VALUING WATER RESOURCE FOR BAGA WATERSHED MANAGEMENT USING WATER POVERTY INDEX (WPI), LUSHOTO, TANZANIA

BY

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ABSTRACT

The study to assess and evaluate factors contributing to scarcity of water and compute water poverty index (WPI) for identifying priority areas for interventions in Baga watershed was undertaken in Lushoto district, Tanzania. Specific objectives of this study were to identify and assess factors contributing to scarcity of water, compute WPI for villages and identification of priority areas for interventions in Baga watershed. Data were collected from households through questionnaire survey and PRA tools. Data analysis was done using Statistical Package for Social Science (SPSS). WPI values were calculated using equation developed by Sullivan (2002). The results indicated that, scarcity of water in Baga watershed was contributed by many factors including increased human activities, global warming; and other factors. The other factors were seasonal water variations, gender inequalities in water collection for households, water quality and quantity, sources of domestic water, physical characteristics and distances to water sources. Computed WPI components for Baga watershed were resource (81.9), Use (55.6), access (54.4), capacity (27.7) and environment (10.3). Environment component scored lowest due to effects of low human capacity in water management affecting more the environment component. Additionally, low human capacity contributed also to low score of access component. Priority areas for interventions in Baga watershed were identified to be capacity and access components. It was concluded that increased human activities in watershed, global warming, seasonal water variations, gender inequalities in collecting domestic water, physical land terrains and distances to water sources contributed to scarcity of water in Baga watershed. And that for integrated natural resource management (INRM) in Baga watershed to bring intended results, priorities for interventions should be given to human capacity and access components of WPI. It is recommended that WPI should be studied in other parts of Tanzania to identify priority areas for interventions in water management.

DECLARATION

I, Abel Malyango Masota, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work and has not been nor concurrently being submitted for a higher degree award at any other university.

Abel Malyango Masota Date

(MSc. Candidate)

The above declaration is confirmed

Prof. Y. M. Ngaga Date

(Supervisor)

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DEDICATION

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ABBREVIATIONS AND ACRONYMS

AFRODAD	African Forum and Network on Debt and Development
AHI	African Highlands Initiative
^0C	Celsius degree
DHS	Demographic Health Survey
EPI	Environmental Performance Index
ESRF	Economic and Social Research Foundation
FAO	Food and Agriculture Organization
ha	Hectare
HBS	Household Budget Survey
HDI	Human Development Index
HWSI	Human Water Stress Index
ICRAF	International Centre for Research in Agroforestry
INRM	Integrated Natural Resource Management
km	Kilometer
m	Metre
MDGs	Millennium Development Goals
MNRSA	Master of Science in Management of Natural Resources for Sustainable Agriculture
MNRT	Ministry of Natural Resources and Tourism
NSGPR	National Strategy for Growth and Poverty Reduction
PPP	Purchasing Power Parity
PRA	Participatory Rural Appraisal
PRSP	Poverty Reduction Strategy Paper
SECAP	Soil Erosion Control and Agroforestry Project
SPSS	Statistical Package for Social Sciences
SUA	Sokoine University of Agriculture
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNICEF	United Nations Children’s Fund
UNIDO	United Nations Industrial Development Organization
USA	United States of America
WHO	World Health Organization
WPI	Water Poverty Index
WWF	World Wild Fund for Nature

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Water is an indispensable element of life. Water uses are often grouped into consumptive and non-consumptive uses. The distinction between consumptive and non-consumptive use of water is a critical aspect of effective water management. Consumptive use of water means that no water is returned to the water source from which it was withdrawn; the water is consumed and is not available for use by other water users downstream (UNIDO, 2003). These include municipal, industrial and agricultural water withdrawals. Non-consumptive water use means that, after use, the water is returned to the source for use by others downstream, such as worshipping, recreation (fishing and boating) and use by environment. The use of water increasingly involves complex tradeoffs among biophysical, economic, ecological and societal values. These tradeoffs are due to value of water differing greatly by time, location, quality, quantity and use (Chohin-Kuper *et al.*, 2003).

Globally, freshwater resources are not evenly distributed as there are variations which can be explained in typography, rainfall pattern and climate changes. Due to these variations in water resources, with some few exceptional cases in world, shallow groundwater is the major water source in both rural and urban areas (Liniger, 1995). For instance, shallow aquifers and surface water have predominantly been used for water supply despite their vulnerability to pollution and contamination in most of rural areas in developing countries. This has resulted into prevalence of waterborne diseases (Liniger, 1995; Chabalala and Mamo, 2001).

Variation in water value has led to water being seen by global community as one of the most stressed resources; hence more emphasis put on addressing global water stress and needs of marginalized people, particularly the poor ones. Poverty itself is thought to be due to lack of access to one or more livelihood entitlements/capitals (natural, physical, financial, human and social capitals), water being inclusive (Mlote *et al*., 2002; Sullivan *et al*., 2003)

World statistics show trends of decline in both water quantity and quality. According to IFAD (2007) and Showers (2002) the decline in water qualities has been due to the following factors:

- High turbidity levels and sediments within important basins, such as Lake Victoria, Lake Manyara and Lake Tanganyika in Tanzania;
- Increasing water resources pollution caused mainly by domestic and industrial wastes; and

- Pollution caused by increasing use of chemical fertilizers and toxic substances especially in horticultural crop production for the urban market in Tanzania (URT, 2002b). Water pollution due to iron, arsenic, heavy metals and other dangerous substances pose a threat both to aquatic and human life.

On the other hand, quantitative decline of water has been witnessed through increased distances to water sources, dying of some useful water sources and power rationing in some developing countries, Tanzania inclusive. Attributing factors to this are increased global population coupled with rapid urbanization, expansion for agriculture and land degradation and climate change (Showers, 2002; Paavola, 2003).

The qualitative and quantitative declines of water lead to global scarcity of water which impact more on poor ones because of poor coping strategies used by them (Gleick, 2002; Rosegrant *et al*., 2002; Sullivan *et al*., 2003). Consequences of global scarcity of water are the experienced water use conflicts in different parts of the world. There are many reported water use conflicts between nations. For instance, Gleick (2008) reported conflicts between Israel, Jordan and Syria; Egypt and Sudan; and Ethiopia and Somalia. Bases of these water use conflicts among nations were development disputes, military target and terrorism. Moreover, Kajembe *et al*. (2003) and WWF (2007) found water use conflicts among communities to be:

- Between pastoralists and farmers e.g. in Usangu plains in Tanzania. Main cause of this type of conflict was due to lack of well organized network of livestock routes to water and grazing land. The situation was more intensified during dry seasons of the year when water becomes scarce for farmers to irrigate agricultural crops and for pastoralists to water their livestock;

- Within and between the irrigation schemes because of some farmers abstracting more water to their farms irrespective of their fellows farmers;
- Between livestock keepers and local communities, particularly during dry seasons when livestock keepers take their livestock to domestic water sources;
- Complaints over water consumption of some exotic tree species planted in watershed. Some of exotic tree species which are criticized on over utilization of water include Eucalyptus, Agrocarpus and Black wattle (German, 2004; Wickama *et al*., 2006);
- Between conservationists and encroachers of water sources (WWF, 2007);
- Conflicts between small scale irrigators and large scale irrigators, mainly investors who abstract big volume of water using ‘Water Right’ (WWF, 2007);
- Conflicts between upper stream and lower stream water users. The conflict is built on the basis that upper stream water users abstract much water. According to WWF (2007) this caused serious conflicts and fights in some of villages in the Great Ruaha River Catchment Area.

Mbonile (2005) and Makarius and Machibya (2005) both in Tanzania observed conflicts between hydroelectricity producers and other users. Additionally, Mbonile (2005) noted conflicts between communities and donor agencies, and communities and river basin authorities e.g. in Pangani river basin.

In order to mitigate these water use conflicts and the need for effective water management, Tanzania adopted integrated water resources management approach (IWRM). This strategy was opted mainly to meet the Millennium Development Goals (MDGs) (URT, 2002b; Madulu, 2002; Dungumaro and Madulu, 2003; URT, 2006). Moreover, the needs for monitoring and evaluation that enhance knowledge on interrelationships between water management interventions and their overall impact on poverty have been emphasized (Sullivan, 2002; Sullivan and Meigh, 2003; Hadjer, *et al*., 2005; URT, 2006).

1.2 Problem statement and justification

Global water resource continues to decline in both quantitative and qualitative aspects. While this is true, conventional approaches which involve physical and modeling can only provide us with detailed assessments of water resource availability, but have failed to link their results to knowledge of human resources and their geographical distributions. This is because the answers provided by conventional approaches do not take into account the socio-economic aspects of local communities, hence not sustainable (Mlote *et al*., 2003). Besides that Hadjer *et al*. (2005) noted that in future sustainable solutions to water management would require more interdisciplinary approaches combining hydrological, climatologically, economic and anthropological aspects.

Baga watershed in West Usambara highlands as other water sources in Tanzania and globally, is experiencing water use conflicts caused by scarcity of water (Wickama, 2006).The most contributing factors to scarcity of water are not clearly known. Identification of such factors would be useful in formulating appropriate interventions and monitoring the progress of such interventions in watershed management.

On the other hand, water managers and policy makers are in need of a tool which would enable them to assessing the full range of interventions for understanding economic, social and environmental impacts on a given sector, a location or group of people. All the above named problems can be addressed by Water poverty index (WPI), as suggested by Sullivan (2002).

In addition to that, WPI is site specific and it has not been established for the Baga watershed and associated six villages. This study therefore applies WPI tool in analyzing factors contributing most to scarcity of water in Baga watershed, hence identifying areas of priorities for water management interventions.

1.2.1 Objectives

1.2.1.1 Overall objective

The overall objective of this study is to value water resource for Baga watershed management using Water poverty index (WPI) tool for identification of areas of higher priorities for mitigating water scarcity.

1.2.1.2 Specific objectives

(i) To identify and assess factors contributing to scarcity of water in Baga watershed;

(ii) To compute WPI for selected villages and the overall WPI for Baga watershed /watershed level;

(iii) To identify areas of priorities within Baga watershed for future interventions.

1.3 WPI conceptual framework

The WPI as suggested by Sullivan (2002) comprises five key components (resource, access, use, capacity, and environment) to capture the complication of the water situation of a given location. Each of these five key components consists of several subcomponents. The resource component of WPI combines groundwater and surface water resources, and targets to capture information on the impact of both quantity and quality of water on human livelihoods. Access component includes domestic use, distances to water sources, time needed for collection and access to water for crop production, sanitation and industrial uses.

The use component focuses on the consumption of water for domestic uses in households, livestock and in different productive and non-productive sectors, including industrial and agricultural sectors.

Capacity is used to refer to people's ability to manage water. Capacity in terms of income to invest and purchase improved facilities and water. Generally, capacity component is a collection of indicators of human development of a location/country, such as health, education, investment in the water sector, GDP and water institutional capacity.

The environment component is very complex. It attempts to evaluate the environmental integrity related to water and ecosystem goods and services. It also captures the combination of variables such as biodiversity, environmental degradation, soil erosion, and water quality. Environment component is intended to measure how ecological sustainability can be achieved by maintaining ecological integrity. For the calculation of the WPI of an area/location, the choice of variables may have to be adjusted according to data availability. Thereafter, WPI key components are standardized to range from 0 to 1 and have no units.

1.4 Indices

Indices are widely use by policy makers as a tool for evaluation of achievements on complex issues. Supporters of indices argue that the benefit of an index is its production of a single or a few numbers developed from use of quantitative and qualitative variables (known as proxies) combined together (Mlote *et al*., 2003; Jollands *et al.,* 2003). This makes using indices for decision making relatively simple, straightforward and easy to understand. Indices assist decision-makers by reducing the clutter of too much information, thereby helping to communicate information succinctly and efficiently (Jollands *et al*., 2003).

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Contribution of forestry sector to water and environment

Estimates of 2002 indicated that 33.5 million ha of Tanzania were covered by forests and that out of this; 1.6 million ha were set aside as catchment forests (URT, 1998; Sjaastad *et al*., 2003). These catchment forests are mainly found in Tanga, Arusha, Manyara, Iringa, Kilimanjaro and Arusha regions (Sjaastad *et al*., 2003). Big rivers and some permanent water sources in Tanzania are originating from catchment forests (URT, 2002b). Forests are also found along these small and big rivers. Some of these rivers include Pangani, Wami, Great Ruaha, Kilombero, Rufiji, Ruvu, Ruvuma, Kagera, Mbwemkuru and Matandu rivers (URT, 2002b). Forests stabilize stream flows, thus reducing disasters such as landslides, erosion and floods in areas of steep topography. Forests also supply water for hydropower and irrigation, fish production and other ecological function of forests, including terrestrial carbon sinks (Moutinho & Schwartzman, 2005).

2.2 Water and its distribution

According to URT (2002b), about 70% of the Earth is covered with water and only 2.5% of this water is freshwater. A considerable share of the atmosphere also consists of water, up to 3% in parts of the tropics. Living plants and animals also contain substantial amounts of water (IFAD, 1999). Seventy percent of the freshwater is frozen in ice caps of Greenland, Arctic and Antarctica, or in deep aquifers, or because it is polluted and the remaining 30% of this freshwater is available as soil moisture classified as groundwater and surface water. And one third of fresh water available as soil water is the water found in lakes, rivers, reservoirs and underground water.

Tanzania is endowed with different sources of fresh water ranging from rivers, lakes, wetlands, springs and ground aquifers. Among the major rivers include Rufiji, Pangani, Ruvu, Great Ruaha, Malagarasi, Kagera, Mara, Ruvuma and Ugalla River Basins. The big lakes include Victoria, Nyasa, Tanganyika and Manyara (URT, 2002b; URT, 2006). Baga River in West Usambara highlands is one of the rivers contributing water to Pangani River (Meliyo *et al*., 2006).

2.3. Freshwater uses

2.3.1 Domestic water uses

Water for domestic uses includes drinking water, water for the home (hygiene and cooking, public services (hospitals) and municipal uses. Billig *et al.* (1999) defines per capita water consumption per day as all water collected by or delivered to the household and used there for drinking, cooking, bathing, personal and household hygiene and sanitation by the inhabitants of the household, excluding water used for gardening and watering animals.

Daily per capita water use varies across the globe: 417 litres in North and Central America, 235 litres in South America, 86 litres in Asia and 47 litres and sometimes below this in Africa (Liniger, 1995). For instance, Hadjer *et al*. (2005) in Benin reported 17.2 l/day in normal years and 5.2 litres/ day in dry seasons of the year. These variations are explained to be due to seasonality, size of households, access to resources and differences between urban and rural areas. Some variations in daily per capita water use are also experienced within a continent i.e. between countries within the same continent (Liniger, 1995; Gleick, 1996; Hadjer *et al*., 2005). In Tanzania, per capita water consumption has been found to range from 25 – 30 l in rural areas (URT, 2002b).

Unsafe drinking water coming from contaminated surface water and shallow underground water is still the main causes of diseases and death in developing countries (Liniger, 1995; WHO/UNICEF, 2006). The same literatures report that, surface water is usually unsafe for drinking due to accumulated pollutants. And that, the safest drinking water is either ground water or rainwater obtained through water harvesting methods, such as roof collections. Because this water is consumed by humans, it has to be freshwater of high chemical and biological quality, and should be accessible to areas of human residency (Liniger, 1995; WHO/UNICEF, 2006).

2.3.2 Agricultural water uses

Tanzania has 43 million hectares suitable for agricultural production and only about 6.3 million hectares are under cultivation (Majule and Mwalyosi, 2003). It is also estimated that out of the cultivated land, irrigatable land is only one million hectares, but less than 200 000 hectares are currently under irrigation (URT, 2002b). Crops grown on irrigated land by smallholder farmers include; paddy, maize, beans, sugarcane and vegetables.

From these statistics, Tanzania's agriculture is mainly rainfed and has remained susceptible to drought as well as the inadequate and erratic nature of rainfall. There are some exceptions of irrigation schemes of different scales which are used during dry seasons (ESRF, 1997; URT, 2002b). Some of the irrigation schemes are found in Pangani, Great Ruaha and Rufiji rivers. According to Majule and Mwalyosi (2003) and FAO (2005) irrigation schemes in Tanzania have been classified into four main categories, based on the technology used and the scale or size of the farm, namely:

i) Traditional or smallholder irrigation;

ii) Village irrigation schemes;

iii) Medium to large scale state farms;

iv) Privately owned irrigated estates.

2.3.2.1. Traditional or smallholder irrigation

This is the most important type of irrigation in Tanzania in terms of extent. Farmers use their limited resources as a result individual irrigation schemes cover relatively small areas. It is reported by Majule and Mwalyosi (2003) that about 150 000 hectares in Tanzania could be categorized under this type of irrigation. Examples of traditional irrigation include Vinyungu in Iringa, Majaluba in Shinyanga and Mwanza and Mapata practised in Mtwara and Lindi (Majule and Mwalyosi, 2003; FAO, 2005).

2.3.2.2. Village irrigation schemes

Under this type of irrigation, the government draws plans and constructs the scheme whereas the farmers are responsible for the distribution of water. Cases where farmers managed to organize themselves to dig irrigation canals exist, such as in Nyeregete village in Usangu plain (Majule and Mwalyosi, 2003).

2.3.2.3. Medium to large-scale state farms

In Tanzania this type of irrigation is owned by government wholly or in part. Schemes are designed and constructed by engineers. Distribution of water and general management of these schemes is usually under a government agency, although District or Village Councils administer some. Water is obtained from reservoirs, properly built river diversions or by pumping. Examples of this type of irrigation schemes in Tanzania include Igurusi, Chimala, Kapunga, Kimani and Madibira in Usangu plains (Majule and Mwalyosi, 2003). According to FAO (2005), the performance of this irrigation scheme is inadequate due to:

(i) Increases in population, thus available water not enough for irrigation and other water uses;

(ii) Wear and tear of irrigation infrastructures

(iii) Catchment degradation and other environmental problems such as water logging and salinity.

(iv) Obsolete of irrigation technology.

2.3.2.4. Privately owned irrigated estates

These are formally planned and designed schemes with full irrigation facilities and usually a strong element of management by the government or other external agencies. Those schemes are developed in the regions of Kilimanjaro, Morogoro and Mbeya. All parastatal managed irrigation schemes also fall under this category. Under this type of irrigation, employees work on the farm. Water is obtained from river diversions or bore holes. Some examples include sugar estate at Arusha-Chini, coffee estates in Kilimanjaro, Mbalali rice farm in Mbeya and Kilombero Sugar Company in Morogoro Region (Majule and Mwalyosi, 2003; FAO, 2005).

In Lushoto district, Baga watershed is used by adjacent local communities for irrigating vegetable crops grown in valley bottoms during dry seasons. Valley bottom cultivation was reported by Meliyo *et al.* (2006) to cover 5% of 6006 ha of Baga watershed. In turn this contributed to 80% of the agricultural income for most households in watershed. Irrigation of agricultural crops in valley bottoms and uplands in most cases is associated with the use of pesticides and agrochemicals which contribute to pollution of water sources (URT, 2002; Nyambo *et al*., 2006; WWF, 2007). It is also reported by Heidecke (2006) that contaminations of groundwater sources in Benin were due to high use of fertilizers and pesticides for cotton production.

2.3.3 Industrial water uses at global, regional and national

Industry uses water, as a raw material, for mixing, cooling or plant cleaning/washing as well as for sanitary uses. Globally, industrial water use differs, depending on levels of industrialization. Total industrial water use in the world is about 22%, with high-income countries using 59%, and low-income countries using about 8% (UNIDO, 2003). Thus, industrialized countries have higher industrial water uses as compared to least industrialized nations. From this it can be concluded that all industrialized continents have higher industrial water uses than Africa continent.

Water is used for transportation through seas, oceans and big rivers. For instance, Ganges River in Bangladesh and Congo River in Democratic Republic of Congo (DRC) are used for connecting the respective countries to other parts of the world. Lake Tanganyika and Victoria are used for communication between Tanzania, Zambia, DRC and Burundi; and Tanzania, Kenya and Uganda, respectively (Dugan, 1990; URT, 2002b).

In Tanzania, regions with more manufacturing and processing industries such as Dar es Salaam, Mwanza, Mbeya, Tanga and Arusha have higher industrial water uses than other regions in the country. Other mode of industrial water uses in the country include the famous hydropower schemes of Kihansi, Kidatu, Hale and Mtera which are sources of electricity used in urban and some rural areas. Hydropower schemes in Tanzania contribute to about 69% of the electric energy in the national grid (Makarius and Machibya, 2005).

Water is also used in production and processing industries such as in beverage industries. Some of these beverage industries include Pepsi, Coca-Cola and Tanzania Breweries companies. Other industrial uses of water are in food and chemical industries. Local communities adjacent to water sources make their livelihoods from it through brewing, making bricks, worship, fishing and selling (Moriarty and Butterworth, 2003). Beside of this usefulness of water, some of industrial uses contribute to water use conflicts and to contamination of freshwater through discharges of used water and oil spillages (Liniger, 1995; URT, 2002; Machibya and Makarius, 2005; Mbonile, 2005).

2.3.4 Livestock water use

Liniger (1995) reported poor documentation and recording of water quantity required for livestock, apart from its number and contribution to world economy. Animal water intake levels (Table 1) are subject to large variation related to environmental temperature, humidity, water quality and availability, diet composition and animal performance level (Luke, 1987; Snowdon, 2000).

Table 1: Typical livestock daily water consumption levels (litre)

Animal production stage	Types of animals

	Dairy cattle	Beef cattle
Dry cow	40	35
Lactating	100	55
Yearling heifer	30	30
Feedlot animals	-	50

Source: Snowdon (2000).

In most cases water quality for livestock is poor compared to that for humans. From this, main water sources for livestock are surface water in most pastoral communities in Sub Sahara Africa, which is unsafe due to high contamination. In Tanzania, pastoralists are mainly found in drier parts of the country where in dry seasons water becomes scarcer resulting into moving to areas where grass and water supplies are reliable (URT, 2002b). In turn this has resulted into conflicts between pastoral and agricultural communities in some parts of Tanzania (Kajembe *et al.*, 2003).

2.3.5 Ecological water use

All ecosystems require water to maintain their ecological processes and associated communities of plants and animals. The ecological use of water includes among others, for recreation, flood control and habitats for aquatic biodiversity. Maintaining wide variety of ecosystems necessitates safeguarding water as a resource (URT, 2002b). They carry sediments that help create coastal wetland features such as marshes that provide habitats for many animals and plants. They also renew the supply of oxygen that fish and other aquatic life need to breathe.

2.4 Scarcity of water and indicators for water and development

Water scarcity currently affects many regions of the world. Without a significant reversal of economic and social trends, it will become more acute over time. Although water is considered a renewable resource, in many parts of the world, water resources have become so depleted or contaminated that they are unable to meet ever-increasing demands.

According to IWMI (1998), water scarce areas are defined as those areas of the world that by 2025 will not have sufficient water to maintain their 1990 levels of per capita food production from irrigated agriculture. Water scarce areas will not be able to meet reasonable water needs for domestic, industrial and environmental purposes. Scarcity of water will result into intense competition among different users which will result into political and national implications. UNEP (2005) also observed that by the year 2025, up to 40% of world population could live in water scarce regions.

Efforts to measure scarcity of water on human development have been developed. These include the Human Development Index (HDI), Hydrological Water Stress Index (HWSI) and Water Poverty index (WPI) (Heidecke, 2006). The WPI is discussed more in this study.

2.4.1 Human development index (HDI)

The Human development index (HDI) has become one of the most common indicators to reflect the state of a country’s development. Prior to the HDI, per capita GDP used to be the most common measure of development (UNDP, 2004). The HDI adds several components to a country's development status, such as:

a) A long and healthy life, as measured by life expectancy at birth;

b) Knowledge, as measured by the adult literacy rate (with a two-thirds weight) and the combined primary, secondary and tertiary gross enrolment ratio (with a one-third weight);

c) A decent standard of living, as measured by per capita GDP (US$ PPP).

Each of the indicator components included has minimum and maximum values, which are standardized for the calculation (See Table 2).

Table 2: Computation of the HDI

	Indicator component	Maximum value	Minimum value
1	Life expectancy at birth (years)	85	25
2a	Adult literacy (%)	100	0
2b	Combined gross enrolment ratio (%)	100	0
3	GDP per capita(US$ PPP)	40 000	100

Source: UNDP (2004).

The actual values of the dataset are standardized using the following equation:

$$(X_i - X_{\min})/(X_{\max} - X_{\min}) = X_i^*$$

Where the X_i^* for all three indicators are averaged to derive the HDI.

2.4.2 Hydrological Water Stress Indicator (HWSI)

One of the most frequently referenced indicators of water scarcity definitions stems from a 1989 study by Falkenmark, Lundqvist and Widstrand. HWSI measures water scarcity based on a ratio of population and the total annual natural water supply, or available water, in a country. It is also known as Hydrological Water Stress Indicator (HWSI). The study used estimates of national water availability and population to calculate annual per capita water availability, and ranked water scarcity levels in four categories:

(a) Availability > 1,700m^3/capita/year - water shortage occurs only irregularly or locally;

(b) Availability < 1,700m^3/capita/year - water stress appears regularly;

(c) Availability < 1,000m^3/capita/year - water scarcity is a limitation to economic development and human health and well-being;

(d) Availability < 500m^3/capita/year - water availability is a major constraint to life. (Source: Falkenmark *et al*. 1989)

2.5 Application of WPI to other parts of the world

Since its development in 2002 by Sullivan and tested in Tanzania, South Africa and Sri Lanka, WPI as a policy tool has been tested in different parts of the world. Lawrence *et al.* (2002) applied WPI to measure global scarcity of water. The results showed that Finland performed the best by scoring 78 while Haiti performed the worst by scoring 35. In their study, some of poor countries performed better than some of developed countries, such as Guyana which performed better than USA. Heidecke (2006) applied WPI in monitoring water sector in Benin. The results from that study showed clear distinction between the North and South communes of Benin and that WPI scores were similar for communes with same poverty levels.

2.6 Factors contributing to scarcity of water

2.6.1 Increased human activities in watershed

There are many links between population growth and environmental degradation, in part because an ever-increasing number of people depend on a fixed natural resource base in order to live. Demographic influences are one of many factors that affect water resource management and increase the pressure on global water resource base. Global population growth is impacting negatively on water availability (UNDP, 2004; Rosegrant *et al*., 2005). This comes from the fact that increase in human population leads to increased needs for water supplies, hence water becoming scarcer. Vigiak (2005) reported that population density in West Usambara highlands in which Baga watershed is found ranged from 200 – 400 inhabitants per square kilometer. In addition to that, population increase has forced agriculture to be carried out on marginal lands which include steep hill slopes and encroachment of riverine vegetation. In Baga watershed, EROAHI (2005) reported that cultivation on steep hill slopes coupled with frequent clearing and burning of cleared vegetation have led to soil erosion and degradation of watershed. Furthermore, Hongo and Mjema (2002) and Sosovele and Ngwale (2002) noted that increased human activities within catchment areas contributed to decline and changing river flow patterns in Kagera and Ruaha catchment areas, respectively. In Tanzania, some measures to rescue water sources from increased human activities included evicting encroachers from water sources, such as in Ihefu plain in Mbalali district (WWF, 2007).

2.6.2 Seasonal water variations

Main seasons of the year are the rain and dry seasons. During rain seasons water is plenty in many places of the world while dry seasons, particularly in developing countries are associated with water shortage. Recently, extended dry seasons and droughts have hit many parts the world including among the world's most drought countries of Somalia, Kenya, Chad and Ethiopia (UNDP, 2007).

Matari (2006) explained that rainfall is responsible for floods if in excess and drought when in deficit. In addition to that Matari (2006) and URT (2007) reported that Tanzania has experienced recurring droughts. The most devastating droughts were those of 1983–84 and 1993–94 and trends showed that Tanzania experiences droughts every four years which affect over 3.6 million people. Droughts prone regions in Tanzania are central areas of Dodoma, Singida and some parts of Coast, Shinyanga, Mwanza and Mara.

Matari (2006) in Tanzania also reported that over twenty year period from 1980 to 2000 floods occurred 15 times, killing 54 people and affecting 800 000 people. It is indicated also that flood prone regions in Tanzania are Tanga, Mbeya, Coast, Morogoro, Arusha, Rukwa, Iringa, Kigoma, Kilimanjaro and Lindi (URT, 2007).

2.6.3 Climate change (global warming)

Climate change is an extended change in the average state of the climate or a change in its variability, persisting for decades or longer (Paavola, 2003). Climate change may include temperature increases (global warming), sea-level rises, changes in rainfall patterns and more extreme weather events such as droughts or cyclones (Ehrhart and Twena, 2006; Nyong, 2005). Barnett *et al*. (2004) in their study in USA reported that the most significant impact of global warming would be a large reduction in mountain icepack and reduction in natural water in rivers. In Africa, for instance Zeray *et al*. (2006) found that due to climatic change, Lake Ziway watershed in Ethiopia, runoff was decreasing hence posing a problem of meeting future demands for water for the increasing population of that country. Tanzania like any other country is experiencing effects of climate changes. It is recorded in URT (2006), URT (2007) and Matari (2006) that temperature increase within the country over past 30 years resulted into drop of water levels of lakes such as Lake Rukwa, Tanganyika, Victoria and Jipe; and rivers. Moreover, increased temperatures have been coupled with increased droughts in Tanzania. Other authors (Ehrhart and Twena, 2006) have also shown that freshwater in Tanzania is expected to decrease by over half from 1990 levels by 2025. A decrease in annual flow of Pangani river in which Baga river pours its water is estimated at between 6 -9 percent (Initial National Communication (2003) as cited by Ehrhart and Twena (2006)).

2.6.4 Exotic tree species with adverse ecological effects on water sources

Exotic tree species were introduced in different parts of the world to meet the fast growing demands of forest products, namely timber, poles, valuable non timber products and woodfuel. Generally, exotic trees have potentialities of growing fast and high degree of tolerance to extreme latitude and longitude. However, global complaints over negative ecological effects of exotic tree species on water and soil have been reported by many authors (Poore and Fries, 1985; Saxena, 1994; German, 2004; URT, 2005; Wickama *et al*., 2006). Reasons for condemnation are almost the same globally, that trees such as Eucalyptus consume more water during growth process and conserve soil poorly. In other places, for instance in Lushoto *Agrocarpus* and *Black wattle* are also alleged to cause the same effects as of Eucalyptus (German, 2004). In turn, different interventions to curb ecological effects of such trees have been proposed. For instance, in Tanzania proposed interventions include eliminating such tree species from all watercourses (URT, 2005).

2.6.5 Gender inequality in water collection and management

Women and children particularly in developing countries spend more hours in fetching water (URT, 2002; Rathgeber, 2003; UN, 2004; Dungumaro 2006). An IFAD study in Mozambique observed that women and children were spending 25-131 minutes/day collecting water for their households (IFAD, 1999). **Other findings in Sub Saharan Africa by Malmberg-Calvo (1994) observed that w**omen and girls spend more time fetching water compared to men and boys. The study cited above reported that women spent more than 700 hours a year fetching water in Ghana, 500 hours in Tanzania and 200 hours in Zambia (Figure **1). These hours and energy spent by women in collecting and managing water for household uses increase burden to women. Also, it is likely that water for domestic use can be considered scarce but the contributed factor is the work load carried out by women, hence being unable to collect enough water to meet families' requirements.**

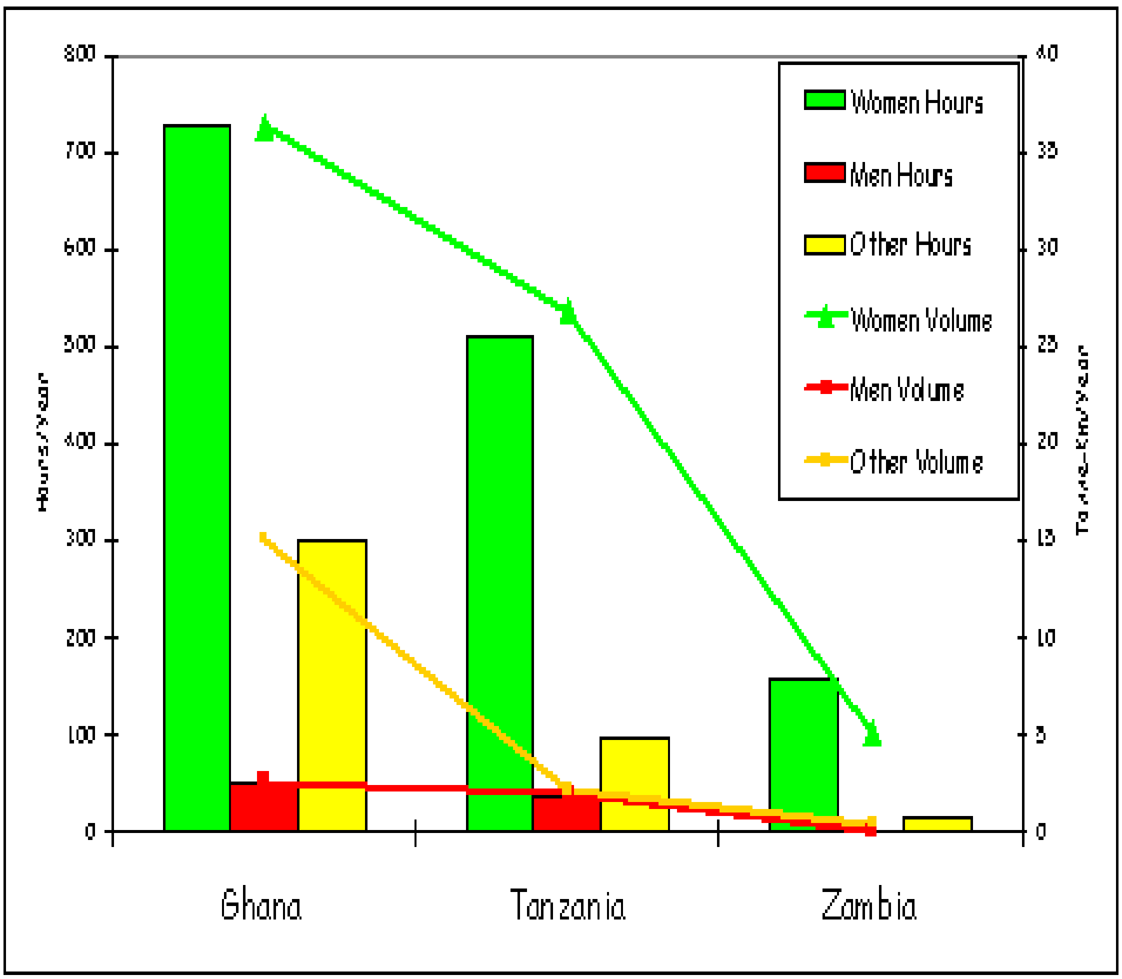

Figure 1: Gender differences in time spending and volume of water collected per kilometer per year in 3 African countries.

Source: Malmberg-Calvo (1994).

Walking time to water sources, mostly in rural areas increases with seasonal water variations, such that both distance and time increase in dry seasons of the year when water is scarce. It is also recorded by URT (2006) that women are main water collectors but very few participate in decision making on water related matters. The contributing factors to this inequality include the more workload for women at household level as compared to men. To demonstrate this, Mlote *et al.* (2003) found that 73% and 68% of domestic water is collected by women in South Africa and Tanzania respectively. Also, because the women are the main water collectors in households, women hardly vandalize water sources because the cost incurred to ensure that there is water for family uses is born by them, hence women playing a vital role in protecting water and water resources (Dungumaro, 2006).

2.6.6 Distance to water sources

Costs of water for domestic use increase with increase in distance to sources. Thompson *et al*. (2001) observed that costs of domestic water in urban areas in East Africa were higher for households without piped water supplies as compared to households with piped water supplies. The higher cost was in terms of sources used, collection time, distances and energy requirements to obtain domestic water. In addition Mlote *et al*.

(2003) found that scarcity of water during dry seasons was associated with increase of distance and difficult terrains to water sources. The distance of 400 m to water sources was found be not a hindering factor to development in Tanzania (URT, 2002b). Long distances to sources of domestic water in rural areas impose heavy workload on women and children. The challenge in Tanzania to water provision remains on how to improve equitable access especially in rural areas (URT, 2003; URT, 2005).

2.6.7 Water quantity and quality

Water quality particularly for domestic use matters. Mlote *at al*. (2003) observed that high amount of fluoride in water; in some areas in Arusha was a contributing factor to scarcity of water by making water chemically unsuitable for domestic uses, as result local communities had to walk long distances to other water sources. Surface water is reported to be of low quality for human consumption, due to accumulation of waste materials and suspended matters coming with water from different areas (Liniger, 1995; WHO/UNICEF, 2006). Also, water quality is lowered more during floods (URT, 2006). Underground water and rainwater obtained through roof collection are thus safer for human consumption.

Scarcity of water for various uses, particularly in semi arid areas of Tanzania is noted more to be in quantitative aspects and this becomes more serious during dry and drought seasons (URT, 2002b; Matari, 2006).

2.6.8 Inadequate human capacity

Human capacity in planning and implementing sustainable development projects at both local and district levels in Tanzania is low, and inadequate (Economic Research Bureau, 2001). The low parameters of human capacity are of human resource, finance, institutional framework, governance and infrastructure. Moreover, URT (2006) and AFRODAD (2006) observed that the country's capacity in supplying safe and clean water to urban communities leaving aside rural communities was low, hence remaining a challenge towards achieving Millennium Development Goals (MDGs). Indications of water scarcity appear not only from pure physical measures of water availability or the lack thereof, but also due to technical and institutional capacity for water governance. Further more, UNEP (2005) identified that water resource management in developing countries are characterized by inadequate technical capacity to treat industrial wastewater and sewage effluents; inadequate financial capacity to invest in water supply and wastewater infrastructure; and inadequate administrative and institutional capacity for effective water governance.

2.7 The concept of poverty and water poverty

Poverty has been defined differently by various authors. For instance, Mwisomba and Kiilu (2002) defined poverty as a condition of living below a certain minimum standard of welfare. Desai (1995) defined poverty as capability deprivation. Capability deprivation to access different livelihood capitals (natural capital, physical capital, financial capital, human capital and social capital); of which water is inclusive (Mlote *et al*., 2002; Sullivan *et al.*, 2003). There are strong links between poverty, the environment and the country's natural resources. The natural resources provide main sources of peoples' livelihoods and play an important role in some key economic sectors, including agriculture, tourism and mining.

Income poverty is mainly measured using two lines, namely, food poverty line and basic needs poverty line. Basic needs poverty line cover, in addition to such food requirements, other essential needs, such as clothing, housing, water, and health (also known as non-food requirements) (URT, 2002c). According to URT (2002c), 36% of Tanzania's rural population was living below basic needs poverty line. Also, literacy rate varies between rural and urban settings. For instance, URT (2002a) reported adult illiteracy rate of 30% of urban Tanzania's population while the illiteracy rate of adult population was at 37% in Tanzania's rural areas. Besides that URT (2005) observed that by 2003, only 53% of Tanzania's rural population was accessing clean and safe water. However, URT (2002c) reports that over half of rural households continued to depend on unsafe water sources.

The woodfuel consumption estimates show that more than 90% of energy used in Tanzania is based on biomass, and most of this comes from forests and woodlands estimated at about 33.5 million ha (URT, 1998). Out of this woodfuel consumption, rural population accounts 85% (Mutunda, 2007). The proportion of land covered by forest in Tanzania by 1990 was estimated at 46% but by 2005 only 37.5% was observed (URT 2006). This decline in forest cover is mainly contributed by harvesting woodfuel, agricultural expansion, and frequent annual wildfires. This continued dependency on woodfuel as source of energy remains a challenge towards poverty alleviation in Tanzania.

CHAPTER THREE

3.0. MATERIALS AND METHODS

3.1 Description of the study area

3.1.1 Geographical location

Baga watershed is found in Lushoto district in the West Usambara Mountains of Tanzania .Lushoto district lies between latitude 4^0 22’ and 5^0 08’ and between longitude 38^0 5’ and 38^0 38’ (Bonifasi, 2004; EROAHI, 2005). Baga watershed is located about 20 – 30 km East of Lushoto town. Altitudes range from 1100 – 1300 meter above sea level (m.a.s.l).

Baga watershed which comprised six villages, namely Mbelei, Kwalei, Kwekitui, Kwadoe, Kwehangala and Dule was selected for this study. The selection of Baga watershed was purposively done due to water use conflicts reported in Wickama (2006), raising from scarcity of water for a number of reasons, including increased human population and human activities, seasonal water variability both in quantity and quality, and physical characteristics of the study area.

Baga watershed is found in Soni and Bumbuli divisions in Lushoto district. However, the main part of Baga watershed is found in Mamba and Bumbuli wards in Soni and Bumbuli divisions respectively. Mamba ward covers four villages namely Mbelei, Kwalei, Kwekitui and Kwadoe, while only Dule and Kwehangala villages in Bumbuli ward are part of Baga watershed.

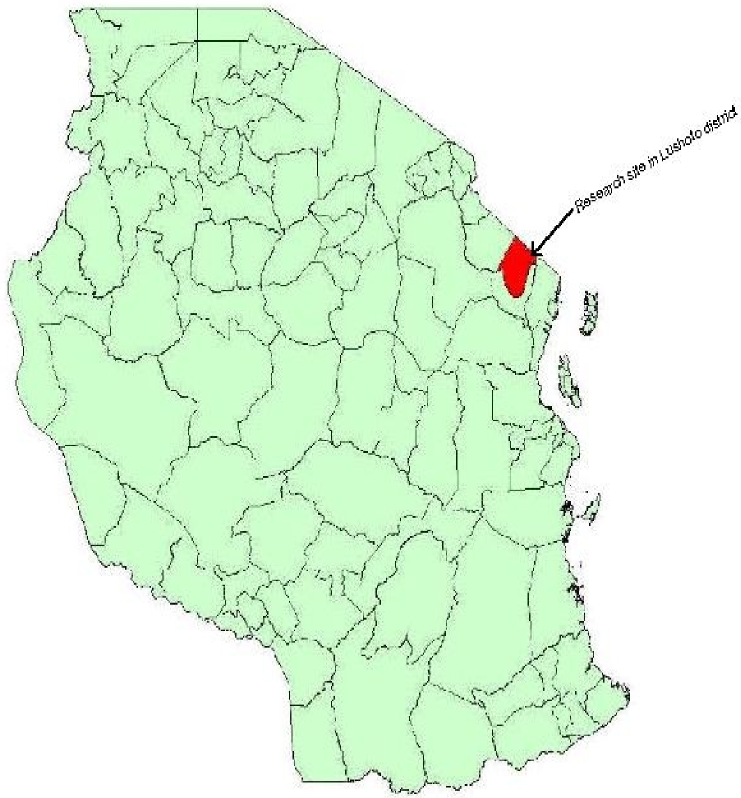

Figure 2: Map of Tanzania showing research site in Lushoto district

3.1.2 Climate, topography and soils

Baga watershed is characterized mainly by humid-warm type of climate. The area experiences bimodal type of rainfall. The long rain period occurs between March and May while short rain occurs between October and December. The mean annual rainfall ranges between 800 – 1700 mm. The annual temperatures vary with altitude. At 500 m.a.s.l., the temperature ranges from 25 – 27 ^{0}C while between altitudes 1500 – 1800 m.a.s.l the temperatures are from 16 – 18 ^{0}C. The period between the months of June to early September marks the coldest period of the year with temperature of 15 – 20 ^{0}C that occasionally drops to 3 ^{0}C (Bonifasi, 2004; EROAHI, 2005).

The soil types that are found in Baga watershed are explained to be mainly highly weathered and leached soils, humic and ferralitic predominantly acidic with pH range of 3.5 – 5.5 and poor in nutrient contents (Bonifasi, 2004; EROAHI, 2005; Wickama *et al*., 2006). This has influenced agricultural production in West Usambara Highlands where the use of organic and inorganic manures for improving soil fertility is more common.

Vigiak (2005) explained the topographic variation in West Usambara highlands in which Baga watershed is found as extreme, with V-shaped valleys and slopes sometimes more than 20%.

3.1.3 Demographic features

According to the URT (2002a), the population in West Usambara highlands was growing at rate of 2.8%. Also this census showed that Baga watershed had a population of 14 138 people in its six villages as shown in Table 3.

Table 3: Population of Baga watershed

Village name	Number of	Male	Females	Total

	households			
Mbelei	573	1 111	1 214	2 325
Kwekitui	574	1 414	1 178	2 592
Kwadoe	567	1 117	1 377	2 494
Kwalei	554	1 293	1 434	2 727
Kwehangala	529	1 169	1 434	2 603
Dule	320	659	738	1 397
Total	3 117	6 763	7 375	14 138

Source: URT (2002a).

3.1.4 Socio-economic activities

The predominant tribe is Sambaa constituting about 80% of total population, followed by the Pare 14%, Mbugu 5% while other tribes are about 1% (Wickama *et al.,* 2006). Local communities in Baga watershed are mainly involved in agriculture. Most of the agricultural activities are on steep slopes and in valley bottoms where irrigation for horticultural crops is possible. Cash crops grown in the area are coffee, banana, fruit trees (temperate fruits) and tea. Other crops grown in the area include vegetable crops, beans, potatoes, cassava and maize. Vegetable crops are grown in valley bottoms during the dry seasons, through irrigation using water from Baga River.

Tree planting is also carried out by local communities for domestic and commercial purposes, such as for woodfuel, building poles, timber and as sources of income. Both exotic and indigenous trees species are planted. Some of the tree species grown in the area are *Gravellia robusta*, *Mshai***,** *Black wattle*, *Agrocarpus*, *Ficus* spp, *Eucalyptus* and *Pinus patula*

Indoor and outdoor livestock keeping (cattle, goats, sheep and local chicken) is also carried out mainly as sources of meat, income and farm yard manures. Petty businesses of agricultural related produces and other commodities are also carried by local communities. There are few members of local community who are employed in government sectors such as teachers, medical, agricultural extension and community development staff and private sector, particularly the Sakarani Roman Catholic Missionaries and Herkulu Tea Estate and factory (Meliyo *et al*., 2004).

3.2 Data collection

3.2.1 Primary data collection

3.2.1.1 Reconnaissance survey

Reconnaissance survey was conducted so as to provide a general picture of the research area. This aimed at identification of study site, sample size and testing questionnaires to find out whether the required information was captured. Where necessary the questionnaires were modified so as to capture missing information.

3.2.1.2. PRA tools

Participatory rural appraisal (PRA) tools were used in this study. The PRA tools which were used included resource mapping, seasonal calendar; Venn diagram, scoring and ranking.

3.2.1.2.1 Resource mapping

This technique was used in mapping water sources for various uses in the study area. In addition to that it was also used in establishing relative locations of social, health and natural resources used by local communities such as sources of timber and other forest products.

3.2.1.2.2 Seasonal calendar

Seasonal calendar was used to trace seasonal variations of natural resources by using knowledgeable members from Baga watershed.

3.2.1.2.3 Venn diagram

Venn diagram was used in studying and establishing relationships and relative importance of various institutions involved in water management.

3.2.1.2.4 Scoring and ranking

Scoring and ranking tool was used to identify user groups' patterns using people's perception and preferences through the use of matrices and objects such as stones.

3.2.3 Sampling procedures

The households included in this study from each village were selected from village registry. From households list of each village a sample of about 5% was selected. The sampling units (households) were selected from all sub villages and randomly located. In total the sample consisted of 166 respondents. The sample was distributed in the study villages as shown in Table 4.

Table 4: The distribution of selected households in the study area

Village name	Number of households	Sampled households	% of sampling
Mbelei	573	32	5.6
Kwekitui	574	33	5.7
Kwadoe	567	27	5.0
Kwalei	554	30	5.4
Kwehangala	529	26	5.0
Dule	320	18	5.6
Total	3 117	166	5.3

3.2.1.3 Questionnaire survey

Primary data was collected from randomly selected household heads from the subvillages in all the six villages in Baga watershed. The data collected through questionnaires were on general demographic features, water resource, use, access, capacity and environment. This included among others biophysical features such as land terrain, water sources, distances and times spent to water sources in rain and dry seasons, water inadequacy, numbers of households served by the same source of water, and number of livestock kept. In addition, information on the presence of laws and conditions on water sources and water uses, water quality and quantity, investments made in water, frequency of waterborne diseases, amount of water used for domestic uses, ownerships of water sources, experienced environmental problems and associated losses were collected. Appendix I is the questionnaire which was used during this study.

Data for the five components of Water poverty index (WPI) namely, Resource, Access, Use, Capacity and Environment was collected during questionnaire survey by the use of subcomponents/variables shown in Table 5.

Table 5: WPI component variables for Baga watershed, Lushoto district

WPI component	Subcomponent /variables used
Resource (R)	▪ Qualitative assessment of water quality
Access (A)	▪ Access to clean water as percentage of households having or using water from piped water supply ▪ % of domestic water carried by women. ▪ % of households reporting illness due to waterborne diseases ▪ Time spent in water collection including waiting (minutes). ▪ Distances of households to affordable water sources (m)

Capacity (C)	▪ % of households below basic needs poverty line of 262 Tshs per adult equivalent per day ▪ Education level (adult illiteracy rate expressed as proportion of households with no formal education to households with formal education
Use (U)	▪ Domestic water consumption. ▪ Agricultural water use, expressed as proportion of irrigated land to total cultivated land
Environment (E)	▪ % of households reporting crop losses due environmental degradation: floods and droughts. ▪ % of households reporting soil erosion on their land

3.2.1.4 Discussions with key informants

A key informant is defined as an individual who is accessible, willing to talk and knowledgeable about issues in question. Key informants are not only members of the clientele, but also informed outsiders (Mettrick, 1993) cited by (Katani, 1999)**.** Information collected from key informants was guided by use of checklists (Appendix II). Key informants during this study were village leaders, members of village formal/informal water institutions, members of village natural resource committees, District Forest Officer (DFO), Ward Medical officer, Ward Community Development officer, District Water Officer, District Agricultural & Livestock Development Officer and staff of African Highlands Initiative (AHI) Benchmark Lushoto office.

3.2.1.5 Participant observation

The researcher became part of the society of study by involved in data collection such that he could compare what was told by local communities and the reality. On top of that, this enabled the researcher to collect data /information which local communities would not say openly to the researcher.

3.2.2 Secondary data collection

Secondary data was collected from various pertinent documents. Sources of information ranged from the six study village offices, AHI benchmark site office at Lushoto, Government of Tanzania reports, United Nations (UN) reports and publications, journals and books. Data was also collected from Research on Poverty Alleviation (REPOA) reports and Sokoine University of Agriculture (SUA). Moreover, other source of information was through internet search.

For the resource component of WPI, qualitative assessment of water quality was done and the qualitative data generated from the analysis of questionnaires was used as a subcomponent variable.

Water consumption per capita per day differs from rural and urban settings (Liniger, 1995; Gleick, 1996; Hadjer *et al.*, 2005). For the purpose of this study data from URT (2002b) on water consumption of 30 litres per capita per day was used. For agricultural water use, the proportion of irrigated land to total cultivated land was used. The two variables were assumed to have positive effects on the WPI, in that an increase in water use was likely to have a positive impact on human wellbeing.

For capacity component, evaluation was made by using indicators from URT (2002c). And for environment component, data on percent of households who experienced losses of crops due to environmental degradation (floods and drought) and percent of households reporting soil erosion on their land were incorporated into the WPI. Soil erosion data was evaluated against data from EROAHI (2005). The reciprocal of the standardized value for environment component was used, as the higher the losses of crops and amount of soil erosion, the more the environmental impact (Sullivan et *al*., 2003; Heidecke, 2006).

3.3 Data analysis

3.3.1 Descriptive statistical data analysis

In this study data collected through questionnaires was analyzed using the Statistical Package for Social Sciences (SPSS) computer programme. Descriptive statistics of frequencies and percentages were used in analyzing factors contributing to scarcity of water in Baga watershed.

3.3.2 Data analysis for components of WPI

Quantitative information on the groundwater at community level was lacking. As a result qualitative data which was obtained from analysis of questionnaire during this study were used for groundwater instead. The results were evaluated against the Environmental Performance Index (EPI) by Esty *et al*. (2008). Due to lack of already established values for evaluating percentage of domestic water carried by women and agricultural water use, these subcomponents were not included in computation of WPI, but were only discussed to stimulate further dialogue among development stakeholders. Other WPI components where shown, were evaluated against values shown in Table 6. The various components of the WPI were standardized ranging from 0 to 1. Each sub-component was scaled as an index itself, based on the range of values on each variable in that location. The subcomponents of various WPI aspects were then added and multiplied by 100, and their sum divided by the weight applied to the component as shown in equation below developed by Sullivan (2002). The resulting WPI is unitless.

$$WPI = \sum_{i=1}^{N} wiXi \Big/ \sum_{i=1}^{N} wi$$

Where: WPI = Water Poverty Index value for a particular location,

Xi = Key component i of the WPI structure for that location (i .e Xi = Resources, Access, Use, Capacity and Environment)

wi = Weight applied to component i, assumed to be constant with a value of = 1.

Table 6: Variables for indicator components of WPI for Baga watershed

Component	Subcomponents	Indicator value	Source of data
Resource	1. Quality of water for domestic uses	100%	Esty et al. (2008)
Access	2. Access to clean water as percentage of households having or using waters supply from piped water supply	53	URT (2006) URT (2005)
	3. Time spent in water collection including waiting (minutes)	30	URT (2005)
	4. % of households reporting illness due to waterborne	100	Esty *et al.* (2008)

	diseases		
	5. Distances of households to affordable water sources	400 m	URT (2002b)
Capacity	6. % of households below basic needs poverty line of 262 Tshs per adult equivalent /day in rural areas	36	URT (2002c); URT (2006)
	7.Illiteracy rate in rural Tanzania	37	URT (2003) URT (2005) URT (2006)
Use	8. Domestic water consumption	30 l	URT (2002b)
	9. Agricultural water use	Varies	
Environment	10. % of crop loss from droughts and floods	33	Paavola (2003) URT (2006)
	11. % of soil erosion on land	40	EROAHI (2005)

3.4 Limitation of the study

3.4.1 Problem of recalling data

Some respondents could not properly recall data for dry seasons of the year; as a result more time was spent during questionnaire administration so as to enable the respondents to recall valuable data for the purpose of this study. However, scarcity of water in the study area was found to be during dry seasons, hence only data for dry season was considered, except where stated.

3.4.2 Physical characteristics

Baga watershed and Lushoto district in general are found in West Usambara highlands characterized by steep slopes and difficult terrains. In addition, very few areas in the study area could be reached by other means of transport except on foot. This posed problems during questionnaire administration by affecting number of respondents who could be interviewed in a day. This was resolved by extending working hours up to evening.

3.4.3 Data availability

Data availability at village levels was fairly poor. For the calculation of the WPI, as presented in this work, data were highly aggregated from different sources/ administration levels including district, national and international levels so as to approximate the situation at the village level.

3.4.4 Unwillingness to disclose sources of income /annual incomes

Respondents interviewed during this study were not open in telling their annual incomes; as a result monthly expenditures for each household were used to establish average annual incomes. Some of respondents were suspicious that income data was collected for taxation purposes. This problem was also solved by further clarifications on the purpose of the study

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

This chapter presents results and discussion on the factors contributing to scarcity of water, Water poverty index (WPI) and identification of areas of high priorities for intervention in Baga watershed.

The chapter discusses household characteristics, increased human activities within water sources including planting exotic tree species with adverse ecological effects, climate changes (global warming) and other factors which are contributing to scarcity of water in Baga watershed. Furthermore, among other factors contributing to scarcity of water in

Baga watershed which are discussed in this chapter include seasonal variations, gender inequality in collecting domestic water in households, sources of domestic water, physical features and distances to water sources. Moreover, results of computed WPI for respective villages and watershed level are discussed.

4.1 Household characteristics for villages

Household characteristics for villages in Baga watershed are presented in Table 7. Average household size in Baga watershed ranged between 5.8 and 6.2. Kwehangala village had a lower average household size (5.8) as compared to other villages in Baga watershed which all had an average household size above this. The deviations between URT (2002a) for Lushoto district average household size of 5.8 and what is observed in this study probably could be due to population growth in study area. Therefore, population growth in Baga watershed villages contributed to water scarcity (Table 7).

Table 7: Village household characteristics in Baga watershed, Lushoto district

Village name	Mbelei	Kwekitui	Kwadoe	Kwalei	Kwehangala	Dule
Average household size	5.9	6.2	6.2	5.9	5.8	6.1
% of households below basic needs poverty line of Tshs 262 Tshs per adult equivalent per day	72.7	61.1	86.7	68.4	66.7	54.5

Illiteracy level (%)	12.2	24.2	33.3	16.7	19.2	16.7

Another important household characteristic in this study is basic needs poverty. The basic needs poverty incidence in Baga watershed ranged from 54.5 and 86.7% (Table 7). Dule village had the lowest poverty incidence (54.5%) while Kwadoe village had the highest poverty incidence (86.7%). Generally, villages in Baga watershed were below the income poverty indicator of 36% in Tanzania's rural (URT, 2002c; URT, 2006). This implies that majority of local communities in Baga watershed were poorer. The reasons for higher income poverty in Baga watershed could be explained by lower prices of cash crops such as coffee and tea, because the main economic activity for inhabitants of Baga watershed is agricultural, and lack of affordable alternative income generating activities, which could be done by majority rural people in West Usambara highlands. URT (2006) supports this argument by reporting low agricultural prices as constraints to poverty alleviation in rural Tanzania. This resulted into low financial investments in water resources management for provision of clean and safe water.

Literacy level of interviewed household heads was analysed for each village and results showed that illiteracy rate in Baga watershed ranged from 12.2 and 33.3% (Table 7). Mbelei village had the lowest illiteracy rate (12.2%) while Kwadoe had the highest illiteracy rate (33.3%) in Baga watershed. Low illiteracy level in Mbelei village can be explained by the presence of Sakarani Roman Missionaries which was established in 1940s, and since then involved in educating Mbelei's local communities (Wickama *et al*., 2006). The highest illiteracy rate in Kwadoe village could be contributed by difficult accessibility either by road or on foot, because of land steepness and scattered households, far away from social services, such as schools. However, villages in Baga watershed were all above Tanzania's rural adult illiteracy indicator of 37%. This implies that adults in Baga watershed were less illiterate. The deviation between the two datasets can be explained by level of aggregation of data at national level. Levels of illiteracy being indicator of poverty contributed to water scarcity as local communities lacked improved knowledge of water management.

4.2 Factors contributing to scarcity of water in Baga watershed

Responses of respondents on factors contributing to scarcity of water in Baga watershed are shown in Table 8.

Table 8: Responses on factors contributing to scarcity of water in Baga watershed, Lushoto district

Factors	Number of respondents	Percent
Increased human activities in watershed	125	75.3
Increased climate changes (global warming)	4	2.4
Other factors	37	22.3
Total	166	100.0

4.2.1 Increased human activities in Baga watershed

According to the respondents interviewed in this study, about 75% reported increased human activities in Baga watershed. as a major contributing factor to scarcity of water

(Table 8). Some of these human activities included agriculture and planting exotic trees species with adverse ecological effects on water sources. Increased human activities in Baga watershed are attributed to many factors. For instance, good climate conditions for agriculture and human lives that are found in the West Usambara highlands can be one of the reasons for increase in human activities within the Baga watershed. It is reported by Meliyo *et al.* (2004) that 80% of agricultural income generated by local communities living adjacent to Baga watershed is through vegetable growing in valley bottoms during dry seasons of the year.

In order to establish the extent of increased human activities in Baga watershed, particularly through agriculture, respondents were asked to indicate distances of agricultural lands from water sources. About 30% of respondents interviewed reported distances of between 0 and 1 m, about 42% reported between 2 m and 60 m, and the remaining 28% estimated distances of more than 60 m from water sources (Table 9). Distances between 0 and 1 m from water sources are more found in valley bottoms where vegetable crops are grown in dry seasons. In valley bottoms some farmers tend to maximize agricultural land by encroaching river banks and not respecting set rules and regulations. Encroachment of water sources through agriculture and other land use activities leads to clearing vegetation in and along rivers hence exposing water sources to direct sunlight, resulting into loss of water and dying of some water sources.

Table 9: Responses on distances of agricultural lands from water sources in Baga watershed, Lushoto district

Classes of distances of agricultural land from water sources (m)	Number of respondents	Percent
0 to 1	49	29.5
2 to 15	40	24.1
16 to 30	13	7.8
31 to 40	4	2.4
41 to 60	13	7.8
Above 61	47	28.3
Total	166	100.0

The use of fertilizers and other agrochemicals by valley bottom cultivators was blamed by domestic water users and environmentalists as a cause for environmental contamination. Some local communities were uncertain of what would happen in future to their health because of the increased use of such chemicals in agriculture, particularly in valley bottoms where sources of domestic water were found. Their worries were supported by WWF (2007) in Iringa and Mbeya regions which reported contamination of water sources by valley bottom cultivators in Great Ruaha Catchment Area through use of chemical fertilizers and spraying insecticides and pesticides.

According to 2002 population census, Lushoto district had a population growth rate of 2.8% (URT, 2002a). Population growth leads to increased demand for natural resource use (land and water). More people will need more timber for building houses, cooking and for income generation. It is also true for demand for land, as more people will need more land for agriculture, building houses and other developments (schools, roads and dispensaries). Due to increased population and scarcity of agricultural land in West Usambara highlands, people have opted to cultivate hill steep slopes which in the past remained intact. Hill steep slopes remained uncleared to protect land from soil erosion. Generally, poor agricultural practices coupled with slash and burn in West Usambara highlands, left the soil exposed, therefore increasing vulnerability of soil to erosion. Soil erosion leads to siltation of many rivers and dams. These in turn have impact on water ecosystem, hence leading to decline in water flow in rivers and sometimes drying of some water sources during dry season. Sosovele and Ngwale (2002) and Hongo and Mjema (2002) both in Tanzania reported increased human activities as one of the root causes of drying and changing flow patterns in Ruaha catchment and Kagera Rivers respectively.

According to Scoones (1998), migration is one of rural livelihood strategies. Migration of labourers to tea and coffee estates in West Usambara highlands and its agricultural potentiality might have contributed to increased population and degradation natural resources, water sources inclusive (Vigiak, 2005; EROAHI, 2005). This explanation is based on the fact that, some of these labourers were normally laid off at the end of production seasons. In order to make their living, some hired plots of land in valley bottoms for growing vegetable crops, some became labourers in vegetable gardens and or they got involved legally or illegally in harvesting natural resources such as tree felling for charcoal, building poles and firewood. Generally, when doing this majority of them did not respect or obey existing regulations on natural resource uses, water inclusive.

Tree planting is and has been part and parcel of human activities in management of watershed in different parts of the world. This has been through planting exotic and natural tree species. Some exotic tree species of Eucalyptus, Agrocarpus and Black wattle were reported by respondents to contribute to scarcity of water in Baga watershed. Eucalyptus, Agrocarpus and Black wattle were established by colonialists and government authorities in the area because they are fast growing trees, which could meet the needs of fast growing human population in West Usambara highlands and for tannin . The increasing human needs from trees included timber, poles, woodfuel, tannin and income. However, the same tree species have been found to have negative ecological effects e.g. on water and soil and some have become invasive e.g. Black wattle. Complaints are over utilization of water and poor conservation of soil e.g. Eucalyptus and Agrocarpus. Many authors in different parts of the world including Poore and Fries (1985), Saxena (1994) and German (2004) have also wrote on the above named negative ecological effects of Eucalyptus and other exotic tree species on water and environment.

To curb ecological effects of such trees various interventions have been proposed. For instance, URT (2005) has proposed elimination of such trees in and around watercourses by harvesting and uprooting them. To date the proposed intervention has not been implemented in many parts of Tanzania, including the study area.

4.2.2 Increased climate change (global warming)

About 2% of respondents interviewed during this study reported that scarcity of water was due to increased climate changes, in particular global warming (Table 8). Global warming which is characterized by prevalence of extended drought seasons and increased temperatures have been reported by Paavola (2003), Ehrhart and Twena (2006) and URT (2006) to be some of the effects impacting Tanzania, particularly the inner parts which were predicted to experience higher temperature increases than the coastal areas. Rainfall was also predicted to decrease by about 0 – 20 percent in the inner parts of the country, with dry seasons becoming longer, hence leading to scarcity of water.

4.2.3 Other factors

About 22% of respondents interviewed during this study reported scarcity of water in Baga watershed being caused by other factors (Table 8) such as seasonal variations, sources of domestic water, gender inequalities in collecting domestic water in households, sources of domestic water, biophysical features and distances to water sources as discussed in Sections 4.2.3.1 – 4.2.3.5.

4.2.3.1 Seasonal water variations

According to the respondents interviewed, about 57% were of the opinion that scarcity of water was noted during dry seasons of the year (Table 10). Scarcity of water during dry seasons is common in rural and some urban areas of developing countries. In most cases, scarcity of water is both in quantitative and qualitative aspects. This is attributed to high dependence on natural water sources (streams and rivers) and shallow wells, which in dry seasons, some of shallow wells dry up and some rivers and streams flow patterns are affected by droughts. If no well established and reliable water provision systems are in place, water could be of poor quality in dry seasons. It is during the same season of the year when women and children have to travel longer distances to search domestic water for their households. Seldom do they get water of required quality and quantity to meet basic water needs for their households.

Table 10: Responses on seasonal water variability in Baga watershed, Lushoto district

Seasons of the year	Number of respondents	Percent
Rain season only	7	4.2
Dry season only	95	57.2
Both rain and dry seasons	64	38.6
Total	166	100.0

Also, scarcity of water was reported to be in both rain and dry seasons of the year as indicated by 39% of respondents interviewed (Table 10). In this case, scarcity of water in the rain season can be largely explained by qualitative aspects. That during rain season, the quality of domestic water collected from natural water sources such as rivers/streams and shallow wells is affected due to openness of water sources and dependency on surface water which is reported by Liniger (1995) and WHO/UNICEF (2006b) to be of poor quality, because of contaminants carried by rain runoffs longer ways.

On the other hand, the remaining 4% of respondents reported scarcity of water during rain season only. This can probably suggest that, during rain season domestic water is relatively easily available from different sources including safe sources, such as rainwater obtained through roof collection. The scarcity of water during rain seasons could be probably due to qualitative parameters, particularly by those households depending solely on surface water for domestic uses. Roof rainwater collection for domestic use is a common practice in rural an urban areas. Additionally, water collected through roofs is reported by Liniger (1995) to be among the liable sources of safe water for domestic uses.

The results of seasonal water variations as presented and discussed above can be used to formulate water management interventions to curb scarcity of water for various uses in Baga watershed and other parts in Tanzania. Some of the interventions include:

- Roof rainwater harvesting and water storage dams. Water collected through this means could be for domestic use, hence reducing workload on women and children of traveling longer distances to search water. On top of that, the women’s time saved could be used in doing other social and economic activities. And when households have enough water storage facilities, the same water could be used for irrigating agricultural crops during dry seasons, hence reducing use of valley bottoms and associated conflicts over water in dry seasons.

4.2.3.2 Gender sensitivity on seasonal water variations

It was found that seasonal water variability were gender sensitive (Table 11). More men respondents (7.9%) reported scarcity of water during rain seasons as compared to female respondents (1.1%). This variation in responses can be explained by qualitative aspects as discussed in Section 2.5.7**.** Generally due to high dependence on natural water sources such as shallow wells, rivers and streams, domestic water in the study area during rain seasons tends to be coloured due to suspended soils and sometimes with some contaminations. Higher responses of men on water scarcity in rain seasons were due to water quality while women respondents were considering more quantitative parameters to satisfy household requirements. Women sometimes are forced to collect water of poor quality which is be boiled for household consumption, in particular for drinking.

Table 11: Responses by gender on seasonal water variation in Baga watershed, Lushoto district

Season of the year	Sex of respondents	
	Male (%)	Female (%)

Rain season only	7.9	1.1
Dry season only	53.9	60.0
Both rain and dry seasons	38.2	38.9
Total	100.0	100.0

On the other hand, more females (60%) as compared to males (53.9%) reported scarcity of water during dry seasons of the year. This observation can be explained by two main reasons. Firstly, as shown in Table 10 it is during dry seasons of the year when scarcity of water is more felt by rural and some urban communities in developing countries. As a result of seasonal water variations, women are more impacted by scarcity of water in dry seasons as compared to men. Secondly, 99.4% of respondents interviewed in this study reported that women were responsible for collecting domestic water (Table 12). Women's responsibilities in collecting domestic water make them more sensitive to seasonal water variations, particularly water shortage during dry seasons of the year. In addition to that domestic water uses by households is a daily activity, which is born by women and children. The findings concurred with what have been reported by other authors (Moriarty and Butterworth, 2003; Dungumaro, 2006; Mlote *et al.* 2003; URT, 2006) that women were responsible most for collecting domestic water, and that this was particularly a dominating characteristic in developing countries, Tanzania inclusive.

Table 12: Responses on responsibility for collecting domestic water for households in Baga watershed, Lushoto district

Sex of respondents	Number of respondents	Percent
Female	165	99.4
Male	1	0.6

Total	166	100.0

Water may be available, but more workload on women, including collecting water for domestic uses could be the real contributing factor to scarcity of water in households. However, Mlote *et al*. (2003) reported 63%of total domestic water being collected by women in Tanzania while 99.4% of respondents interviewed during this study reported the same. The reason for variation between the two observations can be explained by area coverage. That, Mlote *et al.* (2003) included rural and urban areas while this study considered rural areas and one location only. The findings present real situation, particularly in rural settings in developing countries, where women are most responsible for collecting domestic water. Cases of single male headed households exist and that is when men become responsible for collecting domestic water for their households.

Responses of women and men on scarcity of water both in rain and dry seasons were 38.9% and 38.2% respectively. This implies that sustainable water management interventions are required both for rain and dry seasons of the year. During rain seasons when water is plenty some measures are taken that would ensure liable water availability during dry seasons of the year.

4.2.3.3. Sources of domestic water

Sources of domestic water are one of contributing factors to scarcity of water in Baga watershed. About 2% of the respondents interviewed accessed domestic water from piped water supplies, and the remaining 98% from various sources such as from piped water supplies, open shallow wells, and rivers/streams (Table 13). Except for piped water, most of water sources were open, hence rain runoffs, suspended materials and other debris entering freely both in dry and rain seasons of the year. Generally, much of the domestic water in Baga watershed were mainly from natural surface water, which are not safe if used as collected from sources. Some of these sources were seasonal caused by seasonal water variations as discussed in Section 4.2.3.1. Additionally, due to seasonal water variations coupled with increased human activities within water sources as discussed in Section 4.2.1, during dry seasons of the year, water use conflicts were experienced. Water use conflicts were during dry seasons between valley bottom cultivators, livestock keepers and domestic water collectors. Main causes of conflicts were that domestic water collectors were against the use of agrochemicals, encroachment of water sources for agriculture, and abstracting much water from main sources by valley bottom cultivators for irrigating vegetables. This was when source of domestic water was from natural sources such as from rivers and streams. In order to manage such conflicts, water users agreed that domestic water be collected early in the morning before chemical spraying and watering agricultural crops in valley bottoms. This agreement did not take into account that some of agrochemicals persist in water and soils, but only considered the direct contacts with agrochemicals.

Table 13: Responses on sources of domestic water for households in Baga watershed, Lushoto district

Water sources for respondents	Number of	Percent

	respondents	
Rivers /streams	41	24.7
Open shallow wells	6	3.6
Rivers/streams and open shallow wells	87	52.4
Rivers/streams, open shallow wells and piped water	17	10.2
Piped water	3	1.8
Rivers/streams and piped water	12	7.2
Total	166	100.0

Moreover, conflicts between domestic water collectors and livestock keepers were when either intentionally or unintentionally livestock keepers took their livestock to sources of domestic water. To reduce this type of water use conflict, water users agreed on zero grazing, and sometimes setting livestock watering points below sources of domestic water. The implementation of zero grazing could significantly reduce conflicts between domestic water collectors and crop growers and livestock keepers, but the implementation was not fully in place, hence persistence of conflicts among water users in Baga watershed.

4.2.3.4. Land slopes (physical features)

Land slopes (physical features) were also found to be among the other factors contributing to scarcity of water in the study area. West Usambara highlands are characterized by difficult terrains, even on foot. High population in highlands has resulted into land shortage for building houses and for agriculture. This in turn has forced some members to establish their lives in more hilly and steep areas. Geographical variation is particularly important in water management, as substantial differences in water availability and access can sometimes be found even between adjoining villages or communities. Generally, seasonal variations particularly dry seasons were associated with increase of distances of respondents interviewed to water sources. Increase of distances was always associated with changes of land slopes. According to the respondents interviewed, about 61% reported steep slopes to water sources during rain seasons (Table 14). Also about 75% reported that steep slopes increased during dry seasons of the year. From this it can be concluded that, generally dry seasons of the years were coupled with increased distances and difficult terrains to water sources in the study area. The difficulties of accessing water in dry seasons is portrayed by the decrease in respondents collecting water from sources on gentle and flat slopes to steep land slopes. Therefore, water becomes scarcer during dry seasons in Baga watershed. Changes of land slopes covered by water collectors during dry seasons can be used as one of the indicators of scarcity of water, particularly in undulated areas like Usambara highlands.

Table 14: Responses on distances and terrains to water sources for households in Baga watershed, Lushoto district

Rain seasons of the year				Dry seasons of the year			
Average distance to water sources	Land slopes to water	Number of respondents	Percent	Average distance to water sources	Land slopes to water sources	Number of respondents	Percent

(m)	sources			(m)			
237.86	Steep	101	60.8	288.52	Steep	125	75.3
	Gentle	55	33.1		Gentle	36	21.7
	Flat	10	6.0		Flat	5	3.0
	Total	166	100.0		Total	166	100.0

4.2.3.5 Distances to water sources

Average distances to water sources during rain and dry seasons in Baga watershed were about 237.8 m and 288.5 m respectively (Table 14). Generally, the average distances to water sources increased in dry seasons as compared to rain seasons. Average distances to water sources both in dry and rain seasons in the study area (Table 14)**,** if compared with targeted distance indicator of 400 m (URT, 2002b) to water sources can be considered as not a hindering factor to development. West Usambara highlands in which Baga watershed is found are characterized by difficult terrains. Bearing in mind terrain difficulties and locations of water sources in valley bottoms, it seems distances to water sources in both seasons of the year were also contributing factors to scarcity of water, hence hindrance to development. This argument is based on the fact that, even if the amount of energy spent by women to collect sufficient domestic water for their households was not established, but generally substantial amount of women's energy is spent in water collection. This in one way or another contributed to women not fully participating in other development activities**.**

4.3 Computation of WPI for villages and overall WPI for Baga watershed

4.3.1 Computation of WPI for villages

4.3.1.1 Resource component

Table 15 presents results of computed WPI for respective villages in Baga watershed. Villages in Baga watershed scored differently for resource component of WPI (Table 15). The WPI scores for resource component ranged from 100 to 56. Dule village scored the least (56) while Kwehangala scored the highest (100). The explanation for this score differences was that African Highlands Initiative (AHI) had improved some water sources in Kwehangala village as compared to Dule village, resulting into highest local communities' qualitative assessment in Kwehangala village. However, all villages scored above 50 for resource component, showing that water resources were not scarcer in Baga watershed. This is explained by the fact that, West Usambara highlands have many rivers and streams originating from reserved forests. To support this point, about 76% of respondents interviewed during this study reported presence of water sources (streams and rivers), and only about 24% reported absence of water on their agricultural lands (Table 16).

Table 15: WPI values for villages in Baga watershed, Lushoto district

Village name	Component WPI					Overall WPI
	Resource	Access	Capacity	Use	Environment	
Mbelei	88.0	78.7	17.0	54.5	6.5	48.9
Kwekitui	85.0	57.0	33.0	53.0	26.7	51.1
Kwadoe	67.0	55.0	45.0	61.5	10.8	47.9
Kwalei	97.0	55.5	22.5	61.0	11.8	49.5
Kwehangala	100.0	49.5	76.0	50.5	16.0	58.4
Dule	56.0	56.5	23.0	51.0	5.0	38.3
Baga watershed	81.9	54.4	27.7	55.6	10.3	46.0

Table 16: Responses on presence of water sources on agricultural land in Baga watershed, Lushoto district

Water sources on agricultural land	Number of respondents	Percent
Presence of water sources	126	75.9
No water sources	40	24.1
Total	166	100.0

In addition, with exception of Kwehangala village, other villages in Baga watershed scored less than 100 in resource component due to the fact that water sources in Baga watershed have been affected by increased human activities as such as encroachment of water sources for agriculture and presence of exotic species with negative effects on water and soils, coupled with poor farming techniques, vegetation clearing, burning; and use of agrochemicals (pesticides and insecticides) in valley bottoms as indicated in Table 8 and discussed in Section 4.2.1.

Therefore, it was found that water poverty in Baga watershed due to the contribution of resource component is of less extent as compared to other WPI components as discussed below.

4.3.1.2 Access component

Mbelei village had highest (62.5%) and Kwehangala and Kwalei villages had the lowest (0%) percentage of households accessing water from piped water supply (Table 17).

Other villages of Kwekitui, Kwadoe and Dule had lower percentage of households accessing water from piped water supply. This was through adjoining subvillages, and sometimes having improved water sources, particularly in Kwehangala village which local communities regarded them as piped water sources. Villages which adjoined Mbelei and Kwehangala villages through subvillages were Kwekitui and Dule respectively.

Table 17: Village subcomponents values for access component of WPI in Baga watershed, Lushoto district

Village name	Subcomponents/variables used				
	% of households having or using water from piped water supply	% of domestic water carried by women	% of households reporting illness due to waterborne diseases	Time spent in water collection including waiting (min)	Distances of households to affordable water sources (m)
Mbelei	62.5	99.9	20.2	18.8	288.8
Kwekitui	21.3	100	15.2	25.0	446.7
Kwadoe	3.7	100	4.7	19.0	215.0
Kwalei	0.0	100	6.7	20.6	238.0
Kwehangala	0.0	100	19.2	16.7	245.8
Dule	11.2	100	16.7	17.3	255.5

In all six villages making up Baga watershed, the percent of domestic water collected by women was almost 100% (Table 17). It was only in Mbelei village, where 99.9% of the respondents reported women to be responsible most for collecting domestic water. This difference was due to some single-male headed households reporting collecting domestic water on their own.

Reported cases of illness due to waterborne diseases, namely Typhoid, bacterial diarrhea and Schistosomiasis were highest in Mbelei (20.2%) and lowest in Kwadoe (4.7%) villages as shown in Table 17. This could probably be explained to be due to local communities in respective villages assuming that piped water supply and improved water sources are clean and safe, thus sometimes neglecting water treatment before using it.

Time spent in water collection and waiting in Baga watershed varied from 17.3 minutes to 25 minutes (Table 17). Time spent in collection and waiting water was highest in Kwekitui (25.0) and lowest in Kwehangala (16.7) villages. From these results, it is learnt that domestic water collectors in Kwehangala village spent less time as compared to domestic water collectors in other villages in Baga watershed. This could be contributed by already undertaken interventions of providing and improving water sources in Kwehangala, Mbelei and Dule villages.

Distances of households to water sources as a variable for access component in Baga watershed was established (Table 17). On average, distances of households to water sources in the study area ranged from 215.0 to 446.7 m. Average distances to water sources for households were shortest in Kwadoe and longest in Kwekitui villages. This was explained by majority of Kwadoe’s local communities opting to establish their settlements near water sources to reduce hardships of land terrains in accessing domestic water. On the other had, Kwekitui village had one centred domestic water source, hence higher average distances to domestic water in a village. The impact of distance variations to sources of domestic water among villages in the study area in terms of developmental activities was found to be not different. This could probably be explained by the fact that development is influenced by multiple factors, and not distances to water sources alone.

Results of access component of WPI are presented in Table 15. For access component, five villages in Baga watershed scored above 50, except Kwehangala village which scored 49.5. A lower score of Kwehangala village in respect to access component is attributed to lack of piped water supply and a relatively higher percentage of reported illness due to waterborne diseases (Table 17). From Table 15, it can generally be learnt that access component contributed to water poverty differently in all six villages in Baga watershed, but with much effect in Kwehangala village which scored 49.5. The differences of access component in Baga watershed were contributed by the differences in distances to water sources, land terrains and presence of improved water sources in some villages as presented in Table 15 and discussed in Section 4.3.1.2.

There were no other factors such as income (poor versus rich), payments for water, ownership/tenure; presence of excessive mineral water, by-laws/regulations limiting respondents to access water in all six villages. For instance, factors such as income was noted by Mlote *et al*. (2003) to be one of the limiting factors for poor in some parts of South Africa to access safe and clean water. Additionally, Mlote *et al*. (2003) in their study in Arusha, Tanzania observed that high fluoride in water contributed to low score of access component, as a result local communities had to travel longer distances to get clean and safe domestic water. Also, Chohin-Kuper *et al*. (2003) in Tunisia observed that payments for irrigation water affected access of poor to agricultural water use.

In all villages in Baga watershed, elements of membership to using and managing water were noted. Memberships were built on the bases of proximities to water sources and some norms and regulations put in place by users to ensure that water sources are protected from misuses. This is noted to be due to the establishment of formal institutions in water management which is expressed by the presence of water user associations in Baga watershed.

4.3.1.3 Capacity component

As presented in Table 7 and discussed under the household characteristics in Section 4.1, villages in Baga watershed were below basic needs poverty indicator in rural area (36%). However, all six villages in Baga watershed were above Tanzania's rural adult illiteracy rate indicator of 37%. This implies that, adults in Baga watershed were more literate.

Above 80% of Baga watershed's villages scored less than 50 for capacity component (Table 15). This makes, capacity component the second component contributing most to water poverty in Baga watershed. Water capacity as measured by human capacity indicators of income and education (Table 18), particularly income poverty contributed more on water poverty in Baga watershed. This argument is based on the fact that income poverty which is prevailing in Baga watershed has resulted into low investments in providing safe and clean water to local communities.

Table 18: Village subcomponent values for capacity component in Baga watershed, Lushoto district

Village name	Subcomponents/variables used	
	% of households below basic needs poverty line of 262 Tshs per adult equivalent/day	Illiteracy rate (%)
Mbelei	72.7	12.5
Kwekitui	61.1	24.2
Kwadoe	86.7	33.3
Kwalei	68.4	16.7
Kwehangala	66.7	19.2
Dule	54.5	16.7

Generally, it can be said that capacity component was influencing access and use components of WPI. High income can be invested in water through buying water pumps, pipes and chemicals for treating domestic water, to reduce distances to water sources and providing safe and clean water, thus reducing prevalence of waterborne diseases. Moreover, because water is available near homes, women and children workload of collecting domestic water would relatively be reduced. Use subcomponent discussed in Section 4.3.1.4 would be influenced by capacity component through more water being used in households for domestic purposes and more land including uplands rather than valley bottoms being put into irrigation. For instance, the existing difference in water consumption between developed and developing countries, discussed in Section 2.2.1 is because of income which is invested in providing clean and safe water to their local communities. Low capacity for villages in Baga watershed to provide safe and clean water to their communities is demonstrated by the fact that only one village (Mbelei) had piped water supply which was also not satisfying needs of its local communities. Moreover, reliable sources of safe and clean water would result into improved access component as discussed in Section 4.3.1.2.

4.3.1.4 Use component

Subcomponent values for use component in Baga watershed are presented in Table 19.

Daily domestic water consumption for villages in Baga watershed ranged from 22.5 to 30.4 litres. Kwehangala village had the lowest (22.5 l) whereas Kwadoe village had the highest daily domestic water consumption (30.4 l). The variations in domestic water use among villages in Baga watershed can be explained by difficulties in respondents recalling exact amount of domestic water consumed by a household in a day. On the other hand, in rural areas where various water sources exist, some members of households can take bath in rivers and streams and this goes unrecorded. Also, during cold seasons of the year some household members go without bath. The deviation between results in this study and daily domestic water consumption indicator (30 l) can be due to climatic factors, income and rurality of study area. Additionally, at national level data becomes more aggregated and from different sources, hence reducing its accuracy.

Table 19: Village subcomponent values for use component in Baga watershed, Lushoto district

Village name	Subcomponent variable used	
	Domestic water consumption (l/day)	Proportion of irrigated land to total cultivated land
Mbelei	26.8	0.20
Kwekitui	25.8	0.20
Kwadoe	30.4	0.23
Kwalei	26.5	0.34
Kwehangala	22.5	0.26
Dule	25.1	0.18

Results for use component of WPI are presented in Table 15. The use component of WPI for villages in Baga watershed varied from 50.5 to 61.5. Dule village scored the lowest (50.5) while Kwadoe village scored the highest (61.5). For use component all villages were found to be good by scoring above 50. The reason for this observation was because Baga River was running through all six villages. Main water uses from Baga River included domestic, making bricks, local brewing and agricultural uses. Agricultural water use in Baga watershed was for irrigating vegetable crops in valley bottoms, particularly in dry seasons. On the other hand, the area experienced the same climatic conditions and average household size (6 family members), hence the minor variations among villages in use component. This finding concurs with Hadjer et al. (2005) who observed that household size, income, level of urbanization (rural/urban) and climatic conditions were influencing daily water consumption at household level.

4.3.1.5 Environment component

Environmental integrity of Baga watershed was assessed by using crop losses due to floods and drought and soil erosion. Increased human needs for building poles, timber, agricultural land and settlement have affected natural resource base in Baga watershed.

Reported cases of crop losses from drought and floods in Baga watershed ranged from 37.0 to 50.0% (Table 20). Kwadoe village reported fewer cases (37 %) while Dule reported highest cases (50 %). Generally, Baga watershed experienced high crop losses due to drought and floods as compared to crop loss indicator of 33% in Paavola (2003) and URT (2006). Most of crops affected by floods were vegetable crops grown in valley bottoms whereas droughts affected more agricultural crops grown on uplands such as maize and beans. Losses due to floods were more accelerated by hilly terrains, some farmers extending farming seasons in valley bottoms up to nearly rain seasons, loss of forest cover in West Usambara Mountains and climate change. Tanga region in which Lushoto district is found was reported by URT (2007) as one of the flood prone regions in Tanzania.

Table 20: Village subcomponent values for environment component in Baga watershed, Lushoto district

Village name	Subcomponent variable used	
	% of crop losses from drought and floods in the past 10 years	% of reported soil erosion on land
Mbelei	40.6	12.5
Kwekitui	45.5	3.0
Kwadoe	37.0	7.4

Kwalei	43.3	6.7
Kwehangala	38.5	5.0
Dule	50.0	16.0

Another subcomponent which was used to measure environment component was erosion on agricultural land. Reported cases of soil erosion on agricultural land in Baga watershed were of the magnitudes between 3.0 to 16.0 % (Table 20). Kwekitui village reported fewer cases (3%) while Dule reported the highest (16%) of soil erosion. Villages in Baga watershed were performing better in managing soil erosion as compared to soil erosion indicator of 40% (EROAHI, 2005). This could be contributed by soil and water management interventions which were carried out in Baga watershed by SECAP and AHI (Vigiak, 2005; EROAHI, 2005; Wickama, 2006).

Generally, all villages in Baga watershed scored less than 50 in environment aspects (Table 15). This can be explained by lower scores of capacity component in villages as presented in Table 15 and discussed in Section 4.3.1.3**.** Low human capacity in water resources management can be linked to environmental degradation. The linkage between the two is that low human capacity would lead to low investment in environment while increased human's needs for natural resource bases deplete the environment. A good example in West Usambara is the low human capacity as discussed in Section 4.3.1.3 resulted into low investment in agriculture which in turn resulted into low agricultural production, hence leading to land/ environmental degradation. To meet the increasing human needs for food and settlement, local communities in West Usambara highlands opted to intensify their agriculture by clearing more agricultural land and establishing their lives in hilly terrains (Vigiak, 2005). To support this linkage, URT (1997) reported that poverty and environment are more linked, that low human capacity (poverty) will lead to more environmental degradation. In line with this, URT (2002b), reported low human capacity of government in management of water resources and provision of safe water to its members.

The results of overall village WPI showed that Dule village scored the lowest (38.3) and Kwehangala scored the highest overall (58.5) (Table 15). This implied that in Baga watershed, water poverty was highest and lowest in Dule and Kwehangala villages respectively.

4.3.2 Computation of WPI for Baga watershed

Results of WPI for Baga watershed are presented in Table 15. The scores for the five components of WPI at watershed level were between 10.3 and 81.9. Resource component scored the highest (81.9) while environment component scored the lowest (10.3). The overall WPI for Baga watershed is 46.0. The linkages and influences between capacity component and environment, access and use components of WPI are as discussed in Section 4.3.1.3. However, the overall WPI value (46.0) for Baga watershed is nearly similar to WPI value (46.9) which was computed by Mlote *et al*. (2003).as overall WPI for Tanzania. This indicated that, Baga watershed was experiencing water poverty contributed by multiple factors, as discussed in Sections 4.1 – 4.2.3.5, thus hindering realization of development.

4.4 Identification of priority areas for interventions within Baga watershed

Basing on the results of WPI presented in Table 15, areas to be given priorities for interventions in Baga watershed are identified basing on components with lowest WPI values. Scores of WPI components in Baga watershed arranged in descending order to show areas of priorities are as follows: environment, capacity, access, use and resource (Table 15). Low human capacity would in most cases be associated with poor investment and management of environment component. This could be because poor community would depend more on nature (environment) as compared to rich community. It can also be contributed by lack of alternatives, hence more dependence on environment. The rich community has many alternatives to invest resulting into less dependence on nature.

Improvement of human capacity component in Baga watershed would cause positive changes in access, use and resource components by creating awareness on poverty in community and expose them to various alternatives where to invest the little income they have. Moreover, distances to water sources, women and children workload of collecting domestic water, cases of waterborne diseases and others variables making access component would be reduced by improving human capacity. Additionally, improvement of human capacity would influence use component through investing even in uplands rather than depending on valley bottoms for dry season crop production. In doing so degradation of wetlands by valley bottom cultivation would be minimized. Sustainable use of water resource would result in positive effects on water resource component, as water quantity and quality would not be degraded for the benefits of present and future generations. From this, it is proposed that priority areas for interventions in Baga watershed would be intervening WPI components which contributed most to low score of environment. According to WPI component results and discussions, priority components are capacity, access, use and resource which would in turn bring improvement in environment component.

Therefore, for the integrated natural resource management (INRM) in Baga watershed to work effectively, human capacity should be given first priority followed by improvement of access component.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study has revealed that factors contributing to scarcity of water in Baga watershed are many and almost similar to ones reported globally. Increased human activities in watershed, global warming, and other factors contributed to scarcity of water in Baga watershed. Other factors included seasonal water variations, gender inequalities in collecting domestic water, sources of domestic water, physical characteristics and distances to water sources.

Moreover, the study has identified that, almost all local communities in Baga watershed collected domestic water from rivers, opens shallow wells and only 2% accessed domestic water from piped water supply. This showed that, there is a long way towards reducing the proportion of people without sustainable access to safe drinking water in Baga watershed.

Furthermore, the environment, capacity and access components of WPI scored lower than other components. From this, it can be concluded that, priority areas for interventions in Baga watershed be capacity, access and use components which would in turn bring improvement into environment component which scored the lowest. And that for integrated natural resource management (INRM) approaches to bring the intended impacts in Baga watershed, priorities for interventions be given to capacity, access, use, resource and environment components of WPI.

5.2 Recommendations

Basing on the findings from this study, the following recommendations were made:

- Valley bottom cultivation contributes to livelihoods of adjacent local communities; however, there is a need for establishing appropriate distances from water sources to irrigated land to reduce encroachment and pollution of water sources due to direct chemical spraying. This can be achieved by land use planning in valley bottoms;
- WPI being site specific should be developed for different parts of Tanzania, for identification of priority areas for interventions in water management; and
- Exotic trees species of Eucalyptus, Agrocarpus and Black wattle were criticized by local communities and environmentalists for over utilization of water,

becoming invasive and poor water and soil conservation characteristics. It is recommended that both short and long term studies be carried out to identify ways of reducing/curbing their effects in watersheds without compromising positive future benefits.

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LIST OF APPENDICES

Appendix I: Questionnaire for household surveys.

1. GENERAL INFORMANTION

1.1Village………………Subvillage……….Ward…………………..District………

1.2. Respondent number…………Sex: Female [……] Male [……] Age in yrs [……….]

1.3. Marital Status: Single [……..].Married [……].Divorced [……].Widowed [……].

1.4. How many people live in your household? By this I mean, how many people eat and sleep in this household. …………. people

1.5. Please let us know how many of these people in your family are female and male and whether children, working age, adults or elderly/retired?(The number of people in the table must equal the response for Q 1.4.

	Children 0 – 6 years	Schooling age 7- 18	Working age 19-60	Elderly/ Retired 65- ……
Men/boys				
Women/girls				

1.6.Your level of education a) No formal education [……..] b) At least some primary school […….]c) At least some secondary school […….].Above secondary school [……]

1.7. How long you and your ancestors (father, mother, grandfather, grandmother) lived in this village?...................……(Give number of years).

2. RESOURCES AND ACCESS

2.1. How did you acquire land to build a house? a) Buy […….].b) Inherited from father […….].c) Given by village government [……].

2.2. Were you given conditions on land use in relation to water sources management?
Yes […..].No [……].

2.3. If the answer to (Q.2.2) is yes, can you recall some? No [……].
Yes [……], mention some…………………………………………………………………………………
…………………………………………………………………………………………

2.4. Who is frequently responsible for collecting water for domestic use in your household?

a) Female [……]. b) Male [………] How frequent per day (number of 20l buckets of water) [……]

2.5. Where do you get water for domestic use and for livestock?

a) River/stream [……] b) Open shallow wells [……] c) Pond [……]

d) Dug dam [……] e) Piped water [……]

f) Other (specify)……………………………………………………………………….

2.6. Who owns that source of water? a) Myself [........] b) Neighbourers [......]

c) Village government [.....] d) Investor [.......] e) No own [……] f) Don’t know [……..]

2.7. How far is a source of water for domestic uses from home?

Rain season	Dry season
Distance (km)	
Time spent to water source (minutes)	
Time spent in collecting water (minutes)	

2.8. Which season of the year do you think access to water is more inadequate?

a) Rain season only […..] b) Dry season only […..] c) Both rain and dry seasons [….].

2.9. What are reasons for this inadequacy?

a) Water quality […….] b) Water quantity [……]

c) Both water quality and quantity [……]. d) Walking distance to water sources […….]

e) Queuing time […….] e) Imposed laws and conditions [……].

2.10. Have you or member of your household ever suffered from water borne diseases?

Yes […….] No […….]

2.11. If the answer to (Q.2.10) is yes, how frequent does it happen? a) Rare [……..]

b) Frequent [……….] c) Most frequent [……..]

2.12. How many households are served by the same source of water in your area?

Rain season	Dry season
a) Less than 5 people	
b)More than 20 people	
b) More than 50 people	
c) More than 100 people	

2.13. Do you have by- laws and conditions governing management of water sources in your area/ village?

a) Yes […….]. b) No […..]

2.14. If the answer to (Q.2.13) is yes, are of: a) Membership [……] b) Payments […….]

c) Income (Poor/ Rich) [……..] d) Land tenure [………]

2.15. If conditions are of payments, how much do you pay for collecting a bucket of water?

a) Tshs 20/bucket. [........].b) Tshs 50/bucket [……] c) More than Tshs 50/bucket [……..]

2.17. Are you satisfied with the performance of laws and conditions governing management of water in your village? Yes [……] No [……].

2.18. If the answer to (Q.2.17) is yes or no (give reasons)

…………………………………………………………………………………………

3. USE

3.1. What are the main uses of water in your household? a) Drinking and washing [……]. b) Brewing [……].d) Irrigating crops […….] e) Watering livestock [……..].

3.2. What is the quality of water for domestic uses in your household?

i) Poor and unsafe [……] Why?

……………………………………………………………………………………………

…………………………………………………………………..

....

ii) Medium and unsafe […..].Why?

…………………………………………………………………...

iii) Good and safe [……]. Why?

…………………………………………………………………………………………..

……………………………………………………………………………………………

3.3. What kind of treatments do you give to water for domestic uses?..

....

3.4. What are your opinions on general water uses in area/village?...
....

3.5. What are reasons for the answer to Q3.4?...

4. CAPACITY:

4.1. What is the main occupation for your household? If you were to describe the way your family earns its living, what would it be?

a) Main occupation……………………...

b) Secondary occupation………………………………………………………………………….

4.2. Farmer[1] Forest user [2] Animal raising [3] Artisan fisher/miner [4] Tourism [5] Wage labourer [6] Driver [7] Business [8] Other (specify)[9] ……………………………………………………………………………

4.3. Please indicate the number of various types of animals you own

Type of animal	Quantity
a. Cattle/cows	
b. Pigs	
c. Chickens	
d. Goats/sheep	
e. Ducks	
f. Other (specify)	

4.4. How do you keep them? Indoor [……] Free range [………].

4.5. If the answer to (Q.4.4) is indoor or free range (Give reasons)

....

4.6. If the answer to (Q.3.3) is no, why?

a) Lack of enough land [……].b) Lack of capital [……].c) Lack of enough labour […..]

4.7. How much agricultural land does you control/own?......................acres. Do not have my own land […......]

4.8. How much of this agricultural land do you irrigate most during dry seasons?..............acres.

4.9. What was your average annual income in the past 5 years?....................... (Tshs)

4.10. On what uses did you spend that income?...

4.11. Are you a member of water management institution? Yes [……] No [………]. If the answer is yes, since when [………………]

4.12. If the answer to (Q.4.11) is yes, have you ever attended any training in management of water resources? Yes [……] No [……].

4.13. If the answer to (Q. 4.12) is yes, how frequent? a) Once [….] b) More than twice [……] c) Most frequent [……..]

4.14. How much of your annual income do you invest in management of water sources?...

4.15. How much is your village government investing in provision of clean and safe water to its village members?

a) No investment [……..] b) Very little […….] c) Don't know […….]

5. ENVIRONMENT

5.1. How far your agricultural land is from water sources?......................(metres)

5.2. Are there rivers and or streams originating/ passing through your agricultural land? Yes [….] No […..]

5.3. What is the average distance of agricultural land you cultivate from water sources?.................... (metres).

5.4. Have you or your ancestors planted trees on your land? Yes [……] No [……]

5.5. If the answer to Q 5.4, is yes, how many have been planted?...................trees.

5.6. Which is the most common tree species that you planted on your land? ……………………………………………………………………………………

5.7. What other tree species that you planted on your land……………………………………………………………………………………

5.8. What methods/ measures do you use in ensuring that your land produces enough crops?...

5.9 Are these methods/ measures (Q 5.8) having negative environmental effects?

Yes [….] No […..]

5.10. If answer to Q5.9 is yes, mention them…………………………………………………………………………………………

5.11. What are your opinions on the conditions of water sources in your area?

a) Good [……] b) Degraded […….]

5.12. What environmental problems are facing water sources in your village/area?

………………………………………………………………………………………………

5.13. What losses have you experienced in the past 5 years or more to be due to environmental degradation?

…………………………………………………………………………………………………

THANK YOU VERY MUCH FOR PARTICIPATION. YOUR COOPERATION WAS GREATLY APPRECIATED!

Appendix II: Checklist for key informants

1. Communities (Village Leaders and Committees Members)

A: Identification Variables

1. Questionnaire No…………….
2. Name of Respondent(s)………………………………
3. Village………………………Ward………………………..District……………
4. Number of village households and population………………………………….
5. Major economic activities………………………………………………………..

B. Other Issues

1. Do you have water management institutions in you village?

2. Have they ever trained in water management, when and how frequent?

3. What is the relationship between water management institutions in the village?

4. What are water use conditions and rules in your village?

5. What are environmental problems facing your village and their causes?

7. Where do your people get water for various uses and adequacy of such sources?

8. How many households are accessing clean and safe water in this village?

9. What is the quality of water for domestic uses in your village?

10. How much of villagers’ time do they invest in management of water sources?

11. How much of village government annual income is invested in provision of safe and clean to villagers?

2. District Officials and Other Stakeholders

A: Identification Variables.

1. Questionnaire No…….

2. Name of interviewer ………

3. Date of interview…………

4. District………..

B: Other Issues

1. What are your opinions on water quality and quantity in Baga watershed and why?
2. What measures are undertaken by villagers in Baga watershed to reduce the rate of degradation of the watershed?
3. What variables are you using in assessing quality of domestic water?
4. How frequent and in which periods of the year do the area experience water related problems?
5. What factors have contributed to scarcity of water in Baga watershed?
6. What are management interventions which have been undertaken to address the issue of water quality and quantity in Baga watershed?
7. What are your opinions on the performance of water management institutions in Baga watershed?
8. How much is your office investing in water improvement? Percent of households and population accessing safe and clean water?

Appendix III: Computation of WPI for Mbelei village

WPI component	Subcomponent observed values	Established indicator values	Subcomponent WPI	WPI for components
Resource	87.5	100	0.88	88.0
Access	62.5	53	1.18(1)	
	18.8	30	0.63	
	79.8	100	0.798	
	288.4	400	0.72	78.7
Capacity	72.7	36	-2.02(0)	
	12.5	37		
			0.34	17.0
Use	26.8	30	0.89	
	0.2	-		
			0.20	54.5
Environment	40.6	33	-1.23(0)	
	12.5	40		
			0.31	$(0.155)^{-1} = 6.5$

Appendix IV: Computation of WPI for Kwekitui village

WPI component	Subcomponent observed	Established indicator	Standardized subcomponent	WPI for components

	values	values	WPI	
Resource	84.8	100	0.85	85.0
Access	21.3	53	0.40	
	84.8	100	0.85	
	25.0	30	0.83	
	446.7	400	-1.12(0)	52.0
Capacity	61.1	36	-1.70(0)	
	24.2	37	0.65	33.0
Use	25.8	30	0.86	
	0.2	-	0.20	53.0
Environment	45.5	33	-1.38(0)	
	3.0	40	0.075	$(0.038)^{-1} = 26.7$

Appendix V: Computation of WPI for Kwadoe village

WPI component	Subcomponent observed values	Established indicator values	Standardized subcomponent WPI	WPI for components
Resource	66.7	100	0.67	67.0
Access	3.7	53	0.07	
	19	30	0.63	
	96.3	100	0.96	
	215	400	0.54	55.0
Capacity	86.7	36	-2.41(0)	
	33.3	37	0.90	45.0
Use	30.4	30	1.01(1)	
	0.23	-	0.23	61.5
Environment	37	33	-1.12(0)	
	7.4	40	0.185	$(0.093)^{1}=10.8$

Appendix VI: Computation of WPI for Kwalei village

WPI component	Subcomponent observed values	Established indicator values	Standardized Subcomponent WPI	WPI for components

Resource	96.7	100	0.97	97.0
Access	0	53	0	
	93.3	100	0.93	
	20.6	30	0.69	
	238	400	0.60	55.5
Capacity	68.4	36	-1.90(0)	
	16.7	37		
			0.45	22.5
Use	26.5	30	0.88	
	0.34	-		
			0.34	61.0
Environment	43.3	33	-1.31(0)	
	6.7	40		
			0.17	$(0.085)^{-1}$ = 11.8

Appendix VII: Computation of WPI for Kwehangala village

WPI component	Subcomponent observed values	Established indicator values	Standardized subcomponent WPI	WPI for components
Resource	100	100	1.0	100
Access	0	53	0	
	80.8	100	0.81	
	16.7	30	0.56	
	245.8	400	0.61	49.5
Capacity	66.7	36	1.85(1)	
	19.2	37		
			0.52	76.0
Use	22.5	30	0.75	
	0.26	-		
			0.26	50.5
Environment	38.5	33	-1.17(0)	
	5.0	40		
			0.1250	$(0.0625)^{-1}$ =16.0

Appendix VIII: Computation of WPI for Dule village

WPI component	Subcomponent observed values	Established indicator values	Standardized subcomponent WPI values	WPI for components

Resource	55.6	100	0.56	56.0
Access	11.2	53	0.21	
	17.3	30	0.58	
	83.3	100	0.83	
	255	400	0.64	56.5
Capacity	54.5	36	-1.51(0)	
	16.7	37		
			0.45	23.0
Use	25.1	30	0.84	
	0.18	-	0.18	51.0
Environment	50	33	-1.52(0)	
	16	40	0.4	$(0.2)^{-1} = 5.0$