1. Introduction

The eastern Indonesian province of Nusa Tenggara Timur (NTT) is one of the poorest provinces in Indonesia. The majority (80%) of the population of NTT lives in rural areas and livelihoods are largely dependent on agriculture. Producing and storing sufficient food is a challenge and famine is a frequent occurrence in rural areas. Water is a major limitation to land productivity in west Timor, where there is an annual dry season of six to eight months, usually from May to October inclusive. In the major catchments in NTT weirs have been constructed in the lower reaches[4] (e.g. Noelmina-Benain in West Timor, Asesa in Flores, Kambiniru in Sumba) and these weirs supply irrigation water to major food growing areas on the surrounding coastal plains.

Although the construction of a weir and associated irrigation infrastructure can increase food productivity in the irrigation area, irrigation infrastructure can prove ineffective because of inappropriate management (Ancev 2009). From the beginning of the New Order in the mid-1960's to the mid 1990's, Indonesia had invested heavily in irrigation schemes, mostly of small scale by international standards (<5000 ha), and has achieved national rice self-sufficiency (Bruns 1999). Irrigation reforms in Indonesia in 1987 and 1999 attempted to give farmers greater voice in agency-controlled irrigation projects, but Bruns (1999) argued that farmers need empowerment in this role rather just a voice.

The sustainability of irrigation systems depends on wise integrated catchment management to arrest and reverse catchment degradation which would otherwise result in siltation and reduced capacity at the weir. In 1999 there was a national decree (Ministerial Decree 284/1999) to implement management interventions to reduce degradation in

[4] "Catchment" refers to the area of land draining into a river system and bounded by ridge lines or watersheds that separate one catchment from another. Note that "catchment" in this sense is often referred to as "watershed".

Indonesian catchments. A national system was established for prioritizing the catchments most in need of these interventions (Anwar 2003). The three major catchments in NTT listed above were given high priority ranking for intervention due to high susceptibility to erosion (e.g. Witz & Muga 2009) and significant siltation at the weirs in the lower parts of the catchments.

Hasnip et al. (2001) observed that most environmental impact assessments of irrigation developments address impacts on productivity and rarely assess the consequences for the livelihood strategies of the rural poor. This study gives a context for the impacts by describing the variability of access to water and food resources within the village of Linamnutu, in the irrigation area in the lower part of the Noelmina catchment in West Timor.

The weir near Linamnutu was constructed in the early 2000s and irrigation water was supplied to fields in Bena and Linamnutu, growing almost exclusively rice. These irrigated fields replaced smaller areas of rice cultivation using traditional irrigation directly from the river as well as dryland cultivation of a range of crops. Estimates from satellite imagery of the area of irrigated fields in the village of Linamnutu are 290 ha in 1999 (before the construction of the weir) and 590 ha in 2006. Currently irrigated fields at Bena have an area of about 660 ha. The irrigation channels from the weir may provide water for a longer season than the traditional channels. This study at the village of Linamnutu was a case study which aimed to investigate the food and water resources adjacent to a major irrigation system on household and farming water resources and related food security within the case study village.

The study identified issues of concern to the local village community relating to water and food resources. The design of the study was based on engagement with village leaders and district government officers, followed by household interviews. The study provided insight into the role of villagers as co-researchers and the role of researchers in creating a forum for the discussion of issues of access to and availability of water and food resources.

2. Methods

Study site

The study was conducted in Linamnutu village, in the lower part of the Noelmina River catchment in the district (*Kabupaten*) of Timor Tengah Selatan (TTS), in the province of Nusa Tenggara Timur (NTT) (Fig. 1).

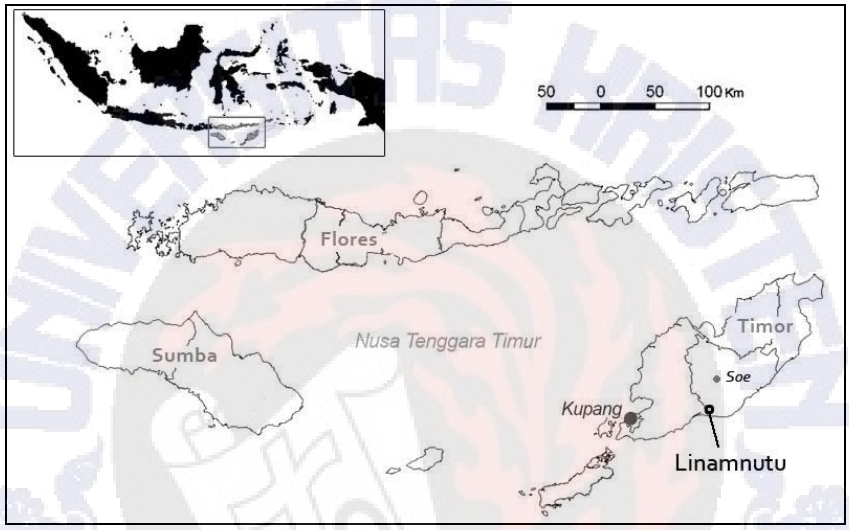

Figure 1.
Location of Linamnutu village, Timor Tengah Selatan (TTS) district, in Nusa Tenggara Timur (NTT) province, Indonesia.

NTT has a monsoonal wet-dry tropical climate and is one of the driest provinces of Indonesia, with some areas frequently experiencing droughts and famine. The rainfall, and therefore the reliability of water resources, varies across west Timor. The southern coastal area has relatively high rainfall.

Linamnutu Village comprises three sub-villages or hamlets (*dusun*): Oetaman, Hausanuf and Linamnutu. As is often the case, the *dusun* are naturally-occurring units separated geographically (Bebbington et al. 2006). Within the *dusun* there are a total of nine neighbourhood units or RW (*rumah warga* or community solidarity units) which are in turn

divided into a total of 20 RT (*rukun tetangga* or neighbour solidarity units).

Development model and participatory approach for research

The study was developed within a framework of community engagement and community development, while its topic focus was on the management and use of natural resources (food and water). Specifically, it investigated food resources and access to water resources of households located in the uplands and lowlands of Linamnutu village, west Timor, among people for whom poverty, poor health indicators and food and water shortages are annual realities. The research team undertook this initial intensive with the intention of developing a longer term partnership with the village.

Although the data collection period was brief, a participatory approach was taken where possible in order to move away from the tendency of rapid rural appraisals for information to be "extracted by outsiders" (Chamber 1994a) and to adopt a participatory rural appraisal approach in which local people play a valued role (Chambers 1994b). Community development was integrated into the study by including village administration and district agencies as partners in the research, contributing to the framing of the research questions, being engaged in design and logistics of the data collection, and commenting on the research findings. This engagement increased the likelihood of research outcomes being taken up (van de Fliert and Braun 2002), particularly by communicating directly to those in a position to implement recommendations.

The field data were collected during a field study intensive for two weeks in November-December 2009 by staff and students from three universities, Satya Wacana Christian University (UKSW, Salatiga, Indonesia), Nusa Cendana University (UNDANA, Kupang, Indonesia) and Charles Darwin University (CDU, Darwin, Australia). The field study intensive was developed from research collaborations and a shared vision by the partner universities for more than a decade.

Community consultations

Discussions were held with village leaders and district government officers before, during and after (both immediately after and one year after) the data collection period to investigate the impacts of this type of research on the community partners in the research. The local language is Dawan and this language was used in all village level negotiations and household interviews.

University research team members visited Linamnutu to discuss the proposed field activities with the village administration three months before the field study. Before the interviews, each household received an explanation of the purpose of the study and assurances that their participation was voluntary and could be stopped at any stage without penalty, and that their responses would be kept confidential and anonymous. These methods were approved by the Charles Darwin University Human Research Ethics Committee (#H09082).

Selection of interviewee households

Households were selected using stratified random sampling, to ensure adequate representation of sub-villages and topographic locations (Fig. 2). The Head of Linamnutu village and UNDANA researchers selected the households to be invited to be interviewed. A total of 59 households were interviewed: from 12 RT distributed in approximately equal numbers across all of the nine RW and three sub-villages. The food groups sampled households in six RT in six RW in all three sub-villages, and the water groups sampled different households in eight RT in eight RW in all three sub-villages.

Villagers were engaged as guides to escort the researchers to the households to be interviewed, but did not take part in the interviews thus protecting the privacy of interviewees. These guides were remunerated for their time.

Interviewers

The field team comprised academic staff and senior students from the three partner universities. Each household was interviewed by a group comprising a staff member and five or six students from the partner universities. Each group included student interpreters with skills in

English, Indonesian and/or *Dawan* languages. In some cases one interpreter had skills in all three languages, and in other cases, there was an interpreter between English and Indonesian, and another between Indonesian and *Dawan*.

Interviews

Interviews were undertaken in a total of 58 households. Of the interviews of households, 28 addressed issues related to food resources and 30 addressed issues related to water resources. Standardised, open ended interview techniques were used (Patton 2002).

The interview questions related to food resources were loosely based on the survey questions for assessing food security listed by Usfar (2007). The interview questions used in the present study sought to investigate the topics listed below.

1. Staple food: rice and/or maize, and other foods grown and eaten.
2. Daily food consumption patterns: number of meals eaten per day, and whether children and adults have the same diet.
3. Food shortage: whether experienced and, if so, when was the last time and cause of food shortage, and if the household was worried about nutrition.
4. Source of staple food: grown and/or bought and the percentage of the harvest kept or sold.
5. Self sufficiency of staples: whether average harvest enough for household supplies for one year.
6. Agricultural practices: wetland/dryland, who works in field, methods of land preparation.
7. Cooperation with other farmers: works with other farmers, member of farmer cooperative groups.
8. Household land ownership: lease/own/share farm.
9. Livestock: is livestock kept and/or sold.
10. Paid off-farm work: how often is this undertaken.
11. Government support: types of support are received during food shortage.

The interview questions related to water access and water management issues sought to investigate the topics listed below.

1. Sources of water: well, rainfall, river, irrigation, soaks.
2. Seasonal availability: number of months that water is available from these sources.
3. Uses of water from various sources: washing, drinking, livestock, garden or plantation (*kebun*), rice field (*padi*)
4. Frequency of household water collection
5. Methods of household water collection: by foot, cart, motor bike
6. Management arrangements for irrigation water
7. Sharing arrangements for wells

Mapping method for household and water sources

Locations of houses where interviews were conducted and of the wells to which these households had access were recorded using GPS units. These locations were mapped using free software, QGIS [5]. Maps were created to highlight correlations between various characteristics recorded for the households.

3. Results

Households and tenure

Most (86%) householders were Timorese, with other ethnicities including Rotenese, Floresian and Sabunese. Households had an average of 4.4 members with usually two members of the household younger than 12 years. All households were headed by farmers, except for one headed by a midwife. Some (19%) households included farmers who also had other paid work (e.g. public servant, labourer and grazier).

All but one household had tenure over their house garden and all but three households had tenure over farming land. Most (57%) households had tenure over some irrigated land, with about half of these also having tenure over non-irrigated farming land (Fig. 2). About a third (36%) of households had tenure over non-irrigated land but not over irrigated land. For those households that had some land tenure, the average area of

[5] http://www.qgis.org/

tenured land per household was 0.76 *are*[6] for domestic garden, 0.78 *are* for dryland cropping and 0.98 *are* for irrigated cropping.

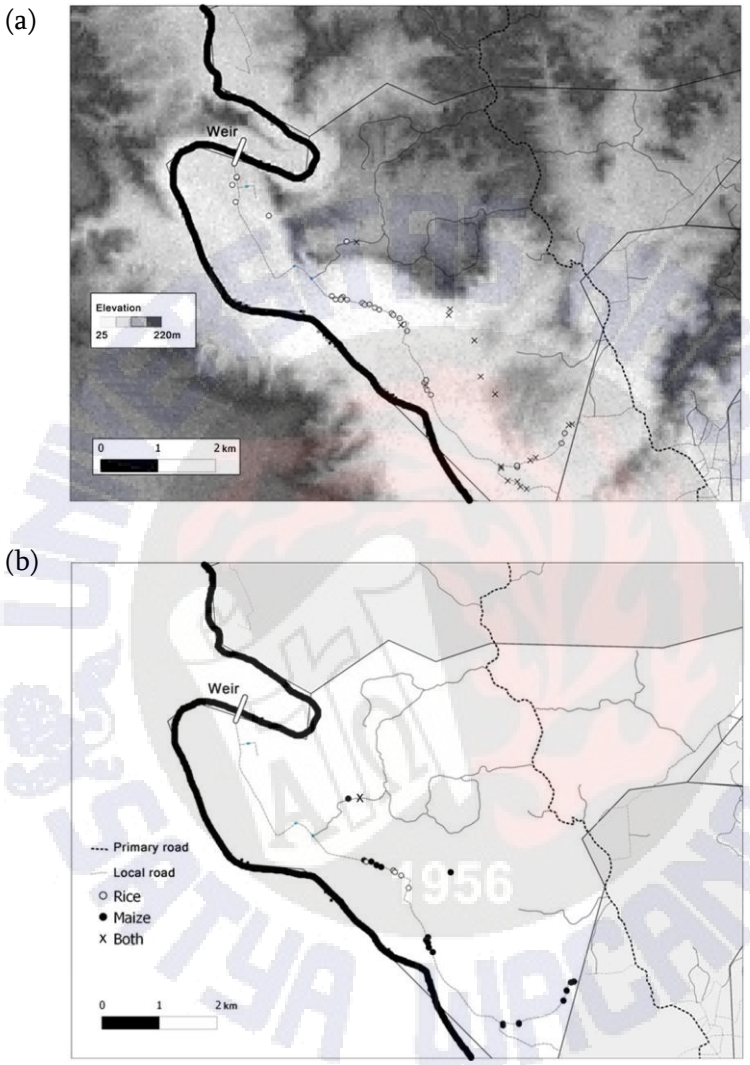

Figure 2.
Houses interviewed in the village of Linamnutu showing (a) households with (o) and without (x) access to irrigated land and elevation indicated with darker shading representing higher land, and (b) staple foods of the households.

[6] 100 *are* = 1 hectare

Water issues

Sources of water

Interviews indicated five sources of water: direct rainfall, river channels, soaks in the stream bed (*oemata* or at the base of slopes *(pancuran*), wells and irrigation channels. In addition, an observation was made of rainwater being collected from metal roofing and directed to plastic barrels in two houses, but these were not houses included in the interviews.

All households used the river and wells for drinking water, while in-channel soaks were used by some households and only during the dry season (Table 1). Incidentally, some interviewees reported resorting to irrigation water for drinking, but only in extreme circumstances due to the associated health risks. Respondents indicated that direct rainfall was only ever used for garden and maize crops, and not for domestic purposes.

Table 1.
Water sources and their use, as reported by households in Linamnutu. Values are the percentage of households reporting a particular use for each water source. Each value is a percentage of 30 households.

Water source	**Water use**					
	Drinking	washing/ bathing	livestock	gardens	maize	paddy fields
River water	100	96.7	80.0	13.3	-	-
In-channel soaks (*oemata*)	10	10	0	0	-	-
Wells*	100	96.7	80.0	13.3	-	-
Irrigation	0	23.3	16.7	16.7	-	96.7
Rainfall	0	0	0	100	96.7	-

*Note: There was some confusion about the terminology used by some respondents from upland households. "Wells" included wells and *pancuran*.

Water availability

Householders reported that river water was available for collection from the river for four to six months of the year, and was acquired for domestic use by walking, once per day or once every second day, or by motor bike once every four days (one household). Wells were accessed all year round by lowland households. However, some upland households reported that wells on higher land became saline or dry during the mid dry season and therefore were unreliable sources. For this reason upland households generally walked down slope to wells or *pancuran* to access water.

Water access

Access to each type of water source differed between upland and lowland households. Lowland households generally lived close to wells. Households that owned a well shared this with one to six other households (an average of three households per well). However, two of the households interviewed reported sharing wells with 30 and 32 households.

Wells were uncommon near upland households, and water was more commonly sourced from soaks lined with rocks at the base of upland slopes (*pancuran)*. It was a steep climb between this water source and the surrounding households. Some passers-by reported visiting this water source up to 6 times a day to meet household needs.

Water quality

We were not able to systematically measure water quality, however preliminary *ad hoc* sampling of well water indicated that the physical properties were in accordance with drinking water standards. However some interviewees reported that during the rainy season, well water is often dirty. All householders reported boiling all water before drinking to avoid health problems.

Management of irrigation water

Irrigation water is primarily used for rice growing, but is also used for washing clothes, bathing and, only in rare emergency situations, for drinking. Householders reported that repeated bathing in irrigation

water resulted in skin problems, and repeated drinking of irrigation water resulted in illness.

The irrigation system is managed by the irrigation officers or *Petugas Pengelola dan Pembagian Air* (P3A). Water flow is controlled by a system of manual gates, which only the P3A are allowed to open or close. The P3A are elected by farmers to represent a certain area of land ownership, for a three year term. There appeared to be confusion among householders about how the P3A was paid. Interviewees reported the following responses when asked how the P3A were paid: (i) 15 kg of rice harvest per 25m^2 of land owned by a farmer within the block (this is the most commonly reported payment method), (ii) 30%-50% of total rice harvest, (iii) not paid at all, (iv) paid by the government, or (v) 60 kg of rice harvest per block[7]. Even neighboring households reported different methods of remuneration for P3A.

For those who believed the P3A did receive payment, they reported a number of uses for that payment, including (i) exclusively for P3A personal use, (ii) divided evenly between costs of seed, repairs and maintenance, (iii) village needs such as to provide for visitors, and the village barn, (iv) half for seed and half for repairs and maintenance.

Many farmers were happy with the management of irrigation waters by their P3A, however some were not. Examples of complaints included: (i) P3A was lazy or not serious, (ii) a lack of technical skills meant the distribution of water was not even, (iii) more water was provided to friends and family of P3A, or those who pay him "on the side", (iv) those further away from gates received less water, (v) poor management of rubbish in channels reduced flow, and (vi) if not well managed, the first water flows of the wet season can result in many pest problems in rice crops.

When asked about options for actions they can take if they are not happy with a P3A, interviewees reported, that they can: (i) withhold payment, (ii) discuss it with the Village Head, (iii) wait for the next election of the P3A, (iv) create a small committee to conduct investigations, (v) talk to the P3A concerned, or (vi) not do anything.

[7] A block has a variable area, from 10 to 100 *are* (*i.e.* 0.1 to 1 ha).

Some farmers also reported that they had better access to water before the weir was built. Others reported being unable to grow crops during the two year period of construction of the weir.

Food issues

Types of food grown

Most households had both rice and maize as staple foods, with few (five and three respectively) having only rice or only maize as staple foods (Fig. 2). The households with only rice as staple were located within the irrigated fields and the households with only maize as a staple were located outside the irrigated fields. Most households grew, rather than bought, their staple foods. All households consumed rice, most (71%) grew rice and some also bought rice, with one household receiving rice as payment for labour in rice fields. The data indicated that rice was also eaten by households where it was not considered a staple. All households grew maize and no households indicated that they bought maize. A total of 19 types of vegetables and 9 types of fruit were grown in village gardens (Table 2). A greater diversity of vegetables and fruits were grown by households that farmed irrigated land.

Table 2.
Vegetables and fruit consumed by households that farmed or did not farm irrigated land. Note the term fruit is used in a culinary, rather than botanical sense.

Households farming irrigated land		**Households not farming irrigated land**	
Vegetables (18)	**Fruit (8)**	**Vegetables (7)**	**Fruit (2)**
banana flowers, beans, cabbage, carrot, cassava and leaves, chili, choko, Chinese cabbage, eggplant, aquatic ipomea*, lettuce, *Moringa oleifera#,* pawpaw flowers, peanuts, pumpkin, spinach, sweet potato, tomatoes	avocado banana coconut jackfruit orange mango papaya soursop	banana flowers, beans, cassava and leaves, eggplant, nuts, papaya leaves, pumpkin	banana papaya

*Aquatic ipomea, *Ipomea aquatica*, is known as *kangkung*
#*Moringa oleifera* is known locally as *marungga*

In most households, meat was consumed infrequently, with frequencies of consumption quoted from between once per month and four times per week, or only at festivals. In one household, meat was only for the children, but in most households children and adults had similar diets. Some households only ate meat when they had money available to buy it. Where meat was consumed, fish and chicken were the most common forms of meat consumed (Table 3).

Table 3.
Sources of animal protein and other foods consumed, with percentage of households consuming different types of protein shown in brackets.

Sources of animal protein consumed	Other foods
fish (61%) chicken (43%) egg (36%) beef (11%) pig (10%) goat (3%) tripe (3%)	Salt fermented palm stalk (*putak*) chili tempe tofu palm starch (*lontar*) with coconut during food shortages coffee

Irrigated fields are mostly prepared using tractors, and non-irrigated fields were mostly prepared by fire and hoe (i.e. slash and burn). Some households reported that, at times, a shortage of tractors prevented timely land preparation and so resulted in reduced production. In most households, the men work in the fields, with the women also working in the fields in a third of households. Approximately a third of the households work cooperatively with other farmers in their fields. Half the households reported that their agricultural practices had changed in the past two years, but only three households report that their staple foods had changed since the construction of the dam, with the addition of rice as a staple in these households.

Land was leased for crop production by five of the 28 households interviewed about food, and about 20% of households cultivated land that they did not own and paid the land owner with a share of the harvest. About a third of farmers work for payment as well as working on their

own land: two thirds of these farmers did so only sometimes and a third did so always.

Food availability

Despite the presence of the weir, half the households interviewed had experienced food shortages. A similar proportion of households considered that an average harvest would be enough to supply staple food to their household for one year while others had shortages or purchased food. Almost all households usually ate three meals per day, with three households eating two meals per day. When recollecting recent years of food shortages householders most commonly referred to 2009, and these food shortages were attributed to "yellow disease" of rice, i.e. infestations of a stem-boring moth larva. One household described 2004 as a year of food shortage because no irrigation water was available during that year because the weir was being constructed and traditional irrigation directly from the river had been discontinued.

Subsistence agriculture is most common, with harvest mostly for consumption by the household: most households keep all their harvest for their consumption, only two households kept half and sold half of their harvest, and another three households sold a little of their harvest or only when money was needed.

Coping with food shortages

During interviews, individual households provided examples of strategies for coping with food shortages. For example, a Rotenese householder reported drinking lontar sap with coconut during times of food shortage. Other households reported selling animals or eggs during shortages of staples. Some householders asked the interview group for advice on how to construct a nutritious and balanced diet for his family.

During householder interviews we were told that some members of the village community had sold land to make cash available to purchase food and then worked as labourers on other people's land to earn cash or receive a portion of the harvest as payment to secure household staples. Some interviewees saw this as a problem.

Other issues raised

Although most (73%) of the households interviewed about food issues were satisfied with the irrigation system, only about half were satisfied with the irrigation management.

There was little evidence of strong membership of farmers' collectives. Some interviewees reported that a sample of farmers from Linamnutu had been sponsored to attend training workshops, including workshops in Bali, but that this knowledge had not been effectively shared upon their return. Thus there appeared to be limited information-sharing among farmers. For example, even neighbouring householders were found to have contrasting opinions on the method and rate of payment to P3A.

4. Discussion

Despite government investment in the irrigation infrastructure that delivers irrigation water to much of Linamnutu village, access to water was variable among households within the village. For some interviewees, the weir had not improved, and may have worsened, their access to irrigation water. Even some lowland households, particularly those furthest from the weir, experienced poor delivery of irrigation water due to poor management and maintenance of the irrigation system (e.g. siltation of irrigation channels). This may be due to poor technical skills or favoritism among P3A officers, in some blocks. (It is noted that many farmers were happy with the services of their P3A.) As might be expected, upland households had less convenient access to domestic water and little or no access to irrigation water.

In a study of the impacts of irrigation systems on small land holders, Hasnip et al. (2001) acknowledged that irrigated agriculture can enhance and sustain rural livelihoods, and lists many potential positive impacts: 'improving agricultural productivity, employment and incomes for irrigating households and farm labour, linkage and multiplier effects for the wider economy, increasing opportunities for rural diversification, and multiple uses of water supplied by irrigation infrastructure.' Hasnip et al. (2001) concluded that most irrigation projects tend to result in greater proportional benefits for the rich. In some cases impacts may be harmful to the poor, particularly where, prior to the creation of the irrigation system, the ownership of land and water rights are highly skewed or

when irrigation 'reinforces land consolidation processes in which some groups lose access or rights to cultivate land or rights to water.'

In Indonesia there has been a devolution of the management of small irrigation systems to local people through the creation of Water Users Associations (WUA), or P3A, each comprising 10 to 30 farmers (Bruns 1999). The aim of the WUAs was for more equitable water distribution and better mobilization of irrigation service fees, through identification of local management problems. However, Bruns (1999) considered that in reality consultative bodies at the district level had no role in making decisions.

Hasnip *et al.* (2001) advocated assessing impacts within Sustainable Livelihoods Framework to ensure a broad scope for assessments of impacts of irrigation projects on all members of the community. The impacts of the irrigation system in the case study at Linamnutu are discussed under the five capitals of the Sustainable Livelihoods Framework, i.e. natural, physical, human, social, and financial capitals (Scoones 1998, Bebbington *et al.*, 1999).

Natural capital

The irrigation system has resulted in easily measured impacts on natural capital: a doubling of the area of irrigated agricultural fields at Linamnutu, and greater access to domestic water.

Physical capital

There are obvious increases in physical capital: construction of the weir, irrigation channels and irrigation gates. Interview responses indicated that, since the creation of the irrigation system and the resulting increase in total agricultural production from the village, there has been a need for improvement to roads for better access to markets so that agricultural produce can be sold. Improvements to roads could also reduce the travel time to secondary school and may result in improved delivery of services to the village.

Human capital

One major factor reducing rice productivity was infestations by a stem borer in rice (IRRI 2003). These infestations may be minimized by

maintaining high water levels after harvest to prevent build up of pest numbers before the next planting, however grasses and maize can also act as hosts for some types of rice stem borers (W Mudita pers. comm.). None of the households interviewed were aware of the potential management of the pest by maintaining water coverage of stems although some households indicated that poor water management early in the season resulted in increased pest infestation. It is expected that the farmers attempting to maintain high water levels may have difficulties in achieving this if water management by P3A officers was poor. For improved management of this pest in rice, most farmers do not yet have knowledge about water management for mitigation of pest infestation, and the system of water management needs to be improved so that the desired water management can be implemented.

The responses to household interviews indicated that there was generally poor knowledge of balanced diet and nutrition within the households, with requests for information about the components of a balanced diet. Lack of knowledge may result in poor nutritional food security. Another study (Wiendiyati et al. 2009) in two rural villages in West Timor found that in the past decade about half the households have added rice to their traditional staple food, maize. It was observed that consuming rice was associated with a trend towards increasing consumption of instant noodles and a reduction in the variety of vegetables consumed

Social capital

In a review of the establishment of local Water Users Associations, Bruns (1999) found a 'top-down' approach which tended to 'disregard existing local organisations, viewed as informal, ad hoc, or personalistic'. Bruns (1999) highlights an underlying perception by government agencies that indigenous irrigation was regarded as 'temporary or emergency works to be replaced by permanent "modern" structures' and the development of modern irrigation systems 'neglected the social capital embodied in existing networks amongst farmers, their mutual trust, shared ideas, and histories of cooperation.'

The study has identified training and information gaps within the village, as outlined under human capital. Farmers were confused about the role and responsibilities of the P3A officers. The P3A officers

themselves in some case lacked skills to adequately manage water flow, and in some cases may not be distributing water equitably. Potential improvements to human capital may be addressed by creating functional networks for improved management, i.e. increasing social capital.

Financial capital

Land tenure also varies between upland and lowland households. It is possible that changes in tenure due to land sales is affecting household income or access to food resources in the longer term. This issue is to be investigated in a subsequent project in Linamnutu.

Participatory methods

Bruns (1999) observed that government officials may in private be highly critical of their own programs but also be reluctant to voice ideas which might be criticised by superiors, and 'sometimes outsiders could function as a channel for raising criticisms and alternatives.' Initial feed-back from village community members indicated that the role of research team as a communication tool or mediator between village perspective and agency staff has been useful. The research findings have been presented in an open seminar to government and NGO officers and key villagers, held in the district capital city soon after the completion of data collection. A technical report has also been provided to the village and district government officers. The authors hope that awareness raised through the research will be a catalyst for improvements to resource management.

5. Conclusions

Construction of weir and irrigation channels has expanded the area of irrigated agriculture, however the benefits of this construction are unequal within the village and approximately 50% of the households interviewed reported food shortages. One of the limitations to equitable benefits is lack of knowledge and poor water management. We suggest that improvements to the positive impacts of the irrigation system in the case study village could be achieved by improving the farmers' knowledge and the effectiveness of the system of management of water delivery.

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