

# Productivity of Water in Agriculture: Farmers' Perceptions and Practices

Henry F. Mahoo, Zakaria Juma Mkoga, Sydney Stephen Kasele,  
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**Comprehensive Assessment of Water Management in Agriculture**  
**Discussion Paper 5**

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Perceptions and Practices**

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## Summary

Stakeholders in agriculture and water related issues have different perceptions about the productivity of water. This is evident by the different definitions of productivity of water, though most of the definitions hinge around the benefits accrued from water use. The viewpoint of smallholder farmers' regarding the productivity of water is important in order to promote the concept of productivity of water in a country like Tanzania. This is because 95 percent of the farmers are smallholders. This paper presents the farmers' understanding of the productivity of water in the Mkoji sub-catchment (MSC) in the Ruaha River Basin in Tanzania. It also presents their practices aimed at increasing the productivity of water in the area. It reveals that the concept of productivity of water has been part of the smallholder farmers in Mkoji. The farmers' concept of productivity of water is the same as that of other stakeholders, only that it is less formal than as expected by experts. Farmers in the sub-catchment judge productivity of water based on the amount of rainfall and its influence of their yields. Productivity of water is high or low if the average seasonal rainfall is 'good' or 'bad'. They put so much value to water that they go to the extent where they are willing to pay more to acquire a piece of land close to a water source. Furthermore, there is evidence that they engage in fights and 'steal' water as a result of the high value they place on water. The farmers have adopted tillage methods, agronomic practices and crop diversification approaches to maximize yield from available water. The paper concludes that these strategies adopted by farmers could be a good starting point for formulating measures to improving productivity of water in the area. Therefore, there is a strong need for an in-depth understanding of farmers' practices to determine the most effective, economical and sustainable options in increasing productivity of water, and to thereby formulate approaches for adaptation, uptake and upscaling. This paper explores farmers' perceptions of productivity of water, practices and coping mechanisms for achieving greater water productivity. The perceptions are generated based on farmers' understanding of water productivity, the value they place on land and water, and the struggle and conflicts resulting from the value they put on water. Furthermore, the paper presents farmers' strategies to estimate productivity of water, and discusses the impact of the farmers' practices, coping strategies and limitations associated with the practices. It was concluded from this paper that the theories and figures of productivity of water are less important to farmers, than their approaches to enhance their ability to effectively utilize water and to maximize production.



# CHAPTER 1

## INTRODUCTION

Smallholder farmers in sub-Saharan Africa (SSA) face economic and physical water scarcity. According to a study done by IWMI (2000), this scarcity will worsen by year 2025 if plausible measures are not taken to arrest the situation. Over 95 percent of these farmers practice rainfed agriculture while a small proportion rely on irrigated agriculture. Agriculture is highly constrained by rainfall unreliability, frequent dry spells, irrigation water scarcity and conflicts over water. This threatens food availability in these countries and tends to increase food aid dependency. Global efforts towards reducing food aid dependency include financing irrigation development to enhance rainfed yields by use of supplementary irrigation. However, it has recently been found that increasing productivity of water through water conservation is a more appealing option than developing new irrigation facilities. The development of new irrigation facilities carry high financial, social and ecological costs (Molden et al. 2001). Therefore, increasing productivity of water in agriculture will enable the scarce water resources to be used by more people and thus ease the competition and conflicts over water.

Stakeholders in agriculture and water issues have different perceptions about productivity of water. This is evident by the different definitions of productivity of water. For example, the definitions of water use efficiencies of the United States Department of Agriculture reflect the concept of productivity of water. They define three types of water use efficiencies which include: i) Water use (technical) efficiency, which is defined as the mass of agricultural produce per unit of water consumed, ii) Water use (economic) efficiency, which is defined as the value of product(s) produced per unit of water volume consumed, and iii) Water use (hydraulic) efficiency, which is defined as the ratio of water actually used by irrigated agriculture to the volume of water supplied. Table 1 shows the definition of stakeholders and indeed their perceptions of productivity of water. The list of the definitions by different stakeholders can be classified into agronomic, economic and social viewpoints, and their background influences their definition and perception. But, how much these definitions and perceptions of productivity of water by stakeholders relate to farmers' perceptions need to be understood.

*Table 1. Examples of definitions of productivity of water by different stakeholders.*

Stakeholder	Useful definition	Scale	Target
Plant physiologists	Dry matter/transpiration	Plant	Productive utilization of light and water resources
Agronomist	Yield/evapotranspiration	Field	Higher yields tons/ha
Larger-scale farmer	Yield/water supply	Field	Higher yields tons/ha
Irrigation engineer	Yield/diverted water	Irrigation scheme	Demand management
Water resources planner	\$/total depletion	River basin	Optimal allocation of water resources

*Source:* Modified from Bastiaanssen et al. 2003



Generally, productivity of water entails the net socioeconomic and environmental benefits achieved through the use of water in a production activity, including agriculture, fisheries, livestock, crops, agroforestry and mixed systems. The productivity analysis can be done at different scales; the crop or animal, a field or farm, an irrigation system, a basin or landscape with interacting ecosystems. The concept drives at producing products and services using less water. The water use may be accounted as depleted or diverted. Water depleted can either be through crop evapotranspiration, incorporated into a product, rendered unavailable or unusable, for example, by being heavily polluted (Molden 1997). The diverted water can give more social and economic water productivity if it can serve multiple uses such as drinking water, industries, fisheries and livestock (van Koppen et al. 2006).

In Tanzania, the concept of productivity of water is not well-understood and the practice of assessing productivity is insufficient. In most irrigation systems there are hardly any efforts to mainstream the assessment of productivity with respect to water, as yet. For example, irrigation schemes in Tanzania obtain water on the basis of permits - defining volume per unit of time - but re-allocations of the same water and subsequent payments by individual users are determined by size of the land being irrigated. Furthermore, the amount of water given to individual farmers is not in terms of volume but through allocated hours of access to irrigation water and according to frequencies of irrigation decided by Water User Associations (WUAs) (Tarimo et al. 2004). Water use in the gravity irrigation systems is seldom accounted for. There is, actually, little attention given to the amount of water diverted from the rivers, since the direct costs incurred are small (mainly in terms of manpower to open and close the gates).

This explains the reasons for sparse record of the amount of water going to fields from the main canal, despite having well calibrated gauges in the main canal and diversion structures in the improved irrigation systems (SMUWC 2001). Measurement of water diverted in these systems is neglected, because the only major cost known is the annual water user fee, which is not regularly paid. A monitoring system for water abstractions and enforcing the water user fee (by the Rufiji Basin Water Office) is not efficient enough to motivate managers to maintain data for assessing the productivity of water (SWMRG-FAO 2003). Productivity of water in such farms is gauged by the cost-benefit analysis (e.g., Chemka 1996), which considers the annual water user fee as a minor component cost in the analysis (James 1988). In the end it is very difficult to calculate exactly how much water was actually used to produce a certain amount of products – hence difficult to gauge productivity of water. Even the farmers practicing micro-irrigation in small plots using buckets and cans to irrigate crops do not keep accurate records of the amount of water used.

Even among professionals the conventional efficiency concept is more persistent than productivity of water. As such, the concept of productivity of water is not directly considered when designing irrigation systems. In practice, irrigation efficiency rather than irrigation productivity is considered in the design of irrigation systems (Halcrow et al. 1992; FAO 2001). Also, the performance of an irrigation system is focused on the efficiency of water use (i.e., ratio of volume of water required by plant to volume of supplied water) (Chancellor and Hide 1997). However, irrigation efficiency terms only provide a partial and sometimes misleading view, because it does not indicate the benefits produced, and water lost by irrigation is often a gain for other uses (Seckler et al. 2002).

Nevertheless, very few appraisals of irrigation systems have been done in the Rufiji Basin and only a handful of them have used indicators of water productivity as measures of performance. For example, Tarimo (1994) used measures of classical efficiency to assess the performance of

smallholder irrigation systems in the Usangu Plains (in the Great Ruaha River Basin). This has been the practice for many other researchers in Usangu and elsewhere in Tanzania (e.g., Makongoro 1997). It is only recently that the UK Department for International Development (DFID) funded project working in the Usangu Plains in Tanzania (i.e., Sustainable Management of the Usangu Wetlands and Catchment) (SMUWC 2001) consistently used concepts and indicators of productivity in assessing the performance of the Kapunga water system (e.g., Box 1).

*Box 1. Some productivity of water components found by the SMUWC in the Kapunga Rice Farm in the Great Ruaha River Basin in Tanzania.*

SMUWC (2001) when assessing the Kapunga irrigation system identified fishing, bird hunting, domestic, and livestock use as some of the water use benefits. The project also promoted the concept of irrigation water reuse, which further improves productivity of water. For example, in the Kapunga Irrigation Project, the field water productivity for paddy was reported to be 0.17 kilograms per cubic meter (kg/m<sup>3</sup>). However, when water reuse was considered, the productivity of water increased to 0.42 kg/m<sup>3</sup>.

A more comprehensive analysis of water use and productivity in the Great Ruaha Basin was done by the RIPARWIN (Raising Irrigation Productivity and Releasing Water for Intersectoral Needs) project (Kadigi and Mdoe 2004) This study on livelihoods and the economic benefits of water utilization showed the highest values of water for livestock, brick making and domestic uses, averaging at around a dollar per cubic meter (m<sup>3</sup>) of water consumed. In terms of total net benefits however, the Mtera-Kidatu hydroelectric power (HEP) plants (downstream the Great Ruaha River) generated the highest annual net benefits (about US\$230 million versus US\$22 million per annum for irrigated agriculture in the Usangu Plains). Despite the low productivity of water in irrigated agriculture, and in particular, irrigated paddy being relatively low (US\$0.02 and US\$0.03 per m<sup>3</sup> of abstracted and consumed water, respectively), the sector plays a very important role in enhancing both the livelihoods of local people and the national economy. The share of the Usangu paddy in the total national production ranges from 14 – 24 percent, and 60 percent is sold outside the area by trading to other regions in Tanzania. Irrigated paddy supports about 30,000 agrarian families in Usangu with the average gross income per family being about Tsh 969,960 or US\$911.90 per annum. Therefore, rice production is one of the key determinants of wealth in Usangu.

Understanding such values of water is very important among stakeholders for efficient allocation of basin water resources. Some disagreements on actual water allocation will still remain due to the differences in values, goals, priorities and aspirations of people (Warner 2006). However, the common understanding on values of water and productivity is a prerequisite in ensuring the equitable sharing of basin water resources. Unfortunately, there is evidence of the problem of a lack of common understanding and practice of the concepts of productivity of water among stakeholders in Tanzania. As a result it is a common practice to evaluate irrigation schemes in terms of yield, while it may have been more logical to measure performance per unit of water use (i.e., kg/l/s/ha).

The concept of crop per drop is very important for Tanzania because agriculture is the leading sector of the economy and accounts for over half of the Gross Domestic Product (GDP) and export earnings (URT 2001). Agriculture supports the livelihoods and food share of over 80 percent of the rural poor who mostly depend on unreliable rainfed agriculture (Kangalawe et al. 2004), which is severely constrained by drought (Boesen and Ravnborg 1992). In recent years there has also been a sharp decline in water resources coupled with an increase in population and competing sectoral water demands important for the national economy. For example, in the upper catchment of the Rufiji Basin [the Great Ruaha (GR) Catchment], irrigated agriculture has expanded dramatically over the past 30 years, particularly in the Usangu area. Several irrigation schemes have been established and have attracted more cultivators from highland regions and pastoralists from northern and central Tanzania. This in turn has not only caused a rapid expansion in irrigated agriculture, but has also created growing conflict and competition over water resources. Water demand for irrigated agriculture has increased enormously, causing serious water shortages downstream to other sectors (including the fragile ecosystems in the Usangu Wetland and the Ruaha National Park, as well as the hydropower sector at the Mtera and Kidatu plants), particularly during the dry seasons (DANIDA/World Bank 1995; Mbonile et al. 1997; SMUWC 2001; Kadigi and Mdoe 2004). In order to facilitate effective implementation of the national poverty reduction strategy (Vision for 2025), among other things, emphasis should be given to the massive agricultural and industrial development with particular emphasis on the enhanced productive use of scarce water resources. Since a big proportion of agricultural productivity in Tanzania is under smallholder farmers, an understanding of these farmers' perceptions of productivity, therefore, remains crucial to advance the concept of crop-per-drop. It is also important to have an understanding of farmers' values for water and their practices with respect to water management, and strategies for coping with an inadequate supply of water. Such an understanding will facilitate the possibility to draw up recommendations for future interventions.

## CHAPTER 2

### METHODOLOGY

#### Description of the Study Area

The focus of this study was the Mkoji sub-catchment located on the southwestern part of the Rufiji River Basin in Tanzania, and lies between latitudes 7°48' and 9°25' South, and longitudes 33°40' and 34°09' East (Figure 1). The Mkoji sub-catchment covers a land area of 3,400 square kilometers (km<sup>2</sup>). The Rufiji River Basin is the largest in Tanzania and it covers an area of 177,000 km<sup>2</sup>. It lies between latitudes 33°55' and 39°25' East, and longitudes 5°35' and 10°45' South. The Basin comprises of three distinct major river systems. These are: the Great Ruaha; the Kilombero; and the Luwegu. The basin supports wide biodiversity, meticulous wildlife, power generation together with intensive rainfed and irrigated agriculture.

The sub-catchment was purposively divided into three zones – upper (27 villages), middle (19 villages), and lower (7 villages). Two villages were purposively selected from each zone, to capture the variability in livelihood and production systems among the water users in the catchment. It was assumed that villages in the respective zones had similar characteristics in terms of farming systems and water uses. As such the survey covered 6 villages and 428 households selected randomly and based on about 10 percent of the population in each sample village. The villages were: Ikhocho and Inyala in the upper zone; Mahongole and Mwatenga in the middle zone; and Ukwaheri and Madundasi in the lower zone (Figure 1).

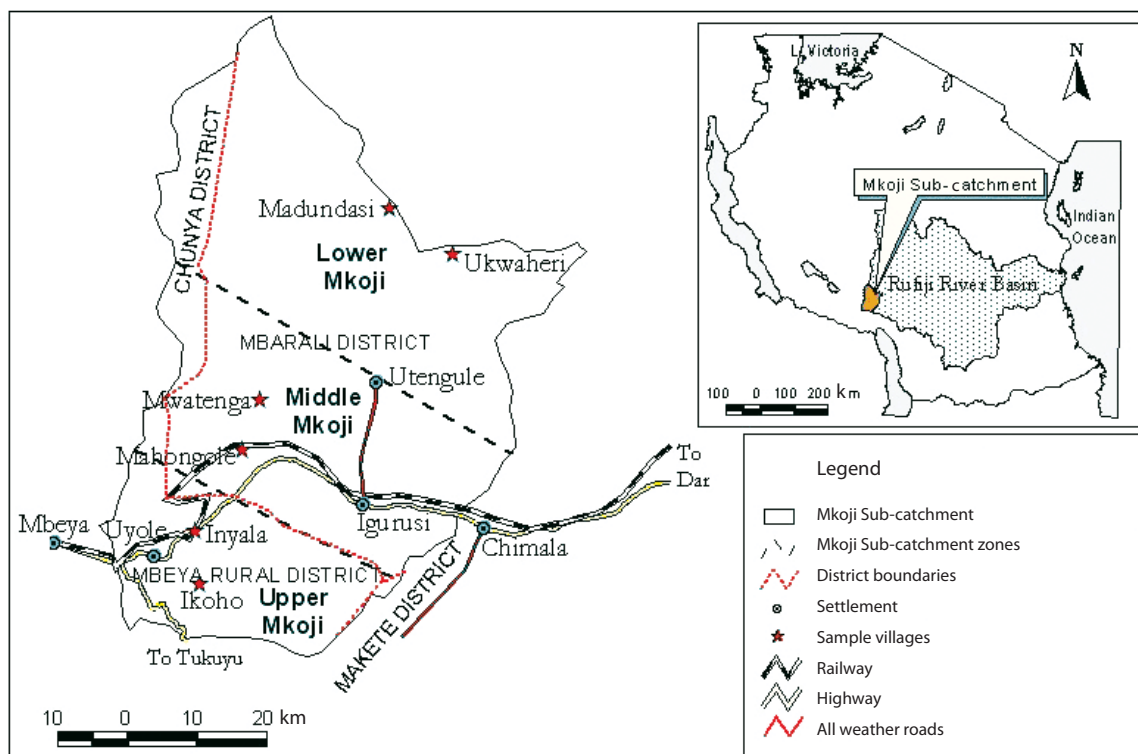
#### Data Collection and Analysis

The study employed a qualitative approach through focus group discussions. Preliminary visits were made to the six sample villages. The visits were important to explain to the villagers and their leaders the purpose of the study and to encourage their active participation.

The criterion for the selection of representatives of the villagers was to have equal representation of village clusters, water users, wealth categories based on their ages and gender. Representatives, who were also key informants, were selected based on the fact that they were knowledgeable on issues of water management. A checklist used to guide the Participatory Rural Appraisal (PRA) was based on soliciting information on the knowledge, attitudes and practices of farmers in measuring and assessing Productivity of Water in Agriculture. It was intended to extract information as to how farmers attach value to water in agricultural production, whether they assess productivity of water in agriculture, the methods of assessment and type of data they keep. Most important is their strategies to enhance productivity of water in agriculture.

Structured questionnaires were used to collect data from the sampled households. Two questionnaire surveys were done. The first survey was conducted between November and December in 2003 and the second supplementary survey was conducted in March 2005. The questionnaires included open and closed-ended questions and the intended respondents were household heads in the selected villages. The questionnaires were designed to clarify and quantify issues raised from the PRA's. Mainly, smallholder farmer perceptions and practices on productivity of water in rainfed and irrigated agriculture. For example, the practice of farmers to classify seasons as a means for

Figure 1. Location of Mkoji sub-catchment in the Rufiji Basin in Tanzania.



assessing available water in rainfed agriculture and the concomitant strategies to cope with bad seasons. It was interesting also to quantify the attitudes of farmers towards the value of land with respect to access to water. In irrigated agriculture the emphasis was to assess the criteria used by farmers in the selection of crop enterprises, which fetches relatively higher productivity of water among the strategies of other farmers to enhance productivity of irrigated agriculture. A total of 428 household respondents were interviewed in both surveys.

Secondary data used in this study included quantities of water, river flows, rainfall data and volumes of abstraction from various reports in the study area. These were obtained from village government offices, Mbeya Zonal Irrigation Office, Rufiji River Basin Office in Mbarali, Mbarali and Mbeya district agricultural offices. Others were obtained from the Tanzania Meteorological Agency office (Dar es Salaam), Agricultural Training Institute, Igurusi, and Agricultural Research Institute, Uyole, which are both in Mbeya.

The value of water in the domestic sector was estimated using the two methods, the first one entailed the use of market prices for water and the second one used the Contingent Valuation (CV) approach. The first method had used the current market prices as charged by local sellers, who carry water from sources to the villages (as at Uyole, which represents the upper MSC), at US\$0.02 per bucket of 20 litres (equivalent to US\$1 per m<sup>3</sup>). The same price is also charged to cover the maintenance and operation costs of the two wells drilled by the SMUWC project in Ukwaheri village and Lutheran Church in Madundasi, respectively (both in the lower MSC).

In the second method the study adopted the use of the Willingness to Pay (WTP) approach. Households were asked individually how much they are willing to pay for an improved water supply. This involved the use of a direct, open-ended question such as: “What is the maximum amount of money they would be willing to pay (for improved domestic water supply)?” In addition, the respondents were given specific choices requiring a “yes” or “no” answer. The questionnaire was designed in the form of a bidding game with several options for combining open-ended and “yes” or “no” questions. This approach was specifically used in the lower MSC where water resources are scarce especially during the dry season and where villagers often walk long distances in search of water for their domestic needs.

The data collected were summarized, coded and the Statistical Package for Social Science (SPSS) computer software was used for analysis. Descriptive statistics such as frequencies, means and cross-tabulations were used to display the results. Structural analysis was employed in the analysis of documented information and qualitative data collected during the PRA sessions. The information generated by interviews, focus group discussions and observational data was described and summarized.

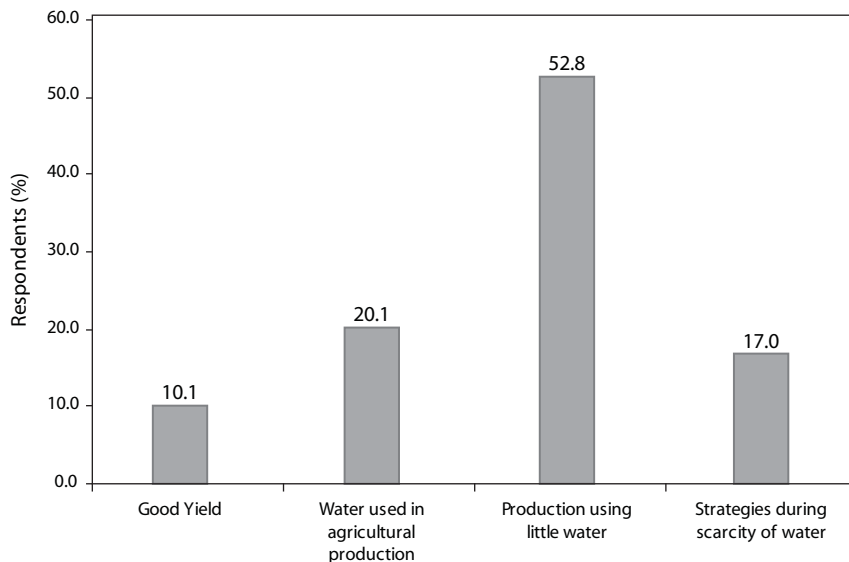
## CHAPTER 3

### RESULTS AND DISCUSSION

#### Farmers' Understanding of Productivity of Water

Farmers in the Mkoji sub-catchment have an understanding of productivity of water. They define productivity of water with reference to the yield from their fields, which to them is dictated by the amount of rainfall. In a 'wet year' (a year when rainfall is above average: 760 millimeters (mm)), farmers consider productivity of water to be high. But when seasonal rainfall is below average, farmers consider productivity of water to be low. Results of the understanding of farmers about productivity of water in the Mkoji sub-catchment are shown in Figure 2. These results show that approximately 53 percent of the farmers interviewed understood productivity of water as efficient utilization of water, while approximately 10 percent of the farmers interviewed understood productivity of water as having a good yield. To the farmers, a good yield means a harvest of approximately 2.5-3.5 tonnes per hectare (t/ha) of cereal crop. Approximately 20 percent of the farmers interviewed understood productivity of water in the light of the importance of water in agricultural production, while 17 percent perceived productivity of water as the coping strategies during scarcity of water. All of these understandings carry the context of benefits of water used.

Figure 2. Farmers' definitions of productivity of water in Mkoji sub-catchment.

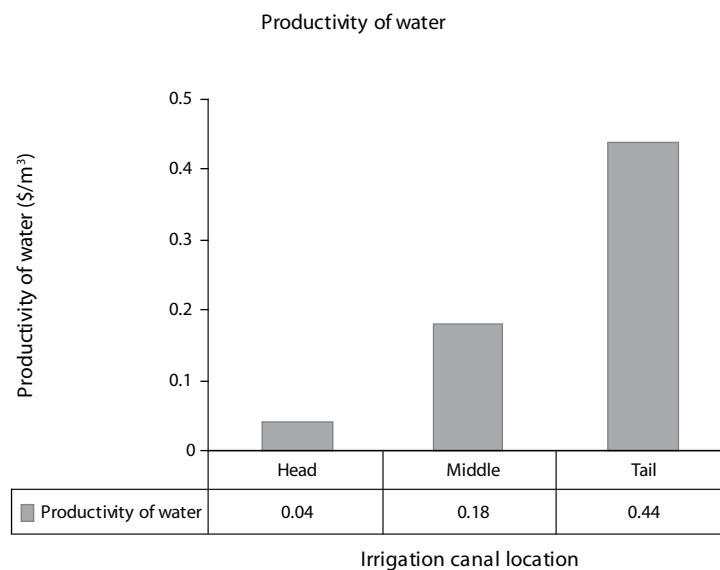


Although the results show that there is a higher percentage of farmers who understand productivity of water to mean efficient utilization of water, the primary focus is yields. Generally, this understanding of the farmers may seem to be similar to the general stakeholders' perceptions of productivity of water, especially the International Water Management Institute (IWMI) concept of 'crop per drop'. However, the farmers' perceptions of 'good rain = good yield' or 'more access to water = high productivity' somehow contradicts the IWMI 'crop per drop' concept. Crop per drop entails producing more crops with less water. The farmers' 'good rain = good yield' can be

translated as the farmer needing a substantial quantity of rain to produce a good crop. If there is limited access to water then fewer crops will be produced and productivity of water (according to farmers) will decline. The farmers' emphasis, in this context, is access to water and not water use efficiency. If there is any rise in productivity due to water use, it is not intentional but situational. For example, in the case of dry season irrigation, and in locations where water is scarce, farmers tend to use little water by using hand carry buckets to irrigate high value crops, resulting in high productivity of water. However, where there is an ad-lib supply of water, farmers tend to use more than they need for crop production resulting in low productivity. Figure 3 shows a typical example of low productivity of water at the head of an irrigation canal as compared to high productivity at the tail end of an irrigation canal. At the head of a canal, access to irrigation water is high tempting farmers to use water carelessly. However, at the tail end of a canal the strategy of farmers is to use the water carefully and to sometimes produce valuable crops. A good example of luxurious water use by farmers can be cited from Kongolo Mswiswi and Luanda Majenje schemes located upstream of Mswiswi and Lwanyo rivers. Kossa et al. (2005) found that in 2003/2004 these schemes abstracted more water for paddy irrigation (2.689 and 4.3 l/s/ha by Kongolo Mswiswi and Luanda Majenje schemes, respectively) than the 1.68 l/s/ha (SMUWC 2001), which is normally taken as the gross water requirement for paddy in the Usangu Plains.

However, most of the time farmers at the head of irrigation canal tend to get more yield than those in the tail end (Figures 4 and 5). Crops at the tail end are mostly affected by water stress causing a reduction in yield. The above discussion proves the fact that most users at the head of the canal apply more water than they need for optimum crop production. This also clarifies the farmers' paradigm of 'more access to water and high productivity' of producing to obtain a high yield and not necessarily to achieve a high productivity. Nevertheless, this should not be confused with 'more access to water' as a social index of productivity of water, which can mainly be translated as access to water for domestic and other amenities. In the farmers' paradigm of productivity of water, the emphasis is on enhancing household food security, which is also an important dimension of the social productivity of water.

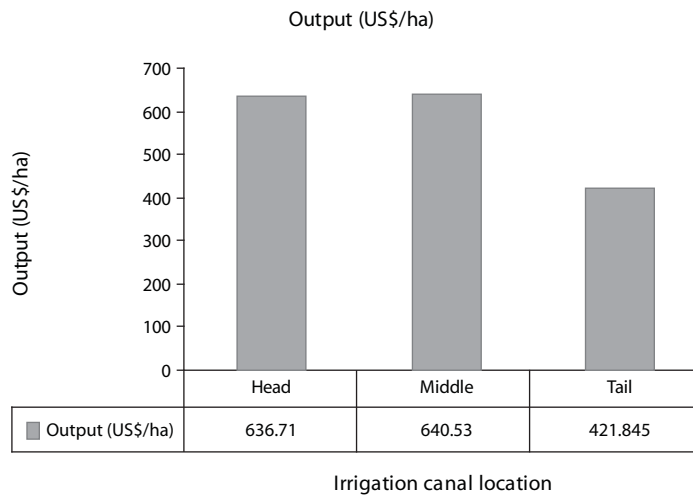
Figure 3. Productivity of water with respect to location (head, middle, tail) in the Herman Canal in Chimala River, Usangu, Tanzania.



Source: Modified from Siwale 2005

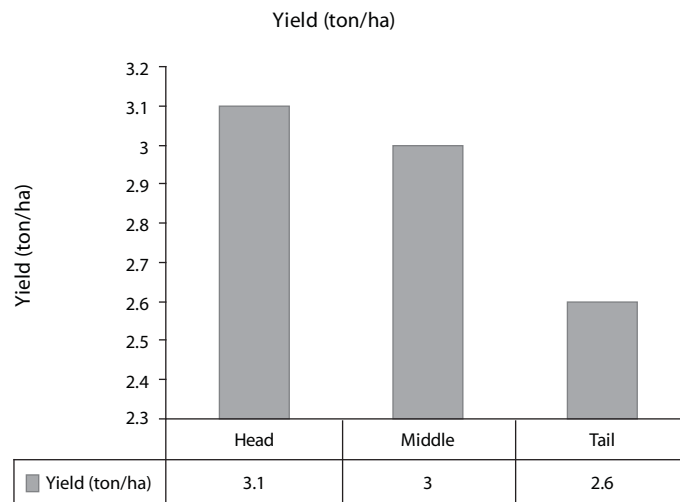


Figure 4. Output of cropped area relative to water supply along the canal in Chimala, Tanzania.



Source: Siwale 2005

Figure 5. Yield of maize along the canal in Makanya, Tanzania.



Source: Mutabazi et al. 2005

## Smallholder Farmers' Value for Water and Land

The farmers' perception of productivity of water is also reflected by the economic value they attach to water and land. In this respect, when a piece of land is close to a water source that can be easily diverted to the piece of land for crop production, then the value of that land is high. This is reflected in the actual renting cost and willingness to pay the rent prices as presented in Figure 6. The results indicate that the highest renting price and willingness to pay the rent price were US\$45/ha and about US\$40/ha, respectively, for land located on the head and tail end of the irrigation scheme. It is interesting to note that land at the tail end of an irrigation scheme is assigned a similar renting value to land with no access to irrigation water (which is equivalent to a plot of land used under rainfed conditions). This fact explains the high renting cost and the willingness to pay more for a plot of land at the head of the irrigation scheme.

Smallholder farmers also value land differently based on its suitability for rainwater harvesting (RWH). Whether it is purchasing or renting, the value of land declines as access to water diminishes. Results in Figure 7 show that plots with access to runoff water commanded higher prices and rental values compared to the plots which are completely rainfed. This is because farmers get higher returns from land under RWH than land that is purely under rainfed agriculture. For example, Mutabazi et al. (2005) found that higher returns were obtained from land that was under rainwater harvesting rather than from land that was purely under rainfed agriculture in Makanya, Western Pare Lowlands in the Kilimanjaro Region (Figure 8). According to SWMRG (2005), arable lands, which are near water sources in Makanya, Western Pare Lowlands, are highly valued to the extent that farmers are not willing to hire them out or sell them.

Figure 6. Cost of renting land with respect to access to water and soil moisture.

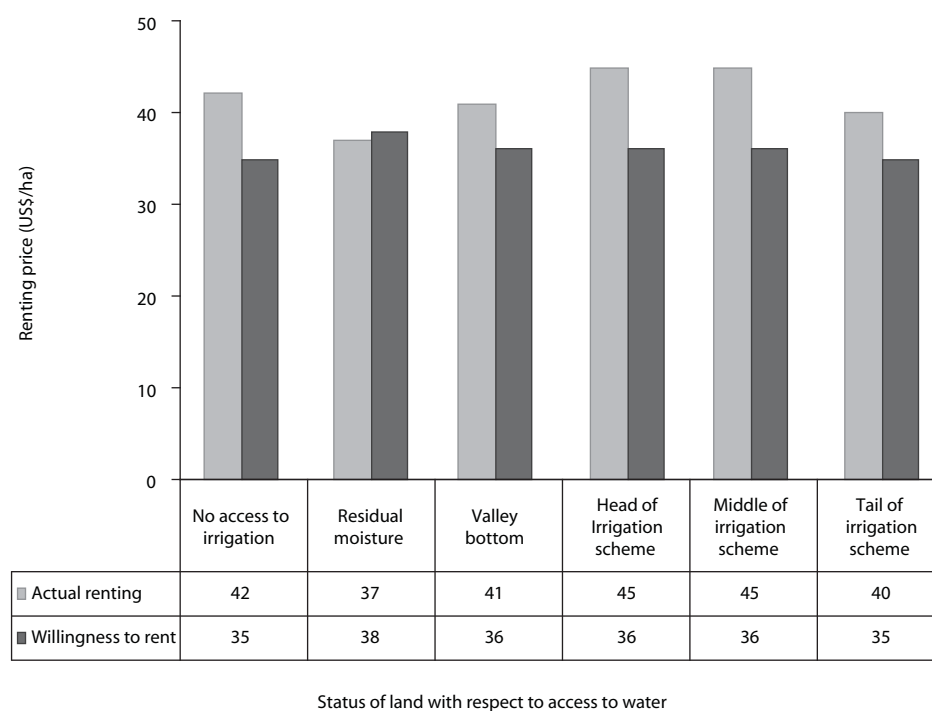


Figure 7. Price and rental value of land with respect to suitability for rainwater harvesting.

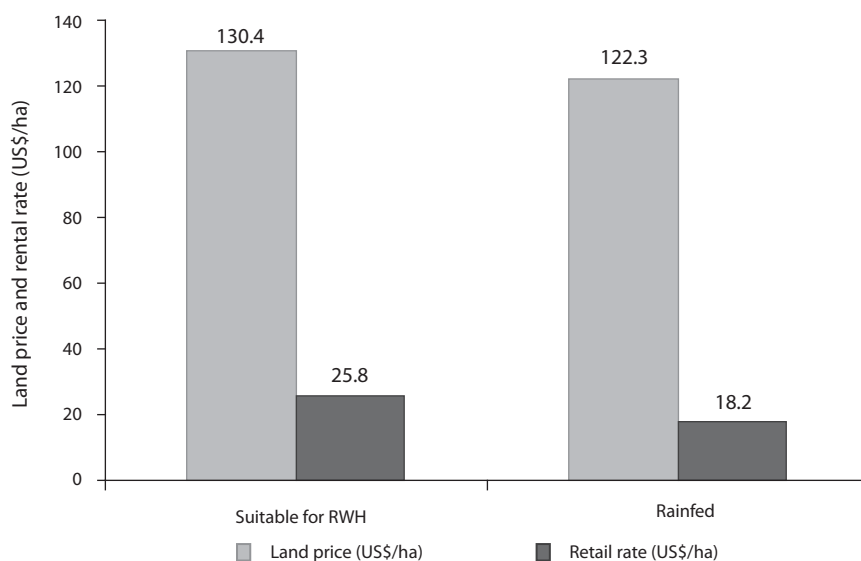
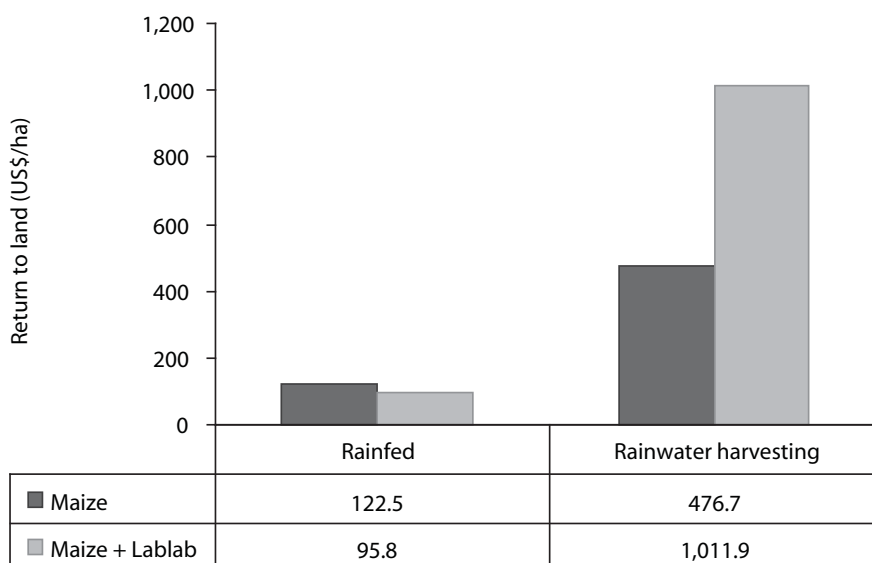


Figure 8. Return to land from maize and lablab under rainfed and rainwater harvesting.



Source: Mutabazi et al. 2005

### Value of Water for Domestic Use

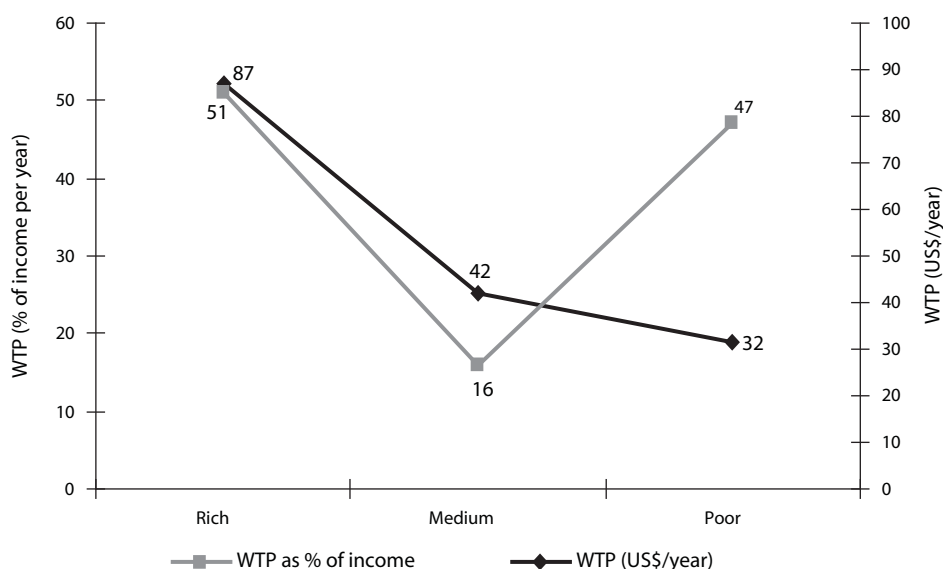
Farmers can also put a monetary value for water through market pricing or willingness to pay. Using both market pricing and WTP methods, farmers put a value of US\$0.02 per bucket. The price of US\$1 per m<sup>3</sup> was, therefore, adopted in the calculation of the value of water in the domestic sector. This value was estimated at US\$1.7 million per year, equivalent to US\$12 per person per year, for the whole of the MSC (Table 2).

Table 2. Values of water used for domestic purposes in the MSC (US\$).

Mkoji zones	Household consumption (m <sup>3</sup> /hh/day)	Domestic water (Mm <sup>3</sup> /year)	Total volume of water (Mm <sup>3</sup> /year)	Value of water (US\$/m <sup>3</sup> )	Value of water (million US\$/year)	Value of water (US\$/person/year)
Upper	0.131	0.76	1.7	1	1.7	12
Lower	0.175	0.73				
Middle	0.143	0.23				

The WTP results showed a positive correlation between wealth and WTP for their essential water needs (during the dry season) with the correlation coefficient of 0.715 ( $P < 0.05$ ). The correlation between wealth and WTP was the strongest in both villages, Ukwaheri and Madundasi. As expected, the respondents from wealthier households were willing to pay more than those from poorer households, making a link between WTP and ability to pay (ATP). However, some respondents indicated that although they could not afford paying much in monetary terms, they would be able to contribute in other ways (e.g., providing family labor for O&M of the water borehole pump). In other words, this illustrates how their desire for an improved water service is not only expressed in their stated financial WTP, but is also expressed as a willingness to draw from their only and most valuable capital (i.e., family labor). On average, the poor ('very poor' and 'poor' households) spend about 47 percent of their income on water for domestic use, whereas the rich ('very rich' and 'rich' households) spend about 51 percent (Figure 9). Similarly the rich spend more money on domestic water (i.e. 87US\$/year) than the poor (32US\$/year).

Figure 9. Willingness To Pay and proportion of income spent on water for domestic uses in the Lower MSC.



During the dry season, the households in the distant sub-villages (e.g., Msisi – in Ukwaheri and Mwashota in Madundasi) spend about 6.5 hours, on average, walking from their homestead to the water source (mainly the borehole pumps). One would logically expect that households that have to walk long distances for water collection (in the dry season) would be willing to pay more for an improved water supply than those with an immediate supply of water source irrespective of their wealth, but the WTP results indicated that this was not the case. In Ukwaheri sub-village, where the borehole water pump is located, the average WTP for an improved water supply was relatively higher in almost all wealth classes than in Msisi sub-village (which is located about 10 kilometers (km) from the water pump). Households in the Ukwaheri sub-village are willing to pay almost twice as much as the households in the Msisi sub-village with values of US\$0.025 and US\$0.014, respectively. During the PRA exercise the participants in the Ukwaheri sub-village remarked that they would be willing to pay even more in order to get additional boreholes.

### **Conflicts and Struggling for Water**

Due to farmers realizing the value of water, they have always been in a struggle over getting better access to it in order to sustain crop production. Farmers are ready to fight and steal water as long as it is the only alternative to get water. There are several instances of fighting and stealing water recorded in the Mkoji sub-catchment. These are presented in terms of conflicts occurring in the upper, middle and lower parts of the catchment.

#### ***Upper and middle Mkoji sub-catchments***

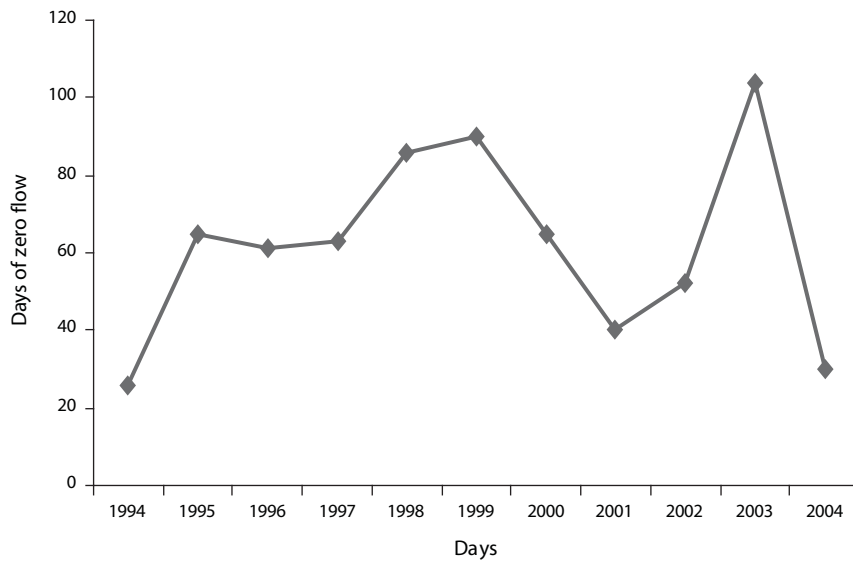
The types of conflicts that occur in these sections of the sub-catchment are the same because of the similarities in the production domains. The upper zone of the MSC is highly populated and has high rainfall, deep soils and intensive agricultural production. In this zone, both rainfed and some irrigated agriculture is practiced. The rainfall pattern and the types of soil allow for crop cultivation all year round. Similarly, the middle zone is engaged in intensive rainfed and irrigated agriculture. However, it is characterized by a high concentration of traditional irrigation systems as well as improved traditional systems. Dry season irrigated agriculture is an important means of livelihood. Therefore, this is an area of high competitive water demand and hence persistent water conflicts. Due to a high abstraction of water by the irrigation schemes, all the rivers draining the Mkoji sub-catchment, including the Mkoji River itself, are perennial during the dry season upstream of the Upper Mkoji. However, a few kilometers downstream, all these rivers dry up and are perceived as seasonal. The dry season irrigated agriculture uses all the water that would have kept the rivers flowing during the dry season. This causes severe water shortages in the downstream areas mostly for domestic and livestock uses. However, this also causes drying of the downstream part of the Great Ruaha River, thereby limiting water availability for the Ruaha Game Reserve and the Mtera Kidatu hydropower generation system. Figure 10 shows the days of zero flow in the river from 1994 to 2004. Among the other effects of the drying of the downstream part of the river is that livestock keepers tend to move their livestock in search of water and green pasture upstream, which results in the occurrence of water use conflicts with farmers in the upstream part of the river. Water use conflicts have devastating effects of lowering productivity of water.

The frequency of occurrence of conflicts is therefore considered as a proxy to the value of water. Table 3 shows the frequency of occurrence of conflicts in the upper and middle sub-catchments of Mkoji. The conflict with the highest frequency of occurrence (60) in the upper section of the MSC was between farmers stealing irrigation water when their turn to irrigate had passed. The most dominant conflict (54%) in the middle Mkoji sub-catchment involved pastoralists driving their livestock in search of water and thus destroying crops and irrigation structures. Livestock keepers consider water as very vital for their livestock, hence their reason to search for water anywhere irrespective of the damage that the animals might cause.

### *The Lower Catchment*

In the lower Mkoji sub-catchment the major production domain is agropastoralism. Therefore, in this area the conflict with the highest frequency of occurrence (80%) was observed to be between pastoralists and irrigators (Table 4). Such conflicts occur when the pastoralists drive their livestock in search of water and destroy crops and irrigation structures. It is also interesting to note that conflicts in the lower zone mostly involved livestock keepers, since this is where there is the highest population of livestock.

*Figure 10. Days of zero flow in the Great Ruaha River in the Ruaha National Park between 1994 and 2004.*



*Table 3. Frequency of incidents of conflict in the Upper and Middle Mkoji sub-catchments.*

Sectors involved in conflicts	Source of conflicts	Frequency of occurrence	
		Upper MSC	Middle MSC
Irrigation vis-à-vis domestic use	Farmers diverting water from irrigation canals and denying others access to water for domestic use	11 (12%)	2 (4%)
Irrigation vis-à-vis livestock	Pastoralists driving their livestock in search of water and thus destroying crops and irrigation structures	10 (11%)	30 (54%)
Upstream irrigators vis-à-vis downstream irrigators	Farmers stealing irrigation water, when their turn to irrigate has passed	60 (64%)	15 (26%)
Upstream irrigators vis-à-vis downstream non-irrigators	Upstream irrigators abstracting all the water and thus denying farmers and livestock keepers downstream of access to water	12 (13%)	10 (16%)
Total		93 (100%)	57 (100%)

*Table 4. Frequency of incidents of conflict in the Lower Mkoji sub-catchment.*

Sectors involved in conflicts	Source of conflicts	Frequency of occurrence
Irrigation vis-à-vis livestock	Pastoralists driving their livestock in search of water and thus destroying crops and irrigators	40 (80%)
Livestock vis-à-vis livestock	Pastoralists denying others access to water	10 (20%)
Total		50 (100%)

Through river basin dialogues held among stakeholders it was found that productivity of water can be increased through mitigating incidents of conflicts by:

- Strengthening water user associations at the apex, system and canal levels, so that agreements and byelaws are meaningfully introduced and implemented. This is in line with the National Water Policy (URT 2002), which emphasized on water management based on local catchment organizations under the basin water officer. Fortunately, the Rufiji Basin Water Office (RBWO) is planning to review the water rights to match supply, upstream and downstream requirements with a strategy of bulk volumes of water allocation for each sub-catchment, giving the apex water user committees the responsibility for distributing water among authorized intakes in the river system(s) under their jurisdiction. In this case the water user associations will have sufficient authority to mitigate conflicts.
- Implementing the Legal-Infrastructure Framework for Catchment Apportionment (LIFCA), proposed by RIPARWIN (2006a), so as to align water licence quotas (as formal allocative instruments), with informal, customary water agreements and the physical design of irrigation intakes. This synergy will provide an opportunity to help set the upper maximum volumetric cap on irrigation abstraction during the wet season and the upper maximum proportional cap on abstraction during the dry season.

- Popularizing use of the River Basin Game (RBG) (Lankford et al. 2004) as a participatory dialogue and capacity building tool, in understanding water use problems and devising water use plans that result in resolving conflicts. This has been effectively demonstrated with water users in the Rufiji and Pangani river basins in Tanzania. For example, a conflict resolution workshop held for two days in November 2004 using the RBG at Mswiswi village in the Rufiji Basin helped to resolve water problems arising in the Mswiswi sub-catchment and led to the formation of the Mswiswi apex body (RIPARWIN 2006b). The RIPARWIN project also used the River Basin Game as a participatory dialogue tool to engage stakeholders during the formation of water users associations (WUAs). For example, during the formation of the Mlowo River System apex water users association, the RBG was used during investigation and analysis of the key issues and problems in relation to water resources. The advantages observed while using RBG in the process were that the game facilitated exhaustive deliberations, discussions and resolutions on various issues concerning water availability, use and allocation. The overall result was that the task of preparing action plans to solve the identified problems was made easier.

### **Smallholder Farmers' Practices and Coping Strategies to Improve Productivity of Water**

Farmers in the Mkoji sub-catchment adopt different management practices to improve water productivity. Most of them are agronomic practices that improve agricultural productivity. Agronomic practices in the Mkoji sub-catchment include mixed cropping; intercropping, planting of drought-resistant crops, crop rotation, growing high value crops, relay cropping, mulching, timely weeding, and pest and disease management. Farmers indicated that planting drought-resistant and early maturing varieties are important strategies during bad years. The survey indicated that 39 percent of farmers preferred to reduce the area under cultivation, while 32 percent opted for planting drought-resistant crops, and 29 percent considered mixed cropping as the best option for expected bad seasons (Figure 11). Typical statements made by some of the respondents during the focus group discussion are given in Box 2. During the focus group discussions farmers reported that they use dry grass and rice husks as mulch in tomatoes, vegetables, seedbed preparations for paddy, and sweet pepper production. The most common mixed cropping system identified was maize and beans, in which both crops are planted at the beginning of the season. Similar strategies to those used in rainfed agriculture were reported in irrigated agriculture.

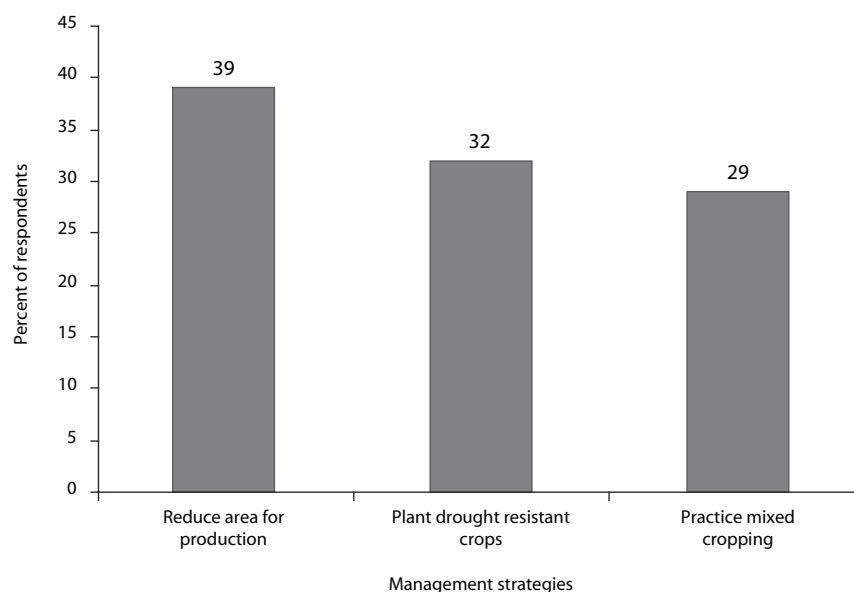
*Box 2. Mixed and relay cropping in Ukwaheri village.*

*“Due to unreliable rainfall, we have some coping strategies like planting mixed crops (sorghum, groundnuts and green gram) and planting of drought-resistant crops such as sorghum and cassava. Also, we are still growing local crop varieties because they are, early maturing and drought-resistant.”* narrated by William Mgwadila, the Executive Officer for the Ukwaheri village.

*“We practice relay cropping, whereby immediately after harvesting rice, we plant chickpeas locally called ‘dengu’ in order to exploit the available residual moisture.”* narrated by Mr. Japheth Shilunga in Ukwaheri village.



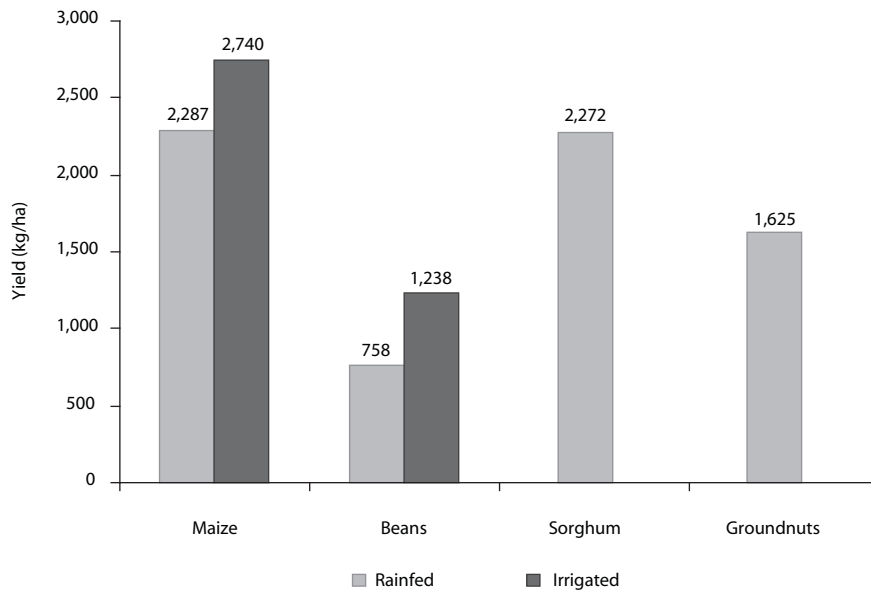
Figure 11. Management strategies for poor season risks in Mkoji sub-catchment.



In the Mkoji sub-catchment, farmers practice crop diversification as a strategy to mitigate risk of crop failure. The farmers cultivate cereals and legumes such as maize, sorghum, millet, beans and groundnuts, either as mono-cropping, mixed cropping or intercropping. In the past, maize cultivation under rainfed agriculture was more popular than other crops. However, as a result of dry spells, which occur at the mid crop-growing season and causes crop failure, there is a gradual shift from maize to beans, which have a shorter growing season. In the 2002/2003 cropping season, about 72 percent (23,079) of the households in the Mkoji sub-catchment cultivated maize on about 2,300 hectares (ha) under rainfed conditions, while about 36 percent (11,443) of households cultivated 1,304 ha of maize during the off-season using irrigation. Forty two percent (13,415) of households cultivated 1,183 ha of beans during the rainy season and about 35 percent of households (11,090) cultivated a total of 726 ha of beans during the dry season under irrigation. Millet and sorghum is increasingly cultivated because these crops have the capacity to withstand moisture stress. About 9 percent (2,735) of the households in the sub-catchment cultivated 3,997 ha of sorghum and millet, which were grown in the marginal parts of the sub-catchment. Figure 12 show average yield data for maize, beans, sorghum and groundnuts in the MSC. In the Upper Mkoji, farmers were also found using the residual moisture to cultivate different types of vegetables that have higher market values.

These strategies are quite rewarding to farmers. For example, a farmer in Ukwaheri village who practiced relay cropping harvested about 230 kgs of chickpeas after getting 15 bags of paddy rice in the main season. He sold chickpeas at US\$1 per kg and used the proceedings to roof his house. It was also found that even in an average rainfall season farmers who grow sorghum get up to 3.6 t/ha as compared to 1.2 t/ha for maize in the Lower MSC. This sorghum yield is sufficient to meet most household food requirements.

Figure 12. Yield of maize, beans, sorghum and groundnuts in MSC.



### Farmers' Practices to Estimate Water Use

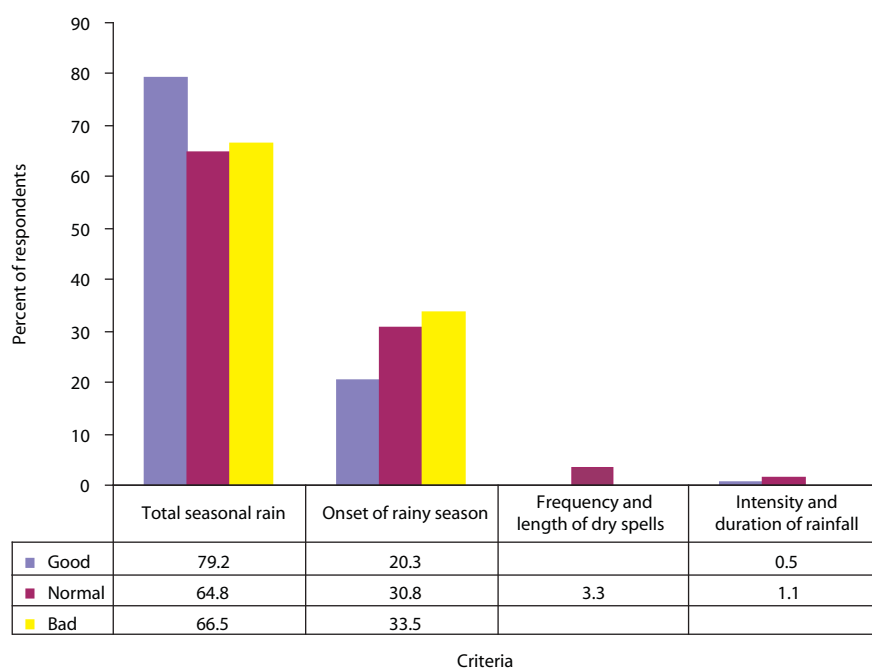
Farmers consider water as an important input in agricultural production. Nevertheless, they do not express the water use as quantities or volumes, but instead they rather use relative expressions. In rainfed agriculture farmers estimate the amount of water that is available for the season by expressing the season as good, normal or bad (Table 5). They base these estimates on the frequency and intensities of storms and whether seasonal crop demand has been satisfied or not. Results from the survey that was carried out in the Mkoji sub-catchment indicated that smallholder farmers classified a season as good, normal or bad using the following criteria: (i) total seasonal rainfall and crop performance; (ii) late or early start and end of rainfall; (iii) length and frequency of dry spells; and (iv) intensity and duration of rainfall (Figure 13). The first two criteria are given more weight in the seasonal classification process.

Before the start of a cropping season, farmers forecast the forthcoming season based on experience and make decisions and plan on appropriate strategies to deal with the expected seasonal condition. Figure 14 shows two important criteria that farmers use for forecasting the forthcoming season in the Mkoji sub-catchment. The first is the early flowering of trees locally known as '*mikusu*' (*uapaca kirkii* sp) and mango trees (*mangifera indica* sp.) The second criterion is high temperatures observed during the months of August and September. The flowering of trees was found to be the most important criteria whereby 75, 72, and 59 percent of farmers used it to predict good, normal and bad seasons, respectively. About 67 percent of the farmers indicated that they plan their strategies in advance using one or all of the above criteria (Figure 15).

Table 5. Criteria used by farmers for classifying seasons in the Mkoji sub-catchment

Classification of season	Criteria used by farmers
Good	Early or timely onset of rainfall, high rainfall amount, prolonged rainy season, occurrence of dry spells not exceeding 5 days and good crop performance.
Normal	Average rainfall, moderate rainfall intensities and prolonged season
Bad	Little total amount of rainfall with dry spells exceeding three weeks resulting in severe moisture stress and poor crop performance

Figure 13. Criteria used by smallholder farmers for classifying rainfall seasons in the Mkoji sub-catchment.



The focus group discussions revealed that the methods and techniques used by farmers to estimate and manage water under irrigation have, to a greater extent, a strong bearing on the types of abstraction structures. In most of the traditional irrigation schemes, flow-measuring devices are lacking at intakes and therefore visual estimation is used to assess and evaluate the available water in the system. These estimates are then used for planning irrigation schedules. In the traditional irrigation systems where there have been external interventions such as by the Government or programme support, staff gauges and flumes are provided and used for measuring water flows. Trained gate operators read the staff gauges in order to know the amount of flow. The information is used as a basis for determining the opening or closing of the gates and for planning irrigation schedules.

Many farmers in the study area operate home gardens and cultivate high value crops in valley-bottoms during the dry season. The crops grown include onions, tomatoes, leafy vegetables, carrots and maize. These crops are manually irrigated using simple tools such as buckets and jerry cans. During the focus group discussions, some farmers informed that they keep records of the number of buckets of water they use in irrigating their crops. For example a farmer at Mahongole village reported that he used 25 buckets of water per day (one bucket has a capacity of 20 liters) to irrigate a 0.1 ha field cropped with maize during the dry season. Another farmer in Mwatenga village informed that he used 30 buckets per day.

Figure 14. Criteria for predicting a forthcoming rainfall season in the Mkoji sub-catchment.

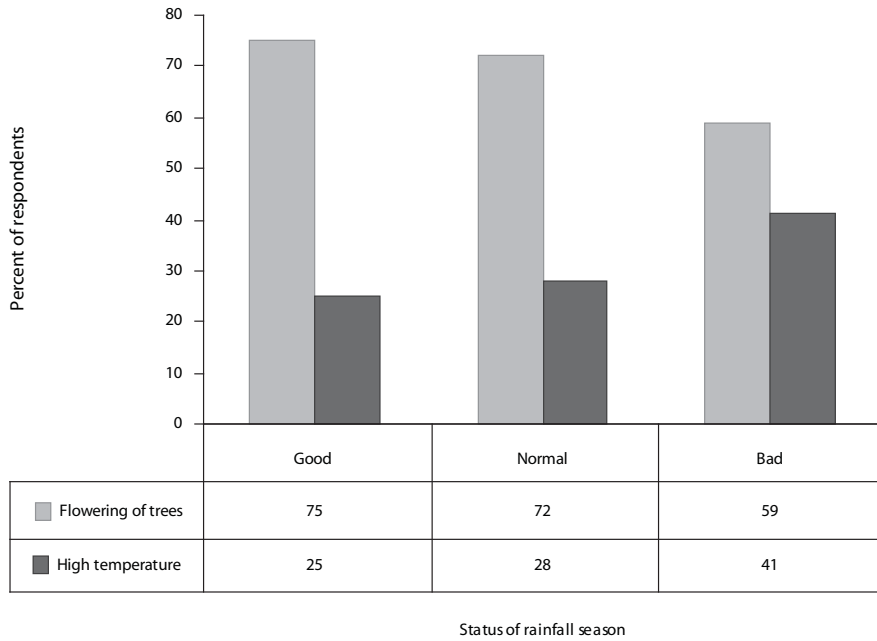
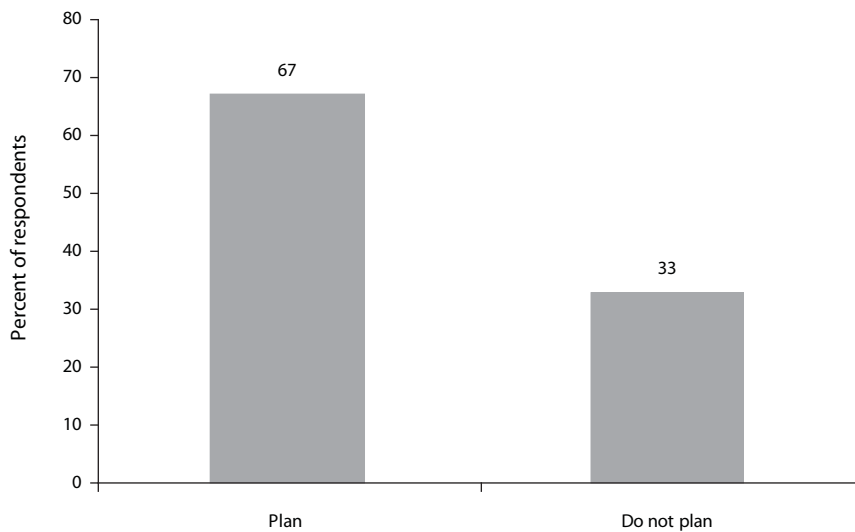
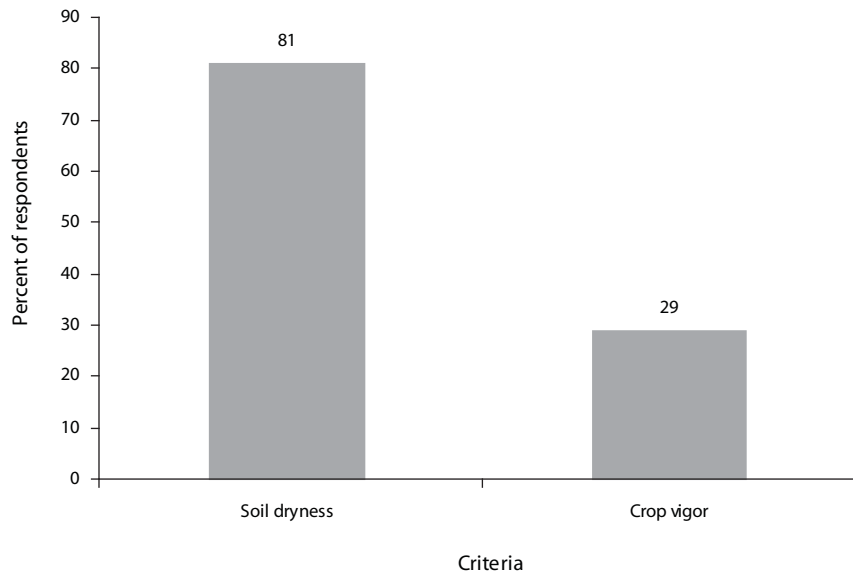


Figure 15. Percentage of farmers planning in advance for a forthcoming season.



Results from both focus group discussions and the questionnaire survey showed that farmers use two criteria to determine when to irrigate. These are: (i) crop vigor, and (ii) soil dryness (Figure 16). In the first criterion farmers observe indications of leaf and shoot wilting, whereas in the second criterion they observe degrees of dryness of the soil such as the appearance of cracks. Some farmers use a hand hoe and stick in the soil to assess dryness. A stick is normally driven into the soil by an experienced person who assesses the dryness of soil as proportional to penetration resistance. An experienced person can also tell the dryness of the topsoil by observing a scooped soil. It was found that both criteria are important, but the majority of farmers (81%) use dryness of the soil as an indicator of when to irrigate (Figure 16).

Figure 16. Criteria used by farmers to decide when to irrigate.



It is evident that there is a very strong link between the farmers' conceptual understanding of water productivity with their actions in order to achieve higher water productivity. For example, a simple analysis showed that farmers' classification of rainfall seasons agrees closely with the real situation. Figure 17 shows the assessment of farmers of the seasons between 1993/1994 and 2003/2004. When seasonal classification assessment was compared to the total annual rainfall recorded at Mbarali weather station, there was a good agreement in terms of farmers' assessment of good season and the corresponding total annual rainfall. Similarly, the bad seasons had correspondingly low total rainfalls.

Farmers further made an analysis of the frequency of occurrence of rainfall seasons. Figure 18 shows the frequency of occurrence of good, normal and bad rainfall seasons as reported by farmers in the study area. The results indicated that most farmers (approximately 62%) reported that a good season occurs once in five years while a bad season occurs twice in every five years. This also corresponds to the typical situation of the semi-arid rainfall characteristics found in East Africa. As discussed earlier, seasonal forecasting is another method used by farmers to estimate the forthcoming rainfall season so that they can make appropriate agronomic decisions. In this way, farmers can always assess productivity of the expected rainwater at the beginning of the season.

Another area where farmers have shown their conceptual understanding of water productivity and the coping mechanisms is in the area of assessing soil moisture for planting. At the onset of a season, though difficult to decide on the time of planting, which is very crucial for the ultimate yield and productivity of water, the farmers have devised checking mechanisms other than seasonal forecasting to assess the situation and make appropriate decisions. They use either a hand hoe or a stick to dig or pierce into the soil to assess the depth of wetting after a heavy storm (Box 3). With experience, a decision to plant is reached for land preparation or planting.

Whenever farmers forecasted drier conditions at any particular period during the season, they devised coping strategies. For example, during the stakeholders' consultation dialogue, participants agreed on a reduction of irrigated land and water use rotation in the dry season. Participants in the focus group discussions suggested that after the formation of WUAs, it would be easy to agree on

Figure 17. Farmer assessment of the seasonal conditions and actual rainfall recorded at Mbarali meteorological station and yield averaged from Mbarali District Agricultural Office production figures.

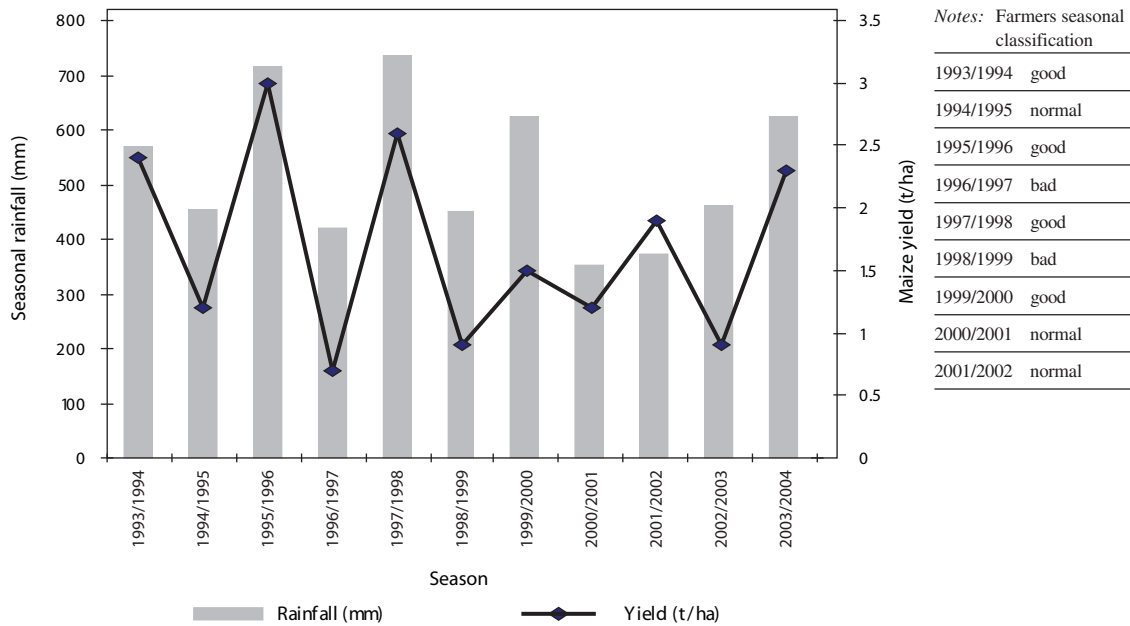
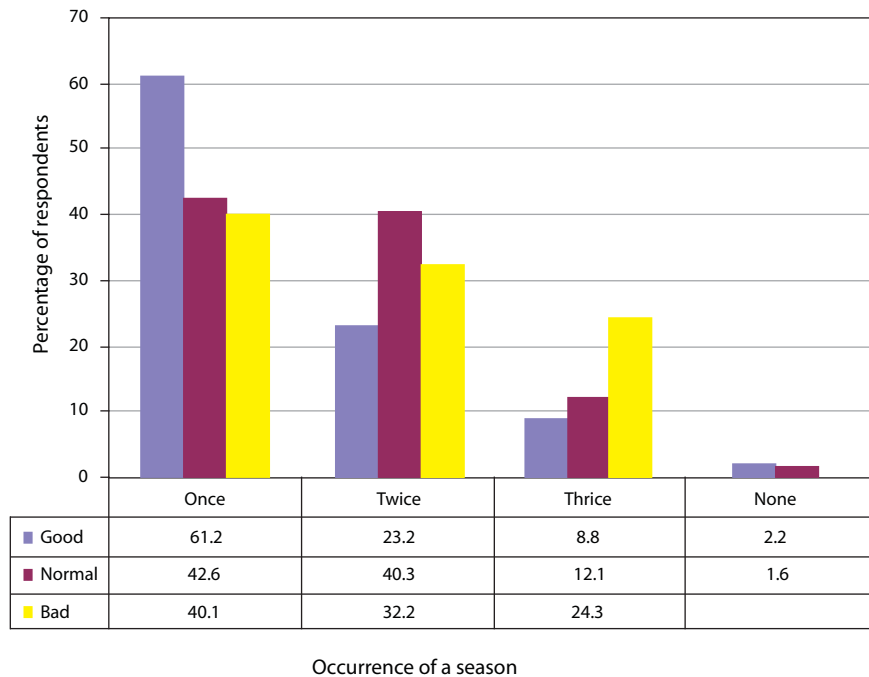


Figure 18. Frequencies of occurrence of good, normal and bad rainfall seasons in five years.



the area to be cultivated in the dry season taking into consideration the available water resources. At both Ipatagwa and Inyala villages, farmers agreed to cultivate only quarter of an acre during the dry season as a strategy to use the limited water resources.

The majority of farmers in the study area regard farming as a business whereby they expect to make a profit. They, therefore, record benefits from water in terms of crop yields and cash outcomes. The crop yield is normally recorded in terms of tins, bags or crates over the cultivated area. The measurements are arbitrary and can be of different weights. From the focus group discussions farmers indicated that they normally use bags to measure the grain yield, especially when they get a bumper harvest (Table 6). If yields are low, they use tins to express the yields. In the case of vegetables such as tomatoes and cabbages they use crates locally called *matenga*.

From the above discussions, it seems that the actions of farmers aim at achieving high water productivity while responding to drier climatic conditions at the same time. Farmers acknowledged the need to achieve a high productivity of water. Furthermore, they were quite aware of crops like sorghum, which can withstand high water stresses, and produce good yields, but the financial returns were low. This is contrary to crops like beans which have the highest financial returns, although the crop requires more water. As a mitigation measure to the seasonal droughts, many farmers recommended the construction of water harvesting structures such as charco dams for the purpose of increasing water supplies especially during periods of water shortages.

*Box 3. Responses from Farmer focus group discussions at Mahongole village on the assessment of soil moisture for a decision to plant cereals after the onset of rains*

‘An experienced person uses a hand hoe to cut deep slices or chunks of soil to estimate the depth and extent of wetting by the rain. If depth of wetting is more than depth of hand hoe then the soil is said to have sufficient moisture for land preparation and planting’.

OR

‘An experienced person drives a strong long stick after a heavy rainfall at the start of the season. A depth of wetting is sufficient for land preparation and planting when the stick can go at least 20 centimeters (cm) deep.’

*Table 6. Rainfed crop yield in good years.*

Crop	Yield (bags/acre)	Yield (kg/ha)	Conversion factor	Price per bag (US\$)	US\$/ ha	*\$/m <sup>3</sup>
Maize	10-14	2,250-3,150	1 bag = 90 kg	16	140	0.019
Beans	3-4	750-1,000	1 bag = 100 kg	54	635	0.086
Groundnut	10-16	1,750-2,800	1 bag = 70 kg	10	400	0.054
Sorghum	7-8	2,625-3,000	1 bag = 150 kg	8	160	0.022
Irish potato	30-40	13,500-18,000	1 bag = 180 kg	8	800	0.11
Paddy	10-14	3,000-4,200	1 bag = 120 kg	20	700	0.095

*Source of data:* Field Survey 2003

*Note:* \* Based on an average of 734 mm of rainfall in a good year

## CHAPTER 4

### SYNTHESIS

The subject of productivity of water propagated by researchers and stakeholders in water and agricultural issues may seem new to smallholder farmers. However, this paper reveals that the concept of productivity of water is not entirely new to farmers in the Mkoji sub-catchment. Farmers in the area have their definitions of productivity of water and how they quantify it. Furthermore, farmers judge productivity of water based on the amount of rainfall and its influence on their yields. Productivity of water is high or low if the average seasonal rainfall is 'good' or 'bad'.

Farmers value water very much because they know that crop yield is related to water, all other things being equal. They will, therefore, do anything including 'fighting and stealing water' if the need be, to get access to it. They are willing to pay more for a plot of farmland if it is close to a water source that they can easily divert to irrigate their fields, or if the field is upstream of an irrigation scheme where they have the advantage of a better service of water delivery. Those who sell or rent plots of farmland put higher fees to plots of land where there is easy access to water. Farmers who value farmland do so relative to water. Thus, a plot of land at the tail end of an irrigation scheme carries almost the same value (if it is to be rented) as a plot of land where there is no access to irrigation water.

Farmers in the Mkoji sub-catchment know that they can maximize productivity of water. To them, the idea of productivity of water is all about effective utilization of water. Their actions aim at both, to achieve water productivity and to respond to a drier climate. For example, ahead of the cropping season, they attempt to forecast what the seasonal conditions will be. Based on the forecast, they strategize and plan to get the optimal yields out of the season. They are very conscious of the amount of water they use in crop production, even though they do not keep records. They have good visual capability to estimate available water and how it can be shared across the season to maximize yield.

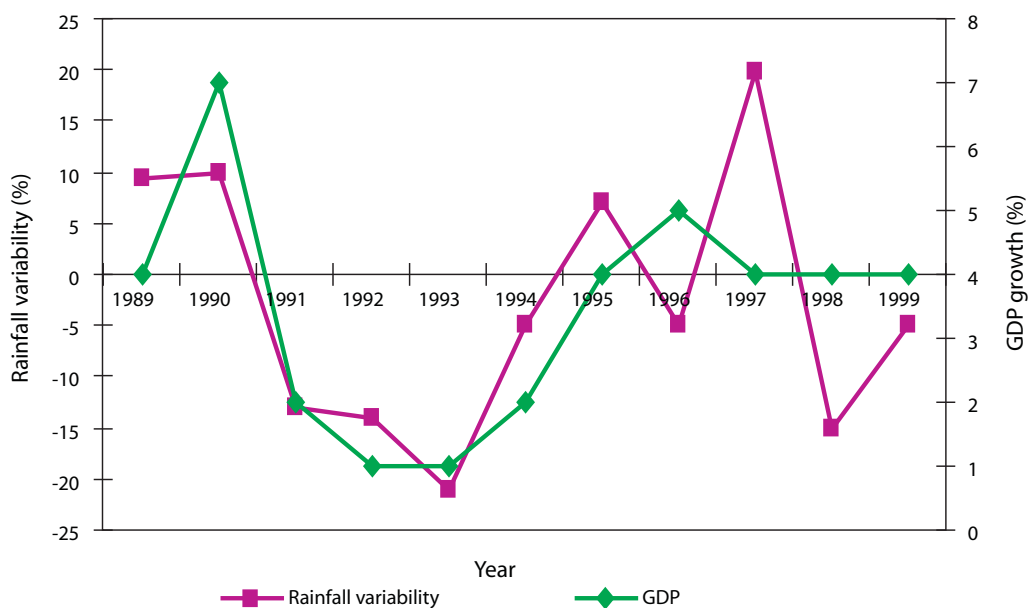
To this effect, it would be correct to conclude that the concept of productivity of water has been part of the smallholder farmers' cropping philosophy in Mkoji. What is important to the farmer, therefore, is not the theories and figures of productivity of water, but effective approaches to enhance their ability to effectively utilize water and to maximize production. The tillage methods, agronomic practices and crop diversification approaches by the farmers, and to maximize yield from available water, are good points to start with in formulating effective measures to improve productivity of water at the farmers' level. The inadequate understanding of the smallholder farmers' ways of coping with limited water resources, and the lack of technologies and management approaches that goes with their understanding makes the task of achieving gains in water productivity daunting. There is, therefore, a strong need for an in-depth understanding of farmers' practices to determine which are the most effective, economical and sustainable in increasing productivity of water, and thereby formulate approaches for adaptation, uptake and upscaling.



However, all this wealth of farmers' knowledge on productivity of water has not been translated into getting high productivity of water, at least close to the potential yield and hence approaching optimum productivity of water. Most farmers produce at subsistence level. The release of high yielding varieties (e.g., with maize, a potential yield of up to 12 t/ha) by the local research firms have had an insignificant impact in raising productivity as evidenced in the popular green revolution. For example, figure 17 shows that, on average, farmers in Mbarali District never exceeded a yield of 2 t/ha between 1994 and 2004. This yield is less than 20 percent of the potential maize yield in the area. In such a situation, non-water factors, such as land degradation and nutrient depletion, limit yield and crop water productivity per unit of water use (Tanner and Sinclair 1983). Much effort should, therefore, be directed to enhancing farmers' practices into management options to improve soil fertility. On the contrary, farmers' in the more advanced countries, such as in the Yellow River Basin in China, have little room in increasing productivity of water through an increase in yield. Much of the potential for an increase in the harvest index was met during the green revolution period (Sinclair and Gardner 1998) for common grains such as wheat, maize and rice.

Utilizing yield potential is even more important in the future, because our national economy is highly dependant on agriculture, which is also heavily dependant on rainfall (Figure 19). For example, in year 2003 the GDP growth rate of 5.6 percent was less than the projected 6.5 percent largely because of the impact that the drought had on the agriculture, manufacturing, livestock and the energy sector. On the other hand, most of the electricity (70%) is generated from hydropower plants, which are susceptible to periods of low rainfall and uncontrolled upstream water use. Low river flows into the hydropower facilities have contributed to shortage of electricity causing significant economic losses. If farmers in the upstream would have adopted better agronomic practices to double their yields, considerable quantities of water would have been released for power generation downstream.

Figure 19. The close relationship between GDP and rainfall variability between 1989 and 1999 in Tanzania.



The future needs much more insight and concerted efforts to harness and efficiently use water resources. The United Nations Economic Commission for Africa (UNECA 2000) projected that considering a population growth by the year 2025 the annual water renewal rate for Tanzania is going to drop to 1,500 m<sup>3</sup> per capita, which is below the water stress threshold. In all these sets of scenarios, the smallholder farmers are at the central role because their contribution to the national economy is large (over 80%). Also, the fact that they are the largest consumers of the renewable water resources, which if efficiently used would improve the water availability situation with effect to the national economy at large. Furthermore, considering the recent government move to develop 1 million hectares of irrigation in the coming 5 years, the farmers' practices in water use and agronomy need to be improved. If we already face water use problems in the current situation with less than 300 ha under irrigation, then we should expect more problems than successes at the end of the 1 million ha project. Unless we combine synergistically, water use efficiency aiming at high productivity of water, and better agronomic practices (to enhance soil nutrient availability), the huge investments in irrigation infrastructure will have little impact. In fact, the initial step would be to assist farmers' with training and tools to enable efficient use of the existing irrigation schemes. The priority would be to align the local knowledge of farmers and that of experts on productivity of water, with the facilitation to enable farmers' realize water use benefits and the need to share water with other users and uses in the water basin.

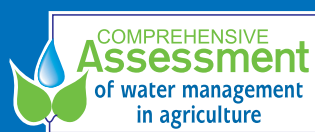


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