perceived risk from natural disasters, rice pests, water scarcity, lack of manpower, lack of access to equipment, and foreign rice imports.

4.4 Water Demand and Water Footprint Calculation

The Water Demand (*WD*) and Water Footprint of rice (*WF*) can be understood as the total amount of water used in growing rice, and the efficiency of water-use compared to rice yields, respectively. These were two of the main methods chosen in this study to compare sustainable water management between the two study sites. The *WD* and *WF* of each community were calculated based on a method introduced by (Chapagain and Hoekstra, 2011) as a part of a global water footprint estimation report with the FAO. There are four main stages of rice cultivation that consume water: saturating the soil (*SAT*), setting the water level (*WL*), evapotranspiration during rice growth (ET_c), and percolation (*PERC*). All of these added together become the *WD*. *SAT* was estimated via a constant value of 20cm used in Chapagain and Hoekstra's study. *WL* was asked for directly in the survey to farmers. ET_c was calculated with farmers' cropping schedules obtained through the surveys and climate information from the official meteorological websites of Japan and Indonesia. CROPWAT 8.0 computer software was employed for these calculations. *PERC* was estimated based on a scale given in Chapagain and Hoekstra's study compared to a rough assessment of soil conditions given by farmers in the surveys. To find out what percent of the *WD* is green water (*GW*) and what percent is blue water (*BW*), one must subtract effective rainfall (P*eff*) multiplied by the area of the rice paddies. *Peff* was estimated using the USDA S.C. Method via CROPWAT 8.0. *Peff* becomes *GW* and the remainder is *BW* to be taken from irrigational sources. *WF* is then calculated by subtracting *PERC* from the *WD* since that water returns to the environment, and the remaining water is compared to the yields reported by the farmers. This final value is expressed as m^3/t. To know what percent of the *WF* is *GW* or *BW*, the percentages found during the *WD* calculation are applied to the total *WF*. To see the actual *WD* and *WF* calculations for Ababi and Tsunai, please refer to chapter 6.

4.5 Water Quality Testing

One more of the four criteria used to assess the sustainability of water management is water quality, which was measured with the Kyoritsu Chemical Check-Lab Corporation's River

Water Test Kit (共立理化学研究所の徳用川の水調査セット). This kit tested for Chemical Oxygen Demand (COD), Phosphates (PO_4), Nitrites (NO_2), Nitrates (NO_3), and Ammonium (NH_4). All of these are indicators of the health of the waterbody, and more specifically, the health of the Nitrogen Cycle. If any pollutants from agricultural runoff or other sources were large enough to impact the health of the water, the kit would detect it. Additionally, the pH, water temperature, air temperature, and time of day were recorded during testing to assure there were no anomalous conditions. Testing of all six tameike in Tsunai was conducted May 20th, June 17th, and August 2nd of 2017 to get a temporal profile of any changes in the ponds' nitrogen cycles. Due to time and financial constraints, testing in Ababi was only done from August 30th to September 11th 2017. Samples were taken near the weir with the highest elevation used by Subak Embukan, by the east wall of Tirta Gangga, and also by the ocean to ensure a variety of data inputs.

4.6 Limitations

- This study will only cover small parts of the overall area where each management system is performed, so there is a chance that the data collected will differ when compared to surrounding communities.
- Japanese and Bahasa Indonesian are not the researcher's first language, so some of the data may have slight discrepancies after being translated.
- There are actually around 336 farmers in Subak Embukan, but only one from each branch was surveyed due to time constraints and lack of resources. There were only two weeks to

collect data in Bali and many of the farmers were illiterate in Bahasa Indonesian, so a native speaker had to read the entirety of the survey to some of them, which took considerable time. Therefore, a statistically representative sample was not achieved, but data was collected systematically via all 12 of the subak branches.

- When calculating evapotranspiration for the Water Footprint in Bali, there was some climate data that was not available on the Indonesia Meteorological, Climatological, and Geophysical Agency's website, so some data points were taken from other websites including worldbank.org, accuweather.com, and holiday-weather.com.
- The River Water Test Kit was mainly designed for testing rivers, so when it was applied to the ponds in Tsunai, the COD was above the highest unit of measurement the kit offered. This is to be expected for stagnant bodies of water, but because of the limitations of the test, the exact COD could not be determined.

Chapter 5: Research Results

5.1 Social Capital Assessment

5.1.1 Bonding Social Capital Part 1: Questions G4 – S7

This section will discuss the results of the survey and connect them with information received from expert interviews, as well as parts of the literature review, to create a comprehensive view of each system's social capital. The first category is bonding social capital. There were 16 questions in the survey that were directly related to measuring bonding social capital. These were chosen because they were indicative of the nature of the relationships between the farmers only, and not of relationships that connect them to what might be considered external social spheres or institutions. In Tsunai, all farmers are Japanese men, are similar in age, live in close proximity to each other, and are bound by the rules of the tameike and ikemori. In Ababi, farmers are predominantly Balinese men, are somewhat more diverse in age, live in close proximity to each other (although having many more members than Tsunai), and are bound by the subak's rules of awig-awig. It was therefore assumed that bonding social capital was likely to exist amongst members of these organizations, and the following questions were asked to measure the intensity said social capital. Questions G4 - S7 represent indirect, yet objective indicators of bonding social capital, while questions S9 – S16 asked for the respondent to report based on their subjective opinion or feeling. Table 5.1 shows questions G4 – S7 and their answers.

Table 5.1: Questions G4 to S7b from the questionnaires given to farmers as well as their averaged responses are outlined below.

#	Question	Ababi	Tsunai
G4	What is your religion?	100% Hindu	100% Buddhist
S1	Average time living in the area?	51 years (Whole Life)	70.7 years (Whole Life)
S2	Average amount of generations living in the area:	3.7	4
S3	Do you have any children or grandchildren?	100% yes	91% yes
S4	Do/did any of your children or grandchildren attend schools in your area?	75% yes	90% yes
S5	Do any of your children help with farming?	75% yes	50% yes
S6(a)	Do you have a spouse?	92% yes	82% yes
S6(b)	Does your spouse help with farming?	91% yes	72% yes
S7(a)	Have you been in a leadership position before?	50% yes	82% yes
S7(b)	Average amount of time spent in a leadership position?	9.9 years	4.7 years

Bonding Social Capital Part 1: Religion

As question G4 in Table 1 shows, both Ababi and Tsunai are religiously homogenous which could indicate like-mindedness in a number of aspects of their lives, as well as a likelihood of participating in similar religious events. As stated in the literature review, however, religion appears to take on a much larger role in agricultural affairs in Bali when compared to the literature on satoyama landscapes in Japan. The GIAHS proposal for Kunisaki did say that there were numerous religious and cultural sites on the peninsula and that much of the land used to be owned and administered by Usa Shrine and Futago Temple, but when asked whether he thought religion was an important part of irrigation management in Tsunai, one ikemori laughed and said no. He and the Tsunai tameike historian went on to explain that although some parts of the peninsula were heavily influenced by religion, Tsunai was not. Unlike Bungotakeda or other communities that were closer in proximity to these historically influential religious institutions, the tameike in Tsunai were actually built with the investment of Kitsuki-han (杵築藩), a domain centered in the south of the peninsula during the Edo Period (1603-1868). This domain sought to expand its total rice production and apparently chose to include Tsunai in its agricultural development.

Subak Embukan in Ababi is likely also influenced by historical regional authorities since it is centered around Tirta Gangga water palace which was built by the late Balinese monarch Anak Agung Agung Anglurah Ketut Karangasem (r. 1908-1950). However, the extent of this monarch's influence on the subak is uncertain, and the influence of Hinduism in the subak's present state is much more pronounced. When asked what his primary role was, the leader of Subak Embukan said, "Organizing the water schedules and teaching subak members about Tri Hita Karana". Indeed, with 12 bedugul water temples dedicated to the goddess Sri dotting the expanse of the terraces in Ababi, it was clear that agriculture and the subak leader himself assume a spiritual function rather than just a managerial one. The leader later explained that even the Balinese Pawukon calendar, which is used to schedule village-related and religious events on auspicious days, is based on the growth period of Balinese rice. The calendar consists of 210 days with six 35-day months, three of which are exactly how long it takes for native Balinese rice to reach maturity: 105 days. With the subak leader's activities and even the rice growth periods being deeply connected to Hindu traditions, it is likely that the religious ties to irrigation in Subak Embukan are stronger than those in Tsunai; although, that is not to say that religious ties in Tsunai are lacking.

There are three separate events held in Tsunai: Daishi Matsuri (大師祭り), Suijin Matsuri (水神祭り), and Ike Matsuri (池祭り), which are the Bodhisattva Festival, Water God Festival, and Pond Festival, respectively. There are also a few shrines which are maintained by the villagers, one of which is dedicated to the mountain where the tameike are situated. This shrine is pictured below.

Image 5.1: Shrine in Tsunai village dedicate to the mountain. All farmers help maintain the premises.

According to Tsunai's historian, however, these sites and events were adopted post-construction of the tameike, showing that the tameikes' conception was not a result of religious activity, but was later seen as deserving of religious reverence and divine protection. No part of these religious events is used to dictate water use or land use, nor the way in which villagers should behave in agricultural affairs. Nevertheless, they do likely build comradery and solidarity as a village and, thereupon, bonding social capital.

Bonding Social Capital Part 1: Ancestral Lineage and Family Participation

Questions S1 – S6 measured the current farmers' time spent involved in their irrigation systems, their family histories, and how much their spouses and children participate in agricultural activities. Question S1 shows that farmers in Tsunai have lived an average of 19.7 more years in their village than farmers in Ababi; however, all farmers from both locations stated that they have lived there their whole lives, indicating that the farmers of both locations have lifelong investments in their system. Tsunai farmers are simply older, on average. Question S2 also shows that Tsunai and Ababi farmers' family histories are comparably deep-rooted in the host villages, and although many farmers in both systems reported that their lineages may go back further, around four generations was the average amount they could remember. The results of questions S1 and S2 suggest the possibility for high bonding social capital, but also the possibility of low bridging social capital since there are not many new people or ideas entering either system.

Question S3 – S5 measured the amount of farmers with children, their children's involvement in the local community, and their children's involvement in farming in general. Almost all farmers have children and grandchildren, although the number is slightly lower in Tsunai. This is to be expected, however, when comparing a developing and developed country. Most agricultural communities in developing countries desire children to help work on the farm, which is evidenced by the results of question S5: 75% of the farmers in Ababi reported that their children are involved in helping out on the farm, while only 50% of the children living on farms in Tsunai help out. Due to the nature of daily tasks being more technologically oriented in Japan, a child's participation has become less necessary for a farmer's success. Farming in Bali is still manpowered on the whole, so human resources are a must. This shows the trade-off between social capital and technology previously predicted in this study. As technology improves and becomes widely available, it is likely that social capital becomes less necessary for success in multiple levels of agricultural operations.

The results of question S4 makes this assumption appear even more plausible since there are more children attending local schools in Tsunai than children in Ababi. Despite these children in Tsunai being more locally tied via education and organizations, their participation in farming is much lower. Many farmers in Ababi reported that their children attend school in Karangasem's urban center, Amlapura, which is roughly 8 kilometers away from the edge of Ababi village. Yet, these children have more responsibilities toward their family's agriculture. This could also be due to cultural or institutional differences in the demand for study time, etc., but even with such differences, access to technology likely has a high chance of playing a hand in a child's need to participate.

Finally, question S6 follows the same trend as S3 – S5 in that spouses in Ababi are also slightly more common and participate in agriculture more than in Tsunai. In this case, however, spouses in Tsunai are more likely to participate than children, suggesting there may also be some kind of generational explanation for the low participation of children there. During the interview with representatives of the agricultural department of Kunisaki City Hall, two of the representatives stated that they grew up on farms and that their parents told them not to become farmers themselves because of the instable income. Indeed, it appears that although many wish to preserve the culture and livelihood of Kunisaki's countryside, at the same time, farmers wish more for their children and encourage them to find more stable jobs. This does not necessarily damage bonding social capital for Tsunai, but it does diminish human capital which social capital depends upon. At any rate, bonding social capital simply based on the number of spouses participating is quite high in both Tsunai and Ababi, but a bit higher in Ababi.

Bonding Social Capital Part 1: Bonding and Role of Leadership Positions

Question S7 asked each farmer whether or not they have been in a leadership position and, if so, how long they kept the position. They were also asked whether their time served in the position was consecutive or sporadic- meaning that if a farmer hypothetically served for 5 years, was it from 1993 to 1998 or did they skip some years and come back to the position at different intervals. 9 of the 11 farmers in Tsunai reported having been an ikemori at least once, most served consecutively, and the average term was around 4.7 years. This is a very high level of participation without any one person remaining in power for too long. This represents not only a healthy degree of involvement with most of the farmers, but a somewhat even power relationship. When an ikemori is in power, he is an authority figure for the years that he serves, but before and after his term, he is on equal footing with other farmers. If a hierarchy between farmers exists at all, it is a dynamic one. The only staunchly authoritative position would be the ward headman, who at the time of this study was simultaneously an ikemori.

In Ababi, only 50% of the respondents were a subak leader or branch leader, and the average term was about double that of Tsunai at 9.9 years. Also in Ababi's case, there was a wider deviation in term periods, ranging anywhere from 4 months to 20 years. According to the deputy head of the Karangasem Office of Forestry and Plantations, the usual trend is that a leader who leads well is constantly reelected, while those who perform poorly are gotten rid of almost immediately. Despite this seemingly practical notion, it is difficult to gauge the power structure and relationship between leaders and farmers. It appears that there is a more obvious hierarchy than in Tsunai, but the leaders are democratically elected by their peers, so it is not necessarily that people are left out or ignored; however, each farmer is not given their turn to lead as a matter of principle. A few of the farmers who had never been a subak or branch leader said during the survey that they did not want to be a leader because it is difficult and requires a higher level of education. One farmer even said that he could not lead because he is illiterate. Perhaps if education was more widely and financially available in the community, the percentage of farmers who occupy a leadership position would increase. This might not reflect a social inequality in the institution of the subak itself, but one borne from Bali's developing society where resources and education are not yet equitably accessible to all citizens.

5.1.2 Bonding Social Capital Part 2: Questions S9 – S16

The eight questions in this section are based on farmers' opinions and feelings and were gauged by the Likert Scale previously discussed in the methodology section. Farmers had the choice of five responses: strongly disagree, disagree, neutral, agree, and strongly agree. These responses were then translated to -2, -1, 0, 1, and 2 respectively and then averaged. Questions S10, S11, S13, and S14 were not measured by this scale because they were supplementary to the questions that preceded them: S9 and S12. Instead of measuring intensity, they helped record more specific qualities about their relationships with other farmers like the frequency at which they communicate and what the goal of their communication typically was. Table 5.2 shows all of these questions and their results.

Table 5.2: Questions S9 to S16 from the questionnaires given to farmers as well as their averaged responses are outlined below.

#	Question	Ababi	Tsunai
S9	I have neighbors in (system name) with whom I am close.	1.5	0.89
S10	On average, I contact at least one of these neighbors ____. (top 2 answers)	Every day / 2-3 times a week	Twice a month / 2-3 times a week
S11	I usually talk to them about _____. (Top 2 answers)	Farming / Group or cultural activities	Farming / Everyday things
S12	I have farmers *outside* of (system name) with whom I am close.	1	0.63
S13	On average, I contact at least one of these neighbors ____. (Top 2 answers)	Once a month / Less than once a month	Once a month / Twice a month
S14	I usually talk to them about _____. (Top 2 answers)	Farming / Group or cultural activities	Farming / Everyday things
S15	I mostly agree with other farmers in my system about farming methods and schedules.	1.42	0.5
S16	I mostly agree with other farmers in my system about everyday affairs.	1.36	0.63

Bonding Social Capital Part 2: Relationships within the Irrigation System

Essentially, questions S9 – S11 serve to display the farmers' feelings about the intensity and nature of their own bonding social capital; although, it was not explicitly explained to them that this was the case. Overall, farmers in Ababi reported having good relationships within their community at a considerably higher intensity than farmers in Tsunai (40% higher). Neither system had negative or neutral averages, however, so bonding social capital still appears to be quite strong for both. The frequency at which the respondents contacted their neighbor(s) or friend(s) was also much higher in Ababi with most farmers saying they interact daily, while most farmers in Tsunai socialize around twice a month (Question S10).

Finally with question S11, we see that the most common topic of conversation during social interactions for both systems is ‘farming and farming strategies’. What is interesting, though, is that the second most common topic was ‘group and cultural activities’ in Ababi, and ‘everyday things’ in Tsunai. Once again, this provides some evidence that speaks to the strength of religion in Bali. Talking about the subak solely as an agricultural entity without also recognizing its religious role is nearly impossible. Despite the existence of religious events in Tsunai, it is not such an essential force like it is in Ababi. One farmer even wrote in the margins of the survey that he used to participate in religious/cultural events, but in his old age, he finds it more difficult to leave the house. Perhaps in Tsunai’s past, the religious landscape was more apparent and significant to farmers, but as stated before, Tsunai has never historically been the site of religious activities as a primary function.

Bonding Social Capital Part 2: Relationships outside the Irrigation System

Questions S12 – S14 mirror S9 – S11 so as to not only gauge the intensity of relationships further away from the system in an equivalent way, but also to estimate a gradient for where the boundaries of bonding social capital might lie. Both systems reported having less social capital outside of their system than inside, but once again, Ababi farmers reported having a higher intensity of good relationships overall. The results of the frequency of social interactions given by question S13, however, show that there actually might be a higher frequency amongst Tsunai farmers to contact other farmers and/or friends from outside their system. This is likely due to having more organizations that help connect farmers from different areas, as well as the outward migration of family members and neighbors previously mentioned. With the establishment of nine GIAHS sites countrywide, numerous farming cooperatives, and city/prefectural support institutions, it is likely easier for farmers to do networking in Japan; and as stated in the literature review and section 5.1.1, children of Tsunai farmers go to school locally, but young adults tend to move away to urban centers for employment. These two factors are likely what heighten the extended bonding social capital in Tsunai. Although some farmers in Ababi also belong to formal farming cooperatives, maintain relationships with governmental offices, and report that young people in their village going to Amlapura or Denpasar for work, it is not as large-scale a phenomenon when compared to Japan.

Question S14 had the same results as its mirror question, S11. This mostly just reaffirms that group and cultural activities in Ababi are stronger than they are in Tsunai. Overall, it seems that although farmers in Ababi have a widespread, open system and report a higher intensity of good relations further from their locality than Tsunai farmers, they contact these distant people less frequently. Farmers in Tsunai have a smaller, closed system and a little less bonding social capital, but have a wider social network.

Bonding Social Capital Part 2: Agreement and Homogeneity of Work Style and Lifestyle

Finally, questions S15 and S16 asked about agreement concerning farming strategies, scheduling, and everyday affairs. Both of these had a higher intensity in Ababi and were actually considerably low in Tsunai. This does not definitely mean that they have low social capital, but it does suggest a higher sense of individuality in Tsunai, despite both Balinese and Japanese culture being known for cultivating a strong group identity. Perhaps instead of this being an effect that is entirely based in culture, the structure of Tsunai's system might also cause this lower intensity of agreement. Since the water in the tameike is collected, taxed, and then bought by participating farmers, it is essentially a commodity. Furthermore, land is individually owned and operationalized. In Ababi, some land is private and some is shared by the community, but most importantly, the water is free, and it is a dynamic and easily accessible source to everyone. Therefore, agreement on farming strategies might be higher in Ababi simply because it is more necessary than it is in Tsunai to ensure equal water shares. When water is bought and sold on a one-to-one basis, there is probably somewhat less concern in an individual farmer's mind about how his consumption affects the whole. Worrying about that is the job of the ikemori. In Ababi, one farmer's action can directly affect his/her neighbor and, therefore, the system demands a higher degree of coordinated action and cooperation at a farmer level.

5.1.3 Bridging and Linking Social Capital

This section will discuss the results of the questions in the survey that measured bridging and linking social capital. These questions were designed to explore what connections each of the farmers have that are not directly related to water management or farming in their immediate area. They were also meant to estimate how much information flow there is between these farmers and people from other social classes, genders, nationalities, etc. This would also include each farmer’s openness to new ideas, which was measured by question S33/S35 in particular. Table 5.3 below shows each of the questions and their responses.

Table 5.3: Questions S26/S29 to S33/S35 from the questionnaires given to farmers as well as their averaged responses are outlined below.

#	Question	Ababi	Tsunai
S26/S29	I often participate in (system name)'s events, festivals, or ceremonies.	1.5	1
S27/S30	I often participate in events, festivals, or ceremonies outside of (system name).	0.73	0
S29/S32	My spouse is equally active in the community’s cultural affairs and events	1.5	0.33
S33/S35	There is a new organic production method being used and promoted in the town next to (system name). The farmer using it apparently experienced a cut in production costs and a rise in revenue. This farmer gives a workshop on this new method in (system name) and offers to train everyone for free. What do you think best reflects your attitude in this situation? (top 2 answers)	I will try it, but only if **a few** other farmers in (system name) try it too / I will try it, but only if **all** the farmers in (system name) try it too	I will try it, but only if **all** the farmers in (system name) try it too / I will try it, but only if **a few** other farmers in (system name) try it too

Bridging and Linking Social Capital: *External Cultural Event Participation*

For questions S26/S29 and S27/S30, both Ababi and Tsunai have a trend of participating in more cultural events that are held in their own communities compared to external events. This suggests that social capital related to religious or cultural affairs tends to be locally centered and therefore more relevant to bonding social capital than bridging. Additionally, following the trend set by the results of the previous questions in this survey, it appears farmers in Ababi are more likely to participate in both internal and external events, while Tsunai farmers’ responses were lower and most even answered ‘neutral’ in response to external events. This is somewhat interesting considering that Tsunai farmers also reported in the section on bonding social capital that they contact people outside of their own system at a higher frequency than Ababi farmers did. This might once again be a symptom of the aging population and tendency for young people to seek work in cities that is so prominent in many Japanese countryside communities. It could also just be that the nature of Japanese cultural and religious events does not require people to go very far to participate, due to the abundance of the events or perhaps a lower deemed importance in them. Either way, it appears these events likely cultivate more bridging social capital in Ababi.

Bridging and Linking Social Capital: Gender

Questions S29/S32 asked about how active each farmer's spouse was relative to their own activeness in cultural affairs. This was asked to indirectly estimate the role of women in each society and how much influence they are allotted in their community and possibly in irrigational or agricultural matters. Although Jha (2004) stated that the role of women in Balinese agriculture was still quite traditional and female farmers often struggled to maintain any amount of influence in the subak, it appears that most farmers in Subak Embukan felt their spouse was comparably active. This is not, however, to say that women have an equal position and have comparable power in society. The government representative from the Karangasem Office of Forestry and Plantations in Amlapura, the leader of Subak Embukan, and all surveyed farmers stated that there has never been a female subak leader or branch leader. Indeed, most women in the rice paddies were laborers who helped their husband or family tend their paddy and likely did not have significant influence on the planning of their operations. Lansing (2006) did point out, however, that women have significant roles in other aspects of Balinese society, usually religiously oriented. Women are often in charge of conducting religious ceremonies and preparing the necessary materials for them. That said, how much this translates into overall social power in Balinese society is uncertain.

One of the respondents to the surveys from Balinese farmers was a woman, but the rice paddy for which she reported on was a community-owned one. She said that her family had a smaller paddy which she also tends, but once again, she did not express in any way that she was an administrator of any sort. During most of her answers in the survey and during subsequent conversations, she always referred to her duties in the context of her family and the immediate community.

Tsunai had considerably lower reported amounts of spousal participation and also has never had a female ikemori in power. The survey was unable to obtain any more details about the role of women in Tsunai, but during interviews and data collection at farmer's houses, the wife usually stayed silent in another room. Once or twice, a farmer's wife served coffee, but unfortunately there was never a chance to sit down and talk with any of them. One farmer wrote in the margins of his survey that his wife was managing three hectares of land for organic crops. Also, there are several organic farms specializing in tourism in other part of Kunisaki peninsula that appear to be managed by women, at least in part (gokunisaki.com, 2017). One of these women whom the researcher briefly contacted was significantly younger than the respondents in Tsunai and was not native to the area. In summation, although it appears that women are not very well included in irrigational or agricultural affairs in Tsunai, it is not necessarily the case for the entire peninsula and individual cases are significant. In the context of bridging social capital, it likely exists between genders, but in a somewhat weak sense in Ababi. For Tsunai, bridging social capital is either incredibly low, or somewhat strong in isolated cases.

Bridging and Linking Social Capital: Resilience and Resistance to Change

Question S33/S35 was an attempt to gauge how strong the 'bubble' is around each of the irrigation systems and whether they are permeable, semi-permeable, or impenetrable by outside forces that would potentially bring bridging or linking social capital. This study acknowledges that this question might not have been perfectly worded due to possible prejudices against agriculture that is explicitly 'organic', but its results may remain useful in some sense regardless. Both systems had the same top two answers, but in opposite orders. Most farmers preferred that their peers give the new farming method their endorsement before they themselves adopt it; however, this condition may be stronger in Tsunai than in Ababi since the top answer in Tsunai was for all farmers to participate rather than just some. This may, however, just have been because of the size of Tsunai's operations. There are only about eleven farmers utilizing the tameike, so having complete participation from all members might be more likely achieved compared to the 300+ farmers in Subak Embukan. The subak being fragmented into clearly defined branches and Ababi village itself having several denominative hamlets makes it so that actions can be taken regionally without the participation of the entire institution or the mandate of the leader himself. Because of this structural difference, this study cannot make a strong claim that resistance to change in Tsunai is significantly higher than in Ababi, but it appears that most surveyed farmers generally are quite cautious about adopting new agricultural methods and would rely somewhat on their peers for confirmation.

Bridging and Linking Social Capital: Involvement in Organizations and Events

This section will discuss question S31/S36 which asked respondents to give the names of organizations and/or events that they are either personally involved in or have family members who are involved. The purpose of this question was to see exactly what kinds of influences from bridging or linking capital may exist. Table 5.4 shows the answers each farmer provided. Each organization/event is classified as being inside or outside of the system.

Table 5.4: All organizations and events that respondents revealed they or their immediate family members participate in. Items are counted by either being inside or outside the system boundary.

Farmer #	Organizations and Events Participated	Ababi	Outside
1	Subak Leader Water Management Training Program	0	1
2	Fish Farming Coop.	1	0

3	Village Choir Group	1	0
4	Gamelan, Government Sponsored Agricultural Classes	1	1
5	n/a	0	0
6	Gamelan	1	0
7	n/a	0	0
8	Gamelan	1	0
9	n/a	0	0
10	Gamelan	1	0
11	Temple Leader	1	0
12	Gamelan	1	0

Farmer #	Organizations and Events Participated	Tsunai	Outside
1	Daishi Matsuri, Ike Matsuri	1	1
2	n/a	0	0
3	Usa-Kunisaki GIAHS Promotion Council, Kunisaki Agricultural Dept., Kunisaki Tourism Department, Kunisaki City Hall Other, Agricultural Coop., Fisheries Coop., Forestry Coop., Land Improvement Bureau, East Oita Promotional Office, Daishi Matsuri, Ike Matsuri	2	9
4	Kunisaki Agricultural Dept., Forestry Coop., Ike Matsuri	0	3
5	n/a	0	0
6	Daishi Matsuri, Suijin Matsuri, Ike Matsuri	3	0
7	n/a	0	0
8	Kunisaki Agricultural Dept., Agricultural Coop., Forestry Coop., Land Improvement Bureau, Suijin Matsuri, Ike Matsuri	2	4
9	Agricultural Coop., Forestry Coop., Ike Matsuri	1	2
10	Daishi Matsuri, Suijin Matsuri, ike Matsuri, Other Matsuri	3	1
11	Agricultural Coop., Daishi Matsuri, Ike Matsuri	2	1

First looking at the organizations and events connected to Ababi, there was very little outside influence on those surveyed. Two of the twelve farmers had received some kind of training from government programs which would constitute bridging and linking capital, but for the most part, farmers typically participate in local organizations like *gamelan* which is a percussive music ensemble usually enjoyed during important ceremonies. With one farmer who also sings in a local choir and another who is a temple leader, the results of this question for Ababi contained nothing particularly anomalous. Religion appears to be the centerpiece of most activities in Bali, including recreation.

According to the government representative from the Karangasem Office of Forestry and Plantations in Amlapura, the government training programs that farmers 1 and 4 participated in are being promoted in accordance to recent changes in the central Indonesian Government's agricultural policy. They not only provide information dissemination, but facilitate information exchanges between Balinese farmers and Javanese farmers, so it is both linking capital because of a top-down governmental relationship, and also bridging capital by exposing Balinese farmers to Javanese farmers' farming strategies and vice versa. It appears that these programs have not been widely utilized, however, so we cannot say that these outside influences are particularly strong.

Tsunai has much more outside influence coming into its system, most of which is governmental or union-like in nature. There are cooperatives and governmental offices for multiple aspects of rural land use, including agriculture, forestry, land improvement and even tourism. Furthermore, being an official member of the GIAHS program has allowed Tsunai support from the Usa-Kunisaki GIAHS Promotion Council which has direct communication with the Ministry of Agriculture Forestry and Fisheries, multiple universities, and the FAO. It also connects the Usa-Kunisaki GIAHS with other GIAHS in Japan for information exchanges. Kunisaki City Hall also stated that many foreign exchange students come and interact directly with farmers on the peninsula through educational programs; although, the Tsunai ikemori said that no students had directly visited their area specifically. Ababi experiences most of its foreign influences through mass tourism. Tirta Gangga water temple is a popular tourist destination and many farmers reported themselves or a member of their family being involved in the tourism industry in some way. As for foreign influences on water use or agriculture, there was one farmer known as “Bodhi”, an American who manages an organic garden behind the back wall of Tirta Gangga. Many of the locals knew him and even helped out on his garden so there could be some bridging capital there, but to what extent, this study cannot say for sure as Bodhi was out of the country during the time of this study.

5.1.4 Structural, Cognitive, and Relational Social Capital

This final section will cover the results of the questions meant to measure Structural, Cognitive, and Relational social capital. A few of the questions from past sections will also be included as their functions overlap for two or more categories of social capital. In contrast with Bonding, Bridging and Linking social capital which constitute the Network Approach, the Social Structure Approach serves to measure how collective action is facilitated by the structure of the managerial body, the norms and values of its members, and how these members interact, rather than focusing on the configuration and scope of the social capital. This would include formal rules and unspoken social norms and how they promote like-action and deter defection. In total, there were 17 questions in this section, but a few will be omitted from the explanation due to their lack of immediate significance to the narrative of this research. Table 5.5 below shows the results of each question.

Table 5.5: Questions S7b to S30/S33 from the questionnaires given to farmers as well as their averaged responses are outlined below.

Type	**#**	**Question**	**Ababi**	**Tsunai**
Structural Social Capital	S7(b)	Average amount of time spent in a leadership position?	9.9 years	4.7 years
	S25/S28	The position and authority of the subak/ikemori are respected.	1.58	0.73
	S26/S29	I often participate in cultural events in (system	1.5	1

		name).		
	S32/S24	Can you estimate how many times you've discovered a leak in the irrigation?	>10	4.13
	S19(Tsunai)	The tameike are necessary for the success of agriculture in Tsunai.	n/a	1.36
	S18/S20	The subak/the ikemori is/are necessary for successful water management in (system name).	1.45	1.2
	S19/S21	The way in which water is disseminated is fair to all farmers in (system name).	1.27	1
	S22(Tsunai)	The price of water from tameike is fair.	n/a	0.9
Cognitive Social Capital	S17(Tsunai)	After achieving GIAHS designation, I have more pride in my community.	n/a	0.89
	S17/S18	Agriculture done in (system name) is special or exceptional among others.	0.6	0.4
	S24/S27	I feel that I have freedom to farm in the manner in which I please.	-0.3	0.2
	S28/S31	Temples, shrines, and other cultural sites in Karangasem/Kunisaki are important to me.	1.5	0.56
Relational Social Capital	S21/S23	Theft of irrigation water sometimes occurs in (system name).	1.45	0
	S24(Tsunai)	If the population of Tsunai were to increase, the frequency of water theft would also increase.	n/a	0
	S22/S25	I feel that I am included in important decision-making on water management.	1.45	0.9
	S23/S26	I feel that the inclusion of all farmers in decision-making is necessary.	1.6	1
	S30/S33	In regards to farming and my general affairs, ________________.	I usually ask others for advice or help / I usually give **and** receive advice or help	I usually give **and** receive advice or help / I work best alone

Structural Social Capital: Leadership Positions and Water Distribution Procedures

Questions S7(b), S25/S28, S18/S20, S19/S21, as well as S19 and S22 were concerned with the management trends of water managers and how these managers are viewed by member farmers. As stated before, branch leaders in the subak tend to serve longer terms than ikemori in Tsunai and many Balinese farmers reported feeling unable to become a leader due to a lack of education or time. This means that the authority of leaders in the subak is likely higher than that of ikemori due to the higher threshold of qualified candidates. Meanwhile, almost all farmers in Tsunai had served as an ikemori and their term lengths deviate less from the average, 4.7 years. Question S25/S28 supports this notion on the nature of leadership as more farmers in Ababi felt that the authority of their leaders is respected than farmers in Tsunai. This is likely for religious reasons and because farmers in Ababi must rely on their leaders considerably. Rather than being inclusive, ikemori often operate amongst themselves, semi-independently from the other farmers in the system, and therefore, Tsunai farmers are less dependent on them on an everyday basis. The fact that water must be paid for also changes the relationship from one solely maintained by trust to one of business, and ikemori might be seen partly as water 'venders' rather than water stewards.

One ikemori also confirmed in an interview that the position is not seen as particularly special. In the past, however, the duties of the ikemori were more demanding and required candidates to be both educated and physically fit. Releasing water from the tameike used to be done manually, and ikemori had to dive to the bottom of the pond in order to operate the releasing mechanism. Technological and structural developments got rid of the need for such expertise. In Ababi, due to the dynamic nature of the irrigation system and the constant rotation of crops year-round, the subak leaders are much more depended upon. Just finding time to interview the leader of Subak Embukan proved quite difficult, as his schedule was almost never open. On top of daily duties, the branches meet monthly to discuss democratically how to split up the water supply for the coming month(s), and the leaders are the main facilitators of this; although, all farmers are also expected to participate.

Questions S18/S20 and S19/S21 went on to show that although leadership positions in Ababi are more respected, both systems' farmers felt that their leaders are necessary for their communities to succeed, so neither managerial system is seen as arbitrary. Although, when asked if the way in which water was distributed is fair, both systems' farmers had lower average answers than the question asking if the leaders were necessary. The difference is not significant enough to say that farmers distrust their leaders, but it does show that perhaps what keeps the system in place is partly owed to necessity rather than having deep trust in those in power. Question S22 similarly showed lower overall attitudes concerning the price of water in contrast to attitudes about the necessity of ikemori. This further suggests that farmers in Tsunai see less importance overall in the position of ikemori compared to the infrastructure the system is based on, represented by question S19.

Overall, the results of these questions show that Ababi's leaders play a role that is seen by farmers as quite important and necessary, while farmers in Tsunai similarly believe their leaders are important, but perhaps less important than in the past and less crucial than the tameike system itself. This supports the previous assumptions of this study in that the subak's dynamic and ever-changing nature requires leaders to be more engaged daily, resulting in stronger bonds between leaders and farmers. Meanwhile, the technological innovation of the connected tameike appears to be the main concern of most farmers in Tsunai, although ikemori are also needed to facilitate the proper distribution of the water collected. Both systems reported that although they need their leaders, they are less confident in whether the way they manage the system is fair to everyone.

Cognitive Social Capital: Level of Pride and Freedom to Choose

Questions S17 – S28/S31 measured the intensity of respondents' emotional investment in their system and how much they feel they are free to act as they please within the system. For question S17/S18, both systems' farmers were reluctant to say for certain that they believed their system was exceptional compared to others. The ward headman of Tsunai even said that he heard that there are communities in Miyazaki prefecture with similar irrigation schemes using connected tameike, so objectively he did not feel Tsunai was exceptional or unique. This is surprising considering how much the Kunisaki-Usa GIAHS Promotion Council emphasized how innovative Kunisaki's tameike were. In the case of the subak, some of the papers included in the literature review stressed that subak have different histories and policies depending on the location, yet, the farmers in Ababi did not feel they were much different than anywhere else in Bali. Even including question S17 for Tsunai, although some farmers did answer 'agree' or 'strongly agree', the overall sentiment on feeling more pride in Tsunai after GIAHS designation did not seem significant enough to make any strong claims. It would make sense to get this result because all ikemori reported no changes after GIAHS designation other than tourism-related things such as the 'long trail' hiking path being revived and maintained. There has been little to no direct, official collaboration from the FAO, MAFF, or the GIAHS Promotion Council.

Question S28/S31 shows, once again, the continuing trend of religious sites and rituals being a larger part of Balinese farmers' lives than farmers in Tsunai. This is even despite all farmers in Tsunai saying they identify as Buddhists. This begs the question of whether religion's role in the Kunisaki Peninsula is as paramount as the GIAHS application suggested, or if this was an outsider's notion used to appeal to the FAO to ensure a smooth designation. It would be interesting to survey the regions of the peninsula better known for religious sites like Bungotakeda or Usa to see if farmers there have dissimilar sentiments to the ones in Tsunai.

Finally, question S24/S27 asked about how much freedom farmers felt they had in choosing how they conduct operations on their farms. Both systems' farmers had considerably low scores, with Bali's score even being negative. This highlights the idea discussed in a previous section stating how Japan as a developed country has higher occurrences of individualistic behavior, despite Japan being known as a group-minded society. Compared to the subak, it appears they are not the most extreme case of hive-mentality. It is also noteworthy that rice paddies in the subak are not typically administered by one or two people like the ones in Tsunai. Many of them are community-owned and almost all of them have multiple farmhands employed there. This could be a big reason farmers felt they had little to no freedom.

Farmers in Tsunai, however, also have mechanisms in place that restrict their decision-making. One of them is obviously the mandate of the ikemori. The farmer gets to decide when to request water for their field, but it all has to go through the ikemori first. Secondly, regulations and promotions made by MAFF and JA coerce farmers to do certain things in order to not be charged penalties or to be given subsidies. After all, all harvested rice in Tsunai is sold to JA according to the ikemori, so if farmers want to grow a variety of rice that JA does not support, they would be missing out on income. The farmers in Ababi grew several different varieties, while everyone in Tsunai grew Hinohikari, so it is likely that Tsunai farmers feel restricted by government regulations, and Ababi farmers feel restricted by the subak itself, thus the similarly low scores.

Relational Social Capital: Water Stealing, Inclusion, and Cooperation

This final section will focus on cooperation and defection, with defection being defined as either going against water schedules and rules or simply stealing water outright. The results of question S21/S23 are expressed inversely on the intensity scale, meaning that if they chose 'strongly agree' for the existence of water theft, the value would be -2 instead of 2 since it would suggest low relational social capital. This means that more farmers in Tsunai felt that stealing occurs than farmers in Ababi; although, one person in Ababi chose 'strongly agree'. This farmer was the single female respondent who, interestingly, went on to explain that she thought 'theft' is a strong word because their community does not use more water than it is allotted, but one or two people within the community sometimes take more than is their fair share. For the purposes of this study, such behavior is considered theft, but it is significant that she had this point of view. The act of taking more than one's fair share not meeting this woman's criteria for theft highlights what many other Balinese farmers tried explaining several times during interviews. Private ownership is not a common concept in the subak. Indeed, when the researcher walked into rice paddies that people were working on, at no time did any of the farmers say the researcher was trespassing. Quite the opposite, most farmers welcomed the researcher upon arrival, despite it being unannounced.

In Tsunai, three farmers agreed that water theft occurs in Tsunai, and three farmers chose to stay neutral. Only two farmers felt certain enough to choose 'disagree'. These results are very counterintuitive because of the scale difference between Tsunai and Ababi. With Tsunai having only around 50ha of agricultural land and only eleven farmers using the tameike, one would assume that any attempt to steal water would be easily discovered; especially since any significant amount of water taken would result in the water level of one of the tameike decreasing. One ikemori and the Tsunai historian also had this opinion. They said they could not say for certain that theft does not exist, but if it does occur, it would be easily discovered. Despite this, most farmers either felt stealing does occur or were not confident enough to say it does not.

Ababi, on the other hand, contains around 336 people and has 76ha of agricultural land, all of which is serviced by a flowing water source where it would be more difficult to detect any water level changes. One would think that theft would positively correlate to anonymity given by scale and numbers, but according to most respondents, this is not the case. This does not mean their answers are necessarily true; especially since only twelve farmers were surveyed. It could be that anonymity also makes it more difficult to catch someone in the act and to have proof of the deed. The comments made by the female farmer also must be considered. Is it that stealing is actually rampant, but farmers do not perceive it so severely? This idea will be further explored in the discussion chapter of this study.

Questions S22/S25 and S23/S26 showed that both systems appear to have fairly high inclusion rates for all or most farmers and that these farmers feel it is a positive thing. Once again, it appears this opinion is more prominent in Ababi which is to be expected given the necessity of participation in monthly meetings and crop rotation schedules. Tsunai's average at 0.9 is important because it shows that although ikemori work amongst themselves, ordinary farmers do not feel as though the ikemori operate completely independent of them and their voices are heard to a satisfactory degree.

Finally, question S30/S33 was asked to measure how much cooperation exists between the farmers in general. This question also served to detect any obvious hierarchical relationships which would be denoted by farmers answering that they give or are given advice, rather than mutual exchanges. If farmers answered that they work best alone, this could also indicate indifference to the collective, not necessarily defection. The most common answer for farmers in Ababi was 'receiving advice or help' which shows there are, in fact, hierarchical relationships in the subak which was previously considered, given the average term length of subak and branch leaders. The second most common answer, however, was 'give and receive advice or help', so it is not a strict or rigid hierarchy. The mutual sharing of ideas is in no way scarce, and information does not only flow top-down.

The most common answer for Tsunai was 'give and receive advice or help' showing that information travels mostly horizontally rather than vertically. All the farmers are among the same age, administer their own land, and have a similar economic status, so this would make sense that there is no obvious higher or lower social class. The ward headman, however, appeared to be well-respected by the ikemori and could be seen on a higher level than other farmers.

Tsunai's second most popular answer was 'I work best alone'. This shows that a few farmers might exhibit anti-social behavior. This could be benign, so the study will refrain from labeling them as defectors, but they could be seen as negative human capital rather than positive human capital; meaning that they simply represent an absence of conflict and not proactive relationship building like the farmers who answered ‘give and receive help or advice’.

5.1.5 Summary of Social Capital Intensity and Configuration for Ababi and Tsunai

Looking at the results of the survey and interviews as a whole, Subak Embukan in Ababi had a higher overall intensity of social capital than the farmers in Tsunai. This is summarized by figures 5.1 and 5.2.

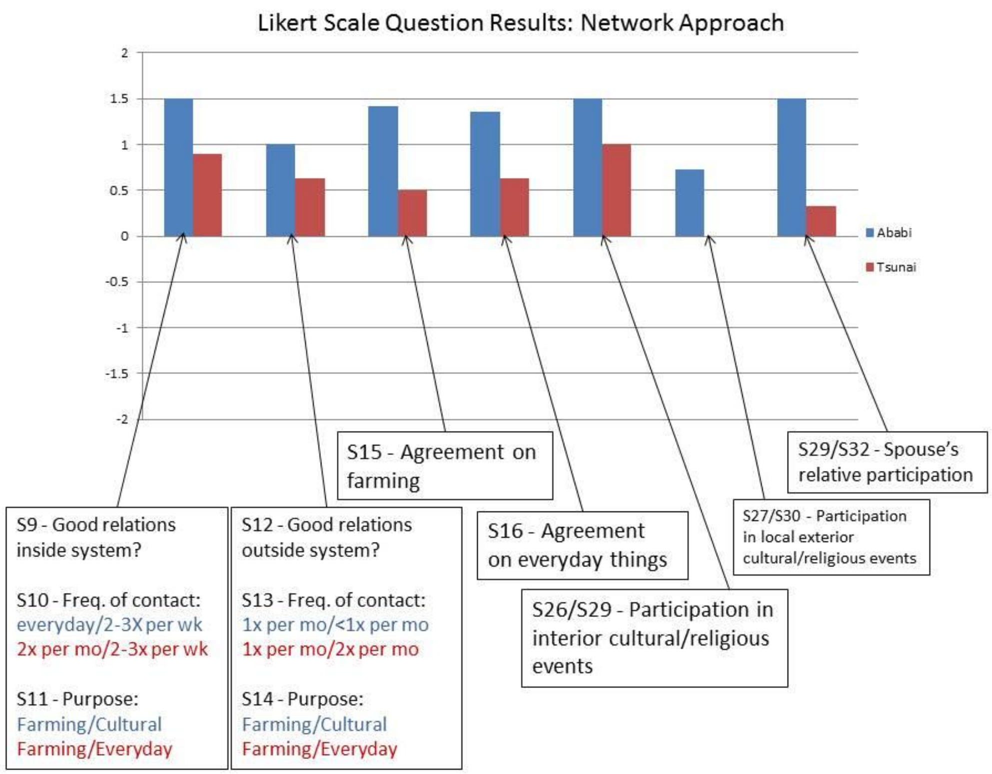


Figure 5.1: Summary of Network Approach questions and their results. Ababi scored higher than Tsunai overall.

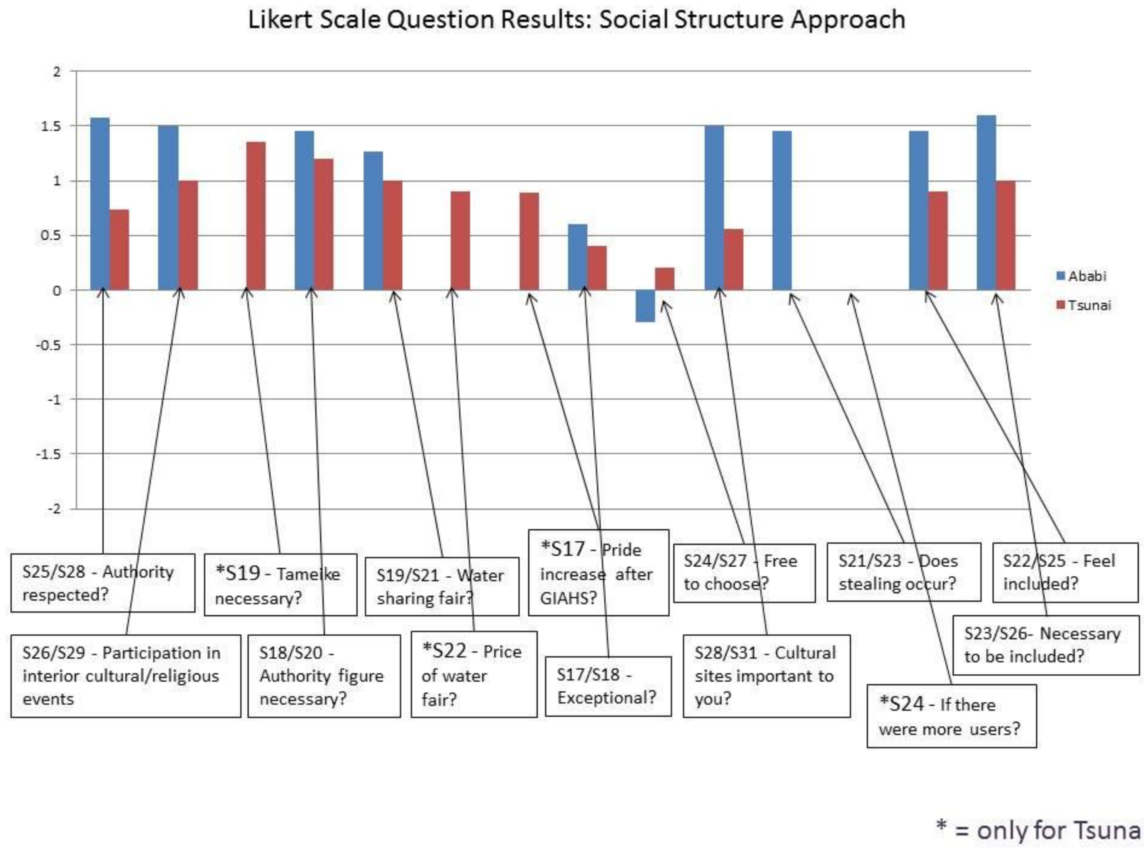


Figure 5.2: Summary of Social Structure Approach questions and their results. Ababi scored higher overall in this category as well.

Neither system, however, appeared to have what would be considered low social capital. This was to be expected since both systems are considered by knowledgeable sources (academic and/or NGO-related) to be examples of culturally significant and successful agricultural communities. That being said, there were some important details regarding the shape or configuration of each system's social capital which provided valuable insight into how each of the communities work as social units.

- The first thing to note is the strength and inseparability of Hinduism's influence on everyday affairs in the subak. Whether it is the bedugul temples being located in the rice paddies themselves, the subak and branch leaders meeting at religious sites and performing rituals to the rice goddess Sri, or the growth period of Balinese rice itself being the basis for the Pawukon Calendar's 35-day months, religion is an incredible binding agent in Bali that connects all farmers. One respondent's wife even converted from Christianity to Hinduism after marriage, and according to the interpreter who helped conduct these surveys, the cost of Hindu funerals in Ababi are even borne on the entire community rather than only the family of the deceased due to their complexity and price. It cannot be overstated how important religion is to the role of the subak and everyday life in Bali. This makes for high bonding social capital.

Religion is homogenous and strong in Tsunai as well with various Buddhist/Shinto festivals and even shrines that are maintained and paid for by the community, but in daily life, it appears to be a religion practiced mainly in private. Most farmers reported that they were somewhat indifferent to religious sights in the peninsula, and participation in the various festivals was not common amongst all the farmers. This could, however, be a symptom of an aging society, where farmers are less mobile and involved in community affairs. Historically, religion as a binding agent may have been more prominent.

- The second important takeaway from these results is that Tsunai appeared to have slightly stronger and more widespread bridging and linking social capital than Ababi. This is because Tsunai farmers reported having close relationships outside of their system at a higher frequency. Furthermore, Tsunai farmers were involved in more external groups and organizations like agricultural cooperatives and government entities than farmers in Ababi. Such organizations do exist in Bali, usually local government offices like the Office of Forestry and Plantations in Amlapura which provides seeds and fertilizer, but it appears their networks are not so inclusive yet. Tsunai's GIAHS designation has also resulted in the creation of even more bridging and linking social capital connected by the FAO, MAFF, and the GIAHS promotion council.

- In regards to structural social capital, the subak has a recognizable hierarchy that is surprisingly not created by the Hindu caste system, but by differences in access to things like education or farming supplies which can often be the deciding factor in whether or not someone can become a subak leader. In theory, however, all member farmers' opinions are included in the monthly branch meetings and only leaders who continually prove themselves are reelected. Tsunai, on the other hand, is more evenly managed by all farmers with 9 out of 11 farmers having served at least one year. The ikemori make more decisions amongst themselves rather than including all farmers in every step of decision-making, but with there being 4 out of 11 farmers serving as ikemori at any one time, such thorough inclusion might not be as necessary compared to the 336 farmers in Subak Embukan.
- Cognitive social capital in the form of perceived freedom to perform agriculture in the manner one chooses was low for both, but remarkably low for Ababi. This suggests that there is top-down pressure on farmers to operate in a certain way. For farmers in Ababi, it is likely this pressure comes from the subak itself since crop rotation and water sharing are so imperative to the subak's performance. For Tsunai, this pressure comes from government entities like MAFF or JA which regulate farmers by choosing what behaviors are rewarded or penalized. One example was growing the rice variety 'Hinohikari' by request of JA.
- Finally, the results for relational social capital revealed that theft of irrigation water is surprisingly more likely to exist in Tsunai based on respondents' answers despite their system being smaller, and thus, a higher likelihood of being discovered. One farmer in

Ababi did report that water was stolen, but questioned whether she would truly call it 'theft'. This shows that theft could actually be higher than was reported in Bali, but perhaps it is forgiven or seen as less threatening than it is in Tsunai.

5.2 Sustainable Water Management Assessment

Now that the social dimension has been thoroughly explored, this section will explain the calculations of the four criteria used to assess the relative sustainability of the water management systems themselves. These four criteria are: Water Demand (*WD*), Water Footprint (*WF*), Water Quality, and managerial effectiveness, which are the total amount of water used, the amount of water used as a ratio to rice yields, how much pollution from agriculture was detected in the irrigation water sources, and the activities carried out by water managers and farmers that lead to sustainable ends, respectively.

5.2.1 Water Demand

The water demand (*WD*) for rice production is expressed as the sum of four main processes in the rice growing cycling, starting with land preparation and ending with the rice harvest. The first stage is the land preparation stage, denoted as *SAT*. This is pictured below.

Image 5.2: A man plowing his field after saturating the soil. The estimated amount of water for this stage is 20cm. (Yadav, 2009)

During this stage, the soil is saturated to the point that it will retain a water layer. The amount of water required for the *SAT* stage was done using a flat value of 20cm, taken from Brouwer and Heibloem (1986). Multiplied by the total rice paddy area, *SAT* was calculated for each system as shown in tables 5.6 and 5.7. Calculations for Ababi are multiplied by two because rice is grown twice a year on average while rice is typically only grown once in Tsunai. Data inputs for paddy area were taken directly from the survey given to all farmers. Fallow land is not included in the calculations.

Tables 5.6 (left) and 5.7 (right) show the SAT calculations for Ababi farmers and Tsunai farmers, respectively.

Farmer #	SAT=	m^3
1	20cm*3.5are*2	140
2	20cm*20are*2	800
3	20cm*30are*2	1200
4	20cm*35are*2	1400
5	20cm*40are*2	1600
6	20cm*32are*2	1280
7	20cm*19are*2	760
8	20cm*18are*2	720
9	20cm*24are*2	960
10	20cm*30are*2	1200
11	20cm*25are*2	1000
12	20cm*15are*2	600
	Ababi Total	**11,660**

Farmer #	SAT=	m^3
1	20cm*26are	520
2	20cm*22are	440
3	20cm*230are	4600
4	20cm*50are	1000
5	20cm*460are	9200
6	20cm*1500are	30000
7	20cm*300are	6000
8	20cm*260.8are	5216
9	20cm*70are	1400
10	20cm*300are	6000
11	20cm*20are	400
	Tsunai Total	**64,776**

The second stage is the water layer (*WL*) stage. This represents what level the paddy is filled to after having been saturated. The global average is about 10cm, but in this study, each farmer was specifically asked in the survey to estimate what depth they fill their paddies to in order to achieve higher accuracy. The values for *WL* were also multiplied by total paddy area. The results are shown in tables 5.8 and 5.9 below.

Tables 5.8 (left) and 5.9 (right) show the WL calculations for Ababi farmers and Tsunai farmers, respectively.

Farmer #	WL=	m^3
1	5cm*3.5are*2	35
2	3cm*20are*2	120
3	5cm*30are*2	300
4	2cm*35are*2	140
5	10cm*40are*2	800
6	4.5cm*32are*2	288
7	5cm*19are*2	190
8	5cm*18are*2	180
9	10cm*24are*2	480
10	5cm*30are*2	300
11	3cm*25are*2	150
12	3cm*15are*2	90
	Ababi Total	**3,073**

Farmer #	WL=	m^3
1	10cm*26are	260
2	10cm*22are	220
3	8cm*230are	1840
4	20cm*50are	1000
5	5cm*460are	2300
6	10cm*1500are	15000
7	10cm*300are	3000
8	7.5cm*260.8are	1956
9	15cm*70are	1050
10	5cm*300are	1500
11	5cm*20are	100
	Tsunai Total	**28,226**

Next, the evapotranspiration (ET_C) stage was calculated. Since many farmers did not measure and record exactly how much water they use in a growing period, this section estimates that amount of water assuming that once WL is set, a farmer will continually add water throughout the growing season to maintain that same water level. Based on the results of survey questions W4 and W5 which asked farmers to estimate how many times per growing season they added water to their paddy, this assumption appears to be valid for the majority of farmers in both systems. Additionally, questions W6 – W9 (refer to appendix) asked for the farmers' usual date(s) for transplanting seedlings, how many days before transplanting they fill their paddies, how many days typically pass before their rice reaches maturity, and how many days before harvest farmers will cease supplementing water. This allowed the calculations to be as accurate as possible instead of assuming every farmer started and ended operations at the same time and used only rice varieties with a typical 120 day growing period.

For Tsunai, climate data inputs for the ET_C calculation were taken from the Japan Meteorological Agency (JMA) (2017) based on a 10-year period from 2006 to 2016. This was done in order to estimate the long-term climate trends and compensate for the static nature of this study. Additionally, the effective rainfall values (*Peff*) were altered to fit the region because the data from JMA only provided monthly averages for Oita prefecture rather than the Kunisaki peninsula specifically. The Kunisaki-Usa GIAHS proposal claimed the coastal areas of Kunisaki peninsula only receive around 1500mm of rainfall per year, but the average for Oita prefecture was around 1700mm. Therefore, all monthly values were proportionally converted to reflect the scenario in which there was 12% less rainfall than the rest of the prefecture. This did not affect the total WD, but did affect the ratio of green and blue water for Tsunai.

Weather data for Ababi was taken from the Indonesia Meteorological, Climatological, and Geophysical Agency (2017) and was processed similarly, but not all values were available, so some supplementary data was taken from other websites including worldbank.org, accuweather.com, and holiday-weather.com. ET_C crop coefficients (K_C) for rice plants in both systems were taken from the FAO (2017). Altitude, latitude, and longitude were measured with Google Maps (2017). Tables 5.10 and 5.11 show the results.

Table 5.10: This table shows the monthly evapotranspiration values of Tsunai farmers. The red values represent two different growing periods happening simultaneously where a second crop is planted before the first is finished.

	EvapoTranspiration (ETc) = *ETo(m/day)*Kc*area(m²)*days*						
Farmer #	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**
1			144.5535	397.5075	473.616	306.4815	
2			122.3145	336.3525	400.752	265.98	
3	637.56	1641.769	2100.791	3281.985	2094.84	1355.591	
4			111.195	733.86	910.8	670.995	84
5			2557.485	7032.825	8379.36	5422.365	552
6			11119.5	23442.75	27324	14054.63	
7			1667.925	4586.625	5464.8	3082.95	
8			966.6552	3898.699	4750.733	3310.726	813.696
9			389.1825	1070.213	1275.12	825.1425	468
10	554.4	4092.525	3812.4	4892.4	1707.75		
11			74.13	298.98	364.32	241.44	9.6
	1191.96	**5734.294**	**23066.13**	**49972.2**	**53146.09**	**29536.3**	**1927.296**
						Total	**164574.3**

Table 5.11: This table shows the monthly evapotranspiration values of Ababi farmers. One can see by the groupings of numbers that there are 2 main growing seasons.

	Evapotranspiration (Etc) = *Eto(m/day)*Kc*area(m2)*days*											
Farmer #	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
1		23.7589	50.3937	49.883	23.1				24.6409	55.1817	51.7482	25.0635
2	132.62	263.772	298.068	109.14				137.97	295.02	318.09	99.9	
3		203.648	431.946	417.94					211.208	472.986	433.566	
4		237.589	503.937	498.83	147				246.409	551.817	517.482	159.495
5		271.53	588.558	451.97	144				281.61	644.478	468.864	156.24
6		217.224	470.846	394.44	67.2				225.288	515.582	409.19	72.912
7		128.977	279.565	228.1					133.765	306.127	236.63	
8		122.189	259.168	256.54	75.6				126.725	283.792	266.134	82.026
9	344.04	162.918				148.554	332.42	357.93	168.966		167.832	356.2272
10		135.765	422.474	456.46	171				140.805	462.614	473.526	185.535
11	359.96	342.645	86.8313				159.47	374.49	372.128	77.7938		170.8875
12		101.824	215.973	213.79	99				105.604	236.493	221.778	107.415
	836.61	**2211.84**	**3607.76**	**3077.1**	**726.9**	**148.554**	**491.89**	**870.39**	**2332.17**	**3924.95**	**3346.65**	**1315.801**
											Total	**22890.63**

The final stage included in the *WD* calculation is percolation (*PERC*) which happens during the same time span in which ET_C is calculated. The values for this measurement were taken from the paper by Chapagain, & Hoekstra (2011) which stated percolation rates range from 2mm/day for heavy clay to 6 mm/day for sandy soils. To measure the percolation rate of each system, question W14 asked farmers to rate the speed at which water percolates from their land's soil on a scale from 1 to 10. Answers ranging from 1 to 2 were treated as 2mm/day, answers from 3 to 4 were 3mm/day, 5 to 6 were 4mm/day, 7 to 8 were 5mm/day, and 9 to 10 were 6mm/day. Tsunai's average was closest to 3mm and Ababi's was about 2mm. Tables 5.12 and 5.13 display the results of this calculation.

Tables 5.12 (left) and 5.13 (right) show the percolation calculations for each farmer in Ababi and Tsunai, respectively.

Farmer #	PERC=	m3
1	(0.2cm*a*#days)*2	149.8
2	(0.2cm*a*#days)*2	840
3	(0.2cm*a*#days)*2	1260
4	(0.2cm*a*#days)*2	1498
5	(0.2cm*a*#days)*2	1680
6	(0.2cm*a*#days)*2	1152
7	(0.2cm*a*#days)*2	684
8	(0.2cm*a*#days)*2	756
9	(0.2cm*a*#days)*2	1008
10	(0.2cm*a*#days)*2	1260
11	(0.2cm*a*#days)*2	525
12	(0.2cm*a*#days)*2	618
	Ababi Total	**11,430.8**

Farmer #	PERC=	m3
1	0.3cm*a*#days	936
2	0.3cm*a*#days	792
3	0.3cm*a*#days	7245
4	0.3cm*a*#days	1800
5	0.3cm*a*#days	16560
6	0.3cm*a*#days	54000
7	0.3cm*a*#days	10800
8	0.3cm*a*#days	9388.8
9	0.3cm*a*#days	2520
10	0.3cm*a*#days	10800
11	0.3cm*a*#days	720
	Tsunai Total	**115,561.8**

Now, to calculate the total annual *WD*, the totals of each stage are added together. This is expressed in the equation below.

$$WD = SAT + WL + ET_C + PERC$$

$$Tsunai\ WD = 64{,}776m^3 + 28{,}226m^3 + 164{,}574.27m^3 + 115{,}561.8m^3 = \mathbf{373{,}138.07m^3}$$

$$Ababi\ WD: 11{,}660m^3 + 3{,}073m^3 + 22{,}890.63m^3 + 11{,}430.8m^3 = \mathbf{49{,}054.43m^3}$$

Now these values must be divided by the total area they represent to make them comparable.

$$Tsunai\ (annual): 373{,}138.07m^3 \div 323{,}880m^2 = \mathbf{1.15m}$$

$$Ababi\ (annual): 49{,}054.43m^3 \div 29{,}150m^2 = \mathbf{1.68m}$$

$$Ababi\ (one\ growing\ season): 1.68 \div 2 \approx \mathbf{0.84m}$$

The results show that Tsunai has a lower annual *WD*, but if *WD* was calculated based on one growing season, Ababi's water demand is much lower. There would be some differences between the WD in Bali's dry season and wet season so both growing seasons would not equal 0.84 meters exactly, but nevertheless, both are certainly less than 1.15 meters. As previously stated, the total area and number of farmers in Subak Embukan are much larger than in Tsunai, so in order to be more certain about the data given by the 12 survey respondents, Ababi's *WD* was also calculated based on data the subak leader gave concerning his subak as a whole. He said the *WL* is usually about 5cm, most farmers grow rice from February to May and from September to December, the average growing period is 105 days, soil retention is very strong, and out of the total 76ha of farmland, 30%-50% is used for rice at a given time. Given these data inputs, the results are calculated below.

$$Subak\ Embukan: 152000m^3 + 38000m^3 + 298395m^3 + 159600 = \mathbf{647995m^3}$$

$$(annual): 647995m^3 \div 380000m^2 = \mathbf{1.71m}$$

Since the total annual *WD* results of Subak Embukan were so close to the results given by the survey respondents, it can be concluded that these findings are likely to be quite accurate, although more farmers would have to be surveyed to be certain.

Finally, to find out what percentage of this *WD* is green water (water from rain) or blue water (water from irrigation sources), effective rainfall (*Peff*) must be subtracted from the *WD*. *Peff* was calculated using the USDA S.C. Method, and the data inputs were taken from the same sources used for the ET_C calculation with Tsunai's initial precipitation values reduced by 12% to better represent the local weather patterns explained in the GIAHS proposal. The monthly *Peff* values are displayed in tables 5.14 and 5.15 below.

Table 5.14: This table shows the total monthly and annual effective precipitation for each Ababi farmer.

Farmer #	Peff=	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	TOTAL
1	350m²*Peff/mo		30.2438	53.095	46.935	19.5481				7.8575	31.01	41.825	39.886	**270.4003**
2	2000m²*Peff/mo	157.55	322.6	303.4	151.98				28.742	89.8	177.2	119.5		**1350.77**
3	3000m²*Peff/mo		259.232	455.1	388.89					67.35	265.8	346.55		**1782.922**
4	3500m²*Peff/mo		302.438	530.95	469.35	124.397				78.575	310.1	418.25	245.632	**2479.692**
5	4000m²*Peff/mo		345.643	606.8	536.4	152.323				89.8	354.4	478	300.774	**2864.14**
6	3200m²*Peff/mo		276.514	485.44	429.12	56.8671				71.84	283.52	382.4	112.289	**2097.99**
7	1900m²*Peff/mo		164.18	288.23	246.3					42.655	168.34	219.482		**1129.184**
8	1800m²*Peff/mo		155.539	273.06	241.38	63.9755				40.41	159.48	215.1	126.325	**1275.27**
9	2400m²*Peff/mo	390.72	290.34				59.04	134.64	71.28	75.432		143.4	372.96	**1537.812**
10	3000m²*Peff/mo		172.821	455.1	402.3	144.706				44.9	265.8	358.5	285.735	**2129.863**
11	2500m²*Peff/mo	407	403.25	134.57				67.863	74.25	112.25	64.3065		187.984	**1451.476**
12	1500m²*Peff/mo		129.616	227.55	201.15	83.7774				33.675	132.9	179.25	165.426	**1153.344**
													Total	**19522.86**

Table 5.15: This table shows the total monthly and annual effective precipitation for each Tsunai farmer.

Farmer #	Peff=	April	May	June	July	August	September	October	TOTAL
1	2600m²*Peff/mo			207.48	373.1	269.1	344.24	120.6484	**1314.568**
2	2200m²*Peff/mo			175.56	315.7	227.7	291.28	102.0871	**1112.327**
3	23000m²*Peff/mo	515.775	974.05	2753.1	3300.5	1190.25	1522.6	533.6371	**10789.91**
4	5000m²*Peff/mo			159.6	717.5	517.5	662	371.2258	**2427.826**
5	46000m²*Peff/mo			3670.8	6601	4761	6090.4	2134.548	**23257.75**
6	150000m²*Peff/mo			15960	21525	15525	19860	4640.323	**77510.32**
7	30000m²*Peff/mo			2394	4305	3105	3972	1392.097	**15168.1**
8	26080m²*Peff/mo			1387.456	3742.48	2699.28	3452.992	1613.595	**12895.8**
9	7000m²*Peff/mo			558.6	1004.5	724.5	926.8	324.8226	**3539.223**
10	30000m²*Peff/mo	448.5	2541	4788	4305	2504.0323			**14586.53**
11	2000m²*Peff/mo			106.4	287	207	264.8	123.7419	**988.9419**
								Total	**163591.3**

The blue water demand (*BWD*) will be the remainder after subtracting *Peff*, and the green water demand (*GWD*) will be the *Peff* itself. The calculations are as follows.

$$Tsunai: 373{,}138.1m^3 - 163{,}591.3m^3 = 209{,}546.76m^2$$

$$Ababi: 49{,}054.43m^3 - 19{,}522.86m^3 = 29{,}531.56m^3$$

Tsunai's BWD is 209,546.76$m^3$and GWD is 163,591.3m^3. This makes the percentages 56% blue and 44% green. Likewise, Ababi's BWD is 29,531.56m^3 and GWD is 19,522.86m^3, or 60% blue and 40% green. These results show that both systems are heavily dependent on their irrigation systems as green water makes up less than 50% of the total water required for their agriculture. Overall, the *WD* calculation has shown that Tsunai uses less water annually, but Ababi uses less water per growing cycle. This is owed to several factors, some of which are human-based and some of which are natural:

1. Ababi's average WL value is 5.04cm while Tsunai's is 9.55cm.
2. Ababi's rice growth period is around 105 days while 120 is the norm in Tsunai.
3. Ababi has lower overall ET_C values because of the difference in climate.
4. As mentioned in the GIAHS proposal, Tsunai has very porous soil while Ababi's appeared to be quite a bit denser.

5.2.2 Water Footprint

The calculation for the water footprint (*WF*) is a continuation of the *WD* calculation, but PERC is removed from the total *WD* because it technically returns to the environment and is not contained within the final product. The no-*PERC* water demands are calculated below.

$$Tsunai: 373{,}138.1m^3 - 115{,}561.8m^3 = \mathbf{257{,}576.3m^3}$$

$$Ababi: 49{,}054.43m^3 - 11{,}430.8m^3 = \mathbf{37,623.63m^3}$$

Next the no-*PERC* water demands are divided by the total paddy area they represent to find out how many cubic meters of water are used per one square meter of land.

$$Tsunai: 257{,}576.3m^3 \div 323{,}880m^2 = \frac{\mathbf{0.795m^3}}{\mathbf{m^2}}$$

$$Ababi: 37{,}623.63m^3 \div 29{,}150m^2 = \frac{\mathbf{1.29m^3}}{\mathbf{m^2}}$$

Next the weighted average harvests of both systems expressed in kg/m^2 will be divided by 1000 to determine how many square meters it would take to produce one metric ton of rice.

$$Tsunai: 1000kg \div \frac{0.45534kg}{m^2} = \mathbf{2,196.16m^2}$$

$$Ababi: 1000kg \div \frac{0.2459kg}{m^2} = \mathbf{4,066.69m^2}$$

Now, the area necessary to produce 1 metric ton of rice is multiplied by how many cubic meters of water is used per 1 square meter of land to get the water footprint, expressed as $m^3\ of\ water/ton\ of\ rice.$

$$Tsunai: 2{,}196.15m^2 \times 0.795m^3 = \mathbf{1,746.57m^3/t}$$

$$Ababi: 4{,}066.69m^2 \times 1.29m^3 = \mathbf{5,248.84m^3/t}$$

The percentages previously found in the *WD* section to determine green and blue water can then be applied to find the blue water footprint and the green water footprint. The overall water footprint results are shown below.

- Tsunai: Blue - 980.84m^3/t, Green - 765.73m^3/t, Total – 1,746.57m^3/t
- Ababi: Blue - 3,159.89m^3/t, Green - 2,088.95m^3/t, Total – 5,248.84m^3/t

Here we find a contradiction compared to the results found in the WD section. The annual WD of Ababi was higher than Tsunai's because of the two separate growing periods, but since the WF is calculated by the total average annual rice harvest, having two growing periods should not matter because it would be calculated with double the harvest as well. Instead of becoming small like the WD of one growing season, however, the WF of Ababi is incredibly high. According to the FAO (2007), it typically takes 1,000 - 3,000 cubic meters of water per tonne of cereal harvested.

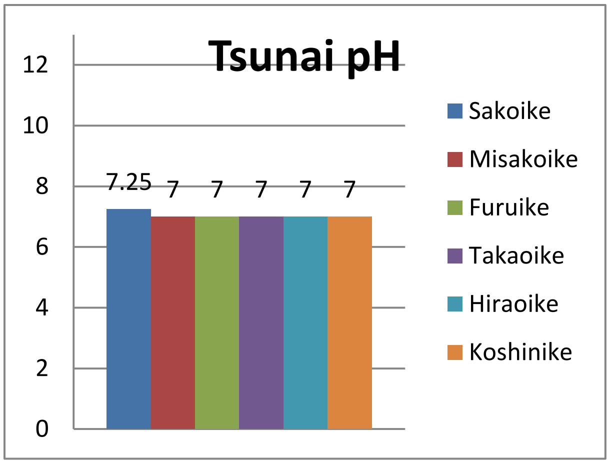
There could be many reasons for Ababi's high WF, but the most important is its harvest size. In Tsunai, the weighted average harvest was 455.34kg/10are which is somewhat low compared to the prefectural average (489kg/10are) and the 2014 national average (536kg/10are) (MAFF 2017). In Ababi, however, the weighted average harvest was only 122.95kg/10are, or 245.9kg annually; a harvest size comparable only to Japan's Okinawa prefecture which is at around 261kg/10are. The 2014 national average for Indonesia was on par with Japan at 513kg/10are (ricepedia.org, 2018). When one begs the question why harvest is so low in Ababi, it cannot be ignored that climatic and ecological factors likely play a role in this, despite this paper's focus being on social and managerial factors. Bali's tropical island climate and tropical forestland not having to withstand a winter or cold period has made it so that rice grows quickly year-round, and therefore there was probably less need or incentive for Balinese farmers in the past to artificially select strains which produce higher yields, but maybe take longer to reach maturity. The subak as it has historically operated has been continuous and dynamic (qualities which match its environment), and the population of Bali and Indonesia was never as great as it is today. The yields of the subak were likely sufficient for most to survive until industrial development efforts began. Instead of selecting strains to increase yield, perhaps Balinese farmers selected for the water efficiency of the plant itself. This is a possibility considering a few of the farmers that were surveyed who still use Balinese rice said that if they used more than 3-5cm in their WL, the rice would be damaged. Furthermore, because Bali has a large rice pest population (rats and brown leaf hoppers), selecting for pest resilient plants was also likely a higher priority than overall yield from one unit of the rice paddy area.

One more consideration for Ababi is the fact that rice is primarily grown for subsistence. Other crops like elephant grass or potatoes are reportedly more profitable as they are sold for cattle feed. Because of this, farmers may also simply care less about their rice yield since it is not their main source of income.

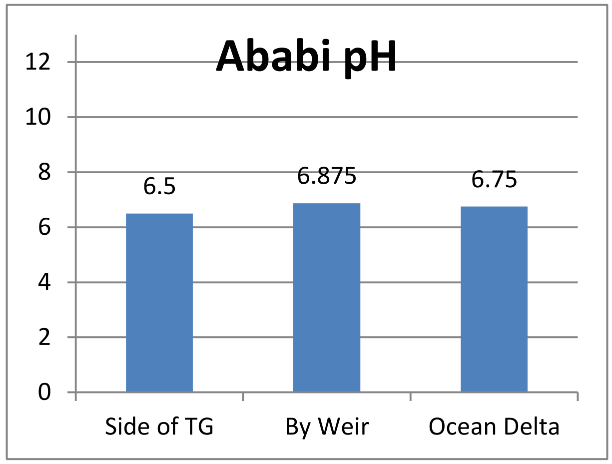
Meanwhile in Tsunai, multiple farmers related to the researcher the concept of *sebyou* (畝俵). The first character '*se'* is a unit of measurement equal to $100m^2$ and '*byou'* is equal to about 60kg of rice; or we could say 600kg/10are. They explained that *sebyou* was the golden number in the Edo period of Japan, and Japanese farmers use it as a point of reference for the success of their own crop even today. This shows that yield to land area efficiency was a principal goal for Japan throughout a good portion of its history which is logical since 73% of Japan is mountainous and there is not a continuous growing season. Also adding the fact that it was the first Asia-Pacific country to develop and has engineered technology and rice varieties to fit their specific environments, this efficiency has probably increased until present day. Tsunai's historian did say, however, that achieving *sebyou* has become less common due to harvesting tools being mass-produced and not allowing for variation in the distance between rice plant rows in the paddies. Despite this, Aomori, Yamagata and Nagano prefectures all have average yields close to or above *sebyou*.

5.2.3 Water Quality Assessment

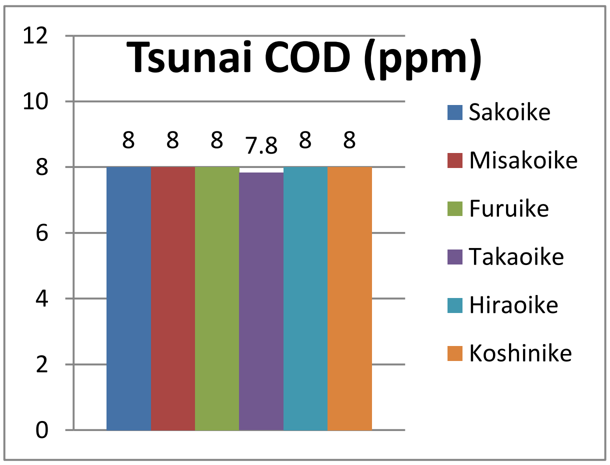
This section will discuss the results of the river water test kit mentioned in the methodology section. The purpose of this chemical analysis was to test the irrigation systems for pollution from agriculture, namely fertilizers containing nitrogen and/or phosphorus. This kit tested for pH, Chemical Oxygen Demand (COD), Ammonium-Nitrogen (NH_4^+-N), Nitrite-Nitrogen (NO_2^--N), Nitrate-Nitrogen (NO_3^--N), and Phosphate-Phosphorus (PO_4^{3-}-N). All sample extraction conditions including weather and water temperature were also recorded to ensure consistency. In Tsunai, all six tameike were measured over a span of four months from May 20th to August 2nd 2017. In Ababi, there were unfortunately only two weeks for water sampling, so all samples were taken between August 30th and September 11th 2017. Sampling locations include the main weir that feeds to Subak Embukan, outside the east wall of Tirta Gangga water palace, and the delta where the river connects to the sea. Graphs 5.1 through 5.12 show the results of these samples below.



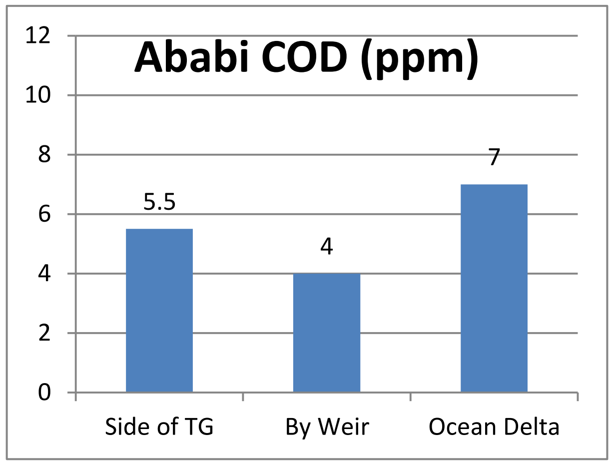
Tsunai pH
12
10
8
6
4
2
0
7.25
7
7
7
7
7
Sakoike
Misakoike
Furuike
Takaoike
Hiraoike
Koshinike



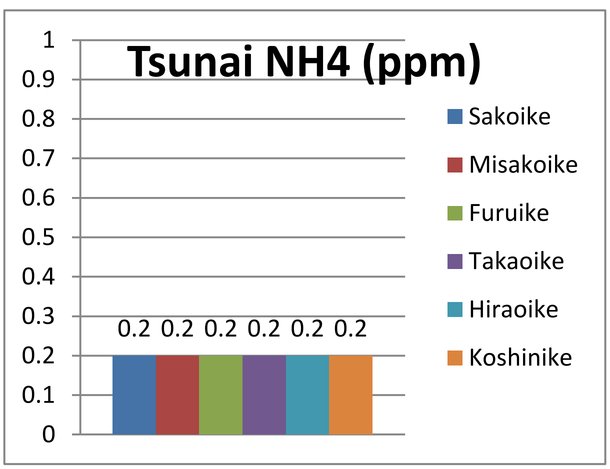
Ababi pH
12
10
8
6
4
2
0
6.5
6.875
6.75
Side of TG
By Weir
Ocean Delta



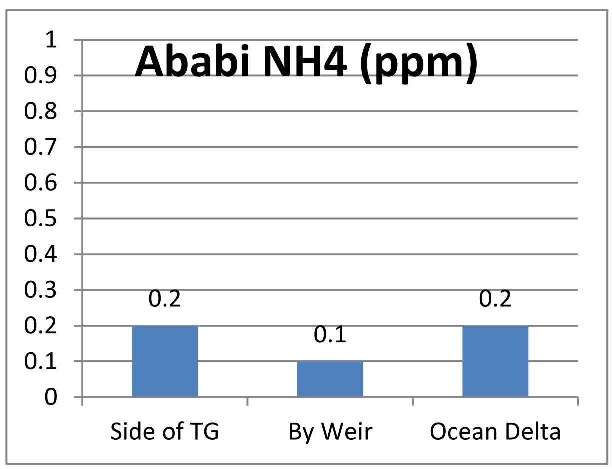
Tsunai COD (ppm)
12
10
8
6
4
2
0
8
8
8
7.8
8
8
Sakoike
Misakoike
Furuike
Takaoike
Hiraoike
Koshinike



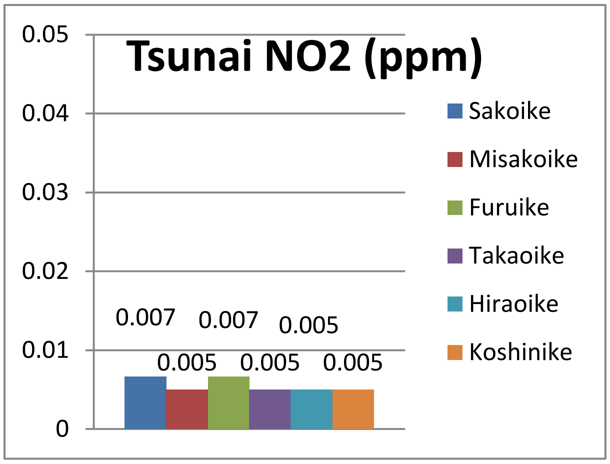
Ababi COD (ppm)
12
10
8
6
4
2
0
5.5
4
7
Side of TG
By Weir
Ocean Delta

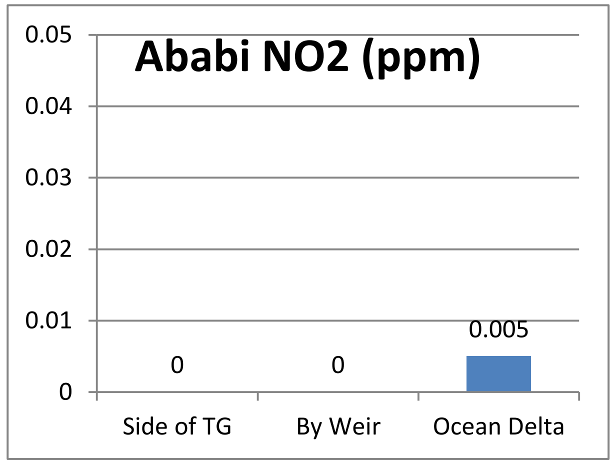


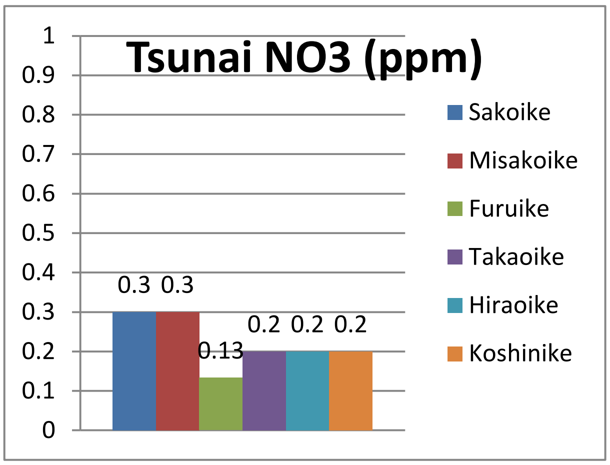
Tsunai NH4 (ppm)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.2
0.2
0.2
0.2
0.2
0.2
Sakoike
Misakoike
Furuike
Takaoike
Hiraoike
Koshinike

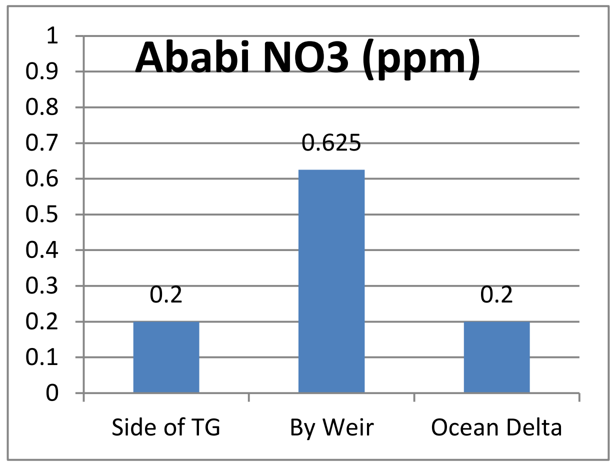


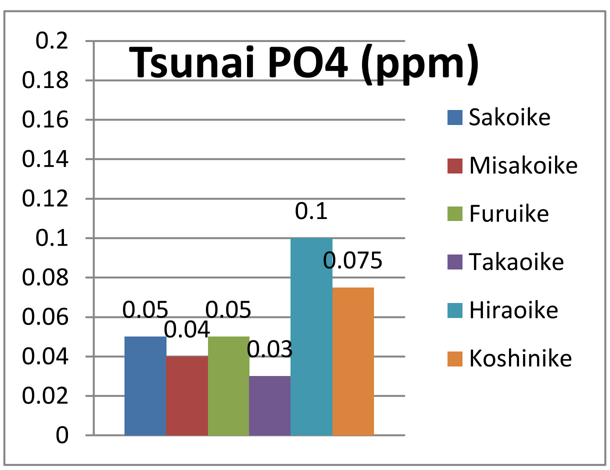
Ababi NH4 (ppm)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.2
0.1
0.2
Side of TG
By Weir
Ocean Delta

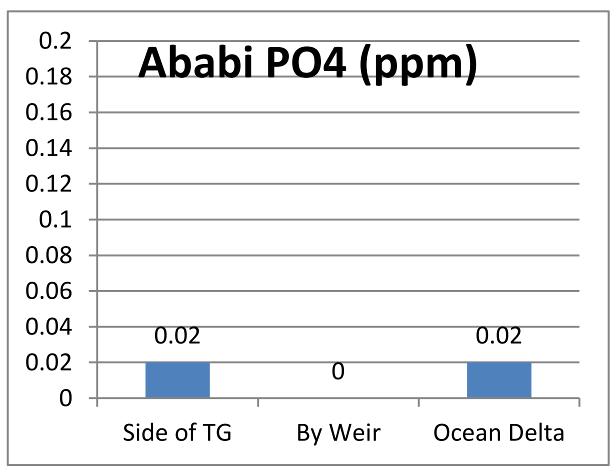

Tsunai NO2 (ppm)
0.05
0.04
0.03
0.02
0.01
0
0.007 0.007 0.005
0.005 0.005 0.005
Sakoike
Misakoike
Furuike
Takaoike
Hiraoike
Koshinike


Ababi NO2 (ppm)
0.05
0.04
0.03
0.02
0.01
0
0
0
0.005
Side of TG
By Weir
Ocean Delta


Tsunai NO3 (ppm)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.3 0.3
0.13
0.2 0.2 0.2
Sakoike
Misakoike
Furuike
Takaoike
Hiraoike
Koshinike


Ababi NO3 (ppm)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.2
0.625
0.2
Side of TG
By Weir
Ocean Delta


Tsunai PO4 (ppm)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0.05
0.04
0.05
0.03
0.1
0.075
Sakoike
Misakoike
Furuike
Takaoike
Hiraoike
Koshinike


Ababi PO4 (ppm)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0.02
0
0.02
Side of TG
By Weir
Ocean Delta

According to Ayers & Westcot (1994), the safe range for irrigation water pH is from 6.5 to 8.4, which both Ababi and Tsunai are well within, averaging at 6.75 and 7, respectively. There were some slight changes over time in Sakoike, but nothing outside of normal bounds.

According to instructions included in the test kit, ideal COD levels for rivers and streams are between 0 and 5 mg/L. Ababi is only slightly above this, but all of the tameike were well above the normal range and possibly above the limits of the test. This is, however, somewhat expected because the tameike are ponds and therefore have less oxygen mixed into them on average compared to moving bodies of water. Furthermore, as seen in image 5.4, the perimeter of the tameike are tightly packed with trees that dump leaf and other organic materials into the water. Since the majority of tameike are surrounded by forest and at a higher elevation that almost all farmland, it is unlikely this high COD is because of fertilizer runoff, and more likely because of a high organic matter content from leaf litter.

Moving on to measurements of the nitrogen cycle, the ideal range for NH_4^--N is ≤0.2mg/L, which both systems are within. Both Ababi and Tsunai also passed concerning NO_2^--N with the ideal range being ≤0.02mg/L. When we come to NO_3^--N, however, the results for both systems are below the usual range which is 1 to 2 mg/L. This could mean one of two things: there are not enough fish and other animals adding nitrates to the water or there are too many plants absorbing nitrates from the water. In Tsunai's case, the latter seems more likely since it is surrounded by trees and there was some thin algae buildup near the shore. Algae was also seen in several Tsunai rice paddies; however, there was not so much algae in any part of the system that would make one believe the environment was being choked. For Ababi, the source of the deviation is unclear; although, Ababi's average nitrate levels were much closer to the ideal range at 0.413 mg/L, so perhaps there is less cause for concern. In either case, having low nitrates is not always a bad thing since too much can be poisonous to fish. With the levels being so low, however, there is more reason for farmers to use nitrogen fertilizers as sufficient nitrogen might not come naturally from the irrigation systems themselves.

Finally, the ideal range for PO_4^{3-}-N was ≤0.05mg/L, and both systems scored rather well. Ababi had about 0.01mg/L on average while Tsunai was about 0.057mg/L. This is technically above the suggested limit, but negligibly so. Overall, both irrigation systems had average scores for water quality, meaning that the chance of pollution from fertilizer runoff and other sources is very small. Furthermore, the Kunisaki-Usa GIAHS proposal sited the existence of two endangered species that reportedly depend on the tameike on the peninsula: the Oita Salamander (*hynobius dunni*) and the Spotted Salamander (*hynobius naevius*). The existence of these species in the tameike of Tsunai could not be confirmed, but if they do inhabit the area, they would make excellent indicator species due to their sensitivity to their environment. The Karangasem GIAHS proposal did not site any animals that are endangered, but during the researcher's time spent in Ababi, numerous fish, snakes, lizards, crabs, and freshwater eels were all sited.

One more consideration for water qaulity in these systems is litter and pollution from human activity. In Tsunai, there were occasional plastic bags in the ponds, but on the whole, all ponds were very clean. Even Sakoike, which is located right behind a busy roadway, showed little to no difference by appearance or chemical test from the other ponds located higher up in the forests. The streams in Ababi, however, contained large amounts of trash of various types. Most of the trash was plastic bottles or food wrappers, but also there were what looked like sacks of epsom salt and other materials that might harm the quality of the water. Furthermore, many farmers and their families use the irrigation water for bathing, defacating, and doing laundry, so these activities could also temporarily change the water quality before it is washed downstream. No obvious abnormalities were found in the chemical test, but the possibility of other chemical changes that the test kit could not measure exists. Below are a few pictures of some examples from each system.

Image 5.3: Flood spillover mechanism in Sakoike by the road (Kunisaki 2017)

Image 5.4: Furuike surrounded on all sides by trees with no pollution from litter (Kunisaki 2017)

Image 5.5: Litter in stream that feeds into irrigation scheme in Ababi (Ababi 2017)

Image 5.6: More trash disposed near water streams (Ababi 2017)

5.2.4 Managerial Effectiveness

This final section analyzes the managerial processes carried out by leaders and farmers and how they promote water use efficiency, protect water quality, and lower the risk of failure in their systems. Some things to keep in mind in this analysis are the scale of the systems, the nature of the water sources, and the style of governance. Tsunai has a total of 11 tameike benefactors each with an average paddy size of around 174 are (the ward headman manages 1500 are and was excluded from this calculation). Tsunai as a ward has 32.4 hectares of active paddy land; 17.1 hectares are fallow land. Their water comes from six man-made ponds (tameike) which are connected by canals so water collected at the top of the catchment area can be transported to the bottom. When farmers need water, they contact the ikemori in charge of the tameike connected to their paddy and pay a fee (refer to economic assessment). There are five ikemori (one for each tameike other than Koshinike) who are elected annually based on the *nyuusatsu* (入札) system. In this system, each ikemori candidate bids the lowest salary they are willing to accept and still perform the job. Upon election, these five men receive requests for water from the other farmers and work amongst themselves to organize when to supply it and not exhaust the tameike. In the survey, some farmers reported requesting water as much as 60 times in a growing period.

Subak Embukan has 336 members, but multiple farmhands typically work on one paddy. The average paddy size from the 11 surveyed farmers was 26.1 are (excluding the subak leader who only managed 3.5 are). In total, there are 76 hectares supplied by the weir system, but only about 38 hectares of it are rice. The water comes from a somewhat narrow stream originating from Mt. Agung. Several weirs and concreted canals are installed to manipulate the water level so as to deliver it to the paddies without damaging the paddy or losing water too quickly. Subak Embukan has one elected leader who is aided by a secretary and an accountant. Below him are 12 different branches each with its own elected leader; however, the main leader had a double role as a branch leader during the time of this study. Water taken from the streams is free to farmers, and farmers are included in deciding the water dissemination process each growing season. Typically, 8 out of the 12 branches will be allowed to plant rice, while the last 4 branches plant things like potatoes, elephant grass, or flowers. The right to grow rice is rotated between these branch groupings and groups are also often made smaller in particularly dry periods.

Considering these differences in scale, water source type, and style of governance, figures 5.3 and 5.4 summarize all of the main water losses inherent in the irrigation systems, and how the leaders and farmers address these losses.

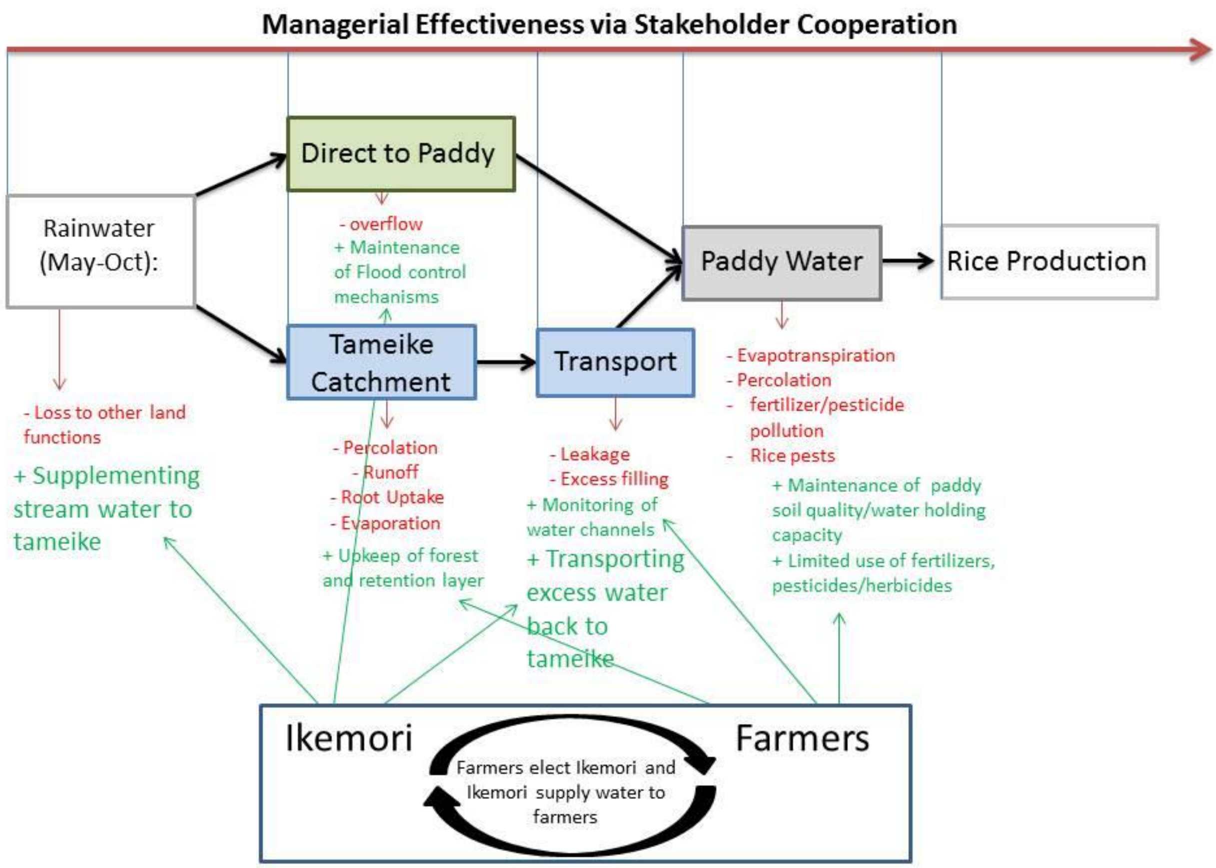


Figure 5.3: From left to right, this figure shows how farmers and leaders in Tsunai address water losses in every stage of rice cultivation.

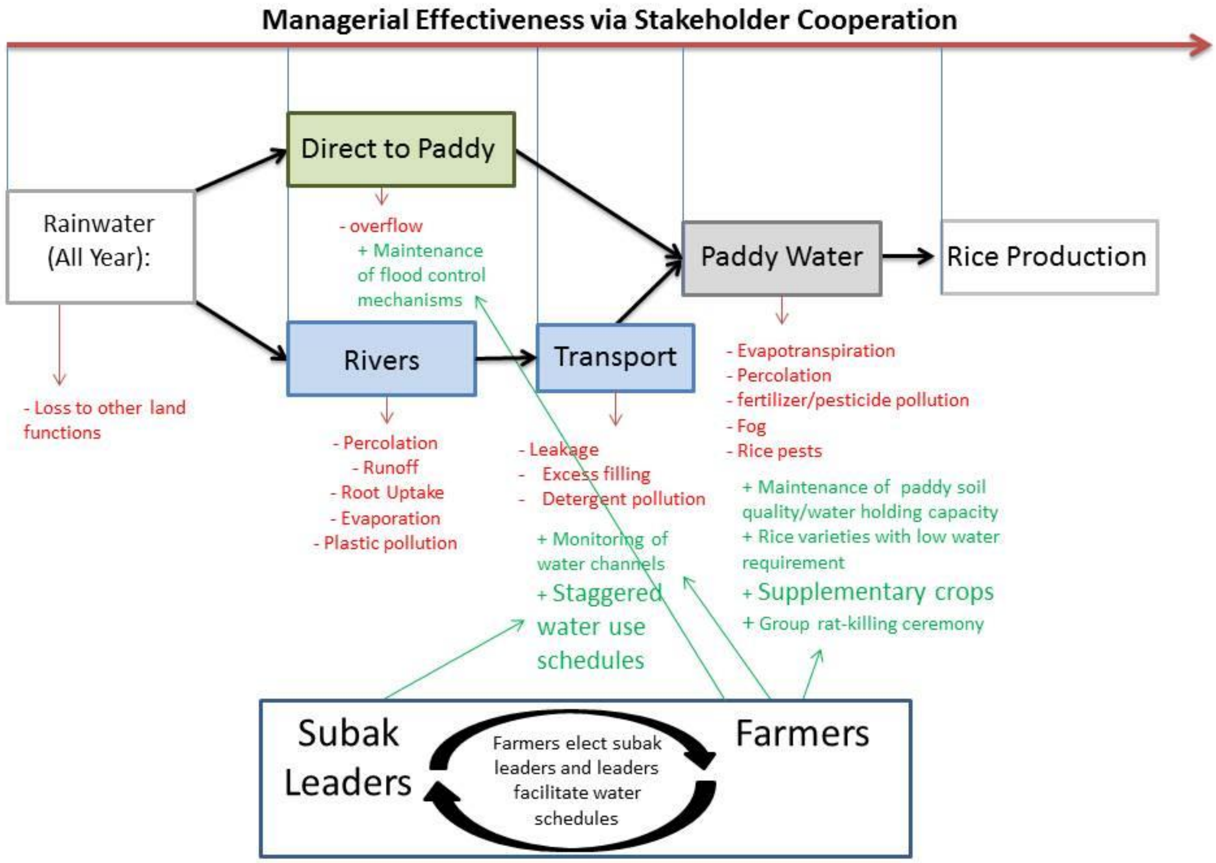


Figure 5.4: From left to right, this figure shows how farmers and leaders in Ababi address water losses in every stage of rice cultivation.

The first important point displayed in these charts is the difference in the sheer amount of duties that are deviated between leaders and farmers. For Ababi, much of the success of water management is borne on the farmers, rather than only the leaders. Leaks and other anomalous conditions of flood channels and feeding channels are usually first discovered and often fixed by farmers themselves. In the survey, question S32/S34 asked how many times respondents had found leaks in the irrigation channels, and the average answer for Ababi farmers was '>10 times'. The second part of the question asked if they reported the leak to anyone and multiple farmers made a point in saying that it depends on the severity of the leak. Most leaks are easily fixed by applying soil/clay and do not require the attention of the whole subak. Only the main vein of the irrigation channels is concrete or stone, so most leaks are in the terraces themselves which are supported by walls of clay and stacked rocks. In these situations, farmers do much more than leaders.

Tsunai farmers reported finding leaks an average of 4.13 times and all farmers stated that they reported the leak to someone else; usually the ward headman. This is because all channels in Tsunai are completely concreted from the tameike all the way to the field the water is delivered to, so it requires some expertise to mend properly. The representatives of the Agricultural Department in Kunisaki City Hall also explained that most large repairs can be funded by the government via application, or at the very least, city hall can aid in contracting a repair company. This is why the chart for Tsunai has the ikemori being more involved in maintaining flood channels and other segments of the irrigation scheme rather than farmers. The system being more structurally sound than Ababi's has reduced the frequency of leaks, but it has also made it more difficult and costly to repair.

The next important thing to note is the importance of being in control of transporting water in Tsunai. For water lost initially during rainfall, protecting against overflow and floods, and transporting water to the rice paddies, there is a way for the system to supplement, conserve or retain water. As shown in the leftmost part of figure 1, rainwater lost to land outside of the system can still be added to the tameike if necessary via a channel from the very small creek on the southern edge of the ward. Direct-to-paddy rainwater has the potential to cause floods and landslides, but once again, the system has a way to transport that water away from the paddies and preserve the crops. Furthermore, even if there is a mistake made where too much water was transported to one farmer's field, channels are installed that can drain the extra water and transport it back to one of the tameike, so long as there is one downstream from the paddy. Truly, Tsunai's system being closed, water amounts being semi-fixed or at least readily measured, and multiple fail-safes being built-in to channels and paddies alike is the greatest asset the system holds.

Conversely in Ababi, the channels are basically concrete-lined streams. There is no water saved, nor transported from one place to another in a fixed amount. The irrigation canals are constantly flowing just as they would have had they been natural streams. Because of this, the principle method the subak employs to utilize water efficiently is not to harness the water, but to change its crop schedules. This is mainly facilitated by the subak and branch leaders, but as stated before, all farmers are included in the process. When the canals have a lower water level than usual and less rain during the dry season, the subak reacts by planting less rice and more place-holding crops. The subak could therefore be characterized as a reactionary institution, while the tameike are an attempt to modify nature to better serve the needs of its benefactors from the production end. After all, the driving point that was made in the Kunisaki-Usa GIAHS proposal was that the Kunisaki peninsula does not have convenient access to large amounts of flowing water. When asked why Subak Embukan chooses to grow rice despite other subak in Karangasem growing corn, fruit, flowers etc., the subak leader replied that Ababi is the most water-abundant area in Karangasem, so it naturally made sense. This resonates with previous claims by John S. Lansing stating that the subak is an entity which reacts to changes in its environment. Ideally, this dynamic process creates an agricultural landscape which constantly approaches equilibrium where all farmers benefit more or less equally.

The final point to be made concerning these charts is the difference in pest control methods. In Bali, John S. Lansing famously asserted that pest control was mostly facilitated by flooding as many paddies as possible because it denied Balinese rats breeding grounds and kept their populations low. This was, however, not always possible due to the lack of water for all subak members to use at the same time, so a balance was reached where subaks chose to coordinate paddy flooding and then stagger paddy flooding to find a balance between water equity between upstream and downstream farmers and also keep rice pests down. Characterizing Subak Embukan with the same concept proved difficult because although some farmers listed 'lack of water' as one of the biggest threats to their agriculture in question E1, all eleven farmers appeared more concerned with rice pests, upstream and downstream alike. Perhaps their water schedules do attempt to deny rats breeding grounds and curb their growth, but the success of this endeavor is questionable. Subak Embukan even has a special ceremony every 10 years where all farmers are tasked with a bounty of at least 4-5 rat corpses which are gathered and cremated. The representative at the Karangasem Office of Forestry and Plantations in Amlapura also stated that pest populations tend to steadily grow and eventually reach a tipping point at which his office then supplies more pesticides and traps to farmers until the population is once again controlled. In any case, whether Lansing's assertion holds true in Subak Embukan or not, it is not enough to completely hold off pest populations.

Tsunai farmers also reported having issues with pests. Only a few farmers reported using pesticides, but as for their answers to question E1, 'rice pests' was in top three threats for all farmers who responded. Aside from pesticides, however, there was no alternative method of combatting pests like paddy flooding in Bali. The biggest threat for most farmers in Tsunai was 'damage from tropical storms' which highlights the necessity of overflow control, but also questions its effectiveness in the current system. There was a typhoon late spring of 2017 that decimated Hita, a town in Oita further inland from Kunisaki. When asked how Tsunai was affected, however, the historian said there were no problems. Frequent worried updates on social media from an ikemori living in the ward next to Tsunai, however, proved that there can be disaster even with the tameike system's flood control mechanisms.

In summation, the managerial effectiveness of both Ababi and Tsunai is relatively high, but for very different reasons. In promoting water use efficiency, Tsunai is much more successful thanks to its ability to control the flow of water with significant flexibility, and its channels being entirely concrete helps to prevent leaks better than many parts of Ababi's irrigation channels. Ababi is more successful toward the tail-end of the water use process thanks to its ever-changing and accommodating crop rotations that react to the weather and environment. Tsunai, on the other hand, is disadvantaged as a monocrop community. If a water shortage were to occur, farmers would likely be slow to act and select a less water-intensive crop for the dry period. The responsibility would fall on the ikemori to ration the water to all the farmers. In regards to risk abatement, both systems have mechanisms in place, but disasters can still occur. Tsunai is sometimes vulnerable to the torrential rain and winds from typhoons and also has some pest problems. Ababi has incredible pest problems during times right before the rat-killing ceremony, and several farmers also reported fogs over their paddies making patches of their rice not bear grain.

5.3 Economic Assessment

This section takes into consideration economic influences on irrigation management and how the farmers are motivated by different events to achieve economic ends. Much of the information for this section derives from expert interviews and official documents, but there was a brief economic assessment section in the survey from which some of the items will be discussed. It is imperative here to remember each system exists in a very different economic climate; Indonesia being a developing country and Japan being a developed country. For this reason, the two systems will not simply be compared as equivalents, but relative to their own countries.

5.3.1 Threats to Agriculture and Economic Risks

In question E1, farmers were given six items and told to rank them from 1-6 based on how threatening they felt they were to the success of their agriculture. These items included: 'tropical storms', 'water scarcity', 'rice pests', 'lack of manpower' (participation of younger generation), 'foreign rice imports', and 'lack of access to equipment, machines, or compounds'. The top three threats reported in Ababi were 'rice pests', 'lack of man power', and 'lack of equipment'. These are all expectable outcomes because of the previous researches emphasizing the damage caused by rats and brown leafhoppers in Bali, the Karangasem GIAHS proposal which stated agricultural land and its workforce are transitioning to the tourism industry, and the information given by Karangasem's government official saying the central government only supplies farmers with fertilizers and pesticides rather than equipment.

‘Rice pests’ being the biggest threat amongst all respondents would logically mean that these farmers are highly motivated to counteract this threat. This would then take the form of Subak Embukan’s ceremonial rat-killings and the use of pesticides; however, only two of the twelve surveyed farmers reported using pesticides, and two others only used herbicides. According to the testimonial of several farmers, this is because the threat of rats far outweighs the threat of insects. In the 10-year interim periods between rat-killings, farmers must combat rodent problems themselves via traps which one farmer said was a part of the government training program discussed briefly in the social capital section. Killing rodents without the cremation ceremony, however, can also be a cultural taboo as killing without the intent to eat is *ahimsa* in the Hindu religion so some farmers may be reluctant to kill rats they find. As far as being an economic threat, these rats have the potential to decimate harvests and may explain why average harvests in Ababi were so low compared to Tsunai. Lack of manpower may also add to this problem as fewer boots on the ground could lead to fewer pests being thwarted and a lower efficiency in the rice harvesting process since rice is harvested by hand. If there are fewer workers per field, it could be argued that the few remaining farmers could then share a larger portion of the harvest and profits, but the lack of equipment could be keeping farmers in such circumstances from achieving their highest potential yields. Conversely, Tsunai’s situation is a successful example of this scenario with one family per paddy and paddy areas much larger per family, on average.

The top three threats to agriculture reported in Tsunai were ‘tropical storm damage’, ‘rice pests’, and ‘lack of water’. The summer typhoons sometimes bring rain and wind amounts that can ruin entire crops and, therefore, create a comparatively larger risk than in Ababi. The representatives of Kunisaki City Hall Agricultural Department even said their own parents were farmers, but they were told not to become one themselves because of the instability of income flow. One year you might make enough to live comfortably, the next year you could make close to nothing. This explains why in question E2, only one farmer from Tsunai reported not having any insurance for their crops or farming equipment. It is almost a necessity there. In Ababi, no farmer reported having insurance on their crops or equipment and tropical storm damage was one of the lowest threats amongst all but one respondent.

Rice pests in Tsunai are mostly insects (brown leafhoppers). Eight of the ten farmers who elected to report their pesticide use said they used pesticides in some amount, and most also used herbicides. This may be one of the reasons their yield was so much higher, on top of using a locally optimized variety of rice. Insect populations can be more easily controlled via these chemicals than rats; although, new chemicals may have to be constantly developed in order to compensate for insect populations that develop a resistance to certain pesticides. This has been found to occur in brown leafhopper populations where organophosphates are utilized (Small & Hemingway 2000). Furthermore, a study by James & Xu (2012) found that pesticides can lower the immunity of some insect populations, increasing the risk of diseases being spread. Pesticide use may have a short term economic benefit, but in the long term it could have negative environmental effects as well.

'Lack of water' being one of the top three reported threats is not against all expectations, but somewhat surprising considering there used to be more land devoted to agriculture in Tsunai's past, and about 35% of the remaining agricultural land today is fallow. One would assume that this would be the time in Tsunai's history with the least water stress; yet it is still a concern. The reason for this was unclear, but for the purposes of the economic assessment, it can be understood that water is a fixed cost for Tsunai farmers that Ababi farmers do not have, giving it a higher value from a business perspective. Because Tsunai farmers do not have free water available at any time, it could be that water is perceived as scarcer that it is in Ababi. This sentiment was not measured, however, so it cannot be taken with much weight.

5.3.2 Livelihood and Financial Security

Question E5/E4 asked the farmers if they received any government subsidies or other funding. Unfortunately, six of the Tsunai farmers elected not to answer this question, but 4 of the 5 who did answer reported receiving a subsidy of some kind. These included *narashi taisaku* (ナラシ対策), *gentan hojokin* (減反補助金), and the New Demand Rice Initiative (新規需要米取組). The narashi taisaku is essentially insurance for the farmers for when the price of rice drops below a certain percentage from the norm. The gentan hojokin is a subsidy provided to farmers who volunteer to reduce the amount of land they use for rice. This was an initiative to decrease supply and, thereupon, increase demand for rice, but it ended in 2017. Finally, the New Demand Rice Initiative is a program that ensures a steady price to farmers in exchange for rice supplies to alternative rice consumers, such as for livestock feed (WCS).

Fifty percent of farmers in Ababi said they received a subsidy, but it is a fertilizer subsidy and not a monetary one. One farmer said that in order to receive it, one simply has to submit a proposal, but this does not necessarily ensure that all farmers receive it or that farmers have steady income; rather, it simply cuts a fixed cost. All government funding for the subak goes to the subak leader and the subak accountant. This means if a farmer's crop was destroyed by pests, fog, or something else, supplemental funds would have to come from the subak leader, but according to the leader of Subak Embukan, the money is mostly used for purchasing equipment, repairs on irrigation infrastructure, maintaining temples, etc. There is very little security for these farmers, which is further evidenced by the answers to question E8/E7 which asked, "In your opinion, is the amount you make from farming and subsidies enough to live a secure and comfortable life?" Only 1 of the 11 farmers who elected to respond said "Yes". All others said, "No" or "Not Sure". Admittedly, there could have been some problems in reliability due to subjective interpretations of the term "comfortable life", but the overwhelming consensus is still worth some weight. Furthermore, in question E7/E6, when asked if they had secondary sources of income, 7 of the 11 who answered said "yes". These included jobs like construction, masonry, food stuffs vending, and others. If this is the case, the money earned from agriculture alone is likely insufficient.

Japan being a developed country with several different subsidies to support their farmers, one might assume that these farmers' incomes are relatively stable. Conversely, only one farmer in Tsunai reported feeling that they have a secure and comfortable life, and half of all farmers in Tsunai have secondary sources of income, including fishing, selling prepared meals, part-time work, etc. It seems despite differences in the countries' levels of development, there are similar opinions on the market and government support for agriculture. Many farmers in Ababi, however, are objectively more disadvantaged having several of them reporting not being able to afford to send their children to school, while no such cases existed in Tsunai.

5.3.3 The Price of Water

Question E3 asked farmers in Tsunai how much they pay in total for water in an average year. Due to privacy concerns, the answer rate to this question was incredibly low, but 3 farmers did provide an answer. The validity of these answers, however, is very questionable. Farmers with larger paddies strangely reported paying less annually for water when compared to their peers. Farmer 6 reported paying ¥13,000 for 15ha at a depth of 10cm (BWD: 97,430m^3), Farmer 8 reported paying ¥11,000 for 2.6ha at a depth of 7.5cm (BWD: 17,405m^3), and Farmer 10 reported paying ¥20,000 for 3ha at a depth of 5cm (BWD: 18,772m^3). There was no detectible correlation between water demand and reported water expenditures, so perhaps there was a misunderstanding due to the way the question was worded. Farmer 6 and 10 both got their water from the same tameike as well, so price varying based on the individual pond also cannot explain it. At any rate, if we compare these water prices given to average yields we might be able to get a very rough estimate of water's relative cost to profit ratio. For this calculation, the payment JA gives for 30kg of rice was reported by one ikemori to be around ¥6,500 for 2016-2017.

$$\boldsymbol{Farmer\ 6}: \frac{4553.4kg}{ha} \times 15ha = 68{,}301kg$$

$$\frac{¥6{,}500}{30kg} = \frac{x}{68{,}301kg}$$

$$= ¥14{,}798{,}550; \frac{¥13{,}000}{¥14{,}798{,}550} = \mathbf{0.0009}$$

$$\boldsymbol{Farmer\ 8}: \frac{4500kg}{ha} \times 2.608ha = 11{,}736kg$$

$$\frac{¥6{,}500}{30kg} = \frac{x}{11{,}735kg}$$

$$= ¥2{,}542{,}583.3; \frac{¥11{,}000}{¥2{,}542{,}583.3} = \mathbf{0.004}$$

$$\boldsymbol{Farmer\ 10}: \frac{5000kg}{ha} \times 3ha = 15{,}000kg$$

$$\frac{¥6{,}500}{30kg} = \frac{x}{15{,}000kg}$$

$$= ¥3{,}250{,}000; \frac{¥20{,}000}{¥3{,}250{,}000} = \mathbf{0.006}$$

Based on these calculations, the cost for water compared to the profit from yield would be negligible. Once again, the true validity of these water prices is unknown, but if they are accurate, this leads us to the conclusion that the price of water is almost completely for the sake of incentivizing the management system, rather than for profiting. The revenue collected from water users goes to taxes and the salaries of the ikemori, which appears not to be unreasonably high. Even if 500kg of each of the above yields were taken from the equation, as most of the farmers use their harvests for subsistence as well, the price of water would remain very minor.

In Ababi, farmers receive subak water for free so it does not enter into fixed costs for them, but according to the answers to question E3 and the testimony of the subak leader, other entities besides farmers utilize water from the same source. In this case, the subak has authority and priority to water rights and these outside entities reportedly pay the subak for however much water is used. This amount is unknown, however, as well as how the amount is measured and how much is typically paid for it. What can be surmised is that income to the subak enters both from government funding and from these third-party users, but only to the subak leader and accountant at the top. This emphasizes the crucial role leaders in the subak play not only in water dissemination, but in budgeting and other economic functions. If leaders do not effectively use the money where it is needed, farmers would be at their mercy and receive no aid that could be comparable to that found in Tsunai. The democratic elections for subak leaders should be a mechanism to prevent such malpractice or what might be considered corruption, and as the results of questions from the social capital section suggested, good leaders serve long terms and bad leaders are ousted almost immediately. Despite this failsafe, however, because many farmers said that lack of equipment was one of the top three threats, perhaps the money going to the subak is still quite little or being used in ways where not all members benefit.

5.3.4 Summary of Economic Assessment

Risks to the success of agriculture in Ababi are rice pests, lack of manpower, and lack of equipment. Rice pests are primarily rats which are combatted with traps and rat-killings every ten years, but problems persist well enough to still have farmers report them as their number one threat. Lansing (2006) observed rat populations being curbed via coordinated water flooding of paddies in subaks north of Denpasar, but this does not seem to be a mechanism in Subak Embukan as the subak leader explained the subak branches rotate every growing season, never having completely coordinated water cover, and thus, never effectively denying rats breeding grounds. It could be that despite the subak leader’s opinion that Ababi is Karangasem’s most water-rich region, compared to other subak on the island, there is still not enough water to facilitate such pest prevention measures, intentional or otherwise.

As far as lack of manpower and lack of equipment go, these are problems borne in the structure of the regional and national market and government policy, respectively. Tourism is the fastest growing and most profitable market in Bali and many young Balinese see it as a better opportunity for quality of life than farming. Unless there is something done by the government to make farming more profitable and stable or citizens integrate farming into the tourism infrastructure, this trend will continue, considering the trends of other emerging industrialized countries. Lack of equipment is both a problem of farming not being very profitable and the way funding and subsidies are distributed in Indonesia. Fertilizers are the only thing directly available to the farmers themselves. Tractors, tools, and other equipment must be funded by individual farmers or come from the funds given to the subak leader who might have other plans in allocation. These are all problems typical of modern developing countries.

Tsunai, on the other hand, is mostly concerned with threats from tropical storms, rice pests, and lack of water. Indeed, tropical storm damage is sporadic and unpredictable and has the potential to completely destroy a crop if flood mechanisms in the tameike system are overwhelmed. Almost all farmers do have insurance for their crops just in case such damage were to occur, but nevertheless, it is still a profession where people cannot always count on having the same income this year as they did last year. Rice pests are mostly insects and are combatted with insecticides, but this has the possibility of creating future problems should insect populations adapt and develop a resistance, making the sustainability of using such chemicals questionable.

It was somewhat of a mystery why lack of water was reported as one of the top three threats to Tsunai considering that, historically speaking, there is very little rice paddy area being supplied compared to 100 years ago. Admittedly, some water is stored by those in the ward who are not growing rice for fire prevention purposes, and water demands for modern rice varieties may be higher than rice of the past. Nevertheless, water appears to be an anxiety most Tsunai famers share. It was conjectured that this sentiment about water scarcity might come from the structure of the tameike system where farmers are forbidden to access irrigation water without going through ikemori and paying a fee, but the fees reported by the three responding farmers were quite negligible, so it is difficult to say. Overall, economic sustainability is quite low for both systems, which affects the irrigation in that loss of human capital to other industries could lead to less effective management.

Chapter 6: Discussion

The results of this study paint a complex and sometimes contradictory picture of the social, environmental, and economic status of sustainability in Ababi and Tsunai. Neither system was found to be perfectly sustainable nor was one ‘better’ than the other, but the results have provided a useful profile of what sustainability looks like when comparing developed and developing countries. Both systems have characteristic weak and strong points which can be analyzed and used to better assist such agricultural communities, as well as predict a rough system life-cycle as a system’s host country transitions from a traditional social paradigm to an industrialized nation. With proper support, agricultural communities in both developed and developing countries may continue to approach sustainability in its ideal form aided by knowledge from other systems. The following sections will discuss the main social, environmental, and economic drivers found in chapter 5 that lead to the methods of irrigation water management implemented by each system. Thereupon, the manner in which these methods translate to sustainable ends and in what way they are or are not sustainable, will be discussed.

6.1 The Role of Religion in Determining Land Use and Irrigation Methods

With Ababi and Tsunai being located in volcanic/mountainous regions, there was much that they had in common in terms of successfully managing irrigation water. The first to note would be the layout choice for land use. As previously discussed in the literature review, land use in Bali was historically dictated by the Hindu philosophies Tri Hita Karana and Tri Mandala which split the island topography into three levels: mountains, villages, and paddies/fields. Despite having a completely separate religious and social background, Tsunai exhibited the same layout with the tameike located in the mountain forest, most of the homes located right below the edge of the forest, and the majority of rice paddies located closer to the ocean. This suggests more practical benefits outside of religious context, and the literature agrees. Strauch & Almedom (2011) concluded in their study on traditional stream water management in Tanzania that minimizing development near the source of the water prevents water pollution from livestock and human activity. Another study stressed how the removal of riparian vegetation could disrupt biotic processes by changing the temperature of stream water (Johnson & Jones 2011). Maintaining mountain water sources also allows irrigation water to flow naturally via gravity so no pumps which would raise operational costs and carbon emissions are necessary. Furthermore, the undisturbed forest surrounding the water source prevents natural disasters like floods or mudslides, and the location of farmers' homes being at a higher elevation than rice paddies protects them from tsunamis. Rather than social capital, this would be the positive result of the system structure which remains constant regardless of everyday social conditions; in other words, before-pipe solutions.

Dividing land use in mountainous areas into different strata may seem like an obvious necessity, but its roots in religion also suggest that eastern religions could promote sustainability in more ways than just social bonding. When asked why mountains are protected so well in Bali, several farmers explained that mountains are for the gods, they are the highest point on the island, and all gifts to humankind originate there. Although this is a theistic interpretation of reality, it is not incongruent with the truth of the situation. In Japan as well, mountains have been the subject and site of worship for centuries and even have roots in Buddhism as Mount Meru is the symbol for the center of the world in Buddhist cosmology (Hori, 1966).

Lansing (2006) explained this phenomenon's existence in Bali by means of the philosopher Hegel who employed the term "Objectified Reason" which refers to the process of strongly shared ideas physically manifesting into reality. Lansing argued that Balinese belief in the duality of order and chaos is what shaped the subak's land use system. Nature in its pure form is chaos, but order was brought to it in the form of the subak irrigation system. Order is then the responsibility of the farmers who must find balance by reacting to changes in nature; or chaos. This chaos can be brought by drought, pests, volcanic eruptions, etc. and in practice this is exactly what the subak does. It is a dynamic, reactionary entity which primarily achieves water balance by what this study will call 'human' solutions. This term refers to irrigation management activities that are performed after landscape and infrastructure are already set. This means that a lack of water is not rectified by building a canal and transporting more water from another area, but by adjusting water use schedules and crop choices to accommodate trends in the local environment. In layman's terms, it is "working with what you got".

Tsunai, on the other hand, despite possessing a religion that uses mountain symbolism and being located in a country with a long history of mountain worship, does not exhibit the same practices as the subak. One could argue that the tameike system is order brought to an otherwise chaotic landscape, but managerial behaviors that are reactionary to changes in the environment or climate are minimal, and so is religion's role in management. There is a shrine in the community specifically for the mountain, but this reverence does not result in human solutions to the extent that it does in Bali. Any changes in water scheduling in response to anomalous environmental conditions would be facilitated by the ikemori, but it would not go as far as all farmers changing crop types on a large scale. Some farmers do have small, personal gardens where they grow vegetables and fruits, but water from the tameike is not used for these. Therefore, there is rigidity in how the tameike system operates in contrast to Ababi. Tsunai mainly employs what this study will calls ‘structural’ solutions. This refers to irrigation methods derived from augmenting nature and creating a more rigid structure to effectively manage and conserve water rather than reacting to what nature delivers the system in a given year.

Buddhism in Tsunai appears to be better conceptualized in a Durkheimian sense rather than a Hegelian one as Lansing used to conceptualize Balinese Hinduism. Emile Durkheim posited that religion has a predominantly social role as it creates a sense of togetherness and identity. He specifically stated that religion is society’s way of “reaffirming the collective sentiments and the collective ideas which make its unity and its personality” (Durkheim, 1954). In the same way, religion has been a way for citizens of Tsunai to maintain unity and positive social capital, but there is no evidence of it determining behaviors in agriculture or irrigation as in Bali.

Thus, the conclusion of this section is that religion is the primary source of social capital in Ababi, but its role goes further than Tsunai in the sense that it is an integral part of the irrigation system’s structure itself as Balinese society has developed over time to reflect Hindu ideas into physical space. The result of this has been the subak walking a tightrope between order and chaos to adjust to environmental threats by means of human solutions. Tsunai’s water management system only benefits from religion in terms of cultivating social capital, while the irrigation structure, despite mirroring Tri Hita Mandala’s three levels of land use, is likely only due to its practical benefits. Most irrigation management therefore takes the form of structural solutions where farmers primarily rely on the infrastructure which is optimized for a single, rigid process.

6.2 Social Capital's Role in Human and Structural Solutions

Human solutions are found in both systems, but are much more prevalent in Ababi. This includes water management methods previously discussed such as staggered watering schedules, crop rotations, or rat killings, but there are also other activities like coordinated measures to thwart bird pests. Farmers tie strings with plastic bags or metal cans across the top of their rice paddies, and when a flock of birds comes to eat the rice a few weeks before harvest, the farmers shake the strings to scare the birds away. This is not an incredibly complex process at first glance, but if you watch it happen in real time, in soon becomes clear how important it is that everyone participates. This is because if one farmer scares birds away to save his crops, the birds will simply go to the paddy adjacent to it and eat that person's crops. This farmer must also scare the birds away (and the farmer after that) to continue the juggling act. If even one farmer refused to participate in this process, that farmer's harvest would be devastated and so would his water efficiency. Water scheduling and crop choices are to the same effect. For this reason, coordinated action for human solutions in Bali is absolutely vital to every farmer's survival, making bonding social capital extremely important.

In Tsunai, human solutions are mostly limited to how much water farmers decide to take at a given time, and in what order the ikemori decide to distribute it. Two farmers (farmers 3 and 10) transplant their rice seedlings to their paddy in April rather than June, so there is definite evidence that staggered water usage occurs, but whether this is the choice of the farmers themselves or the ikemori is unclear. At any rate, it is done far less than in Ababi, proportionally speaking, as 80% of Tsunai farmers still take the bulk of their water in June. The ikemori who were interviewed did say that staggered water schedules were used more in Tsunai's past, but as of now, human solutions are not so pronounced, and other examples like fertilizer and pesticide use are done individually, requiring less mutual trust and coordinated action. Crop choices are heavily dictated by linking social capital as hinohikari rice is the regional standard in Kyushu, and it is the variety that is accepted by JA. The only other crop grown widely in Tsunai that is less-water intensive than rice is shiitake mushrooms which are grown by other farmers in the forest and are not connected to the tameike system, leaving rice fields to serve only a singular purpose. This singular purpose is, however, highly optimized for water efficiency and high yields.

Structural solutions in Ababi would include the canals built to deliver mountain stream water to the paddies as well as the weirs installed to adjust water levels. Additionally, the rice terraces created to increase surface area on uneven ground are included in this. Bonding social capital's role in structural solutions would be important for the planning and building stages of these infrastructures, but for operations and maintenance, bonding social capital's benefits are less clear. Farmers reported finding and mending many leaks in the irrigation structures, but most of the time these leaks were located in smaller canals or in the paddies themselves where an individual could remedy the problem alone. Any larger repairs would be helped via funding from the subak leader or government, which would be bridging or linking social capital.

Structural solutions in Tsunai take the form of the tameike and canals which connect to the rice paddies. Bonding social capital's role in maintaining this system is similar to Ababi in that leaks are found by farmers, but any significant repairs would have to be done by a source that would be considered bridging or linking social capital. In Tsunai's case, however, because the canals are completely concreted, a higher degree of expertise would be needed to fix leaks and therefore a higher reliance on bridging and linking social capital exists in structural solutions' case as well.

In summary, Ababi primarily adopts human solutions to dynamically react to changes in the environment. This takes the form of staggered water schedules, supplementary crop choices, and collaborative pest control measures. These human solutions rely primarily on bonding social capital as it is needed to ensure participation and compliance amongst members. Structural solutions serve a passive role in Ababi's water management, but are also very important. This is especially true for the landscape usage dictated by Tri Hita Karana and Tri Mandala. The irrigation infrastructure, however, is not especially optimized to retain water as there is no point at which water is saved up and the canals are only partially concreted. Serious repairs and repair funding for this infrastructure comes from subak leaders and/or the government which would be bridging and linking social capital, but the vast majority of repairs are done on a small-scale, individual basis. The main form of social capital supporting water management in Ababi is bonding social capital which derives from Hindu practices and beliefs. These beliefs not only connect people by giving them common values, but shape the very philosophy behind their operations.

Tsunai primarily relies on structural solutions which optimize water efficiency and rice yields, providing economic benefits. Because the infrastructure is optimized to serve a singular purpose, there is a higher reliance on the bridging and linking social capital of outside sources; primarily in crop choice since almost all the rice that is produced is sold to JA. This also means that supplementary crops that would be less water-intensive are seldom used. Like Ababi, the land use is also separated into mountain, village, and paddy which preserves forests, maintains water quality, and lowers the risk of damage from natural disasters. Human solutions like pest control are done on an individual basis and require less bonding social capital to succeed. Almost all human water management is in the hands of the ikemori. It can therefore be concluded that the main form of social capital governing water management in Tsunai is linking social capital which derives from government/organizational incentives and support; however, the main key to success for Tsunai is the tameike system and the ikemori who are obligated to collaborate and ensure water is properly distributed rather than social capital.

6.3 Environmental Sustainability of Water Management Methods

The previous section summarized the water management methods adopted by both systems and how they tie to certain types of social capital. Now the varying effects these managerial orientations have on the environment will be explored. In section 5.2, Tsunai was characterized as having a high water demand, a low water footprint, acceptable water quality, and high managerial effectiveness owing to a system than saves up water and allows for water to be circulated in a controlled manner. Ababi was characterized as having a low water demand, a high water footprint, acceptable water quality, and high managerial effectiveness owing to social networks and collaboration. This means that when an irrigation system relies heavily on before-pipe solutions and optimizes water retention and yield density, one can likely expect for the environmental outcome to be a higher water demand from the surrounding ecosystem, but a lower water footprint per ton of rice yield. In other words, Tsunai's system is one of high intensity, having high inputs and high outputs. On the other hand, irrigation systems that rely on human solutions might expect to have a lower overall water demand, but also lower yields which increase the water footprint. Systems like this are low intensity and are arguably less taxing on the ecosystem.

In addition to Tsunai's system being more taxing on the natural water supply, its transport canals have been completely sealed off from the environment which negatively impacts wildlife by inhibiting sedentary animals like mussels from benefitting from water percolation (Shimizu et al. 2017). Growing a monoculture of rice also does not serve to encourage biodiversity and allows pest populations to multiply (Cheng et al. 2016). In turn, this has the possibility of increasing the necessity for pesticides which may lead to water quality issues in the future as infrastructure degrades; although, the rice paddies are typically equipped with borders that prevent chemical leaching. If Tsunai were able to adopt some of the human solutions employed by Ababi, perhaps economic stability could be maintained while also providing additional services to the environment like biodiversity protection, a more diffuse water demand, and less dependency on fertilizers and pesticides. Shiitake mushrooms are already one crop that is commonly grown in the Kunisaki Peninsula, but they do not make use of the paddy land as they are grown in forested areas. Leafy vegetables that have quick turnover as well as other popular crops like tomatoes, carrots, etc. could be some alternatives to the high intensity rice production of the status quo. Furthermore, since these crops' growth periods are not completely dependent on the wet season, the times at which water is taken from the tameike will be naturally staggered. Such shifts in the paradigm would relieve water stress on the region, hinder the increase of pest populations, provide more stable income as farmers could work year-round, and also maintain the quality of the soil given that some of the supplementary crops are nitrogen-fixing, like soybeans. Looking into the future, crop diversity will also allow farmers to adapt better to climate change (Klocker et al. 2018).

Oppositely, Bali is facing population increases both from citizens and tourists and needs to improve its overall yields which would also improve its water footprint. Not only that, but a higher yield can protect the soil from accumulating too much nitrogen from fertilizers (FAO 2018). Additionally, access to education and other public services needs to be heightened to ensure farmers' well-being and ability to participate in subak water management. Yield could be addressed by regionally developed rice varieties similar to how Japan's hinohikari was developed. At present, Ababi farmers are using native Balinese rice which has a low water demand but also low yields, and a C4 GMO rice plant that was developed for Java. Although the C4 variety is supposed to have improved photosynthetic properties, several farmers reported having problems growing it in Bali. One farmer even found that his C4 plants were infertile and many of the rice husks were empty. A rice variety that is optimized to grow in Bali's environmental conditions would likely better contribute to higher yields instead of a copy-and-paste approach like the C4 rice. Access to capital would likely be how farmers can improve their economic situation since subsistence farming will likely grow more and more unfeasible going into the future. This would allow farmers to receive better educations and gain access to technology that can improve their operations. Figure 1 below summarizes the relationship of different forms of social capital, their favored irrigation management method, and their general outcomes.

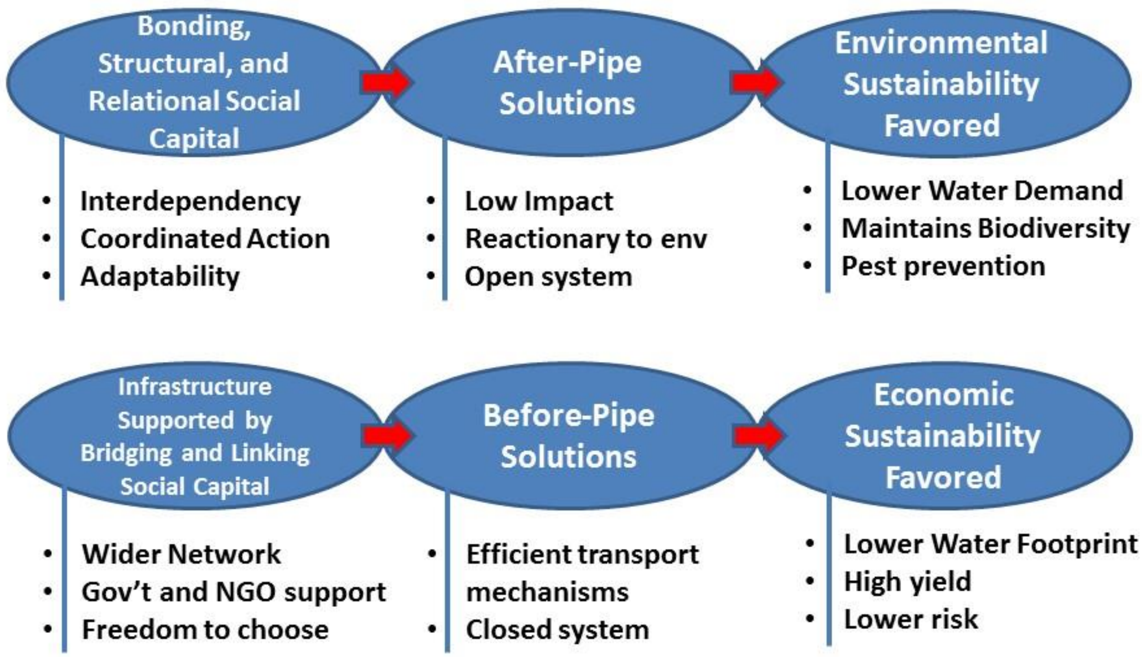


Figure 6.1: From left to right, certain forms of social capital tend to cultivate corresponding managerial solutions which result in different sustainable outcomes

6.4 Obstacles to Improved Sustainability

The biggest obstacles holding Tsunai back from diversifying their crops and embracing human solutions are a lack of human capital and a lack of proper support from the government. As all of the farmers living in Tsunai are quite old, their farming operations must be mechanized to be manageable alone. Rice can be easily done with the available machinery, and changing to other crop types on a large scale would require investment in new equipment as well as education on growing methods. Furthermore, since there are no subsidies to support this transition, farmers would need to do marketing themselves and such know-how is scarce amongst these communities. In other words, there is a severe lack of bridging and linking social capital that could assist this transition. Once again, it appears that even to improve irrigation water usage in satoyama landscapes, the younger generation's absence is a crushing blow to sustainability. Klocker et al. (2018) even pointed out that "established farmers have strong 'cultural links' to their existing enterprise – and to particular crops – and these attachments can block change". One hope that was discovered in this research was women engaged in farming. Both the wife of one of the Tsunai farmers and the woman briefly mentioned from Akimachi Meiji in Kunisaki are embracing crop diversity and even organic methods.

One more consideration is the policies of the local government in Kunisaki. They mentioned in the interviews that tameike water is exclusively used for rice and other crops are fed by different sources. If there were a way to change it so that any farmer could transport water to their fields, it could help. The reason the current rule is in place is because tameike would be emptied completely if they supplied every vegetable field on top of the rice paddies, but if rice were slowly decreased, it could free up some of the tameike water for alternative use.

The biggest obstacles for Ababi's water management are a lack of capital/funding and a lack of meaningful advancement in crops sciences. With better harvesting equipment and rice plants optimized for max yields, the subak could begin to lessen their water footprint. Their current water demands are actually quite low and the impact from farming activities is quite low, but if current population trends continue, the subak will need to adapt and create a higher carrying capacity. At present, the central government is only giving aid through fertilizer subsidies and educational seminars, but in order to give Ababi some structural solutions, capital will need to be procured and used effectively. In order for the subak to not begin to resemble

Tsunai 20 years from now, some method of retaining the younger generation is also needed. Luckily, Bali is already in an advantageous position because of its booming tourism industry. With the help of proper land management policies, the tourism industry could be corralled into favoring agrotourism rather than luxury hotels that would cause further water stress on the region.

Chapter 7: Conclusion

In this research, two purportedly sustainable agricultural communities were analyzed in an attempt to discover how social capital does or does not contribute to 'sustainable' irrigation management which was defined as 1) having a low negative impact on the environment, 2) using water efficiently, 3) maintaining water and soil quality, and 4) properly managing the water so that it is equitable and economically sound to all users. Kunisaki in Oita, Japan and Karangasem in Bali, Indonesia were chosen because they are both recognized by the GIAHS program of the FAO and/or significant academic research to be successful examples of sustainable irrigation management that have been developed by centuries of human collaboration and innovation. Furthermore, to add a temporal dimension to the study, it was necessary to have an example of a system from a developing country and a developed country so as to predict how the sustainability profile of irrigation can evolve over time. This is an important factor because of the current global trend of traditional agricultural practices being abandoned as younger generations seek employment in city centers. Kunisaki was an example of this trend in an extreme case, hosting a very small labor force density. Karangasem still appears to have a rather large labor force, but every year the subak is losing a little of the younger generation to the tourism industry. Predicting the non-intervention scenario of Karagasem's agricultural operations and its sustainability profile can be aided by analyzing Kunisaki's history, and the present needs of Kunisaki can be better assessed from the example of Karangasem.

Social capital was measured by the Network Approach and the Social Structure Approach which consist of six dimensions: bonding social capital, bridging social capital, linking social capital, structural social capital, cognitive social capital, and relational social capital. Farmers in Karangasem were found to have more social capital overall, but especially more bonding and relational social capital facilitated by Hinduism and the subak's need for collaborative, synchronized action. Such actions were dubbed as ‘human’ solutions, meaning that they were reactionary managerial practices that occurred after infrastructural considerations. The result of this social configuration was a lower impact on the environment, but lower efficiency and economic success, as yields were quite low and were mainly for subsistence purposes. However, this study did not gather much information on crops other than rice which were reportedly more profitable, so perhaps economic conditions are better for some farmers than this research suggests.

Social capital in Kunisaki was lower than in Karangasem, but not nonexistent. There was especially bridging and linking social capital thanks to government subsidies, agricultural cooperatives, and the GIAHS program’s domestic support system. Most of the managerial success in Kunisaki, however, seems to be owed to the tameike infrastructure and the groups of ikemori which allow for water to be transported efficiently. Locally optimized hinohikari rice varieties also optimized yields, making the water efficiency quite high, but the water demand from the environment is high as well. These were dubbed ‘structural’ solutions. These have an impact on the environment that is higher than in Karangasem’s case, but also produce more rice making it more economically sustainable. However, as Japan’s population continues to decrease and rice often floods the market, a new paradigm seems ideal to ensure future income and to decrease the water stress on the environment.

After carefully reviewing the results, this study would like to suggest a positive correlation between the openness and scale of irrigation operations and the amount of social capital needed for the success of said irrigation operations. Indeed, it cannot be overstated how dependent the varying, wide, and complex subak is on its members to cooperate and share information. Without the participation of all members, large portions of the landscape would experience failure. This cooperation is contingent upon strong bonds and effective knowledge transfers made possible through social capital. Oppositely, the streamlined, closed, and efficient tameike system of Kunisaki requires a smaller team of managers who are given monetary incentives to manage effectively. Social capital is still important in this case, but its absence would likely not cause the collapse of the system. Furthermore, the more open and dynamic a system is, the lower the impact it is likely to have on the environment as farmers are able to employ more human solutions which are reactionary to the ecosystem, rather than being something that alters the ecosystem permanently like structural solutions. The tameike are such a solution, as they were intended to augment the landscape of a region that did not naturally have an adequate water supply; although, they are somewhat benign and arguably beneficial to biodiversity. As for Karangasem, they also employed structural solutions in building irrigation canals, but the change in natural water flows was not altered as drastically as in Kunisaki's case.

As farming operations become increasingly independent, are optimized for a single purpose, and less social capital is needed, the economic benefits increase for farmers while environmental benefits decrease. Therefore, a method for reducing the environmental impact while maintaining high efficiency is needed in this case. The introduction of more diverse crop types and reductions in fertilizer applications would reduce Kunisaki's total water demand and negative impact on the soil. However, this only seems possible with the introduction of younger labor forces who can facilitate such changes, as this paradigm shift would require new farming methods and marketing strategies. There were a few examples of younger female farmers who were contributing in some way to this goal.

For the subak to be sustained going into the future, it is likely that access to capital and proper, government-led land-use regulation between the agriculture and tourism sectors are necessary. The private sector should also find ways to promote agro-tourism which would hopefully provide additional income to struggling farmers. The nature of the subak calls for sufficient labor forces as it almost completely relies on collaborative action for success. With complex issues like pest control and water scheduling which require dynamic solutions to environmental changes, the continued loss of labor forces would cause significant harm to the subak and the environment. This research only covered two case studies to back up its claims and therefore requires further research on additional agricultural communities on volcanic island landscapes inside and outside of the GIAHS system to be more certain of the proposed dynamic between social capital and sustainable water management, as well as suggest more ways to improve systems both developed and developing.

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9. Appendices

9.1. English Version of Questionnaire____

Survey for Environmental, Social, and Economic Analysis of Tirta Gangga Subak

This survey was made to gather data to be used in the researcher's graduation thesis and will take approximately **12 minutes** to complete. The purpose of this study is to analyze the relationship between social capital (people and their role in social groups, networks, bonds of trust and reciprocity, etc.) and the degree to which irrigation water is sustainably managed. The answers you give to this survey are strictly confidential and your identity will absolutely not be revealed under any circumstances. Still, if at any point you feel uncomfortable answering a question, you may leave it blank. However, please try to fill each answer out to the best of your ability, so the data can be effectively used. The results of this study can hopefully be used to help farming communities in mountainous landscapes all over the world and also provide useful information to support the future GIAHS of Karangasem. Thank you for your cooperation.

General Information

1. Age: _________

2. Sex: Male / Female

3. Household size: _________

4. Religious affiliation:
   a. No affiliation b. Hinduism c. Buddhism d. Islam e. Christianity
   f. Personal Religion/Spiritual g. Other _______________

Water Footprint Calculation

This section is to help the researcher measure how much total water is used to make a certain amount of rice for Karangasem farmers. If you do not know the answer to one of the questions, please leave it blank. The measurements do not have to be 100% precise.

1. Please try to estimate how much water in total you think you use during an average growing season (example: 20,000 liters, 20 cubic meters)
   ____

2. What is the total area of your rice fields? How much do you use during an average growing season and how much do you leave for fallow?
   TOTAL: _________ ha

Use: _________ ha
Fallow: _________ ha

3. At what depth do you initially fill your rice fields with water?
_________ mm / cm (circle one)

4. How low do you allow the water level to decrease before you add more water?
__________ mm / cm (circle one)

5. How often does this refilling happen in an average growing season?
About ___________ times per growing season

6. How many days before sowing rice do you saturate your fields?
Around__________ days

7. On average, in what month or months do you usually sow your rice?
____

8. How many days does it usually take for your rice to mature? (If you grow more than one type of rice, please write the maturing time for all)
Type 1: Around __________ days
Type 2: Around __________ days

9. How many days do you let your paddy dry out before harvesting?
Around__________ days

10. Do you use any fertilizers? How much of each do you use per 1 hectare?
Brand name: ______________ ______________ ______________
Amount: (N) _________(P) _________(K) ________(Mixed)_________
Brand name: ______________ ______________ ______________
Amount: (N) _________(P) _________(K) ________(Mixed)_________
Brand name: ______________ ______________ ______________
Amount: (N) _________(P) _________(K) ________(Mixed)_________

11. Do you use any pesticides? If so, how much of each do you use per 1 hectare?
Brand Name:(______________) Type:(______________) Amount:(____________)
Brand Name:(______________) Type:(______________) Amount:(____________)
Brand Name:(______________) Type:(______________) Amount:(____________)

12. Do you use any groundwater (water pumped from wells, etc.) on your rice? If so, about how much?
Yes / No ____________

13. Is the soil in your field mostly clay, or it is a type of soil that might leak water easily? Please circle one of the (—) below based on the clay content of your field.
100% clay <———————————> water escapes almost immediately

14. From where do you get your seedlings and what type are they?
____

15. Can you estimate your average yield per 1 hectare?
_________ kg/ha

Social Capital Analysis

1. How long have you lived in the Tirta Gangga area?
_________ years

2. How long has your family lived in the Tirta Gangga area? (If you do not know how many years, please estimate how many generations. Example: <4 generations)
_________ years / generations (circle one)

3. i) Do you have children? ii) Do they or did they attend school in the vicinity of the Tirta Gangga area? iii) Do they often help with farming activities?
i) Yes / No
4. ii) Yes / No
5. iii) Yes / No

6. i) Do you have a spouse? ii) Are they employed? iii) Do they often participate in the farming activities?
i) Yes / No ii) Yes / No iii) Yes / No

7. Have you even been a subak leader? For how many years did you serve? Were they consecutive years or sporadic?
Yes / No __________ years Consecutive / Sporadic

8. If not, would you like to be a subak leader? Why or why not?
Yes / No
____
____

9. There are farmers in the **Tirta Gangga area** with whom I am close.
a. Strongly Disagree b. Disagree c. Neutral d. Agree e. Strongly Agree

10. On average, I contact at least one of these farmers ________________.
a. Less than once a month b. Once a month c. Twice a month d. Once a week
e. 2-3 times per week f. Everyday

11. I usually talk to them about _____________. (Circle all that apply)
a. Farming or farming strategies b. Everyday things c. Group or cultural activities
d. other _______________

12. There are farmers **outside the Tirta Gangga area** with whom I am close.
a. Strongly Disagree b. Disagree c. Neutral d. Agree e. Strongly Agree

13. On average, I contact at least one of these farmers ________________.
a. Less than once a month b. Once a month c. Twice a month d. Once a week
e. 2-3 times per week f. Everyday

14. I usually talk to them about _____________. (Circle all that apply)
a. Farming or farming strategies b. Everyday things c. Group or cultural activities
d. other ______________

15. I often agree with other farmers in my subak concerning farming methods and schedules.
a. Strongly Disagree b. Disagree c. Neutral d. Agree e. Strongly Agree

16. I often agree with other farmers in my subak concerning everyday affairs outside of farming.
a. Strongly Disagree b. Disagree c. Neutral d. Agree e. Strongly Agree

17. Agriculture done by subaks around Tirta Gangga is exceptional among other subaks.
a. Strongly Disagree b. Disagree c. Neutral d. Agree e. Strongly Agree

18. The subak are necessary for successful water management in Karangasem.
a. Strongly Disagree b. Disagree c. Neutral d. Agree e. Strongly Agree

19. The way in which water is disseminated is fair to all farmers in the Tirta Gangga area.
a. Strongly Disagree b. Disagree c. Neutral d. Agree e. Strongly Agree

20. The price of water is also fair.
a. Strongly Disagree b. Disagree c. Neutral d. Agree e. Strongly Agree

21. Theft of irrigation water sometimes occurs in the Tirta Gangga area.
a. Strongly Disagree b. Disagree c. Neutral d. Agree e. Strongly Agree

22. I feel that I am included in important decision-making on water management.
a. Strongly Disagree b. Disagree c. Neutral d. Agree e. Strongly Agree

23. I feel that the inclusion of all farmers in decision-making in an area is necessary.
a. Strongly Disagree b. Disagree c. Neutral d. Agree e. Strongly Agree

24. I feel that I have freedom to farm in the manner in which I please.
a. Strongly Disagree b. Disagree c. Neutral d. Agree e. Strongly Agree

25. The authority of the subak is respected.
a. Strongly Disagree b. Disagree c. Neutral d. Agree e. Strongly Agree

26. I frequently attend cultural/religious events in the Tirta Gangga area.
a. Strongly Disagree b. Disagree c. Neutral d. Agree e. Strongly Agree

27. I frequently attend cultural/religious events in other parts of Bali.
a. Strongly Disagree b. Disagree c. Neutral d. Agree e. Strongly Agree

28. Temples, shrines, and other religious sites in Karangasem are important to me.
a. Strongly Disagree b. Disagree c. Neutral d. Agree e. Strongly Agree

29. My spouse is equally active in the community's cultural affairs and events.
a. Strongly Disagree b. Disagree c. Neutral d. Agree e. Strongly Agree

30. In regards to farming and my general affairs, ________________________________.
a. I usually ask others for advice or help b. I usually give advice or help to others
c. I usually give **and** receive advice or help d. I work best alone

31. There is a new organic production method being used and promoted in the subak next to yours. It seems that the farmer using this new method experienced a cut in production costs and a rise in revenue. The farmer is giving a workshop on this new method in your area and offers to train everyone for free. What do you think best reflects your attitude in this situation?
a. I will definitely try it
b. I will try it, but only if a few other farmers in my subak try it too
c. I will try it, but only if all the farmers in my subak try it too
d. I won't try it, even if other farmers in my subak try it

32. Have you ever discovered an irrigation canal that was leaking water? How many times? Did you inform someone of this discovery?
Yes / No __________ times Yes / No

33. Please list all of the local organizations and events that you or your family actively participates in other than the subak. Then, indicate which member or members of your family participate, and whether it is an organization or event exclusive to the Tirta Gangga area or one that extends outside of your area.

Example:

Tourism Promotion Council Self Outside

Organization/Event	**Family Member**	**Tirta Gangga area/Outside**

Economic Analysis

1. Based on past experience, please rank the following items from 1 (least threatening) to 6 (most threatening) in regards to the optimal success of your farming operations.

___ Tropical Storms
___ Water Scarcity
___ Rice Pests
___ Lack of manpower (participation of younger generation)
___ Foreign Rice Imports
___ Lack of access to equipment, machines, or compounds

2. Do you have insurance on your crops or equipment?
a. Yes, for crops b. Yes, for equipment c. Yes, for both d. No, neither

3. Do industries other than agriculture (such as bottled water companies) use the same water source as your subak?
Yes / No

4. On average, I usually pay a total of IDR______________ for water during a growing season.

5. Do you receive any subsidies from the government for farming rice?
Yes / No

6. If so, what must you do to continue receiving the subsidy?

____
____

7. Other than farming, do you have any other jobs or sources of income? What kind of job?
Yes / No ____

8. In your opinion, is the amount you make from **farming only** enough to live a secure and comfortable life?
Yes / No / Not Sure

9. Please write one good side and one bad side about doing agriculture in the Tirta Gangga area.

____
____
____
____
____

9.2 Bahasa Indonesian Version of Questionnaire____

Survei untuk Analisis Lingkungan Hidup, Social dan Ekonomi di Subak Tirta Gangga.

Kami memohon bantuan Bapak dan Ibu untuk mengisi sebuah survei penelitian ilmiah. Survei ini disusun untuk mengumpulkan data dalam rangka penelitian ilmiah untuk penyusunan Thesis S-2. Survei ini akan membutuhkan waktu sekitar **15 - 20 menit** untuk diselesaikan. Tujuan dari penelitian ini adalah untuk menganalisa hubungan antara kapital / modal sosial (manusia dan peran mereka dalam kelompok sosial, jaringan, jalinan kepercayaan dan transaksi sosial di masyarakat) dan tingkat kebersinambungan (*sustainability*) dari pengelolaan air irigasi. Jawaban yang akan Bapak dan Ibu berikan dalam survei ini beserta informasi terkait identitas Bapak dan Ibu akan kami jaga kerahasiaannya. Apabila terdapat pertanyaan yang Bapak dan Ibu rasa tidak nyaman untuk dijawab, silahkan membiarkan kosong dan tidak diisi. Kami memohon agar Bapak dan Ibu dapat memberikan jawaban dari pertanyaan dari survei ini dengan jujur apa adanya agar survei ini dapat kami gunakan dengan baik. Hasil dari penelitian ini diharapkan dapat digunakan oleh komunitas pertanian di daerah pegunungan dan perbukitan diseluruh dunia serta juga untuk mendukung perkembangan GIAHS Karangasem. Kami mengucapkan terima kasih yang sedalam-dalamnya untuk bantuan Bapak dan Ibu.

Informasi Umum

5. Usia: __________

6. Jenis Kelamin: Laki-laki / Perempuan

7. Jumlah anggota keluarga inti: __________

8. Agama:
a. Hindu b. Budha c. Islam d. Kristen e. Katolik
e. Kepercayaan terhadap Tuhan Yang Maha Esa
g. Lainnya ________________

Perhitungan Penggunaan Air

Bagian ini akan digunakan untuk mengukur berapa banya air yang digunakan oleh petani di Karangasem untuk menghasilkan beras. Apabila Bapak dan Ibu tidak dapat menjawab pertanyaan yang ada silahkan untuk membiarkan kosong tidak terisi. Ukuran yang diberikan tidak harus 100 % tepat.

16. Berdasarkan perkiraan Bapak dan Ibu, berapa banyak air yang Bapak dan Ibu gunakan di sawah yang Bapak dan Ibu tanami padi setiap musim tanam contoh (20,000 liter, 20 meter kubik).

____

17. Berapakah luas total dari area sawah yang Bapak dan Ibu miliki? Dari area sawah tersebut, berapakah luas dari sawah yang Bapak dan Ibu tanami padi? Berapa luas yang Bapak dan Ibu tidak tanami?
Total: _________ m^3 / ha (lingkari salah satu)
Ditanami: _________ m^3 / ha
Tidak ditanami: _________ m^3 / ha

18. Seberapa dalam air yang Bapak dan Ibu gunakan untuk mengairi sawah pada saat awal menanam padi?
_________ mm / cm (lingkari salah satu)

19. Seberapa dalam air pada sawah, Bapak dan Ibu biarkan untuk berkurang (tersisa) sebelum Bapak dan Ibu menambah air?
__________ mm / cm (lingkari salah satu)

20. Rata-rata berapa kali Bapak dan Ibu menambah air untuk sawah dalam satu musim tanam?
Sekitar ___________ kali setiap musim tanam.

21. Setelah mengairi sawah untuk pertama kalinya, berapa hari Bapak dan Ibu membiarkan air di sawah tersebut berkurang sebelum mulai menanam padi?
Sekitar__________ hari

22. Biasanya pada bulan apa saja Bapak dan Ibu mulai menanam padi?
____

23. Berapa hari yang diperlukan sampai padi yang ditanam siap untuk dipanen? (Apabila Bapak dan Ibu menanam lebih dari satu macam padi, mohon isi masa tanam untuk setiap macam padi tersebut)
Tipe 1: Sekitar __________ hari
Tipe 2: Sekitar __________ hari

24. Berapa hari Bapak dan Ibu membiarkan sawah mengering sebelum padi dipanen?
Sekitar__________ hari

25. Apakah Bapak dan Ibu menggunakan pupuk? Jika ya, berapa banyak pupuk yang digunakan untuk setiap 1 hektar sawah?
Merek Pupuk: ______________ ______________ ______________
Jumlah: (N) _________(P) _________(K) ________(Campur)_________
Merek Pupuk: ______________ ______________ ______________
Jumlah: (N) _________(P) _________(K) ________(Campur)_________

Merek Pupuk: _______________ _______________ _______________
Jumlah: (N) _________(P) _________(K) ________(Campur)_________

26. Apakah Bapak dan Ibu menggunakan pestisida? Jika ya, berapa banyak pestisida yang digunakan untuk setiap hektar sawah?
Merek:(_______________) Tipe:(_______________) Jumlah:(_____________)
Merek:(_______________) Tipe:(_______________) Jumlah:(_____________)
Merek:(_______________) Tipe:(_______________) Jumlah:(_____________)

27. Apakah Bapak dan Ibu menggunakan air tanah (air yang dipompa dari bawah tanah atau sumur air) untuk sawah yang Bapak dan Ibu tanami? Jika ya, berapa banyak? Ya / Tidak _____________ Jumlah air tanah _____________

28. Apakah jenis tanah di sawah yang Bapak dan Ibu tanami dapat menahan air (seperti tanah liat atau lempung) atau tanah yang tidak dapat menahan air sehingga air di sawah cepat berkurang? Mohon lingkari salah satu dari tanda (—) dibawah berdasarkan tingkat tanah liat di sawah.

100% tanah liat, air tidak mudah surut	<— — — — — — — — — — — —>	air langsung berkurang

29. Dari mana Bapak dan Ibu mendapatkan bibit untuk menanam padi? Tipe bibit apa yang Bapak dan Ibu gunakan?
____

30. Berapa banyak hasil dari setiap hektar sawah yang Bapak dan Ibu tanami?
_________ kg/ha

Analisa Modal / Kapital Sosial

34. Sudah berapa tahun Bapak dan Ibu tinggal di area Tirta Gangga?
_________ tahun

35. Sudah berapa tahun / generasi keluarga Bapak dan Ibu tinggal di area Tirta Gangga?
_________ tahun / generasi (lingkari salah satu)

36. i) Apakah Bapak dan Ibu memiliki anak?
Ya / Tidak

ii) Apakah sekolah mereka ada di area Tirta Gangga?
Ya / Tidak

iii) Apakah mereka ikut membantu dalam bertani?

Ya / Tidak

37. i) Apakah Bapak dan Ibu memiliki Istri atau Suami?
Ya / Tidak

ii) Apakah mereka bekerja?
Ya / Tidak

iii) Apakah mereka ikut membantu dalam bertani?
Ya / Tidak

38. Apakah Bapak dan Ibu pernah menjadi Ketua Subak?
Ya / Tidak

Apabila ya, Berapa lama Bapak dan Ibu menjadi Ketua Subak dan apakah masa jabatan Bapak dan Ibu berurutan atau?
__________ tahun
Berurutan selama __________ tahun
/ Tidak berurutan.

39. Apabila tidak, apakah Bapak dan Ibu ingin menjadi Ketua Subak? Kenapa?
Ya / Tidak
____
____

40. Saya memiliki hubungan sangat baik dengan rekan sesama petani di area Tirta Gangga.
b. Sangat tidak setuju b. Tidak Setuju c. Netral d. Setuju e. Sangat Setuju

41. Rata-rata, saya berbincang-bincang dengan rekan sesama petani di area Tirta Gangga yang memiliki hubungan sangat baik dengan saya________________.
a. Kurang dari satu kali dalam sebulan
b. Satu kali dalam sebulan
c. Dua kali dalam sebulan
d. Setiap minggu
e. 2-3 kali seminggu
f. setiap hari

42. Saya biasanya berbincang-bincang dengan rekan sesama petani tersebut mengenai _____________. (Lingkari semua yang berlaku)
a. Pertanian dan strategi pertanian
b. Hal sehari-hari
c. Aktivitas kelompok dan budaya
d. Hal lainnya _______________

43. Saya memiliki hubungan sangat baik dengan rekan sesama petani **di luar area Tirta Gangga**.

a. Sangat tidak setuju b. Tidak Setuju c. Netral d. Setuju e. Sangat Setuju

44. Rata-rata, saya berbincang-bincang dengan rekan sesama petani **di luar area Tirta Gangga** yang memiliki hubungan sangat baik dengan saya________________.

a. Kurang dari satu kali dalam sebulan
b. Satu kali dalam sebulan
c. Dua kali dalam sebulan
d. Setiap minggu
e. 2-3 kali seminggu
f. setiap hari

45. Saya biasanya berbincang-bincang dengan rekan sesama petani tersebut mengenai _____________. (Lingkari semua yang berlaku)

a. Pertanian dan strategi pertanian
b. Hal sehari-hari
c. Aktivitas kelompok dan budaya
d. Hal lainnya _______________

46. Saya sering kali sependapat dengan petani lainnya dalam kelompok Subak saya terkait metode dan jadwal pertanian.

a. Sangat tidak setuju b. Tidak Setuju c. Netral d. Setuju e. Sangat Setuju

47. Saya sering kali sependapat dengan petani lainnya dalam kelompok Subak saya terkait hal lainnya selain masalah pertanian.

a. Sangat tidak setuju b. Tidak Setuju c. Netral d. Setuju e. Sangat Setuju

48. Pertanian yang dilakukan di sekitar area Tirta Gangga berbeda / unik dibandingkan dengan Subak lainnya.

a. Sangat tidak setuju b. Tidak Setuju c. Netral d. Setuju e. Sangat Setuju

49. Subak sangat penting bagi keberhasilan pengelolaan air di Karangasem.

a. Sangat tidak setuju b. Tidak Setuju c. Netral d. Setuju e. Sangat Setuju

50. Metode pembagian air kepada petani di area Tirta Gangga sudah dilakukan dengan adil.

a. Sangat tidak setuju b. Tidak Setuju c. Netral d. Setuju e. Sangat Setuju

51. Harga air sudah adil dan sesuai.

a. Sangat tidak setuju b. Tidak Setuju c. Netral d. Setuju e. Sangat Setuju

52. Pencurian air irigasi terkadang terjadi di area Tirta Gangga.

a. Sangat tidak setuju b. Tidak Setuju c. Netral d. Setuju e. Sangat Setuju

53. Saya merasa bahwa saya dilibatkan dalam proses pengambilan keputusan yang penting

dalam pengelolaan air.
a. Sangat tidak setuju b. Tidak Setuju c. Netral d. Setuju e. Sangat Setuju

54. Saya merasa bahwa melibatkan petani dalam proses pengambilan keputusan di sebuah area adalah penting.
a. Sangat tidak setuju b. Tidak Setuju c. Netral d. Setuju e. Sangat Setuju

55. Saya merasa bahwa saya memiliki kebebasan untuk bertani dengan cara-cara yang saya sukai.
a. Sangat tidak setuju b. Tidak Setuju c. Netral d. Setuju e. Sangat Setuju

56. Pengelola Subak dihargai dan dipandang.
a. Sangat tidak setuju b. Tidak Setuju c. Netral d. Setuju e. Sangat Setuju

57. Saya sering menghadiri acara keagamaan atau budaya di area Tirta Gangga.
a. Sangat tidak setuju b. Tidak Setuju c. Netral d. Setuju e. Sangat Setuju

58. Saya sering menghadiri acara keagamaan atau budaya di daerah lain di Bali.
a. Sangat tidak setuju b. Tidak Setuju c. Netral d. Setuju e. Sangat Setuju

59. Pura dan tempat religious lainnya di Karangasem sangatlah penting bagi saya.
a. Sangat tidak setuju b. Tidak Setuju c. Netral d. Setuju e. Sangat Setuju

60. Suami atau istri saya juga aktif dalam kegiatan dan acara budaya di komunitas saya..
a. Sangat tidak setuju b. Tidak Setuju c. Netral d. Setuju e. Sangat Setuju

61. Terkait dengan masalah pertanian dan masalah umum lainnya, ___________
a. Saya biasanya bertanya untuk mendapatkan bantuan dan saran
b. Saya biasanya memberikan bantuan dan saran
c. Saya biasanya memberikan dan mendapatkan bantuan dan saran
d. Saya lebih baik apabila bekerja sendiri

62. Apabila ada metode pertanian baru secara organik yang diperkenalan dan digunakan oleh kelompok Subak lainnya disekitar kelompok Subak anda, dimana petani yang menggunakan metode baru ini dapat mengurangi biaya pertanian dan memperoleh peningkatan pendapatan, apa yang akan Bapak dan Ibu lakukan apabila terdapat penyuluhan dan pelatihan gratis yang diberikan oleh petani dari kelompok Subak tersebut?
a. Saya pasti akan mencoba metode tersebut
b. Saya akan mencoba metode tersebut apabila beberapa petani di kelompok Subak saya ikut mencoba juga.
c. Saya akan mencoba metode tersebut apabila semua petani di kelompok Subak saya ikut mencoba juga.
d. Saya tidak akan mencoba metode tersebut, meskipun petani lain di kelompok Subak saya ikut mencoba juga.

63. Apakah anda pernah menemukan kebocoran air pada saluran irigasi pada subak anda?
Ya / Tidak

Berapa kali?
__________ kali

Apakah anda memberikan informasi ini kepada orang lain?
Ya / Tidak

64. Mohon tuliskan semua organisasi dan kegiatan lokal yang Bapak dan Ibu serta keluarga ikuti secara aktif **diluar kelompok Subak**. Kemudian mohon tuliskan anggota keluarga Bapak dan Ibu yang aktif berpartisipasi dalam organisasi dan kegiatan lokal tersebut. Pada akhirnya mohon tuliskan apakah organisasi atau kegiatan tersebut hanya terdapat di area Tirta Gangga atau berada di luar area Tirta Ganga.

Contoh:

Kelompok Promosi Kesenian Diri sendiri Diluar

____

Organisasi / Kegiatan	**Anggota Keluarga**	**Area Tirta Gangga / Diluar**
____________________	________________	______________________
____________________	________________	______________________
____________________	________________	______________________
____________________	________________	______________________
____________________	________________	______________________

Analisa Ekonomi

10. Berdasarkan pengalaman Bapak dan Ibu, mohon berikan peringkat dari 1 (Paling sedikit membahayakan) sampai 6 (Paling membahayakan) terkait dengan keberhasilan proses bertani.
___ Badai Tropis
___ Kekurangan air
___ Hama
___ Kurangnya tenaga kerja (partisipasi generasi muda)
___ Import beras dari luar negeri
___ Kurangnya akses ke peralatan, mesin dan bahan pertanian

11. Apakah Bapak dan Ibu memiliki asuransi untuk tanaman, hasil tanam dan peralatan yang Bapak dan Ibu miliki?
a. Ya, untuk tanaman dan hasil tanam
b. Ya, untuk peralatan
c. Ya, untuk semuanya
d. Tidak, untuk semuanya

12. Apakah ada industri lain selain pertanian (seperti air minum atau hotel) yang menggunakan sumber mata air untuk Subak?
Ya / Tidak

13. Rata-rata, berapa banyak biaya yang Bapak dan Ibu keluarkan untuk air pada saat musim tanam Rp_____________.

14. Apakah Bapak dan Ibu mendapatkan subsidi dari pemerintah untuk menanam padi?
Ya / Tidak

15. Jika ya, apa yang harus Bapak dan Ibu lakukan untuk terus mendapat subsidi tersebut?
____
____

16. Selain pertanian, apakah Bapak dan Ibu mempunyai pekerjaan lain atau sumber penghasilan lainnya? Jika ya, Mohon tuliskan pekerjaan atau sumber penghasilan tersebut?
Ya / Tidak ____

17. Menurut pendapat Bapak dan Ibu, apakah penghasilan dari pertanian sudah cukup untuk hidup layak baik masa kini dan masa depan?
Ya / Tidak / Tidak Tahu

18. Mohon tuliskan satu hal baik dan satu hal kurang baik mengenai pertanian di area Tirta Gangga.
____
____
____
____
____

綱井の環境的、社会的、経済的な持続可能性の調査

このアンケートは修士論文で使われるデータを集めるために実施され、完了するまでに約 **12 分**かかります。この研究の目的は「社会資本として利用価値が見直されつつある農業用水がどの程度まで持続可能的に管理されているのか」、あるいは「十分に活用されているかどうか」を分析することです。アンケートの質問に対するあなたのご回答や個人的な情報は絶対に公開いたしません。もしも答えにくい質問がございましたら、その解答欄は空白のままで結構です。しかしながら、これらのデータが効率的に使用されるように、あなたの知りうる限りでのご回答をお願いいたします。私の将来の夢は国東の研究事例を通して、山間部において水管理に問題を抱える農業システムに解決策を提供すること、さらには国東半島宇佐地域世界農業遺産の発展を促進することです。ご協力ありがとうございます。

一般情報

1. 年齢:____________

2. 性別: 男 / 女

3. 世帯員数:____________

4. 関係している宗教:
   a. 特にない　b. 仏教　c. 神道　d. 修験道　e. キリスト教　f. 個人的な宗教　g. その他____________

水田に使用する用水量の計算

以下の質問は米の収穫量ごとに綱井で利用されている農業用水の総量を計るために行われます。回答ができない場合は空白のままにしてください。

1. 米作りにおけるすべての期間を通して、平均的にどのぐらい農業用水を利用すると思いますか。(例 : 10,000 リットル、10 立方メートル)

   ____

2. あなたが所有している田んぼの総面積はどれくらいですか。そのうち実際にコメ作りに使用する田んぼはどれくらいですか。また、どのくらい休耕していますか。（例：総面積４ヘクタール、田植え４ヘクタール、休耕０ヘクタール）
総面積：__________________
田植え：__________________
休耕：__________________

3. どの深度まで田んぼに水を入れますか。
__________________センチ・ミリ（1 つに〇をつけてください）

4. どの深度まで田んぼの水が減ったらまた水を追加しますか。
__________________センチ・ミリ

5. 一回の米作りサイクルで平均何回ぐらい田んぼの水を追加しますか。
__________________回くらい

6. 田植えの何日前から田んぼを入水させますか。
__________________日

7. 平均して、何月何日に田植えをしますか。
____

8. 田植えしてから、あなたのお米は収穫するまでにだいたい何日かかりますか。（米を二種類以上作る場合では、すべてを書いてください。）
__________________日

9. 刈り入れする前に何日くらい田んぼを乾燥させますか。
__________________日

10. 追肥をどのくらい撒布しますか（10a あたり）。
ブランド名:_______________
量：(N)_________ (P)_________ (K)_________ （複合肥料）_________
ブランド名:_______________
量：(N)_________ (P)_________ (K)_________ （複合肥料）_________
ブランド名:_______________
量：(N)_________ (P)_________ (K)_________ （複合肥料）_________

11. ヘリコプター農薬散布に参加しますか？
はい・いいえ

12. コメ作りにおいて、殺虫剤と除草剤をつかいますか。
a. 両方使う　　b. 殺虫剤のみ使う　　c. 除草剤のみ使う　　d. 使わない

13. （質問 12 で a.、b.、c. を選んだ方へ）何の薬品をどのくらい利用していますか（10a あたり）。
ブランド名:________________ 種類:________________ 量:________________
ブランド名:________________ 種類:________________ 量:________________
ブランド名:________________ 種類:________________ 量:________________

14. 田んぼの土は粘土系ですか。或いは水がちょっと通りやすい系ですか。以下の（一）一つに◯をつけてください
粘土ばかり＜ーーーーーーーーーーー＞すぐなくなってしまう系

15. 地下水も使いますか。もし使うなら、どのくらいですか。
はい・いいえ　____________________リットルぐらい

16. どの池から水があなたの田んぼに届けられますか？
____

17. 椎茸ホダ場を管理していますか。それにどのぐらいの農業用水を利用しますか。
はい・いいえ　____________________

18. イネの苗はどのように調達していますか？品種は？
____

19. 平均して 10 アール当たりの収量はどれくらいですか。
____

社会資本

1. あなたはいつから綱井に住んでいますか。
______________年・月（一つに◯をつけてください）

2. あなたの祖先はいつから綱井に住んでいますか。ご存知のない場合では何世代ぐらいあったか概算してみてください。（例：５代以上）
______________年・代

3. 子どもさんやお孫さんはいますか。
はい・いいえ

4. （質問３で「はい」と答えた方のみ回答してください）
お子さんやお孫さんは綱井の学校に在学していますか。あるいは卒業生ですか。
a. 全員在学中　b. 一部在学中　c. 全員卒業　d. 一部卒業　e. その他

5. お子さんやお孫さんはよく農業の活動に参加していますか。
はい・いいえ

6. ｉ）配偶者はいますか。ｉｉ）有職者ですか。ｉｉｉ）よく農業の活動に参加しますか。
ｉ）はい・いいえ　　　ｉｉ）はい・いいえ　　　ｉｉｉ）はい・いいえ

7. 池守になったことはありますか。何年やりましたか。連続的な年でやりましたか、それとも散発的にやりましたか。
はい・いいえ　　　＿＿＿＿＿＿年　　　連続的・散発的

8. 池守になったことがないなら、なりたいですか。なぜですか。
はい・いいえ
＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿
＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿
＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿

9. 私と仲がいい農家の方々は**綱井**にいます。
a. まったく同意しない b. 同意しない c. どっちとも言えない d. 同意する e. 強く同意する

10. 平均して、私はその仲がいい農家たちの一人以上に＿＿＿＿＿＿連絡します。
a. 一ヶ月に一回以下　b. 一ヶ月に一回くらい　c. 一ヶ月に二回くらい
d. 一週間に一回くらい　e. 一週間に二三回くらい　f. 毎日

11. いつもは話題が＿＿＿＿＿＿＿です。
（該当するものすべてに◯をつけてください）
a. 農耕のこと　b. 団体のことや文化的な活動　c. 日常的なこと　d. その他＿＿＿＿＿＿

12. 私と仲がいい農家の方々は**隣の区**にいます。
a. まったく同意しない b. 同意しない c. どっちとも言えない d. 同意する e. 強く同意する

13. 平均して、私はその仲がいい農家たちの一人以上に＿＿＿＿＿＿連絡します。
a. 一ヶ月に一回以下　b. 一ヶ月に一回くらい　c. 一ヶ月に二回くらい
d. 一週間に一回くらい　e. 一週間に二三回くらい　f. 毎日

14. いつもは話題が________________です。
（該当するものすべてに◯をつけてください）

a. 農耕のこと　b. 団体のことや文化的な活動　c. 日常的なこと
d. その他_____________

15. 私は他の綱井にいる農民と農耕の方法や農耕するべきスケジュールに関してよく同意します。

a. まったく同意しない b. 同意しない c. どっちとも言えない d. 同意する e. 強く同意する

16. 私は他の綱井にいる農民と日常的なことに関してよく同意します。

a. まったく同意しない b. 同意しない c. どっちとも言えない d. 同意する e. 強く同意する

17. 綱井が世界農業遺産と指名されてから、もっと綱井の誇りを持つようになりました。

a. まったく同意しない b. 同意しない c. どっちとも言えない d. 同意する e. 強く同意する

18. 他のところと比べて、綱井における農業は例外的です。

a. まったく同意しない b. 同意しない c. どっちとも言えない d. 同意する e. 強く同意する

19. 綱井の農業が成功できるために、ため池が必要です。

a. まったく同意しない b. 同意しない c. どっちとも言えない d. 同意する e. 強く同意する

20. 綱井の農業が成功できるために、池守さんが必要です。

a. まったく同意しない b. 同意しない c. どっちとも言えない d. 同意する e. 強く同意する

21. 水の割り振られる方法は、すべての農民にとって公平です。

a. まったく同意しない b. 同意しない c. どっちとも言えない d. 同意する e. 強く同意する

22. ため池の水の値段も公平です。

a. まったく同意しない b. 同意しない c. どっちとも言えない d. 同意する e. 強く同意する

23. 農業用水が何方かに勝手に盗まれることは時々あります。

a. まったく同意しない b. 同意しない c. どっちとも言えない d. 同意する e. 強く同意する

24. 綱井の農民人口が増えたとしたら、農業用水が勝手に盗まれることも増えます。

a. まったく同意しない b. 同意しない c. どっちとも言えない d. 同意する e. 強く同意する

25. 私は水管理についての意思決定に含まれていると感じます。

a. まったく同意しない b. 同意しない c. どっちとも言えない d. 同意する e. 強く同意する

26. すべての農民が意思決定に含まれる必要はあると思います。

a. まったく同意しない b. 同意しない c. どっちとも言えない d. 同意する e. 強く同意する

27. 私は自由に農業の方法が決められると感じます。
a. まったく同意しない b. 同意しない c. どっちとも言えない d. 同意する e. 強く同意する

28. 池守さんの役割が尊敬されています。
a. まったく同意しない b. 同意しない c. どっちとも言えない d. 同意する e. 強く同意する

29. 綱井の祭りによく参加します。
a. まったく同意しない b. 同意しない c. どっちとも言えない d. 同意する e. 強く同意する

30. 国東半島のその他の地域にある祭りによく参加します。
a. まったく同意しない b. 同意しない c. どっちとも言えない d. 同意する e. 強く同意する

31. 国東半島のお寺、神社、他の文化的なところが私にとって重要なものです。
a. まったく同意しない b. 同意しない c. どっちとも言えない d. 同意する e. 強く同意する

32. 私の配偶者は文化活動や行事においても同様に活動しています。
a. まったく同意しない b. 同意しない c. どっちとも言えない d. 同意する e. 強く同意する

33. 農耕のことや総務に関して、________________________。
a ほとんど私が助言や手伝いを頼みます
b. ほとんど私が助言や手伝いを頼まれます
c. 助言や手伝いを頼むことと頼まれることもあります
d. 一人でやるのがいいです

34. 水路の漏れているところを発見したことはありますか。何回くらいですか。何方かに教えましたか。
はい・いいえ　　　______________回　　　はい・いいえ

35. 新しい有機農業を綱井の隣の区のある農家が実践しています。その農家は生産費を減らしたり、収入も増やしたりすることができたそうです。その農家は綱井でワークショップを行って、皆さんに無料でその農業の方法を教えてくれるらしいです。この状況によって、あなたの姿勢に最も当たっている回答を選んでください。
a. 多分やってみます
b. いくつかの綱井の農家が賛成したら、多分やってみます
c. すべての綱井の農家が賛成したら、多分やってみます
d. 他の綱井の農家が賛成しても、私は多分やりません

36. あなたかあなたの家族が参加している組織、団体、イベントなどの左に☒を入力してください。そして、自分か家族のどなたかかどうか表してください。(例：☒ ツーリズムおおいた ___自分/他____)

- ☐ 国東半島宇佐地域世界農業遺産推進協議会 ____________________
- ☐ 国東市農政課 ____________________
- ☐ 国東市観光課 ____________________
- ☐ 国東市社会教育課 ____________________
- ☐ 国東市役所のその他 ____________________ ____________________
- ☐ 大分県農業協同組合中央会 ____________________
- ☐ 大分県漁業協同組合 ____________________
- ☐ 大分県椎茸農業協同組合 ____________________
- ☐ 大分県森林組合連合会 ____________________
- ☐ 大分県土地改良事業団体連合会 ____________________
- ☐ ツーリズムおおいた ____________________
- ☐ 国東半島ツーリズム会議 ____________________
- ☐ 国東七島藺振興会 ____________________
- ☐ 大分県東部振興局 ____________________
- ☐ 大分県北部振興局 ____________________
- ☐ 大分県東部振興局日出水利耕地事務所 ____________________
- ☐ 大分県農林水産部 ____________________
- ☐ 自然保護推進室 ____________________
- ☐ 総合地球環境学研究所 ____________________
- ☐ 農林水産研究指導センター ____________________
- ☐ 別府大学 ____________________
- ☐ 日本文理大学 ____________________
- ☐ 大分大学____________________
- ☐ 立命館アジア太平洋大学 ____________________
- ☐ 六郷満山霊場会 ____________________
- ☐ 綱井のだいし祭り____________________
- ☐ 綱井のすいじん祭り__________________
- ☐ 他の綱井の祭り__________________
- ☐ 修正鬼会 ____________________
- ☐ 国東病院の祭り ____________________
- ☐ その他の祭り____________________
- ☐ その他の組織_______________ ___________________ __________________

経済的分析

1. 過去から今までの体験に基づいて、あなたの農業の成功に対して、以下の項目を**1**（最も脅威が少ない）**～ 6**（最も脅威が多い）として、ランキングにしてください。

___ 台風と豪雨
___ 水不足
___ 米害虫
___ 人材不足
___ 外国の米の輸入
___ 設備や機械へのアクセス不足

2. 作物や設備を守るために保険に入っていますか。
a. はい、設備と作物　b. はい、設備のみ　c. はい、作物のみ　d. 入っていない

3. 平均的な年にはどのくらいの合計で水を支払っていますか。
約____________________

4. 米を耕作するためにどんな助成金を得ていますか。

____

5. その助成金を得続けるために、何をしなければいけませんか。

____

____

6. 農業以外、他に仕事や収入源はありますか。それはどのような仕事ですか。
はい・いいえ　____

7. あなたの考えでは、農業収入と助成金のだけで、安定的に暮らせますか。なぜですか
はい・いいえ・よくわからない

____

____

8. 最後には、綱井におけるため池農業用水システムと農業に関して、長所と短所を一つずつ書いてみましょう。

____

____