EVALUATION OF LIVELIHOODS AND ECONOMIC BENEFITS OF WATER UTILIZATION: THE CASE OF GREAT RUAHA RIVER CATCHMENT IN TANZANIA

By

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ABSTRACT

A study was conducted in the Great Ruaha River (GRR) catchment from mid 2002 to end of 2004 to evaluate existing livelihoods, values and benefits of water utilisation; the effect of these benefits on poverty alleviation, and the opportunity cost of water transfer from irrigated agriculture to other uses downstream. The findings showed that the values of water for livestock, brick making and domestic uses are the highest, averaging at around one US dollar per m^3 of water consumed. For irrigated paddy and dry season irrigated (non paddy) crops, the values were estimated to average at Tsh 38.6 (US $ 0.04) and Tsh 182 (US $ 0.17) per m^3 of consumed water respectively. For hydroelectric power (HEP) generation, the values of water were estimated at Tsh 226 (US $ 0.21) per m^3 of water consumed and Tsh 46.66 (US $ 0.04) or Tsh 21.37 (US $ 0.02) per m^3 of water consumed for nature conservation (i.e. for the Usangu Eastern Wetland or Ruaha National Park respectively). In terms of total net benefits, HEP generates the highest net benefits (about Tsh 247,332 or US $ 230 Million per annum). Irrigated agriculture generates annual net benefits of about Tsh 23,888 or US $ 22 Millions per annum. For domestic uses, brick making, livestock, fishery, Usangu Eastern Wetland and Ruaha National Park the net benefits were estimated at Million Tsh 1,663; 16; 186,117; 106; 41,518; and 53,297 or Million US $ 1.56; 0.01; 174.92; 0.10; 39.02; and 50.00 respectively. The decomposition analysis of total income showed that irrigated agriculture is an inequality-decreasing source of income. This implies that, ***ceteris paribus***, additional increments of income from irrigated crops will reduce the overall income inequality amongst the agrarian households in the Upper GRR catchment. The study

recommends that irrigated agriculture should not be abandoned – rather, efforts need to be directed towards identifying the potential for enhancing its water use efficiency and productivity. Achieving this would however, requires raising awareness among water users; promoting good practices; and ensuring active participation among the local communities in sustainable land and water resources management.

DECLARATION

I, Reuben Mpuya Joseph Kadigi, hereby declare to the Senate of Sokoine University of Agriculture, that this thesis is my own original work and has not been submitted for a higher degree award in any other University.

Signature ______________________ Date 17.10.2006

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DEDICATION

To my parents: *Baba* Lucas Ibrahim Kadigi and *Mama* Willickister Mbuke Nkuba for their heartfelt love, care and constant encouragement.

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ACRONYMS AND ABBREVIATIONS

AMC	Arusha Municipal Council
ASDS	Agriculture Sector Development Strategy
BoT	Bank of Tanzania
CFTC	Commonwealth Fund for Technical Co-operation
CVM	Contingent Valuation Method
CWP	Crop Water Productivity
CWR	Crop Water Requirement(s)
d.w.	dry weight
DADP	District Agricultural Development Plan
DALDO	District Agriculture and Livestock Development Officer
DANIDA	Danish International Development Agency
DEM	Digital Elevation Model
DFID	Department For International Development
DFO	District Fisheries Officer
ELRMC	Economic Long Run Marginal Cost
f.w.e	fresh equivalent weight
FAO	Food and Agriculture Organisation of the United Nations
FBD	Forest and Beekeeping Division
GoT	Government of Tanzania
GR	Great Ruaha
GRPP	Great Ruaha Power Project
GRR	Great Ruaha River

GWh	Gigawatt hour
ha	hectare
HEP	Hydroelectric Power
hh	household
HIPC	Heavily Indebted Poor Countries
HV	High Voltage
ILCA	International Livestock Centre for Africa
IR	Irrigation Requirement(s)
IWMI	International Water Management Institute
IWRM	Integrated Water Resources Management
kg	kilogramme
km^2	kilometre squared
kWh	Kilowatt hour
l/s	litre per second
LDCs	Less Developed Countries
LRMC	Long Run Marginal Cost
LV	Low Voltage
m	metre
m.a.s.l	metre above sea level
m^3	cubic metre
m^3/s	cubic metre per second
MAFS	Ministry of Agriculture and Food Security
MATI	Ministry of Agriculture Training Institute

MBOMIPA	*Matumizi Bora ya Malihai Idodi na Pawaga* (Sustainable Use of Wildlife Resources in Idodi and Pawaga)
MK	Mtera-Kidatu
MKCE	Mtera-Kidatu Combined Evaporation from the HEP dams
MKUKUTA	*Mkakati wa Kukuza Uchumi na Kuondoa Umaskini Taifa*
mm	millimetre
Mm^3	Million cubic metre
Mm^3	Million cubic metre
MV	Medium Voltage
MW	Megawatt
MWLD	Ministry of Water and Livestock Development
NAFCO	National Agriculture and Food Corporation
NCPI	National Consumer Price Index
NPES	National Poverty Eradication Strategy
NSGRP	National Strategy for Growth and Reduction of Poverty
NTFP	Non-timber Forest Products
ODG	Overseas Development Group
PMS	Poverty Monitoring System
PPA	Participatory Poverty Assessment(s)
PRA	Participatory Rural Appraisal
PRSP	Poverty Reduction Strategy Paper
PW	Productivity of Water
RBM-SIIP	River Basin Management and Smallholder Irrigation Improvement Project

RBWO	Rufiji Basin Water Office
RF	Rainfall
RIPARWIN	Raising Irrigation Productivity and Releasing Water for Intersectoral Needs
RNP	Ruaha National Park
SL	Sustainable Livelihood(s)
SLF	Sustainable Livelihood Framework
SMUWC	Sustainable Management of the Usangu Wetland and its Catchment
SPSS	Statistical Package for Social Sciences
SUA	Sokoine University of Agriculture
SWECO	Swedish Consulting Group, Stockholm
SWMRG	Soil-Water Management Research Group
T	Tonne
TAM	Total Available soil Moisture
TANAPA	Tanzania National Parks
TANESCO	Tanzania Electricity Supply Company
TDK	Turbine Discharge at Kidatu
TEV	Total Economic Value
TGI	Total Gross Irrigation
TLU	Tropical Livestock Unit(s)
Tsh	Tanzanian shilling
TVP	Total Value of Product
UGR	Usangu Game Reserve

UN	United Nations
UNDP	United Nations Development Programme
URT	United Republic of Tanzania
US $	United States Dollar
US	United States
UVIP	Usangu Village Irrigation Project
VMP	Value of Marginal Product(s)
WB	World Bank
WMO	World Meteorological Organisation
WTAC	Willingness-To-Accept-Compensation
WTP	Willingness-To-Pay
WUA	Water Users Association(s)

CHAPTER ONE

1.0 INTRODUCTION

1.1 Challenges in water management and allocation

Rivers and other surface water sources provide humans with wealth of goods and services, including the benefits accrued from irrigated agriculture, domestic uses, hydro-power generation, fishing opportunities, water supply for livestock and wildlife, employment, climate regulation, water purification, nutrient cycling, recreation opportunities and amenity value, to mention a few. According to Webb and Iskandarani (1998); Dinar and Subramarian (1997); and The United Nations (1997), however, water availability is declining in most parts of the World. This is mainly attributed to increasing demands for water exerted by rapid human population growth, and expanding economic activities. requiring water such as irrigated agriculture and industrial processes. The available information shows that, worldwide humans withdraw about 4,000 km^3 of water a year, or about 20% of the world's rivers' base-flow (Shiklomanov, 1997). Of all sectors, irrigated agriculture is often considered as the largest consumer of water virtually everywhere it is practiced. The sector is estimated to withdraw about 70% of all the global water (World Meteorological Organization, 1997). But, the same sector also plays a significant role in enhancing food security, improving livelihoods and alleviating poverty. Currently, the sector is reported as accounting for about 40% of the global food production even though it represents only 17% of global cropland (World Meteorological Organization, 1997).

Besides the importance of irrigation, planning and execution of interventions in this sub-sector have often taken place without consideration of other uses (e.g. consideration of how irrigation water or drainage return flow is being used downstream and the possible impacts to the users).

Several researchers have noted that the failure to recognize this and understand the boundary characteristics when planning and describing irrigation water use can lead to erroneous conclusions (Molden, 1997; Palacios-Velez, 1994; van Vuren, 1993; Wolters and Bos, 1990; Bos and Wolters, 1989). Based on this understanding, Bos and Wolters (1989) identified several flow paths of water entering and leaving an irrigation project, clearly identifying water that returns to a water basin and is available for downstream use. They furthermore pointed out that the portion of water diverted to an irrigation project that is not consumed, is not necessarily lost from a river basin, because much of it is being reused downstream. In other words, water loss due to low efficiencies is not lost to a larger system.

Stating it even more implicitly, Willardson (1985) noted that water use efficiency of a single irrigation field is of little importance to the hydrology of a basin, except when water quality is considered, and concluded that "basin-wide effects of increasing irrigation efficiency maybe negative as well as positive." There is therefore a need to clearly understand the tradeoffs between management options/interventions and impacts of drainage return flows to downstream users.

The challenges discussed above are not uncommon in the Great Ruaha River (GRR) catchment. Water scarcity is increasing and largely associated with human population growth and over-abstraction of water resources by upstream users. This problem has been exacerbated further by development of irrigated agriculture and increased human immigration. The area (particularly the Usangu Plains) has attracted cultivators from highland regions and pastoralists from northern and central Tanzania (Kadigi *et al.*, 2004; Kadigi and Mdemu, 2004; Mbonile *et al.*, 1997). The establishment of irrigation schemes, like the large-scale Mbarali and Kapunga Irrigation Schemes and smallholder schemes (e.g. the Majengo, Kimani and Motombaya schemes) has attracted more immigrants. All these, have resulted into a concomitant expansion of rainfed and irrigated agriculture as well as growing conflicts and competition for water resources. The growth of irrigated agriculture in this catchment is thus, viewed in two stances. On the one hand, the growth is seen as having the potential to improve economic gains and enhance rural livelihoods. Currently, about 30,000 households in the Upper GRR Catchment (in Usangu area) are benefiting from irrigated agriculture through cultivation of about 40,000 ha of paddy [Sustainable Management of the Usangu Wetland and its Catchment (SMUWC), 2001]. The sector supports the local people with food and cash from crop sales, which help them to pay school and medical costs and buy other goods and services to improve their lives. On the other hand, however, the sector is also seen as a major cause of troubles, which mainly leap from excessive use of water in irrigation systems leading to serious water shortages downstream. This is reported as a common problem, particularly during the dry season when people are experiencing deficit of water for domestic use and animal drinking, less pasture for animals, less water for hydropower generation, less area for fish breeding and growth and less area suitable for wildlife. Tourism in the Ruaha National Park also suffers as the Great Ruaha River (GRR) dries up (Kadigi and Mdemu, 2004; Kadigi and Mdoe, 2004; SMUWC, 2001).

The above paradox decodes to the central challenges facing water resource managers in the GRR catchment and in other river catchments and basins: the challenge of balancing the different water demands and the challenge of making irrigated agriculture produce more food using less water and release adequate water for use by other sectors, while concurrently improving economic benefits, enhancing livelihoods and maintaining the ecosystem integrity. These challenges call for a realistic evaluation of the current utilization of water resources and search for means that will put into practice appropriate systems for management and allocation of water resources in order to ensure adequate supply of water for the different daily demands today and for the future: search for means, which will also ensure that the welfare of the poor is not jeopardized.

Using the case study of the GRR catchment in Tanzania, this study evaluated livelihoods and economic benefits of water utilization in different sectors. Realizing the inherent difficulties in capturing all benefits of water utilization, the study was restricted only to a few, but 'important' water uses (irrigation, livestock, hydropower generation, domestic uses, brick making, fisheries and nature conservation). In addition, an assessment of poverty and income inequality was done so as to pinpoint the effects of different water benefits on income distribution and poverty alleviation.

1.2 Legislations and policies dealing with water management and allocation

Food security, poverty alleviation and sustainable development through "wise" use of water and other natural resources are some of the fundamental goals highlighted in most policies, particularly in the developing world. In Tanzania, the *Water Utilization (Control and Regulation) Act* of 1974 - amended in 1981 (Act no. 109) and 1997 (Act no. 370) and the new *Water Policy* (URT, 2002) are the paramount legislations/policies, which deal with water management and utilization. Beside these, there are also many other legislations and policies, which directly or indirectly affect water management and utilization (e.g. those concerning with agriculture, energy, fisheries, mining, forestry and wildlife to mention a few). The *Tanzania's Development Vision 2025* provides the guiding framework for all these and other policies. The vision is for Tanzania to move from a less developed country (LDC) to a middle-income country by 2025, with a high level of human development. Specific targets include: a high quality livelihood, which is characterized by sustainable and shared growth (equality), and freedom from abject poverty; good governance and the rule of law; and a strong and competitive economy capable of producing sustainable growth and shared benefits. Along with this vision is the *Tanzania's Poverty Reduction Strategy Paper (PRSP)*, which was launched in October 2000. The PRSP sets out Tanzania's medium term strategy for poverty reduction and the indicators it will use for measuring progress. It views irrigation as an important strategy for increasing food security. The PRSP is further supported by the *National Poverty Eradication Strategy (NPES)*, which sets out Tanzania's strategy and objectives for poverty eradication through to 2010. The first PRSP is furthermore succeeded by the currently launched *National Strategy for Growth and Reduction of Poverty*

(NSGRP), better known by its Kiswahili acronym as MKUKUTA (*Mkakati wa Kukuza Uchumi na Kuondoa Umaskini Taifa*), the final version of which was produced in June 2005. The NSGRP is a broader, comprehensive and more outcome-focused than its predecessor (the PRSP) and has deliberately set out to mainstream cross-cutting issues as integral to the strategy and not as "an add on". A very important feature of the development of the review leading to the NSGRP has been national ownership and the implementation of extensive consultation with a wide range of stakeholders on the content and focus of the strategy with the aim to make it a national strategy. The NSGRP is based on the achievement of three major clusters of broad outcomes for poverty reduction, namely: growth and reduction of income poverty; improved quality of life and social well being; and good governance and accountability.

With the adoption of the PRSP, the GoT has emphasized the importance of agricultural development as a growth engine of its national, and primarily agriculture based, economy. The specific priorities and targets of the government have been laid down in the Agricultural Sector Development Strategy (ASDS). The ASDS defines its primary objective as that of creating an enabling and conducive environment for improving the productivity and profitability of the agricultural sector as the basis for improved farm incomes and rural poverty reduction in the medium and long term.

In consideration of the strategic activities/interventions stipulated in the ASDS and philosophy employed in the National Irrigation Development Plan (NIDP) and also the results of the study on the National Irrigation Master Plan (NIMP), the

"*Sustainable Irrigation Development*" was selected as a purpose of the NIMP with emphasis on comprehensive measures through "Effective Use of Natural Resources", to largely contribute to attainment of the primary objective of ASDS.

The NIMP proposes two pillars of scheme-wise development and subject-wise improvement, and the well harmonization of them as a strategic approach to the sustainable irrigation development. The subject-wise improvement aims at creation of appropriate environment for sustainable irrigation development, mainly from a viewpoint of enhancing quality. The scheme-wise development aims at expansion of irrigation area and variation using effective use of national resources including financial resource. The subject-wise improvement programme and scheme-wise development shall be prepared in consideration of five elements: "Economically Sound", "Technically Appropriate", "Socio-logically Sustainable" and "Environmentally Friendly" (JICA, 2002).

In nutshell, the key priority areas for achieving poverty reduction in Tanzania include: reducing income poverty through equitable economic growth; improving human capabilities, survival and social well being; and containing extreme vulnerability among the poor. If these targets are to be met in a sustainable fashion, balancing the conflicting water demands is one of the key issues that need to be addressed.

In the GRR catchment, the key policies/institutions dealing with water resources management include:

(i) **The National Water Policy**: which was revised in order to incorporate the concepts of Integrated Water Resources Management (IWRM) (URT, 2002). The policy was revised under the auspices of the then Ministry of Water and Livestock Development (MWLD), with support from the River Basin Management and Smallholder Irrigation Improvement Project (RBM-SIIP). Along with this, three sets of legislations have been formulated for submission to the parliament to accompany the new National Water Policy: the Water Resources Act (URT forthcoming a), the Rural Water Supply Act (URT, forthcoming b) and the Urban Water Supply Act (URT, forthcoming c). These three Acts, as read in tandem, recognize community contributions and joint efforts towards a concerted water management system or arrangement.

(ii) **The National Forest Policy (1998)**: which states its overall goal as that of enhancing the contribution of the forest sector to the sustainable development of Tanzania and the conservation and management of her natural resources for the benefit of present and future generations. One of its objectives is to ensure ecosystem stability through conservation of forest biodiversity, water catchments and soil fertility. The policy gives the responsibility of managing forest resources to the forest sector in collaboration with the stakeholders. Participatory forest management, decentralization and privatisation are among the salient features of the policy. The policy emphasizes that sustainable forest management requires strategic sectoral planning which takes into account changes in the macro-economic policies towards market economy; participation of the private sector and other relevant stakeholders. This is also expressed in the 2002 forest legislation. The policy encourages community and private sector involvement in forestry. Emphasis is shifted from central control to an approach that encourages cooperation in management with rural people and communities. The policy also underscores the need for local peoples control over land and natural resources. The ownership of land and natural resources, access and the right to use them are of fundamental importance for a more equitable and balanced development as well as for the care to the environment.

(iii) **The Rufiji Basin Water Office (RBWO)**: This has its head office in Iringa and a sub-office in Rujewa (Mbarali district) and has been set-up with a specific set of tasks and roles including that of measuring and monitoring the available water resources; allocating and regulating the existing and new water rights within the basin; issuing, administering and collecting the water abstraction fees associated with the issued water rights; mediating and resolving water conflicts within the basin. Since its establishment, the RBWO is progressively formalizing all existing water uses in formally issued and administered water rights. In irrigation, these water rights are issued in absolute terms (e.g. in l/s), differentiating between a wet and dry season allocation, which is accompanied by a water abstraction fee payable to the RBWO. In general, the water rights are not issued to individuals, but to the local institutions of smallholder irrigation schemes. These local institutions are then responsible for collecting the fees from their members, and for the operation and maintenance of their irrigation schemes. Formal water rights are currently being issued to water users when they register their use with the RBWO. This requires all existing water users to register in order to obtain a formal water right, leaving users who do not register their water uses excluded from the legal system, turning them into illegal water users.

(iv) **Historical water rights**: in the Middle Usangu there are fewer formal water resources management institutions. Water resources are primarily allocated and distributed based on the historic water rights' arrangements and the traditional village institutions. Water rights are linked to the ownership or rent of land or canals or to labour provided for the maintenance of irrigation canals.

(v) **Village committees**: some villages have village committees to deal with specific issues. Most villages in the Upper GRR catchment, for example, have village water committees that deal with domestic water, and irrigation committees for irrigation water. The irrigation committees are mainly present in villages, where dry season irrigation is practiced. The irrigation committees have sub-committees or canal committees that oversee day-to-day water allocation, using inter-scheme and intra-scheme water rotations, and mediate or arbitrate conflicts. They have formulated several bylaws to enhance management, although in most villages these bylaws have not been fully operational due to a weak enforcement capacity. The irrigation committees usually concentrate on the core tasks of repair and maintenance of intake structures, as the members of the irrigation committees can only commit limited amounts of time due to high labour demands.

(vi) **Informal traditional arrangements**: In addition to the water and irrigation committees, there are also informal traditional arrangements that influence water allocation and distribution, particularly in the Upper Usangu. The chiefs (locally dubbed *mwene*) play an important role in the traditional water management arrangements. They had to oversee conservation of water resources and they were chairpersons for the environment subcommittees of village governments.

(vii) **Water Users Associations (WUAs)**: with the onset of increased water scarcity during the dry season, the need to regulate the water distribution between the different water users and uses has become ever more evident. The attention of the RBWO and the Mbeya-Rural District has recently gone out towards the establishment of a WUA Apex organization that could function as a user platform to address water management concerns at the sub-catchment level. This WUA Apex will become a federation of the lower level WUAs, to take care of tasks such as the implementation of rotation schedules and water distribution plans in the sub-catchment along its streams and rivers, and among its WUAs and plan the use and development of land and water resources in the sub-catchment, in particular with regard to better use and regulation of the scarce water resources.

(viii) **Other recently established local institutions**: Besides the WUAs, other local water groups have been established recently, but under different laws and regulations. Irrigation associations and cooperatives have been formally established and registered in those irrigation schemes that have received project support in the modernization of their infrastructure. In those projects, the establishment of the irrigation association or cooperative and the registration of a formal water right has become a conditionality of the support received.

1.3 Problem statement and justification of the study

Water is a fundamental resource for socio-economic development, thus, most governments have developed various policies and strategies underlining this recognition and thereby the whole issue of sustainable management of water resources with emphasis on equitable allocation, environmental conservation and community participation, just to mention a few. But, this endeavour is faced by several problems including the snag of general paucity of information that would allow formulation of effective policies and strategies. Information on water based livelihoods and economic benefits, for example, would have significantly served as a good "road-map" toward the achievement of balanced intersectoral water allocation and in guiding sectoral practice and development programmes. This information is also critical and absolutely crucial for addressing problems that relate to social and income inequalities. But, such information is not readily available for most river basins and catchments in the developing world (including the GRR catchment in Tanzania). While some basic information exists, much of which (e.g. in the case of GRR catchment) is centred on general assessment of water resources and utilization characteristics [e.g. water supply dynamics and causes of shortages, upstream/downstream competition for water and conflicts (SMUWC, 2001; Baur *et al.*, 2000; and Kikula *et al.*, 1996)]. Much is also known about the typologies of farming systems, livestock, land, water, fisheries, game, and forestry resources (SMUWC, 2001). There is also a considerable work on technical issues allied to hydrological descriptions and modelling, water quality, and some environmental aspects (SMUWC, 2001; Mwakalila, 1996; Faraji and Masenza, 1992); and on irrigation water use efficiency, management and development (Machibya, 2003;

SMUWC, 2001; Lankford, 2001; Maganga and Juma, 2000; Department for International Development (DFID), 1998; Mbonile *et al.*, 1997; DANIDA/World Bank, 1995; and the Usangu Village Irrigation Project (UVIP), 1993).

Common to these previous studies is the acknowledgement of the complexities and problems associated with irrigated agriculture and the potential that irrigation has in improving rural livelihoods and economic benefits. But, these studies do not inform much about the magnitude of potential positive or negative outcomes resulting from different water uses. Gaps still exist in the knowledge, particularly of the values of water and benefits of goods and services that are simultaneously provided by water resources and their inter-linkages with other benefits. Much also remains unknown about the spatial, temporal, and scalar dynamics that emerge when economic, social and ecological demands compete in conditions of water scarcity. As Revenga *et al.* (1998) point out water policies need to be fully informed of such aspects if multiple (often non-commensurate) economic, social and environmental objectives are to be met in a sustainable way. This is particularly important where there is growing competition over water resources like in the GRR catchment where there is serious competition between irrigated agriculture in the upper part of the catchment (in the Usangu Plains) and other water uses downstream, including the Usangu Eastern Wetland, Usangu Game Reserve (UGR), Ruaha National Park (RNP) and hydropower generation at the Mtera – Kidatu system (Figure 1).

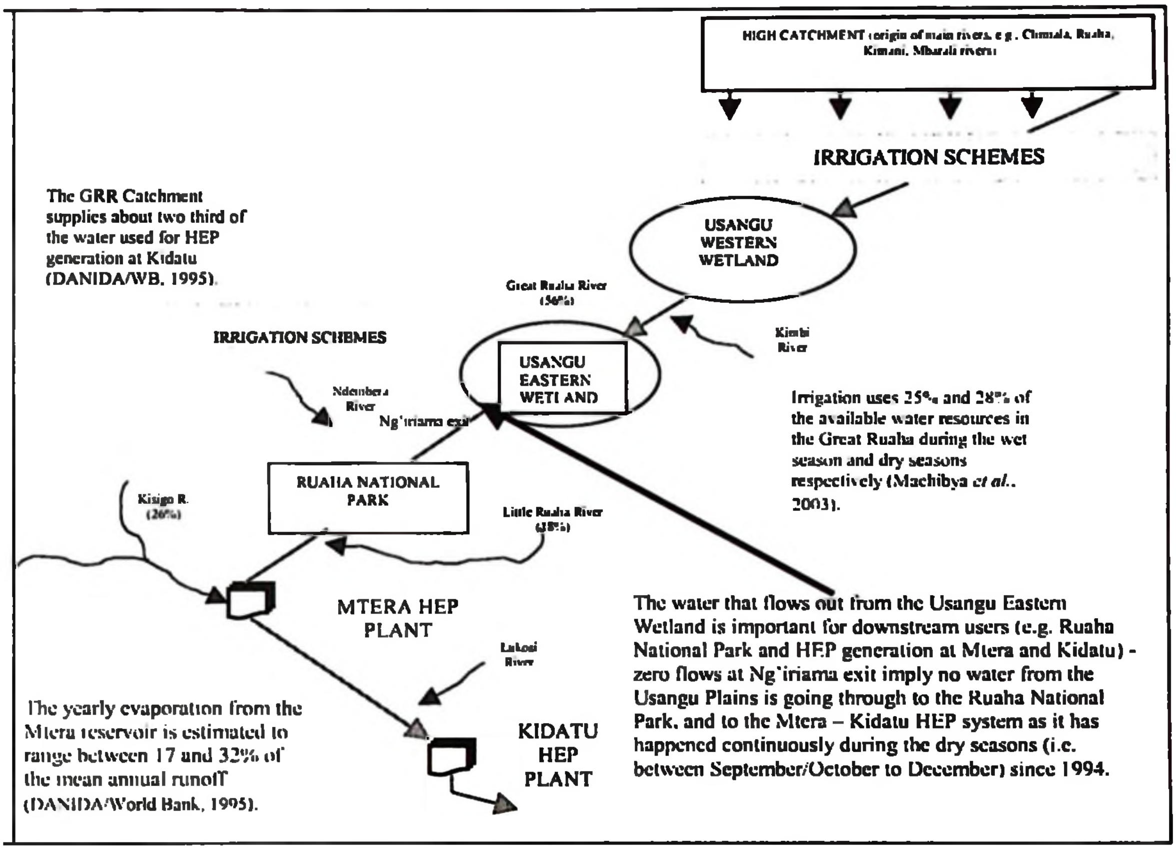

Figure 1: A schematic presentation of competing water uses in the GRR catchment

The competition between irrigation and hydropower generation is however under debate. This debate started in early 1990s following the popular belief among water resource managers and policy makers that the failure of the Mtera-Kidatu reservoir system in the early 1990s, which resulted in power rationing in the country, was due to increased upstream water abstractions causing water not to reach the Mtera reservoir. Based on this belief, most recommendations have been suggested, including that of designing strategies and means to save water from irrigated agriculture and transfer it for other uses downstream, including HEP generation and wildlife or nature conservation in the Ruaha National Park (DANIDA/World Bank, 1995). But, there are also several questions that need to be answered before such a recommendation is taken up, including the basic question of whether there is a real competition between irrigation and HEP generation or not. If there is competition and water can be saved from irrigated agriculture, would and could this water be available for HEP generation at the Mtera-Kidatu system? Is the present water storage capacity at Mtera sufficient for that? What is the overall effect of water transfer from irrigated agriculture to wildlife or nature conservation and HEP generation?

A number of researchers have attempted to answer these questions. Yawson *et al.* (2003), and Machibya *et al.* (2003), for example, consider the belief that irrigated agriculture is in direct competition with HEP generation in the GRR catchment as not holding up to close scrutiny. Yawson *et al.* (2003) associate the failure of the Mtera-Kidatu reservoir system in the early 1990s as more related to unaccounted for and unnecessary spillage and less to sudden decrease in water inflows into the Mtera-Kidatu reservoir system. A huge amount of unrecorded water might have been spilled from the reservoir system, which is basically the problem of the reservoir regulation and management.

On a similar ground, Machibya *et al.* (2003) also add that saving water from irrigation is not likely to benefit the HEP sector because of two reasons: first, irrigation uses little proportion (25% in wet season and 28% in dry season) and therefore the saving, particularly in the dry season, will not be potential enough for HEP recharging; and secondly, irrigation efficiency is not as low as previously thought to be (i.e. 15 – 30%). In this case there is therefore, a limited scope for water saving through improving irrigation efficiency in the Upper GRR catchment (in Usangu Plains) irrigation schemes and releasing it to the Mtera-Kidatu reservoir system for hydropower generation.

However, the experiences gained during the fieldwork in the study area (through field observations and discussions with various stakeholders) support the viewpoint that there is competition over water resources between irrigated agriculture and other users downstream (HEP inclusive). As already noted, the development of irrigated agriculture in the study area has attracted immigrants from other areas. This has in turn contributed to increasing human populations and demand for irrigation water and a subsequent decline in both water inflows and outflows to and from the Usangu wetlands downstream through the Ng'iriama outlet. In sense, both the opposing viewpoints tend to concur on the assertion that water, which flows out from the Usangu Eastern Wetland is important for downstream users, including HEP generation at Mtera and Kidatu (see, for example in Machibya *et al.*, 2003 and DANIDA/World Bank, 1995). In other words, zero flows at Ng'iriama imply no water from the Usangu Plains is going through to the Ruaha National Park, and to the Mtera – Kidatu HEP system, as it has continuously happened in the dry season (i.e. between September/October to December) since 1994. In other words, water which is not used for irrigation and other purposes in the upper part of GRR catchment is naturally transferred to downstream users through the Great Ruaha river, with the buffer constituted by the Usangu wetlands (Kadigi and Mdoe, 2004). By virtue of these irrigation schemes being located upstream, it then follows that the additional amount of water, which is consumed in these schemes, will not be available for downstream uses, including the Usangu wetlands, UGR, RNP as well as HEP generation at the Mtera and Kidatu plants.

As human population and irrigation activities continue to grow, water demand for irrigated agriculture and other uses in the GRR catchment will also continue to increase with possible upsurge in conflicts and competition over water resources. Managing for these conflicts requires a thorough understanding of the benefits of water utilization in its competing uses; possible trade-offs and implication of water transfer from one sector to another. Often, the lack of this knowledge has resulted in inefficiencies as well as significant externalities (e.g. reduced flows for downstream users and degraded ecosystems).

1.4 Objectives of the study

1.4.1 General objective

The main objective of the study was to evaluate livelihoods and economic benefits of water utilization in order to provide information that would enrich understanding and decision-making among stakeholders of water based livelihoods, values and economic benefits of water utilization.

1.4.2 Specific objectives

The specific objectives of the study were:

(i) To analyse the water based livelihoods in the Upper GRR catchment,

(ii) To evaluate the benefits/value of water in its different uses,

(iii) To explore the effects of these benefits on income distribution and poverty alleviation,

(iv) To assess the opportunity costs of water transfer away from irrigated agriculture, and

(v) To identify opportunities and strategies for improvement of water use efficiency and productivity.

1.5 The study area

1.5.1 Location and size

The Great Ruaha River (GRR) catchment covers an area of about 68,000 km^2 and it lies between longitude 34^0 and 36^0 E and latitude 6^0 to 9^0 S. The catchment is located within the Rufiji River Basin (178 000 km^2), in the southwestern part of Tanzania (Figure 2). Most of the GRR catchment lies within the Iringa and Mbeya regions, while a smaller part of the northern portion of the catchment lies within the Dodoma and Singida regions.

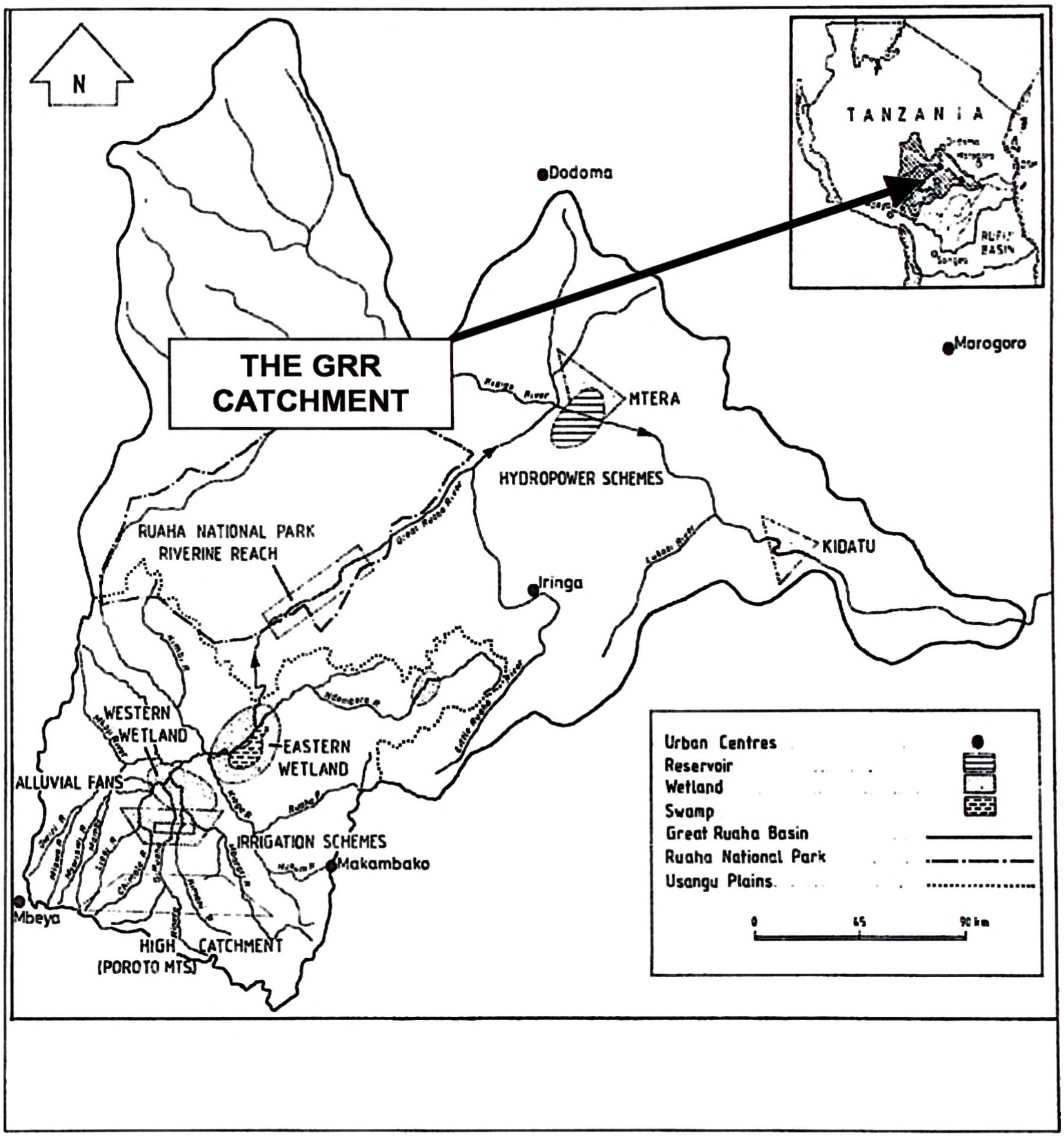

Figure 2: Map of the Great Ruaha River (GRR) catchment (Source: Mwakalila, 2005)

The GRR catchment encompasses the Usangu area (the Upper GRR catchment), which has a total area of 20,811 km^2. The Usangu area is located at approximately latitudes 7^{0}41' and 9^{0}25' South, and longitudes 33^{0}40' and 35^{0}40' East. It encompasses the Usangu Plains in which the Usangu Wetland (which has an area of about 1,800 km^2) and the UGR (4 148 km^2) are located. The Usangu area is not located within a single administrative entity. It falls into two regions and eight districts, with the larger part (about 60%) falling within the Mbeya Region, but primarily in Mbarali District (54.69%). Small parts of the Mbeya Rural District (3.17%) and Chunya (2.3%) also fall within the Usangu area.

1.5.2 Topography and climate

The GRR catchment is characterised by two distinct landscapes. In the northwestern and central lowlands are dry and flat plains, which is a natural sedimentation sub-catchment and part of the East African Rift Valley. The plains are characterised by a large number of seasonal and few permanent swamps. There are only minor variations in altitude, ranging from about 700 m at the Mtera Dam to about 1100 m at the southern part of the Usangu Plains. The plains are to the southeast, south and west surrounded by rolling to dissected Upper Plateaus, which form part of the Southern Highlands. The altitude ranges from about 1100 to almost 3000 m at the Kipengere Range and the Poroto Mountains.

The annual mean temperature varies from about 18^0C at the higher altitudes to about 28^0C at the lower and drier part of the catchment. Minimum and maximum average monthly temperatures vary from 5^0C to 13^0C and 22^0C to 27^0C, respectively in the higher altitudes and from 15^0C to 24^0C and 28^0C to 34^0C, respectively at Mtera in the lower part of the catchment. Most of the lower part of the study area, comprising the Usangu Plains and the Pawaga/Idodi areas is semi arid or semi-arid to sub-humid, whereas the highest part of the catchment is humid with a sub-humid belt in between.

The rainfall regime in the catchment is typically of the unimodal type with a single rainy season from November through May, and hardly any rainfall during the rest of the year. In the high rainfall areas the dry season is shorter as the rain season tends to continue until June. The heaviest rainfall generally occurs in December to January or March to April. The long-term annual rainfall for selected four weather stations in the study area is presented in Figure 3.

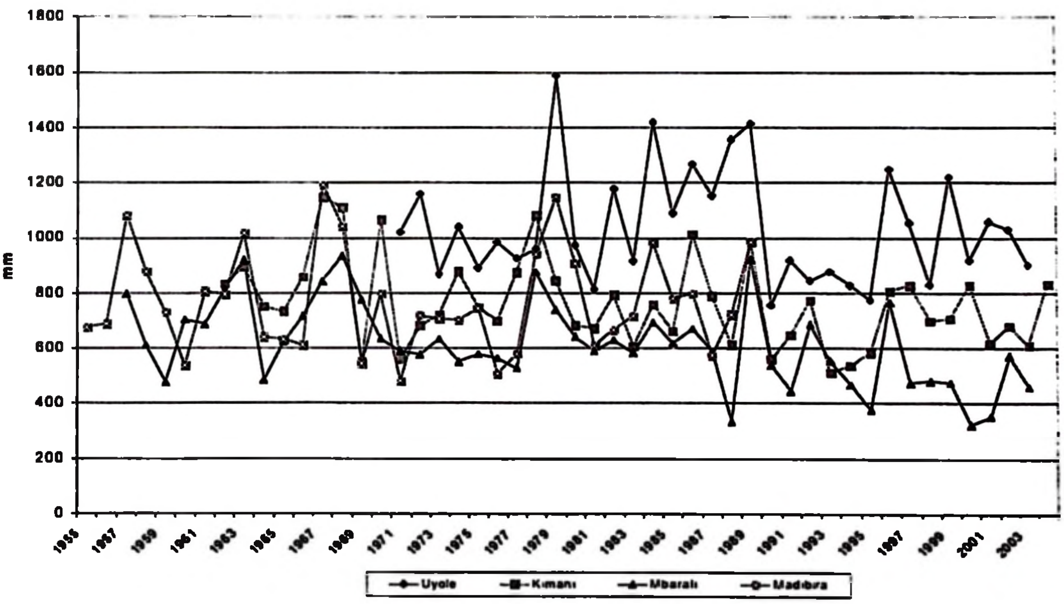

Figure 3: Long-term annual rainfall for selected weather stations in the study area

The Kipengere Range, the Poroto Mountains in the Southern part of the catchment and the highlands in Kilolo Divisions (next to the Udzungwa Escarpment) in the Eastern part of the catchment receive the highest annual rainfall, about 1400 – 1600 mm. The annual rainfall decreases towards the northwestern part of the catchment, and is only about 500 mm per annum at Mtera. Rainfall in wet and dry years may be 40 – 60% higher and lower, respectively, than the corresponding mean annual rainfall (DANIDA/World Bank, 1995).

1.5.3 Surface water resources

The Great Ruaha River (Figure 4 and Plate 1), which has given name to the catchment, is the main river draining through the whole catchment. It originates from a number of large and small streams in the northern slopes of the Poroto and Kipengere mountains, from where the bulk of flow is generated. From the mountains the streams descend steeply down the escarpment, often contained in narrow valleys and on reaching the Usangu Plains their gradient decreases abruptly.

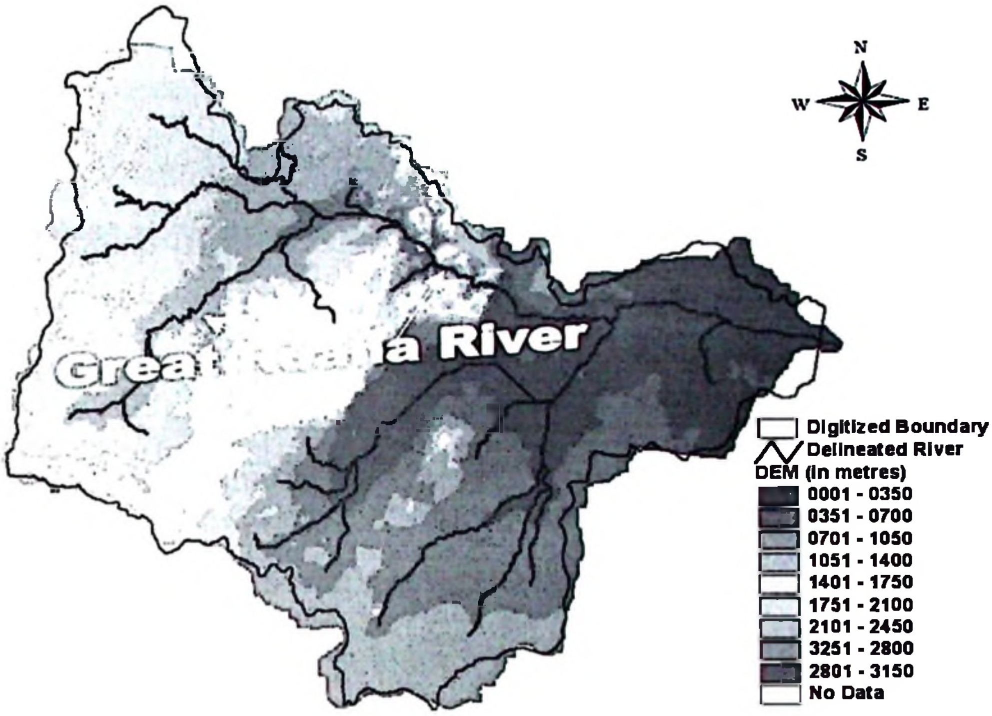

Figure 4: The Great Ruaha River (GRR) delineated within the Digital Elevation Model (DEM) of the Rufiji River Basin (Modified from Yawson, 2003)

Plate 1: Part of the Great Ruaha River close to Upagama village

The major rivers draining down to the Usangu Plains are perennial, including the Mbarali, Great Ruaha, Kimani and Chimala rivers, although flows can be very small at the end of the dry season. There are as well a large number of small rivers, which often dry up during the dry season, including the Umrobo, Liosi, Mlomboji, Hununi, Ipatagwa, Mswiswi, Luriwa and Mwanzali rivers.

In the Usangu Plains these tributaries join the Great Ruaha River. In the Northern part of the plains, the Great Ruaha River enters into the *Ihefu* swamp (in the Usangu Eastern Wetland) where the Ndembera River joins it. Downstream the swamp, the river enters into a confined course through a very dry area. There are no important tributaries until its two major tributaries; the Little Ruaha and Kisigo join it. After which, the Great Ruaha River enters the Mtera Reservoir and thereafter it is joined by the Lukosi River before it supplies water to the Kidatu hydropower plant. The Great Ruaha River provides 56% of runoff to Mtera. The Little Ruaha River provides an additional 18% and the Kisigo River 26% of the total runoff to Mtera. Downstream the Mtera plant, the GRR is joined with another major feeder river (the Kilombero), to form the Rufiji River after supplying water for hydropower generation at Kidatu.

1.5.4 Land use practices

Cultivation is primarily found in the highlands and along the main road almost all the way from Mbeya to Dodoma. The main irrigation areas are found in the southern part of the Usangu Plains and in a minor part of the Pawaga Plains in the northern part of the Upper GRR catchment. However, a major part of the catchment consists of almost unutilised land and the Ruaha National Park (RNP) covers most of the central part of the catchment. The RNP has a higher diversity of wildlife, both terrestrial and aquatic (including birds and reptiles) than most of other parks in Tanzania and supports approximately between 6,000 and 8,000 elephants. Areas where traditional pastoralism is dominant include parts of the Usangu Plains, the areas around Mlowa, Izazi, and the whole area joining the northern shores of the Mtera Reservoir.

The major food crops grown in Usangu Plains include rice, maize, sorghum, and beans. Other crops include onions, tomatoes, sugarcane, vegetables and fruits (mainly citrus, mangoes and pawpaw). Irrigated crops include paddy, maize, beans, cassava, sweet potato, sugar cane, tomatoes, onions, and vegetables. Paddy is the major crop under irrigation and is normally grown during the wet season, on the lower alluvial fans having clay soils. Maize and dry season irrigated crops are grown on the upper alluvial fans and foothills, where the soils are sandy loams containing less clay. Water resources in the Upper GRR catchment support local livelihoods through irrigation of about 40 000 ha of paddy, grass growth in the wetland for livestock, and fishing in the rivers and wetlands.

The area under paddy in the Upper GRR catchment (in Usangu area) depends on the river flows and rainfall in each sub-catchment. The maximum irrigated land under paddy amounts to about 42,000 ha, during a normal-to-wet year when average weather conditions are favourable, and when irrigation is essentially supplemental to the water provided by rainfall (SMUWC, 2001). In dry years the area under irrigation is comparably smaller: the core irrigated area is 24,500 ha, including a paddy crop of 22,000 ha and a non-paddy crop of 2,500 ha. During these bad years, both paddy and non-paddy crops are irrigated using mostly river flows with less reliance on rainfall than in good years, and some land is therefore left idle.

The irrigated non-paddy mixed cropping in the Upper GRR catchment (2,500 ha) includes maize, beans, vegetables and fruits, and extends throughout the year, mainly in the Chimala and Mkoji subcatchments. Dry season irrigation plots are usually very small (about 0.1 - 0.2 ha) and the main crops irrigated in these plots include maize, beans, tomatoes, sugar cane, onions, and vegetables. Land for rain-fed agriculture in the Upper GRR catchment (Usangu area) varies from one year to another between 50,000 ha and 65,000 ha depending on the amount and distribution of rainfall.

Forestry constitutes another important form of land use in the GRR catchment. It provides a range of both timber and non-timber forest products (NTFPs), which serve as an important source of livelihoods for the local communities. Honey is one of these products and it falls under the NTFPs category. It is collected mainly from the woodlands in the northern hills of the GRR catchment. A small honey production and processing business also exists in Njombe. Woodland also provides the local people with spices, herbs, and medicinal plants. In the absence of alternatives, these traditional sources are very important to local people.

Another type of NTFPs constitutes fruits. These are collected from *Tamarindus indica, Adonsonia digitata* (baobab), *Vangueria infausta, Azanza garckeana* and

Zanha capensis. Species such as *Adonsonia digitata* (baobab) also serve as focal points for traditional ceremonies, often having spiritual and/or religious significance.

Other NTFPs constitute a variety of wildlife products and by-products (e.g. wild game, nuts, mushrooms, insects, thatching and mat-making materials, withies, gums and resins, relish, cosmetics, poisons, dyes, stimulants, tannins, aromatics, litter for nursery soil and essential oils).

1.5.5 Hydropower generation

The GRR catchment gained national importance following the establishment of the largest hydropower system in the country (the Mtera - Kidatu system). The system has a total installed capacity of 284 MW and has the biggest installation capacity in the country. It provides more than 50% of the total 559 MW available in the national hydropower grid.

The Mtera-Kidatu hydropower system was constructed as part of the Great Ruaha River Power Project (GRPP), which was implemented in three phases. The first phase started in 1970 and ended in 1975. This involved construction of a 40m high and 350m long earth-rockfill dam (with storage capacity of 125 Mm^3) and an underground power plant at Kidatu (installed with two generating units each with a capacity of 50 MW totalling to 100 MW).

The second phase commenced in 1977 and ended in 1981. It consisted of additional installation of two 50 MW units at Kidatu, thus bringing the ultimate capacity of the plant to 200 MW. However, it was latter realized that the Kidatu reservoir volume was too small for annual regulation and continuous operation of the four generating units. To take care of the water availability during the dry season of normal years as well as a series of dry years, adequate storage had to be provided upstream of Kidatu. A main storage dam was therefore constructed during phase II at Mtera (about 170 km upstream of Kidatu). The Mtera dam (Plate 2) is the largest dam in the country in terms of height, crest length and concrete volume. Its impounded reservoir is also the largest man-made lake in Tanzania. The dam has a maximum storage capacity of 3700 Mm^3 and a minimum capacity of 500 Mm^3. The maximum capacity for the reservoir corresponds to a maximum supply level of 698.50 m above sea level, with the minimum level corresponding to 690.00 m above sea level.

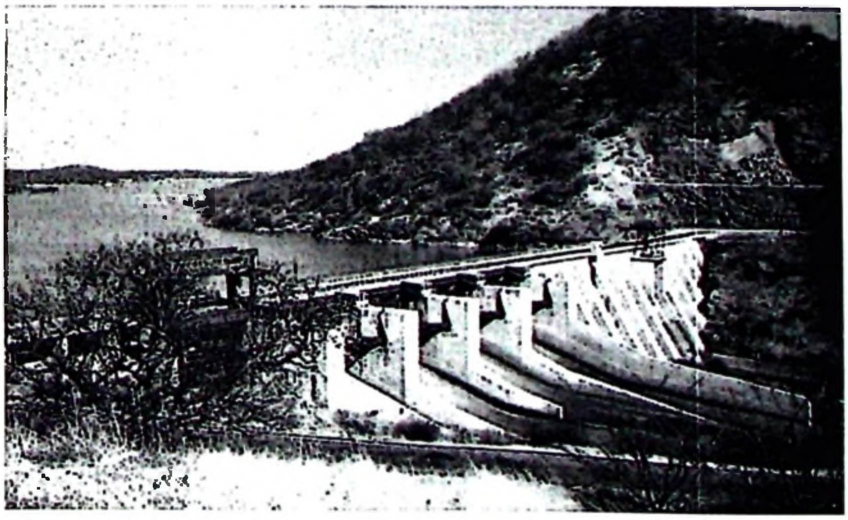

Plate 2: The Mtera dam, commissioned in December 1980 (SWECO, 1997)

The average annual evaporation from the water surface of the reservoir was estimated at 2,440 mm (SWECO, 1981a, b) or 2,100 mm when the net evaporation or the actual loss of water is considered, that is, when the evaporation reduced by rainfall on the surface is considered and some allowance is made for unspecified losses such as evapotranspiration through aquatic plants, and ground water seepage (SWECO, 1997).

The third phase started in 1984 and ended in 1988. This comprised the construction of an underground power plant at Mtera, installation of two generating units each 40 MW, totalling to 80 MW. The Mtera power station is the second largest powerhouse in Tanzania after Kidatu (204 MW). Electrical power generation at this station started in May 1988 with the annual production for the period 1989 to 1994 averaging at about 429 GWh (SWECO, 1997).

1.6 Organisation of the remainder of the thesis

The remainder of this thesis is organized into four main chapters. The next chapter presents a review of different literature on water resources allocation, approaches to livelihood analysis and valuation of economic benefits of water utilization as well as the previous studies done elsewhere in Tanzania. This is followed by the conceptual framework of the study and methods used in the study as well as the limitations of the study. Following the conceptual framework and methods used in the study is the results and discussion chapter which presents and discusses the results of livelihood analysis; values and benefits of water for different sectors; the effects of these benefits on income distribution and poverty alleviation; the opportunity costs of water transfer away from irrigated agriculture to other uses downstream; and the water management problems and constraints. The thesis winds up by presenting some concluding remarks and providing recommendations emanating from the study.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Overview

This chapter presents a review of literature related to water resources management and allocation including the neo-classic economic theory and its counter theory, approaches of poverty/livelihood analysis and valuation of economic benefits of water utilization as well as previous studies done in the study area and elsewhere in Tanzania.

2.2 The neo-classic economic viewpoint on water resources and its counter theory

Water is globally regarded and treated as a social and basic good where the social aspects are given the most attention. Water being a basic good and a human right has called for government regulations to safeguard this right in the interest of the economic weak and disadvantaged group. This has been so from time immemorial until recently when the increase in population and the effects of human activity on the quantity and quality of water have resulted into an evolution thinking whereby water is now being considered as not only a social good but also an economic good (Briscoe 1996; Global Water Partnership 2000a; 2000b; Rosegrant and Binswanger, 1994).

The concept of "water as an economic good" emanated from the understanding that water is finite, its allocation should therefore, consider its nature of being scarce and water should not be considered as 'free.' According to the economic efficiency principle, the resource should be allowed to flow to the sector generating the highest marginal value. Several authors (e.g. Perry *et al.*, 1997, Schreiner and van Koppen, 2001) have however, argued that the concept of "*water as an economic good*" is still vague and questionable, particularly when the poor are concerned: it ignores the crucial question of "benefits for whom" and the distribution of wealth within society. The hypersensitivity of this counter argument stems from the fact that water being essential resource for all types of life if its allocation is left purely to market mechanisms, other characteristics of water, such as social and environmental values might be negatively affected. It should however be noted that, the economic nature of water does not limit itself to market mechanisms. It is possible to estimate the economic value of water for social and environmental purposes as well. The problem of considering water as an economic good mainly comes from the fact that these non-market uses of water are rarely taken into account in economic studies, as they should be, because of the difficulty in valuing them as well as the lack of appropriate valuation techniques. Thus, water being an economic good does not strictly mean that water allocation should be driven only by market mechanisms. The economic value of water, while still important, is only one of the criteria that need to be considered in valuation of water resources.

The uncertainty of the ability of the market mechanism to solve the problem of water allocation worldwide, especially when the poor are concerned has even influenced the Rio conference to further re-emphasize that water is *a social good* (UNCED, 1992). This implies that people are entitled to use water even when they cannot afford to pay the full price of water provision.

It is argued in this thesis that whether water is treated as an *economic good* or *social good* or *both* there is still a need for water managers and decision makers to be informed of the value of water in its competing uses and the implications of water transfer from irrigated agriculture to other sectors (implications on the livelihoods of the poor people) before embarking on devising strategies to balance water demands amongst competing sectors.

2.3 Assessment of poverty, livelihoods and income inequality

This section presents a review of different approaches used for analysing livelihoods, poverty and income inequality. In particular, the approaches are reviewed under the categories of Participatory Poverty Assessments (PPAs), Sustainable Livelihood (SL) and other approaches for measuring poverty and income inequality.

2.3.1 Participatory Poverty Assessments (PPAs)

The approaches commonly labelled "Participatory Poverty Assessments (PPAs)" include a number of poverty measures, which put individuals and households at the centre of the assessment, and see poverty through their eyes. They draw on a range of methods including among others, well-being or wealth ranking and livelihood analysis. The methods are cheaper and are increasingly becoming useful in assessing rural poverty and livelihoods.

The PPAs have received particular attention over the past fifteen years following the agreement by the World Bank Group and IMF that nationally-owned Participatory Poverty Reduction Strategies (PRSPs) should provide the basis for all concessional lending and debt relief under the enhanced Heavily Indebted Poor Countries (HIPC) Initiative. Since then, PRSPs have been created in many countries as a framework for coordinating anti-poverty measures. This has merged with the need to monitor progress towards the *Millennium Development Goals* and bi-lateral donors' wish to streamline development assistance as well as improve the performance of sector ministries.

In Africa, the first PPAs were conducted during the early 1990s (Ehrhart, 2002). Together with information generated through surveys and individual interviews, their findings were meant by the World Bank to show the complex relationship between poverty profiles, public policies, expenditures and institutions.

In Tanzania, the two most commonly recognized PPAs are the 1994/5 PPA, instituted by the World Bank, and the 1997 Shinyanga PPA, conducted by the Regional Government of Shinyanga as part of a UNDP funded Human Development Report Project (Attwood, 1998; Ehrhart, 2002).

The World Bank PPA illuminated aspects of poverty and wellbeing important to poor people themselves. It also showed how surveys can distort understanding of poverty by papering-over the unequal access to economic and non-economic resources experienced by individuals in the same household. Indeed, findings from this PPA contributed to growing recognition of poor communities and households as heterogeneous units whose members face an array of circumstances demanding a range of policy responses.

The 1997 Shinyanga PPA worked in a single Region (the largest sub-national administrative unit in Tanzania). It built the capacity of local government staff to engage in participatory public planning and provided key information for a Human Development Report (Attwood, 1998).

In the preparation of the Tanzania's first PRSP the GoT designed a comprehensive Poverty Monitoring System (PMS). This included PPA as a key tool for qualitative research related poverty reduction policy. The country carried out its first national PPA in 2002/03. Using PRA tools associated with the Sustainable Livelihoods Framework, research was conducted in thirty field sites selected to represent a wide range of different livelihood contexts in the country. The aim was to gather information on the different factors pushing people towards poverty in these different contexts. The research aimed to identify more and less vulnerable social groups by comparing "the number and intensity of things pushing them towards poverty versus the number and effectiveness of their available responses" (Social Development Direct, 2006).

Additionally, some more PPAs are reported in the literature. These include the PPA Study commissioned by the Arusha Municipal Council (AMC) in 2001 and that by Ellis and Mdoe (2003). The former attempted to "understand the poverty situation so as to contribute to enhancing the living conditions and the lives of the people of AMC in general and the poor in particular" (Equitable Community Development Foundation, 2001). Ellis and Mdoe (2003) employed the wealth ranking approach to gain perceptions about poverty/wealth and livelihood circumstances in Tanzania using the case study from selected villages in Morogoro region. In choosing their field locations and villages they used criteria, which represent rural livelihood patterns in Tanzania in a broad sense, and those, which capture livelihood "gradients" of varying types. They found that rural poverty is strongly associated with lack of land and livestock, as well as inability to secure non-farm alternatives to diminishing farm opportunities. And that, the rural poor and women stumble upon an institutional context that is neutral or hindering rather than enabling them to construct their own conduits out of poverty.

2.3.2 Sustainable livelihood (SL) approach

Different authors define the term "livelihood" differently. Chambers and Conway (1992) for example, define livelihood as comprising the capabilities, assets (stores, resources, claims and access) and activities required for a means of living. This definition has been widely cited in the development literature with minor modifications being made by a number of researchers e.g. Carswell (1997), Hussein and Nelson (1998), Scoones (1998), Carney (1998). Ellis (2000), for example, builds on this definition by bringing in a more explicit consideration of the claims and access issues, and in particular the impact of social relations and institutions that mediate an individual or family's capacity to secure a means of living. He defines livelihood as comprising the assets (natural, physical, human, financial and social capital), the activities, and the access to these (mediated by institutions and social relations) that together determine the living gained by the individual or household.

The Sustainable Livelihood (SL) conceptual framework is a particular form of livelihoods analysis used by a growing number of research and applied development organizations, including DFID of the United Kingdom, the United Nations Development Program (UNDP), as well as nongovernmental organizations (NGOs) such as CARE and Oxfam (DFID 1997; Carney *et al.*, 1999). It is primarily a conceptual framework for analysing causes of poverty, peoples' access to resources and their diverse livelihoods activities, and relationship between relevant factors at micro, intermediate, and macro levels. It is also a framework for assessing and prioritising interventions. The SL framework takes as a starting point an expanded definition of poverty that looks *beyond* the economic indicators of poverty. According to Carney and Ashley (2000) the SL approaches are:

(i) **People – centred**: Sustainable poverty elimination will be achieved only if external support focuses on what matters to people, understands the differences between groups of people and works with them in a way that is congruent with their current livelihood strategies, social environment and ability to adapt.

(ii) **Responsive and participatory:** Poor people themselves must be key actors in identifying and addressing livelihood priorities. Outsiders need processes that enable them to listen and respond to the poor.

(iii) **Multi–level:** Poverty elimination is an enormous challenge that will only be overcome by working at multiple levels, ensuring that micro - level activity informs the development of policy and an effective enabling environment, and that micro – level structures and processes support people to build upon their own strengths.

(iv) **Conducted in partnership:** With both the public and the private sector.

(v) **Sustainable:** Key dimensions to sustainability are economic, institutional, social and environmental sustainability. All are important and a balance must be found between them.

(vi) **Dynamic:** External support must recognise the dynamic nature of livelihood strategies, respond flexibly to changes in people's situation and develop longer-term commitments.

The overall conceptual framework for sustainable livelihoods is illustrated in Figure 5 (Carney 1998; DFID 2001).

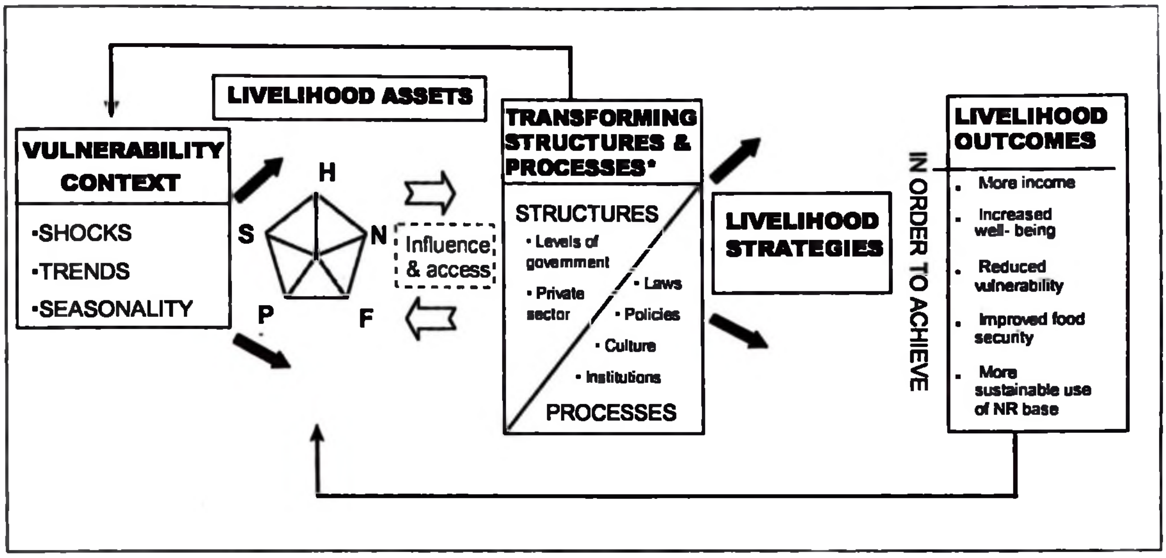

Figure 5: DFID's SL framework (Source: Carney *et al.*, 1999)

The starting point is the **vulnerability context** within which people operate. Attention is next given to the assets that people can draw upon for their livelihoods. Assets interact with policies, institutions, and processes to shape the choice of livelihood strategies. These, in turn, shape the livelihood outcomes, which are often the types of impact people are interested in. However, those outcomes are not necessarily the end point, as they feed back into the future asset base. The vulnerability context encompasses:

(i) *trends* in population, resources, and economic indicators such as prices, governance, or even technology;

(ii) *shocks* such as changes in human or animal health, natural disasters, sudden economic changes, or conflict; and

(iii) *seasonality* in prices, agricultural production, employment opportunities, resource availability, or health.

The **asset base** upon which people build their livelihoods includes a wide range of assets. The sustainable livelihoods framework suggests an asset portfolio of five different types of assets:

(i) *Natural capital (N)* includes land, water, forests, marine resources, air quality, erosion protection, and biodiversity.

(ii) *Physical capital (P)* includes transportation, roads, buildings, shelter, water supply and sanitation, energy, technology, or communications.

(iii) *Financial capital (F)* includes savings (cash as well as liquid assets), credit (formal and informal), as well as inflows (state transfers and remittances).

(iv) *Human capital (H)* includes education, skills, knowledge, health, nutrition, and labour power.

(v) *Social capital (S)* includes any networks that increase trust, ability to work together, access to opportunities, reciprocity; informal safety nets; and membership in organizations.

Policies, institutions, and processes affect how people use their assets in pursuit of different livelihood strategies. These refer to both formal and informal institutions and organizations that shape livelihoods by influencing access to assets, livelihood strategies, vulnerability, and terms of exchange. They may occur at multiple levels, from the household to community, national, and even global levels (e.g. public and private sectors, community institutions, policies, laws as well as culture).

Given the interaction of livelihood assets with the vulnerability context and institutions, various **livelihood strategies** may take the lead in singular or in combination. These strategies refer to the choices people employ in pursuit of income, security, well-being, and other productive as well as reproductive goals. They are the patterns of behaviour adopted by the household as a result of the mediation processes on the household assets and have been classified according to different criteria. Scoones (1998) and Swift (1998), for example, classify rural livelihood strategies into three broad types according to the nature of activities undertaken: agricultural intensification and extensification, livelihood diversification, and migration.

Ellis (2000) classifies livelihood strategies based on the observation that for the majority of rural households in Sub Saharan Africa (SSA), farming alone does not provide a sufficient means of survival. Most rural households increasingly rely on constructing a diverse portfolio of activities and income sources in order to survive and to improve their standard of living. This includes both on - and off - farm activities undertaken to generate income (i.e. monetary and non-monetary contributions to household consumption) in addition to that from the main household agricultural activities. Ellis (2000) divides these activities into natural resource and non-natural resource based activities. He identifies seasonality, risk, labour markets, credit substitution, and asset strategies (investment to enhance future livelihood prospects e.g. developing networks, education) as factors which might induce voluntary motives for the adoption of diverse livelihoods.

Devereaux (1999) and Davies (1996) amongst others have made the distinction between ***survival***, ***coping***, ***adaptive*** and ***accumulative*** strategies. Accumulative strategies are those which increase consumption outcomes and stocks of assets in response to opportunity. Adaptive strategies are those that seek to spread risk of consumption failure in response to anticipated adverse trends. This may be through the intensification of existing livelihood strategies or by diversification into new activities. Coping strategies are those that absorb the impact of an adverse shock by drawing down assets and reducing consumption. When there is no respite coping may lead to survival strategies. With survival strategies not only is consumption drastically reduced, but household assets are extensively, most often irreversibly eroded, in an attempt to ward off destitution and death.

Siegel and Alwang (1999) classify household livelihood strategies on the basis of how they manage risk, differentiating between ex-ante strategies which seek to reduce or mitigate risks, and ex-post strategies which are ad-hoc responses to unforeseen events and outcomes. Such strategies are typically part of a sequential planning process, in which a combination of risk prevention, risk mitigation and coping are practised in anticipation of, and in response to, risky events and outcomes.

Livelihood outcomes encompass many of the types of impact of interest. Potential outcomes include conventional indicators such as income, food security, and sustainable use of natural resources. Outcomes can also include a strengthened asset base, reduced vulnerability, and improvements in other aspects of well-being such as health, self-esteem, sense of control, and even maintenance of cultural assets, and thus have a feedback effect on the vulnerability status and asset base.

2.3.3 Other approaches for measuring poverty and income inequality

A number of other approaches are used to measure poverty and income inequality (Gaiha, 1993; Adams, 1994). Examples include the *Theil's entropy index*, *Theil's second measure*, *Coefficient of variation* and *Gini coefficient*. These measures are also used to decompose incomes and pinpoint the contribution of different sources of rural income to total inequality. One however, must identify the appropriate measures prior to the exercise of decomposition, as some measures (e.g. the *Theil's entropy index* and *Theil's second measure*), are not decomposable when the sources of income are overlapping and not disjoint. A typical example of income decomposition is that, which is given by Adams (1994), who uses *Coefficient of variation* and *Gini coefficient* to evaluate the impact of non-farm income on income inequality in rural Pakistan. He decomposes the total income into five sources: non-farm, agricultural, livestock, rental and transfer and he contends that, non-farm income represents an inequality-decreasing source of income in rural Pakistan.

2.4 Valuation of economic benefits of water utilisation

Numerous measures of the value of water have been suggested in the literature, depending on the type of use and value under consideration and on the existence of competitive markets. A detailed discussion of these measures is given in Young (1996). They can be classified into the following categories (Hussain *et al.*, 2001):

(i) *The conventional market based approaches*, which estimate the economic value of water for goods or services that are bought and sold in commercial markets (use values). The standard method for measuring the use value of water resources (goods or services) traded in the market place is the estimation of *consumer surplus* and *producer surplus* using market price and quantity data (e.g. units of electricity sold, amount of fishes sold and other goods and service traded). The total net value, or economic surplus, is the sum of consumer surplus and producer surplus.

(ii) *The replacement cost, substitute cost and damage cost avoided approaches*: these are related approaches that estimate values of ecosystem services based on either the costs of avoiding damages due to lost services, the cost of replacing environmental assets, or the cost of providing substitute services. The replacement cost method uses the cost of replacing an ecosystem or its services as an estimate of the value of the ecosystem or its services. Similarly, the substitute cost method uses the cost of providing substitutes for an ecosystem or its services as an estimate of the value of the ecosystem or its services (e.g. the flood protection services of a wetland might be replaced by a retaining wall or levee). The damage cost avoided method uses either the value of property protected, or the cost of actions taken to avoid damages, as a measure of the benefits provided by an ecosystem. For example, if a wetland protects adjacent property from flooding, the flood protection benefits may be estimated by the damages avoided if the flooding does not occur or by the expenditures property owners make to protect their property from flooding. These approaches are most appropriately applied in cases where damage avoidance or replacement expenditures have actually been, or will actually be, made.

(iii) *Observed indirect or implicit or revealed preference approaches*, which infer to the willingness to pay from the actual consumers' behaviour, that reveals their preferences. The hedonic price method is used when the service provided by water is part of a bundle of attributes of a property: for example, the aesthetic value of a particular landscape, of which water is the main component, proximity to water intakes for irrigation and availability of canal or ground water. North and Griffin (1993) applied this method to value the improved access to domestic water in Philippines. The travel cost method can be applied to assess the amenity value of a lake or a river, revealed by the cost tourists are ready to incur to visit the site (the travel cost method).

(iv) *Stated preference approaches* (contingent valuation method) are applied when there is no market, in particular for non-use values such as aesthetic or cultural values, and when willingness to pay cannot be inferred from actual behaviour of economic agents. Surveys are conducted, in which hypothetical markets are presented to people, who are then asked to express their preferences for a good or service. Particular precautions should be taken in the design and application of questionnaires so as to avoid or limit various possible biases. Contingent valuation method can also be applied for use value, for example to assess the value of improved domestic water supply in developing countries (Altaf *et al.*, 1993; Whittington and Swarna 1994; Whittington *et al.*, 1991; Whittington *et al.*, 1990).

2.4.1 The Residual Imputation Method

The "residual" imputation method falls under the category of ***the conventional market based approaches*** and has been widely used to derive economic benefits of water utilization, particularly in irrigated agriculture (Hussain *et al.*, 2001; Renwick, 2001; Young, 1996). The method entails identification of the incremental contribution of each input to the value of total output. The derivation of the residual value of water in this approach is based on two principle postulates: i) competitive equilibrium, which requires that the prices of all resources be equated to returns at the margin. "Profit-maximizing" producers are assumed to add productive inputs up until the point that Value Marginal Products (VMPs) are equal to opportunity costs of the inputs, and ii) the Total Value of Product (TVP) can be divided into shares, so that each resource is paid according to its Marginal Productivity and the TVP is thereby completely exhausted.

In the 'residual' imputation method, both simple and more advanced analytical models can be used, but experience has shown that many researchers have centred their analysis on simplicity of the functional forms giving little attention to other factors (e.g. the nature of factor substitution, whether variable, constant or a unit), which may dictate the type of functional forms.

For "intermediate good uses" of water, models of the "profit-maximizing" firm can be used. However, the general characterization of most rural producers (peasants) in developing countries as risk aversors, drudgery aversors, sub-optimal producers, partial engagers in incomplete markets, and the like, would make these models to be seen as inadequate portrayals of the economic behavior of most rural producers. But, as Ellis (1996) argues, the degree of market integration of most contemporary peasants, means that some elements of the economic calculus characterized by "profit maximization" are almost always present in peasant economic behavior. It is furthermore argued that the *risk aversion* and the *drudgery aversion theories* are merely logical modifications of the "profit maximization" models, not different theories (Ellis, 1996). The pursuit of security as a goal, for example, occurs because risk avoidance cannot be purchased in the market (c.f. the *risk aversion theory*). Unstable input and output markets are part of the problem, and no market in crop insurance exists. Just as important, time for non-farm activity is pursued by the households as a separate goal because labour time cannot be purchased or valued in the absence of a labour market (c.f. the *drudgery aversion theory*). It is however, desirable that some recognition to uncertainty be incorporated into the analysis. A more practical alternative for acknowledging uncertainty is to use "sensitivity analysis." The effect of (sensitivity to) important variables on the estimated value of water is determined by varying one element (e.g. crop yields or prices in irrigated agriculture) at a time to determine the sensitivity to erroneous forecasts.

2.4.2 Change in Net Income Method

The Change in Net Income Method is one of the approaches grouped under the category of *the conventional market based approaches*. It is a simplified approach derived from the Residual Imputation Method and is commonly used to assess the benefits or value of water, when water is used as an intermediate good (i.e. when it is used as an input to produce another good – e.g. crops or electricity in irrigation and hydropower generation respectively). The value of water in this method is basically derived from change in revenue of the associated enterprise output(s). The approach stems from the principle of production theory which asserts that the value of an intermediate good is the net economic contribution of that good to the value of the final output. Examples of its application to value the use of water in irrigation are given by Hussain *et al.* (2001), Renwick (2001) and Young (1996). Using this method, Hussain *et al.* (2001) define the average value of water as the ratio of the difference of net output values between the situation *with* water and the situation *without* water, on the volume of water used.

Depending on the period of adjustment of economic decisions, which is considered and the associated costs, different values may be estimated (Ward and Michelsen, 2002; Young, 1996). For short-term allocation decision only operational and maintenance costs are computed, whereas for long-term decision allowing new investments, capital costs of assets (e.g. land, farm machinery and equipment, irrigation system, power plant, dam etc.) are also subtracted. For a given use of water in a given site, long run values are therefore less than short run values because of the higher costs included in the former, including depreciation.

The value of water can be calculated from a private water user point of view (e.g. the farmer or the power plant, as in Turpie *et al.* 2003). As one single individual decision cannot significantly affect the price of inputs or outputs, the water value is computed using market prices as experienced by individual users. From a national perspective (e.g. in FDB, 2003), social value of outputs and inputs (*shadow prices*) must be considered, taking into account the distortions brought by government interventions in markets (e.g. subsidies to farm equipment, taxes or subsidies on farm inputs and outputs, minimum wage, electricity tariff). S*hadow prices* are "adjusted" prices derived to take care of distortions in the market prices, which often arise as a result of taxes, subsidies, fixed prices and exchange rates, or mandated wage or interest rates. If the transfer of water between the two sectors is large enough to have an impact on either output or input prices, these effects should be accounted for. Similarly, external effects of the transfer on other uses need also to be evaluated.

Different expressions of water values can also be computed according to the volume of water, which is considered. Generally, two types of volumes are distinguished: abstraction from the natural environment and net consumption. The former does not include return flows that may be reused downstream and therefore, provides a downward biased water value; the latter does not include system losses and then leads to an overestimation of water value. In the case of irrigation, Renwick (2001) recommends a value per unit of depleted water (evaporation plus drainage outflow) as a performance benchmark of system wide allocation efficiency. For cross-sectoral comparison it may be useful to refer to a common denominator such as the raw untreated water flowing in the stream. This implies subtracting treatment and transport costs from the value of water at its off stream use location. In the present study, it was assumed that no major differences exist in terms of water quality requirement (i.e. there is no treatment costs). In addition, no transport costs is considered in some uses (e.g. hydropower generation as the plants are located directly on the river). For irrigation, transport costs are embedded in investment costs of irrigation systems, which are not integrated in short-term values.

However, the *Change in Net Income* method has the following three limitations:

(i) The results are highly sensitive to errors in computing the various inputs' contribution to the total value. If an input that should be represented in the production function is omitted, this will lead to the contribution of that input to be attributed to the residual claimant, thereby overstating the value of water. In agriculture for example, it is important to capture all cash and non-cash costs of production such as return to management and family labour, in the short run, and depreciation of capital costs (machinery and equipment), and land in the long run.

(ii) As stated above, various biases stem from the use of administrated prices that do not reflect the real economic value of inputs and outputs. Again, if government intervention or market failures lead to prices for input factors and products which deviate from the competitive equilibrium prices, then the imputed value of the residual will accordingly be inaccurate.

(iii) Another problem is the difficulty of accurately forecasting the levels of output associated with the factor inputs (the *with* and *without* situations). Over - or under - estimates of the level of production from a given bundle of inputs will bring about corresponding over - or under-estimate of the residual value.

2.4.3 Contingent Valuation Method (CVM)

The contingent valuation method (CVM) falls under the category of *stated preference approaches*. It involves directly asking people, in a survey, how much they would be willing to pay (WTP) for specific environmental goods and services.

In some cases, people are asked for the amount of compensation they would be willing to accept (WTAC) to give up specific environmental goods and services. It is called "contingent" valuation, because people are asked to state their willingness to pay, *contingent* on a specific hypothetical scenario and description of the environmental good or service.

The CVM is referred to as a "stated preference" method, because it asks people to directly state their values, rather than inferring values from actual choices, as the "revealed preference" methods do. It is one of the only ways to assign monetary values to non-use values of water and other environmental services—values that do not involve market purchases and may not involve direct participation. These values are sometimes referred to as "passive use" values. They include everything from the basic life support functions associated with ecosystem health or biodiversity, the enjoyment of a scenic view or a wilderness experience, to appreciating the option to fish in the future, or the right to bequest those options to your grandchildren. It also includes the value people place on simply knowing that a river or wetland exists.

The CVM has been successfully applied in many studies on household water supply in developing countries, where it has been used as a direct method, for example, of estimating the economic benefits of improved water supplies using the WTP approach (Altlaf *et al.*, 1993; Barbier *et al.*, 1997; Whittington and Swarna 1994; Whittington *et al.*, 1991; Whittington *et al.*, 1990).

The WTP approach is however, subject to a number of biases. According to Dixon *et al.* (1994) and Navrud (1989), these biases include:

(i) *Strategic bias*: which may occur when respondents try to act strategically, a reflection of what they feel will be done with their answers. If they feel they may actually have to pay the amount they answer, they may undervalue their true responses. If they feel that stating high values will bring about changes they would like to see but they know they will not actually have to pay this amount, they may overstate the amount they would actually be willing to pay,

(ii) *Information bias*: can arise either as a result of providing too little information about the choices offered or from misleading statements by the interviewer,

(iii) *Instrumental bias*: can arise if the respondent is hostile to the means by which payment would be collected. The vehicle chosen for payment (e.g. taxation, user fees) may result in different WTP responses. Moreover, some people accustomed to certain public goods and services being provided free of charge may protest at any kind of payment and be unwilling to pay anything,

(iv) *Starting-point bias*: the interviewer may bias the respondent's answer by establishing a reference point for an acceptable range of bids,

(v) *Hypothetical bias*: people may not give answers which reflect their true values, particularly if they have no incentive to answer correctly questions which take time and thought, and

(vi) *Constant budget bias*: this originates from the hypothesis that each individual has a type of mental budget for the environmental goods and services.

Another problem associated with CVM is how to decide whether WTP or Willingness-to-accept-compensation (WTAC) is the most appropriate measure. WTP is constrained by income while WTAC is not. Empirical evidence suggests that WTAC far exceeds WTP for goods without close substitutes and for which individuals have legal or customary property rights. In numerous experiments, Kahneman and Knetsch (1992a, b) have shown that the mere granting of ownership will cause individuals to value a good more highly than they would be willing to pay to obtain the same item. In practice, this means that WTAC should be used when individuals are forced to give up something or suffer some damage (e.g. from polluted water). Similarly, WTP is the appropriate measure when an individual is being asked about an improvement from the present state. Actual experiments have shown this consistent asymmetry between WTP and WTAC for the same item, always depend on the state of initial ownership (Knetsch, 1993).

2.4.4 Averting Costs Approach

In the context of the WTP approach, Musser *et al.* (1995) also introduce another approach of *Averting Costs* as a lower bound of the WTP. The *Averting Cost Approach* falls under the category of *alternative/replacement cost approaches*. Averting costs are costs incurred in order to prevent harm. These could be expenses such as those incurred to prevent people from drinking contaminated water, for example by boiling water or hauling water from an alternative source. The calculation of averting costs is based on actual market behavior, in contrast to the individual statements of WTP, which are hypothetical (Musser *et al.*, 1995). In general, however, comparing the deducing of WTP from market behavior such as averting costs, with the use of CVM surveys to estimate WTP, the later provides the particular advantage that it can be used in situations where related market behavior is unavailable (Webb and Iskandarani, 1998). It can also be used to measure the effects of changes to the environment on social welfare and may also help in validating estimates of consumer's surplus obtained by more conventional methods (Dixon *et al.*, 1994). WTP, can therefore, save as the best approach for measuring values of some environmental goods or services if the survey is properly planned and conducted.

While the intangible benefits of water may be measured from Willingness-to-Pay (WTP), the associated costs can be monetized using the concept of *Opportunity Costs* – the returns foregone where a scarce resource is used for one purpose instead of the next best alternative. Laughland *et al.* (1993) for example, have used this approach to assess the implications of the opportunity cost of time for the measurement of averting costs. They use the data that were collected through a survey of individuals in Pennsylvania during a Giardia contamination incident to calculate the cost of boiling, hauling, or purchasing water to avoid infection.

2.4.5 The Hedonic Pricing Approach

The *Hedonic Pricing Approach* is another method of deriving benefit estimates based on revealed choices about related goods. It is therefore grouped under the category of ***observed indirect or implicit or revealed preference approach***. The approach relies on the notion that the price of marketed goods can be decomposed into attributes, and that an implicit price exists for each of these attributes. The approach can be used to place monetary values on property attributes such as proximity to water intakes for irrigation, availability of canal or ground water, proximity to roads, market and major population centres, productivity and fertility index or land rent and annual lease revenue (Hussain *et al.*, 2001).

A sub-method of the hedonic pricing approach is the ***Hedonic Property Value Approach***. North and Griffin (1993) have applied this approach in their study using data from a sample of rural households in one region of the Philippines. They estimate the determinant of the rental value of dwellings using the bid-rent approach to the hedonic price model. In particular, they did a research on the relative valuation these households place on owning a private source of water and distance to a public or communal source. They formulate a bid-rent function that characterizes the trade-offs each household is willing to make between housing attributes (e.g. distance to water source) and paying more rent. They found that households in all income ranges were willing to pay about half of their monthly imputed-rent to have piped water in the house. But there was lower willingness to pay for water in the yard. At this time, the poor households were more willing to pay for proximity to a town or improved housing materials than for a closer shared water source.

2.5 Previous studies on water-based livelihoods and benefits

Several authors in the field of water management and utilization assert that water resources have the potential to improve economic benefits and rural livelihoods. In crop production, irrigation has significantly contributed to improved welfare among farming households in many areas. It has provided means and opportunities for "rural livelihood diversification." Lankford (2002), for example, provides an evidence of livelihood diversification among farmers in Chanzuru (Morogoro, Tanzania). In the GRR catchment, people are also employing a number of livelihood diversification and coping strategies, including those that relate to farming practices, business and market relations, and those that relate to social and cultural relations (SMUWC, 2001). But, as also argued in Ellis and Mdoe (2003), the poorer groups have the most ineffective coping strategies, which erode their asset base. They depend mainly on food crop production, distress sales of household goods and sale of labour for their livelihoods, while the better off combine crop farming with other activities (e.g. rising livestock holdings and wide spread engagement in non-farm self-employments). According to SMUWC (2001), the poor are also far less likely to farm irrigated rice and indeed, they may have given up doing so because of their disadvantageous position at the tail end of irrigation systems, increased drought, their inability to access water at critical times and constraints on making intensive labour inputs. Richer people on the other hand, are more likely to be able to sell stored assets (e.g. grains and livestock) to weather disasters without substantially eroding their asset base.

SMUWC (2001) also reports a gradual transition of the Sangu people from pastoral to crop farming. The Sangu people were traditionally a pastoral society, but recently only a smaller proportion of the Sangu people own livestock. Similarly, incoming pastoralists from north and central Tanzania have also been incorporating irrigated agriculture in their production systems. The Maasai, for example, have begun to engage in paddy and maize cultivation as a strategy to reduce dwindling herd sizes (SMUWC, 2001).

Water resources also add value to other natural resources. Water supports the lives of wildlife by improving the habitats they live in and hence increasing their number. This has in turn, a number of livelihood implications, as in the case of MBOMIPA (Matumizi Bora ya Malihai Idodi na Pawaga or Sustainable Use of Wildlife Resources in Idodi and Pawaga) where wildlife has attracted tourists and provided other opportunities for rural income diversification, particularly for the people residing close to the Ruaha National Park (Ashley *et al.*, 2002). It has benefited the local communities through, for example, wildlife income earned by village government, which is invested in essential services (e.g. health and education), and productive infrastructure (e.g. roads and irrigation). In addition, donor funds have been used to improve roads through the villages. This has many positive effects for local residents, while also stimulating tourism; it encourages tourists to move away through the bush to the villages, and stimulates development of other income generating activities (e.g. craft shops and camps) (Ashley *et al.*, 2002). On the other hand, however, wildlife has also caused some negative effects on livelihoods, particularly of the people who live close to the Park. The most evident ones are those of wild animals straying into villages and eating or damaging crops, predating livestock and in some incidences causing serious health hazards (e.g. human carnage by wild animals).

It is however, worth noting that while a good number of studies have been done on rural livelihoods in Tanzania, the economic valuation of water resources has received little attention. It is only in early 2000s that researchers have emerged and started to incorporate this latter valuation. Examples include the recent studies by Turpie *et al.* (2003) who did a preliminary economic assessment of water resources of the Pangani River Basin; and FBD (2003) in their economic analysis of catchment forest Reserves in Tanzania. Yet, none of these studies has covered the valuation of water resources in the GRR catchment. None has also assessed the impact of irrigated agriculture on income inequality and the opportunity costs of water transfer from irrigation to other sectors. This information is key to the achievement of sustainable water resources allocation as will help informing water resources managers and decision makers on the implication of various water management and allocation decisions. This study was therefore geared towards that end.

CHAPTER THREE

3.0 THE CONCEPTUAL FRAMEWORK AND METHODS USED IN THE STUDY

3.1 Overview

This chapter comprises four main sections. The next section presents the conceptual framework for the study - which is followed by a section describing the data used for the study including data collected through semi-structured interviews, informal discussions and secondary data as well as the selection of the sample villages and households. The last two sections present the methods of data analysis and limitations of the study respectively.

3.2 The conceptual framework for the study

The conceptual framework for this study (Figure 6) draws on a number of livelihood frameworks, models and approaches, including the Sustainable Livelihood Framework (SLF) by DFID (1999), CARE's Livelihood Model, the UNDP's approach to promoting Sustainable Livelihoods (SL), and the Oxfarm's SL framework.

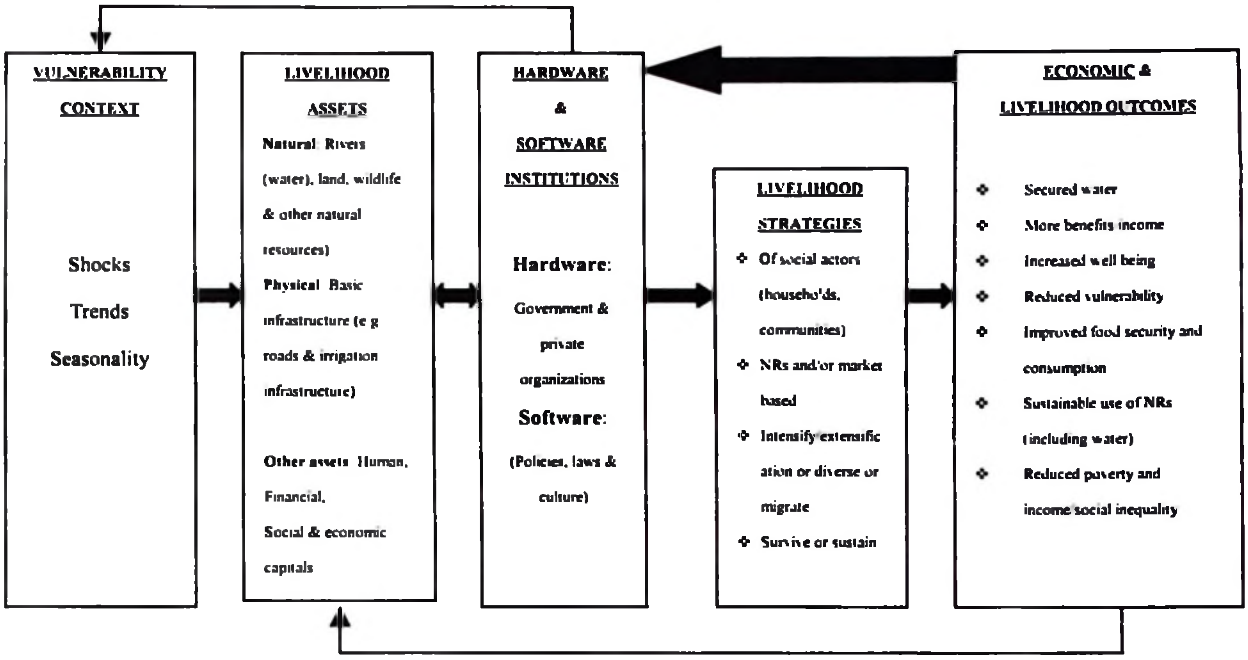

Figure 6: The conceptual framework for the study

The analysis of vulnerability context considered the shocks, seasonality and trends in agricultural production (e.g. development of irrigation and types of farming system); emergence of new income generating activities; commodity marketing aspects (including access to commodity markets and trends of input and output prices); and water resources availability (e.g. river flows, rainfall patterns and water abstraction).

At the village level, the vulnerability indicators included the lack of infrastructure (e.g. year round passable roads and irrigation infrastructures); lack of community level institutions, and underprivileged access to the water resources. Household income levels; access to livelihood assets; household structure and dependency ratios were also used as indicators for household vulnerability.

The analysis of livelihood assets involved an evaluation of the basic material and social, intangible and tangible assets that people in the study area have in their possession. These assets were considered as the building blocks or 'capital' base from which livelihood is constructed. The study considered a wider range of asset portfolio (including water, land and livestock holdings, economic and financial assets), which is essential for the pursuit of any livelihood strategy. Access to financial capital was assessed from the ability of household to save and borrow from formal organizations (e.g. banks) and informal structures (e.g. relatives, private money lenders) and ownership of liquid assets such as livestock, means of production (i.e. farm and non-farm equipment such as tractor, water pump, rice mill, workshop equipment and the like).

Access to social capital was evaluated using indicators such as membership to organizations, networks, social relations and associations that increase trust, ability to work together, access to opportunities, reciprocity and informal safety nets. The access to human capital was evaluated from the number of illiterate people, education level and the number of people employed in farming, off-farm and non-farm activities per household.

The analytical framework in this study has also considered the role of both software and hardware institutions which influence the access to benefits like land, money, or employment, of individuals and households. The underlining assumption was that access to all of these could affect the ability to make a living and achieve security. Institutions that are already in place (e.g. the RBWO and other organizations dealing with water management in the GRR catchment; policies, laws and culture) play an important role in shaping the choices made by local people about their livelihoods.

The ability to pursue different livelihood strategies was considered as dependent on the basic material and social, tangible (e.g. stores and material resources) and intangible assets (e.g. claims and access) that people in the study area have in their possession. Among others, livelihood strategies of social actors – natural resources and/or market based, diversification, intensification or extensification and migration were considered to be the key livelihood strategies in the study area. The nature and drivers for these strategies, therefore, formed a part of the livelihood analysis in this study.

The livelihood outcome and trade-offs were evaluated using different indicators, including value and benefits generated from water utilization; secured access to water; improved well being and capabilities, and reduced income inequality and poverty.

The following mathematical expression was used to represent the relationship between individual components of the framework:

$$L_W = f(V_C, A_L, I_{HS}, S_L) \quad (1)$$

Where L_W = livelihood outcomes and economic benefits of water utilization by the household,

V_C = the vulnerability context within which the household operates,

A_L = a vector of assets that the household draws upon (natural, physical, financial, social and human capitals),

I_{HS} = a vector of hardware and software institutions which influence utilization of assets by the household in pursuit of different livelihood strategies, and

S_L = a vector of choices the household employs in pursuit of income, security, well-being and other productive as well as reproductive goals.

3.3 Data for the study

This study has benefited from both primary (own survey data) and secondary data (including time series, sectoral and cross-sectoral data) collected between early 2002 and late 2004. The details on the methods and types of data collected are presented in the subsequent subsections.

3.3.1 Semi-structured interviews, informal discussions and secondary data

At the household level, a detailed questionnaire (Appendix 1) was administered to a total number of 580 households. The questionnaire sought to elicit a set of information that would help analysing the value of water and benefits accrued from different uses at the household level (i.e. irrigation, brick making, livestock keeping, fishing and other domestic water uses). The questionnaire encompassed issues of crop production for both paddy and non-paddy crops (acreage, inputs, outputs, prices, quantities produced, sold and consumed domestically, quantities in store and produces received or given in-kind), other sources of income, aspects of water resource management (water conservation practices, sources of water for irrigation, type of irrigation system, irrigation practices) and utilization, access to sources of irrigation water and amount of money paid as water fee.

The primary data collected were complemented by secondary information collected from the different sources, including:

(i) The Mbarali District Agricultural and Livestock Development Office: Collected secondary data on crop production (cultivated area and quantity produced), marketing and price data at the district level, which formed a useful input in analysing the trends of benefits and values of water in crop production at the district level.

(ii) The Ministry of Agriculture and Food Security (MAFS): Obtained data on rice production and marketing (including producer and retail prices) at the national and regional levels. These were used for analysing the benefits and share of the Usangu (Upper GRR catchment) rice to the national production.

(iii) Tanzania Electric Supply Company (TANESCO) Mtera, Kidatu and Head Office in Dar es Salaam: Collected data on power generation, dam levels, turbine discharge volume, spill/valve discharges, electricity tariffs and generating costs (including repair and maintenance costs, transport, security payments, salaries and other costs). These were used for analysing the value and benefits of water utilization in hydropower generation.

(iv) Bank of Tanzania (BoT): National Consumer Price Indices (NCPIs): These were useful in calculating real prices (i.e. converting nominal prices into real prices), and

(v) SMUWC and RIPARWIN databases: Obtained river flow data, climatic data, water inflows and outflows for the Usangu Eastern Wetland and the Ruaha National Park, which were used in estimating the value and benefits of water utilization for nature conservation.

3.3.2 Selection of the sample villages

For the household survey, ten sample villages (Table 1) were purposely selected - covering the major three zones in the Upper GRR catchment (i.e. the Upper, Middle and Lower Usangu). The sample villages (Figure 7) were purposively selected to capture a wide range of water-based livelihoods and production systems in the catchment.

In addition other four study sites were included in order to capture the other important water uses in the GRR catchment (i.e. the Usangu Eastern Wetland, RNP, and the Mtera and Kidatu hydropower stations). The first two sites represent water uses for nature conservation and the remaining represent water uses for hydropower generation.

Table 1: Sample villages and their major production systems

Name of village	Zonal representation	Production systems
Inyala	Upper	Rainfed (maize, potatoes and wheat) and dry-season irrigation (maize, beans, potatoes, vegetables)
Mahongole Ihahi	Middle	Dry season irrigation (maize, beans, vegetables) and wet season irrigation (paddy)
Uturo Ukwavila	Middle	Dry-season irrigation (maize, beans, potatoes, vegetables); wet season irrigation (paddy) and rainfed (maize)
Mwatenga Kapunga	Middle	Wet season irrigation (paddy)
Ukwaheri Madundasi Upagama	Lower	Rainfed (maize, sorghum/millet) and livestock keeping

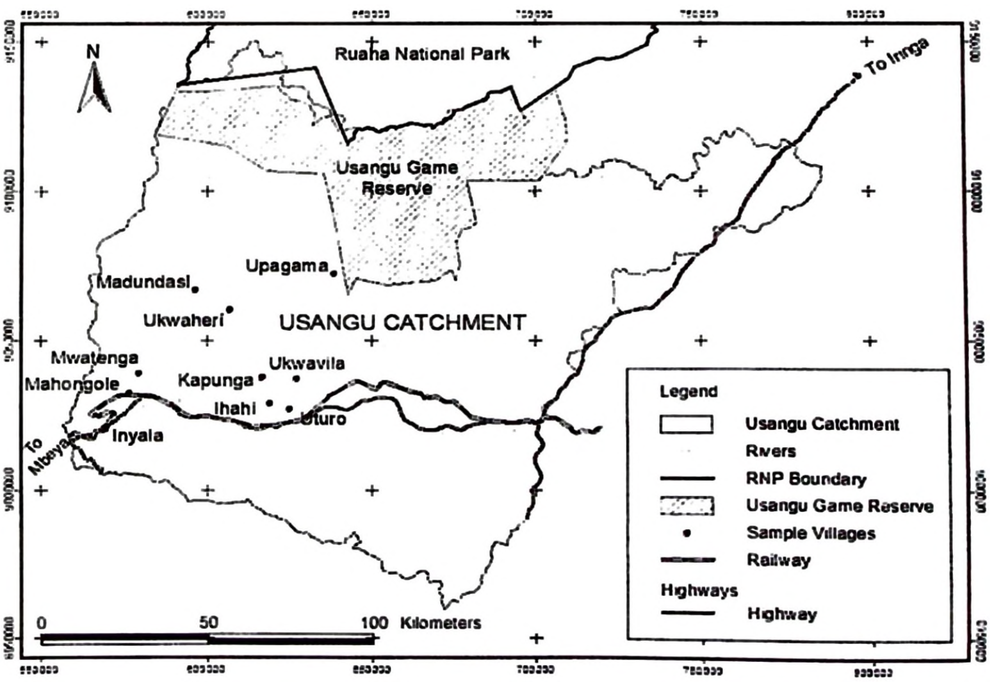

Figure 7: Map of the Upper GRR catchment showing the location of the study villages

3.3.3 Selection of the sample households

A range of Participatory Rural Appraisal (PRA) methods (including Livelihood analysis and Wealth ranking) were applied as a footing step to the study. These helped to identify wealth groups and livelihood typologies that acted as the sampling frame for a stratified random sample.

The wealth ranking exercise was conducted in all the ten sample villages and 10% of the total households were chosen in each village (from the village registers) in order to provide a logistically feasible sampling frame. The wealth ranking exercise eventually resulted in identification of five wealth groups ("very rich", "rich" "medium", "poor" and "very poor").

The "very rich" and "rich" households were relatively a small group, covering only about 13% of the total households. They were food secure all year round and have a fairly secure livelihood base. The "medium" wealth class constituted about 35% of the households, with a smaller base of assets to draw on, but the majority of the households in this class are still food secure all year round. The "poor" and "very poor" households (generally combined and discussed in this thesis under the "poor" stratum) made up more than half of the total households (52%).

Land holding was listed as one of the most important determinants of wealth. The major types of land ownership include: inheritance (51%), Government given (18%), borrowed (13%), hired (12%) and land ownership through purchase (6%). Those who are not able to cultivate their own land can hire it for money or in ex-change of agricultural produce especially the crop that was grown on that particular farm for that specific season. In terms of land ownership the determining factors for wealth include the total area cultivated and that which is inherited (owned). In addition, the quantity of crops harvested is another important determinant. In Upper Usangu (represented by Inyala village), the priority crops were maize, beans, potatoes and vegetables. Paddy was the priority crop in the middle part (represented by Kapunga, Mahongole, Mwatenga, Ihahi, Uturo and Ukwavila villages) and maize, millet and sorghum are important crops in the Lower Usangu (represented by Ukwaheri, Madundasi and Upagama villages). Hence the measure for wealth is not only dependent on the number of hectares cultivated but also on the crop yield which is commonly expressed in number of bags.

Possession of paddy was considered as the most important factor determining the well being of a family, particularly in the Middle Usangu. According to the key informants in the wealth ranking exercises, a person who harvests adequate rice has almost everything such as money, food, can build a good house, and has social status in the community. The poor category of farmers harvests little rice because they cultivate little land using mostly family labour. Again, because of low life standards, the poor is more likely to become sick and hence reduced time for working on-farm. The poor have therefore, problems in securing their food.

Livestock (mainly cattle and shoats) was also listed as another important indicator of wealth (Table 5), particularly in Lower Usangu, where the majority of people are the Sukuma agropastoralists who migrated from Shinyanga and Mwanza regions in northern part of Tanzania. Other than cattle and shoats, the villagers, particularly in the Upper and Middle Usangu considered owning pigs as an important activity that can help promote a person to a wealthier rank.

Table 2: Indicators for different wealth ranks among households in the Upper GRR catchment

Assets and activities	Wealth categories				
	Very rich	Rich	Medium	Poor	Very poor
Natural capital: Land owned	Up to 8 - 20 ha or more	4 - 8 ha	1.2 – 4 ha	0.4 – 1.2 ha	Less than 0.4 ha or do not own land at all
Financial capital: Livestock owned	Cattle: 20 – 200 or more, shoats: 50 – 180, pigs: 10 – 20	Cattle: 15 – 20, shoats: 20 – 50, pigs: 5 – 10	Cattle: 2 – 15, shoats:3 – 20, pigs: 2 – 5	Less than 2 cattle or no cattle, shoats: 1 – 2, pigs: 1 – 2, a few chickens	A few chickens only
Human capital: Labour	Hire labour	Hire labour seasonally	May hire labour seasonally	May sell labour	Selling labour
Human capital: Education	Primary level or above	Primary level	Primary level	Many have not been to school	Many have not been to school
Human capital: Health services	Can always pay for health services (Hospitals, Dispensary, Clinics, traditional healers)	Can pay for health service	Can afford to pay for services from Dispensaries and traditional healers	Can afford to pay for services from traditional healers /use traditional medicines	Can not afford paying for health service (use traditional medicines)
Physical and financial capital: Other assets owned	Vehicles, Milling machine, Sewing machine, Refrigerator, Bicycles, TV, Radio, (ox-carts, oxen ploughs), private water point	Bicycle(s), Radio, Implements (ox-carts, oxen ploughs)	Bicycle(s), Radio	Few have radios	None

The sample households for this study were therefore, taken randomly from the list of households under each wealth group (10% from each of the wealth category as identified during the wealth ranking exercises) resulting in a sample size of 580 households (24 from the "very rich" category, 71 from the "rich" category, 226 from the "medium" category, 188 from the "poor" category and 71 from the "very poor" category).

The purpose of the wealth ranking, apart from the perceptions about poverty and wealth gained from the exercise was to ensure that the sample drawn represent the full range of livelihood circumstances in the study area, rather than being accidentally clustered around the mode of the range.

Paddy being the major crop under irrigation in the study area, then a total number of 140 paddy-growing households from three villages in the Middle Usangu (Ihahi, Uturo and Ukwavila) were purposefully and categorically chosen out of the total sample of 580 households for a closer analysis of the value of water in paddy production and a comparison of profit margins between paddy farming systems (Figure 8). The three villages were selected because they represent a mosaic of paddy farming systems (low input to high input and rainfed to irrigated types). All the three villages are also located adjacent to the Kapunga National Agriculture and Food Corporation (NAFCO) farm, where some farmers from these villages also hire plots for rice production. The following five types of paddy production systems were identified:

(i) *Farming System Type 1: "Rainfed subsistence farmers"* - involved smallholder farmers who cultivated rain-fed paddy in 2002/03 using hand hoe and family labour,

(ii) *Farming System Type 2:* "Rainfed paddy growers using high level of inputs" - involved smallholder farmers who cultivated rain-fed paddy in 2002/03 using tractor, fertilizers and hired labour,

(iii) *Farming System Type 3:* "Irrigated paddy growers on NAFCO plots" - involved smallholder farmers who hired NAFCO plots in 2002/03, cultivated irrigated paddy using tractor, fertilizers and hired labour,

(iv) *Farming System Type 4: "Small irrigated paddy growers using high level of inputs"* - involved smallholder farmers who cultivated irrigated paddy outside the NAFCO farm in 2002/03 using tractor, fertilizers and hired labour, and

(v) *Farming System Type 5* "*Small irrigated paddy growers*" represented the most common smallholder paddy growers in the Upper GRR catchment cultivating irrigated paddy using hand tools and family labour.

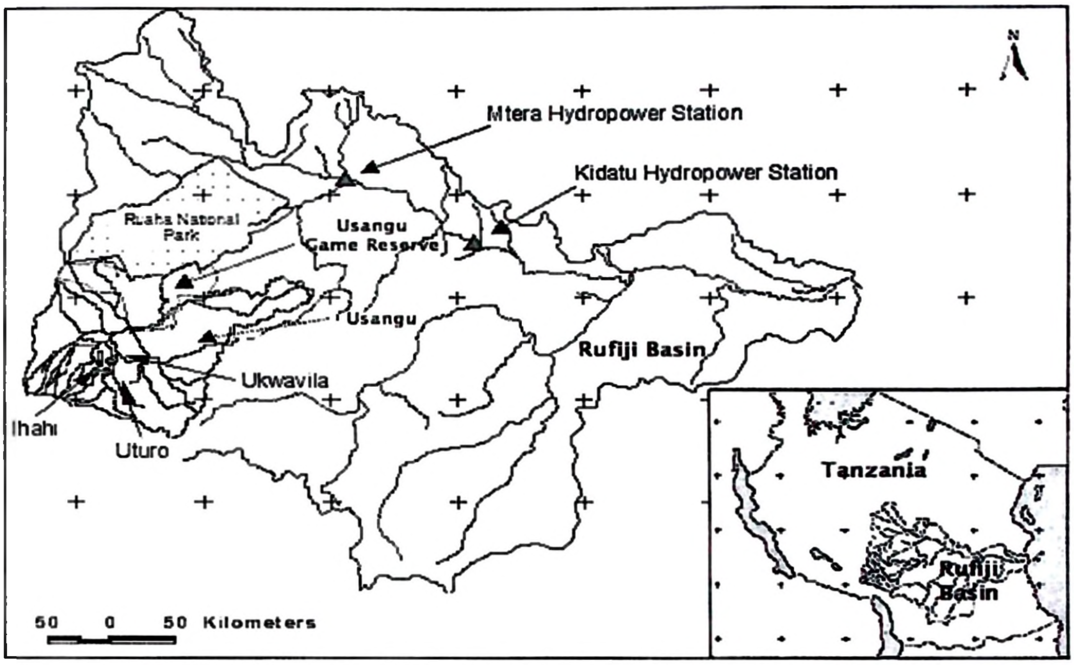

Figure 8: The map of Rufiji Basin showing the Usangu area, the villages selected for a closer study on the value of water in paddy production, UGR, RNP and locations of hydropower stations

3.4 Methods of data analysis

Both qualitative and quantitative techniques were used to analyse the data. For more precise analysis, computer-based statistical programs (MINITAB and SPSS) were used. Descriptive statistics, charts and graphs were employed to present the results.

Different analytical tools were used to analyse livelihoods and value or benefits of water utilisation in different sectors. These are explained in the following sub-sections.

3.4.1 Evaluation of livelihoods, poverty and income inequality

The qualitative analysis of livelihoods and poverty was done using Livelihood analysis and Wealth ranking exercises (PRA – based approaches) and the results of the qualitative analysis were complemented with quantitative analysis of livelihoods, poverty and income equality using the *Coefficient of variation* and *Gini coefficient* approaches adapted from Adams (1994).

Corresponding to the *coefficient of variation*, the following decomposition was used:

$$w_i c_i = 1,\ w_i = \mu_i / \mu,\ c_i = \rho_i\, [(\sigma_i / \mu_i) / (\sigma / \mu)] \qquad (2)$$

Where,

$w_i c_i$ = the factor inequality weight of the i-th source in overall inequality;

μ_i = the mean income from the i-th source;

c_i = the relative concentration coefficient of the i-th source in overall inequality;

ρ_i = the correlation coefficient between the i-th source and total income, and

σ_i = the covariance involving the i-th income source.

The following equation was used for the decomposition corresponding to the *Gini coefficient*:

$$w_i g_i = 1,\ w_i = \mu_i / \mu,\ g_i = R_i * (G_i / G),\ R_i = cov(y_i, r) / cov(y_i, r_i) \quad (3)$$

Where,

$w_i g_i$ = the factor inequality weight of the i-th source in overall inequality;

g_i = the relative concentration coefficient of the i-th source in overall inequality;

G_i = the Gini coefficient of the i-th source of income;

y_i = series of income from the i-th source;

r_i = series corresponding ranks;

G = total income Gini coefficient, and

R = correlation ratio.

The two decomposition techniques (the *coefficient of variation* and *Gini coefficient*) were purposely used in this study to pinpoint the contribution of different sources of income to total inequality. This is useful because conventionally, most studies have often attempted to evaluate the distributional impact of certain types of income by merely comparing the size of distribution of that particular income with that of the total rural income as a whole. Because it neglects the twin issues of income weights and covariance between income sources, any approach, which merely compares the size distribution of one particular income with that of total income, is likely to arrive at erroneous conclusions regarding the distributional impact of that particular income.

In this study, the total household incomes were divided into five groups of income (paddy, dry season irrigated crops, rainfed crops, livestock and "others"). The latter category ("others") includes incomes from brick making, fishery, transfers, labouring, rental and other non-farm activities. It should however, be noted that the agricultural income was disaggregated further into four categories (i.e. paddy, dry season irrigated crops, rainfed crops and livestock) because these components were presupposed to have different effects on income inequality at least in the context of the study area where irrigated agriculture and livestock keeping are important economic activities.

3.4.2 Evaluation of economic benefits of water utilisation

The analysis of the benefits of water in crop production, hydropower generation, livestock, brick making and fisheries involved the use of the **Change in Net Income Approach** as given in the following equation.

$$AW_V = (NVO_w - NVO_{wo})/W \quad (4)$$

$$NVO_x = GVO_x - C_x, \quad (5)$$

Where, AW_V = the average value of water

W = volume of water used

NVO_w = the net output value *with* irrigation or rainfall water in irrigated or rainfed agriculture respectively

NVO_{wo} = the net output value *without* irrigation or rainfall water in irrigated or rainfed agriculture respectively

GVO_x = the gross output value, and

C_x = the total cost of production

Before applying the Change in Net Income Approach, the analysis of the value of water in crop production started with modelling of Crop Water Productivities (CWPs) using the FAO's CROPWAT model (8.0 Beta version) (FAO, 1992). This is a computer programme used to calculate crop water requirements (CWRs) and irrigation requirements (IRs) from climatic and crop data. The programme also allows the development of irrigation schedules for different management conditions and the calculation of scheme water supply for varying cropping patterns.

The climatic data (gathered from the weather stations found in the study area) were used in the model to calculate the reference crop evapotranspiration (ETo). The ETo together with rainfall, crop parameters (crop types, crop coefficients, crop growth stages, crop heights, depletion factors from total available soil moisture (TAM) and planting dates) were used in the simulation of CWRs. For crops under irrigation, soil information (soil types) and irrigation schedules (of fixed intervals) required to replace the soil moisture to field capacity were also used in the simulation.

Taking into account local precipitation, potential evaporation, crop growth coefficients and cropping patterns (e.g. planting dates), the volumes of water used in irrigation (both 'abstracted' and 'consumed') at the farm level were modelled as follows (e.g. in irrigated paddy):

$$PAW_T = CWR + Pe + Lp \qquad (6)$$

Where, PAW_T = Total water 'abstracted' for irrigation

CWR = Crop water requirement or actual water use by crop (ETc);

CWR ('consumed') = ETo * CropKc

Pe = Deep percolation

Lp = Water used for land preparation

ETo = Reference crop evapotranspiration

CropKc = Crop coefficient

The irrigation requirement for the crop (IR_p) was taken as the difference between the total crop water requirement and the effective rainfall. For irrigated crops, the productivity of water for abstracted water (PW_W) was calculated as the ratio of crop yield to total water abstracted for irrigation (PAW_T) or Total Gross Irrigation (TGI). For rainfed crops the CWPs were estimated based on rainfall (RF), effective rainfall

(ER) and actual crop water use or evapotranspiration (ETa). The productivity of rainfed water (PW_{RF}) was calculated as the ratio of crop yield to the total amount of rainfall received and this was taken as comparable to PW_w for irrigated crops. For comparison reasons both PW_w and PW_{RF} were labelled as productivity of abstracted water. The productivity of consumed water (PW_{ETc}) was calculated as the ratio of crop yield to Crop Water Requirement (CWR) or Crop evapotranspiration (ETc).

The gross margins and returns to labour were calculated for each farming system and for each year from 1994 to 2003 using the following assumptions:

(i) Operational costs were assumed to be constant over the period and equal to those observed during the survey (in 2002 and 2003).

(ii) The variability of yields over the period was assumed to be constant across farming systems and equal to the one observed at district level (Appendix 2 for paddy and Appendix 4 for non-paddy crops). Series of yields for each farming system were calculated using the average yield observed during the survey (2002 and 2003) for the farming system, and the series of yield at district level.

(iii) Crop prices were assumed to be identical for all farming systems. The district level series of real prices was used (in 2002/03 Tsh).

The net output values were modelled as:

$$NVO = (Y_P \times P_P) - C_{OP} - C_L - C_{FL} - C_{HL} - C_W \quad (7)$$

Where, Y_P = the crop yield

P_P = the price of crop

C_{OP} entails all variable costs (seeds, fertilisers, pesticides, energy, transport and packaging, financial costs associated with the purchase of variable inputs, set at 10% of the total variable costs)

C_L = the land rental price

C_{FL} represents the cost of family labour, priced at average hired labour wage, including field operation and management

C_{HL} = the cost of hired labour

C_W = the irrigation fee.

In the hydropower sector, production was considered to depend on two important aspects: the availability of water to be captured in the reservoir (the inflows) and the necessary (effective) head to generate the power. The Mtera and Kidatu hydropower plants were designed to operate as a single system, in a way that water is mainly captured into the Mtera reservoir and used to produce power both at Mtera and Kidatu. The analysis of the value of water in hydropower therefore took into account this aspect and was done using the following three scenarios (see also Table 3):

(i) Scenario S1: This scenario considered the Mtera and Kidatu plants as a single producing system and the turbine discharges at Kidatu as the volume of water used for HEP generation. The scenario is based on the argument that given the design of the system, the outflow from Kidatu is in essence incorporating the outflow from Mtera, plus additional flows into Kidatu. Water from Mtera passes through both sets of turbines so should only be counted once. However, the scenario does not incorporate the consumptive water use (i.e. the water consumed through evaporation from the Mtera and Kidatu reservoirs). Turpie *et al.* (2003) also used this option in their assessment of water value in the Pangani river basin.

(ii) Scenario S2: Like in scenario S1 this scenario also considered the Mtera and Kidatu plants as a single producing system but rather than using the turbine discharge volumes it used the combined net evaporation for Mtera and Kidatu reservoirs as the volume of water used for HEP generation by the system (the consumptive use).

(iii) Scenario S3: This scenario also considered the Mtera and Kidatu plants as constituting a single producing system but it combined the turbine discharges at Kidatu and the net evaporation losses for both the Mtera and Kidatu reservoirs and treated them as the volume of water used for HEP generation. The scenario is based on the argument that the water passing through the turbines could have been consumed upstream. There is therefore lost opportunity for upstream users in letting the water flow downstream. However, this assumption, that the water could have been "consumed" by the upstream users, might in practice not always be the case - particularly as much of the flows entering the system are high wet season flows. Of course by storing water and then releasing it downstream, the hydropower scheme provides opportunities for other users, which strictly should also be taken into consideration.

Table 3: Main characteristics of hydropower scenarios

Hydropower scenario	Water volume considered	Water volume in Mm^3
Scenario S1	Turbine discharge at Kidatu (non-consumptive use)	3,002
Scenario S2	Net evaporation at Mtera and Kidatu (consumptive use)	1,094
Scenario S3	Turbine discharge at Kidatu + Net evaporation at Mtera and Kidatu (consumptive and non consumptive uses)	4,096

The valuation of the electricity produced by the Mtera-Kidatu hydropower plants was based on the data collected from the plants and TANESCO Head Office in Dar es Salaam. Two types of values were used:

(i) the Long Run Marginal Cost (LRMC) of electricity production, of Tsh 135.19 ($ 0.1271) per kilowatt hour (kWh) given by TANESCO (2002) and (The East African Community, 2004), and

(ii) the average electricity tariff for 2002 and 2003 of Tsh 69.79/kWh (source: TANESCO).

However, recent studies in Tanzania have used the second value (the average electricity tariff). FBD (2003), for example, valued power production at Tsh 25.9 per kWh as the price of power to domestic consumers in 2003 under the assumption that this price was equal to the price that would be attained in a competitive market, less Tsh 2.32 per kWh as the operational costs of power generation. Turpie *et al.* (2003)

used the average revenue, for all users, from power generation in 2003, on the basis that electricity tariffs depend on the customer consumption (the tariff rises to Tsh 90 per kWh after the first 100 kWh). Considering that electricity tariffs are regulated by the state and do not reflect the real economic value of electricity, the LRMC is therefore preferred in the present study (details about the calculation of LRMC are given in Appendix 5). The second value (the average electricity tariff) is also used in order to highlight the sensitivity of the value of water to electricity value.

The net output value of hydropower was calculated using the following equation:

$$NVO = KWh \times P_E - C_{OP} - C_G \qquad (8)$$

Where, KWh = the quantity of electricity produced (in kWh)

P_E = the value of electricity

C_{OP} = the sum of operational costs

C_G = the sum of generating costs

For the livestock sector, the average number of livestock owned per household was converted into Tropical Livestock Units by applying the Tropical Livestock Units (TLUs) conventionally used for Sub-Saharan Africa. According to the International Livestock Centre for Africa (ILCA) (1990), Jahnke (1982) and Williamson and Payne (1978) the units are given as follows: an adult cow is equivalent to 0.7 TLU; a donkey to 0.5TLU; a pig to 0.3 TLU; goats and sheep to 0.1TLU; and poultry 0.01TLU.

The calculation of water use by livestock was mainly based on estimates given by King (1983) and SMUWC (2001). According to King (1983) an African indigenous adult cattle with 350 kg live-weight in semi arid area consumes about 25 litres of water per day but informal discussions with herdsmen and cattle owners revealed that water consumption by cattle (250 kg) is about 40 litres per day in the dry season when forage has low moisture content and 20 litres per day during the rainy season. These latter estimates are in line with the estimates given by SMUWC (2001) and were adopted in the calculation of water uses by livestock in this study.

Livestock production in the study area can be defined as that of low input category involving family labour (for herding) as the major input, mostly provided by young members of the family. Labour was valued at Tsh 5000 per month, which is the wage reported to be commonly paid to hired herdsmen in some villages in the Upper GRR catchment. The calculation of the value of water was then done using the **Change in Net Income Approach**.

For domestic uses, the value of water was estimated using the **Contingent Valuation Methods (CVM)**. Households were asked individually how much they are willing to pay for improved water supply. This involved the use of direct, open-ended question such as: "What is the maximum amount of money you would be willing to pay for having good quality or piped water supplied to your household?" In addition, the respondents were given specific choices requiring a yes or no answer. The questionnaires were designed in the form of a bidding game with several options of combining open-ended and yes or no questions.

For nature conservation (the Usangu Eastern Wetland and Ruaha National Park in particular), the value of water was estimated using the **Opportunity Cost Approach** based on:

(i) Simulated flows and evaporation data for the Usangu Eastern Wetland by Kashaigili *et al.* (2005),

(ii) Actual daily river-flow measurements recorded at Msembe station (1Ka59), which is located along the Great Ruaha River (GRR) in the Ruaha National Park, and

(iii) Estimated environmental base flows or minimum flows required in the dry season (Kashaigili *et al.*, 2005).

Kashaigili *et al.* (2005) developed an EXCEL based water balance model and used it to simulate the inflows to the Usangu Eastern Wetland over the period 1958 – 2004. The model treated the wetland as a simple reservoir, using dependent variables of storage and area, as well as outflows controlled by the water level at the N'giriama exit. They modified and fitted the storage-area and storage-elevation relationships derived by SMWUC (2001) with the power function to calculate the wetland area and the volumes of water stored from water level measurements at N'giriama exit and used climatic data from nearby meteorological stations. They calculated inflows using the following relationship:

$$\Delta S = P + Q_{in} - E - Q_{out} \qquad (9)$$

Where:

ΔS = change in water storage within the wetland

Q_{in} = total inflow to the wetland including contributions from groundwater

Q_{out} = total outflow from the wetland at N'giriama exit

P = rainfall falling directly onto the wetland (a function of wetland area)

E = evaporation from the wetland (also a function of wetland area)

The values or benefits of water were then estimated using the different volumes of water estimated by the model (for the Usangu Eastern Wetland) and river flow measurements at the Msembe station (for the Ruaha National Park) as equal to the returns foregone by not using this water in irrigation purposes upstream in the Usangu Plains.

3.5 Limitations of the study

This section presents a discussion of limitations or difficulties associated with water valuation and how these were handled in this study.

3.5.1 Practical problems to value irrigation water

In establishing values for irrigation water five main problems were encountered and dealt with as explained below:

(i) All methods to value irrigation water, and specifically the Change in Net Income method, rest on observing responses of crop yields to various water applications. Water productivity may vary according to soil type; fertility; climate of the year; farmer (management ability, experience, scale of farming operation, attitude towards risk and financial constraints); irrigation schedules and level of other inputs. In the absence of field observations of yield response to various levels of water application, an agronomic model, CROPWAT was used in this study.

(ii) As yields, prices and water applications greatly vary from year to year, it is recommended to compute values of water for a series of climatic years when data permit. Gaps in the time series climatic data may lead to inaccurate estimates of crop water uses. For this reason data from areas with similar climatic conditions in Dodoma region were used to fill in the gaps in climatic data and the CROPWAT model allowed the calculation of water requirements over a period of time.

(iii) In farming systems of developing countries, a large part of the production is usually used for household consumption. The economic value of total output includes the value of marketed output as well as the one of home consumption. The choice of appropriate price for the latter is an issue, especially when no market exists for these products. During the study home (household) consumption was valued at current prices in the village or nearby markets.

(iv) Non-cash costs such as family labour are not easy to assess. It is generally not recommended to use the minimum wage, as it is a distorted price. If field labour requirements are generally accurately evaluated, family labour devoted to management of farming activities is generally neglected. Young (1996) suggests using a percentage of the gross income (5% in the case of staple crops), which has been also adopted in this study.

(v) A massive transfer of water is likely to affect the national supply and prices of crops. To take this into consideration, demand and supply functions for crops (i.e. functions that express the price of crops against their demand or supply respectively) should be used instead of fixed prices. Because of lack of data to enable a comprehensive analysis of the demand and supply functions the prices used in this study were only fixed prices.

3.5.2 Practical problems to value water in agropastoral farming systems

Providing accurate and comparable estimates of the economic value of water is especially difficult where the different water uses overlap or are interdependent. Agricultural water use has a role in maintaining complex agro-ecological systems and isolating just a single aspect is fraught with difficulties.

In agropastoral farming systems, exact figures of the economic value of water can hardly be given due to the synthesis between different water using activities. Cattle, sheep and small ruminants, for example, consume a considerable amount of water through the water embedded in fodder, but simply accounting all this embedded water as livestock water consumption misses the point that livestock may graze on crop residues that would otherwise be lost. In fact, livestock grazing on crop residues might contribute to crop production. Livestock may graze on grasslands, feed on crops and water that would otherwise be unfit for human consumption, thus perhaps competing with the environmental water uses, but not with other human related uses. Then there is also the aspect of cattle that obtains drinking water from irrigation canals, benefiting from infrastructure initially planned to serve solely purposes of crop cultivation. Capturing these inter-linkages is normally difficult and the analysis of the value of water for livestock in this study has therefore considered only the water that is used by livestock as drinking water.

3.5.3 Practical problems to value water use in hydropower

As in irrigated agriculture, the economic value of water in hydropower generation is highly site specific (Young, 1996). The amount of potential power generation per unit of water depends on natural conditions at the site as well as the investment in water storage and generating facilities (their efficiency). Energy production from hydropower is therefore determined by the amount of water that flows through the turbines, the distance that water drops (effective head) and power plant efficiency, constrained by turbine and generator capacities.

Two steps are required to derive the value of water in hydropower generation (Young, 1996). The first step is to value the electricity produced from a specific hydropower plant. The second step is to calculate, using the *Change in Net Income method*, the portion of the total value of electricity output attributable to the water used for generation. Because electricity is typically sold into a power grid relying on a number of sources (hydro plus thermal), it is not convenient or even possible to specifically derive the demand for the hydro portion of the regional or national electrical supply. Also, because electricity prices are often set by government policy, which seldom reflects the marginal cost of new supply, observed electricity rates might be inappropriate for economic evaluation. Therefore, in the first step, the value (*shadow price*) of electricity is usually calculated via an alternative cost technique, based on estimated marginal costs for the next least-cost technology of electricity production. If not properly applied, this technique can lead to underestimated values of hydro-electricity because HEP is the most flexible form of electricity – i.e. it can be mobilized at any time, provided that there is enough water stored in dams and can therefore supply peak demands, contrary to most other forms of electricity (a thermal power station for example, cannot be stopped or started so easily). Thus, the marginal value of hydro electricity might probably be higher than the average value of electricity produced by another source. Its value also depends on the composition of power stations in the country. When available, the best option is to use the long-run marginal cost (LRMC) reflecting incremental cost of supplying a small increment of electrical power. In this study both the average electricity price (tariff) and the LRMC (as given in the TANESCO Power System Master Plan and the East African Power Master Plan Study - The East African Community (2004)) were used.

Nevertheless, care must also be taken to distinguish between base load generation and the load because of the cost of bringing less efficient and more expensive alternative capacities rapidly on line (thermal power). Alternative cost valuation of peaking power is particularly difficult because of site-specific characteristics of alternative capacities and the problem of allocating fixed costs between peaking and base load operations. For this reason, only base load values were estimated in this study.

3.5.4 Practical problems to value water for nature conservation

Estimating the value of water for nature conservation is a particularly challenging task. This requires an understanding of the relationship between water flows and nature or resource productivity, in addition to the understanding of demand for these resources. This in turn requires a multidisciplinary research work, and is often dependent on the existence of long-term data series on both the flow characteristics and biological aspects. Nevertheless, there are some components of the value of water which are almost impossible to quantify and sometimes even difficult to identify. Conservation of biodiversity and gene pools, aesthetic, socio-cultural and historical values are all examples of important components of the value of water, but they are not easily handled by economic analysis. In this study, the value of water for nature conservation was estimated using the Opportunity Cost Approach.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Overview

This chapter presents the results of analysis and discussion of water-based livelihoods in the Upper GRR catchment; value and economic benefits of water utilization, effect of water-based benefits on income distribution and poverty alleviation; and opportunity costs of water transfer away from irrigated agriculture. In addition, the chapter also presents a discussion of the problems and constraints facing water resources management in the GRR catchment.

4.2 Livelihood analysis

4.2.1 Livelihood assets

The results of quantitative analysis of the available key livelihood assets as revealed from the household surveys are summarized in Table 4.

Table 4: Household assets for the sample villages in the GRR catchment

	Upper Usangu			Middle Usangu			Lower Usangu		
Capital (Assets)	Poor	Medium	Rich	Poor	Medium	Rich	Poor	Medium	Rich
Average household size (persons)	4.3	5.2	4.9	5.1	5.4	6.3	7.3	7.7	8.1
Adult labour equivalent (%) of hh size	62.0	69.0	73.0	52.0	59.0	60.0	50.0	53.0	53.0
Area of land owned (ha)	1.4	2.4	3.2	2.1	3.6	4.8	3.6	5.8	7.4
Land under rainfed cultivation (ha)	0.2	0.8	1.4	0.9	0.2	0.3	2.0	5.1	6.2
Land under paddy cultivation (ha)	-	-		0.6	2.5	3.3	1.5	0.5	1.1
Land under dry season irrigation (ha)	1.4	1.2	1.0	0.4	0.9	1.2	-	-	-
Livestock per household owning Livestock (TLU)		4.1	5.2	1.4	8.7	10.0	3.4	31.4	131.8

The "very poor" and "poor" categories are combined and grouped as "poor" and the "rich" and "very rich" categories grouped as "rich." Due to the hilly nature of topography in the Upper Usangu paddy cultivation is uncommon. Likewise, lack of irrigation water during the dry season makes dry season irrigation a rare activity in Lower Usangu.

As it can be seen from Table 4 there is a significant variation in terms of number of persons per households among the three areas of Usangu (Upper, Middle, and Lower Usangu). The average household sizes in Lower Usangu are the highest. This can largely be attributed to the socio-cultural characteristics of the agropastoral households living in this area. Most of these households, especially those owning huge livestock herds reported to be polygamists having more than one wife and many children. They value big family sizes because of their potential to provide manpower or family labour for various farm activities. It is, for example, not uncommon to find many agropastoral households in Lower Usangu using child labour instead of adult labour in some farm activities such as cattle herding, which are basically high labour demanding in terms of total mandays per year but can as well be done using a relatively cheaper labour (child labour). They do this as an additional strategy in trying to offset high labour demands and save labour for other farm activities especially during peak periods.

Generally, the poorer households have less labour available and their labour resources for household farming activities are further reduced by the fact that they often sell-out labour, whereas the richer households can afford to hire labour.

In the Upper and Middle Usangu, the availability of suitable land for agriculture is limited. In the Upper Usangu plots of land with moderate slopes are limited, whereas in the middle part, the same is true for land that has secure access to dry season irrigation water and land that is suitable for paddy cultivation. In other words, access to suitable agricultural land is the major determinant of household livelihood in the

Upper and Middle Usangu (Table 5). Often the access to land and access to water are inseparable: paddy cultivation requires both suitable soils, as well as sufficient access to water, irrigable land is only useful in combination with secure access to irrigation water. This suggests a high social value of water in terms of its contribution to household wealth.

Table 5: Major indicators of household wealth in different parts of the study area

	Upper Usangu	Middle Usangu	Lower Usangu
Main indicators	Access to land with moderate slopes and dry season irrigable land and secure water	Access to land for paddy cultivation and/or access to dry season irrigable land (water)	Size of livestock herd

In the lower part, much more land is available due to a lower population density, but generally this land can be defined as of poor quality, mainly due to seasonal availability of water. However, the use of draught animal power enables the majority of the agro-pastoral farmers in this area to cultivate relatively large areas on heavy clay soils during the wet season.

About eighty percent of the households in the sample villages engage in livestock keeping, but livestock numbers in the Upper and Middle Usangu households are relatively smaller, and they consist mainly of chicken, sheep and goats and sometimes one or two cattle. In Lower Usangu, livestock numbers are quite high and livestock keeping is an important source of livelihoods.

The livelihood platform of the poor households is less favourable in comparison to that of the average households. In the Upper GRR catchment (Usangu area), specific bottlenecks in the livelihood platforms of the poor include limited access to natural resources such as irrigable land and irrigation water, human capital and labour (especially at peak of wet season), physical production capital such as agro-chemicals or livestock, and social capital such as the membership of local societies and associations.

The limitations in the livelihood platforms mean that the poor households are thus most likely to be hit by production problems such as labour shortages, pests and low soil fertility problems and droughts. In addition, when such problems occur, the poor households are also the ones that are most likely to be hit hardest, as they do not have the resource base to cope with shocks or to overcome short periods of crisis. Poor households often experience a critical period at the peak of the rainy season, when they have fully exhausted their household reserves and when labour shortages, food shortages, disease prevalence and cash demands are high.

Collective labour arrangements, lending and borrowing mechanisms were ranked as the most important forms of social capital in the Upper Usangu (Table 6). In the Middle Usangu, cooperation and social interaction are primarily dependent on income generating clubs and livelihood associations, the membership of which is dominated by middle-income households. In Lower Usangu, the value of collective arrangements and drawing on social networks were strongly stressed. Collective action, good social relationships and traditional ceremonies are important mechanisms that support the local livelihood strategies. Collective labour arrangements, traditional ceremonies and informal groups such as drinking circles crosscut social strata and result in higher levels of social capital for poor households.

Table 6: Weighted percentages for the common social assets in the study area (%)

Type	Upper Usangu	Middle Usangu	Lower Usangu	Usangu Total
Collective labour arrangements	39	16	46	34
Income generating clubs and livelihood associations	12	44	5	20
Lending and borrowing	31	13	3	16
Traditional ceremonies	4	10	18	11
Drinking circles	6	5	13	8
Kin arrangements	1	2	12	5
Membership to political parties	4	5	1	3
Religious meetings	2	3	1	2
Village meetings	1	2	1	1
Total	100	100	100	100

In general, vulnerability in terms of access to physical and natural resources increases gradually from upstream to downstream. The lower villages, like Ukwaheri and Madundasi, for example, suffer the most severe water shortage problems, as no water reaches these villages during the dry season. Furthermore, these villages have less favourable conditions for agriculture with suitable lands widely scattered, and there is poor or limited local infrastructure (e.g. roads are not passable during the wet season and irrigation infrastructure is generally lacking). However, related to other livelihood aspects, the agropastoral community in the lower villages is less vulnerable as the households in this area own more livestock and larger pieces of land compared to households in the upper and middle villages (Table 4).

The pattern of household wealth distribution may also serve to provide a general overview of the equity and fairness of the distribution of livelihood assets and benefits among households. Although land and water resources are not the only factors that influence wealth distribution, analysing them can provide some additional insight into the equity and fairness of the distribution of these assets.

The household wealth distribution in the Upper Usangu consists of a relative large middle class, a significant class of poor households and a relatively small class of very poor households, and of rich and very rich households, especially when compared to the wealth class distributions in the Middle and Lower Usangu (Figure 9).

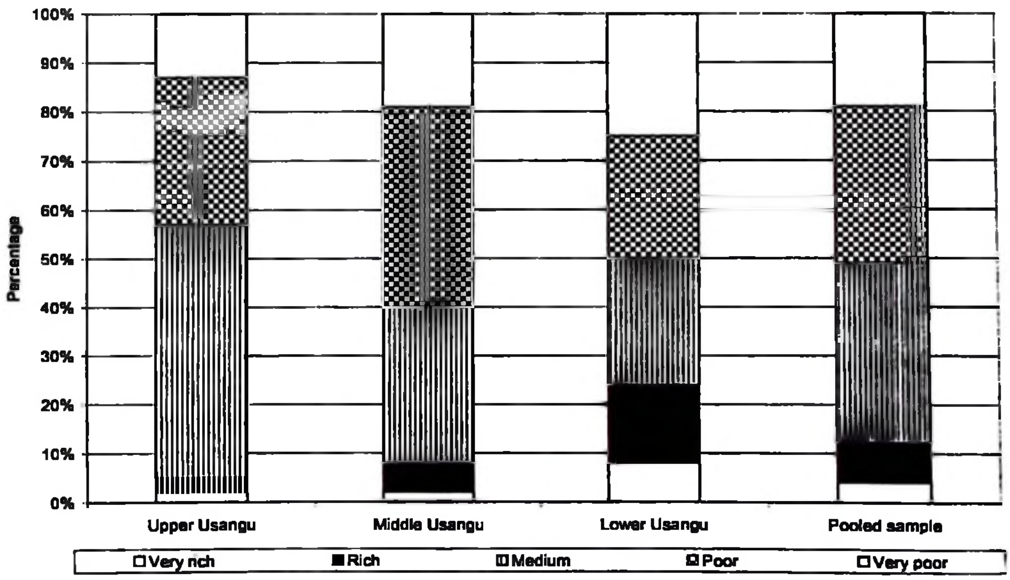

Figure 9: Household wealth distribution in the study area

Access to land is an important constraint on the income generating capacity of individual households, as in the uppermost part of the Upper Usangu tillable land with moderate slopes is limited, whereas in the lower part of Upper Usangu dry season cultivation of cash crops is fully dependent on access to irrigable land. As a result, access to land is one of the major determinants of household wealth in this zone.

The household wealth distribution in the *lower* part of the Middle Usangu (represented by villages like Mwatenga and Ukwavila) is related to the capacity of the household to produce paddy. As paddy cultivation is widespread during the wet season, there are relatively more medium income households. The higher strata households are those with access to prime agricultural land (i.e. land or plots located in the upstream parts of the modernized irrigation schemes, e.g. in Kapunga village) and the economic capacity to control the timing of rice marketing through early access to water or through storage.

Villages in the Middle Usangu are characterised by a larger stratum of 'poor' to 'very poor' households, some 60% of the total households. The larger part of 'poor' households is concentrated in the *upper* parts of Middle Usangu (represented by a village like Mahongole) where paddy cultivation is relatively scarce. Household wealth in this area is closely associated with the size and type of landholding (mainly for rainfed and irrigated agriculture), as well as the access to water resources during the dry season. Being part of the most densely populated section of the Upper GRR catchment, both land and water resources are increasingly becoming under competition. The characteristics of the production domain in this area contrast with those of the Upper Usangu and lower parts of Middle Usangu, in that the poor households at present have little alternatives at their disposal to make better use of the available natural resources outside their traditional rainfed maize cultivation.

Villages in the Lower Usangu are characterised by a relatively uniform household wealth distribution, with almost 50% of the households in the poor and very poor category (25% each), and a reasonable distribution of the remaining households among the medium, rich and very rich wealth ranks. The household wealth distribution in the Lower Usangu is primarily associated with possession of livestock. In other words wealth is thereby primarily determined by the number of livestock owned by the household, which determines both the level of income as well as the main household assets.

4.2.2 Dominant livelihood strategies and coping mechanisms

The different livelihood platforms and institution contexts lead to different livelihood strategies and coping mechanisms in the three major parts of the Upper GRR catchment. In general, three major farming systems could be noted as characterising the study area: a year round maize-mixed farming system in Upper Usangu, an intermediate paddy farming system in Middle Usangu, and an agropastoralist farming system in Lower Usangu. All the three farming systems suffer from dry season water scarcity and from pressures to release more water for downstream uses, but there are also considerable differences between them, as it will be discussed below.

The favourable micro-climatic condition in the most upper parts (e.g. in Ikhoho village) is relatively temperate with higher and prolonged rainfall allowing the households to engage in year round rainfed agriculture. The cropping pattern is typically diversified, permitting households to engage in a multiple strategy: maize (as the major staple and household subsistence crop), Irish potato, onions and tomatoes (as primary cash crops), as well as other vegetables and pulses (for both subsistence and petty cash). The farming system in the upper villages, though dominated by rainfed agriculture, is mixed with livestock for supplementary income.

The Upper Usangu villages, which border the Middle Usangu (e.g. Inyala village) are however characterised by a somewhat less favourable climate than the uppermost higher altitude area, with slightly less rainfall over a more protracted period. Rainfed agriculture has to be restricted to the wet season, while the successful raising of crops during the dry season depends on irrigation. The predominant farming system in these villages is characterised by a diversified multiple cropping strategy, dominated by rainfed maize as the major household staple and subsistence crop, supplemented by limited rainfed horticulture (potatoes, onions, tomatoes) as cash crops, and irrigated cash crops during the dry season (green maize, onions, tomatoes).

Villages in the Middle Usangu (e.g. Kapunga, Uturo, Mwatenga, Ihahi and Ukwavila) are characterized by the wet season oriented paddy-farming system. Their geological features make the major parts of land in these villages suitable for paddy cultivation, as wet season peak flows flood the lands, and water can be easily retained on the fields as standing water.

Villages in the Lower Usangu (e.g. Ukwaheri and Upagama) are relatively scarcely populated and the area has the largest number of livestock in the Upper GRR catchment, owned mostly by immigrant pastoralists, the Sukuma people from Northern Tanzania. Livestock is the main source of income, accounting for almost 70% of the total household income in the Lower Usangu (versus about 30% for the pooled sample). There is also additional rainfed agriculture and in some parts of the wetland areas paddy is grown. There is no dry season irrigated agriculture, as the water in the streams does not reach this area during the dry season.

Seasonal and permanent migrations also serve as important coping mechanisms. As Mcdowell and de Haan (1997) and Swift (1989) argue, these need to be considered in terms of the context within which they are occurring.

During the dry season, for example, cattle keepers with large herds (about forty cattle or more) in the Middle and Lower Usangu are forced to move their herds close to the permanent *Ihefu* swamp in the Usangu Eastern Wetland, as their own areas cannot provide enough pasture to sustain their herds during the dry season.

Until recently, livestock keepers in the Upper GRR catchment have grazed their livestock around the *Ihefu* swamp. Of recent, however, the Government of Tanzania has gazetted this area under the name of Usangu Game Reserve, which means that livestock is no longer permitted to enter this area for grazing, thus severely restricting the 'livestock carrying capacity' of the Upper GRR catchment. Although the Usangu Game Reserve was gazetted already in 1998, the restricted access to the grazing grounds is only recently being enforced, affecting in particular the pastoral households in the Lower Usangu. Despite this restriction, a number of livestock keepers are still entering and grazing their livestock illegally in the reserve and the number of immigrant households entering the Upper GRR catchment is substantial.

About 39% of the interviewed households in the sample villages, for example, reported as immigrants from other areas. The majority are the Sukuma agropastoralists originating from Shinyanga, Mwanza and Tabora regions (39%). Other immigrants originate from the Lower GRR catchment in Iringa region and other areas in Mbeya region (23% and 20% respectively) (Figure 10).

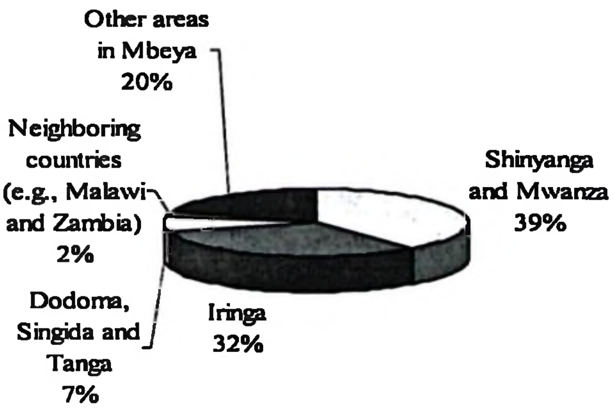

Figure 10: Areas of origin and percentages of immigrant households

More than half of the immigrant households reported to have migrated to the sample villages before 1988. High immigration fluxes were reported to have occurred between 1968 and 1970, in 1984, early and late 1990s and in 2000 (Figure 11). When asked to rank the drivers of their migration to the Upper GRR catchment, most of the immigrant respondents (93%) pointed out the search for farmland and suitable grazing land for livestock as the major drivers (Table 7). Other factors such as migration through marriage, search for new jobs/employment or official transfers from other working stations were given less weight, representing only about 7% of the total drivers.

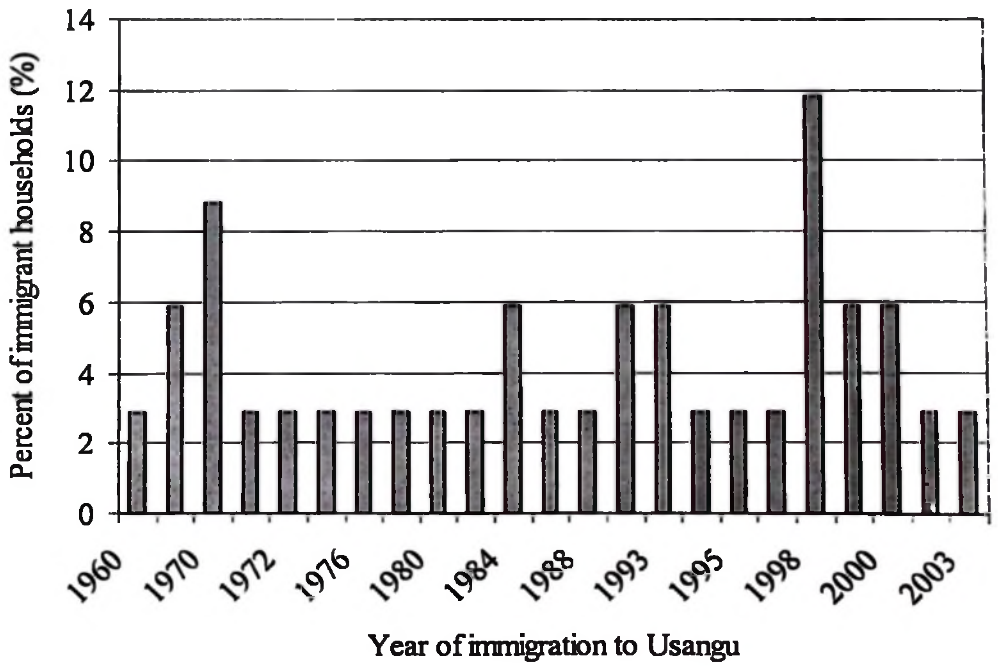

Figure 11: Trend of household immigration to the Usangu Plains in the Upper GRR catchment

While there is no precise explanation for the pattern of immigration as shown in Figure 11, droughts in the areas of origin might have influenced it. The years with high percentages of immigration precede dry years in Shinyanga, Mwanza and Tabora regions (e.g. the years 1994 - 1997 were characteristically dry years and they precede the year 1999 which had the highest percentage of immigrants). Following a successive occurrence of droughts from 1993 to 1997 most households in these regions, particularly those with big herds of cattle, might have decided to migrate to the Usangu Plains where they could get enough pasture for their cattle and land for farming. This is also supported by the results presented in Table 7.

Table 7: Major reasons for migration influxes to the Upper GRR catchment

Reason	Frequency	%
Search for farmland	169	75
Search for livestock grazing land	40	18
Migration through marriage	11	5
Search for new jobs or transfers	5	2
Total	225	100

In general the livelihood strategies and coping mechanisms for the agropastoral households in the study area have changed over time, due to several factors. Most of the interviewed agropastoral households in the lower villages (more than 80%), for example, attributed this change to the trend of diminishing availability of water resources. The diminishing natural grazing grounds for their cattle has pushed them towards intensification and expansion of their cropping activities, while diminishing floods allow for the reclamation of flood plains into agricultural land, which were until recently seasonally inundated. As the use of draught animal power enables them to cultivate larger areas on heavy clay soils, a shift towards rainfed agriculture has been noted. The agropastoral households in the Lower Usangu are now increasingly engaging in the production of rainfed maize, millet and groundnut, and when possible paddy followed by chickpea - which is grown on residual soil moisture. This extension of rainfed agriculture is mainly taking place in natural flood plain ecosystems.

4.2.3 Sources of income

The analysis of sources of income for the sample households showed that the "poor" households are more relying on off-farm activities as sources of income than the "medium" and "rich" households. Given their limited access to land and water resources, the poor households are not able to generate sufficient income from agriculture and therefore they have to supplement their household income with income from non-farm activities and selling labour (Figure 12). These observations are in line with observations from other studies in semi-arid areas in Tanzania, that the poor are more and more relying on off-farm livelihood diversification (Morris *et al.*, 2000).

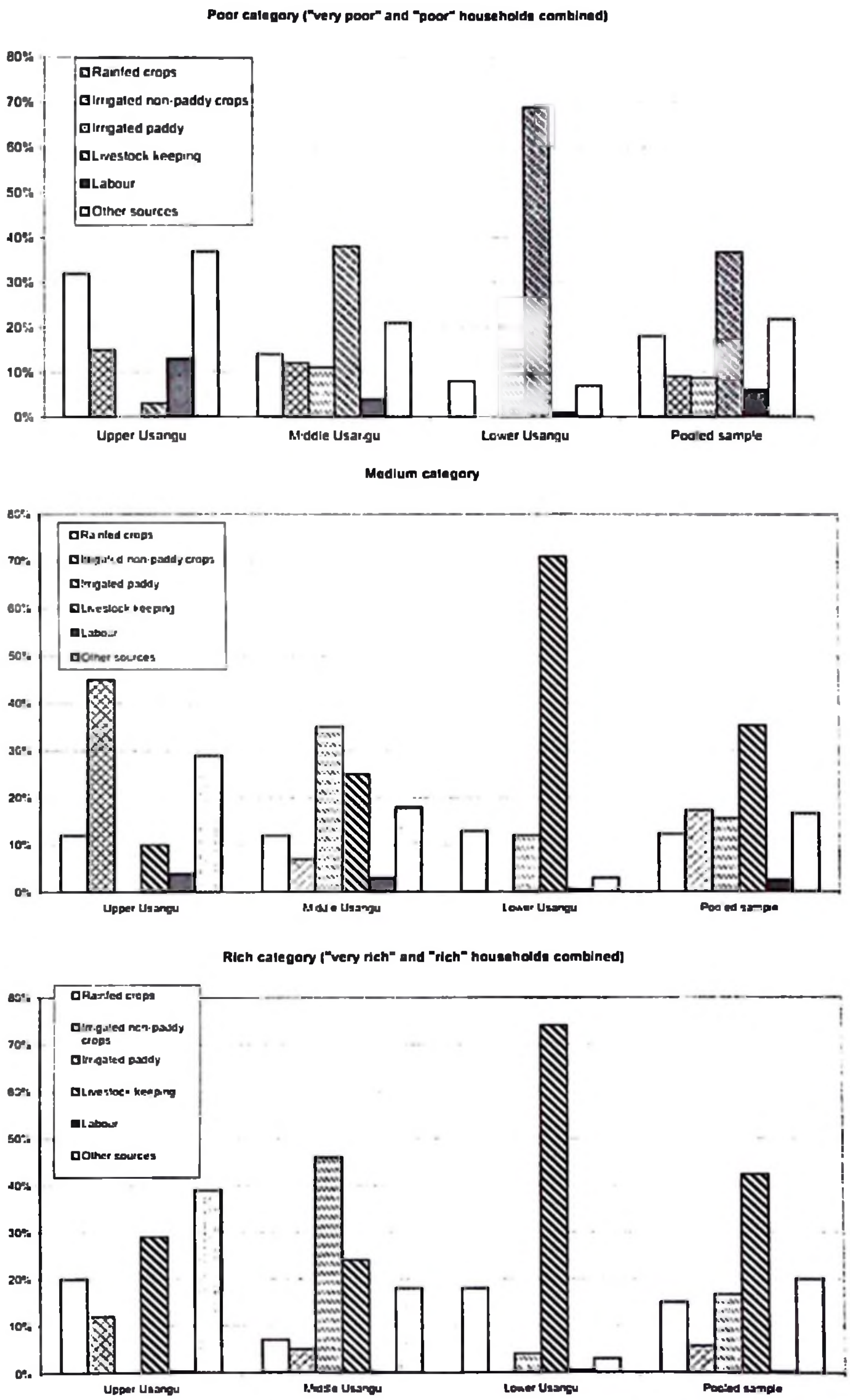

Figure 12: Sources of income for the "poor", "medium" and "rich" household categories in the Upper GRR catchment

Figure 12 indicates that livestock is slightly a more important source of income for the poor households than it is for other wealth classes. This is due to the relatively high income generated by livestock, which makes the impact on a small household budget more significant in poor households. The main parts of these sources of income related to livestock keeping for poor households are income derived from smaller livestock such as chicken and small ruminants (sheep and goats). In the Lower Usangu there are not so much differences between sources of income for poor and other wealth categories (medium and rich). This implies that the size of the cattle herd is the main determinant for wealth in this zone.

Figure 13 summarizes the contribution of selected water related activities to the income of average households. It shows that crop production and livestock activities, which all depend on water as a critical input in the production process, account for more than 90% of household incomes in the study area. This indicates the high social value of water when it comes to livelihood activities.

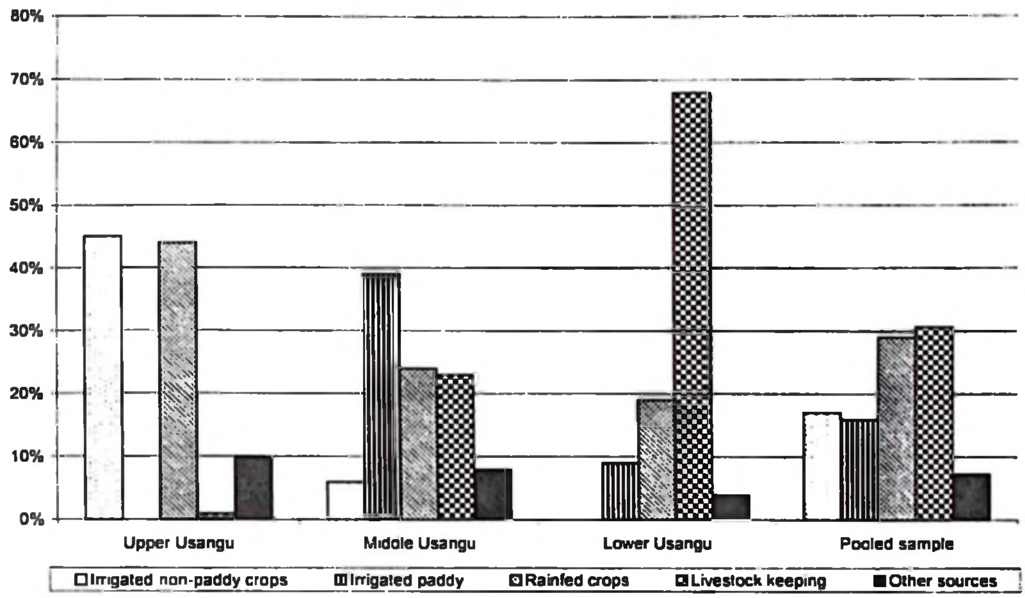

Figure 13: Percentage of income derived from water related activities in the Upper GRR catchment

For the subset of poor households, the direct dependence on water related activities is lower, illustrating the impact of the reduced access of poor households to natural resources, which forces them to rely more on other sources of income. The percentages of income accrued from crop production and livestock activities for the poor were 50%, 75%, and 92% in the Upper, Middle and Lower Usangu respectively.

4.2.4 Dependency and low income probability

The association between large families and poverty is also an important indicator of vulnerability. Large families are generally expected to be far more common among the poorest households of the bottom quintile and family sizes to be smaller for households in the upper income quintiles. Small households, those with very young children and those dominated by older people are also more likely to be poor and vulnerable.

Table 8 presents a probability analysis, which provides an overview of the impact of family size and composition on vulnerability to poverty as reflected from the household survey conducted in the study area. The findings show that households made up of three or more adults and three to four children are more than twice as likely to be in the bottom quintile as households with a single adult and one to two children. The female–headed households are also more likely to be vulnerable than the male head-households (compare probability of 27% versus that of 21%).

Table 8: Probability analysis of low-income households in the study area

Family type	% in the lowest quintile
Female headed household	27
Male headed households	21
Single adult 1-2 children	12
Single adult more than 2 children	32
2 adults 3 – 4 children	30
2 adults with 6 –10 children	35
Household with 11+ people	38

In a close analysis of the percentages shown in Table 8, one would argue that, vulnerability among households in the Upper GRR catchment, as in most other rural areas in the developing world, increases with the number of dependants. This is evidenced by the higher probability value for the households with 6 to 10 or more children.

4.3 The value and benefits of water utilisation

4.3.1 Value of water in paddy production

4.3.1.1 Land use and paddy production

The statistical data on paddy areas and production were available by administrative districts. Since, the main part of the Upper GRR catchment (the Usangu area) is located in Mbarali district, the current study has therefore used the data corresponding to this district to analyse the dynamics of paddy production, prices and value of water in paddy production. Figure 14 shows that both areas and yields vary with time, in relation to rainfall, leading to a variable production, with an upward trend (see Appendix 2 for the details of the statistics). Yields may also vary according to the farming systems or farmer types. As shown in Table 10 the average yield for year 2002/03 ranges from 0.8 T/ha for type 1 to 3 T/ha for type 4.

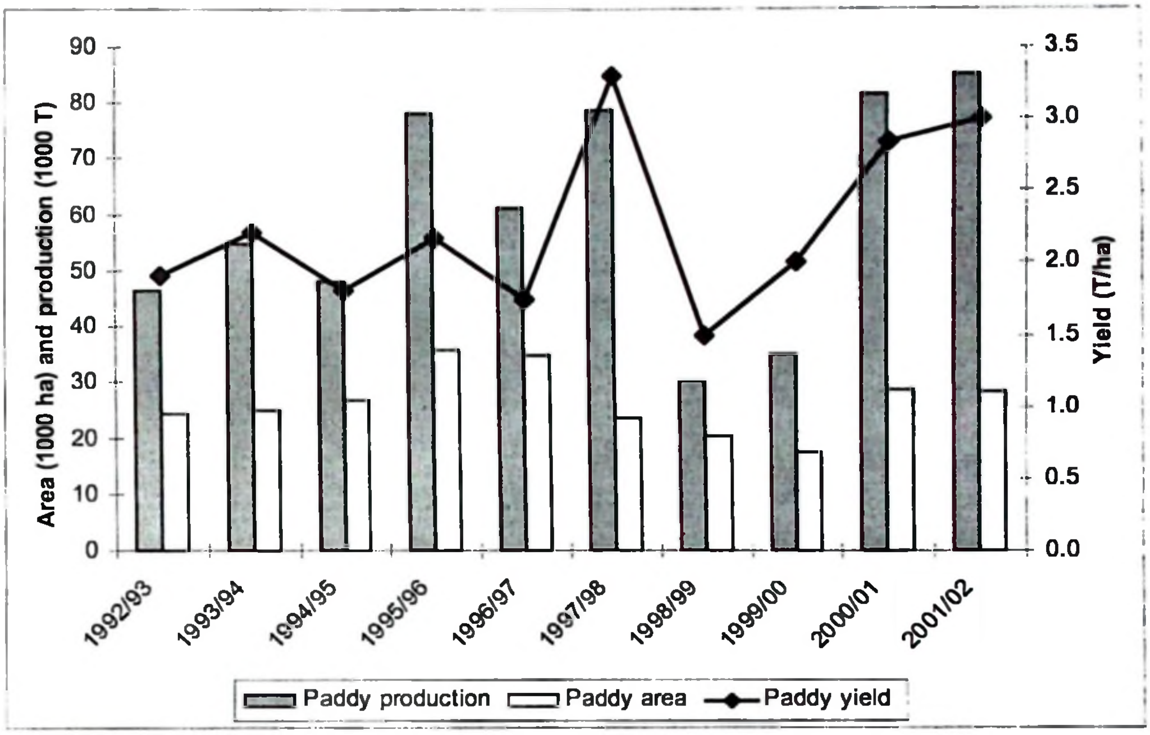

Figure 14: Mbarali district: Paddy production, area under cultivation and yield 1992/93 - 2001/02

Discussions with agricultural officers at the regional level indicate that the actual annual contribution of the Mbarali paddy to the regional (Mbeya) production might range from 55% to 65%. This estimation seems to be more reliable than the value calculated from official statistics (40%), because the latter do not capture the informal exportations to neighbouring countries. The current study estimates the contribution of Mbarali district to the regional (Mbeya) paddy production at 60%. The data obtained from the District Agriculture and Livestock Development Office (DALDO) in Mbarali also showed that, of the total rice produced in the Upper GRR catchment, about 60% is sold outside the area, mainly to major consumption centres in Dar es Salaam, Mbeya and Morogoro regions.

The contribution of Mbeya region to the national rice production has increased significantly from the early 1990s making it the largest rice-producing region in the country, ranging from 14 to 24% (Figure 15). This can be attributed to the growth of irrigated agriculture in the past thirty years. Conversely, the share of drier regions like Shinyanga in the total production has decreased, more likely because of the protracting droughts that have occurred in the past ten years in these regions.

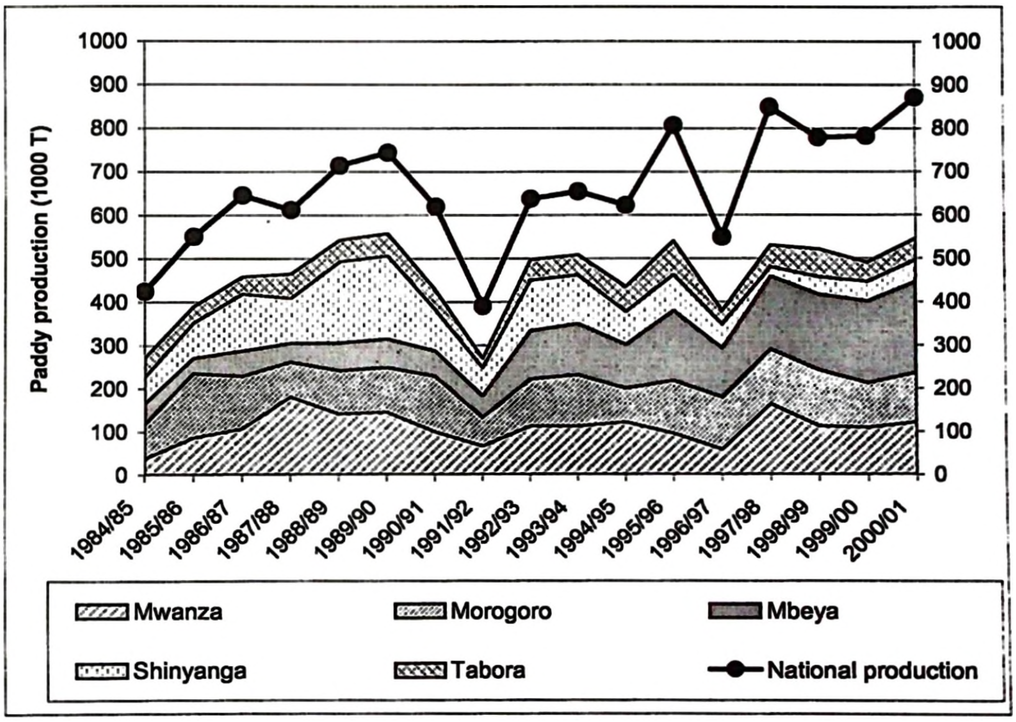

Figure 15: Paddy production trend for the five major producing regions in Tanzania and for the country as a whole, 1984/85 - 2000/01

4.3.1.2 Paddy prices

Despite the general increase in 'nominal' terms (prices observed on the market), the national average 'real' or 'constant' producer prices (which, reflect the relative evolution of the price of a particular commodity compared to other prices, once taken into account the general inflation rate) have generally shown a declining trend with up and down fluctuations (Figure 16).

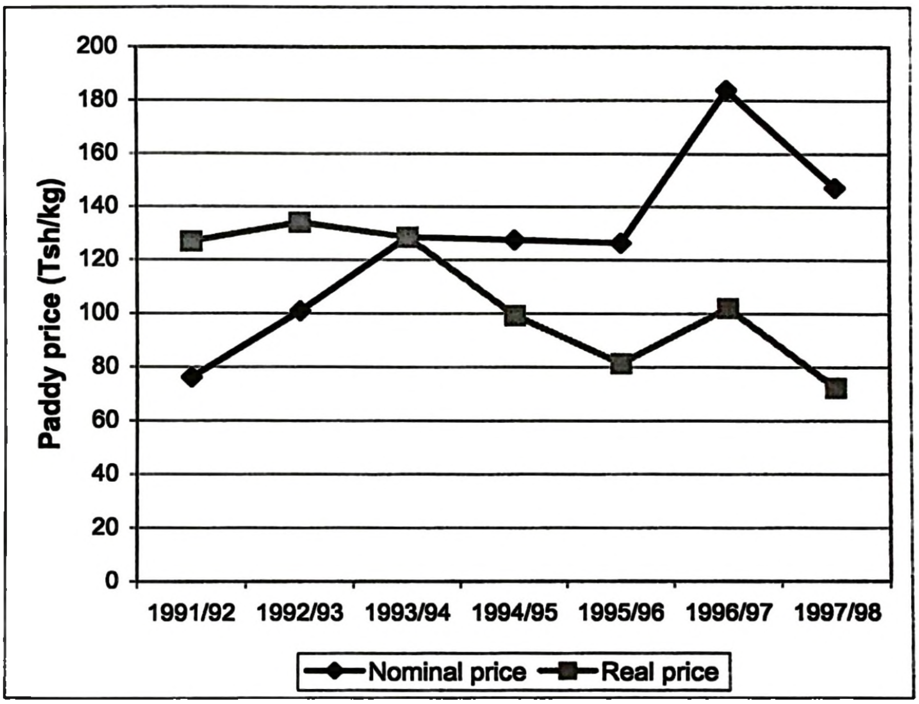

Figure 16: Average prices for paddy at the national level, 1991/92 - 1998/99

As at the national level, the average producer prices for paddy in Mbarali district have increased only in nominal terms (Figure 17 and Appendix 3). In real terms paddy prices have declined over time. This has resulted in falling trends for real values of paddy production, with obvious consequences on farmers' income. The average real producer prices for paddy at the district level (Mbarali) for the period 1993 - 2001 are negatively correlated with paddy production (correlation coefficient $= -0.584, P < 0.10$).

The intra-annual price variability has added to this declining trend over time and farmers in the study area have also responded in different ways. Early land preparation and planting is one of the commonly adopted strategies, particularly for those who can afford it. Most farmers plant their nursery fields and transplant paddy as soon as the available water supplies allow them, since an early harvest means good producer prices for paddy. Although yields are lower, a farmer who harvests in late April or early May, may be able to obtain up to about Tsh. 27,000 (US $ 25.4) per bag of paddy compared to Tsh 6,000 (US $ 5.6) to 12,000 (US $ 11.3) later in the season (July and August). By the end of the harvesting season, the sale price can fall to as low as Tsh 4,800 or US $ 4.5. It should however be noted that very few farmers are able to store their paddy until the beginning of the harvesting season or at the end of the dry season when prices are high.

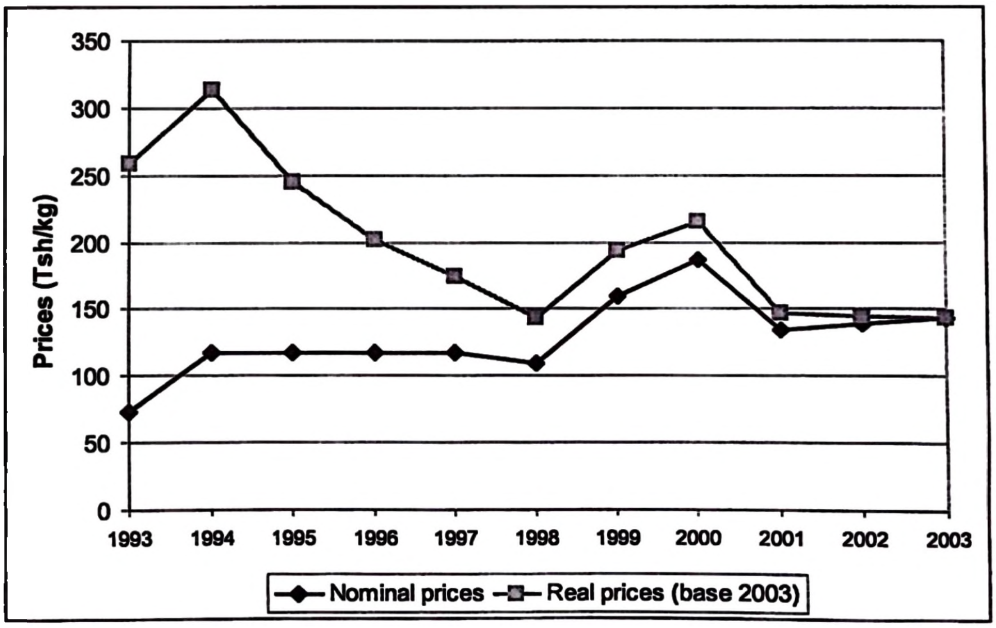

Figure 17: Mbarali district: The trend of average nominal and real paddy producer prices, 1993 - Mid Dec. 2002

4.3.1.3 Production costs and gross margins for paddy

Paddy production involves the use of a number of inputs including seeds, tools/equipment, labour, fertilizers/manure and water to mention a few. In the Upper GRR catchment, however, few inputs are used apart from labour and irrigation water. Some farmers use improved seed varieties but these are relatively expensive, and new seeds need to be purchased at the beginning of each season, when farmers have little cash available. Most farmers keep a small proportion of each year's harvest as next year's seed, so that new seeds do not need to be purchased at the beginning of the season.

The use of fertilizers, pesticides, herbicides or manure is rare. Purchased inputs are not commonly used because of liquidity. Farmers could afford these more expensive inputs considering the higher yields they can expect, but often do not have enough cash at the right time to make those purchases. The use of manure is also uncommon because it is difficult to carry sufficient quantities to the distant paddy fields.

Land renting is common on both the large-scale NAFCO farms and on smallholder systems (Types 3, 4, and 5), and its cost varies with location of the irrigation system and relative location of the plot along the furrow (top/head-end or tail-end). For example, a farm/plot in villages close to the urban settlements like Rujewa can cost up to Tsh 75,000 (US $ 70.5) per ha at the top-end of the scheme, while the tail-end plot costs only Tsh 50,000 (US $ 47.0) per ha. A plot in the Kapunga smallholder scheme, which is about 26 km from the main settlement of Chimala, can be hired for

Tsh 50,000 (US $ 47.0) at the top-end and Tsh 25,000 (US $ 23.5) per ha at the tail end. Dry season plots are rented for between Tsh 25,000 (US $ 23.5) and Tsh 37,500 (US $ 35.3) per ha. For gross margin calculations, an average rental rate of Tsh 30,000 or US $ 28.2 per ha was used (for Types 3 and 4) and Tsh 25,000 or US $ 23.5 per ha (for Type 5).

Farmers who have liquid capital (cash) normally hire oxen for ploughing and labour for puddling, transplanting and harvesting (Types 2, 3 and 4). But most farmers (Types 1 and 5), who do not have enough money, resort to using their own labour in ploughing their fields by hand hoe. It costs approximately Tsh 30,000 (US $ 28.2) per ha to hire oxen and/or labour for ploughing or transplanting work. Hiring labour for harvesting costs less at around Tsh 20,000 (US $ 18.8) per ha.

In general, the main characteristics of the paddy farming systems in the study area can be summarised as in Table 9. The variation in returns to labour and gross margins for the different paddy production systems (farmer Types) is shown in Table 10. As shown in Table 10, returns to labour and gross margins vary among different production systems.

Table 9: Main characteristics of paddy farming systems in the Upper GRR catchment

Item	Farming system type				
	Type 1 (Rainfed Subsistence farmers)	Type 2 (Rainfed paddy growers with high inputs)	Type 3 (Irrigated paddy growers on NAFCO plots)	Type 4 (Small irrigated paddy growers with high inputs)	Type 5 (Small irrigated paddy growers with low inputs)
Average plot size (ha)	0.35	0.54	6.00	1.27	1.25
Average family Labour (mandays/ha)	206.00	183.00	102.00	113.00	167.00
Hired Labour (mandays/ha)	0.00	39.00	41.00	52.00	0.00
Average operational costs (Tsh/ha)	22,600.00	135,200.00	200,852.00	229,080.00	70,500.00
Share in the total paddy area (%)	7.00	3.00	15.00	35.00	40.00

Table 10: Variability of paddy gross margin across farming systems, values in Tsh, 2003

Item	Farming system type				
	Type 1 (Rainfed Subsistence farmers)	Type 2 (Rainfed paddy growers with high inputs)	Type 3 (Irrigated paddy growers on NAFCO plots)	Type 4 (Small irrigated paddy growers with high inputs)	Type 5 (Small irrigated paddy growers with low inputs)
Farm/plot size (ha)	0.35	0.54	6.00	1.27	1.25
Paddy price (Tsh/kg)	144.00	144.00	144.00	144.00	144.00
Yield (Kg/ha)	818.00	1575.00	1600.00	3028.00	2500.00
Gross income (Tsh/ha)	117,580.00	226,390.00	229,980.00	435,270.00	359,360.00
Operational Costs:					
Plot renting (Tsh/ha)	0.00	0.00	30,000.00	30,000.00	25,000.00
Seeds (Tsh/ha)	6,570.00	6,570.00	9,920.00	8,580.00	8,250.00
Fertilizer (Tsh/ha)	0.00	14,930.00	22,740.00	19,370.00	0.00
Tractor hiring charge (Tsh/ha)	0.00	24,310.00	30,000.00	20,670.00	0.00
Hired labour (Tsh/ha)	0.00	58,230.00	62,200.00	77,930.00	0.00
Bags and twine (Tsh/ha)	5,900.00	10,860.00	11,670.00	22,070.00	6,040.00
Transport (Tsh/ha)	7,960.00	7,960.00	16,000.00	29,600.00	24,800.00
Financial costs (10% of expenses) (Tsh/ha)	2,040.00	12,290.00	18,250.00	20,820.00	6,410.00
Total operational costs (Tsh/ha)	22,470.00	135,150.00	200,780.00	229,040.00	70,500.00
Gross margin (Tsh/ha)	95,110.00	91,240.00	29,200.00	206,230.00	288,860.00
Gross return to an average plot (Tsh)	33,300.00	49,300.00	175,200.00	261,900.00	361,100.00
Family Labour (mandays/ha)	206.00	183.00	102.00	113.00	167.00
Hired Labour (mandays/ha)	0.00	39.00	41.00	52.00	0.00
Gross return on family labour (Tsh/manday)	462.00	499.00	286.00	1,825.00	1,730.00

On average, the return to labour in paddy production for smallholder farmers (outside the NAFCO system) who irrigated their paddy fields and used tractor, fertilizer and hired labour during the 2002/03 season (Type 4) was higher than any of the other paddy production systems. They also obtained the second highest gross margin per hectare, after type 5. The smallest return to labour was obtained by the smallholder farmers who hired plots in NAFCO farm (Type 3). The latter also obtained the lowest gross margin per hectare. When gross margins per hectare are compared, the differences among the above five production systems would be described as determined more by the extent to which commercial inputs were used and less by the differences in economies of scale, including of course the levels of crop and water management. As the evidence in this study indicates, commercial inputs were relatively very expensive and their use might have eroded a large share of profit margins. It should however be noted that what is important from the household perspective might be the total net income from their plot or the return to labour and not the gross margin per hectare.

As both paddy yields and prices vary over time (depending on climatic and marketing conditions), paddy gross margins also change (Figure 18).

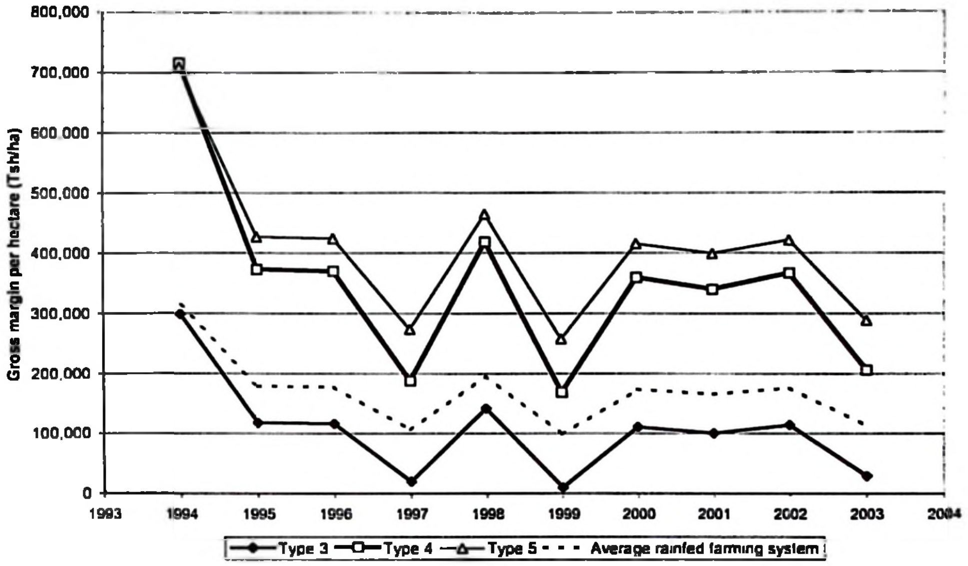

Figure 18: Variability of paddy gross margin over time across farming system

4.3.1.4 Water abstraction and consumption for irrigated paddy

The volumes of water abstracted and consumed at the farm level as estimated by the use of CROPWAT (for each farming system and a series of climatic years) are given in Figure 19. Water use by type 5 is not represented in this figure but can be explained as falling very close to that of type 4. The major difference between types 4 and 5 is that type 4 farmers use commercial inputs (fertilizers, hired labour and tractor) while type 5 farmers generally do not use these inputs. This can also help explaining the higher gross margins for the average type 5 farmers than those in type 4.

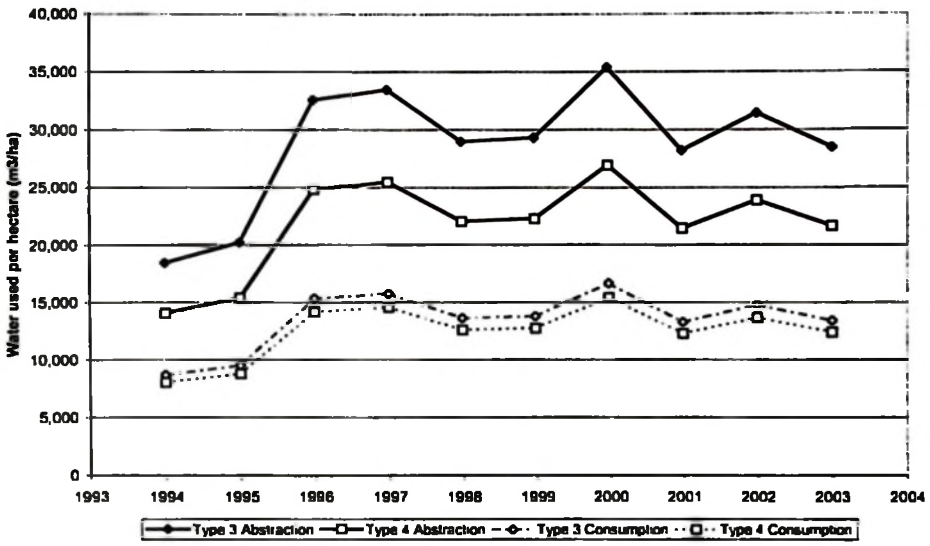

Figure 19: Water abstraction and consumption for different paddy farming systems

4.3.1.5 Productivity and value of water for irrigated paddy

The average productivity of irrigation water for paddy was estimated as ranging from 0.059 to 0.250 kg per m^3 of abstracted water depending on the farming system and from 0.126 to 0.265 kg per m^3 of consumed water [averages calculated over the period 1994 - 2003 (Table 11)]. Among irrigated farming systems, smallholder farmers growing irrigated paddy outside the NAFCO system, using tractor, fertilisers hired labour and family labour (Type 4) show the highest productivity and smallholder farmers on NAFCO farms (Type 3) the lowest.

In terms of the value of irrigated water, smallholder farmers growing irrigated paddy with low inputs (Type 5) obtain the best results because of their very low costs of production and relatively high yields. Smallholder farmers on NAFCO plots (Type 3) get negative values because their gross margins per hectare are lower than those in rainfed farming system and they abstract and consume more water. The ratio of total amount of water consumed by the crop to the total amount of water supplied through irrigation was the lowest for smallholder farmers on NAFCO plots. This implies low irrigation efficiency for farming system Type 3. As expected, in all farming systems the value of abstracted water was less than for consumed water. "Abstracted water" as used in this case refers to "gross water requirement" or the actual amount of water supplied to meet crop evaporation and deep percolation/seepage or root zone soil moisture deficit. This can be distinguished from the term "net water requirement," which refers to the actual amount of water required to replenish evapotranspiration and deep percolation/seepage or root zone soil moisture deficit.

The above findings support the argument given by SMUWC (2001) that average productivity on the NAFCO rice irrigation system is lower than that on the traditional smallholders irrigation system. The main causes of low yields in the NAFCO systems were identified to be low planting densities, weed infestation and poor water level control arising from large plot sizes. The soil surface is uneven and farmers do not use smaller plots (*vijaruba*) to control water level and movement. Early on in the season, irrigation water in the NAFCO farms is used to level the fields, soften soil and suppress weeds. This is particularly a serious problem when only one hectare is cropped but the whole area of six hectares has been irrigated, or a small nursery often with area ranging from 300 to 500 m^2 in a six hectares plot, all of which has been irrigated (Plate 3). Actually this is very critical as every six-hectare area has its nursery and the problem is that during this time (November) river flow is at its lowest rate and temperature is high, evaporation losses are therefore high. Tertiary canals are sunken leading to slow advance rates. Much water is therefore used per area and for long period. These in turn result in longer periods of evaporation, low efficiency and productivity and hence low values of water.

The practice on the traditional smallholders irrigation systems (Types 4 and 5) is very different. Plots are smaller enabling greater care over water levels (Plate 4). The whole small banded basin (*jaruba*) is cropped and the nurseries are prepared at special places (often under trees) to minimize evaporation losses and supplementary irrigation of nurseries is done by using hand cans when too much moisture is depleted from soil.

Table 11: Irrigation water value per farming system calculated from gross margin (without family labour), average values in Tsh for the period 1994 – 2003

	Type 1 (Rainfed Subsistence farmers)	Type 2 (Rainfed paddy growers with high inputs)	Type 3 (Irrigated paddy growers on NAFCO plot)	Type 4 (Small irrigated paddy growers with high inputs)	Type 5 (Small irrigated paddy growers with low inputs)	Average rainfed paddy farm
Yield (kg/ha)	842.00	1,620.00	1,646.00	3,116.00	2,572.00	1,231.00
Gross income (Tsh/ha)	156,670.00	301,610.00	306,470.00	580,000.00	478,900.00	229,137.00
Operational costs (Tsh/ha)	22,470.00	135,150.00	200,780.00	229,040.00	70,500.00	59,170.00
Gross margin (Tsh/ha)	134,200.00	166,460.00	105,690.00	350,960.00	408,400.00	169,967.00
Volume of water abstracted (m^3/ha)	6,705.00	6,705.00	28,652.00	21,816.00	22,851.00	6,705.00
Volume of water consumed (m^3/ha)	6,319.00	6,319.00	13,471.00	12,466.00	12,667.00	6,319.00
Productivity of abstracted water (kg/m^3)	0.13	0.25	0.06	0.15	0.12	0.19
Gross margin per m^3 abstracted (Tsh/m^3)	21.78	27.66	4.27	17.82	19.45	27.77
Average value of irrigation abstracted water (Tsh/m^3)			-2.91.00	13.41	16.00	
Minimal value of irrigation abstracted water (Tsh/m^3)			-3.96.00	4.59	8.92	
Maximal value of irrigation abstracted water (Tsh/m^3)			-1.10	41.35	38.09	
Productivity of consumed water (kg/m^3)	0.14	0.27	0.13	0.26	0.21	0.20
Gross margin per m^3 consumed (Tsh/m^3)	23.11	29.35	9.08	31.19	35.09	29.47
Average value of irrigation consumed water (Tsh/m^3)			-8.93	32.96	40.69	
Minimal value of irrigation consumed water (Tsh/m^3)			-12.15	11.28	22.70	
Maximal value of irrigation consumed water (Tsh/m^3)			-3.38	101.65	96.87	

Plate 3: A typical paddy nursery in the Kapunga NAFCO farm

Plate 4: In the traditional smallholder paddy irrigation systems, plots are smaller enabling greater care over water levels

The values of water estimated in this study can be compared with those of other studies in Tanzania and elsewhere in Sub-Saharan Africa (SSA). In the Pangani River basin in Tanzania, for example, Turpie *et al.* (2003) estimate the average gross income per unit of water used in irrigation at the range of Tsh 100 to 1,400 per m^3, depending on area of the basin and type of irrigation. The outputs, inputs and prices used by Turpie *et al.* (2003) are based on small sample sizes and should therefore be viewed with caution as the authors themselves note. Using the same criteria, the gross income per m^3 of water consumed in irrigation in the Upper GRR catchment would range from 23 to 47 Tsh/m^3 in irrigated paddy systems, which is 4 to 30 times less than in the Pangani river basin. The differences may be attributed to higher water consumption and lower yields in the Upper GRR catchment than in the Pangani river basin.

Generally, water productivity of paddy in Sub-Saharan Africa ranges from 0.10 to 0.25 kg per m^3, with average yield of 1.4 metric tonnes per ha and water consumption per hectare close to 9,500 m^3 (Rosegrant *et al.*, 2002). Among developing countries, China and some South-East Asian countries have higher water productivity for rice, ranging from 0.4 to 0.6 kg per m^3.

The value of irrigation water varies from year to year depending on paddy prices, yields and climatic conditions. The standard deviation of the value of irrigation water for abstracted water ranges from 0.90 (for Type 3) to 10.72 (for Type 4), and for consumed water from 2.77 (for Type 3) to 26.35 (for Type 4). The minimum and maximum values are given in Table 11. The lowest values are found to be in 1999, a year which had also recorded the minimum average yield with water use close to the average for 1994 - 2003. The highest values are obtained in 1994 where the highest paddy price was recorded and the difference in water use between rainfed and irrigated systems was minimal.

The value of irrigation water is also sensitive to assumptions on the value of family labour. In Table 11 the values of water have been calculated from gross margins, with family labour being unaccounted for. Table 12 compares the values of water calculated using the Change in Net Income Approach, taking into account the cost of family labour valued at the official minimum wage (Tsh1500/manday), half of minimum wage and zero (in this latter case only family labour in management is considered). The highest values appear when family labour is valuated at the minimum wage, as irrigated farms use less family labour than rainfed farming systems. In this case, irrigation water values are at the lowest end of the range cited in the literature.

Table 12: Sensitivity of value of water consumed for irrigation to the value of family labour

Assumption on value of field family labour, values in Tsh/m^3	Type 3	Type 4	Type 5
Tsh 1,500/manday	11.92.00	52.02.00	46.52.00
Tsh 750/manday	4.06	41.01	45.87
Tsh 0/manday	-9.49	29.99	38.64
Tsh 0/manday and no management family labour (gross margin)	-8.93	32.96	40.69

4.3.2 Value of water for non-paddy crops

4.3.2.1 Productivity of water for rainfed non-paddy crops

Summarised in Figure 20 are the Crop Water Productivities (CWPs) based on rainfall, effective rainfall and actual crop water use or evapotranspiration for major rainfed crops grown in the Upper, Middle and Lower Usangu respectively. The CWPs for high value crops (tomatoes and onions) and Irish potatoes for the Upper and Middle Usangu are generally higher than CWP figures for grains. There is also a difference in CWP for cereals among the three parts of Usangu. The CWP figures for dry beans and sorghum are relatively lower in the Middle Usangu compared to the Upper Usangu.

For maize, the CWPs were higher in the Lower Usangu compared to those in the Middle and Upper Usangu. Generally the CWPs under rainfed were higher in the Lower Usangu for most cereals compared to the Middle and Upper Usangu and the CWPs for high value crops were generally higher than those for cereal crops.

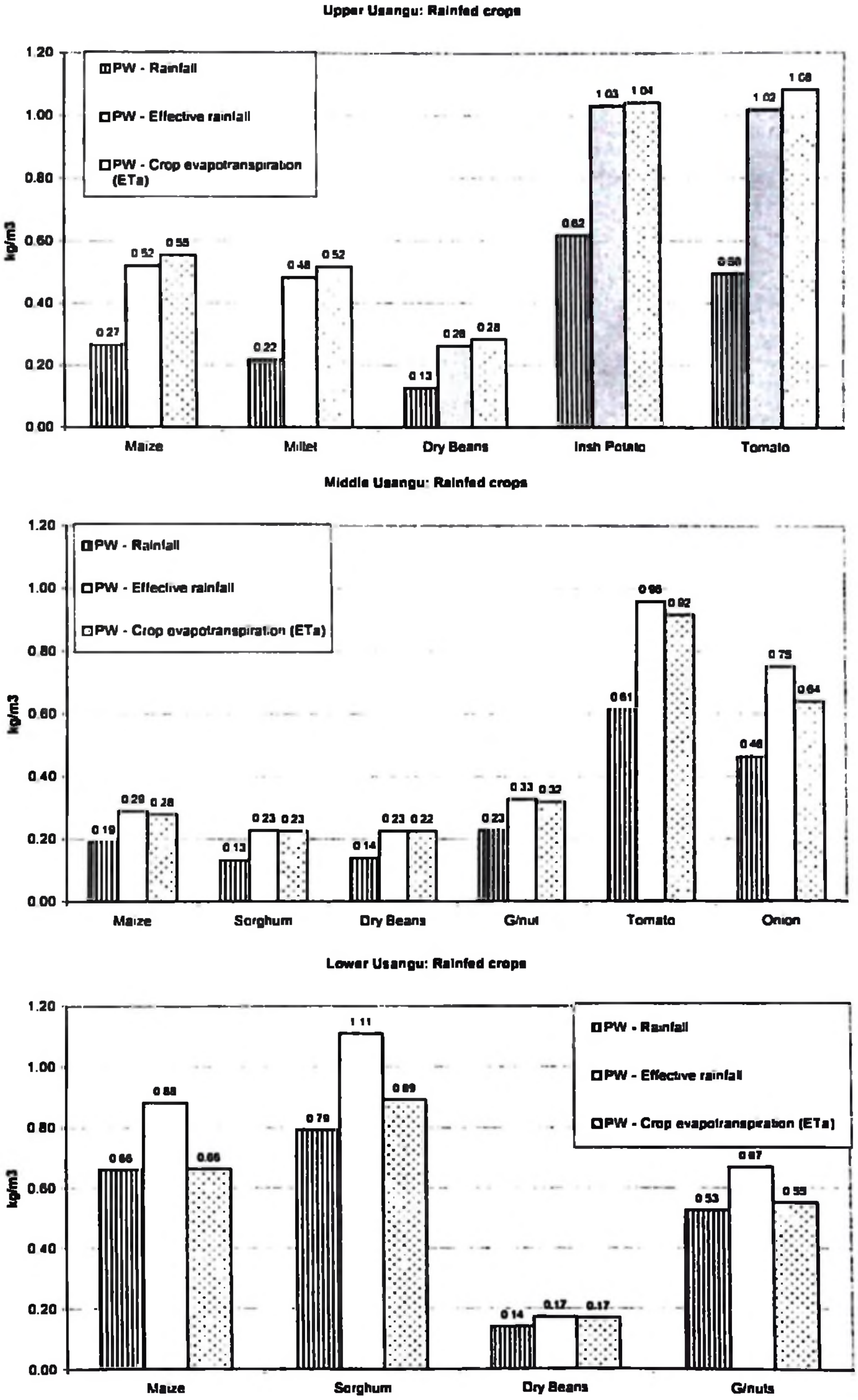

Figure 20: Crop water productivities (CWPs) for major rainfed crops grown in the Upper GRR catchment

4.3.2.2 Productivity and value of water for irrigated non-paddy crops

For irrigated non-paddy crops (which also refer to dry season irrigated crops in the study area), the CWPs for tomatoes, onions and potatoes were higher compared to those of irrigated cereal crops. With the exception of irrigated maize and dry beans, the CWPs for irrigated crops in the Middle Usangu were higher than those in the Upper Usangu (Figure 21). In general, the CWPs for irrigated maize, dry beans, tomato, and onions were higher than those of the same crops grown under rainfed conditions.

The economic values of water as estimated using the Change in Net Income Approach based on Total Gross Irrigation (TGI) and net on-farm water consumption (ETa) modelled using the CROPWAT model are shown in Figure 22. The values of water are given for the Upper and Middle Usangu only because there is no dry season irrigation in the Lower Usangu. Overall, the values are generally higher for irrigated non-paddy crops in the Upper Usangu than those in the Middle Usangu. More specifically the value of water was relatively the highest for tomatoes in the Upper Usangu (averaging at about US \$ 0.21 and 0.29 per m^3 of abstracted and net consumed water respectively). These values are more than twice the values of water for the same crop in the Middle Usangu (c.f. US \$ 0.10 and 0.14 per m^3 of abstracted and net consumed water respectively).

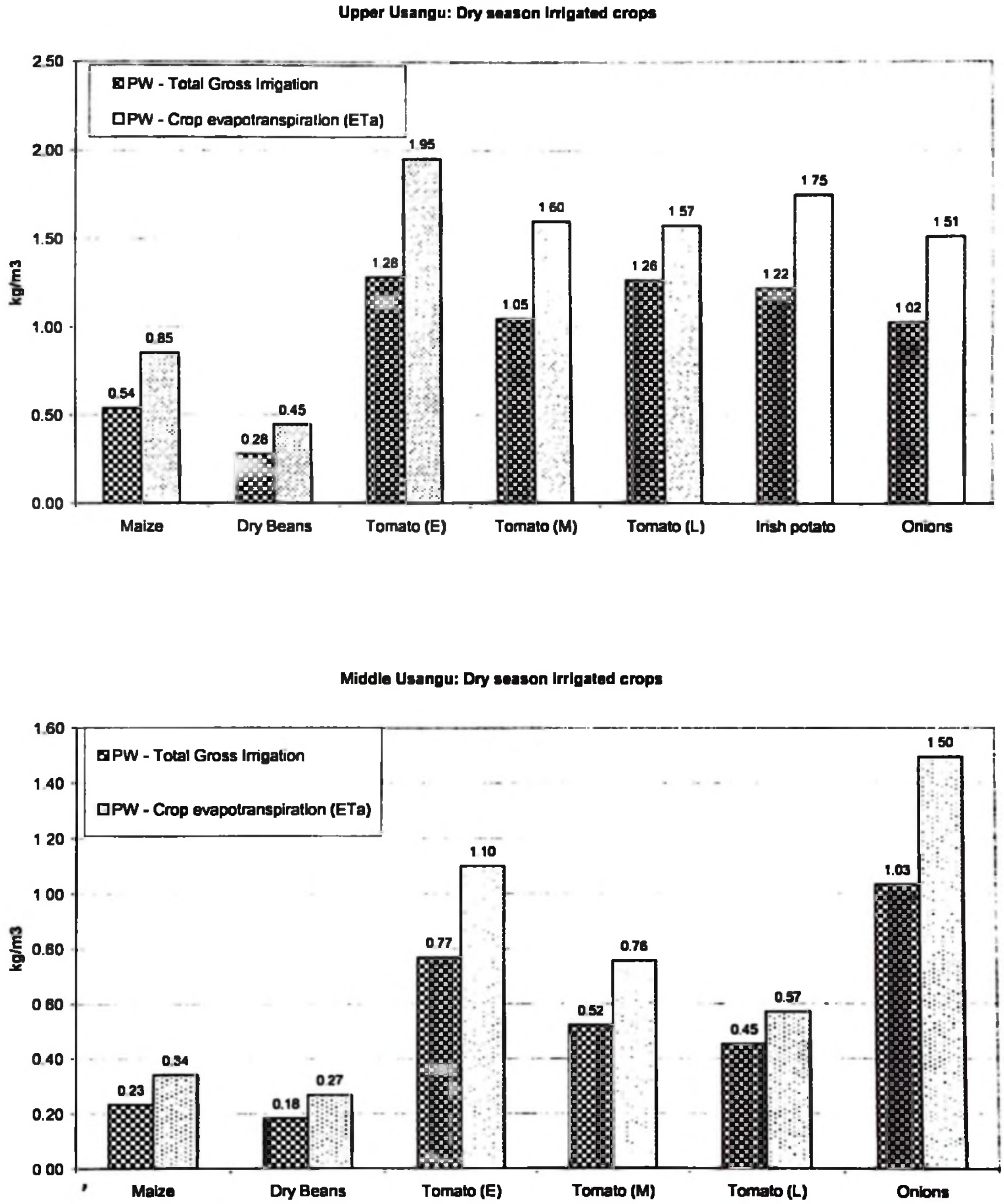

Figure 21: Productivity of water (PW) for dry season irrigated crops in the Upper GRR catchment

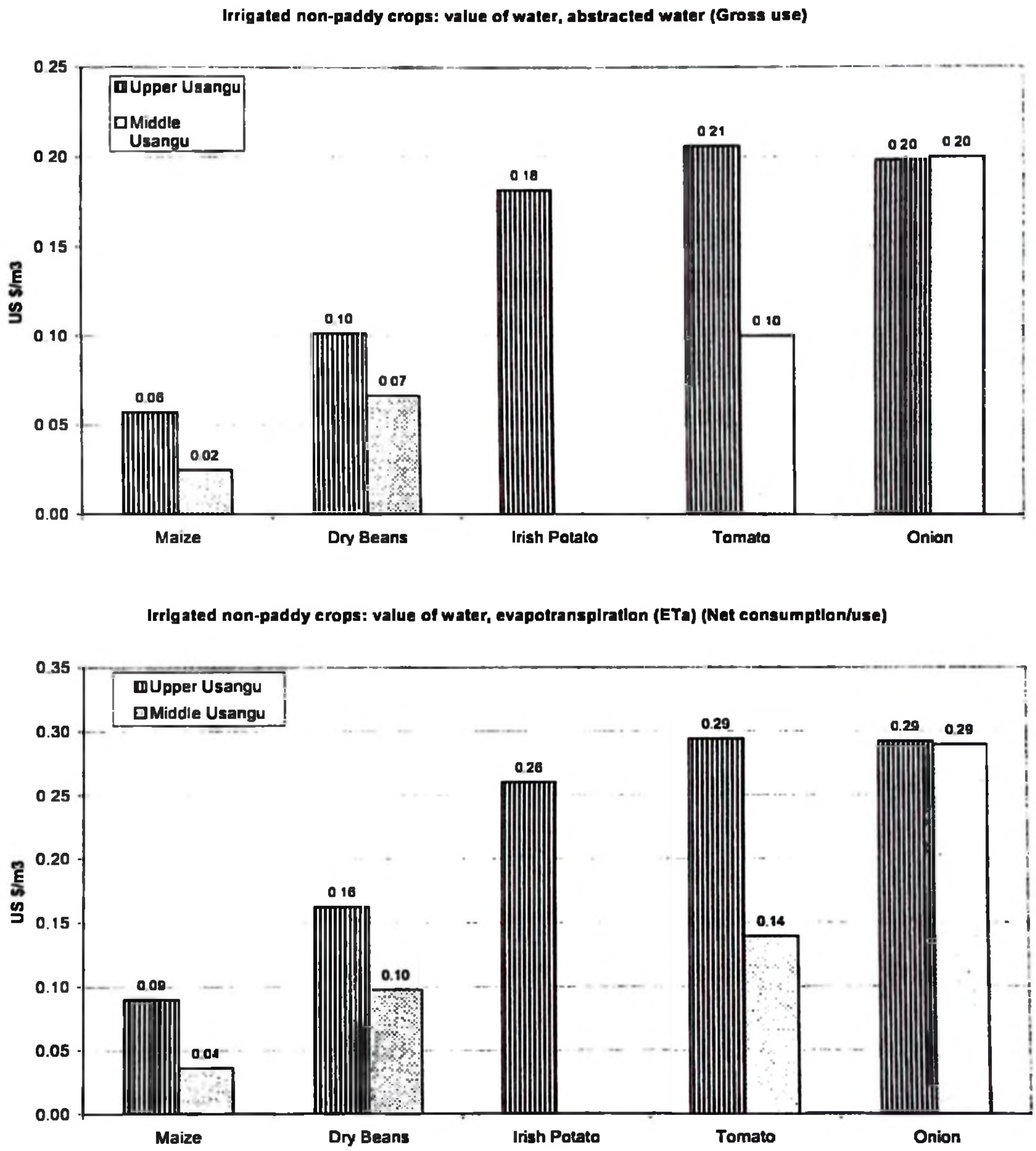

Figure 22: The value of water for irrigated non-paddy crops in the Upper GRR catchment

The differences in the value of water between the Upper and Middle Usangu can be attributed mainly to the differences in crop yields - which are in turn associated with the differences in water utilization and management practices. Dry season crops are more important as sources of income in the Upper Usangu (Plate 5) than in the

Middle Usangu where wet season irrigated paddy is an important crop. The dry season irrigated agriculture is more commercialised in the Upper Usangu than in the Middle Usangu. Farmers are therefore more careful with the little water they get during the dry season so that they irrigate their crops and get good harvest. On contrary, the dry season irrigation in the Middle Usangu is mainly done for subsistence purposes in an attempt to offset the dry season food insecurity. In addition, so much water is consumed in dry season irrigated plots and yields are relatively lower than in the Upper Usangu case.

Plate 5: Farmers harvesting their dry season irrigated tomatoes in Inyala village (Upper Usangu) ready for the market

Of all the dry season irrigated crops, onions perform relatively better and equally so in both the Upper and Middle Usangu with average values of about Tsh 212.72 and

308.45 per m^3 of abstracted and net consumed water respectively for both the Upper and Middle Usangu. In both areas the lowest values were recorded for maize (Tsh 63.82 and 95.73 versus Tsh 21.27 and 42.54 per m^3 of abstracted and net consumed water for the Upper and Middle Usangu respectively).

4.3.3 Value of water for hydropower generation

4.3.3.1 HEP water storage, inflows and outflows

For HEP generation water storage is normally done during the wet season whereas water for running the turbines is needed for all the year round (Figure 23). Filling up of the Mtera reservoir occurs mainly during the wet season (from December to May) whereas the outflow (turbine discharges and spillovers) is more constant over the year. It should also be noted that 2003 was a dry year, the period of increasing storage was therefore shortened due to low level of inflows.

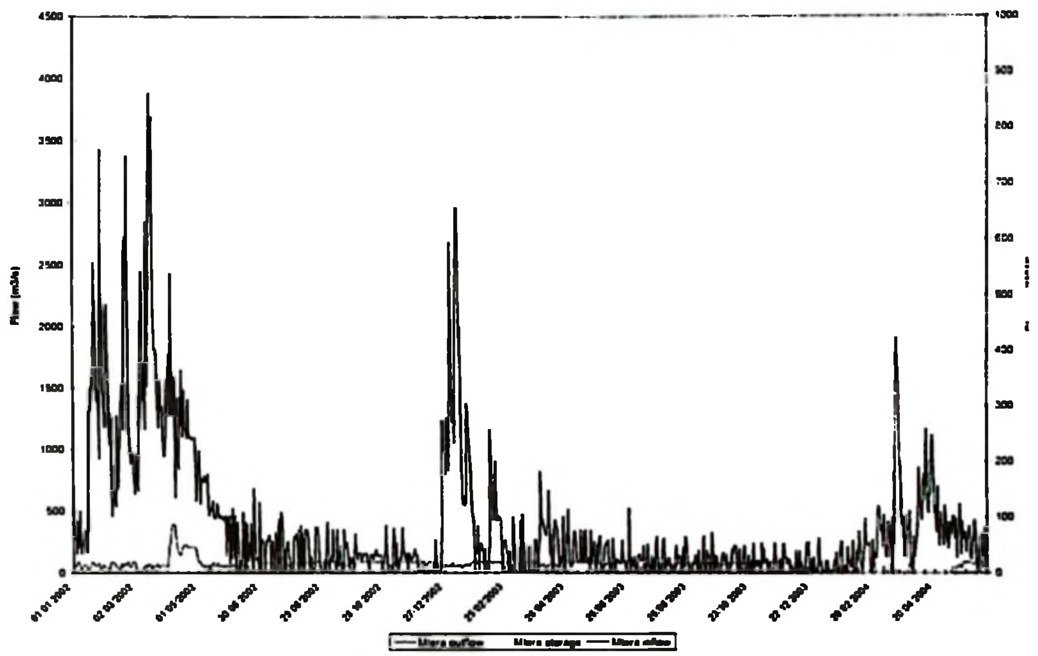

Figure 23: Mtera water storage, inflows and outflows from 1st January 2002 to 9th June 2004

4.3.3.2 Electricity tariffs

A closer look at the final output prices (e.g. electricity tariffs for this case) and existing pricing mechanisms would also help showing the dynamics of the value of electricity and hence the value of water for HEP generation. The average electricity tariffs in Tanzania (for the period from 1992 to 2003), for example, have generally increased in the local currency (i.e. in Tsh per kWh of electricity sold). In US $ the same have been increasing only from the period 1992 – 1996 but declining for the period 1998 to 2003 (Figure 24). This can partly be attributed to the effects of inflation and distortions caused by government interventions in the markets (i.e. the effects that stem from the government administered tariffs or prices that do not reflect the real economic value of electricity inputs and outputs or prices which deviate from the competitive equilibrium prices). Note that, electricity tariffs in Tanzania are not frequently adjusted in line with the depreciation of the shilling.

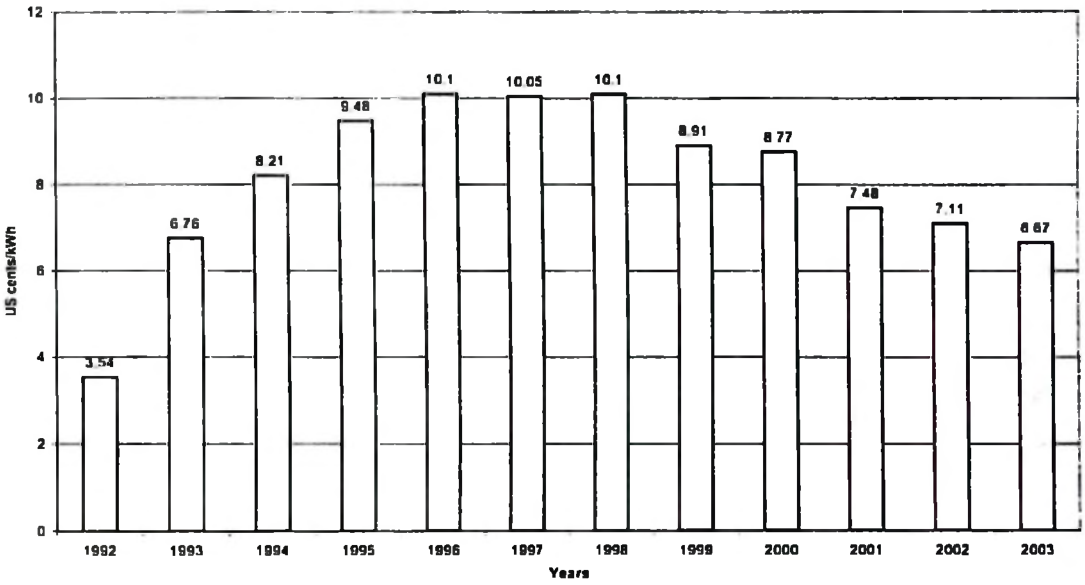

Figure 24: Average electricity tariffs in US cents per kWh, 1992 – 2003

4.3.3.3 HEP - water values

The value of water for hydropower generation showed different figures depending on the scenario chosen (Table 13). As expected, the highest values are obtained when only consumptive use of water is considered (scenario S2), and the lowest when both consumptive and non-consumptive uses are taken into account (scenario S3). The value of water is also extremely sensitive to electricity value, with values obtained using the average electricity tariff being half of the values computed using the long run marginal cost. They also probably depend on the dam operation, but as data on power production and water releases and evaporation were only available for 2002/03, it was not possible to assess this assumption.

Table 13: Value of water in hydropower production for the Mtera-Kidatu system in 2002/03

Item	S1: Turbine discharges at Kidatu (TDK)	S2: Mtera-Kidatu combined evaporation (MKCE)	S3: TDK plus MKCE
	Water scenarios		
Electricity production (kWh)	1,839,424,000.00	1,839,424,000.00	1,839,424,000.00
Water used (Mm^3)	3,002.00	1,094.00	4,096.00
Energy efficiency (kWh/m^3)	0.61	1.68	0.45
Generating costs (Tsh/kWh)*	1.14	1.14	1.14
Electricity value**			
LRMC (Tsh/kWh)	135.19	135.19	135.19
(US $/kWh)	0.13	0.13	0.13
Average tariff (Tsh/kWh)	69.79	69.79	69.79
(US $/kWh)	0.07	0.07	0.07
Water value**			
LRMC (Tsh/kWh)	81.70	226.08	59.57
(US $/kWh)	0.08	0.21	0.06
Average tariff (Tsh/kWh)	41.63	116.16	30.20
(US $/kWh)	0.04	0.11	0.03

(*) Exclude capital investment costs (e.g., costs for dam, reservoir and generating plant)
(**) Exchange rate in 2003: Tsh 1064/US $
LRMC = Costs or values estimated using the Long Run Marginal Cost of electricity. The LRMC is adapted from TANESCO (2002) and The East African Community (2004).
TDK = Turbine Discharge at Kidatu
MKCE = Mtera-Kidatu Combined Evaporation from the HEP dams.

The figures in Table 13 can be compared with the estimates given by Turpie *et al.* (2003) in their preliminary economic assessment of water resources of the Pangani River Basin. They estimated the value of water used in hydropower generation at Tsh 3.8 per m^3 (for the Nyumba ya Mungu plant); Tsh 9.5 per m^3 (for the Hale plant); and Tsh 30.7 per m^3 (for the New Pangani plant), using an average electricity value of Tsh 73/kWh (the average revenue per kWh) and the volume of water flowing through turbine for 2001 (equivalent to scenario S1 in Table 13 except that Turpie *et* *al.* (2003) treated the three plants as separate HEP systems). The differences of water value among the three plants can be attributed to the difference in their hydropower systems and heads (energy efficiency of Nyumba ya Mungu, Hale and New Pangani plants are equal to 0.052, 0.130 and 0.420 kWh/m^3 respectively, compared to 0.61 kWh/m^3 for the Mtera-Kidatu system).

It should also be noted that the value of water for HEP generation varies depending on the volume of water considered (if evaporation, inflow or discharge volume) and the type of HEP system considered (if a single plant or several plants sharing water from the same river system).

As already mentioned, the values of water presented in Table 13 were computed using the turbine discharge volumes at Kidatu, evaporation from the Mtera-Kidatu reservoirs and gross water use or combination of two. In addition, the Mtera and Kidatu plants were treated as a single HEP system. However, based on the understanding that turbine discharge is related to generation of power one would also argue that at full capacity utilization discharge at Kidatu will produce a maximum of 204 MW and 80 MW at Mtera. Full capacity utilization discharge at Kidatu cannot produce 284 MW (i.e. 204 MW plus 80 MW). This means that attributing discharge at Kidatu for both Mtera and Kidatu may be seen as underestimation of discharge to cater for the total 284 MW installed generation capacity. The amount of water discharged at Mtera, which is not related to power generation (i.e. for environmental flows) is very small compared to generation (i.e. 1 cubic metre per second). Therefore, both discharges for HEP generation at Mtera and Kidatu should be included in the computation. Based on this argument, the value of water for HEP generation was estimated at Tsh 30.12 and 56.58 per m^3 of water for the Mtera and Kidatu plants respectively (Appendix 6).

4.3.4 Value of water for domestic uses

According to the CVM results, the average amount of money that the respondents were willing to pay per bucket of 20 litres was Tsh 20.3 – equivalent to Tsh 1015 (US $ 0.95) per m^3 (Table 14). This can be compared to the market price for domestic water, which was reported in the Upper Usangu (Tsh 20 per bucket in Uyole area) and the price charged to cover the maintenance and operational costs for a well that was drilled by the SMUWC project in Ukwaheri village (Tsh 20 per bucket of 20 litres).

Table 14: Values of water for domestic uses in the Upper GRR catchment

	Average daily household water use (m^3/hh/day)	Average annual household water use (m^3/hh/year)	Average WTP per m^3 (Tsh/m^3)	Average WTP per m^3 (US $/$m^3$)	Average WTP per year per household (Tsh)	Average WTP per year per household (US $)
Upper Usangu	0.13	47.80	980.00	0.92	46,859.00	44.00
Middle Usangu	0.18	63.90	1,005.00	0.94	64,194.00	60.30
Lower Usangu	0.14	52.20	1,060.00	1.00	55,327.00	52.00
Pooled sample	0.15	54.60	1,015.00	0.95	55,448.00	52.10

A special concern is the availability of water for domestic uses in the Lower Usangu (e.g. in Ukwaheri, Madundasi and Upagama villages), particularly during the dry season when the water situation is critical and water availability is reduced to a level that makes it difficult to meet even the basic household water needs. As a result, in some areas of the Lower Usangu, people have to walk for up to 15 km to fetch domestic water. This is also reflected by the relatively higher average WTP per m^3 of water for the sample households in the Lower Usangu as compared to those in the Middle and Upper Usangu.

4.3.5 Value of water for brick making

In the Upper GRR catchment, brick making is normally a dry season activity. About 35% of the total households in Upper Usangu, and 25% both in the Middle and Lower Usangu are involved in brick making. The average number of bricks made per household per annum was estimated at 971; 507, and 422 for the Upper; Middle, and Lower Usangu respectively (Table 15). On average, a cubic metre of water produces about 400 bricks. Using the Change in Net Income Approach the average value of water for brick making in the Upper GRR catchment was estimated at Tsh 1,155.79 per m^3 of water used (Table 15).

Table 15: Value of water for brick making in the Upper GRR catchment

	Upper Usangu	Middle Usangu	Lower Usangu	Usangu Average
Average number of bricks produced/hh/annum	971.00	507.00	422.00	633.00
Gross income (Tsh)	19,420.00	10,140.00	8,440.00	12,667.00
Operational costs (Tsh)	14,374.88	8,414.76	7,058.88	9,950.00
Gross margin (Tsh)	5,045.12	1,725.24	1,381.12	2,717.00
Volume of water used (m^3)	2.61	1.27	1.06	1.58
Productivity of water (bricks/m^3)	372.00	411.00	418.00	400.00
Gross margin per m^3 of water used (Tsh/m^3)	1,933.00	1,360.60	1,309.12	1,534.24
Average value of water (Tsh/m^3)	1,333.77	1,020.45	1,073.48	1,155.79

Although the productivity of water for brick making in the Upper Usangu was the lowest (in terms of the number of bricks produced per m^3), the gross margin and the average value of water per m^3 was the highest. This can mainly be attributed to the relatively higher level of output (i.e. number of bricks produced per annum) in the Upper Usangu than in the Middle and Lower Usangu as well as the higher gross revenue - operational cost ratio in the Upper Usangu (1.35) than in the Middle and Lower Usangu (1.21 and 1.20 respectively).

The market prices for bricks varied slightly among the sample villages with the average price of Tsh 20 per brick. In few cases however, prices of up to Tsh 35 per brick were reported particularly for the households who sold their bricks during the wet season when brick supply is limited to the quantity carried forward from the last dry season. Most of the bricks are normally sold during the dry season when the weather condition allows for house construction.

4.3.6 Value of water for livestock

Of the three major parts of the Upper GRR catchment, the Lower Usangu recorded the highest average figures for the number of TLUs owned by households, the amount of water consumed by livestock, gross margins and hence the highest value of water for livestock (Table 16). Overall, the average value of water in the livestock sector in the Upper GRR catchment was estimated at Tsh 1,176.55 (US $ 1.11) per m^3.

Table 16: The value of water in the livestock sector in the Upper GRR catchment

	Upper Usangu	Middle Usangu	Lower Usangu	Overall Average
Average number of livestock (TLUs)	2.40	4.90	47.50	18.30
Gross income (Tsh)	303,621.25	616,266.67	5,518,797.85	2,146,229.00
Variable costs (Tsh)	106,594.00	145,488.02	809,602.64	353,895.00
Gross margin (Tsh)	197,027.25	470,778.64	4,709,195.21	1,792,334.00
Volume of water consumed (m^3)	37.54	81.87	745.00	288.14
Gross margin per m^3 of water used (Tsh/m^3)	5,248.04	5,750.46	6,321.03	5,773.18
Average value of water (Tsh/m^3)	1,066.26	1,173.56	1,289.83	1,176.55

It should however be noted that the values given in Table 16 are short run values based on *direct* water consumption by livestock (drinking water only) and average annual turnover or net income generated from livestock (sales of live animal and livestock products and by-products) taking into account only the variable costs and not fixed costs (e.g. equipments, building and depreciation costs). But, livestock production also has a significant component of *indirect* water consumption, which is the water needed to produce the food for livestock (e.g. water embedded in pasture and other foodstuffs). This water is normally not available for immediate use in other sectors and may entail some significant opportunity costs. However, even if one would take into account all these costs, the picture for the value of water in livestock sector would hardly be different, because of the low variable costs for cattle holding in the study area. The major variable costs consist of medication and in some cases, hiring labour for herding when family labour is inadequate. Until recently, there also used to be a cattle tax, but this has been abolished, even further reducing the costs of livestock keeping.

4.3.7 Value of water in fishery

4.3.7.1 Fish catch

Records from the District Department of Fisheries in Rujewa indicate transport of between 37 and 372 tonnes dry weight (d.w.) of fish per year with an average for the period from 1985 to 2002 of 158 tonnes (d.w.) of fish. These data lead to an estimation of average production of 315.5 tonnes of fresh fish weight equivalent (f.w.e.) a year as a working estimate and a total of some 240 - 1,500 tonnes per year of fish transported out of the Upper GRR catchment, which represent mainly the catch from commercial fishermen.

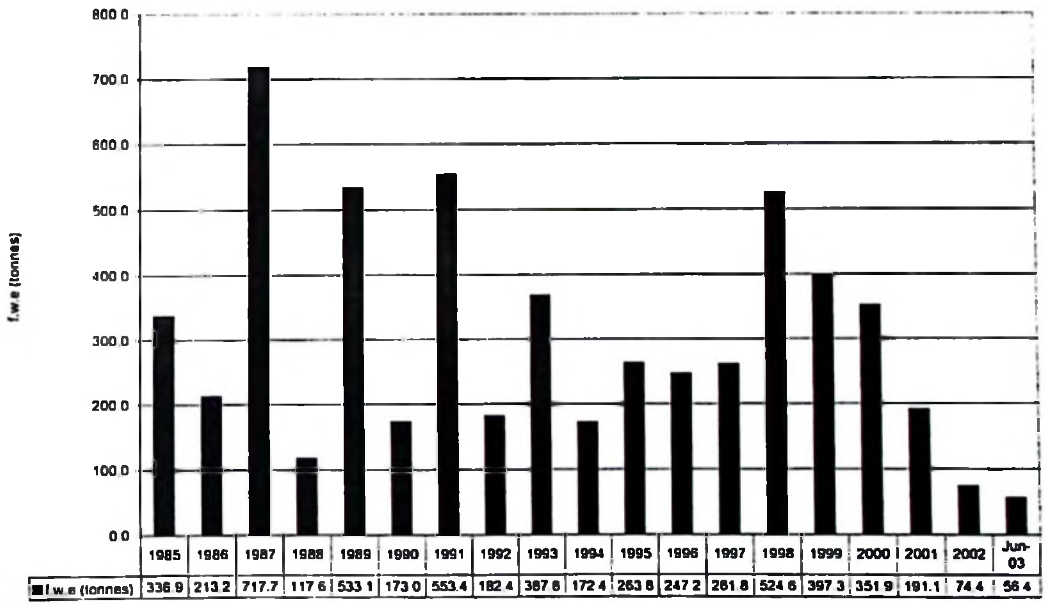

Figure 25: Total annual quantities of fish transported through the District Department of Fisheries in Rujewa, 1985 – June 2003

Based on the above statistics it is estimated that fishery in the Upper GRR catchment produces an average of some 700 tonnes of fish a year, with annual production ranging from about 400 to 1200 tonnes a year, depending upon rainfall patterns (Figure 26). The fishing activity and fish yield begin to increase at the beginning of the wet season (January) and decline after the rains stop and the waters recede (April-May).

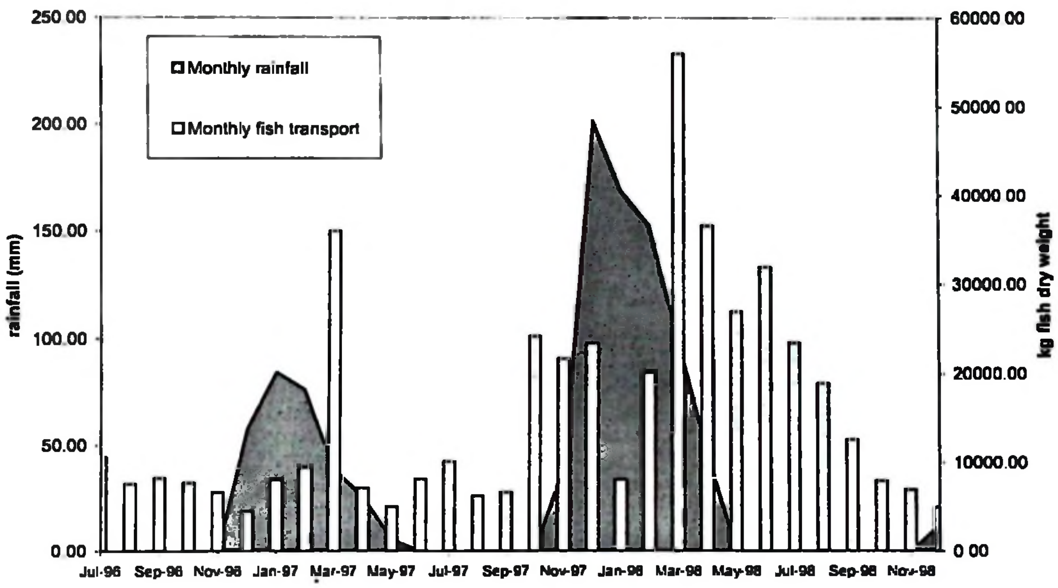

Figure 26: Rainfall and fish transport through the District Department of Fisheries in Rujewa, July 1996 – 1998

As shown in Figure 25 fish transportation through the Mbarali District Department of Fisheries has declined substantially in the recent years (from 1989 – 2003). This can mainly be attributed to the establishment of the Usangu Game Reserve in 1998, which encloses the Usangu Wetlands. This has meant that nearly all the dry season and a major part of the wet season fishing activity is now completely illegal.

4.3.7.2 Employment in fishing

Of the entire sample households about 20% reported as involved in fishing either on a part or full time basis. Using this percentage, the number of fishermen in the Upper GRR catchment was estimated at about 600 people. About half of them (300) work on a part-time basis with a short period (usually from 1 to 3 months) a year spent on fishing as a means of generating cash. The rest of the fishermen obtain all, or most, of their living from this activity and may spend more than six months or so at the fishing sites. Most of the full-time fishermen come from villages in Makete District in the hills above the Usangu Plains. Part-time fishermen fish for a short period because they alternate this occupation with work on their farms.

Plate 6: Opportunistic fishermen building fences and setting fish traps across the river

The involvement of part-time fishermen increases with the arrival of the annual floods. When the waters rise there is much opportunity for small-scale fishing with minimum gears and many of these part-time fishermen are from big centres and villages around the wetlands. There is a further group of opportunistic, subsistence fishermen (Plate 6). These will range from children fishing the irrigation drains and streams, to villagers building fences and setting fish traps along the residual watercourses at the end of the dry season.

4.3.7.3 Processing and transportation

The fishing and processing is carried out mainly in temporary camps which change their location to follow the pattern of inundation and drying out. A major part of the catch is processed at the remote fishing camps and transported by canoe to locations that are accessible by vehicle. The well-packed fish is then transported further to the main Iringa-Mbeya road. A significant quantity is transported in small quantities by bicycles, from the small fishing camps to the main centres and main road.

4.3.7.4 Prices, value of catch and returns

There is generally little fluctuation in the fish price from the period of high catches in the wet season and the low catches of the dry season. The fishermen get between Tsh 150 and 250 per kg (w.f.e.), which is sold in the markets of Makambako, Njombe, or Mbeya for Tsh 400 – 500 per kg dry weight (equivalent to approximately Tsh 800 to 1000 per kilogram fresh weight). The unit of trade is normally considered to be a fish although this may be a number of small fishes or cut pieces of a larger fish. The processed weight of this fish (or fish equivalent) is 500 - 600g, which can be assumed to represent a fresh-weight of 1kg.

A lot of the Upper GRR catchment's catch goes to other destinations outside the area (e.g. Mbeya town and Rungwe) (Figure 27) and may continue as an export trade with Malawi and Zambia.

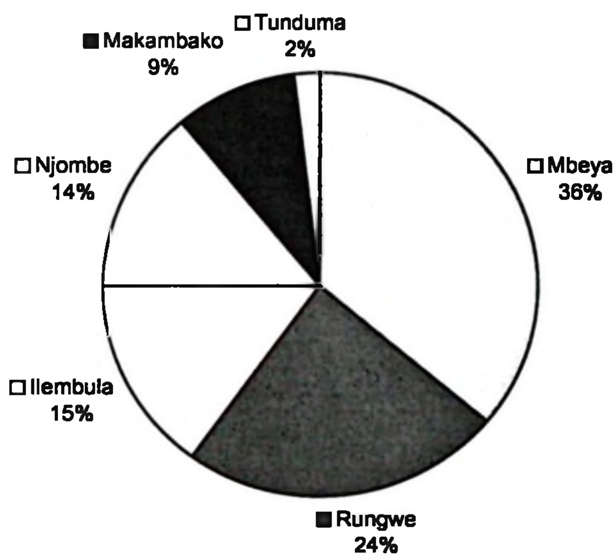

Figure 27: Destinations of the fish passing through the Rujewa Revenue Records, 1988 – June 2003

Table 17 presents the average annual value of fish production, associated costs of production, and returns. The value of production is estimated based on reported catch per unit effort, number of trips per annum, home consumption, amount sold by each fisherman and price received. The estimated average annual total value of the catch was Tsh 261,571.5 (US $ 245.8). This includes the value of fish consumed at home, estimated at Tsh 30,580.5 (US $ 28.7). The value of catch differed between the two types of fishermen (part time and full time fishermen), reflecting their differences in catch per unit effort and the average number of trips per annum.

For both types of fishermen, the average annual economic return equals Tsh 175,595.80 (US $ 165). On a per-trip basis, the economic returns equal Tsh 1,178.5 (US $ 1.1) per fisherman. With a yield estimate of 700 tonnes a year the value of fish catch for the whole of the Upper GRR catchment was estimated at some Tsh 350 million (equivalent to US $ 329,000).

Table 17: Average annual value of production, costs and returns per type of fishermen, 2002 and 2003

Item	Part time Fishermen (N = 59)	Full time Fishermen (N = 57)	Total (N = 116)
Fishing trips per annum	29.00	271.00	149.00
Catch per trip (kg)	10.10	9.10	9.50
Annual production (catch) (kg)	293.40	2464.70	1413.90
Quantity of marketed catch (kg)	259.90	2099.20	1176.90
Quantity of home consumption catch (kg)	15.50	319.90	165.30
Total value of production (Tsh)	54,279.00	455,969.50	261,571.50
Value of marketed catch (Tsh)	48,081.50	388,352.00	217,726.50
Value of home consumption (Tsh)	2,867.50	59,181.50	30,580.50
Costs of production			
Cash costs (Tsh)*	11,441.70	98,770.10	54,973.60
Non-cash costs (Tsh)**	4,784.10	55,552.30	31,002.10
Total costs (Tsh)	16,225.80	154,322.40	85,975.70
Returns			
Economic returns (Tsh)***	38,053.20	301,647.10	175,595.80
Per trip (Tsh)			
Financial returns (Tsh)****	31,855.70	234,029.60	131,750.80
Financial returns excluding non-cash costs (Tsh)*****	36,639.80	289,581.90	162,752.90
Per trip (Tsh)	1,263.44	1,068.57	1,092.30

*Cash costs include costs such as boat rental (for rentals), fishing gear maintenance and repair and other variable cash costs such as torches, batteries, baskets, hooks and transportation.
**Non-cash costs include family labour cost for fishing gears (e.g. boat and net maintenance and repair) - labour costs are estimated at the rate of Tsh 1500 per manday)
***Economic returns = total value of production less total cost of production
****Financial returns = marketed catch less total cost of production
*****Financial returns excluding non-cash costs = value of marketed catch less total cash costs of production

4.3.8 Value of water for nature conservation

4.3.8.1 Water uses: inflows, evaporation, outflows and environmental flows

Shown in Figure 28 is the trend of annual inflows, evaporation and outflows from the Usangu Eastern Wetland, inferred from simulation data by Kashaigili *et al.* (2005). The trend of the Great Ruaha River flows in the Ruaha National Park is graphically presented in Figure 29 and the average volumes of water used by the wetland and

Ruaha National Park per annum and estimated environmental flows are given in Table 18.

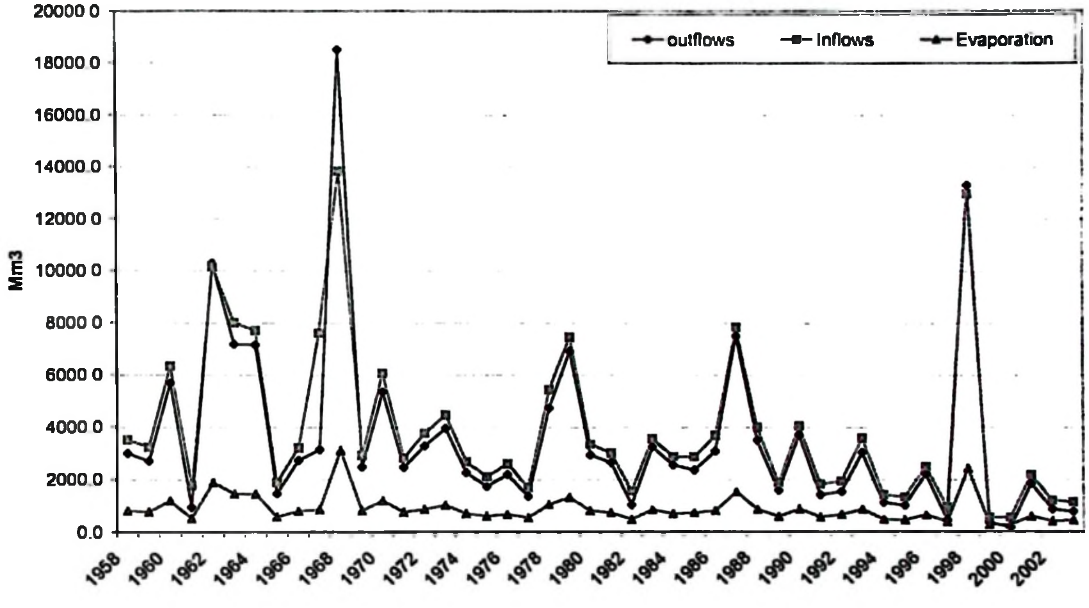

Figure 28: Simulated annual inflows, evaporation and outflows from the Usangu Eastern Wetland, 1958 – 2004

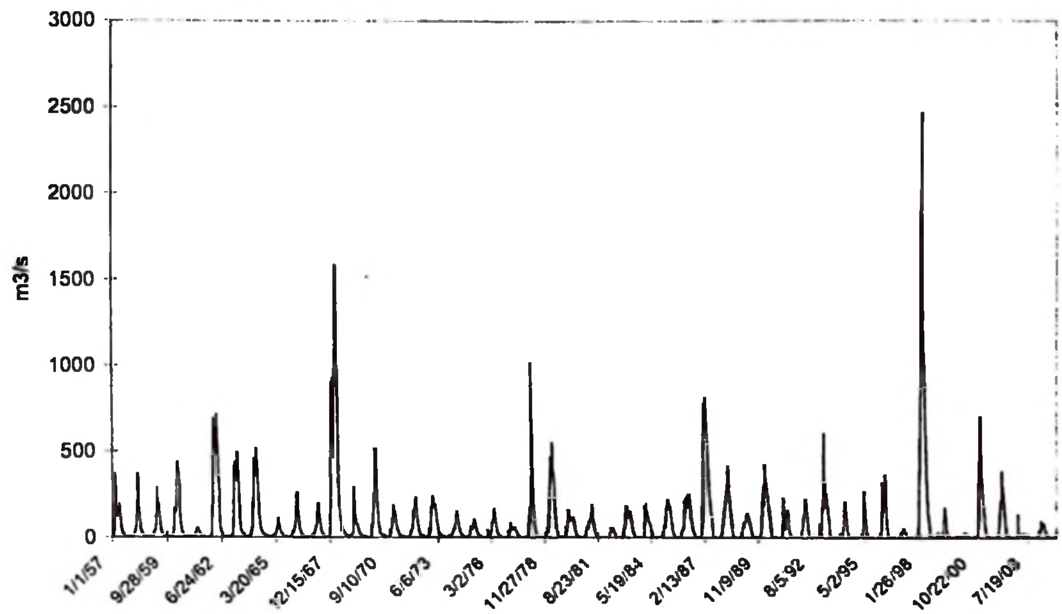

Figure 29: The Great Ruaha River flows at Msembe (1Ka59) in the Ruaha National Park, 1957 – 2004.

Table 18: Estimated inflows, evaporation and environmental flows to the Usangu Eastern Wetland and Ruaha National Park

Variable	Mean	Median	StDev	SE Mean
Annual inflows to the wetland, 1958 - 2003 (Mm^3)	3923.00	2977.00	3036.00	448.00
Annual inflows to the wetland, 1990 - 2003 (Mm^3)	2591.00	1629.00	3167.00	846.00
Annual evaporation from the wetland 1958 - 2003 (Mm^3)	889.80	780.00	533.80	78.70
Annual evaporation from the wetland 1990 - 2003 (Mm^3)	676.00	529.00	540.00	144.00
Annual outflow from the wetland, 1958 - 2003 (Mm^3)	3523.00	2606.00	3464.00	511.00
Annual outflow from the wetland, 1990 - 2003 (Mm^3)	2276.00	1270.00	3332.00	891.00
Estimated Environmental Flow to the wetland (Mm^3 per day)*	0.59			
Estimated Environmental Flow to the wetland (Mm^3 per year)*	89.90			
Annual GRR flows at Msembe - RNP, 1958 - 2004 (Mm^3)	2494.00	1694.00	2490.00	363.00
Annual GRR flows at Msembe - RNP, 1990 - 2004 (Mm^3)	2401.00	1694.00	2939.00	759.00
Estimated Environmental Flow to the RNP (Mm^3 per day)*	0.04			
Estimated Environmental Flow to the RNP (Mm^3 per year)*	6.60			

Source: Simulation by Kashaigili *et al.* (2005) and own calculation.
*Environmental Flows for 153 days of dry season (July – November)

The annual inflows to the Usangu Eastern Wetland and river flows at Msembe have varied between years depending mainly on the amount of rainfall received. The correlation coefficients between inflows to the wetland and river flows at Msembe with rainfall were positive, equal to 0.887 and 0.925 respectively, at 95% significant level.

The average annual inflows to the Usangu Eastern Wetland were estimated at 3,923 and 2,591 Mm^3 for the period 1958 – 2003 and 1990 – 2003 respectively (Table 18). During the same periods, the mean annual evaporation from the Usangu Eastern Wetland was estimated at 889.8 and 676 Mm^3 respectively. The mean annual river flows at Msembe in the Ruaha National Park was estimated at 2,494 and 2,401 Mm^3 for the period 1958 – 2004 and 1990 – 2004 respectively.

The data for the period starting from 1990 onwards was analysed separately in order to capture the period in which the GRR had started to dry up in the Ruaha National Park. The GRR was formerly known to be perennial but was first noticed to be drying up during the dry season in 1993 (Kadigi and Mdoe, 2004). It has since then continued to dry up during the dry season with increasing periods of no flow. This has disrupted the lives of animals that depend on it by causing widespread mortality of fish and hippopotami in the Park creating unaesthetic conditions in the remaining pools. According to the records provided by the Park Ecologist, about 5,000 fishes and 49 hippos died in 2003 as a result of drying up of the GRR. While the actual causes of drying up of the GRR in the Ruaha National Park are not well understood, most researchers (e.g. SMUWC, 2001; DANIDA/World Bank, 1995) mention expanding irrigated agriculture in the Upper GRR catchment as the main contributor.

Kashaigili *et al.* (2005) provide an estimate of the dry season inflow of about 7 m^3/s to enter the Usangu Wetlands so as to maintain an environmental flow of about 0.5 m^3/s through the Ruaha National Park. To achieve this the flows of the perennial rivers discharging into the wetland (the GRR and its tributaries of Mbarali, Kimani, Ndembera) will have to be apportioned in such a way that 20% is used for human needs upstream the wetland (irrigation, livestock, brick making and other domestic uses) and the remaining 80% flows into the wetland.

The available surface water resources flowing to the wetland was estimated at 8.5 m^3/s and the water for human needs at 2.23 m^3/s. Maintaining the outflow of 0.5 m^3/s from the Usangu Eastern Wetland to the Ruaha National Park will imply reducing the current level of surface water use by human in the Usangu Plains by about a half unless this demand is met through use of other sources of water (e.g. borehole and shallow wells).

4.3.8.2 The value of water utilisation for nature conservation

Using the Opportunity Costs Approach and the different water volumes provided in Table 18, the values or benefits of water utilisation for nature conservation (in the Usangu Eastern Wetland and Ruaha National Park) were estimated as equal to the returns foregone by not using it for irrigation purposes upstream in the Usangu Plains (Table 19).

The opportunity costs of water utilisation for nature conservation were estimated at Tsh 21.37 and 46.66 per m^3 of abstracted and consumed water respectively. Using the inflow/river flow data for the period 1958 – 2003/04, the net benefits foregone were estimated to average at about Tsh 83,833 and 53,296 Million per annum for the Usangu Eastern Wetland and Ruaha National Park respectively or Tsh 55,369 and 51,308 Million respectively for the period 1990 – 2003/04. For consumptive use (evaporation), the net revenue foregone was estimated to average at Tsh 41,515 and 31,540 Million per annum for the period 1958 – 2003 and 1990 – 2003 respectively.

Table 19: The value of water for nature conservation in the Usangu Eastern Wetland and Ruaha National Park

Type of water considered	Quantity of Water (Mm^3)	WOC (Tsh/m^3)*	Net benefits (Million Tsh/yr)	Net benefits (Million $/yr)
Annual inflows to the wetland, 1958 - 2003	3923.000	21.370	83,832.700	78.800
Annual inflows to the wetland, 1990 - 2003 (Mm^3)	2591.000	21.370	55,368.500	52.000
Annual evaporation from the wetland 1958 - 2003 (Mm^3)	889.800	46.660	41,514.700	39.000
Annual evaporation from the wetland 1990 - 2003 (Mm^3)	676.000	46.660	31,539.600	29.600
Annual outflow from the wetland, 1958 - 2003 (Mm^3)	3523.000	21.370	75,284.900	70.800
Annual outflow from the wetland, 1990 - 2003 (Mm^3)	2276.000	21.370	48,637.100	45.700
Estimated Environmental Flow to the wetland (Mm^3 per day)	0.590	21.370	12.600	0.010
Estimated Environmental Flow to the wetland (Mm^3 per year)	89.900	21.370	1,921.100	1.800
Annual GRR flows at Msembe - RNP, 1958 - 2004 (Mm^3)	2494.000	21.370	53,295.700	50.100
Annual GRR flows at Msembe - RNP, 1990 - 2004 (Mm^3)	2401.000	21.370	51,308.300	48.200
Estimated Environmental Flow to the RNP (Mm^3 per day)	0.040	21.370	0.900	0.001
Estimated Environmental Flow to the RNP (Mm^3 per year)	6.600	21.370	141.000	0.100

*WOC = Weighted opportunity costs taking into account the share of wet and dry season irrigated crops and net values for abstracted and consumed water.

4.3.9 A cross-sectoral comparison of water values

Figure 30 shows that the economic values of water for livestock uses, brick making and domestic uses are the highest. The high value for domestic uses is commonly observed in cross-sectoral water value estimates (Briscoe, 1996; Rogers *et al.*, 1996), and is due to the fact that domestic uses are crucial for health and sanitation, and are relatively low in terms of volume (cf. Cornish *et al.*, 2004). However, in the case of the Upper GRR catchment, the household income levels suggest that there might be a discrepancy between the willingness to pay and the ability to pay. The economic value of water in livestock and brick making is estimated at more than Tsh 1,000 per m^3 of water consumed.

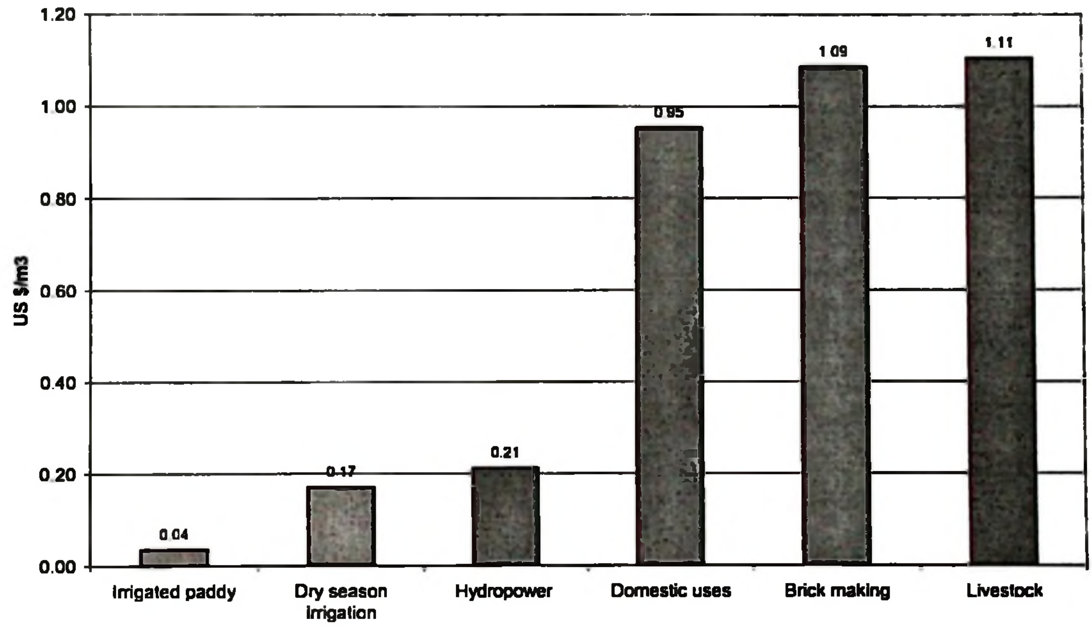

Figure 30: Value of water for different water uses in the Upper GRR catchment

Using the net values of water obtained for each use and the total number of households in the Upper GRR catchment (about 30,000), the annual net benefits of water utilisation for the study area was estimated as shown in Table 20 below. It should however be noted that, the net benefits of water utilisation in irrigation, domestic uses, brick making, livestock and fishery refer only to the Upper GRR catchment in the Usangu Plains, the area in which irrigation competes with downstream uses (Usangu Wetlands, Ruaha National Park and HEP generation at Mtera and Kidatu hydropower stations). The annual net benefits for the former uses would therefore be higher than the ones given in Table 20 if water use for the whole of Great Ruaha catchment is captured.

Table 20: The annual net benefits of water utilization in different sectors in the GRR catchment

Water user*	Net Water Value (Tsh/m^3)	Gross Water Use (Mm^3/yr)	Net Water Consumption (Mm^3) ***	Net Benefits Million (Tsh/yr)	Net Benefits Million (US $/yr)
Irrigated paddy	38.60	979.00	542.00	20,921.20	19.66
Dry season irrigation	182.00	24.30	16.30	2,966.60	2.79
Hydropower	226.08	4,096.00	1,094.00	247,331.52	232.45
Domestic uses	1,015.00	1.64	1.64	1,662.57	1.56
Brick making	1,155.79	0.01	0.01	15.52	0.01
Livestock	1,176.55	158.19	158.19	186,117.10	174.92
Usangu Eastern Wetland	46.66	3,923.00	889.80	41,518.07	39.02
Ruaha National Park**	21.37	2,494.00		53,296.78	50.09

*Values of water for irrigated agriculture, domestic uses, brick making, livestock and fishery refer only to the Upper GRR catchment (Usangu).

**Data on consumptive use of water for the Ruaha National Park were lacking, the estimates of net benefits were therefore done based on gross water use (river flow data).

***For domestic uses, brick making and livestock the working assumption was that all water, which is drawn is consumed (i.e. Gross Water Use = Net Water Consumption).

4.4 Water benefits and their effects on income distribution and poverty alleviation

The decomposition of the coefficient of variation and Gini coefficient was used to assess the effects of different benefits of water utilization and sources of income to overall income inequality. Presented in Table 21 are the results of analysis with respect to the distinction between inequality -increasing versus inequality -decreasing sources of income. In analysing whether an income source is inequality -increasing or inequality –decreasing, it was assumed that the additional increments of that income source are distributed in the same way as the original units.

Table 21: Relative concentration coefficients of source incomes in overall income inequality

	Paddy	Dry Season Irrigated Crops	Rainfed Crops	Livestock	Others*
Average annual income, y (Tsh)	969,960.00	1,030,583.00	1,758,053.00	2,146,229.00	507,710.00
Average annual income, y (US $)	912.00	969.00	1,652.00	2,017.00	477.00
Correlation coefficient between total income and source incomes (ρ)	0.57**	0.14	0.76**	0.69**	0.51**
Relative coefficient (c)	0.91	0.23	1.20	1.16	1.39
Relative coefficient (g)	0.34	0.05	1.37	1.20	1.24

*Refer to other sources of income (brick making, fishery, transfer, labouring, rental and other non-farm sources of income).
**Significant at the 0.05 level.

Both decompositions showed that irrigated agriculture (paddy and dry season irrigated crops) represent inequality decreasing sources of income. This means that, *ceteris paribus*, additional increments of income from paddy and dry season irrigated crops will reduce the overall income inequality. This shows the importance of the income accrued from irrigated agriculture, particularly for the poor and it suggests a possible avenue for targeting development interventions (e.g. interventions that aim at improving the productivity in irrigated agriculture for poverty alleviation).

The income decomposition in this study showed that rainfed crops, livestock and sources of income grouped under the "others" category represent inequality-increasing sources of income.

These findings can be compared with those of other studies done elsewhere in Tanzania (Collier *et al.*, 1986); Burkina Faso (Reardon *et al.*, 1992); and in Nigeria (Matlon, 1979) – all find that "non-farm" incomes have a negative impact on rural income distribution. However, studies by Adams (1994) in rural Pakistan, Chinn (1979) and Ho (1979) in Taiwan indicate that non-farm income reduces rural income inequality.

This disparity can partly be explained by the differences in study sites. In land-scarce, labour-rich settings – like Taiwan and much of Asia, for example, small and inadequate landholdings, as scarcity of suitable land for irrigated agriculture in the Upper GRR catchment, may tend to 'push' poorer households out of agriculture. Thus in these settings the "others" income category may be expected to have a favourable impact on equity. The obverse, then, could hold in land-rich settings or land with easy access to irrigation water where most agrarian households will tend to be kept in agriculture and most of the richer households pulled into the "non-farm" sector.

4.5 The opportunity costs of water transfer away from irrigated agriculture

Looking at the results presented earlier in Table 20 one would argue that, of all sectors in the GRR catchment, HEP generates the highest annual net benefits (Tsh 247,332 million) – higher than those from irrigated agriculture (cf. Tsh 2,967 and 20,921 million for dry season irrigated crops and wet season irrigated crop/paddy respectively), but a number of other aspects need to be considered as well.

Other aspects that need to be considered include, for example, a thorough evaluation of the opportunity costs of water in irrigated agriculture, and hence of water transfer from this sector to other uses downstream (including HEP generation at Mtera and Kidatu). The question of whether HEP generation is superior to irrigated agriculture, in terms of generating both higher economic benefits and pro-poor returns is also worth considering. Just as important, the issue of benefit sharing is critical and it needs a closer analysis. Recognizing that only 10% of the total population in Tanzania (1% in the rural areas) for example, have access to electricity (URT, 2003) versus, for example, the share of the GR paddy in the total national production (which ranges from 14 – 24%), and the fact that more than half of all the paddy produced in the Upper GRR catchment (60% according to official records from the Mbarali District Agriculture and Livestock Development Office in Rujewa) is sold outside the area through inter-regional trading to other regions in Tanzania, one would also see the role that irrigated agriculture plays, particularly in enhancing both the local and national economies as well as the national food security at large. But the multiplier effects of HEP generation to the rest of the economy are also considerable. Considering, for example, the current impact of power shortages and rationing due to declining of water in Mtera and Kidatu storage dams, one would also argue that the national economy suffers greatly when there is power cuts/rationing due to low water levels in the storage dams. The performance of sectors depending on electricity (e.g. the industrial sector), for example is affected when there is power cuts.

All these notwithstanding, the results of analysis in this study show that the opportunity cost of water transfer from irrigated agriculture in the Upper GRR catchment to other alternative uses downstream average at about Tsh 15 ($ 0.01) or Tsh 39 ($ 0.04) per m^3 of abstracted or consumed water respectively. The amount of water currently consumed in irrigated paddy was estimated at about 542 Mm^3 per annum (Table 20). However, it should be noted that the estimate considers only the wet season abstractions, if dry season irrigation is taken into account (August to November), then the figure might be higher, but the contribution of dry season flow downstream is considered as insignificant because dry season irrigated paddy is uncommon in the Upper GRR catchment.

By extrapolating the figures reported by SMUWC (2001) based on the actual field measurements of the annual depth of water applied in paddy fields for the NAFCO and Peri-NAFCO smallholder irrigation schemes (averaging at 1850 mm), the mean annual rainfall (669 mm), effective annual rainfall (479 mm), irrigation annual demand (1371 mm) and mean wet season irrigated area for paddy (of 42,000 ha), the annual volumetric water consumption was estimated at 576 Mm^3 (Kadigi *et al.*, 2004). Having 60% of the total paddy produced in the Upper GRR catchment traded inter-regionally outside the area to other regions also implies that 60% or 325.2 Mm^3 (according to the current estimate) of the water consumed in the Upper GRR catchment for paddy irrigation or 345.6 Mm^3 (as per the estimate made after extrapolating the SMUWC (2001) water measurements), is traded outside the Upper GRR catchment as "virtual water". "Virtual water" is defined as the water needed to produce a commodity or service (Allan, 2003). Without irrigated paddy this water would be utilized in alternative ways, either as evaporation from seasonal swamps within the Upper GRR catchment or made available for other inter-sectoral uses.

Table 22 presents a comparison of the benefits of water utilization in irrigated paddy and HEP generation. As shown in this Table, the annual net evaporation from the Mtera-Kidatu HEP reservoir system for the period from July 2002 to June 2003 amounted to about 1,094 Mm^3. If we consider this as equal to the total annual consumption (i.e. scenario 2 for HEP generation), then the net revenue for Mtera-Kidatu HEP system for the same period is estimated to amount to about Tsh 247,332 Million (US $ 232.5 Million). In irrigated paddy, the same amount of water would enable an expansion of about 42,780 ha of land over the current area in the Upper GRR catchment (of about 42,000 ha) leading to total production of about 106,940 more tonnes of paddy than the current production level of about 105,000 tonnes.

Currently, irrigated paddy supports about 30,000 agrarian families in the Upper GRR catchment. In other words, the additional quantity of 106,940 tonnes of paddy could support extra livelihoods of more than the current number of paddy-farming families with average gross income per family of about Tsh 969,960 or US $ 911.90 per annum, which implies that irrigated paddy plays an important role in lifting the households in the study area out of poverty.

Table 22: Comparing the benefits of water utilization in irrigated paddy and HEP generation, July 2002 - June 2003

	PADDY		HEP		
	Abstracted Water	Consumed Water	S1 (Turbine discharge)	S2 (Evaporation)	S3 (S1 + S2)
Production (tonnes for paddy or kWh for HEP)	105,000.00	105,000.00	1,839,424.00	1,839,424.00	1,839,424.00
Net Revenue (Million US $)	19.70	19.70	232.50	232.50	232.50
Share of the national total supply (%)	14 – 24.00	14 – 24.00	59 – 65.00	59 – 65.00	59 – 65.00
Amount of water used (Mm^3)	979.00	542.00	3,002.00	1,094.00	4,096.00
Productivity of Water (kg/m^3 for paddy) or (kWh/m^3 for HEP)	0.11	0.19	0.61	1.68	0.45
Net real value of water (Tsh/m^3)	15.31	38.60	81.70	226.08	59.57
Net real value of water ($\$/m^3$)	0.01	0.04	0.08	0.21	0.06

4.6 Water management problems and constraints

When asked to rank the problems and constraints related to management and utilisation of water resources in the GRR catchment most respondents ranked increasing irrigation activities upstream, poor management and low productivity of irrigation water as the most critical problems (Table 23). Other problems and constraints include increasing human and livestock population and inadequate involvement of key stakeholders in decision-making related to water management and utilisation. Other problems and constraints, and their respective weighted percentages are summarized in Table 23.

Table 23: Weighted percentages of the major problems and constraints in the study area

Problems/Constraints	Upper Usangu	Middle Usangu	Lower Usangu	Pooled sample
a) Increasing irrigation activities upstream, poor water management and low productivity	28	21	34	28
b) Increasing human population, livestock numbers and hence increasing demand for water resources	25	12	35	24
c) Inadequate involvement in decision-making related to water management and utilisation	12	23	12	16
d) High input prices, low producer prices and uncertain market environment	11	21	8	13
e) Strenuous access to clean and safe water for domestic uses, particularly in the dry seasons	15	12	5	11
f) Change in climatic conditions and river flow regimes	9	11	6	8
Total (N = 580)	100	100	100	100

The problem of inadequate community involvement was exemplified by the perceptions of local communities in the study area on the decision of the Government to gazette the major part of the Usangu Eastern Wetland as a Game Reserve. During the interviews conducted in different villages, it was revealed that, most of the households in the study area were not consulted during the process of gazetting the Usangu Game Reserve (UGR) - although interviews with some livestock keepers in Upagama village have revealed that, some consultations were made in Idunda village, where very few livestock keepers reside and could therefore, not adequately represent and safeguard the interests of livestock keepers' access to grazing areas in the wetland.

Most respondents suggested a reconsideration of the gazettement of the Usangu Game Reserve – setting aside some part of the reserve for other land uses (mainly livestock grazing, crop cultivation and licensed fishing in the *Ihefu* swamp). Some suggested the new border for the game reserve to be moved back so that it passes through the Kidumka, Lasti, Msua to Maweshi areas.

When asked to comment on whether the gazettment of the Usangu Game Reserve has in anyway affected their families, about 92% of the interviewed households reported as being negatively affected and none of them reported as positively affected (Table 24).

Table 24: Households' perceptions on the effects of gazettement of the Usangu Game Reserve

Response	Number of sample households	%
Negatively affected	534	92
Positively affected	0	0
No effect	46	8
Total	580	100

As most of the respondents have argued, the gazettement of the Usangu Game Reserve has resulted into a denial of their right to have free access to the wetland resources – a right they have inherited from their ancestors. The contribution of the Usangu Eastern Wetland to their livelihoods has been enormous, resulting from a range of economic activities - from grazing around the Ihefu swamp, fishing and farming to harvesting of grasses and reeds (including *ukindu*) just to mention a few. The problems and constraints discussed under this section can be summarised and translated into the following two major challenges:

(i) The challenges of improving water use efficiency and productivity in irrigated agriculture, saving water from irrigation schemes in the Upper GRR catchment and releasing it downstream for other uses (including the environment and HEP generation at Mtera and Kidatu).

(ii) The challenge of ensuring that government water/natural resources officials win the support of local communities in ensuring sustainable management of water and other natural resources. Along with this is the challenge of resolving the existing "paradigm dichotomy" between the natural resource conservationists and local communities in the Upper GRR catchment: the former advocate for a total protection of the Usangu Wetlands (i.e. banning all exploitative/consumptive human uses in the Usangu Wetlands – c.f. the gazettement of the Usangu Game Reserve), while the local communities do not see any compelling reasons for that. The latter stakeholders (local communities) prefer leaving aside part of the wetland for other economic uses (notably livestock grazing, fishing and other land uses). They therefore, suggest for reconsideration of the gazettement of the Usangu Game Reserve.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

This study arose from recognition of the existing gap in the information, which would allow achieving efficient, equitable and sustainable use of water resources to meet water demands of different sectors. The study has used the case of GRR catchment to evaluate livelihoods and economic benefits of water utilization. The GRR catchment case is not unique in Tanzania and in other countries of the developing world. It has been used in this study only as an illustration of the need to understand the value and benefits of water utilisation in different sectors so as to inform policy and water allocation decisions. The main objective of this study was therefore, to evaluate livelihoods and economic benefits of water utilization in order to provide information that would enrich understanding and decision-making among stakeholders of water based livelihoods, values and economic benefits of water utilization. The specific objectives of the study were to analyse water based livelihoods; values of water and economic benefits of water utilisation; the effects of these benefits on income distribution and poverty alleviation; and the opportunity costs of water transfer away from irrigated agriculture to other uses downstream. In addition, the study also aimed at identifying the opportunities and strategies for improvement of water use efficiency and productivity.

These objectives were achieved through a research work that was conducted for the period starting from mid 2002 to end of 2004. The study was financed by the RIPARWIN project – a DFID funded research project implemented by the Overseas

Development Group (ODG), University of East Anglia (UEA), United Kingdom; the Soil Water Management Research Group (SWMRG) of Sokoine University of Agriculture (SUA), Tanzania; and the International Water Management Institute (IWMI) through its Africa Regional Office in Pretoria, South Africa (SA).

The conclusions and recommendations emanating from the major findings of this study are summarized in the following subsections.

5.1 Conclusions

5.1.1 Livelihood analysis

Access to irrigation water and suitable land for wet and dry season irrigated agriculture constitutes one of the most important determinants of livelihood in the Upper GRR catchment. Cultivation of paddy (which is the major crop under irrigation in the area), for example, requires a land with suitable soils, as well as easy access to water - which are largely determined by the ability of a household to own or hire such a land.

Livestock is another key determinant of livelihood, particularly in the lower parts of the Upper GRR catchment, where the majority of people are agropastoralists who migrated from Shinyanga and Mwanza regions in northern part of Tanzania.

Collective labour arrangements, lending and borrowing mechanisms are the most important forms of social capital in the upper most part of the catchment. In the middle part (Middle Usangu), cooperation and social interactions are primarily dependent on income generating clubs and livelihood associations. The value of collective arrangements and drawing on social networks are strongly stressed in the lower parts of the catchment. Collective actions, good social relationships and traditional ceremonies are important mechanisms that support the local livelihood strategies. They crosscut all social strata and result in higher levels of social capital for poor households in the Lower Usangu.

In general, the livelihood platform of the poor households is less favourable in comparison to that of the average households. Specific bottlenecks include limited access to natural resources such as irrigable land and irrigation water, human capital and labour (especially at the peak of wet season), physical production capital such as agro-chemicals or livestock, and social capital such as the membership of local societies and associations. These bottlenecks lead to increased level of vulnerability among the poor households.

Vulnerability can generally be said as increasing gradually from upstream to downstream, particularly in terms of access to physical and natural resources. Villages in the lower parts of Usangu (e.g. Ukwaheri and Madundasi), for example, suffer the most severe water shortage problems, as no water reaches these villages during the dry season. Furthermore, these villages have less favourable conditions for agriculture with suitable lands widely scattered, and there is poor or limited local infrastructure (e.g. roads are not passable during the wet season and irrigation infrastructure is generally lacking). However, related to other livelihood aspects, the agropastoral farming community in the lower villages is less vulnerable as the households in this area own more livestock and larger pieces of land compared to households in the upper and middle villages.

The livelihood strategies and coping mechanisms for the households have generally changed overtime, responding to the diminishing availability of water and land resources. The diminishing natural grazing land for example, has pushed agropastoral household in the middle and lower parts of the Upper GRR catchment towards intensification and expansion of their cropping activities using draught animal power and adoption of seasonal migration of cattle to dry season grazing grounds close to the permanent *Ihefu* swamp.

Overall, crop production and livestock activities, which all depend on water as a critical input in the production process, account for more than 90% of household incomes in the Upper GRR catchment. Given limited access to land and water resources by the poor households, the same are not able to generate sufficient income from agriculture and they have therefore, to supplement their household income with income from other sources, mainly from non-farm activities and labouring.

5.1.2 Value and benefits of water utilisation

Of all water uses in the GRR catchment the values of water for livestock, brick making and domestic uses are the highest, averaging at around Tsh 1,064 (US $ 1.0) per m^3 of consumed water. The high value for domestic uses is commonly observed in cross-sectoral water value estimates and is due to the fact that domestic uses are crucial for health and sanitation, and are relatively low in terms of volume.

When irrigated agriculture is compared with HEP, the value of water is lower for the former than for the latter use. This however does not necessarily imply that HEP generation is superior to irrigated agriculture in all aspects. Therefore, in addition to using the common yardstick of "more money per drop" one has to consider other aspects as well. Among the important aspects to be considered is the whole question of what does each of these sectors do in reducing food insecurity and income-inequality? Just as important, the question of "benefit for whom" needs not to be overemphasized. Only a few people in the society may enjoy the benefits from a sector generating high monetary values per drop of water used while the majority are not.

5.1.3 Water benefits and their effect on income distribution and poverty alleviation

The decomposition of total income using the coefficient of variation and the Gini coefficient showed that of all the household income-generating activities, irrigated agriculture represents an inequality-decreasing source of income. The rest (rainfed crop farming, livestock keeping, brick making, fishery, transfers, labouring, rental and other non-farm activities) represent inequality-increasing sources of income. This implies that, *ceteris paribus*, additional increments of income from paddy and dry season irrigated crops will reduce the overall income inequality amongst the rural households in the Upper GRR catchment. The same also suggests that one of the possible avenues for targeting poverty alleviation interventions could be through the improvement of productivity of water in irrigated agriculture.

5.1.4 The opportunity costs of water transfer from irrigation

The opportunity cost of water transfer from irrigated paddy in the upper GRR catchment to other alternative uses downstream is considerable both at the local and national levels. Rice from Usangu (the upper part of the GRR catchment) constitutes about 14 – 24% of the total national supply in Tanzania. If farmers in this area stop producing irrigated paddy, there will be a shrinkage in the national annual rice production with possible increase on paddy and rice prices, unless this gap is covered by increase in rice production from other regions. It is however worth noting that this gap does not necessarily refer to the net loss of income to farmers in the Upper GRR catchment as the farmers may shift their resources from producing irrigated paddy to production of rain-fed paddy or non-paddy crops or other income generating activities.

5.1.5 Water management problems and constraints

The major problems and constraints related to water resources management in the GRR catchment spring mainly from the challenge of balancing water demands between irrigated agriculture and other water uses downstream. The drying up of the Great Ruaha River in the RNP and power shortages/rationing due to declining water levels in the Mtera and Kidatu dams are some of the examples closely linked to the increase in water use for irrigation purposes. This in turn translates to the challenge of improving water use efficiency in irrigated agriculture, saving water from this sector and releasing it downstream for use in other sectors, including wildlife conservation in the RNP and HEP generation at Mtera and Kidatu.

Other problems relate to the challenge of resolving the existing "paradigm dichotomy" between the natural resource conservationists and local communities in the Upper GRR catchment. The former group advocates for a total protection of the Usangu Wetlands (i.e. banning all exploitative/consumptive human uses in the wetlands), while the latter (local communities) do not see any compelling reasons for that.

5.2 Recommendations

(i) As far as the improvement of the livelihoods of poor people in the GRR catchment is concerned, the introduction of low-cost labour saving technologies - that can reduce the impact of labour shortages and credit-schemes - that increase the access to financial resources is critical. This is about making the existing livelihood platforms and income levels allow the poor households to change their patterns and to make some short-term investments for long-term benefits. Most poor households lack the resources to overcome transition periods, they are underrepresented in credit facility groups and livelihood associations, they are less likely to benefit from improved marketing opportunities as they already have troubles in producing enough for themselves.

(ii) The scope for reducing income-inequality and improving water values and benefits for the vulnerable households critically depends on the accompanying arrangements and institutional mechanisms. Institutional reforms (e.g. establishment and strengthening of WUAs and Apex bodies) are needed to ensure that the vulnerable groups have access to the institutional platform through which water and land resources are managed. Past experiences suggest that the formation of WUAs and Apex bodies might not happen without some external support in facilitating the formation process. This suggests an important role for the regional and district level institutions, and the RBWO in supporting the organization of local water users. The Mbeya and Iringa region government authorities have a key role in organizing local stakeholders, supporting the establishment of WUAs in the GRR catchment throughout their districts, and in representing their district's interests at the larger river basin and national levels. WUAs and Apex bodies are about ensuring active involvement of the local communities in making water management and allocation decisions. This is a reflection of new recognition of water resources management insight of local people's cultures and the determinative power of the local communities to shape their future livelihoods.

(iii) While the quest for balancing water demands between irrigated agriculture and other sectors remains important it is recommended that any intervention to transfer water from irrigated agriculture to other uses downstream (including HEP generation) should be undertaken with caution and irrigation should not be abandoned completely as it plays a significant role in lifting the poor agrarian households in the Upper GRR catchment out of poverty and in enhancing the national food security at large. Efforts should be directed towards identifying the potential for enhancing water use efficiency and productivity in irrigated agriculture, raising awareness among water users, and promoting good practices.

(iv) Generally, water use efficiencies and productivity of water in irrigated agriculture are low and too much water is used, particularly in the upstream paddy irrigation schemes. Improving water management in these schemes is key and could be done by using both supply and demand management approaches. The amount of water abstracted and used in irrigation systems, for example, can be reduced and the remaining supply being cascaded through the systems to encourage reduced demand. This can be done using time-based means – which may involve a schedule of opening and closing the offtake on different days of the week in order to pass compensation flows downstream, and to share water between a series of intakes or by reducing the duration of irrigation need (e.g. by using early maturing varieties and other techniques).

(v) Alongside with this preceding recommendation is the need to sensitise farmers and advising them to ensure that most of the water they abstract from rivers (for irrigation purposes) is evapotranspirated through useful crop growth rather than through weeds, or via evaporation from bare land. A small amount of water may not help the crop at all, whereas more water increases growth, but too much water does not add growth and may in fact harm the crop. This is often the tragedy behind top and tail-end farmers on irrigation systems in the Upper GRR catchment – the former have too much water, a certain proportion of which they do not need, while the tail-end farmers need more water, a proportion of which they urgently need – if only to secure an adequate crop.

(vi) In time of scarcity downstream water scarcity can be solved locally by developing the locally available untapped water resources, such as boreholes or stock dams in the Ruaha National Park or by improving the water management of the electricity-generating reservoirs. Even in the Upper and Middle Usangu water scarcity during the dry season does not preclude further expansion of water use for irrigation during the wet season through new infrastructure development. The construction of more storage capacity or ground water development could mitigate dry-season water scarcity especially for domestic users.

(vii) The issue of water benefits sharing is also important and it probably needs new ways of approaching it (e.g. through the process of strengthening dialogues between stakeholders as useful platforms for discussing their problems and possible means of solving them and sharing water benefit equitably).

(viii) While this study has provided useful information on water based livelihoods and economic benefits of water utilization – information, which can be integrated in a wider water management and allocation decision-support tool, at least in the GRR catchment. Yet, future research work is needed, particularly on the potential multiplier effects of water utilization not only at the catchment level but also at the national and international levels. It is therefore, recommended that the future research work goes further into the analysis of the multiplier effects of water utilization and develops stochastic economic models to assess the marginal value of water for different allocation scenarios, taking into account different sources of risk (e.g. climate and price variability). Because of data limitation, the comparisons of the values of water in the current study were based on short run period, using data of less than five years. While short run values are also important in guiding re-allocation decisions, they need to be complemented by long run values. The consideration of peak load water value in electricity generation, for example, which is generally higher than the base load water value, would require a change in time scale, with a special focus on the pattern of reservoir filling up and releases and irrigation calendar. This in turn would imply the use of dynamic models to fine-tune the intra-annual water allocation.

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APPENDICES

Appendix 1:The questionnaire administered to the sample households

A1: INTERVIEW AND BASIC HOUSEHOLD INFORMATION

A1.1 DATE OF INTERVIEW	A1.2 NAME OF INTERVIEWER	A1.3 VILLAGE/SUB-VILLAGE NAMES

A1.4 HOUSEHOLD NAME	A1.5 HOUSEHOLD CODE	A1.6 HOUSEHOLD WEALTH RANK

A1.7 RESPONDENT'S NAME	A1.8 RESPONDENT'S AGE (Years)	A1.9 RESPONDENT'S GENDER
		1 = Male; 2 = Female

A1.10 RELATION (IF NOT HHH)	A1.11 AGE OF HHH (Years)	A1.12 GENDER OF HHH
		1 = Male; 2 = Female

A1.13 ORIGIN OF HHH	A1.14 ETHNIC GROUP AND AREA OF ORIGIN IF NOT NATIVE	A1.15 YEAR OF MIGRATION IF NOT NATIVE
1 = Native 2 = Immigrant		

A1.16 REASON OF MIGRATION	A1.17 PLANS TO LEAVE THE AREA?	A1.18 IF YES, PLANNED DESTINATION
	1 = Yes; 2 = No	

A1.19 MEMBERS OF HH CURRENTLY RESIDENT (Enter code and short description, as underlined)

ID	Name	Age (Years)	Sex		Relation to HHH		Education level		Main Occupation	
			1 = Male 2 = Female		1 = Head 2 = Wife 3 = Husband 4 = Child 5 = Other relatives 6 = Other permanent		1 = None 2 = Std IV 3 = Std VII 4 = Std VIII 5 = Std IX 6 = Form IV 7 = Form VI 8 = Higher		1 = Child 2 = Student 3 = House/farm 4 = Farmer 5 = Fisherman 6 = Govt/Parastatal employee 7 = Private sector employee 8 = Self employed (non-farm)	
			Code		Code		Code		Code	
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										

If more than 10 HH residents, continue on another sheet of section A1.19

Total Resident HH members: [ ]

A1.20 MEMBERS OF HH PERMANENTLY OR MOSTLY AWAY (Enter code and short description, as in A1.19)

ID	Name	Age (Years)	Sex		Relation to HHH		Education level		Main Occupation	
			Code		Code		Code		Code	
11										
12										
13										
14										
15										

If more than 5 family members permanently or mostly away, continue on another sheet of section A1.20

Total family members permanently or mostly away: [ ]

A1.21 MEMBERS OF FAMILY PERMANENTLY OR MOSTLY AWAY (same people as for A1.20)										
ID	When left	Years away	Current place of residence		Sends money home?		How often?		How much each time?	Year total
	Year person left	No of years away	1 = In this district (name) 2 = In Tanzania (place) 3 = In Dar es Salaam 4 = Abroad (country)		1 = Yes 2 = No		1 = Each week 2 = Each month 3 = Few times (year) 4 = Occasionally		Amount each time	Calculate amount for year
11			Code		Code		Code			
12										
13										
14										
15										

Total Estimated Remittances in the past year (period from..................to.......................) [ ]

B: ASSETS 1: LAND, LIVESTOCK AND HOUSING

B1.1 CROPLAND OWNED AND OPERATED BY THE HOUSEHOLD

What is the current price to buy rainfed land in this area (Tsh per acre)? [ ]

Shambas and Gardens

Field ID	Area	Ownership	Rent In Land	Rent Out Land	Use of Field	Field Cultivated By
	Area of each field or plot (acres)	1 = owned (idle) 2 = owned (used) 3 = own (rented out) 4 = rented in 5 = borrowed	Amount paid (Tsh)	Amount received (Tsh)	Crop, mixture, idle, fallow, wet season irrigation (WSI), dry season irrigation (DSI), rainfed (RF) **(Transfer crops to D)**	1 = jointly 2 = women 3 = men
A						
B						
C						
D						
E						
F						
G						
H						
I						
J						
Sub-Totals (Rental Tsh)						

Total number of plots (Sum codes 1 – 3 under ownership)	Total area owned	Total area used for farming (including land rented in or borrowed)

B1.2 LIVESTOCK

(All data here refer to the past year up to the date of interview)

Type	Number now	Number year ago	Number born	Number died	Number bought	Number sold	Number gifts in	Number gifts out	Number eaten at home	Current price*
Cattle										
Goats										
Sheep										
Pigs										
Chickens**										
Ducks**										
Others...										

*Adult animal or bird, price that could be obtained by selling now

**Count only adult chicken, ducks or turkeys

Number sold → Enter in Q sold column (section D2.5)

Number eaten at home → Enter in Q consumed column (section D2.5)

B1.3 HOUSEHOLD CONSTRUCTION

Wall construction	Roof construction	Piped water	Drinkable water	Electricity
1 = concrete 2 = brick 3 = wood 4 = mud & wattle	1 = tiled 2 = corrugated iron 3 = asbestos 4 = thatch	1 = Yes 2 = No	1 = Yes 2 = No	1 = Yes 2 = No

C: ASSETS 2: HOUSEHOLD ASSETS, CREDIT AND SAVINGS

C1 SELECTED FARM AND HOUSEHOLD ASSETS

Item	Number owned	Current price (Tsh)*
Hand hoe		
Spade		
Bush knife (panga)		
Wheel barrow		
Ox cart		
Ox plough		
Water container (jerrican)		
Cooking pot (sufuria)		
Bowl		
Bucket		
Hurricane lamp		
Torch		
Bed		
Watch		
Clock		
Radio		
Radio cassette		
Television		
Telephone		
Refrigerator		
Bicycle		
Sewing machine		
Motorbike		
Tractor		
Car or Jeep		
Pickup		
Truck		
Fishing equipment (specify)		
•		
Brick making equipment (specify)		
•		
Others (specify)**		

*If known, current typical purchase price of item from shop or store

**For assets not found on this list cross-out the assets listed but not owned by the household and substitute new assets

C2. SAVINGS AND CREDIT

C2.1 Does anyone in this household belong to any credit group or scheme? (1 = Yes; 2 = No) ☐

C2.2 If yes,

Name	Sex	Name/Type of scheme	Last amount borrowed	Purpose of loan	Interest rate	Loan Repayment Period	Grace period
	1 = Male 2 = Female						

C2.3 Does this scheme also allow for savings? (1 = Yes, 2 = No) ☐

C2.4 If yes, is this regular saving? (1 = Yes; 2 = No) ☐

C2.5 Amount (Tsh):

C2.6 How often? [ ]

C2.7 Aside from the scheme, do any members of the household have savings with a credit organization or bank? (1 = Yes, 2 No) [ ]

C2.8 If yes, estimated total amount of savings at time of interview (optional) (Tsh): [ ]

D1: CROP OUTPUTS AND INCOME

D1.1 Transfer crops from section B1.1. Use the "Month" column to state the harvest month as 1 = January...12 = December. List each harvest separately for crops that had more than one harvest during the past year.

Crop*	Month	Unit	Quantity Consumed		Quantity Sold		Total Produced	Avg price Tsh	Gross Income	Variable costs	Net Total Income	Net Cash Income
			Qty A	% B	Qty C	% D	E = A +C	F	G=E*F	H	I=G-H	J=I*D
TOTALS												

*Separate crop outputs and income as Wet Season Irrigated (WSI), Dry Season Irrigated (DSI) or Rainfed (RF), e.g. WSI-paddy, RF-paddy

Continue on another copy of this section if more room needed

D1.2 Working space for variable inputs (include labour and irrigation water where applies)

Crop	Name of Input	Quantity Used K	Price per Unit L	Cost of Input M = K*L	Total Cost for each Crop (sum of M values)

D2: LIVESTOCK OUTPUTS AND INCOME

D2.1 Milk cattle owned (number) [ ]

D2.2 Total Days Milked (per cow) [ ]

D2.3 Average Daily Milk Yield (litres) [ ]

D2.4 Current price for milk (Tsh/litre) [ ]

D2.5 Other livestock and livestock products

Type	Unit	Quantity Consumed		Quantity Sold		Total Produced	Avg price Tsh	Gross Income	Variable costs	Net Total Income	Net Cash Income
		Qty A	% B	Qty C	% D	E = A +C	F	G=E*F	H	I=G-H	J=I*D
Sub-Total Livestock and livestock products											

D2.6 Working space for variable inputs in livestock enterprises (include labour – mandays)

Activity	Name of Input	Quantity Used K	Price per Unit L	Cost of Input M = K*L	Total Cost for each Crop (sum of M values)

D3: OUTPUTS AND INCOME FROM FISHING

D3.1 Do you, or any member(s) of your household practice fishing? 1 = Yes; 2 = No

D3.2 If yes, where do you fish?

D3.3 How far do you have to walk to the fishing site?

D3.4 How frequent do you fish (per week/month)?

D3.5 Which months do you practice fishing?

D3.6 How do you compare between the catches in this year and last year (1 = decreased; 2 = increased)?

D3.7 What do you think are the reasons for the increase/decrease?

D3.8 Income from fishing (for the last 12 months)

Quantity Consumed*		Quantity Sold*		Total Catches*	Avg price Tsh*	Gross Income	Variable costs	Net Total Income	Net Cash Income
Qty A	% B	Qty C	% D	E = A +C	F	G=E*F	H	I=G-H	J=I*D

*Estimated kilogram

D3.8 Working space for variable inputs in fishery enterprise (including labour – mandays)

Name of Input	Quantity Used K	Price per Unit L	Cost of Input M = K*L	Total Cost for each Crop (sum of M values)

D4: OUTPUTS AND INCOME FROM BRICK MAKING

D4.1 Do you, or any member(s) of your household practice brick making? 1 = No; 2 = Yes.

D4.2 If yes, where do you get water for brick making?

D4.3 How far do you have to walk to the source of water?

D4.4 Which months do you practice brick making?

D4.5 Income from brick making (for the last 12 months)

Quantity used at home		Quantity Sold		Total bricks made	Avg price Tsh	Gross Income	Variable costs	Net Total Income	Net Cash Income
Qty A	% B	Qty C	% D	E = A +C	F	G=E*F	H	I=G-H	J=I*D

D4.6 Working space for variable inputs in brick making (include water and labour)

Name of Input	Quantity Used K	Price per Unit L	Cost of Input M = K*L	Total Cost for each Crop (sum of M values)
Water*				

*Work out the total amount of water used by extrapolating the amount used to make a specific number of bricks as remembered/known by the respondent (can put price of water if purchased)

D5: OUTPUTS AND INCOME FROM USE OF OTHER NATURAL RESOURCES

D5.1 Output and income from other activities involving the use of natural resources+

Activity	Quantity Consumed		Quantity Sold		Total Produced	Avg price Tsh	Gross Income	Variable costs	Net Total Income	Net Cash Income
	Qty A	% B	Qty C	% D	E = A +C	F	G=E*F	H	I=G-H	J=I*D
Sub-Total Other Sources of Income										

+Income-generating activities based on use of natural resources (activities other than the ones covered above, e.g. beer brewing, handcrafts manufacture, pot making, charcoal making, other forest products, etc.)

D5.2 Working space for variable inputs in other sources of income (include labour - mandays)

Activity	Name of Input	Quantity Used K	Price per Unit L	Cost of Input M = K*L	Total Cost for each Crop (sum of M values)

D6: OUTPUTS AND INCOME FROM NON-FARM ACTIVITIES

D6.1 This section relates to wages, salaries, non-natural resources businesses such as trading, shop keeping, bicycle repair etc., pensions and other income sources not listed elsewhere). Each household member who has earned outside income during the past year should be interviewed. For example, if there are more than one HH members who have earned wages, salaries, self-employment incomes (i.e. own-business income), or have received pension payments during the year, then fill in this section of the questionnaire one for each person).

Code	Type of work	Amount Earned Last Month (Tsh)*	Amount Earned Past Year (Tsh)**	Place of Work	Remarks
				1 = Nearby 2 = District 3 = Town (name) 4 = City (name)	
1	Wages – Seasonal				
2	Wages – Regular				
3	Salary – Govt Sector				
4	Salary – Private Sector				
5	Business Income***				
6	Pension Payment				
7	Other Non-Farm****				
YEAR TOTAL (Tsh)					

*Enter earnings for past month. For regular pay this should equal daily pay x number of days worked per month
**Enter earnings for year up to date of interview For regular earnings, this should equal monthly x 12
***Net personal income from business (i e. gross income – costs). Specify the activity/business (e.g. shop keeping) and the number of people employed in the business (how many people do you employ?)
****Examples: property rents other than land, insurance payments etc.

D6.2 Number HH members earning from non-Farm Incomes [ ]

D6.3 Total Non-Farm Income earned by household members (sum of years total for all non-farm earners in the household (Tsh)

[ ]

D7: INCOME FROM LABOURING ON OTHER FARMS

This section is meant for calculation of income from selling labour to other farmers and organizations. Complete one per household member. The information should be based on whole year (last season)

D7.1 Labouring on wet season irrigation

Jobs	Unit (e.g. days, hrs, or piece)	Fee per unit (Tsh) A	Quantity of units in one season B	Total income A x B
Land clearing				
Hoeing				
Nursery/seedlings				
Repair or make vijaruba				
Intake repair *				
Canal clearing*				
Irrigating				
Transplanting				
Weeding				
Applying fertilizer, herbicides, etc.				
Bird scaring				
Harvesting				
Threshing				
Packing				
Drying				
Transporting				
Others (specify)				
Sub-Total of wet season irrigation				

* Paid work, possibly by the village government and/or Water Users' Association

D7.2 Labouring on dry season irrigation

Jobs	Unit (e.g. days, hrs, or piece)	Fee per unit (Tsh) A	Quantity of units in one season B	Total income A x B
Land clearing				
Hoeing				
Nursery/seedlings				
Repair or make vijaruba				
Intake repair *				
Canal clearing*				
Irrigating				
Transplanting				
Weeding				
Applying fertilizer, herbicides, etc.				
Bird scaring				
Harvesting				
Threshing				
Packing				
Drying				
Transporting				
Others (specify)				
Sub-Total of dry season irrigation				

* Paid work, possibly by the village government and/or Water Users' Association

D7.3 Labouring on rain-fed land

Jobs	Unit (e.g. days, hrs, or piece)	Fee per unit (Tsh) A	Quantity of units in one season B	Total income A x B
Land clearing				
Hoeing				
Planting				
Repair or make vijaruba				
Weeding				
Applying fertilizer, herbicides, etc.				
Bird scaring				
Harvesting				
Threshing				
Packing				
Drying				
Transporting				
Others (specify)				
Sub-Total of rain-fed land				

D7.4 Grand Total income from Labouring on other farms (D7.1 + D7.2 + D7.3): Add this value to other seasonal wage box in section D6.1

E: IRRIGATION

E1 Do you practice irrigated agriculture? 1 = Yes; 2 = No

E2 If yes, what is (are) the source(s) of water for irrigation? (Indicate the name of furrow and river/stream/spring that the furrow abstracts/gets water from)

E3 What is the name of village in which the intake is located? (Indicate also the approximate distance from the farm to the intake)

E4 What are the other villages served by this furrow?

E5 When was the furrow built (approx. year)?

E5.1 Who built the furrow?

E5.2 How is the furrow managed (indicate if by a traditional furrow irrigation committee, an officially registered Water User Association/Institution, or by an officially registered irrigation co-operative or a private person)?

E5.3 Does this furrow have an official Statutory Water Right issued by the Water Office? When was Statutory Water Right granted/applied for (if the water right has not yet been granted)?

E5.4 If there is a Statutory Water Right for the furrow, how much water do you have the right to abstract:

1. In the dry season?
2. In the wet season?

E5.5 How is the amount of water measured in the furrow?

E5.6 How is the amount of water abstraction (from the river/source to the furrow) controlled?

E5.7 Do you pay for the water you are abstracting from this furrow? 1=Yes; 2 = No

E5.8 If yes, how much do you pay?

E5.9 How often do you pay (once per month, per year)?

E5.10 What is the money you are paying used for?

E5.11 Has there been any external assistance to make modifications to the furrow e.g. to build concrete intake, to realign furrow, to establish officially registered Water User Association etc. 1=Yes; 2 = No

E5.12 If yes, what interventions were undertaken?

E5.13 When did these interventions take place?

E5.14 Who funded the project?

E5.15 What is the type of the system (to be classified by enumerator)?

Codes:
1=Large-Scale NAFCO irrigation scheme; 2=Traditional smallholder irrigation system (no external interventions), using water from the river; 3= Traditional smallholder irrigation system (no external interventions), using drainage water from a NAFCO farm; 4=Externally modified irrigation system; 5=Large-scale smallholder irrigation scheme (e.g. Kapunga Smallholder Scheme, Madibira); 6=Baluchi Irrigation system, 7=others (specify)

E5.16 List the irrigated crops you cultivated in the last season (during the rainy/dry seasons). (For each crop state also the total area that was irrigated using water from the furrow you have just mentioned):

Crop	Irrigated area (Ha)	State if Dry/Wet season	Qty of crops produced	Notes

E5.17 When do you have surplus water in the furrow/fields?

E5.18 What happens to surplus water in the furrow and in the fields? (Where does it drain to?)

E5.19 When do you stop abstracting water from the river/furrow (if at all)?

E5.20 For other (non-paddy) irrigated crops, how often is each crop irrigated during the wet/dry seasons?

E5.21 For which months is each crop irrigated?

E5.22 Do you plan to increase the area under irrigation? 1=Yes; 2 = No

E5.23 If yes/no, why?

E5.24 Is the furrow used for activities/services other than irrigation? 1 = Yes; 2 = No

E5.25 If yes, what are the other uses?

F: WATER FOR DOMESTIC USES

F1 Where do you get water for your daily domestic uses during the wet seasons?

F2 Where do you get water for your daily domestic uses during the dry seasons?

F3 How much water does your household use per day during the wet season?

F4 How much water does your household use per day during the dry season?

F5 How far do you have to walk to fetch water during the wet season?

F6 How far do you have to walk to fetch water during the dry season? [ ]

F7 Do you pay for water you are using for your domestic needs? 1 = Yes (for both seasons); 2 = No; 3 =Yes (but only during the dry season) [ ]

F8 If yes, how much per container (specify the container)?

Wet season:	Dry season:

F9 Suppose you get a water tap or pedal well installed in your village, how much would you be willing to pay for the service (per a 20 litres container of water)? (Enumerators should continue asking the respondent giving specific choices in the form of a bidding game – increase the amount by 10%, then 5% and continue increasing by 5% till the maximum WTP for the respondent is arrived at. Provide justification for the increase in value – relate this to operation and maintenance costs/service provision). [ ]

G: TRANSFERS, FOOD SECURITY AND COPING STRATEGIES

G1 Physical Transfers and Payment In-Kind (including gifts from relatives e.g. food, clothes, food aid from government, food-for-work etc.)

Description (and units)	How often (times per year)	Amount each time	Total amount	Approx. Value per unit	Approx. Total Value
Approx. Total Value for all Items					

G2 Regular Food Consumption of Household (main staple foods eaten during past week)

3 Main Staple Foods (Last Week)	Number of days	Amount Eaten per Day		Current Price per Unit	Cost of Main Foods	
		Unit (e.g. kg)	Quantity		Per Day (Tsh)	Per Week (Tsh)
Rice						
Maize Flour						
Other						
•						

G3 Food Stocks and Losses

Crop	Date of Last Harvest	Total Stored Last Harvest	Amount in store now	When Store Run Out	Loss In store	Estimated Quantity Lost	% Loss	Main Reason for Loss
	Approx. date	Quantity	Quantity	Approx. date	1 = Yes 2 = No	Amount	Estimate proportion lost	1=rodents 2=insects 3=damp/rot

G4 Response to Shocks (last 3 years - enter here events such as drought, floods, theft of livestock, animal or crop pests or disease: Go to section h for family illness shocks

Event (Describe event)	When Happened	Effects of Event*	Response to Event* (How Did the Household Recover from the Event)
	Date event occurred	E g hunger, crop loss (specify), house damage etc	E g sale of animals to raise cash (give details), HH member migrated for work (details), gift from relatives etc

*Write down accurate details (e.g. 4 cattle died, 1 acre of maize/paddy lost, 5 goats sold to buy food etc.

H: FAMILY HEALTH DETAILS

H1.1 Current illness in the household (i.e. at the time of interview – only for current members aged 15 to 60)

HH Member	Illness Start Date	Symptoms of Illness	Name of Illness	Treatment	Cost of Treatment	Unable to Work	Loss of Income
Name (ID as in section A1.19)	Month & Year	1 = Head 2 = Chest 3 = Stomach 4 = Limbs 5 = Multiple	As Given by Clinic (If attended)	1 = Clinic 2 = Traditional	Estimated Cost so far (Tsh)	Number of Weeks	Estimated Loss so far (Tsh)

H1.2 Economic impact on household

H1.2.1 Use of Savings: 1 = Yes; 2 No [ ]

H1.2.2 Loan taken out: 1 = Yes; 2: No [ ]

H1.2.3 Estimated amount spent (saving used, loans and expenses associated with treatment): [ ]

H1.2.4 Have assets been sold to cover medical costs? 1 = Yes; 2 = No [ ]

H1.2.5 If yes, specify the assets sold e.g. 3 goats (2002), 0.4 acres land (2003)

H1.2.6 Have relatives, friends or community helped you? 1 = Yes; 2 = No [ ]

H1.2.7 If yes, specify type of help e.g. cash, gifts, food and where from (family or community) [ ]

H1.3.1 Past Serious Illness (past 3 years) [Only applies to past illness or different illness experienced by adults aged 15 – 60]

Current or past HH Member	Relation	Duration of Illness	Recovery	Name of Illness	Symptoms of Illness	Treatment	Cost of Treatment
Name (ID as in section A1.19 if still in HH)	Relation to HHH if is no longer in HH	Months	Did this person recover? 1 = Yes 2 = No	As given by Clinic	1=Head 2=Chest 3=Stomach 4=Limbs 5=Multiple	1 = Clinic 2 = Tradit.	Estimated Cost (Tsh)

H1.3.2 Economic impact on household

H1.3.2.1 Use of Savings: 1 = Yes; 2: No [ ]

H1.3.2.2 Loan taken out: 1 = Yes; 2: No [ ]

H1.3.2.3 Estimated amount: [ ]

H1.3.2.4 Have assets been sold to cover medical costs? 1 = Yes; 2 = No [ ]

H1.3.2.5 If yes, specify the assets sold e.g. 3 goats (2002), 0.4 acres land (2003)

H1.3.3 Details of main individuals who care for sick people in the household

Name	Sex: 1 = Male; 2 = Female	Age	Approx. time spent caring (hours per day)

I: EXPENDITURE FOR OTHER GOODS AND SERVICES

I1 Goods and services purchased by the household for the past 12 months (not included elsewhere above)

Item	Quantity purchased K	Price per Unit L	Expenditure M = K*L
Cereals or cereal flour			
Pulses (e.g. beans)			
Fruits			
Vegetables (including tomatoes & onions)			
Milk			
Sugar			
Tea leaves			
Cooking oils			
Salt			
Drinks (e.g. beers and soft drinks)			
Charcoal/firewood			
Fuel/kerosene			
Soap			
Clothes (textiles)			
Furniture (specify: bed, chair, sofa)			
Poles/timber			
Corrugated iron sheets			
Thatch grasses			
Domestic utensils (e.g. bowls, plates, pots)			
Bricks			
School fees			
Development levy			
Taxes			
Village contributions			
House rent			
Electricity			
Others (specify)			
Total Expenditure for Other Goods/Services			

J: LIVELIHOOD DIVERSIFICATION

J1 At present members of this household gain a living by: (the purpose here is to reconfirm the main activities found in the household survey)

1		2		3	

J2 Has this pattern of activity changed over the past five years or so? 1 = Yes; 2 = No

J3 If yes, then what were the main activities for gaining a living five years ago?

1	
2	
3	
4	

J4 Paying attention just to farming activities, does the household have 1 = MORE; 2 = LESS or 3 = SAME farm activities different crops or animal types) than 5 years ago?

J5 Why?

J6 Has the household started "new" farming activities in the past 5 years? 1 = Yes; 2 = No

J7 Why?

J8 Would they like to engage in any specific new farming activity or expand any existing activity? 1 = Yes; 2 = No

J9 If yes, what is preventing this from happening?

J10 Moving now to non-farm activities, does the household rely 1 = MORE; 2 = LESS or 3 = SAME on non-farm activities now than before?

J11 If the household is relying MORE on non-farm activities than before, what are the main reason for this?

J12 If the household is relying FEWER on non-farm activities than before, what are the main reason for this?

J13 Would members of the household prefer to have 1 = MORE; 2 = LESS or 3 = SAME on non-farm activities in the future?

J14 If members of the household would prefer to engage in MORE non-farm activities, what type of activities and what main things that prevent them from doing this?

J15 If members of the household would prefer to engage in LESS non-farm activities, what are the reasons stopping them from specialising more in agriculture?

J16 During the past five years, has the situation of this household been 1 = IMPROVING; 2 = WORSENING; 3 = STAYING THE SAME?

J17 What are the main reasons given by household members for these changes or trends?

J18 During the past ten years, has the amount of land available to the household for agriculture 1 = REDUCED; 2 = STAYED THE SAME; 3 = INCREASED?

J19 If available land has REDUCED or INCREASED, what have been the reasons for these changes?

Appendix 2: Mbarali district: Paddy production trend and contribution to the regional production, 1992/93 - 2001/2002

Year	Mbarali Area Under Paddy (ha)	Mbarali Paddy Production ('000T)	Mbarali Average Paddy Yields (T/ha)	%Change Mbarali (ha)	%Change Mbarali (T)	Regional production ('000T)	Mbarali % of regional (Mbeya) production
1992/93	24,444	46.44	1.9			112	41.5
1993/94	24,900	54.78	2.2	18.0	15.8	119.8	45.7
1994/95	26,777	48.20	1.8	-12.0	-18.2	102.2	47.2
1995/96	36,000	78.00	2.2	61.8	20.4	162.2	48.1
1996/97	35,000	61.25	1.8	-21.5	-19.2	113.9	53.8
1997/98	23,834	78.65	3.3	28.4	88.6	169.2	46.5
1998/99	20,342	30.51	1.5	-61.2	-54.5	175.5	17.4
1999/00	17,600	35.20	2.0	15.4	33.3	189.8	18.5
2000/01	28,800	81.64	2.8	131.9	41.7	211.4	38.6
2001/02	28,400	85.20	3.0	4.4	5.8	NA	NA
Average	26,610	59.99	2.2			150.7	39.7
StDev	5,796	20.03	0.589			39.5	13.03

Source: Mbarali District Agriculture Office and own calculation
StDev = Standard Deviation

Appendix 3: Mbarali district: Average producer prices for paddy (Tsh per kg)

Year	Nominal prices	%C nominal prices	NCPI	NCPI %C	Real prices (base 1994)	Real prices (base 2003)	%C Real prices
1993	72.94	NA	67.8	25.2	97.04	258.95	NA
1994	117.65	61.3	90.2	33.0	117.65	313.95	21.2
1995	117.65	0.0	115.8	28.4	91.64	244.55	-22.1
1996	117.65	0.0	140.1	21.0	75.75	202.13	-17.3
1997	117.65	0.0	162.6	16.1	65.26	174.16	-13.8
1998	109.38	-7.0	183.5	12.9	53.77	143.48	-17.6
1999	159.38	45.7	197.9	7.8	72.64	193.85	35.1
2000	187.5	17.6	209.7	6.0	80.65	215.22	11.0
2001	134.38	-28.3	220.4	5.1	55.00	146.76	-31.8
2002	139.06	3.5	230.5	4.6	54.42	145.21	-1.1
2003	143.74	3.4	240.7	4.4	53.87	143.74	-1.0
Average (1993-2003)	**128.82**				**74.33**	**198.36**	
Average (1994-2003)	**134.40**				**72.06**	**192.30**	

%C = Percentage change; NCPI = National Consumer Price Index;
Real prices = Nominal price ÷ Deflator; Deflator = $NCPI_t \div NCPI_0$

Appendix 4: Production trend for non-paddy crops in Mbarali District, 1989/90 – 2003/2004

CROPS	1989/90		1990/91		1991/92		1992/93		1993/94		TOTAL		AVERAGE		YIELD
	ha	T	ha	T	ha	T	ha	T	ha	T	ha	T	ha	T	TONS/ha
Maize	22700	52210	28000	50400	27700	55400	22888	35798	21300	51120	122588	244928	24517.6	48986	2.00
Sorghum	490	392	565	452	500	400	757	1011	578	1072	2890	3327	578	665	1.20
Finger millet	450	315	440	308	400	240	430	344	397	397	2117	1604	423	321	0.76
Sweet potato	685	6165	700	4900	735	8820	876	4818	556	8891	3552	33594	710.4	6719	9.50
Cassava	700	4900	705	5288	670	6700	617	3394	534	4806	3226	25088	645.2	5018	7.80
Beans	760	608	880	704	800	640	770	61-6	786	786	3996	3354	799.2	671	0.84
Sunflower	1100	990	1000	900	1300	1170	900	810	1200	960	5500	4830	1100	966	0.88
Groundnuts	2885	2019	2700	2430	300	2100	3098	24782	2800	2240	14483	11267	2896.6	2253	0.78
Onions	260	2860	246	1968	326	3260	280	2800	375	3000	1487	13888	297.4	2778	9.40
Tomatoes	200	1800	205	1845	240	2160	304	2432	300	2100	1249	10237	249.8	2067	8.30
Sugarcane.	600	9000	510	10710	505	9090	410	7380	510	7650	2535	43830	507	8766	17.30

CROPS	1994/95		1995/96		1996/97		1997/98		1998/99		TOTAL		AVERAGE		YIELD
	ha	T	ha	T	ha	T	ha	T	ha	T	ha	T	ha	T	TONS/ha
Maize	20454	24544	22346	67035	25665	17223	28771	74805	34984	31486	132220	215093	26444	43019	1.63
Sorghum	680	1100	730	660	800	730	992	1248	3364	4586	6566	8324	1313.2	1665	1.30
Finger millet	470	423	506	500	1000	500	336	336	1900	1843	4212	3602	842.4	720	0.86
Sweet potato	1294	7764	1000	6700	1159	8229	1660	16600	4820	28636	9933	67929	1986	13586	6.84
Cassava	666	3996	701	6300	758	5738	617	6170	1187	6980	3929	29184	785.8	5837	7.43
Beans	906	725	834	800	840	934	5897	5897	6060	4545	14537	12901	2907.4	2580	0.89
Cotton	0	0	0	0	108	221	414	251	248	133	870	605	174	121	0.70
Sunflower	1060	848	780	1400	1707	1366	2300	2070	1729	864	7576	6548	1515.2	1310	0.86
Groundnuts	3200	2240	2940	1470	3000	2100	8364	10037	9200	4740	26704	20587	5340.8	4117	0.77
Onions	305	2135	370	3300	370	2960	400	4000	320	2560	1765	14955	353	2991	8.50

	1994/95		1995/96		1996/97		1997/98		1998/99		TOTAL		AVERAGE		YIELD
	ha	T	ha	T	ha	T	ha	T	ha	T	ha	T	ha	T	TONS/ha
Tomatoes	330	2640	300	3000	280	2240	370	3700	400	2800	1680	14380	336	2878	8.56
Sugarcane.	400	6000	660	13200	600	12000	720	10800	680	10200	3060	52200	612	10440	17.10

	1999/00		2000/01		2001/02		2002/03		2003/04		TOTAL		AVERAGE		YIELD
CROPS	ha	T	ha	T	ha	T	ha	T	ha	T	ha	T	ha	T	TONS/ha
Maize	10000	15000	32500	74750	33000	66000	30000	6110	29500	59000	135000	220860	27000	44172	1.64
Sorghum	1000	10000	5400	7020	9000	7200	7000	196	5700	12180	28100	36596	5620	7319.2	1.30
Finger millet	350	280	1800	2000	1200	840	640	92			3990	3212	997.5	803	0.81
Sweet potato	550	2750	3000	32500	3200	25600	400	1240	3350	30150	10500	92240	2100	18448	8.78
Cassava	1000	6000	2800	29200	2200	15400	1000	2600	2300	23460	9300	76660	1860	15332	8.24
Beans	900	360	6000	5200	11000	8800	10000	450	13400	9380	41300	24190	8260	4838	0.59
Sunflower	90	27	1200	1440	1600	1600	1400	64	850	425	5140	3556	1028	711.2	0.69
Groundnuts	2700	1080	17000	10250	12000	10800	11000	3200	16700	15030	59400	40360	11880	8072	0.68
Onions	340	2720	1500	12000	1700	25500	750	4600	800	8000	5090	52820	1018	10564	10.38
Tomatoes	400	3600	1100	7700	1100	8800	730	6400	720	7200	4050	33700	810	6740	8.32
Sugarcane.	720	14400	2000	40000	1700	11900	880	12300	730	14600	6030	93200	1206	18640	15.46

Appendix 5: Calculation of the Economic Long-Run Marginal Cost (LRMC) used in valuation of water for hydropower generation

The economic long-run marginal cost (LRMC) for the recommended long-run generation and transmission expansion plan was calculated by simulating the relevant plan with a small increment in the energy demand for the reference forecasts scenario and calculating the resulting incremental costs. The results are as follows:

1) Recommended Plan (Plan A) – Full Industrial List Scenario

The marginal cost of energy was calculated by increasing the energy demand in the recommended plan by 8 GWh/yr from 2005 to 2026. Dividing the present value of the incremental energy, the LRMC of energy was calculated to be $ 0.0639/kWh.

The average cost of capacity added over the period from 2005 to 2026 is $ 847.60 kW. Calculating the annual capital charges over the average economic life of 34 years, and taking into account the grid system load factor and the average capacity reserve from the recommended plan, results in LRMC for capacity of 0.0213/kWh.

The total LRMC of generation is, therefore, $ 0.0852/kWh (0.0639 + 0.0213 kWh).

The cost of high-voltage (HV) transmission investment over the same period is 62.6% of generation investment, corresponding to high voltage transmission LRMC of $ 0.0133/kWh (62.6% x 0.0213).

The total economic LRMC of generation and high voltage transmission for the recommended plan, excluding losses, is $ 0.0985/kWh (0.0852 + 0.0133).

Medium– and low-voltage (MV and LV) sub transmission and distribution investment costs were not included in the planning and analysis of this planning study. An indication can be taken from the results of the latest tariff study (1993 by London Economics), where the peak LRMC for Medium– and low–voltage systems was determined to be 29% of the value for generation and high-voltage LRMC (29% x 0.0985) = $ 0.0286/kWh.

Total LRMC for generation, transmission and distribution would then be about $ 0.1271 per kWh, excluding losses.

Economic LRMC by component	$/kWh*	Tsh/kWh (2003 prices)**
Energy	0.0639	67.97
Capacity	0.0213	22.66
HV Transmission	0.0133	14.15
MV and LV Sub transmission and Distribution	0.0286	30.42
Total Economic LRMC	0.1271	135.19

Source: (*) TANESCO (2002). Power System Master Plan, 2001 Update Report, September 2002.

(**) Own conversion

2) Alternative Development Plan (Plan B – Early Mchuchuma – Full Industrial List

This scenario envisages early development of Mchuchuma Power Plant to replace Zambia Import alternative assuming "Full Industrial List Scenario". The ELRMC for this alternative plan was calculated by using the same method used for the recommended plan as described above. The results are summarised below as follows:

Summary Economic LRMC by component	$/kWh*	Tsh/kWh (2003 prices)**
Energy	0.0726	77.22
Capacity	0.0213	22.66
HV Transmission	0.0133	14.15
MV and LV Sub transmission and Distribution	0.0311	33.08
Total Economic LRMC	0.1383	147.10

Source: (*) TANESCO (2002). Power System Master Plan, 2001 Update Report, September 2002.

(**) Own conversion

Appendix 6: Value of water in HEP generation using discharge volumes and treating the Mtera and Kidatu plants as separate systems, July 2002 - June 2003

a) Mtera Hydropower Plant - Treated as a Separate System: values estimated using the electricity LRMC of Tsh 135.19 per kWh

Month	Units	Turbine Discharge	Energy Efficiency	Gross Revenue	Operating Costs	Generating Cost	Net Value
	(kWh)	Mm^3	(kWh/m^3)	(Tsh/m^3)	(Tsh)	(Tsh/kWh)	(Tsh/m^3)
Jul-02	31,246,000.00	133.23	0.23	31.71	67,412,689.00	2.16	29.55
Aug-02	49,826,000.00	212.29	0.23	31.73	78,471,172.00	1.57	30.16
Sep-02	48,195,000.00	205.52	0.23	31.70	71,361,722.00	1.48	30.22
Oct-02	55,828,000.00	237.80	0.23	31.74	67,408,736.00	1.21	30.53
Nov-02	48,322,000.00	206.13	0.23	31.69	75,124,912.00	1.55	30.14
Dec-02	48,339,000.00	206.83	0.23	31.60	89,773,114.00	1.86	29.74
Jan-03	43,451,000.00	184.78	0.24	31.79	66,958,033.00	1.54	30.25
Feb-03	45,136,000.00	193.05	0.23	31.61	65,880,000.00	1.46	30.15
Mar-03	51,291,000.00	218.42	0.23	31.75	70,128,701.00	1.37	30.38
Apr-03	40,014,000.00	171.89	0.23	31.47	64,813,345.00	1.62	29.85
May-03	52,593,000.00	223.89	0.23	31.76	81,763,679.00	1.55	30.20
Jun-03	47,659,000.00	202.88	0.23	31.76	86,272,783.00	1.81	29.95
TOTAL	561,900,000.00	2,396.71	0.23	31.69	885,368,886.00	1.58	30.12

b) Kidatu Hydropower Plant: Treated as a Separate System: values estimated using the electricity LRMC of Tsh 135.19 per kWh

Month	Units	Turbine Discharge	Energy Efficiency	Gross Revenue	Operating Costs	Generating Cost	Net Value
	(kWh)	Mm^3	(kWh/m^3)	(Tsh/m^3)	(Tsh)	(Tsh/kWh)	(Tsh/m^3)
Jul-02	113,839,000.00	267.44	0.43	57.55	108,412,303.00	0.95	56.59
Aug-02	104,745,000.00	246.23	0.43	57.51	90,417,867.00	0.86	56.65
Sep-02	101,519,000.00	238.13	0.43	57.63	102,090,037.00	1.01	56.63
Oct-02	111,527,000.00	261.78	0.43	57.60	95,408,746.00	0.86	56.74
Nov-02	100,210,000.00	233.63	0.43	57.99	98,460,295.00	0.98	57.00
Dec-02	111,334,000.00	262.55	0.42	57.33	93,571,617.00	0.84	56.49
Jan-03	109,142,000.00	258.34	0.42	57.11	109,341,324.00	1.00	56.11
Feb-03	95,183,000.00	223.68	0.43	57.53	93,792,380.00	0.99	56.54
Mar-03	112,232,000.00	264.25	0.42	57.42	100,992,144.00	0.90	56.52
Apr-03	109,131,000.00	256.29	0.43	57.57	94,628,557.00	0.87	56.70
May-03	112,569,000.00	264.37	0.43	57.56	119,725,937.00	1.06	56.50
Jun-03	96,093,000.00	225.14	0.43	57.70	106,443,984.00	1.11	56.59
TOTAL	1,277,524,000.00	3,001.83	0.43	57.53	1,213,285,191.00	0.95	56.58