Potential for Payments for Watershed Services and Climate Change Adaptation in Pangani River Basin, Tanzania

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Makarius C. S. LALIKA

Promotor: prof. dr. Patrick Meire
Co-promoter: prof. dr. Yonika Mathew Ngaga

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verdedigd door **Makarius C. S. LALIKA**

Promotor: Prof. Dr. Patrick Meire, PhD.

Co-promotor: Prof. Dr. Yonika Mathew Ngaga, PhD.

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JURY MEMBERS

Prof. Dr. Patrick Meire, PhD. (Promotor)

Ecosystem Management Research Group, Department of Biology, University of Antwerpen, Belgium

Prof. Dr. Yonika Mathew Ngaga, PhD. (Co-Promotor)

Department of Forest and Environmental Economics, College of Forestry, Wildlife and Tourism, Sokoine University of Agriculture, Tanzania

Prof. Dr. Steven Van Passel, University of Antwerpen, Belgium **(Chair)**

Prof. Dr. Maciej Zalewski, University of Lodz, Poland

Prof. Dr. Johan Bastiaensen, IOB, University of Antwerpen, Belgium

Prof. Dr. Nathalie Holvoet, IOB, University of Antwerpen, Belgium

Dr. Jan Staes, Ecosystem Management Research Group, UA, Belgium

"To waste, to destroy, our natural resources, to skin and exhaust the land instead of using it so as to increase its usefulness, will result in undermining in the days of our children the very prosperity which we ought by right to hand down to them amplified and developed."

Theodory Roosevelt, December 3, 1907

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SUMMARY

Watershed ecosystems deliver multiple watershed services which are crucial for human well-being, the society and the economy. They also perform key ecological functions essential for water quality and quantity. Nevertheless, they have been degraded. For many years, the actual value of watershed services has been neglected, underestimated and not factored in land use decisions for sustainable management strategies. The problem is vividly experienced in developing countries which are characterized by: (i) lack of sufficient number of skilled manpower to spearhead conservation activities; (ii) limited budget for financing conservation programmes; (iii) escalating human population which overwhelm the capacity of watersheds to provide watershed services; and (iv) climate change and climate variability which aggravate the situation of water scarcity. In response to these problems, conventional conservation e.g. creation of protected areas (by fencing or fining encroachers) and participatory approaches (e.g. joint natural resources management approaches) were initiated. Unfortunately, they have so far failed to yield the desired outcomes. In recent years market-based approaches have been recommended as paradigm shift towards watershed conservation for sustainable flow of watershed services.

This thesis reports findings of a research carried as an attempt to develop a concept for Payments for Watershed Services (PWS) Scheme to conserve watershed ecosystems for sustainable flow of watershed services along the Pangani River Basin (PRB) in Tanzania. Specific objectives include: identification of ecosystem goods and services delivered by watersheds; determination of government involvement in financing conservation; analyzing the effects of water grabbing and foreign direct investments on the delivery of watershed services; assessing watershed dynamics and irrigated agriculture as adaptation option to water shortages, climate change and climate variability; analyzing policy constraints in water and watershed governance; and investigating drivers for respondent's willingness to pay (WTP) and the marginal effects for willing or unwilling to pay for watershed conservation.

Results shows that the PRB delivers four categories of ecosystem (watershed) services. They includes: provisioning services (such as paddy, maize and natural foods from the forest); regulating (i.e. water flow, air purification and climate

modification); supporting (e.g. soil erosion and nutrient cycling); and cultural (scenic beauty and recreation). Water is used for irrigated agriculture (maize and paddy), production of hydroelectric power (i.e. electricity) at Nymba ya Mungu Dam, Pangani and Hale power plants, and enhance nutrient cycling and ecological processes at Kirua Swamp.

However, conservation of watersheds along the PRB is constrained by lack of commitment and financial support from government institutions. For instance, findings from this study indicate that the budgets for financing conservation activities was €159490, 62 and €329665, 85 for the 2004/05 and 2008/09 financial years, respectively. Nevertheless, only €82693, 72 and €234537, 77 were allocated to conservation activities for the 2004/05 and 2008/09 financial years, respectively. This testifies the lack of enthusiasm and interest on watershed conservation. In addition, water officers responsible for water distribution, allocation and rationing facilitate illegal water abstraction thereby accelerating water grabbing malpractices.

Results on the effects of water grabbing indicate that the mean yields before water grabbing is higher than yields after water grabbing. Responses from the respondents indicate that local drivers for water grabbing include poor water governance, corruption and lack of transparency. Global drivers for water grabbing include climate change and climate variability, population growth, change of consumption patterns and global economic growth.

Enforcement and implementation of clauses stipulated in the Land policy, Land use Act and the Village Land Act about sustainable land uses would bring about a win-win situation between investors and smallholder farmers. Furthermore, transparency in land acquisition; promoting investments that ensure smallholder farmer's social security, ground water research, and rainwater harvesting would restore the former situation.

Watersheds along the PRB have undergone changes caused climate variability and population increase. Findings from human population census indicate an increase of trend of population which exerts pressure on water demands. Smallholder farmers adapt to water shortages through water rationing, irrigating during the night, using short term seed varieties and drought resistant crops.

Results on rainfall variability indicate a positive and statistical significant ($p < 0.05$) influence on water flow. This implies that one m^3 rainfall influences the increase of water flow at the magnitude of 0.466 m^3s^{-1}. Due to climate variability and rainfall fluctuation, the government through the Ministry of Agriculture, Food Security and Cooperatives should encourage and support smallholder farmers to carry out irrigatition as adaptation option to the failure of rainfed agriculture. With regards to conservation, a holistic approach for watershed conservation is recommended for the attainment of long-term objectives along the PRB.

Nevertheless, sustainable watershed conservation and long term conservation objectives require a sound policy framework supporting water and watershed governance. It was revealed that watershed conservation and water governance along the PRB are constrained by policy failures and lack of commitment among leaders to enforce laws, regulations and by-laws. Lack of accountability coupled with corruption is also reported as the catalysts for watershed degradation. Uncoordinated water governing institutional structures and untrustworthy financial management sums up watershed conservation problems. Building the capacity of water users association would bring about positive outcomes for both watershed conservation and water governance. Measures aimed at improving water flow should also focus on strategies for improving the welfare of the smallholder farmers and their willingness to participate fully in conservation programmes.

Results from the probit model on drivers for respondent's WTP for watershed conservation show that marital status, household size and distance from the water source positively influenced small scale farmers' WTP. Moreover, occupation, income from irrigation, and amount paid for irrigation influence negatively small scale farmers' WTP. The result also reveal that education level, total land size and yield with irrigation influence positively on the amount that respondents are WTP. Overall, results from regression model indicate a positive influence ($p < 0.001$) on the amount that respondents are WTP. The goodness fit of the model (0.62) explain 62%

variation of the variables included. The rest i.e. 38% could be explained by external factors. Although these statistical analyses are in favour of PWS scheme, limitations, weaknesses and criticisms identified in Chapter 1 in Subsection 1.4 necessitates further research before its implementation.

SAMENVATTING

Ecosystemen in rivierbekkens leveren verscheidene diensten die cruciaal zijn voor het welzijn van de mens, de maatschappij en de economie. Ze spelen ook een essentiële rol naar waterkwaliteit en kwantiteit toe. Toch zijn deze ecosystemen vaak gedegradeerd en werden ze gedurende vele jaren verwaarloosd, onderschat en niet in rekening gebracht bij beslissingen omtrent duurzaam landgebruik. Dit probleem is prangend aanwezig in ontwikkelingslanden die vaak gekarakteriseerd worden door: (i) een gebrek aan voldoende geschoold personeel om de beheersdoelstellingen in de praktijk om te zetten; (ii) een gebrek aan voldoende budget voor deze doelstellingen; (iii) een exponentieel stijgende populatie die de capaciteit van het rivierbekken overstijgt; en (iv) klimaatsverandering en klimaatsvariabiliteit welke de problemen omtrent het gebrek aan water enkel maar verergeren. Als reactie op deze problemen werden er vaak conventionele maatregelen toegepast, bv. het creeëren van beschermde gebieden d.m.v. afsluitingen en het beboeten van overtreders. Deze maatregelen hebben jammer genoeg gefaald. Recent echter worden mark-gebaseerde benaderingen aangeraden die een verschuiving moet teweeg brengen in het paradigma omtrent het behoud van rivierbekkens en voor een duurzame exploitatie moet zorgen van de diensten die ze leveren.

Dit proefschrift rapporteert de bevindingen van een onderzoek uitgevoerd om de "Betaling voor Rivierbekken Diensten" (Payment for Watershed Services, PWS) te ontwikkelen, die een duurzaam behoud van ecosysteemdiensten (Ecosystem Services, ES) in het Pangani Rivier Bekken (PRB) in Tanzania voorziet. De specifieke doelstellingen zijn: (i) identificatie van ecosysteemgoederen en –diensten geleverd door rivierbekkens; (ii) bepaling van de betrokkenheid van de overheid in het financiële beleid; (iii) analyse van het effect van waterroof en directe buitenlandse investeringen in de levering van diensten van het rivierbekken; (iv) beoordeling van de rivierbekken dynamieken en van irrigatielandbouw als aanpassingsoptie voor watertekorten, (v) klimaatverandering en klimaatvariabliliteit; (vi) analyse van beleidsbeperkingen in water- en bekkenbestuur; en (vii) onderzoek naar de bereidheid tot betalen van respondenten (willingness to pay, WTP) voor het behoud van het stroomgebied.

De resultaten toonden aan dat het PRB vier categoriën van (bekken)ecosysteem diensten levert. Deze omvatten: (i) voorziende diensten (zoals rijst, mais en natuurlijk voedsel uit het bos); (ii) regulerende diensten (i.e. waterstroming, luchtzuivering en klimaatwijziging), (iii) ondersteunende diensten (nutriëntcyclering); en (iv) culturele diensten (schoonheid van het landschap en recreatie). Het water wordt gebruikt voor irrigatie (mais en rijst), de productie van electriciteit in waterkrachtcentrales in de Nymba ya Mungu dam, de Pangani en Hale energiecentrales, en de verhoogde nutrientcyclering en ecologische processen in het Moeras van Kirua.

Echter, het behoud van de rivierbekkens in het PRB is beperkt. Dit komt door een gebrek aan bereidheid en financiële ondersteuning van overheidsinstellingen. Bijvoorbeeld: uit onderzoek blijkt dat de budgetten om de beheersmaatregelen te financieren respectievelijk op €159.490,62 en €329.665,85 lagen in 2004/05 en 2008/09. Toch werd maar €82.693,72 en €234.537,77 daadwerkelijk gebruikt. Dit toont duidelijk aan dat er een gebrek is aan enthousiasme en interesse om de riviebekkens te beheren. Daarenboven blijkt ook dat de waterbeheerders die verantwoordelijk zijn voor de distributie, toewijzing en rantsoenering van het water, zelf de illegale onttrekking van water vergemakkelijken. Dit versnelt natuurlijk de misbruiken en de waterroof.

Resultaten over het effect van waterroof tonen aan dat de gemiddelde opbrengst voordat er wateroof was, hoger lag dan na de waterroof. De antwoorden van respondenten hierover tonen aan dat de locale redenen voor deze waterroof te vinden zijn in slecht waterbeheer, corruptie en het gebrek aan transparantie. Globale redenen zijn de klimaatsverandering en de klimaatsvariatie, populatiegroei, veranderingen in voedingspatronen en de algehele mondiale economische groei.

Bepalingen omtrent duurzaam landgebruik werden uitgewerkt door het Agentschap voor grondbeleid (Land policy), de Acte van landgebruik (Land Use Act) en de Acte van dorpslandgebruik (Village Land Act). Het opleggen en in de praktijk brengen hiervan zou een win-win situatie creeëren voor zowel de investeerders als voor de kleinschalige landbouw. Daarenboven zou de voormalig (goede) toestand hersteld kunnen worden door wat meer transparantie inzake de toewijzingen van land; het promoten van investeringen die de sociale zekerheid van kleinschalige landbouwers verzekert, herstel van de grondwatertafel, en het gebruik van regenwater.

Stroombekkens in het PRB zijn sterk veranderd door klimaatsverandering en populatiegroei. Het onderzoek toont aan dat de toegenome bevolking extra druk heeft gelegd op de watervoorraden. Kleinschalige landbouwers hebben zich kunnen aanpassen door slim met het water om te gaan: door rantsoenering, irrigatie gedurende de nacht, en door gewassen te telen die slechts een korte groeiperiode kennen en bestand zijn tegen droogte.

Resultaten over de regenval tonen een positieve en statisch significante ($p < 0.05$) invloed op de waterhoeveelheid aan. Dit impliceert dat 1 dosis regenval het debiet met 0.466 m^3s^{-1} doet toenemen. Als gevolg van de klimaatsverandering en de fluctuatie in de regenval zou de overheid (het Ministerie van Landbouw, Voedselveiligheid en Cooperatieven) kleinschalige landbouwers moeten aanmoedigen om een aangepaste irrigatie (op basis van regenval) toe te passen en hen hierin te ondersteunen. Met het oog op het behoud is hier een integraal waterbeheer nodig van het hele rivierbekken om zo de lange termijn doelstellingen in het PRB te halen.

Een duurzaam bekkenbeheer en –behoud op lange termijn heeft een gezond beleid nodig dat het beheer ondersteund. Deze studie toonde aan dat bekkenbeheer en waterbehoud in het PRB beperkt is door een falend beleid en het gebrek aan bereidheid bij de leiders om de wetten, regelementen en statuten te doen gelden. Een gebrek aan verantwoording, gekoppeld aan corruptie werd aangeduid als één van de katalisatoren voor de degradatie van het stroombekken. Een ongecoördineerd waterbeleid dat verspreid zit over verschillende instanties en een onbetrouwbaar financieel management maken de problemen alleen maar groter. De oprichting van een vereniging van watergebruikers zou kunnen leiden tot positieve resultaten voor zowel het beheer als het behoud van waterbekkens. Maatregelen ter verbetering van de waterstroom moeten zich ook richten op strategieën die het welzijn van kleinschalige landbouwers verbetert en hun bereid maakt om ten volle deel te nemen aan programma's voor natuurbehoud.

Bevindingen uit de probit en regressie modellen geven aan dat burgelijke staat, grootte van het huishouden en afstand tot een waterbron de bereidheid van kleinschalige boeren tot betalen, alsook het maximale bedrag dat men wenst te betalen, positief beïnvloeden. Daarnaast hebben beroep, inkomsten uit irrigatie en het bedrag betaald voor irrigatie een negatieve invloed op de bereidheid tot betalen van kleinschalige boeren. Uit de resultaten bleek ook dat opleidingsniveau, totale perceeloppervlakte en de opbrengst door irrigatie positieve invloed hadden. De determinatiecoëfficient van het model was 0.62, i.e. het model verklaart 62% van de variatie a.d.h.v. de modelvariabelen. Op basis van deze statistische analyse en empirisch bewijs van deze studie is de PWS regeling haalbaar.

CHAPTER 1

1.0 INTRODUCTION

1.1 An over view

"To waste, to destroy, our natural resources, to skin and exhaust the land instead of using it so as to increase its usefulness, will result in undermining in the days of our children the very prosperity which we ought by right to hand down to them amplified and developed."

Theodor Roosevelt, December 3, 1907

This introductory statement by the former US president is relevant for today's water resources situation. The statement indicates that a natural wealth, a watershed, in this case requires an urgent attention and extra care in order to continue offering ecosystem services (ES). Ecosystem services (ES) are defined as "the direct and indirect contributions of ecosystems to human well-being" (TEEB, 2010). Therefore, sustainale conservation efforts need to be undertaken in order to safeguard watershed ecosystems thereby enhancing water flow and use of ES in a sustainable manner.

Water is an important ES and a basic natural resource for socio-economic development in developing countries. It is a basic natural resource which sustains life and ecological needs (Savenije, 2002; URT, 2002; Heathcote, 2008; Lein and Tasgeth, 2009). It is fundamental for all social-economic development activities such as industrial production, irrigated agriculture, livestock keeping, mineral processing, hydropower production, navigation and recreation and tourism (URT, 2002). The delivery of water is arguably one of the most precious and finite ES from watersheds and an integral part of the environment whose quantity and quality determines how it can be used.

However, water resources are becoming increasingly scarce and contested as a growing number of industries, rural and urban populations require more water for consumption, agricultural and industrial purposes (Kerr, 2002). As scarcity grows, the social and biophysical interdependencies become more apparent as natural resource management decisions taken upstream to an increasing extent produce downstream outcomes or externalities. The obligations to ensure the provision of water resources often fall on the local natural resource managers, whereas beneficiaries of such services might not be aware of the land use practices that are essential for their sustainable provision.

Issues related to water and sanitation are also echoed by the Sustainable Development Goals (SDGs) especially goal number six (6) which emphasizes ensuring the access to water and sanitation for all. However, problems of water access and sanitation are still reported across the globe. For instance, the 2016 report on sustainable development goals (UN, 2016) indicates that, apart from drinking water, sanitation and hygiene, the SDG number six (6) goal also addresses issues of quality and sustainability of water resources. This implies that there is a need to expand the global cooperation on water management in order to enhance survival of people and other life forms on the planet.

Statistics from the 2016 report on sustainable development goals show that globally, 91% or 6.6. billion of people had access to improved drinking water sources in 2015 as compared to 82% way back in 2000. Conversely, around 663 million people were still using unimproved sources or surface water in 2015. With respect to water stress, this report indicated that more than 2 billion people around the globe were subjected to this problem and numbers of victims were expected to rise. And the proportion of population using improved sanitation across the globe increased from 59 % to 68% between 2000 and 2015 where as 2.4 billion were still susceptible to poor hygiene and inadequate sanitation facilities. Furthermore, an estimated number of 946 million population continued to defecate in open areas. In this context, it is high time to undertake research and studies on water quantity, quality and conservation of water sources.

1.2 Water as a human right

The link between water, human rights and development has been recognized for quite long time (Salman and Lankford, 2003; UNDP, 2006). Water resources and human rights represent key issues drawing attention of the global community. In turn, the two issues have been placed at the top priority of the World development discussions thereby generating dialogue that has been complex and extensive (Salman and Lankford, 2003).

Access to safe water is a fundamental human need and, therefore, a basic human right. The right to access to clean water and sanitation has been acknowledged a "commonly agreed premise." The outcry on right to water was echoed in November 2002, by the Committee on Economic, Social and Cultural Rights by adopting General Comment No. 15 on the right to water. Furthermore, Article 1.1 states that "The human right to water is indispensable for leading a life in human dignity. This is a prerequisite for the realization of other human rights". To emphasize on the issue of the right to water, Comment No. 15 also defined the right to water as the right of everyone to sufficient, safe, acceptable and physically accessible and affordable water for personal and domestic uses.

Lack of access to water have a clear link with poverty and this is associated with violation of human rights and dignity (Salman and Lankford, 2003; UNDP, 2006). Poverty is prevalent in water shortage-stricken areas and it has been established that majority of poor people across the globe (especially, in developing countries) are located in areas with extreme water shortages and poor sanitation.

The development and hence the recognition of the crucial of water to the realization of the rights was cherished in the Universal Declaration of Human Rights, the International Covenant on Economic, Social and Cultural Rights, and the Declaration on the Right to Development. This was confirmed some 10 years after Dublin, Rio, and Vienna, in General Comment No. 15, issued by the Committee on Economic, Social and Cultural Rights in 2002 (Salman and Lankford, 2003). There are key processes that ensure accessibility to sufficient safe water is a human right. These are: (i) fresh water is a legal entitlement, rather than a commodity or service provided on a charitable basis; (ii) achieving basic and improved levels of access should be accelerated; (iii) the "least served" are better targeted and, therefore, inequalities decreased; (iv) communities and vulnerable groups should be empowered to take part in decision making processes; and (v) the means and mechanisms available in the United Nations human rights system should be used to monitor the progress of States Parties in realizing the right to water and to hold governments accountable (WHO, 2003).

Although water is essential to all life, access to water was not included in the universal declaration of human rights. Furthermore, despite the importance of water resources in our daily life and its implications to the ecological integrity, this vital ES is at the center of tug-of-war caused by various drivers. The degradation of the watershed ecosystem is a key factor associated with significant reduction of watershed services (WS). As water is so important to life and is being recognized as a human right, access to water is crucial. However we see that our water resources are declining due to ecosystem degradation and that a large part of the population has no access to enough and clean water.

Water availability enhances sustainable development through economic growth, social development and environmental sustainability. Statistics from the World Water Development Report 2015, *"Water for a Sustainable World"* indicate that 2.3 billion people gained access to improved drinking water sources (i.e piped supplies and protected wells) Between 1990 and 2010 (Connor and Miletto, 2015). UNESCO's endeavors are to provide women and children with easy accessibility to water and free them from the burden of fetching water for hours every day.

Apart from domestic uses, water is used for various purposes ranging from domestic, agriculture to industrial uses, to name just a few. Projections show that between 2000 and 2050 water demand for manufacturing industries will increase by 400% (Connor and Miletto, 2015) leading all other economic sectors. Problems of water utilization in the African continent have been witnessed in various economic sectors. For instance less than 10% of hydropower production potential is utilized whereas hardly 5% of water resources potential in the African continent are developed and average per capita is only 200 m^3 as compared to to 6,000 m^3 in North America.

Globally, water demands and stress are attributed to innumerable drivers ranging from local to international scales. These drivers includes but not limited to: concentration of human population in some parts of the World; macroeconomic policies encompassing changing consumer preference and consumption patterns; water, food and energy nexus and security policies; urbanization processes and urban development; just to name a few (USCB, 2012). It is projected that by 2030, changing consumer behaviors and the rapid increase of other sectors of the economy will increase water demands and water deficit by 40% (WRG, 2009; WWAP, 2012).

The problem of water scarcity is more severe in Sub-Saharan Africa where by 2050 human population growth is predicted to 2.4 billion people (Connor and Miletto, 2015; WWAP, 2014) . The heterogeneously distribution of water resources in this part of the African continent makes the situation even worse (UNDESA, 2013). Todate, irrigated agriculture the largest user of water resources accounting about 70% of all freshwater withdrawals globally.

1.3 Water resources and ecosystem degradation

Ecosystem degradation refers to the environmental problem that diminishes the capacity of species to survive. This environmental problem occurs in different forms and is manifested in reduction of the richness of the ecosystems and biodiversity and other ES they provide (TEEB, 2010; Connor and Miletto, 2015). Despite the awareness created so far about the importance of ecosystems and biodiversity to human welfare, ecosystems and biodiversity loss and degradation still continue on a large scale in different part of the globe (TEEB, 2010). This loss necessitated the establishment of an international initiative on the the economics of ecosystems and biodiversity (TEEB) aimed at analyzing, quantifying and documenting the values of biodiversity and ES, the growing costs of biodiversity loss and ecosystem degradation, and the benefits of action addressing these pressures (TEEB, 208; 2009; 2010; 2011). Uncovering and understanding the social, cultural, economic benefits and values of ES from ecosystems (majority of which are available in free access) is crucial to planning for their conservation and restoration.

Apart from from biodiversity loss, ecosystem degradation affects enormously the capacity of ecosystems to offer freshwater. Habitat loss and fragmentation affects not only biodiversity erosion and loss, but also results in the depletion fresh water which is among the components of ecosystem degradation. Watershed degradation for instance, reduces its capacity to enhance ecological integrity including the regulation of water movement through hydrologic cycle, the storage capacity of fresh water and release gradually, and reduces its ability to provide other ES. Although the loss of biodiversity as such is an important issue, recent insights into the functions of nature made clear that ecosystems deliver a lot of services to human societies.

The growing interests in ES studies, valuation and quantification have been documented (MEA, 2005; TEEB, 2008; 2009; 2010; 2011). However, institutional failures and lack of adequate information about the potential contribution of ecosystems and biodiversity to societal wellbeing has contributed to the continued degradation of the resource base. This degradation ecosystem ans their associated ES alerted ecological economists and ecologists to look for ways on how to restore the situation. The inauguration of the Millenium Ecosystem Assessment report (MEA, 2005) was a key step towards the realization of the potential for ecosystem conservation for sustainable supply of ES. Despite some problems in its practical application in decision making process and ecosystem utilization plans, the Millenium Ecosystem Assessment document will remains as a key pioneer report for ES assessment, documentation, valuation and watershed conservation at large.

On the other hand, watersheds degradation is believed to have been caused by land conversion into other land uses (e.g. agriculture, settlements areas, mining, etc.), timber harvesting and logging in riparian zones, and fire incidences. The degradation of watersheds and riparian trees along river banks affects the physical and chemical condition of river tributaries, river regimes and the entire ecological integrity along a river basin (Calder, 2007; Liquete et al., 2011).

The proliferating human population increase coupled with economic development play a role in watershed degradation and increased water demand (de Fraiture and Wichelns, 2010 add SDGs, UNESCO, etc.). Economic progress and economic development is changing people's consumption behaviour. As people change their status from poor to rich, their consumption and consumer preference behaviour changes as well (Rulli et al., 2012; Molden and de Fraiture, 2010). The combination of population increase and economic development affects watersheds in many ways. Population increase and economic development call for more land for agriculture to cater for the increased food demands; secondly, more land for urban development which increases the competition for water. Climate change (CC) and climate variability are also among the drivers for environmental degradation worldwide and they pose a great threat to watersheds and sustainable water flow.

CC refers to the change in the statistical distribution of weather patterns when that change lasts for an extended period of time (e.g. decades or millions of years). This change may sometimes refer to a change in average weather conditions, or in the time variation of weather around longer-term average conditions (i.e. more or fewer extreme weather events) (IPCC, 2007; Seneviratne, 2012; Sheffield et al., 2012). The reduced water flow or water fluctuation may be not attributed to CC, but rather due to climate variability. Thus climate variability refers to the climatic parameters of a region varying from its long-term mean. Every year in a specific time period, the climate of a location is different. Some years have below average rainfall, some have average or above average rainfall (WMO, 2013; Munishi and Sewere, 2014). Climate varies over seasons and years instead of day-to-day like weather. Some summers are colder than others. Some years have more overall precipitation as opposed to other years. As advocated by Bates et al. (2008), the records of climate projections provide abundant evidence that freshwater resources are vulnerable and have the potential to be strongly impacted by CC, with wide-ranging consequences for human societies and ecosystems.

The combined effects of CC and variability are felt through reduced rainfall, increased temperature and reduced water flow along the Pangani River Basin (PRB) in Tanzania (Zorita and Tilya, 2002; Welling et al., 2012). Tanzania, for instance, does not contribute highly to CC and variability. However, scientists expect the country to suffer significant negative impacts from climate change. Predictions include rise in temperatures, changes in rainfall patterns and reducing water flows (Barchiesi et al., 2011). It is predicted that PRB will be especially hard hit by negative CC impacts. Predictions indicate that the ice cap on Mount Kilimanjaro, the highest peak in the African continent is expected to disappear completely by 2025 (Barchiesi et al., 2011; Munishi and Sewere, 2014; Lalika et al., 2015). Climate researchers in Tanzania predict a 1.8° - 3.6° Celsius temperature increase, decreasing rainfall and increased evaporation in the basin. All these circumstances together are expected to result in a 6-10 % decrease in annual service flows in the basin (Barchiesi et al., 2011).

Furthemore, a detailed CC modeling study for the PRB shows that CC impacts are expected to include: decrease in rainfall during the dry season (May– October); 2) increase in evapotranspiration, mostly in October, by approximately 10 mm; 3) increase in rainfall during the wet season (November–March); 4) minimum temperature increase by approximately 2°C (range of 1° to 3°C) during all months; and 5) maximum temperature increase by 1° to 3°C in July–November (Mwakalila, 2014). The seasonality of stream flows in the PRB is therefore likely to change because of hotter and drier periods and water use conflicts are expected to increase in the future as CC aggravates water stress. Morover, the expected decrease in water flows to CC will jeopardize important natural resources, livelihoods, industrial productivity and the local and national economies (Munishi and Sewere, 2014). Therefore, it is high time to carry our studies on understanding CC impacts in the water sector, promoting collaboration between the water and CC sectors and introducing adaptation actions for watershed conservation.

1.4 Why incentive-based conservation framework?

Environment and human development challenges in tropical and sub-tropical developing regions have contributed to increasing interest in Markets for Environmental/Ecosystem Services (MES) as an approach to integrate economic growth, ecological integrity and poverty reduction goals (Hopes et al., 2005; Howarth *et al.,* 2008). Normally, ES are considered to represent the flow of goods and services derived from nature for society. The application of market mechanisms to value and allocate these services is partly derived from existing market failures, which has contributed to a reduced flow of important ES and higher cost of man-made substitutes (Rojas and Aylward, 2003). The attraction of MES to policy makers is that environmental degradation (e.g. deforestation) and rural poverty (in upper watershed zones) may be mitigated in an integrated approach by appropriate use of market (incentive-based) solutions that link downstream users' demand for these services (e.g. improved water flows, lower sediment loads, etc.) with upstream suppliers of these ES through improved land use practices, moderated by market mechanisms (e.g. incentive or compensation payments) (Hopes et al., 2005; Wunder, 2005).

Integrating or linking buyers and sellers of ES is among the key features for PES implementation. However, from environmental economics point of view (Tacconi, 2012), focusing much on just the link between buyers and sellers of ES is rather narrow. Instead Tacconi (2012) suggested that in order for an initiative to be called PES scheme, it should be transparent for additional provision of environmental services through conditional payments to voluntary providers. The weakest part of this analysis is that there is no clear explanation of who should pay and it is not known whether the payments are voluntary or mandatory. The environmental perspective differs slightly from the then former PES definition by Wunder (2005) which analyzed PES by 5 key features namely: a voluntary transaction where; a well-defined service (or a land-use likely to secure that service); is being 'bought' by a (minimum one) ES buyer from a (minimum one) ES provider; and if and only if the ES provider secures ES provision (conditionality).

However, while PES as a market-based model for nature conservation have gained attention across the globe due to the attractive simplicity of focus on the use of incentive , a number of scholars have criticised Wunder's (2005) PES definition and its implementation as a whole (Van Hecken et al., 2015a). According to Pattanayak et al. (2010), Van Hecken and Bastiaensen (2010) and Adhikari and Agrawal (2013), and the promised gains from its implementation have so far been difficult to realize.

Furthermore, despite the potential of PES for environmental conservation, the concept of coasean PES schemes has been criticized or qualified by various scholars. Büscher et al. (2012), advocate that PES is an undesirable neoliberal scheme, receiving wide support from international institutions and developed countries in order to promote the commodification of fragmented ES for commercial purposes, focused on creating new business opportunities rather than addressing the fundamental flaws of the limitless capitalist economic system (Büscher, 2012). Hiedanpää and Bromley (2014), Vatn (2014) and Van Hecken et al. (2015b), advocate that in recent years, PES have been subjected to severe criticisms due to their weaknesses in conceptual and practical application. Many scholars have also indicated that real world PES schemes hardly ever are the simple, straightforward market-based systems that were originally promised, but usually require the careful negotiation and crafting of complex hybrid institutional arrangements that mix elements of conditional ES payments with deliberate government, donor or community governance and regulation (Muradian et al., 2012; Van Hecken et al., 2015a). More operationally, some scholars have criticized real PES - scheme from the suppliers point of views failure to sufficiently benefit land owners residing upstream(too low payments), in the same perspective others have criticized PES initiatives because the majority of them lack the quality of voluntary transaction (Milne and Adams, 2012).

As reaction to various criticisms of his former PES definition, Wunder (2015) came up with modified and detailed explanatory information that includes key issues of PES definition from different school of thoughts (Table 1). Therefore, according to his new definition, PES refers to: voluntary transactions; between service users; and service providers; that are conditional on agreed rules of natural resource management; and for generating offsite services.

This new modified PES definition can be incorporated in PES as an approach to integrate economic growth, ecological integrity and poverty reduction goals to finance conservation in developing countries. PES is a market-based approach to conservation financing based on the twin principles that those who benefit from ES (e.g clean water) should pay for them, and that those who contribute to generating these ES should be compensated for providing them. The approach seeks to create mechanisms to arrange for transactions between service users (who are assumed to be rich) and service providers (upstream poor communities) that are in both parties' interests, thus internalizing what would otherwise be an externality (Rojas and Aylward, 2003).

The PES approach has the following potentials (i) generates new financing, which would not otherwise be available for conservation; (ii) is likely to be sustainable, as it depends on the mutual self-interest of service users and providers (iii) is likely to be efficient, in that it conserves services whose benefits exceed the cost of providing them (Hopes *et al.,* 2005; Wunder, 2005).

Table 1: A revised PES definition

Feature	Wunder (2005)	Wunder (2015) – modified	Explanatory note (for modified proposal)
Term	Payment for environmental service	Payment for environmental service	a)"Environmental" and alternative term "ecological" are used as close substitutes b) "Payments" should functionally compensate ES provision costs, provide on top an additional ES incentive, balanced with strategic rewards to pre-compliant ES providers.
Acronym	PES	PES	Collective organization of ES providers and/or users (more frequently occurring on user side) may de facto restrict the degree of voluntariness of individuals
Transfer	Transaction	Transaction	a) Could be market-based (with competitive forces in play), but in most cases is not b) In most cases involves a written contract c) Is often facilitated by an intermediary
Demand side	Buyer	Service users	a) ES use(r)s including here some non-use benefits (e.g. option and existence values). b) Enrolled ES users become ES buyers ex post c) ES users may organize in single units (e.g. a firm), clubs (e.g. user association), or government-financed PES (local, national) — as highest-level aggregation of ES users d) Often intermediaries (e.g. civil society) bring together ES users and providers
Supply side	Seller	Service providers	a) ES providers may be landowners (with or without title), tenants, concessionaires — effective stewardship managing ES provision is key requirement b) ES providers may be individuals or collectively organized/contracted c) Enrolled ES providers become ES sellers ex post
Conditional	Yes	Yes	a) Conditionality by design is the single sine qua non defining feature of PES b) Implementation will exhibit varying degrees of de facto achieved conditionality

Nature related action	ES provision(or land use proxy)	Agreed rule of natural resource management	a) Compliance of ES providers is normally (but not always) w.r.t. pre-agreed resource use rules, not payments for hard-to-measure (and fluctuating/risky) ES provided b) "Land use" would restricts us from including marine PES c) Most PES are area-based.
Service	ES well defined	Offsite services	a) PES adequate for internalizing offsite externalities (i.e. spatially set apart from provider's land-use jurisdiction). b) ES may be bundled, but clear ES target delimitation may improve implementation
Additional for environment	*-	-	Desirable impact, but not a definitional feature
Welfare gains	-	-	Desirable impact, but not a definitional feature

Source: Adapted from Wunder, 2015

* Factor not mentioned; left open-ended

Supporters of PES advocate that it is one way to deliver better conservation through linking financially downstream ES users back to the upstream communities who manage the resource that provides the service (Ferraro, 2001; Wunder, 2007; 2008; Pagiola, 2008; Wunder et al., 2008; Pattanayak et al., 2010). Thus PES schemes refers to the voluntary transaction in which a well-defined ES (or corresponding land use) is 'bought' by a minimum of one ES buyers from a minimum of one ES provider if, and only if, ES provision is secured (conditionality). As it is often difficult to provide reliable measures for ES, proxies based on changes in land use or management are often used. Once some PES criteria or conditions are not met, it results in some approaches being termed PES-like schemes (Wunder, 2005).

Some examples of prevailing PES schemes include those where payments are made for ecological tourism (Clements et al., 2010), water provision (Dudley and Stolton, 2003; Asquith et al., 2008; Muñoz-Piña et al., 2008; Pagiola, 2008; Wunder and Albán, 2008), forest carbon / REDD+ mechanisms (Burgess et al., 2010; Clements, 2010), delivery of biodiversity outcomes (Clements et al., 2010; Sommerville et al., 2010; Gross-Camp et al., 2011) and pollination of crops (Ricketts, 2004).

The concept of PES emerged as a potential tool for achieving ecosystem conservation and improving the livelihoods of ES providers and consumers. The emergence of direct economic incentives for the conservation of ES come into being as solutions to the failure of both command-and-control mechanisms (e.g fine and fence) (Landell-Mills and Porras, 2002) and the Integrated Conservation and Development Projects (ICDPs) (Ferraro, 2001).

Historically, better conservation and improved livelihoods were the key issues of the ICDPs seeking to link conservation with socio-economic development of local resource users by introducing alternative sources of livelihood that reduce pressure on the environment (Ferraro, 2001). ICDPs operated under the assumption that removing the obstacles to sustainable development (poverty, shortages of capital, technology and skills) would encourage people to embark on pro-conservation paths. Unfortunately, many of these ICDPs didn't achieve their intended objectives especially on the conservation side. These projects were criticized for being too expensive given the conservation outcomes they achieved. Critics attribute this failure to the unrealistic project assumptions that enhanced economic development necessarily leads directly to improved conservation outcomes.

Thus proponents of PES advocate that this is an improved approach that focuses directly on creating a conditional benefit transfer between providers and beneficiaries of an environmental service. As such, PES approaches do not implicitly assume that natural 'win–win' solutions with simultaneous gains in both conservation and development always exist (Howarth et al., 2008). On the contrary, the payment option is being pursued in recognition of existing 'hard trade-offs' between conservation and development, which cannot be addressed by indirect changes in the productive logic of households, but which a direct compensating PES can help to bridge. Conversely, if both service providers and users have fully overlapping interests (e.g. both would naturally choose to conserve the same forest areas), then there is no rationale for introducing a PES scheme. It is conflicting interests that provide the justification for PES (Robertson and Wunder, 2005).

While proponents of market-based incentives for conservation advocate that PES offers a new approach to securing revenue streams for maintaining, conserving, and restoring ecological functions, its uptake remains significantly hampered. Furthermore, while interest in market-based approaches to watershed conservation is growing throughout the World, relatively little information is available on how these approaches work in practice in Pangani River Basin (PRB), Tanzania. Putting in place PES for water mechanism, for instance, might significantly contribute to the improved protection of the watershed consequently guarantee the continuous flow of the water ES while at the same time rewarding those who are responsible for protecting the catchment.

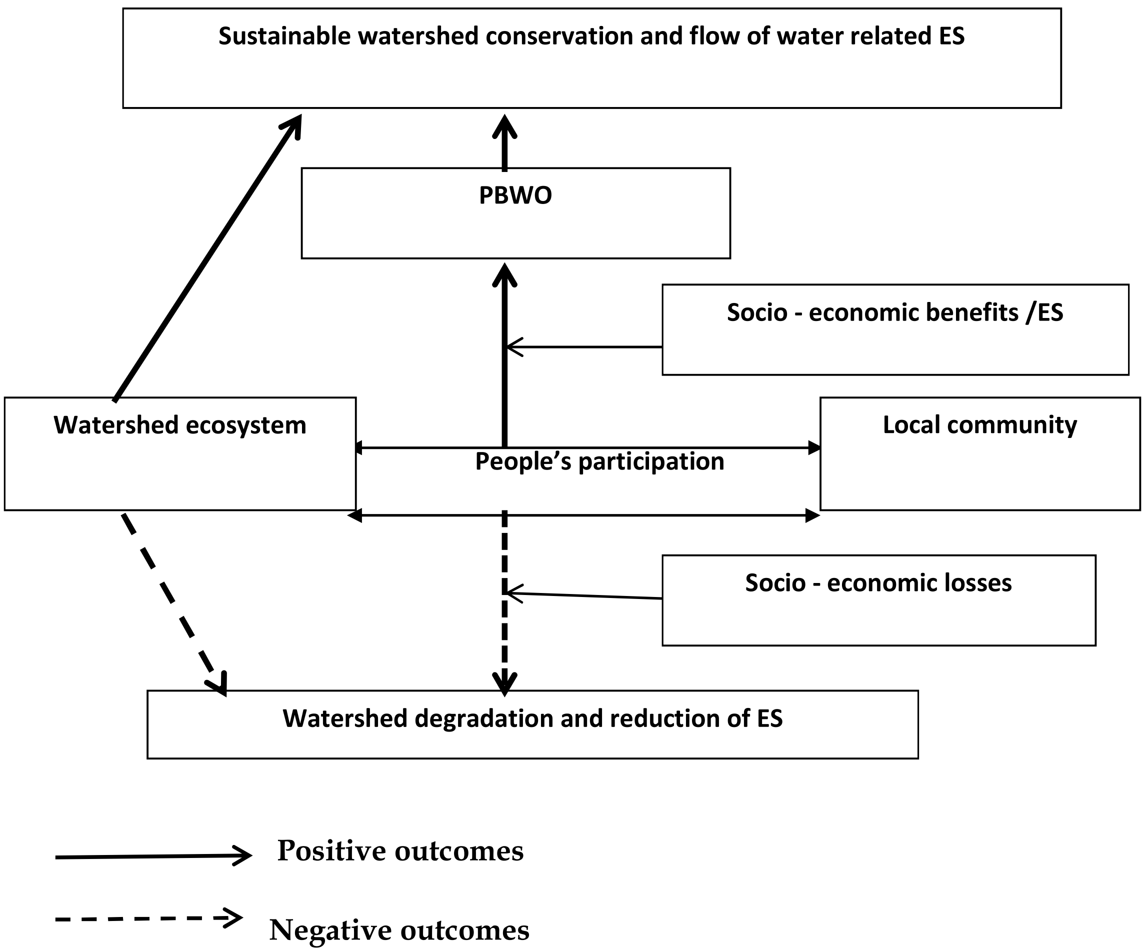
Quite a number of studies (Mbonile, 2005; Notter, 2010; Turpie et al., 2005; Ngana et al., 2010; Komakech et al., 2011) have been conducted in the Pangani Basin but none has specifically focused on the PES as a socio-economic incentive for watershed conservation. Most of the available research information is in the form of hard scientific documents with little information in the potential of PES for watershed conservation and improved livelihoods of the people living in the upper catchment.

One of the major reasons suggested for this lack of information is the inadequate attention given to the market based approaches of watershed conservation. Many interesting findings have not addressed sufficiently these aspects. For instance, the watersheds in the PRB produce vital environmental goods and services. However, mechanisms for rewarding upstream communities who implement or involve in conservation activities is also lacking. Moreover, no study has been conducted on PES for the watershed conservation which would motivate upland communities to utilize watersheds sustainably so that water can continue flowing and regulate ecological integrity and support development and communities' livelihoods. Thus this doctoral research was undertaken so as to come up with the missing information.

Once a mechanism for rewarding those who involve in conservation programmes is in documented and understood, it will be easier to pass the message to the downstream communities who are supposed to contribute part of their revenue from ES (water) utilization for watershed conservation. Also, the information could be used to resolve water use conflicts between communities and conservationists; upstream and downstream water users; hydroelectricity producers and other water users; communities and donor agencies; farmers and pastoralists; rural and urban areas; and communities and river basin authorities.

1.5. Theoretical framework on PES and valuation of ES

Proponents of PES, mainly environmental and ecological economists believe that effective incentives and returns for conservation can enhance people's WTP for watershed conservation. PES initiatives use the direct payments approach of cash payments to individuals (Ferraro and Kiss, 2002). There are a number of advantages of direct payment under PES as opposed to indirect conservation approaches. Direct payment under PES schemes are preferred because they are: institutionally simpler; more cost-effective in offering benefits to buyers of ES; more effective in generating economic growth among upstream communities by improving cash flow, diversifying income sources, reducing income variance and they provide new sources of finance for conservation (Ferraro, 2001; Ferraro and Kiss, 2002). The link between these attributes is indicated potrayed in the ***overarching conceptual framework*** below.



Over-arching Conceptual Framework for the Study

As potrayed in the conceptual framemwork, watershed conservation is considered to be influenced by socio-economic benefits / ecosystem services (ES) as reward to local communities (who reside upstream) for their participation in sustainable conservation activities and /or for sustainable land uses. The interaction between local communities and watershed ecosystem is linked by peoples' participation motivated by socio - economic benefits /ES. If socio-economic benefits/ES motivate positively watershed conservation, then sustainable conservation and flow of water related ES will be attained. However, on the contrary, if the interaction will be negative and lead to loss of socio-economic benefits/ES, then it is likely that local communities will be discouraged to participate fully in watershed conservation, consequently leading to reduction of ES.

Patanayak et al. (2010) advocated that reduced ES can be resolved via transactions (market) given that there are clear enforcement and proper definition of property rights and transaction costs are minimal. Valuation of ES derived from PES programmes, thus is debated by a number of scholars. Different scholars and researchers determined the benefits of ES by using innumerable economic methods. Total economic value (TEV) and contingent valuation method (CVM) are just few of the approaches used by environmental and ecological economists to value ES. TEV provides an estimate of the economic value of the resource under study (Kramer et al., 1992).

This approach distinguishes between use values and non-use values, the latter referring to those current or future (potential) values associated with an environmental resource which rely merely on its continued existence and are unrelated to use (Pearce and Warford, 1993). Typically, use values involve some human 'interaction' with the resource whereas non-use values do not. TEV is a monetary measure of a change in an individual's wellbeing due to a change in environmental quality. It measures people's preferences for that quality. It is, therefore, anthropocentric because it relates to preferences held by the people. The economic value of something is established by an actual or hypothetical exchange transaction (Geogiou et al., 1997).

Contingent valuation method (CVM) is frequently used to elicit respondents willingness to pay (WTP) for goods and services. CVM as a stated preference method has proven to be a useful technique for uncovering the passive use values of assessing water catchment quality (Riddel and Loomis, 1998). It remains to be an important tool for resource economists because forest catchments present bundles of goods and services that cannot be easily valued. In fact the components of a forest ecosystem often move together. For example, a forest with greater levels of species diversity may also have higher levels of watershed services and aesthetic value than less diverse forests (Hawkins, 2003; Kramer and Mercer, 1997). Thus, one can think of contingent valuation as a tool that is appropriate for valuing complex environmental goods such as forest ecosystems precisely because it leads to a holistic approach rather than focusing on individual components. Estimating economic values for forest catchment can improve the formation and implementation of policies to manage those ecosystems (Kulindwa, 2005). Thus, estimated WTP values can be used in cost-benefit assessments of ecosystem conservation programs and indeed in the current study on payment for water services and climate change mitigation in the country.

1.6 Water resources and distribution in Tanzania

Freshwater resources in Tanzania are divided into two main categories, i.e. internal water bodies (which are found within the country) and the shared ones which are shared with the bordering countries. Internal water bodies include rivers, lakes, wetlands, springs, reservoirs, and groundwater aquifers (URT, 2002). Shared water bodies are normally referred as transboundary water bodies. These are mainly large rivers and lakes.

In order to enhance water resources management, the government of Tanzania divided water bodies into nine hydrological zones. They includes: (i)Pangani basin; (ii) Wami/Ruvu basin; (iii) Rufiji basin; (iv) Ruvuma and Southern Coast basin; (v) Lake Nyasa basin; (vi) Lake Rukwa basin; (vii) Lake Tanganyika basin; (viii) Lake Victoria basin, and (ix) the internal drainage basins (URT, 2002) (Figure 1).

Transboundary water bodies includes: Lake Tanganyika (shared by Tanzania, the Democratic Republic of the Congo, Burundi and Zambia); Lake Victoria (shared by Tanzania, Kenya and Uganda); and Lake Nyasa (shared by Malawi, Tanzania and Mozambique). Transboundary rivers includes Mara river (shared by Tanzania and Kenya); Ruvuma river (shared by Tanzania and Mozambique); and Songwe river (shared by Tanzania and Malawi).

Figure 1: Location of different hydrological zones in Tanzania

Source: United Republic of Tanzania (URT), 2002

This research was carried out in the Pangani River Basin (PRB) which is located within the Pangani Basin (PB). The PRB extends from the northern highlands to the north-eastern coast of Tanzania. It lies between latitude 03º 05' 00" and 06º 06' 00" South and longitude 36º 45' 36" and 39º 36' 00" East. PRB, the largest river basin within Pangani Basin (PB) and covers an area of about 43,650 km² and 3, 900 km² (IUCN, 2003). The terms "PRB" and "PB" have different meanings. The former refers to the basin where the Pangani main river and its tributaries flow whereas the later incorporates the PRB and other three smaller basins i.e. Umba, Zigi-Mkulumuzi Coastal and Msangazi Rivers catchments (Figure 2) (IUCN and PBWO, 2008). In short PRB is a subset of PB which is also a shared transboundary resource between Tanzania and Kenya.

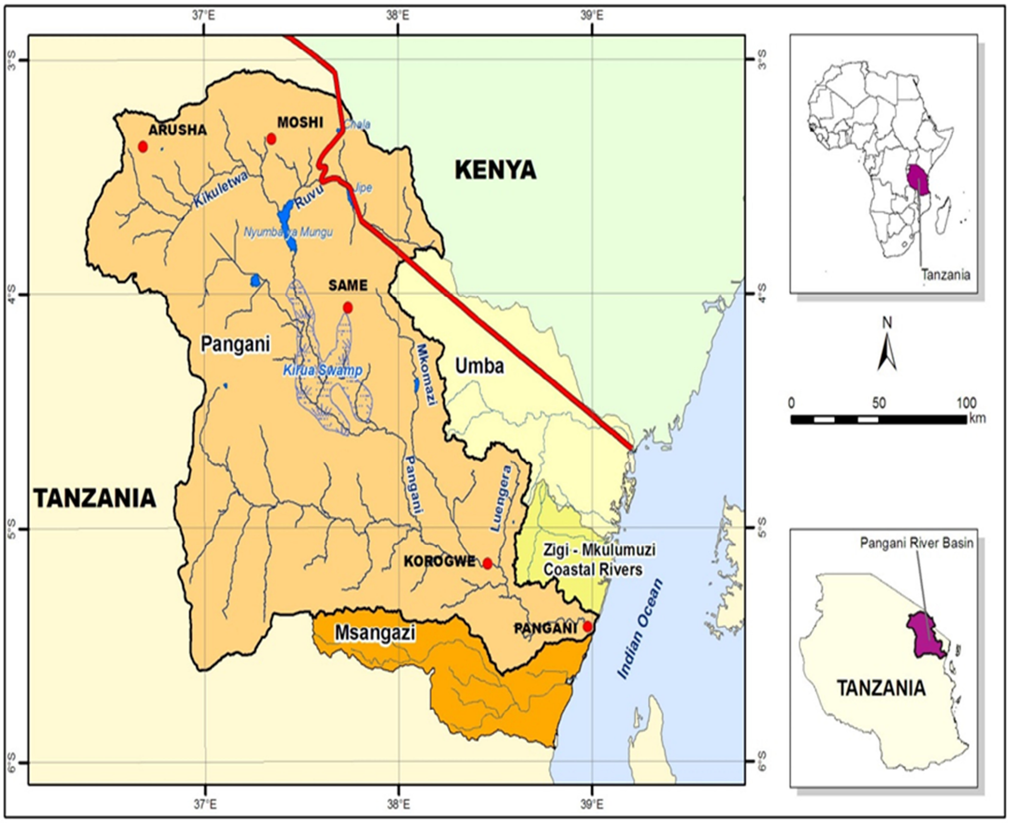


Figure 2: Location of Pangani River Basin and Pangani Basin, Tanzania

More information about the PRB (e.g. drainage pattern, climate condition, forest and vegetation types, and socio-economic activities) is found in the subsequent chapters under materials and methods section.

1.7 Research questions and scope of the study

The main focus of this Doctoral Thesis was to look into different drivers that should be considered when planning to establish a PES scheme for sustainable flow of ecosystem services (e.g. water) and climate change adaptation.

Therefore, the scope of this Thesis was to investigate some aspects of the potential for payment for watershed services (i) as a policy tool for watershed conservation and (ii) as an adaptation option to the changing climate and climate variability along the Pangani River Basin, Tanzania.

This Doctoral research was guided by the undersigned research questions:

- ***How the knowledge on watershed dynamics and climate change and variability can enhance conservation for sustainable water flow?***

- ***Are potential water users willing to pay for water as part of a PES program to contribute to watershed conservation and enhance the flow of ES?***

- ***How water grabbing affects water flow and welfare of communities living downstream?***

- ***Can irrigated agriculture serve as an adaptation strategy in rainfall stressed regions?***

- ***Can the contingent valuation method be used to solicit opinions from local communities their willingness to pay for watershed conservation?***

Specific objectives are as follows:

1) To analyze ecosystem services and their implication for conservation at watershed and sub-catchment level;
2) To investigate the financial contribution of the government sectors in watershed services conservation;
3) To examine the role of water grabbing and foreign direct investments in crop production and delivery of ecosystem services;
4) To examine irrigated agriculture as adaptation strategy to water shortages and climate change;
5) To assess watershed dynamics and impacts of climate variability on hydrological flow;
6) To explore policy constraints and policy tools for watershed conservation and water governance; and
7) To assess people's willingness to pay for watershed conservation.

As explained above, this doctoral research was about gathering information for the establishment of a PES scheme and developing strategies for climate change adaptation. Although the findings of this study are not exhaustive, the conclusions and subsequent recommenadations in chapter 9 and 10 form the basis for further scientific research in future. Therefore, a research is certainly needed on the 'willingness to provide' and the negotiation and elaboration of a viable institutional set-up in which conditional PES payments can be integrated.

1.8 Structure of the Thesis

This PhD Thesis comprises 10 chapters. With the exception of **chapter 1, 2** and **10,** other **chapters** (i.e. **3-9**) are based on independent papers published, accepted or under peer review for publication considerations in relevant journals. **Chapters 3- 9** comprises of key sections such as Introduction, Materials and Methods, Results, Discussions and Conclusions. The chronological structure of the entire Thesis is displayed hereunder:

Chapter 1: Presents the essence of the problem and justification why water should be treated as an exceptional natural asset than others. This chapter elaborates also the distribution of the major river basins in Tanzania including the Pangani River Basin (PRB), the focal point for this thesis. Towards the end, the chapter explains the aim and scope of this thesis, outlines specific objectives and finally the chapter gives the chronological structure of the thesis.

Chapter 2: Presents an overview, the history and state of the art for Payment for Watershed Services (PWS). Within this chapter, there are sub-sections such as watershed as a concept; definition of PWS; categories of watershed services; PWS as a policy tool for conservation; selected payment for watershed services programmes across the globe; challenges facing PWS implementation; and conclusions.

Chapter 3: Analyzes ecosystem services and their implication for conservation at watershed and sub-catchment level. In this chapter types of ecosystem functions and ecosystem services in the study areas are identified. Furthermore, a comparative analysis is made between two communities residing in either side of River Kikuletwa.

Chapter 4: Investigates government's financial contribution for watershed conservation. It also analyses water discharge, billable water and actual sold water. The chapter determines funds allocated for financing and implementation of conservation activities; document projected and actual revenue collection from downstream water users.

Chapter 5: Analyzes the combined effects of foreign direct investments (FDIs) and water grabbing on ecosystem services (water). These effects are examined by assessing crop yield before and after water grabbing. Moreover, the chapter identifies drivers for water grabbing in PRB; population dynamics and increase trend; and finally identifies land and water deals in Tanzania.

Chapter 6: Reveals the impact of climate change and variability on ecosystem services (water) and problems faced by communities living in those areas. In addition, the chapter analyzes population increase in the PRB; determines the trend of rainfall and temperature in the PRB; assesses irrigated agriculture as adaptation option to climate change and climate variability and water shortages in the study areas.

Chapter 7: Presents findings on watersheds dynamics and changes of watershed services. Furthermore, the chapter reports the impacts of climate change and climate variability on water flow. Specifically, the chapter determines stream flow, water level and rainfall and temperature trends; identifies drivers of water fluctuation; and finally it examines adaption strategies to water shortages, climate change and climate variability.

Chapter 8: Describes gaps in watershed and water management from institutional and policy perspectives. The chapter identifies water user associations, water right and water use fee for irrigation; examines policy gaps in watershed conservation and water governance and examines policy instruments for watershed governance.

Chapter 9: Presents peoples' willingness to pay for watershed services. The chapter determines the amount that smallholder farmers are willing to pay for a unit increase of water. It also reveals the amount that people are willing to pay and reasons as to why they are willing or not willing pay and recommends if the PWS programme is feasible or not.

Chapter 10: Provides general discussions and conclusions which are basically the synthesis of the key issues and conclusions of this entire doctoral study. It also describes the implications of key findings of the study and recommends areas for further research.

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CHAPTER 2

1.0 Payment for Watershed Services (PWS): An Overview

1.1 The watershed concept

The term watershed is defined differently by various ecologist, hydrologists, and school of thoughts. While some of them define a watershed with respect to locations, size, use and spatial scales, other defines the concept as a word used interchangeable to mean the same thing. Smith et al. (2006) defined a watershed as the area of land that feeds water to a river, through the process of precipitation draining through the landscape, into tributaries and into the main river channel. Blomquist and Schlager, (2005) defined a watershed as a landscape encompassing land, water, forest and related vegetation resources, managed under multiple institutional contexts. Watersheds are also called 'catchments', 'drainage basins' or 'river basins. Thus 'river basin' is usually used to describe a watershed covering a large area of land that drains into a major river, while 'sub-catchments' or 'micro-catchments' are much smaller parts of a basin that drain into a tributary stream (Smith et al. (2006).

With the view of definition of watershed at catchment scale, Tiffen and Gichuki (2000) defined a watershed as a landscape that forms an upper area of one or more catchments with hydrological linkages to the lower parts of the catchments. In other words, it is the area of land from which rainwater can drain, as surface runoff, via a specific stream or river system to a common outlet point such as a dam, lake, sea or ocean. Other school of thoughts perceives a watershed and water catchment as synonymous. To them a watershed is equal to a catchment i.e. a basin and drainage area defined by topographical, biophysical and water flowing from different points to a single destination known as a river system (Bruneau, 2005).

1.2 Categories of watershed services

Ecosystems provide valuable tangible and intangible benefits which are critical to human welfare (Constanza et al., 1997, MEA, 2005). Watershed ecosystems in particular provide multiple ecosystem services (ES), i.e the tangible and intangible benefits that human beings derive from their interaction with nature. These ES from watersheds can be grouped into four main categories (Costanza et al., 1997; De Groot et al., 2002; MEA, 2005), i.e. provisioning services (e.g. fresh water, fuel, and food); regulating services (e.g. water and floods control, air purification, soil erosion control, climate regulation, etc); supporting services (e.g. soil formation, nutrient cycling and primary production); and cultural services such (e.g. recreational, spiritual, religious and other nonmaterial benefits) (MEA, 2005). However, an updated definition and typology of ES classification by The Economics of Ecosystems and Biodiversity (TEEB) view ES by highlighting the growing costs of biodiversity loss and ecosystem degradation (Balmford et al., 2008; TEEB, 2008; Ring et al., 2010).

Specifically, TEEB (2008; 2009) perceive ES by integrating aspects of ecology, economics, biodiversity and ecosystem service valuation. This updated typology is a new response from ecological economists who perceive that the MEA (2005) analysis deliberately failed to accommodate the economics of ecosystem change.

The key contribution of TEEB (2008; 2009) and De Groot et al. (2010) to the updated ES literature goes beyond the MEA (2005) prior vision. These are: i) ES has to be analyzed by looking at biophysical characteristics of natural ecosystems with human benefits. In this context, it is crucial to evaluate the trade-offs of ecosystems and biodiversity degradation in a special and systematic way; ii) determining ES provision is essential for any ecosystem valuation and is vital the economic valuation; iii) A clear distinction between benefits, services and functions should be made in order to enable economic valuation possible and accessible to the audience; and iv) Economic assessment should include a wide range of parameters which accommodates societal benefits as well.

Thus, sustainable flow of ES from watershed depends highly on how humans interact with nature and on how natural ecosystem functions to deliver ES. Different ecological economists have subjected ecosystem functions to a number of explanations with respect to the ES they offer (De Groot et al., 2010). While some of these experts interpret ecosystem functioning with respect to internal function of the ecosystem (e.g. nutrient cycling and internal food-web interaction), other experts describe ecosystem functions with respect to the benefits delivered by human beings (De Groot et al., 2002).

De Groot (1992) defined ecosystem functions as "the capacity of natural processes and components to provide goods and services that satisfy human needs, directly or indirectly." On the other hand, TEEB (2008) defined ecosystem services as "the direct and indirect contributions of ecosystems to human well-being." TEEB perception on ES follows the MEA definition except that it makes a finer distinction between services and benefits and explicitly acknowledges that services can benefit people in multiple and indirect ways. Based on this updated definition by TEEB, an updated list of ES classification of is displayed in Table 1.

Table 1: Typology in ecosystem services in TEEB

Main service types	
Provisioning	**Habitat services**
• Food (e.g. fish, game, fruit)	Maintenance of life cycles of migratory species (incl. nursery service)
• Water (e.g. for drinking, irrigation, cooling)	Maintenance of genetic diversity (especially in gene pool protection)
• Raw Materials (e.g. fiber, timber, fuel wood, fodder, fertilizer)	
• Genetic resources (e.g. for crop-improvement and medicinal purposes)	**Cultural and amenity services**
• Medicinal resources (e.g. biochemical products, models & test-organisms)	Aesthetic information
• Ornamental resources (e.g. artisan work, decorative plants, pet animals, fashion)	Opportunities for recreation & tourism
	Inspiration for culture, art and design
Regulating	Spiritual experience
• Air quality regulation (e.g. capturing (fine)dust, chemicals, etc)	Information for cognitive development
• Climate regulation (incl. C-sequestration, influence of vegetation on rainfall, etc.)	
• Moderation of extreme events (eg. storm protection and flood prevention)	
• Regulation of water flows (e.g. natural drainage, irrigation and drought prevention)	
• Waste treatment (especially water purification)	
• Erosion prevention	
• Maintenance of soil fertility (incl. soil formation)	
• Pollination	
• Biological control (e.g. seed dispersal, pest and disease control)	

Source: Adapted from Costanza et al., 1997; TEEB, 2008; 2009; De Groot et al., 2002; 2010.

Sustainable flow of ES from watersheds depends highly on the integrity of ecosystem functions. As revealed in the Millennium ecosystem Assessment (MEA, 2005) many ES are being misused. Various ecologists and ecological economists have confirmed that efforts to increase the supply of one ES (such as food production) cause degradation of ecosystem and the supply of ES delivered by that ecosystem (MEA, 2005). Changes in consumer behavior and food preference, economic growth, population increase, climate change and variability have negative consequences on watershed ecosystems and their capacity to deliver ES, water in particular.

One of the greatest contemporary challenges facing the conservation experts and ecological economists is how to offset tradeoffs between conservation and utilization of ES from watersheds. While ecologists advocated watershed conservation for sustainable flow of ES (Pagiola, 2008; Pagiola, 2004a; b; MEA, 2005), poor local communities residing adjacent to watershed ecosystem thrive to exploit the resources from therein. The conflicting demands from watershed ecosystems are many (e.g. welfare vs conservation) and pose watershed degradation. Thus, a new conservation paradigm that aims at integrating economic ideas and conservation approaches in policies could bring about the attainment of the win-win objective. In recent years market based approaches for conservation have been spearheaded as potential approaches for the sustainable provision of ES while enhancing watershed integrity (MEA, 2005; Porras et al., 2005; Huang, 2009; Stanton et al., 2010). Market based approaches can complement regulatory approaches and / or become a key tool for lessening environmental predicament in the absence of a regulatory framework and support decentralization through resource management problems at the local level. Furthermore, the potential for market based approaches lies in the fact that they can also offer a way of improving livelihoods or at least lessening the adverse livelihood implications of land-use restrictions (Pagiola, 2008; Porras et al., 2005). As subset of market based approaches for conservation, payment for watershed services (PWS) is thought to be the best option for watershed conservation, enhancement sustainable flow of ES and for attaining conservation goals and livelihood objectives.

1.3 Payment for watershed services as a policy tool for conservation

The interest in payments for watershed services (PWS) as a policy tool for watershed management is growing tremendously notwithstanding being handicapped with funding, technical knowhow, institutional and policy failures, and poor governance (Porras et al., 2008; Stanton et al., 2010).

Payment for watershed services (PWS) has gained momentum as an alternative conservation paradigm after the failure of conventional conservation approaches (fence and/or fine). Sustainable flow of clean water for socio-economic and ecological integrity requires a healthy watershed ecosystem (Stanton et al., 2010). Pre-conditions for a watershed ecosystem do deliver a sustainable supply of watershed services (WS) depends on the interaction between the climate, pristine vegetation, water and soil condition of the particular watershed (Huang, 2009; Stanton et al., 2010). Thus, in order for a healthy watershed ecosystem to deliver WS and offset the tradeoffs between conservation and livelihoods, a new conservation approach has been proposed, i.e. PWS.

The term PWS has been defined differently by a number of ecological economists and conservation experts. Santon et al. (2010), referred a PWS as the initiatives driven primarily by voluntary action at the national, regional, and local levels, used to provide financial or in-kind incentives to land managers and land stewards to adopt practices that can be linked to the improvements of valuable WS. According to this definition PWS are market based motivations, incentives or payments (in cash or credit) aimed at motivating and changing the behaviour and attitudes of upstream communities to change unsustainable land use practices that degrade watersheds thereby curtailing their capacity to deliver WS.

PWS are preferred as conservation tool in the sense that they have the potential for internalizing costs that are perceived as negative externalities (Barbier and Swanson, 1992). As conservation tool, PWS are mechanisms for correcting the failure of conventional market to value WS. This is normally done by creating a favourable environment by bringing together sellers of WS (water) who are basically the guardians of watershed ecosystem and buyers of WS (water), the downstream water users (Gutman, 2006; Pagiola et al., 2004a; b). The concept of choice behavior is applied in the establishment and subsequent implementation of PWS schemes. A well-structured payment project can normally be economical and well-organized to influence stakeholder's preferences on land and water management in the entire watershed ecosystem. This kind of structure can enhance management of water resources in a holistic or in an integrated way. It can also help to create the awareness of stakeholders in the entire river basin on the value of WS and carry out environmental friendly land uses for sustainable water flow.

So long as PWS are sub-sets of payment for ecosystem services (PES) this work has adopted Wunder's criteria for analyzing ES. According to Wunder (2005) five criteria must be fulfilled in order the establish a feasible payment scheme: (i) A voluntary transaction where (ii) a well-defined environmental service (ES) (or a land use likely to secure that service) (iii) is being "bought" by a (minimum of one) ES buyer (iv) from a (minimum of one) ES provider (v) if, and only if, the ES provider secures ES provision (conditionality). In support of these criteria Lopa et al. (2011) emphasized that in order for a PWS scheme to become fully operational and deliver long term benefits for conservation and people's welfare, sustainable financing mechanisms need to be put in place that can continue after the initial establishment of the scheme. Unfortunately the majority of PWS in developing countries are surrounded by uncertain future and the sustainability of these established schemes is questionable. The majority operational PWS programmes are found in Latin America and Asia. Table 2 shows examples of selected PWS across the globe.

Table 2: Selected PWS programmes across the globe

Country	Programme activities	Source
Tanzania	**Equitable Payments for Watershed Services: Payment for Drinking Water;** It aims at improving the quality and flow of water for downstream users by compensating upstream farmers to engage in various land-use practices to control soil erosion brought on by unsustainable farmland expansion and irrigation practices, deforestation and illegal mining activities in river systems and within forest reserves.	Lopa et al., 2011
South Africa	**Working for Water (WfW) in South Africa; Water and Poverty Alleviation Program;** This is a government-led watershed rehabilitation project aimed at alleviating poverty through the provision of temporary work and skills development on watershed enhancement projects, involving mainly the removal of invasive alien plants. WfW trains teams to remove alien invasive plant species and thereby improve water supply.	Turpie et al., 2008
Australia	**Murray-Darling Basin: Water Transpiration Credits;** Land clearing has exacerbated salinization problems in many parts of the Murray-Darling Basin. This occurs because the lost vegetation no longer takes up water and transfers it back to the atmosphere so water tables rise and bring dissolved mineral salts to the surface. State Forests of New South Wales recently launched a pilot project which is testing how irrigation farmers can purchase transpiration credits from other landowners downstream. Irrigation farmers are purchasing transpiration credits from State Forests which plants trees on state land upstream	Johnson et al., 2002
Vietnam	**Rewarding Upland Poor for Environmental Services Programme (RUPES).** RUPES is a research program coordinated by the World Agroforestry Program (ICRAF) based in Bogor, Indonesia, whose mission is to develop practical environmental services schemes throughout Southeast Asia. RUPES is geared toward defining watershed ecosystem service schemes and the reward structures for the beneficiaries of these schemes.	Dung, 2003; Dung et al., 2004
France	**Vittel (Nestlé Waters) Payment for Water Quality.** Vittel catchment is at the foot hills of Vosges Mountains in north-eastern France. Perrier-Vittel is the world's largest bottler of natural mineral water. Its most important water sources are in heavily farmed watersheds where nutrient runoff and pesticides threaten the aquifers the company relies on. Perrier-Vittel has found that reforesting sensitive infiltration zones, financing farmers to build modern facilities, and switching to organic farming practices are cheaper than building filtration plants.	Perrot-Maître, 2006; Perrot-Maître and Davis, 2001.
Ecuador	**The Quito Water Fund (FONAG).** Is an example of a water trust fund aimed at improving water supply for the municipal drinking water, electrical utilities, private brewery, and water bottling companies. Generated funds are invested in critical conservation projects that involve strengthening parks and protected areas, supporting rural families to restore degraded lands and adopt sustainable farming practices, reforestation, and educating children about sustainable water management.	Echavaria, 2004
Brazil	**Water Producers Program in Espirito Santo State, Brazil.** It aims at compensating landowners and dairy producers who own remnants of native forest (standing forest) in strategic hydrological areas and thus conserve	Perrot-Maître and Davis, 2001

	and increase water quality and flow.	
United States of America	**Paying for Wetland Mitigation banking;** Is a market mechanism developed by the government aimed at conservation and restoration of degraded wetlands at a very minimum cost. Under this program, a "bank" of wetlands habitats is created, restored or preserved and later is made available to developers who must "buy" habitat mitigation as a condition of government approval for development.	Salzman and Ruhl, 2004; Pagiola et al., 2004a
Costa Rica	**FONAFIFO Program: Program for fund mobilization for forest catchment protection.** Under the Forest Law No 7575 enacted in 1996, the government of Ecuador established National Forestry Financing Fund (FONAFIFO) for financing farmers who involve in sustainable land uses. Under this programme participant were required to have a sustainable forest management plan certified by a licensed forester.	Pagiola, 2004; Zbinden and Lee, 2004.
Columbia	**Cauca River: Payment for Improvement of Stream Flow;** In this programme large agricultural producers in the Cauca Valley contribute fees through their water users' associations to finance watershed management practices in upland areas to improve base flows and reduce sedimentation in irrigation canals. A regional public development agency carries out watershed management activities and provides technical assistance to local communities and landowners carrying out watershed protection. Conservation activities includes: reforestation, erosion control, land purchases and protection agreements for springs and stream buffers, and economic development in upland communities.	Perrot-Maître and Davis, 2001.
United States of America	**Catskills project: Payment for Drinking Water Management Programme;** New York City initiated a voluntary agreement with the farmers, forestry landowners, and timber companies in the quest of their contribution to watershed conservation. Mostly rural Catskill / Delaware watersheds are the sources of drinking water for NYC dwellers. Under this agreement, a watershed agricultural council (WAC) was established to provide leadership for the improvement of land use practices upstream for sustainable and quality water flow.	Perrot-Maître and Davis, 2001.
India	**Benefit sharing programme between Sukhomajiri and Chandigarh villages.** The program aimed at improving water availability and stop sediment load transport to the Chandigarh village. This was carried out by collecting fees from downstream water users to fund infrastructure improvements and investment in watershed management. The program involved construction of a water reservoir in Sukhomajiri village for irrigated agriculture in Chandigarh village.	Kerr, 2004; Pagiola et al., 2004b (eds)
Ecuador	**Pimampiro payments for watershed services scheme.** Pimampiro is a small town in the state of Imbabura in northern Ecuador located along the Pisque watershed, which feeds into the Chota River, the main water source for the state. Water shortages exacerbated by pollution from agricultural activities necessitated the establishment of a payment scheme for watershed conservation for adequate water supplies. Under this initiative, landowners in Pimampiro were paid to manage the forest in the watershed in order to protect water sources.	Echavarria, 2004; Pagiola, 2004; Rojas and Aylward, 2003; Wunder and Albán, 2008.

Source: Adapted from different publications as indicated in the table

In the course of their implementation, some of the PWS programmes indicated in Table 2 have brought about multiplier effects to the environment. For example the initial aims of RUPES in Asia (Dung, 2003; Dung et al., 2004) and Cuencas Andinas in South America (Porras et al., 2008) focused on poverty reduction and livelihood improvement objectives. In later implementation phases these schemes have incorporated hydrological measurement and valuation researches. Through implementation, PWS programmes in Costa Rica have empowered smallholder farmers and indigenous communities to participate in conservation activities and in Los Negros in Bolivia, stakeholders are involved programme implementation by linking conservation and hydrological flow. Smallholder farmers are currently aware on the land use-water-nexus and they are implementing environmentally friendly agriculture including agroforestry, organic farming and other agro-conservation practices. These conservation activities are indicators of the multiplier effects of PWS programmes.

Despite the positive outcomes documented so far from PWS programmes, majority of them are hypothetical in nature, are donor dependent and are faced with the problem of sustainability. Specifically, it is difficult to manage and ensure the availability of funds from downstream buyers of watershed services for paying guardians of watersheds. Another challenge facing PWS programmes is how to deal with *"free raiders"*, i.e. individual who enjoy the service without incurring any cost for it. Practically it is hard to deal with stakeholders who take advantage of using water flowing along a river near their location (Lopa et al., 2011). Before reaching its final destination to the service buyers, a river flows from far away in the watershed across a number of villages or towns. It is therefore, difficult to deal with water abstractors (*"free raiders")* who are not part of the PWS scheme.

Land tenure and property rights (Ostrom et al., 1993), cost-benefit studies analyzing opportunity costs for alternative land uses are not well dealt with before the establishment of these programmes. Land ownership is one of the key criteria for PWS establishment. Unfortunately, majority of reviewed PWS initiatives neglected this aspect which later brought a lot of problems during the distribution of PWS benefits.

The majority of PWS programmes across the globe are found in developing countries where poor people depend entirely on natural resources to make their ends meet. PWS schemes are established without (the consent of the majority, i.e. poor) and critical analysis of the opportunity cost for alternative land uses and the cost benefit analysis. This leads in uncertainty of the programme and the sustainability of the conservation activities (Lopa et al., 2011; Echavaria, 2004).

It is quite difficult to ensure the service paid for, satisfy those people on demand who pay for it. Normally is hard to assure steady water flow and satisfy the demand of service buyers. In other words it is not clear that those paying through water use fees for PWS are getting the service and thus realize the value for their money. These uncertainties were reported in Mampiro payments programme (Echavarria, 2004); equitable Payments for Watershed Services (Lopa et al., 2011); the FONAG and FONAFIFO Programmes (Pagiola, 2004).

The majority of PWS in Table 2 have long term goals while majority of buyers of the services thrive to solve short term problems. A degraded watershed takes sometime in order to regenerate and enhance water flow. Sometimes it is even difficult to substantiate and give assurance that after certain time scale watershed conservation would result into increased water flow. Generally, there is little evidence yet that PWS schemes listed in Table 2 are matching up to the high expectations placed on them. There is still a lack of evidence that investing in land-management measures upstream has advantages over other measures to address downstream water-related problems. There is also insufficient evidence that payments to landholders would be effective in changing their behaviour or would make significant improvements to their livelihoods (Porras et al., 2008).

1.4 Challenges facing PWS implementation

Through the literature search and survey, it has been realized that there is a big gap between theory and practice about PWS implementation (Johnson et al., 2002; Dung, 2003; Dung et al., 2004). While upstream communities (sellers of WS) are not sure of receiving payments as reward for their involvement in watershed conservation, downstream communities (buyers of WS) are curious if their contribution would bring about a unit increase of water flow. This situation is really a big blow to the efforts of ecologists and conservation specialist dedicated to PWS initiatives.

The premise of PWS initiatives is that upstream communities are poor and their counters parts residing downstream are rich. Furthermore, Pagiola et al. (2005) asserted that in order for PWS to be an option and operational there must exist sellers and buyers of WS especially for private sector PWS initiative. Unfortunately, in many watersheds settings, there are no effective buyers of WS. Even where there are potential buyers, it is difficult to change the buyer's opinion (Wunder, 2005). Worse still, it is extremely difficult to convince the buyer in large and pristine watersheds.

Another challenge facing PWS initiatives across the globe is related to contract negotiations between sellers and buyers of WS and practical implementation of PWS initiatives. For instance Porras et al. (2008) linked supply and demand for WS in its practical implementation of PW programme. To him it was difficult to determine the following: (i) how to grade payment levels for a PWS programme? (ii) How to implement the transactions between sellers and buyers of WS? (iii) What is the unit (cash or in-kind) of the transaction and duration of the payments? and (iv) how to enforce and monitor the performance of the signed contract between buyers and sellers of WS?.

Other challenges of PWS programmes identified during this review include: difficult in clear linkages between conservation and increased water flow; uncertainty in willingness to pay for watershed conservation; and marginal effects of PWS on community wellbeing of sellers of WS.

1.5 Conclusions

Payments for watershed services (PWS) come into being as substitute for the failed conventional and regulatory approaches for watershed conservation. Despite gaining attention across the globe, much is still needed for effective implementation. Also, many of those on-going programmes are surrounded by uncertainty in terms of their sustainability. Majority of donor funded programmes won't last long as soon as the funding phase out. Thus self-revolving fund is crucial in order to ensure their future existence.

The majority of PWS programmes especially in developing countries are yet to show clearly their tangible contribution either to the community welfare or restoration of the degraded environment. While it is possible to visualize the signs of watershed restoration as a result of PWS activities, this review has indicated that is difficult and extremely tricky to quantity a unit increase of water flow as a result of PWS implementation. Furthermore, this review has not come up with clear evidence that paying upstream communities would improve their understanding and change their attitudes towards conservation. Similarly, it was also not clear that the amount paid would improve their income status and their livelihoods. Therefore, in-depth studies need to be undertaken in order to validate the positive outcomes of PWS initiatives.

Although PWS programmes are yet to bring about the intended objectives (to enhance socio-economic and ecological objectives), the awareness among the stakeholders (including resource marginalized communities) is a testimony of their potential as conservation tools. However, before implementation of these PWS programmes, there is a need to carry out cost benefit analysis studies in order to be sure of the opportunity costs for changes former land use to PWS initiatives.

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CHAPTER 3

Analysing Ecosystem Services at Watershed Scale: Implications for Conservation in Upper Kikuletwa Sub-Catchment, Tanzania

This chapter is based on:

Lalika, M.C.S., Meire., P. Ngaga, Y. M. Ngowi, S. E. and Schaafsma, M. (2014). Analysing Ecosystem Services at Watershed Scale: Implications for Conservation in Upper Kikuletwa Sub-Catchment, Tanzania. In: Donke, M. (ed.), ***"Welcome to Africa: Climate Change Adaptation in Eastern Africa."*** 4 – 12 March, 2013, Khartoum / El-Obeid, Sudan. Peer reviewed and edited conference proceedings: 204 - 223. **ISBN 978-3-942934-03-9.**

ABSTRACT

Catchment forests perform myriad ecological functions including provision of ecosystem services. They are, however, increasingly degraded due to anthropogenic activities in such a way their capacity to regulate and supply watershed services is significantly dwindling. We carried out this study in order to identify and document ecosystem goods and services in Upper Kikuletwa Sub-Catchment, Tanzania. A structured questionnaire was administered so as to solicit socio-economic data. Qualitative data was collected through group focus discussions and formal and informal interviews. Statistical Package for Social Sciences was used to compare means and MS excel was applied to generate figures. T-test and one-way ANOVA was applied to test the variation between location and across villages. Wild fruits, vegetables, grasses, birds, mushrooms are the ecosystem goods available in the area. Ecosystem services encompass control of soil erosion, climate regulation, water flow regulation, production of hydroelectricity, water purification, etc. The reason for WTP was people's reliance on irrigated agriculture. We concluded that sustainable supply of ecosystem goods and services in depends largely on how forests and watersheds are conserved. Therefore, we recommend designing of a feasible PWS scheme that could ensure increased and sustainable supply ecosystem goods and services especially water flow for irrigated agriculture.

Key words: *Catchment forest, climate change, watershed services, smallholder irrigators*

1.0 INTRODUCTION

1.2 Background of the problem

Forest ecosystems and their multiple ecosystem services (ES) provide the fundamental basis for human well-being, society and economy (Costanza et al., 1997; De Groot et al., 2002; Landell-Mills and Porras, 2002) that are key to local and global development. The global community can only fare well if the functions and production capacity of forest and their associated ES are maintained (Aylward, 2005; Carpenter et al., 2006; MEA, 2005). As the size of the human population increases, however, demand for ES is projected to increase at an alarming rate. In turn the sustainable conservation of forests and production of most ES is under threat and, in many places, in decline (Farraro, 2001; Brauman et al., 2007; Ferraro, 2009; Ferraro et al., 2002). Access to ES is also constantly reshaped under increasing commercial pressure on forests and land.

Recently, there has been an outcry for the rapid decline of ES that watersheds used to offer in the past (Costanza et al., 1997; De Groot et al., 2002; Kremen, 2005; MEA, 2005). Similar situation have been witnessed in different parts across the globe where dramatic fall of ES have posed serious challenges to forests and watershed conservation (Kulindwa, 2005; Kulindwa et al., 2006; Georgiou et al., 1997; Dixon, 1997). Growing population coupled with increasing human needs has resulted in greater demand for ES including supply of drinking water, water for industrial activities and energy production (hydro power production) and irrigated agriculture (Msuya, 2010; Notter, 2010; Lalika et al., 2011; Ngana et al., 2011). While the capacity of watersheds to provide ES has become erratic and increasing arithmetically, catchment forests and watershed degradation has been increasing exponentially.

ES especially water from catchment forests are vital for the wellbeing of human and natural environment, and are central to any economy in the world (Zoumides and Zachariadis, 2009). From an economic perspective, water resources are essential inputs to agriculture production and the global demand for water has increased over time with increasing population, rising incomes, and changes in dietary preferences (de Fraiture and Wichelns, 2010). Water shortages have posed strong challenges to catchment forest and watershed conservation. Overexploitation of forest areas potential for water conservation threatens the resource base on which irrigated agriculture depends (Falkenmarket al., 2007).

Like elsewhere around the globe, catchment forests and watersheds in Upper Kikuletwa Sub-Catchment (UKSC) in Pangani River Basin (PRB) are currently facing a number of environmental problems most of which are related to deterioration of water flow and failure to recognize and value economic benefits of hydrological services they provide (Kulindwa, 2005; Turpie et al., 2005). Research and previous studies on forest health conducted in PRB shows that between 1952 and 1982, catchment forest in PRB has been in tremendous decline (Newmark, 1998).

Problems related to catchment forests and watershed degradation have been tackled in a number of ways in Tanzanian. In Kibungo sub-catchment in the south-eastern Uluguru Mountains (UM), the government of Tanzania has developed the policy foundation for Payment for Environmental Services (PES) (Lopa et al., 2012) by building on earlier consultancy studies (Kulindwa, 2005; Mwanyoka, 2005; Kulindwa et al., 2006). CARE International and WWF Tanzania have jointly been implementing the Equitable Payments for Watershed Services (EPWS) project with special emphasizes on fair and equitable distribution of benefits accruing from the sale of ES to downstream users.

Payments for Watershed services (PWS) has also been extensively and successful been implemented in Latin America (e.g. Costa Rica, Bolivia, Ecuador, Columbia, Guatemala, etc), Mexico, USA and in Asia as means for rewarding guardians of catchment forest for their involvement in conservation initiatives (Ferraro, 2001; Ferraro and Kiss, 2002; Pagiola et al., 2005; Wunder, 2007, Pagiola, 2008; Wunder et al., 2008; Clements et al., 2010). Despite the positive signs and success stories of PWS implementation across the globe, there is limited information on the available ES in UKSC. Moreover, mechanisms for rewarding upstream communities residing adjacent to watersheds are not known. We carried out this study in order to bridge the existing information vacuum. Findings of this study and subsequent policy recommendations will form the basis for the establishment of PWS in UKSC.

1.2 Theoretical framework for the study

Figure 1 presents the framework of analysis that guided our study. It is a hypothetical payment scenario where key players and beneficiaries of ES were expected to interact in a winwin situation. The framework demonstrates the prevailing situation in terms of water and money flows for a fair and feasible PWS scheme.

Black arrows show water flowing downstream from catchment forests. In return water supply authorities and water basin offices (PBWO) receive money (dotted arrows) as payments for provision of the service. While the service (water) originates from watersheds upstream where the forest guardians (poor local communities) are found and play a significant role to conserve the watersheds, there is no any flow of resources (funds) to them (Figure 1). Making downstream water users understand the need for donating more funds for catchment forest conservation. Furthermore, this conservation mechanism is vital to the welfare of the upstream communities.

In this paper we present types of ecosystem goods and services; different approaches used in the restoration of catchment forest and watersheds in UKSC; willingness to pay for watershed services and returns to scale from irrigated agriculture. In addition, the paper recommends further action for the restoration of UKSC as single unit.

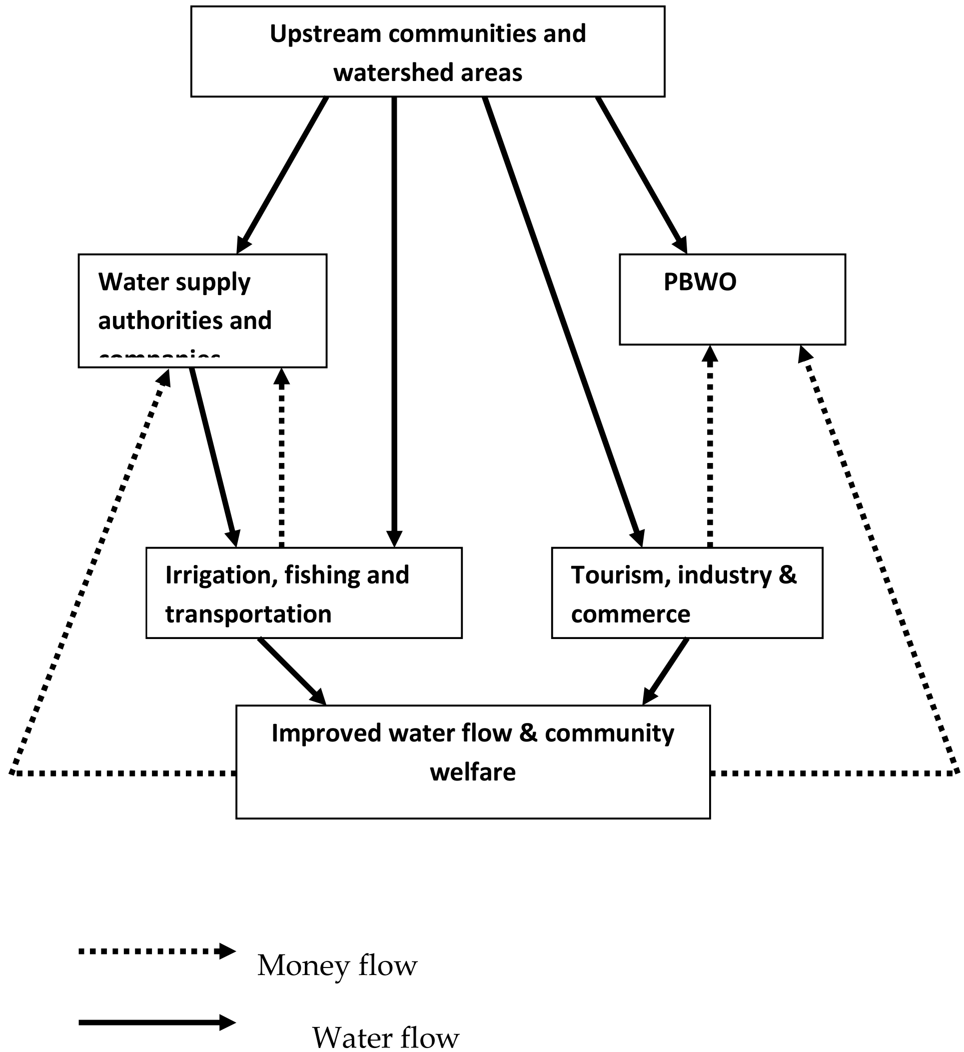

Figure 1: Analytical framework for the study

2.0 MATERIALS AND METHODS

2.1 Location of the study area

The study was carried out in Upper Kikuletwa Sub-Catchment (UKSC) in Pangani River Basin Tanzania (Figure 2).

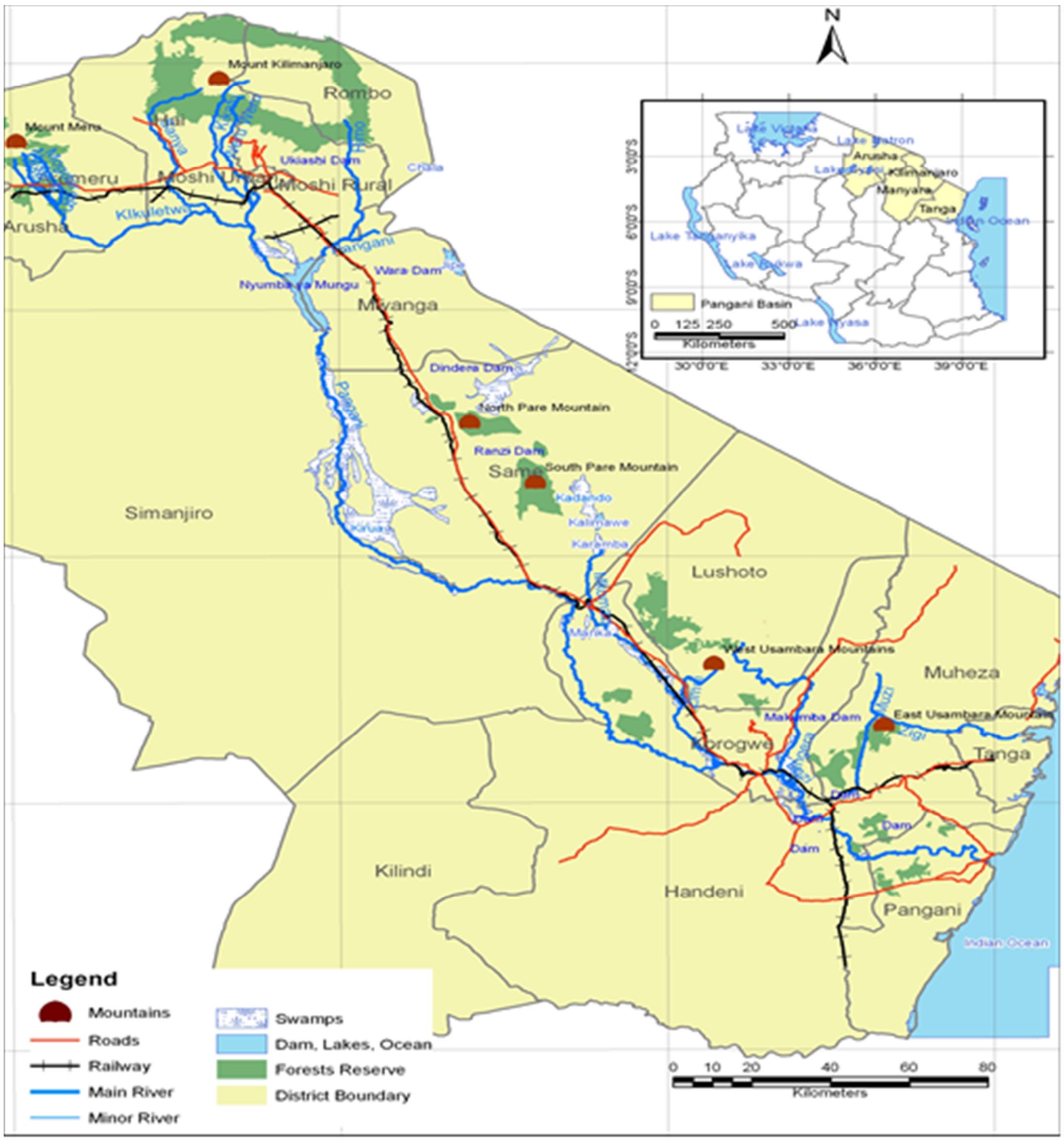

Figure 2: Location of the study area in Pangani River Basin, Tanzania.

UKSC located in North-western part of Pangani River Basin which originates from both Meru and Kilimanjaro Mountains between 30 and 50 south of Equator. UKSC is (9,320 km2) a source of Kikuletwa River and major tributaries of the river include Usa River, Makumira, Ngarenaro, Maji ya Chai and Tengeru. Irrigated agriculture is a key economic activity in KCSC because rainfall is erratic and unreliable. Average rainfall ranges from 1000 to 700 mm and varies with elevation. Precipitation decreases from the lower forest boundary down to the plains where it is less than 700mm annually. Temperature is closely related to altitude. It ranges from 150C to 300C with the minimum temperature 120C to 170C. Vegetation mainly riverine forest is found along Kikuletwa River and around water sources.

2.2 Data collection

2.2.1 Sampling procedure

A simple random sampling technique was used to select the sampling units in order to avoid bias. This technique allows selection of a sample from the entire population in such a way that every member of the population has an equal chance of being selected. The sampling frames for this study were the village registers containing the list of all household in the respective villages. In each village, households were randomly selected using a table of random numbers. The respondents were selected by matching their numbers in the register. For the purpose of this study, the study was divided into two parts. Western Kikuletwa where the majority are indigenous (Meru tribe) and Eastern Kikuletwa inhabited by emigrants who settled in the area after the downfall of plantation (sisal) economy.

A total number of 242 respondents were interviewed, 112 and 130 in Western and Eastern Kikuletwa respectively (Table 1).

Table 1: Interviewed household heads

Region	Village	Total households	Sample size	Sampling Intensity (%)
Eastern	Makiba	660	66	10
Kikuletwa	Kwaugoro	640	64	10
Western	Kikuletwa	640	64	10
Kikuletwa	Karangai	480	48	10
	Total	**2420**	**242**	**10**

2.2.2 Research phases

The study was divided into two parts. The first one involved reconnaissance survey with the aim of familiarizing the researcher with the study area and select study villages. Another key activity during phase one was to carry out questionnaires pre-testing. This is an essential step for socio-economic studies not only because it helps the researcher to check the questions for their validity and reliability but also is very important in identifying weaknesses, ambiguities and/or omissions before modifying the questionnaires to suit the prevailing environment for the main study.

Phase two involved questionnaire survey in the four villages (Table 1). A structured questionnaire containing both open ended and closed questions was the main tool for collecting socio-economic data. Questions were mainly on water utilization, types of water sources, methods of watershed conservation, type of crops irrigated, payment methods for water utilization, willingness to pay for water utilization, types of economic activities; other goods and services available PRB; just to name a few.

2.3 Data analysis

The 242 structured questionnaires were coded, cleaned and wherever applicable data from open-ended responses were categorized and transformed to enable further analysis. All quantitative analyses were performed using Statistical Package for Social Sciences (SPSS) version 16.0. Multiple responses were carried out to obtain frequency and percentages of responses and MS Excel was used to create figures.

To test crop production, two statistical methods for hypothesis testing were employed. While t-test was used to test the differences between yields in the two locations Eastern and Western Kikuletwa, one way ANOVA was employed to test and compare mean yields across villages.

3.0 RESULTS

3.1 Ecosystem goods and services delivered by UKSC

Figure 3 presents our results on ecosystem goods accrued in UKSC. In this study, goods are defined as use values that are used directly for consumption.

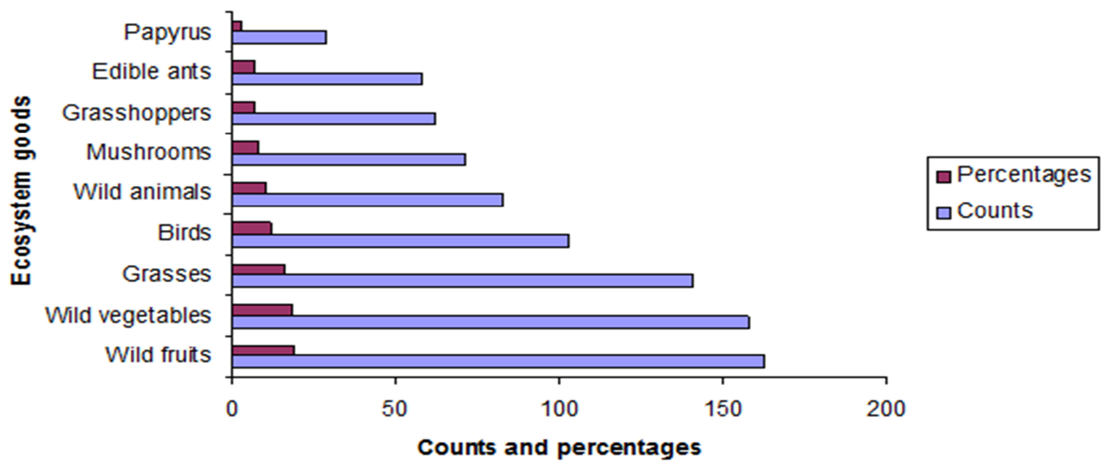

Figure 3: Ecosystem goods delivered by PRB, Tanzania

In rural UKSC, local communities collect wild fruits from catchment areas either for sale or household use. During our survey we identified indigenous fruits such as syzgium cumminii, ficcus thoningii, etc. Local people engage in this kind of petty business as employment and income generation activity as well (Yemiru et al., 2010). According to personal communication Santoni Todayo (personal communication, 2012) in UKSC the return to scale from this kind of business was reported to be meagre to solve financial difficulties confronting many families. Other ecosystem goods include wild vegetable for domestic consumption, grasses for house construction, etc. With respect to ES, we identified a number of them as revealed in Table 2.

Table 2: Respondents opinion about ecosystem functions and services along UKSC

Ecosystem services	Frequency (n)	Percentage (%)
Soil erosion control	180	21
Climate regulation	153	19
Water flow regulation	159	19
Hydroelectric power production	108	13
Water purification	88	10
Hazard mitigation	81	10
Wild habitat	39	5
Spiritual and artistic inspiration	36	4

Results in Table 2 shows that majority of the respondents (21%) indicated control of soil erosion as the ES they enjoy most in UKSC. This may be attributed to the fact that the area is mountainous, thus presence of natural vegetation (natural trees, herbs and grasses) slows down surface runoff and sediment load transport. Furthermore, soil erosion control enhances maintenance of productivity of farms (nutrient retention) and safeguarding water sources, river, streams and springs from siltation (De Groot et al., 2002).

A good land cover (e.g. Meru Mountain, Arusha National Park, and other protected areas) regulates climate thereby playing a decisive role in reducing temperature and modifying rainfall. The presence of natural vegetation in this area improves microclimate condition and air purification for settlements, human and animal health and crop production. The cool weather condition attracts many tourists and has been termed as the "Northern Tourist Circuit" due to its favourable and good weather condition for tourism industry.

A good and intact land cover regulates surface runoff, ground and surface water discharge, environmental flow and water supply eventually. During our study we noticed that water from river Nduruma, Themi, Tengeru, Malala and presence of different water streams and springs testifies the role of catchment forest in water regulation (Costanza et al., 1997). The catchment forest acts as sponge by regulating water flow gradually downstream. Water flowing downstream enhances economic undertakings such as irrigated agriculture, water for domestic uses, industrial activities, to name just a few.

3.2 Approaches used to conserve water sources

Four main methods were revealed i.e. retaining riparian vegetation (46%); tree planting (33%); prohibiting river bank cultivation (12%), and removing weeds and sediments (9%).

Table 3: Methods used in conserving water sources in PRB, Tanzania

Approaches	Counts (n)	Percentage (%)
Retaining natural vegetation	129	46
Tree planting	94	33
Prohibiting river bank cultivation	34	12
Removing weeds and sediments/muds	25	9

From ecological point of view retaining natural vegetation and avoiding river bank cultivation are recommended techniques for optimizing multiple benefits of watershed function. Some of the retained trees in their natural habitats for watershed conservation include Rauvolfia caffra, Melicia excelsa and Ficus sycomorus and varieties of herbs species.

3.3 Ecosystem services and irrigated agriculture

Average yield in irrigated and rainfed agriculture are presented in Table 4. These results revealed that irrigated agriculture seemed to outweigh yields under rainfed agriculture. Apparent reason for this variation in crop yield is that rainfall is not reliable and predictable due to a number of reasons including climate change and variability. The highest amount that smallholder irrigators are willing to pay was Tanzania shillings 50,000/=.

Table 4: Crop yield and benefits from water uses in UKSC, Tanzania

Location	Village	Variable	Land size (ha)	Yield with irrigation (kg)/year	Yield without irrigation (kg)/year	Amount paid for irrigation water (Tshs)/year
Eastern Kikuletwa	Makiba	Mean	2	600	1549	4376.70
		Maximum	7	8000	6000	36000.00
		STD	1.3	1059	1137.4	5227.90
	Kwaugoro	Mean	1.8	1124	569.2	3461.70
		Maximum	10	10000	6000	15000.00
		STD	1.6	1390	890.1	2625.40
Western Kikuletwa	Kikuletwa	Mean	1	967	490	44250.80
		Maximum	4	5000	7500	600000.00
		STD	1	942	974.1	128528.90
	Karangai	Mean	1	14067	756	12222.20
		Maximum	4	32000	20000	36000.00
		STD	1	4583	2909.4	7098.00

Based on the findings presented in Table 4, we carried out one-way ANOVA in order to test whether the average yields for irrigated crops were significantly different between the two locations and across villages. Findings are summarised in Table 5.

Table 5: Comparison of average crop yield for different locations in UKSC, Tanzania

Location	Mean + SD	t and f-value
Eastern Kiluletwa	966.1 ± 1195.8	
Western Kikuletwa	882.8 ± 2628.8	0.45 NS
Villages	**Means + SD**	**t and f-value**
Makiba	1085.7 ± 1189.1	
Kwaugoro	846.5 ± 1195.4	0.115 NS
Kikuletwa	730.6 ± 983.9	
Karangai	1083.1 ± 3840.8	0.985 NS

F - value = 0.922; P - value = 0.43; ***NS =*** *Non Significant (i.e. P > 0.05)*

Findings in Table 5 revealed that there was no significant different (P = 0.45) in crop yields between Eastern and Western Kikuletwa. With respect to yields between and across villages we found no significant different too. Similarly, ANOVA results between the two locations indicated no significant variations in crop yields.

4.0 DISCUSSION

Ecosystem goods presented in Table 3 typifies rural phenomenal and village scenario where local communities harvest these nutritious non-timber forest products (NTFP). Wild fruits, vegetable and mushrooms are readily available ecosystem goods that are harvested freely in the wilderness. In UKSC these NTFP not only support the community wellbeing, but they also plays a key role in income generation (MEA, 2005). Thus, initiatives aiming at sustainable conservation against environmental degradation and climate change are key to sustainability. It is, therefore, high time to put emphasize on conservation of these ecosystem goods especially in areas where majority are poor and reliant on natural resources (Egoh et al., 2007; 2011; 2012).

ES displayed in Table 2 depend on each other and sustainability of one ES relies on how other ES are utilized and managed. For instance water regulation that enhances water flow for irrigation, power production (HEP), industrial purposes, and domestic uses depends largely on how UKSC is conserved to control soil erosion and regulate climate. A well conserved catchment forest acts as sponge by releasing water gradually and modifying climate (Lalika et al., 2011). Once a catchment forest is degraded beyond repair, it implies that other ES such as water purification, hazard mitigation, wild habitat maintenance are compromised.

For instance, once UKSC is sustainably conserved, the local communities most of which are poor will be able to enjoy the benefits from therein, and improve their welfare as well. Other multiple benefits will be indirectly realised as such. They, according to Egoh *et al.* (2008), include maintenance of a favourable climate, both at local and global scales, which in turn are important for, among others, human health, crop productivity, recreation and even cultural activities and identity.

Water regulation influences forest ecosystems on the regulation of environmental flows (Costanza et al., 1997; de Groot et al., 2002). Thus, the capacity of a catchment forest or watershed to perform this essential ecological function depends largely on how local communities utilize the resources from therein. According to Costanza et al. (1997), ES associated with water supply relate to the consumptive use of water by households, agriculture and industry. Local communities in UKSC have been exploiting unsustainably, thereby threatening future water supply. Consequently, water for irrigation and other domestic uses for instance, is nowadays compromised contrary to the past (Kulindwa, 2005). Thus striking the balance in water regulation is vital because too little as well as too much surface runoff can cause serious problems (Costanza et al., 1997). A clear example is the excessive water flow that culminated in land slide in Same District in Eastern Arc Mountains along PRB, Tanzania two years back.

Retaining natural vegetation has been a key approach for conservation of nature since time immemorial. Protected areas where catchment forest and watersheds a found, the ideal conservation approach is in situ conservation. We found similar scenario for UKSC where conservation of catchment forest within their natural environment was preferred over other methods. This could be a key to the revival of water supply and environmental flow. Ecologically, advantages are many as this approach would enhance realisation of multiple ecological and socio-economic ES including conservation of ecological diversity and community wellbeing.

The absence of significant variation (difference) in crop yield (Table 5) denotes similarities in production potential of the two locations and across villages. The difference in crop yield just by one bag of 100kg and/or below in some instances is quite small. Thus, water which is an important ES for irrigation should be managed equally to boost agriculture productivity for community wellbeing. Machethe et al. (2004) reported similar findings that irrigated agriculture plans should include water regulation an important ES for poverty alleviation directives.

5.0 CONCLUSIONS

The study has indicated that ecosystem goods and services delivered by UKSC are mainly regulating and provisioning. While wild fruits and vegetables were reported to be the preferred ecosystem goods in UKSC, ES that preferred by majority of respondents are soil erosion control, climate regulation, water flow regulation and hydroelectric power production. In some instances, it was difficult to draw a line to demarcate ecosystem goods viz-a-viz ES due to their close complementarities. Generally, provisioning and regulating categories are the ecosystem goods and services found in UKSC and developing countries at large. And this calls for integrated approach for their conservation and restoration of catchment forest in the study area. Water flow regulation and water supply enhance irrigated agriculture through the provision of water for crop production. Results from a comparative analysis through t-test and one way ANOVA indicated non-significant variation in crop yield between Eastern and Western Kikuletwa and across villages in UKSC. Similarly, human being dependency on rainfed agriculture is a typical phenomenon in UKSC as is the case for majority of small holder farmers in less developed economies. Furthermore, the capacity of UKSC to provide goods and services sustainably depends on how the ecosystem good and services are utilized and managed. In the context of above remarks, we propose that any conservation intervention should be geared towards restoration of UKSC as a single unit at an integrated and holistic approach by bringing together all interested parties.

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CHAPTER 4

Paying to Conserve Watershed Services in Pangani River Basin Tanzania

This chapter is based on:

Lalika, M.C.S., Meire., P. and Ngaga, Y. M. (2015). Paying to Conserve Watershed Services in Pangani River Basin Tanzania. In: Hipel, K, W, Fang, L., Cullmann, J. and Bristow, M. (eds.). "*Conflict Resolution in Water Resources and Environmental Management*". Springer (Heidelberg). Germany. **Peer reviewed and edited book chapter. ISBN 978-3-319-14214-2**

ABSTRACT

Human beings depend on the integrity of watersheds to provide ecosystem services (e.g., water) that they need for their survival. The current watershed degradation represents the most serious threat to the provision of watershed services. The worldwide demand for integrated approaches to provide solutions to water flow reduction represents a significant shift towards management focussed on the sustained use of water catchment areas. This paper reports the findings of a study that was carried out to explore the potential for paying for the management of watershed areas in the Pangani River Basin in Tanzania. Site visits enabled the collection of hydrological data, and documented reviews and structured questionnaires were used to collect socioeconomic data. MS Excel was applied in drawing figures. We found that the minimum and maximum quantities of water discharge were 11 300 365m^3 and 15 839 833m^3 and 7 787 600m^3 and 8 602 361m^3 in Arusha and Moshi, respectively. Similarly, the minimum and maximum revenue collections from water users were €987766, 60 and €1659160, 71; and €920916, 40 and €1456075, 49 as projections and actual revenue collection, respectively. We conclude that water supply problems are caused by watershed degradation and obsolete water infrastructures. We recommend the integration of payment for watershed conservation approaches into watershed management to enhance sustainable water flow.

Key words: Watershed degradation, Water flow, Ecosystem services, Forest cover, Conservation

1.0 INTRODUCTION

Many ecosystem services (ES) from watersheds have gained attention in recent years across the entire globe (De Groot, 1994; Pattanayak, and Kramer, 2001; Pattanayak, 2004). Governments, international conservation organisations, private firms, and individual firms are progressively paying attention to the value of the innumerable ES provided by these watersheds (Krishnaswamy *et al.,* 2006; Lopa *et al.,* 2011). This awareness has drawn attention to the economic benefits of intact ecosystems and conservation initiatives, which had been taken for granted until recently (Pagiola *et al.,* 2002; Lalika *et al.,* 2011).

Increase of human population and pressure on watersheds in recent years (MEA, 2005; Lalika *et al.,* 2011) in search of ES is to blame for degradation of the resource base (Egoh *et al.,* 2012). The current conservation and incentive structures for sustainable conservation of watersheds across the globe have rarely motivated the upstream communities who pay the opportunity cost for watershed conservation (Panayotou, 1994; Costanza *et al.,* 1997; Daily *et al.,* 2000; Landell-Mills and Porras, 2002; MEA, 2005). As a result, land uses that provide watershed services are rarely enhanced at a socially and economically optimal scale, marginal upstream landowners continue to remain poor, and the downstream water users are gradually facing water supply fluctuations.

As in elsewhere around the globe, watersheds in the Pangani River Basin (PRB) are currently facing environmental degradation, due to the lack of sustainable approaches to conservation (Kulindwa, 2005; Mwanyoka, 2005; Turpie *et al.,* 2005; Sotthewes, 2008; Notter, 2010; Lalika *et al.,* 2011). Kilimanjaro Mountain, for instance, which is located within the PRB, is facing rampant environmental degradation to such an extent that even the distinctive snow at its peak is projected to disappear completely by 2020 (Kamugisha, 2009). Environmental changes to the mountain through anthropogenic activities have contributed to the inefficiency of watersheds to supply water downstream (Kulindwa, 2005; Ngana *et al.,* 2010, Notter, 2010; Msuya, 2010). For PRB residents, their livelihoods, quality of life, community and children’s health, and ultimately, the ability to survive are dependent upon effective watershed and water management. Degradation of watersheds means water scarcity and the emergence of conflicts among water users (Mbonile, 2005).

Water shortages especially during the dry season contribute to hydroelectricity production fluctuation, resulting in power cuts. The three hydroelectric power plants located along the PRB contribute up to 17% of the country's power capacity, which is mainly from hydropower (Ngana, 2001; IUCN, 2007). Power production at Nyumba ya Mungu Dam (NyD), the biggest reservoir for hydropower generation in the PRB, and its sister hydroelectric power plants (Hale and New Pangani) rely on water from the PRB watersheds. Recent studies carried out in the PRB (Ngana *et al.,* 2010, Notter, 2010; Msuya, 2010; Lalika *et al.,* 2011; Hellar-Kihampa, 2013) indicated that there is a need for direct and innovative solutions for ecosystem conservation. Paying communities who reside in proximity to watersheds is perceived to be the ideal approach for sustainable watershed conservation (Muñoz-Piña *et al.,* 2008; Cantor *et al.,* 2012; Thatcher, 2013).

While successful stories for payment for watershed services (PWS) implementation have been reported widely at global and local scales (Landell-Mills and Porras, 2002; Pagiola *et al.,* 2002; Pattanayak, 2004; Pagiola *et al.,* 2005; Pagiola, 2008; Cantor *et al.,* 2012), there is limited information on how PWS would be able to enhance watershed conservation in the PRB. Similarly, information on the amount of money to be set aside for watershed conservation is not known. Therefore, enhancing PWS as a policy option for watershed management in the PRB is crucial. Once the mechanism for benefit sharing and rewarding upstream communities for their involvement in watershed conservation is known, it will be easier to bring together sellers of ES (upstream communities) and buyers of the service (downstream water users). We carried out this study in order to identify and examine watershed conservation techniques that are in place in the PRB; to determine funds allocated for financing watershed conservation; and to document projected and actual revenue collection from downstream water users in the PRB.

2.0 MATERIALS AND METHODS

2.1 Location and description of study area

This study was conducted in four villages, namely, Kaloleni, Rau River, Chekereni and Lekitatu, along PRB, Tanzania (Figure 1). The PRB extends from the northern highlands to the north-eastern coast of Tanzania. It lies between latitude 03º 05' 00" and 06º 06' 00" south and longitude 36º 45' 36" and 39º 36' 00" east.

The PRB is the largest river basin within the Pangani Basin (PB) and covers an area of about 43,650 km^2 (IUCN, 2003). The terms "PRB" and "PB" have two different meanings. The former refers to the basin where the Pangani main river and its river tributaries are located, whereas the latter incorporates the PRB and the other three smaller basins, i.e. Umba, Zigi-Mkulumuzi and Msangazi (IUCN, 2003; Faraji, 2007, IUCN; 2007). PB is a shared transboundary resource between Tanzania and Kenya (IUCN and PBWO, 2008).

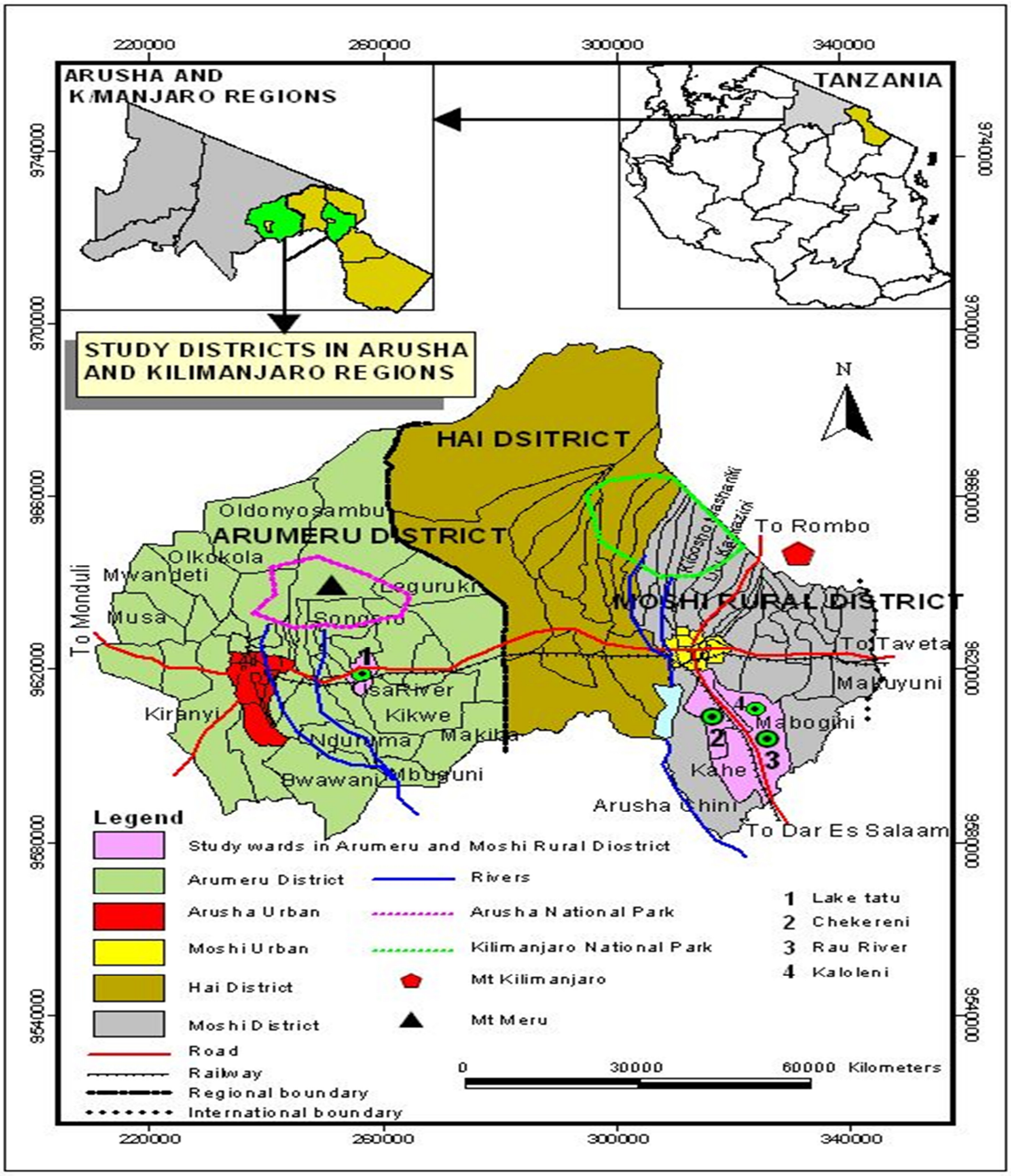


Figure 1: Location of the studied villages in Pangani River Basin, Tanzania

The PRB, which is the focus of this study, drains the southern and eastern sides of Mt. Kilimanjaro (5,985 m) as well as Mt. Meru (4,566 m), then passes through the arid Maasai Steppe in the west, draining some of the Eastern Arc Mountains (Pare and Usambara Mountains, which are World Biodiversity Hotspots) (Newmark, 1998; Mwanyoka, 2005; Mbeyale, 2009), before discharging into the Indian Ocean at Pangani Estuary. The PRB hosts an estimated 3.8 million people, 80% of whom rely directly or indirectly on irrigated agriculture for their livelihoods (IUCN, 2007; IUCN and PBWO, 2008; Kamugisha, 2009).

Vegetation in the PRB ranges from forests on mountain slopes, to semiarid grasslands (IUCN, 2003). The major vegetation types include forests, woodlands, bush lands, grassland thickets and plantation forests (Turpie *et al.*, 2005). Excessive forest utilization has led to forest degradation and previous studies show that the natural forest in the Kilimanjaro region declined by 41 km^2 between 1952 and 1982 (Lambrechts *et al.,* 2002). The main causes of forest degradation and deforestation include encroachment for settlement and agricultural, and increasing demand for forest products (mainly timber and fuel wood) (IUCN, 2003).

2.2 Research design and sampling procedure

We used a cross-sectional design as suggested by Casley and Kumar (1988) and de Vaus (1993) to execute field activities. The design allowed us to collect information at one point in time. To avoid bias in choosing respondents for our questionnaire survey, we adopted a simple random sampling technique. This technique allowed us to select respondents from the entire population in such a way that every member of the population had an equal chance of being selected. The sampling frames for this study were the village registers containing the lists of all households in the respective villages. The sampling units for our study were households, because household are where all decisions are made with the head of the household being the ultimate decision maker. In each village, we randomly selected households using a table of random numbers by matching their numbers in the register books. Within each of the identified four villages, a random sampling technique was adopted to identify respondents, and 10% of the total households in each village were selected for interviews. Due to the variations of total population in the study villages, 10% of all households were adequate to get a representative sample for our study. Therefore, a total of 163 household heads were sampled as indicated in Table 1.

Table 1: Total number of households sampled for questionnaire interviews

Village	Total households	Sample size	Sampling intensity (%)
Kaloleni	490	49	10
Rau River	340	34	10
Ckekereni	550	55	10
Lekitatu	250	25	10
Total	**1630**	**163**	**10**

2.3 Data collection methods

We executed this study in two main phases to collect both primary and secondary data. During phase one, we carried out a reconnaissance survey with the aim of familiarizing ourselves with the study area, pre-testing questionnaires and selecting study villages. Questionnaire pre-testing is an essential step for socioeconomic studies not only for checking the validity and reliability of the questions, but also for identifying weaknesses, ambiguities and/or omissions necessary for the main study.

In phase two, we collected socioeconomic data in the four villages using a structured questionnaire as the main field tool. We also used writing pads to document interesting and useful information from respondents whenever appropriate. During this research phase, we also carried out field excursions to identify the location of spatial features (such as springs, rivers, wetlands, dams and swamps/marshes); catchment forests; and irrigation farms. During field excursions, we conducted formal and informal interviews in order to attain insights on watershed services in the PRB. We collected data on water discharge from gauging stations after every hour for twenty-four hours. We also consulted response officers from the Arusha Urban Water and Sewerage Authority (AUWSA) and Moshi Urban Water and Sewerage Authority (MUWSA) for more data and information on water discharge and production.

Moreover, we collected secondary data from relevant published and unpublished reports. This information was collected from regional and district water authorities (e.g. AUWSA and MUWSA), Pangani Basin Water Office (PBWO) and the International Union for Nature Conservation (IUCN) Water and Nature Initiative (WANI) project. We conducted a literature survey and review in order to understand the water flow situation and supply and the efforts made so far by different actors for watershed conservation in the PRB. Various reports for studies conducted in the PB were also extensively reviewed. They include River Health Assessment Final Report (PBWO and IUCN, 2007); Pangani Basin: A Situation Analysis Volume 2 (PBWO and IUCN, 2009a); Pangani River Basin Flow Assessment: Basin Delineation Final Report (PBWO and IUCN, 2008a); Development of Climate Change Scenarios (PBWO and IUCN, 2008b); and Hydroelectric Power Modelling study (PBWO and IUCN, 2009b). Key issues during secondary data collection include water supply, quantity of water sold, budgets for watershed management, revenues from water sales, water user payment mechanisms, main water users, and problems related to water flow, just to name a few.

2.4 Data analysis

Later on the 163 structured questionnaires were coded, cleaned, categorized and transformed to enable analysis. Quantitative data (collected through the structured questionnaires) were analysed using Statistical Package for Social Sciences (SPSS) version 12.0. Multiple analysis was carried out to obtain frequency and percentages of responses from respondents, and tables were constructed. Data on quantities of water production, revenue projections and actual collection for water utilization were summarised, and MS Excel was used to draw figures based on the data. Before being used in MS Excel, information related to finances were converted from Tanzanian shillings (Tshs) to Euros (€). The exchange rates used is: 1€ = 2,273 Tshs.

3.0 RESULTS

3.1 Watershed management techniques

We found that water control and decision-making with respect to watershed management are guided by various local approaches and different management techniques in the study area. As indicated in Table 2, building concrete walls/canals (92%); retaining riparian vegetation (85%); tree planting (85%); uprooting weeds and removing muds in water canals (81%); and removing muds in water sources (81%) are the water management methods that are in place in the study area.

Table 2: Watershed management techniques in PRB, Tanzania

Activity	Frequency (n= 161)	Percentages (%)
Building concrete walls/canals	148	92
Retaining riparian vegetation/trees	137	85
Planting trees	136	85
Uprooting weeds and removing muds in water canals	130	81
Removing muds and weeds in water sources	131	81
Total responses	**682***	**424***

*The total responses for frequency (682) and percentage (424%) are greater than 161 and 100%, respectively, due to multiple responses.

From the table above it is evident that almost all techniques are applied in watershed management as the range between the techniques with the highest and lowest score is just 11%. Nonetheless, from an ecological point of view, retaining riparian vegetation and planting trees are favourable techniques for watershed management because they have multiple benefits as far as watershed functioning and delivery of ecosystem services is concerned. Some of the retained trees in their natural habitats (e.g. *Rauvolfia caffra*, *Melicia excelsa* and *Ficus sycomorus* and varieties of *herbs* species) control soil erosion, purify the air, and serve as habitats for wild animals.

3.2 Water supply and sale for domestic uses

Analysis of water discharge indicated that Moshi had high figures in terms of maximum and minimum water discharge as compared to Arusha (Figure 2).

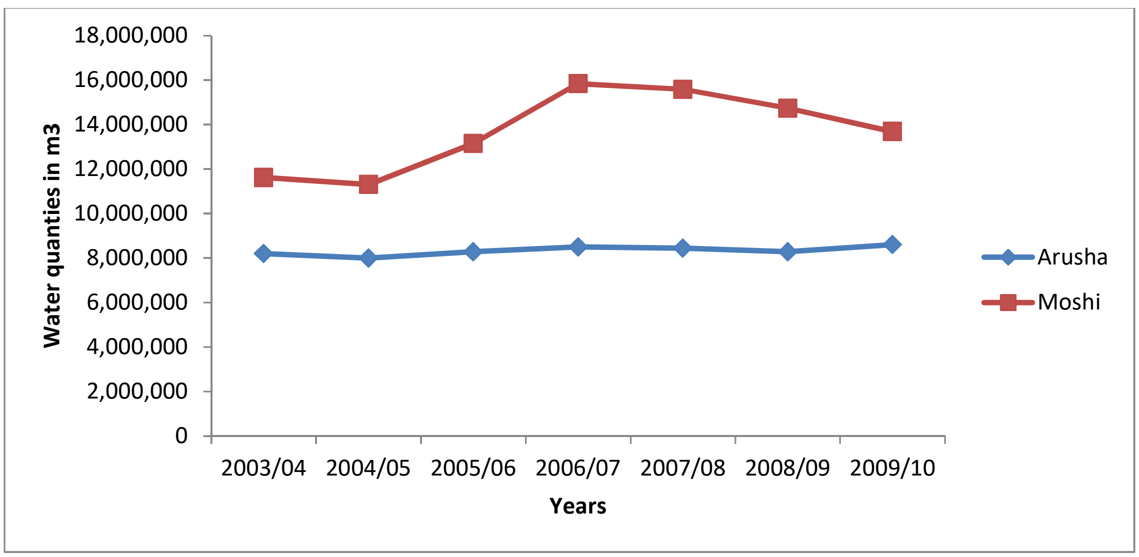


Figure 2: Water discharge from 2003/04–2009/10 in Moshi and Arusha, Tanzania.

The minimum and maximum quantity of water discharged in the study sites is 11 300 365 m^3 and 15 839 833m^3 and 7 787 600 m^3 and 8 602 361 m^3 in Moshi and Arusha, respectively. In both cases, sources of water for domestic use are natural springs and bore holes. We found that water sources for Moshi town are from *Shiri* and Nsere springs and two boreholes, namely Mawenzi, Kilimanjaro Christian Medical Centre (KCMC) and Karanga. MUWSA is the government agency responsible for water abstraction, water infrastructure development and water supply in Moshi town. Like MUWSA, AUWSA is the government agency responsible for water abstraction, water infrastructure development and water supply in Arusha town. AUWSA has a mandate of managing water sources for Arusha town. These sources include Masama, Oldadae, Olesha and Midawe springs; and Sekei, Sanawari, Ilboru, Ilkieri and Sakina boreholes.

We also documented the total quantity of billable water (i.e. water expected to be sold). We found that the highest quantity of billable water for the 2009/10 financial year in Moshi and Arusha was 6,881,888.8 m^3 and 12,135,143 m^3, respectively (Figure 3).

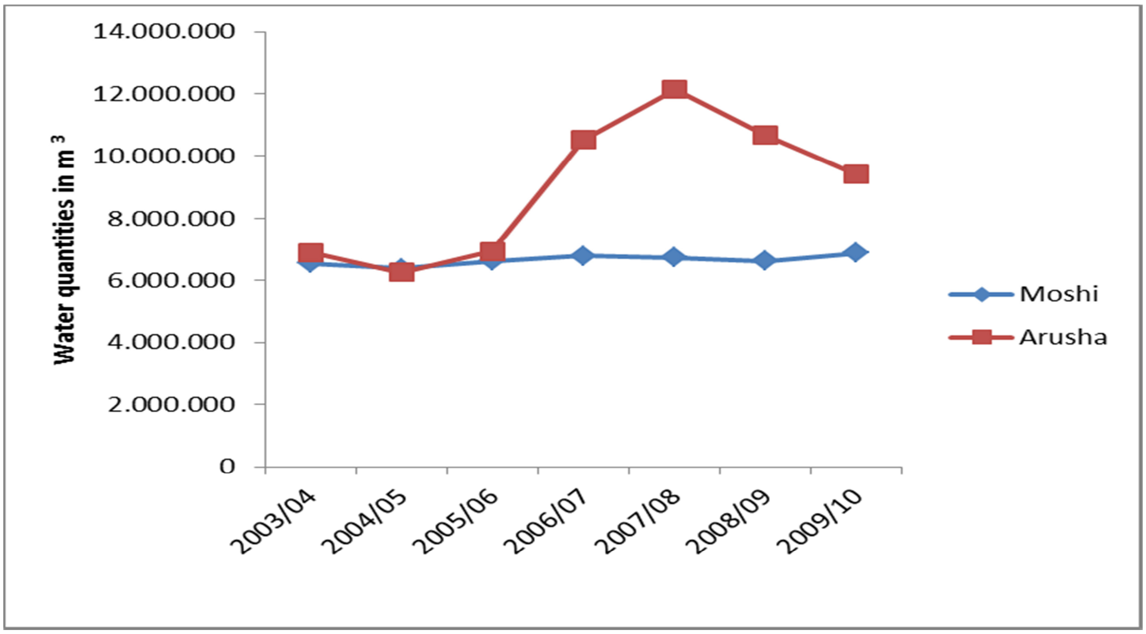


Figure 3: Quantity of billable water from 2003/04–2009/10 in Moshi and Arusha, Tanzania

Findings for billable water indicated that minimum quantities were 6,396,876 m^3 and 6,265,965.96 m^3 for the financial year 2004/05 for Moshi and Arusha, respectively. The low quantity of billable water is attributed to water leakage while on transit; obsolete water pipes that burst due to high pressure; illegal water abstraction; poor meter reading and deliberate destruction of water pipes.

3.3 Quantity of water sold

Our findings on the quantity of sold water indicated that there was an increase from 5,004, 853 m^3 to 6,140, 488m^3 for the 2003/04 and 2009/10 financial years, respectively, in Moshi town. Similarly, we observed an increase of water sold from 6, 265, 966 m^3 to 12, 135, 143 m3 for the 2004/05 and 2009/10 financial years, respectively, in Arusha (Figure 4).

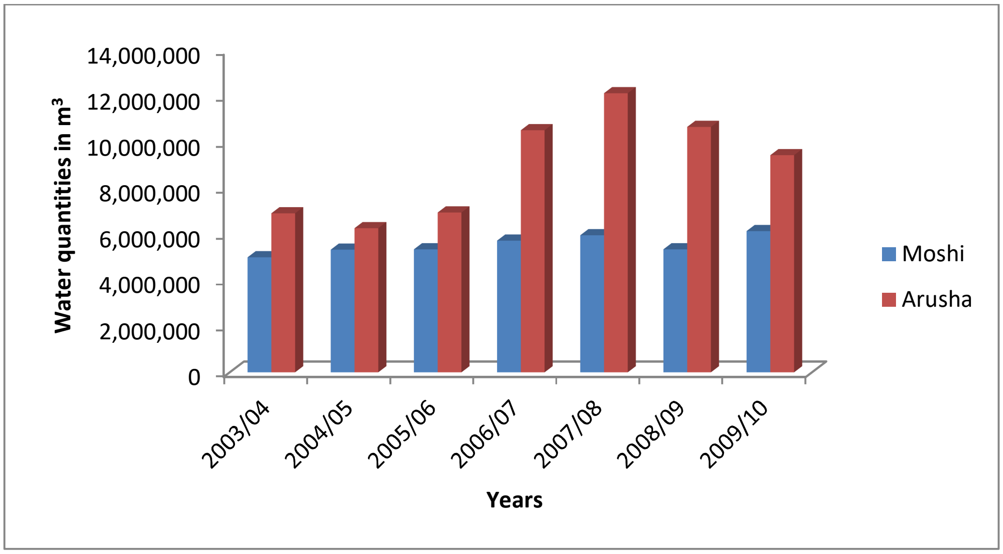


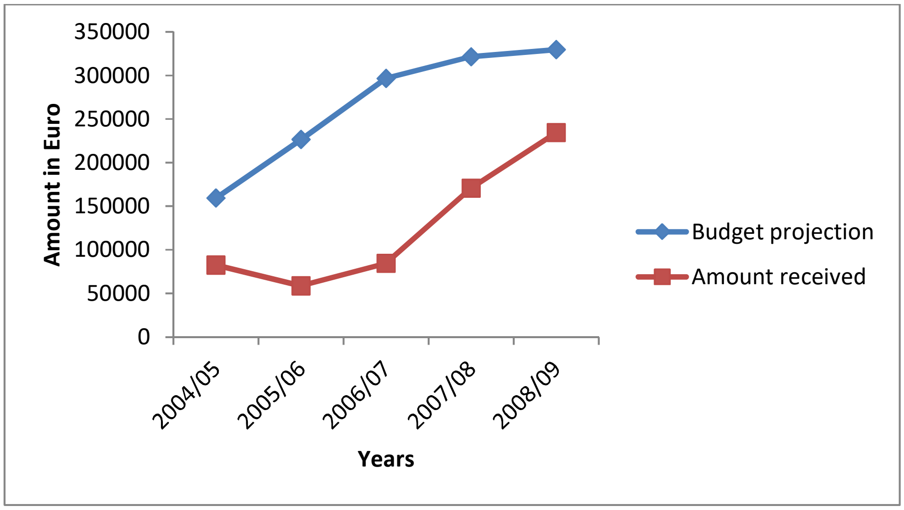
Figure 4: Quantity of water sold from 2003/04–2009/10 in Moshi and Arusha, Tanzania

We also found that the gap between billable and sold water is caused by water leakages while in transit either to the central tanks for storage or by illegal abstraction. However, a number of standing community water taps are fixed in villages where water pipes cross from watersheds to users downstream. This is a direct incentive for local community involvement in sustainable watershed conservation. In other words, this forms the basis for water users to realise the benefit of watersheds and to be convinced to pay for their conservation. In both cases, Arusha had a higher quantity of sold water than Moshi. This trend is similar to of billable water, shown in Figure 3 above.

3.4 Financing watershed management in PRB

3.4.1 Budget allocated and amount received

With respect to financing conservation programmes, we found that watershed management is not given outstanding priority as compared to social services sectors (e.g. health, education, roads, etc.), which is why the amount donated for watershed conservation is less than what was projected (Figure 5).



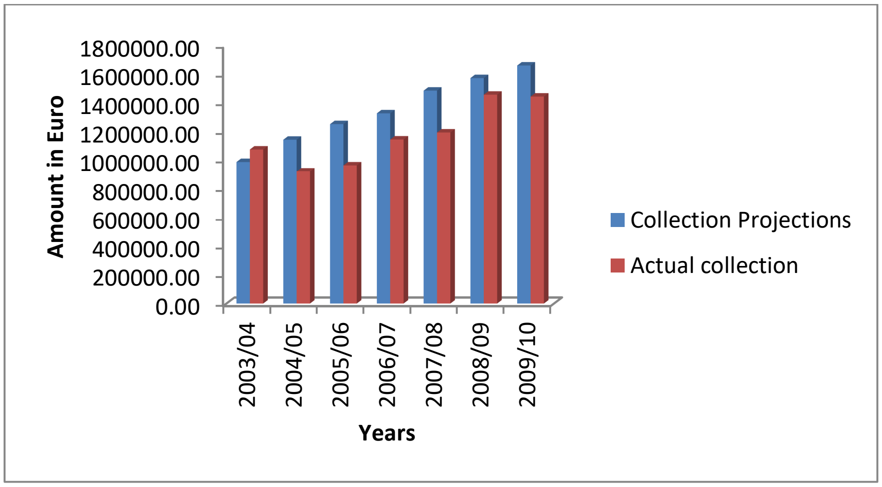
*Exchange rate used: 1€ = 2273 Tshs

Figure 5: Fund allocation for financing watershed conservation between 2004/05–20007/08 in PRB, Tanzania. (Source: PBWO database, 2009).

As indicated in Figure 5, the PBWO (the sole and mandatory institution that collects water user fees) had projected budgets of €159490, 62 and €329665, 85 for the 2004/05 and 2008/09 financial years, respectively. Surprisingly, only €82693, 72 and €234537, 77 were made available for the 2004/05 and 2008/09 financial years, respectively (Figure 5). Potential sources of the budget include water user fees from Tanzania Electricity Supply Company (TANESCO), Ministry of Water and Irrigation (MoWI), other water user fees (from industries, small- and large-scale irrigators, water abstractors, domestic users), and water right application fees.

3.4.2 Projected and actual revenue collections

We were also interested in finding out the projected and actual revenue collected from water users in the PRB. Findings indicated that projections were €987766, 60 and €1659160, 71 for the 2004/05 and 2009/10 financial years, respectively, whereas the actual collection was €920916, 40 and €1456075, 49 for the 2004/05 and 2009/10 financial years, respectively (Figure 6).



*Exchange rate used: 1€ = 2273 Tshs

Figure 6: Revenue collection from 2003/04–2009/10 in Moshi, Tanzania.

Contrary to finances for watershed management where the budgets were not attained in any financial year, there is an exception for projected and actual revenue collected. As indicated in Figure 6, the actual collection for 2003/04 was greater (€1074874, 81) than the projected collection (€987766, 60). This might be attributed to efficiency in user fees collection, or motivation given to employees in charge of water revenue collection, just to name a few.

As in Figure 6 above for Moshi town, the actual collection in Arusha town (Figure 7) was less than the projected collection with the exception of 2003/4 and 2004/05 where the actual collection was greater than the projected collection.

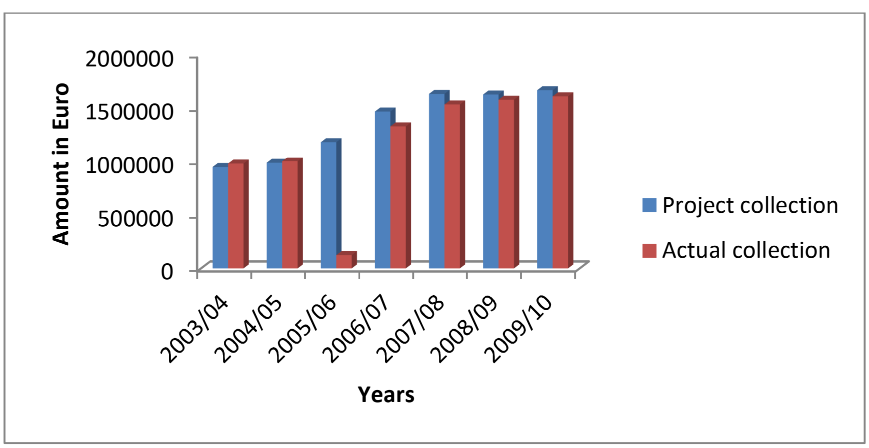


Figure 7: Revenue collection from 2003/04–2009/10 in Arusha, Tanzania.

The reason for the actual collection surpassing the projected collection might be attributed to efficiency in the whole process of revenue collection. Nonetheless, we found a shocking fall in the actual collection compared to the projected collection in the 2005/06 financial year (Figure 7). The reason for this dramatic fall in actual collection might be due to drought, poor water infrastructures (pipes), inefficiency of personnel responsible for revenue collection, and, of course, little water flow caused by the degradation of the watershed ecosystem upstream. If revenue collection increases due to payment from water users, a certain percentage could be diverted to finance forest conservation which might result in more water availability in the long run.

4.0 DISCUSSION

4.1 Water resource management techniques

As indicated in Table 2, concrete canals were preferred by a majority of smallholder irrigators on the ground that concrete canals prevent water infiltration as water flows downstream. *Their preference for concrete canals may be attributed to their desire for sufficient water irrigation. From an economic perspective, water is an essential input for production in primary, secondary and tertiary sectors, as well as for household consumption (UNESCO, 2006).*

However, stakeholders in the study area seemed to focus more on the economic benefits of water rather than the ecological aspects. In view of this reality, Zoumides and Zachariadis (2009) contend that although water pricing is potentially an effective tool in terms of economic efficiency, its environmental effectiveness is not guaranteed; thus, it may not drastically improve water resource management.

Retaining riparian vegetation (85%) and tree planting (85%) were also applied as water conservation methods as well as to enhance ecological integrity. Various studies (Costanza *et al.,* 1997; De Groot *et al.,* 2002; Krishnaswamy *et al.,* 2006; Notter, 2010; Lopa *et al.,* 2012) have indicated that natural vegetation has the potential to offer hydrological functions including groundwater recharge; water quality improvement; regulating the timing and extent of runoff; storing water; reducing salinization; filtering and decomposing organic material; and many more. These hydrological functions and services are particularly important for enhancing sustainable water flow in the PRB either because rainfall is highly seasonal or locally limited, or because intensively cultivated and densely populated agrarian landscapes downstream are affected by soil-hydrological processes in the watersheds. Thus, the advantages of watershed conservation through ecological approaches (i.e. retaining natural vegetation) are innumerable. Apart from enhancing water flow, ecological conservation approaches enhance watersheds to provide multiple ES and regulate ecological functions (Cheng *et al.,* 2002; Lu *et al.,* 2001; Muñoz-Piña *et al.,* 2008; Pattanayak, 2004).

4.2 Water production and supply

Water supply in PRB depends mainly on natural flow from various springs, boreholes and rivers originating from Kilimanjaro and Meru Mountain watersheds. Frankly speaking, water supply in Moshi and Arusha towns is not sufficient and MUWSA and AUWSA, the legal water abstractors, are yet to fulfil customers' demands. Sustainable water supply is crucial in the area and MUWSA and AUWSA are trying their best to accomplish this.

The current watershed degradation and reduction of water (Notter, 2010) is attributed to the lack of a holistic/integrated approach towards watershed management (Msuya, 2010). Ngana (2001) asserts that ineffective enforcement of conservation laws, climate change, population growth, socioeconomic and political changes and lack of an effective institutional framework contribute to the decrease in water in the basin.

Increased population in the basin, coupled with economic activities requiring water as an input such as hydropower generation, irrigated agriculture, industries, tourism, mining, livestock keeping, domestic uses, fisheries, wildlife and forestry activities, has further aggravated the situation (Mbonile (2005). Water scarcity is a problem in many places due to unreliable rainfall, multiplicity of competing uses, degradation of sources and catchments (Faraji, 2007; Kulindwa, 2005; Turpie *et al.,* 2005; 2007). Mbonile (2005) found that water scarcity threatens food security, energy production and environmental integrity and, consequently, there are water use conflicts between various water actors, including communities and conservationists; upstream and downstream users; hydroelectricity producers and other users; communities and donor agencies; farmers and pastoralists; rural and urban areas; and communities and river basin authorities.

Comparing the quantities of billable water and sold water for Moshi and Arusha, the quantity of billable water presented in Figure 3 is higher for both of the towns than that of sold water displayed in Figure 4. This might be due to the differences in efficiency of workers and the level of water infrastructures. In fact, intact and good water pipes retain much more water than obsolete water pipes. Other reasons for the differences are that water users in Arusha might be more civilised and, therefore, they do not abstract water from pipes illegally while it is on transit to reservoirs and storage tanks.

4.3 Financing watershed management and revenue collection in PRB

Despite being stipulated clearly in the Tanzania National Water Policy (URT, 2002) on integrated water management and the need to finance catchment areas for sustainable water flow, little has been done on the ground in PRB. For quite some time, watershed management in Tanzania has been financed by the World Bank through the Ministry of Natural Resources and Tourism (Forestry and Beekeeping Division) and District Natural Resource Offices. In some cases, international conservation organisations such as World Wildlife Fund for Nature Conservation (WWF), International Union for the Conservation of Nature (IUCN), CARE International and other local conservation organisations have been in the forefront in addressing the need for conserving critical watershed areas.

On the other hand, setting aside funds for nature conservation has been quite a problem in PRB. This is attested by Figure 4 which indicates that the minimum budget for watershed management was €159490, 62 while the actual amount of money given was merely €82693, 72. Similarly, the maximum budget was €329665, 85 while the actual amount collected was €234537, 77. This implies fees for water utilization are not properly dealt with and this finding is in line with that of Turpie *et al.* (2005), who found inefficient collection of fees from water users.

Furthermore, lack of sufficient quantity and quality of manpower, and skilled and committed personnel; poor water infrastructures; energy (electricity) fluctuation; and low capacity of the watershed to produce water, are among the factors leading to low revenue collected from water users. As portrayed by Figure 5, only €1456075, 49 was collected as revenue from water users, while the projected collection was €1659160, 71 for the 2008/09 calendar year. Similar findings with regards to poor revenue collection in PRB are reported by Kulindwa (2005), Msuya (2010) and Turpie *et al.,* (2005).

Despite the significant advances in scientific understanding of forest and water interactions, the roles of forests in relation to the sustainable management of water resources in PRB remains a contentious issue. Uncertainty, and in some cases confusion, persist because of difficulties in transferring research findings to different watershed scales, different forest types and different forest management regimes.

We also think that priorities and key decisions by policy makers have been geared towards financing social services for political gains at the expense of nature conservation. This may partially be due to the gap existing between research and practice. The policy gap, which persists at least in part because of a general failure to communicate results of hydrological research effectively to policy-makers and to challenge conventional assumptions with scientific evidence, also plays a key role.

If conservation initiatives are to be successful, deliberate efforts should be made to manage watersheds using a holistic approach. This can be achieved by integrating financial matters in water resource management, which could improve people's willingness to pay for and improve water supply in the long run. This is only possible, however, once water users are assured of sustainable water flow and supply.

5.0 CONCLUSIONS

Water supply in PRB is handicapped by a higher water demand than the watershed can provide multiple water uses; rampant influx of water users in the area; electricity cut-off, especially where the water supply requires pumping; obsolete water infrastructures (e.g. water pipes) that cause water leakages before reaching downstream users; and lack of transparency in utilization of the collected revenues, just to name a few.

On the other hand, commitment for watershed conservation is still low among stakeholders in PRB and this is testified by the low revenue collected compared to the projected amount. The low amount of revenue collected is contributed to by the inefficiencies of the methods used during revenue collection. Retaining natural vegetation around water sources is by far the most sustainable ecological approach for watershed management and sustainable water flow in PRB as it has multiple benefits including ecosystem integrity.

As mentioned above, enthusiasm for financing watershed conservation in PRB is still low. This may be partially due to scepticism about misuse of contributions, lack of concrete plans on how to collect and utilize funds from water users, or lack of people's awareness of the clear link between conservation and increase of water availability. The current study is the basis for securing funds from downstream users for financing upstream communities, who are principally the guardians of watersheds. In addition, it is high time that a strategy be conceived that would incorporate the tourist sector in the payment for watershed services. Nevertheless, awareness and capacity building among water users is essential for sustainable watershed conservation through PWS. Therefore, it is crucial to increase the potential for the establishment of PWS schemes in PRB and in other river basins facing similar problems.

5.1 Acknowledgement

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CHAPTER 5

Water Grabbing and Foreign Direct Investments: Constraints on Crop Production and Delivery of Ecosystem Services

This chapter is based on:

Lalika, M.C.S., Meire., P., Ngaga Y. M. and Sayi, Y. N. (Under review). Water Grabbing and Foreign Direct Investments: Constraints on Crop Production and Delivery of Ecosystem Services. ***Land Use Policy.***

ABSTRACT

Water and land acquisitions for food and energy production have increased rapidly in the last couple of years. The dramatic proliferation of foreign direct investments (FDIs) in developing countries is a clear indicator that water and fertile land are increasingly under pressure globally. This paper reports the pressure of water grabbing and its impacts on crop yield along Pangani river basin (PRB). Results indicated that the mean yields before water grabbing were statistically ($P < 0.001$) higher than yields after water grabbing. Responses from the study smallholder farmers indicated that local drivers for water grabbing include poor water governance, corruption and poor transparency, whereas global drivers include climate change, population growth, change of consumption patterns and economic growth. Water grabbing and population increase have affected ecosystems services. The impacts includes loss of fish and bird species, water for electricity production, livestock uses, and domestic uses. Although FDIs have potential to contribute to economic development, the implementation process in PRB has had detrimental effects to smallholder farmers and the local economy. We recommend enforcement of land laws, policies and by-laws in order to benefit smallholder farmers. Furthermore, we recommend enforcement of the Land policy, Land use Act and the Village Land Act; implementation of FDIs that aim at improving food security; transparency in land acquisition; promote investments that generate social security, ground water research, and rainwater harvesting.

Key words: *Ecosystem services, Land grabbing, population growth, climate change, water*

1.0 INTRODUCTION

For quite sometime, foreign direct investments (FDIs) have been a key strategy to boost the economy in developing countries (World Bank, 2010; White and Dasgupta, 2010; Borras et al., 2012). Majority FDI's target African countries where there is still ample virgin land and fresh water (Woodhouse and Ganho, 2011; GRAIN, 2012; Merselli et al., 2013). However, the limited capacity to manage administrative and regulatory FDIs, universal land tenure uncertainty and rural livelihood insecurity necessitates the urgent need for African governments to be careful with land deals in areas with fertile soil, ample water and other provision of ecosystem services (ES). Some of the FDIs destroy valuable ES which are difficult to regenerate or restore.

Water resource depletion and rising demand on limited water supplies result in putting at risk ES, thereby creating water use conflicts and significant deterioration of water and aquatic life (UNDP, 2006; URT, 2002). Commercial pressure on land and water and its consequence on small farmers are among the major issues being discussed at local, national and international scale (Cotula et al., 2009; 2011; Hall, 2011; Rulli et al., 2012; World Bank, 2010). Water has been the prime target of the continued pressures exerted by developed countries and international commercial firms in their aquisitions of land for FDIs on the African continent (Cotula and Vermeulen, 2009a; b; GRAIN, 2008; White and Dasgupta, 2010; Borras et al., 2012).

Throughout history human development has depended on water and the potential of water availability as a productive resource (UNDP, 2006). Water for life and livelihoods are two of the foundations for human development. Yet, in recent years (World Bank, 2010), large section of local communities in the African continent have not benefitted significantly from water related ES due to the way FDIs are established and implemented. In different parts of Tanzania, for instance, ES are deteriorating due the establishment of large scale plantations. The establishment of jatropha, sugarcane, aloe vera, oil palm; croton megalocarpus and white sorghum (Sulle and Nelson, 2009; Gordon-Maclean et al., 2008) have resulted in exclusive rights for land and water which led to what is popularly known as "water grabbing". Excessive water withdrawals and abstraction by FDIs resulted in water stress and scarcity thereby affecting downstream smallholder irrigators (Lankford, 2005a; b; Lankford and Mwaluvanda, 2005; Sotthewes, 2008; Franks et al., 2011).

Since mid 1990's, water grabbing has been the order of the day along the Pangani River Basin (PRB). Mushrooming foreign companies mainly engaged in flower irrigation are causing for water stress and scarcity and water use conflicts (Mbonile, 2005; Ngana et al., 2010; Lalika et al., 2011). This situation has been worsened by policy failures to enforce clauses and conditions stipulated in signed investment contracts (Sulle and Nelson 2009; Matondi, 2010; Komakech and van der Zaag, 2011). Despite the presence of well-developed institutional structures and policy frameworks on water, environment and land management in the country including the National Water Policy (URT, 2002); Land Policy (URT, 1995); Land Act of 1999 (URT, 1999a) and Village Land Act of 1999 (URT, 1999b), Environmental Policy (URT, 1997), smallholder farmers in the PRB are still affected by land and water grabbing malpractices. Many FDIs occupy fertile soil proximity to river basins with exclusive rights to control water as well (Arduino et al., 2012; Alden-Wily, 2012; Woodhouse and Ganho, 2011).

Policy failures to regulate allocation and enhance equitable water distribution have been exacerbated by the increase of human population along the PRB (Mbonile, 1999a; 1999b). The repercussions of population increase may reflect the now classical economic theory of population growth and resource scarcity of Malthus (1798). Malthus feared that the interaction between people and resources (water) would mean that the combined effects of population growth and increasing demand on a fixed water resource base would have consequences on water stress at an extraordinary scale. We argue that his views hold water in today's modern life along the PRB.

Nevertheless, nor information on population growth on water grabbing neither the negative impacts of water grabbing on crop yield in the PRB have been given any attention in quantitative assessments. The objectives of this study were: i) To determine the effect of water grabbing on crop yield along PRB; ii) To identify drivers for water grabbing in PRB; iii) To analyze population dynamics in PRB; and iv) To review and analyze land and water deals in Tanzania. Findings of this study and subsequent recommendation are useful to land use for policy makers for making decisions on different land uses and allocation. In addition, our policy recommendations could be instrumental for other stakeholders aiming to achieve a more equal water distribution along the PRB.

2.0 MATERIALS AND METHODS

2.1 Description of the study area

2.1.1 Location

This study was conducted in four villages namely Patanumbe and Valesca villages in Meru District, Arusha Region; and Mawala village in Hai District and Ngasinyi villages in Moshi Rural District, Kilimanjaro Region along the PRB, Tanzania (Figure 1). The PRB extends from the northern highlands to the north-eastern coast of Tanzania. It lies between latitude 03° 05' 00" and 06° 06' 00" South and longitude 36° 45' 36" and 39° 36' 00" East.

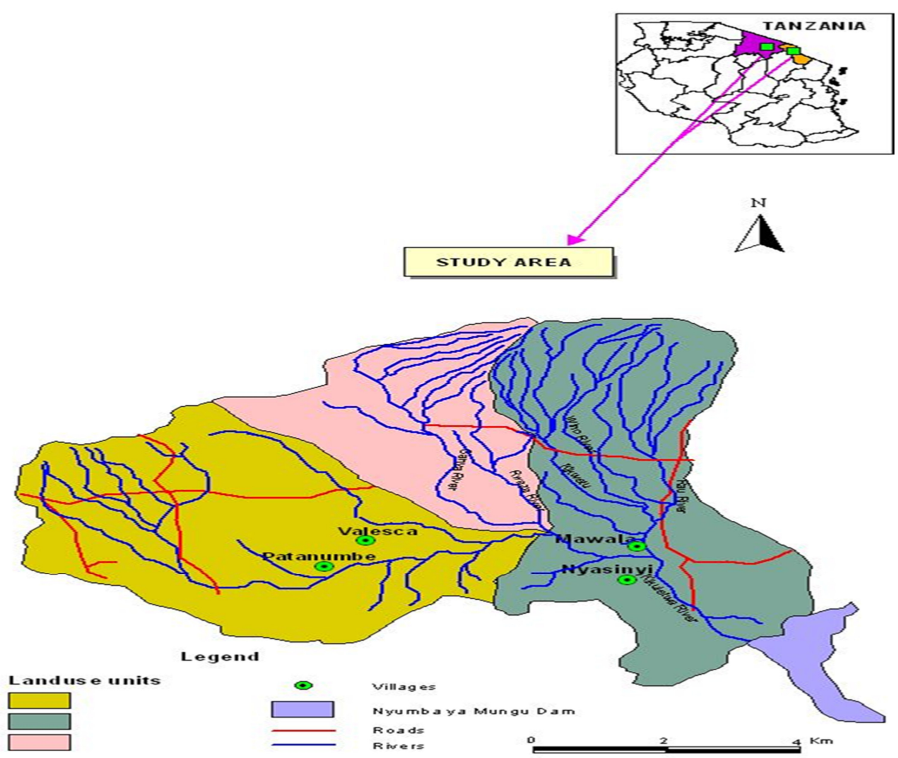


Figure 1: Location of the study area along Pangani River Basin, Tanzania

2.1.2 Hydrology and drainage pattern

The hydrology and drainage pattern in the PRB catchment varies considerably. The PRB comprises of several sub-catchments of widely different characteristics. The Pangani River (PR), which is also referred (in other publications) as the Pangani Mainstem, rises as a series of several small streams and springs on the southern sides of the Africa's highest peak, Mt. Kilimanjaro, and on Mt. Meru (IUCN and PBWO, 2008; IUCN, 2007). These streams (Nduruma, Tengeru, Sanya, Malala, etc.) create the Kikuletwa and Ruvu Rivers (Himo, Muraini, etc) which drain further downstream into the Nyumba ya Mungu (NyM) dam (IUCN and PBWO, 2008; 2011; IUCN; 2007). The NyM dam has created a man-made water reservoir of ecological and economic importance along PRB. The overflow of the dam (outlet), is known as the Pangani River Maisteam and flows for 432 km before emptying into the Indian Ocean at the Pangani estuary.

The NyM resevoir is the largest water body in the PRB and was constructed in 1965 to enhance river flows for hydropower generation. It was later incorporated into irrigation plans (Mulungu, 1997; Ndomba et al., 2008). Besides the power station at the outlet of this dam, other hydropower power plants in the PRB are located near Hale and New Pangani Falls. Water released from the NyM dam is essential for supporting ecosystem services downstream. These include nutrient cycling at Kirua Swamp, sedimentation and support of enhancement of ecological processes (e.g. hindering salt water intrusion and coastal erosion) at the estuary mouth in Pangani Town (Ndomba et al., 2008; Shaghude, 2006; Sotthewes, 2008; Valimba, 2005; 2007). Other river tributaries draining in the PRB are Mkomazi and Luengera from the Pare and Usambara Mountains ranges respectively.

2.1.3 Forest and vegetation types

Forest and vegetation in PRB range from forests on mountain slopes to semiarid grasslands (IUCN, 2003). The main vegetation types include forests, woodlands, bushland, along with grassland thicket and plantation forest (Turpie et al., 2005). Plantation forests have replaced natural forests in the highlands, and the larger part of the lowlands is composed of woodland, bushland, grassland and thicket. Forests perform vital hydrological functions in the PRB including the regulation of run-off, prevention of soil erosion, water storage and improvement of water quality (IUCN, 2003; Msuya, 2010). According to IUCN (2003), dominant forest types in PRB include: *mangrove forests* (located at the confluence of the Pangani River and the Indian Ocean and protecting the coastlines and soft sediment shorelines from erosion, trapping sediments and recycling nutrients); *East African coastal forests* (containing remarkable levels of biodiversity and endemism); *afromontane forests* (playing a key part in hydrological functions); and *riverine forests* (controlling erosion along the river banks). Research and previous studies on forest health conducted in the PRB shows that between 1952 and 1982, catchment forests in the PRB declined at a fairly high rate of 3.8% of forest cover per year, whilst farmlands and settlements increased dramatically by 83% of forest cover per year (Kaoneka, 1993; Lambrechts et al. 2002; Newmark, 1998).

2.1.4 Climate

Variations in the local climate in the PRB are mostly related to topography. The flatter, lower-lying south-western half of the Basin is arid and hot, while the mountain ranges along the northern and south-eastern catchment boundaries have cooler, wetter conditions. The high altitude slopes above the forest line on Mt Meru and Mt Kilimanjaro have an Afro-Alpine climate and receive more than 2500 mm of rainfall per year. Mean annual rainfall increases in a southerly direction along the mountain ranges, and varies from about 650 mm per year in the North and South Pare Mountains, to 800 mm per year in the Western Usambara Mountains, and 2000 mm per year in the Eastern Usambara Mountains.

2.1.5 Population and economic activities

The PRB has an estimated 4.5 million people (data from 2007) and population densities vary between highlands and lowlands. About 90% of the basin's population resides in the highlands with some 900 people per km^2, while lowland densities were around 65 people per km^2 (IUCN, 2003). The main causes of forest degradation and deforestation include encroachment for settlement and agriculture as well as increasing demand of forest products (mainly timber and fuel wood) (IUCN, 2003). In terms of human population, PRB is a densely populated area in Tanzania, posing serious challenges to sustainable watershed management (Msuya, 2010).

2.2 Data collection

2.2.1 Sampling procedure

We adopted a purposive sampling procedure where four villages were earmarked for the questionnaire survey (two in Arusha and Kilimanjaro regions respectively). Our decision on the location of the villages was based on their proximity to rivers and the reliance of the local communities on water for irrigation. Based on these two criteria, our main target was smallholder irrigators. Within each village, we selected respondents using a table of random numbers that corresponded to the household numbers in the village register. Household heads were the target for interview, but wherever the head of the household was not around we randomly picked any household member within that particular household who of 18 years or above. According to Tanzania regulations and laws, any one at 18 years or above is regarded as mature person. We adapted the 10% sampling intensity giving a total of 170 respondents were interviewed (Table 1).

Table 2: Sampled and Interviewed respondents

Region	Village	Total households	Sample size
Kilimanjaro	Mawala	330	33
	Ngasinyi	440	44
Arusha	Valesca	500	50
	Patanumbe	430	43
	Total	**1700**	**170**

2.2.2 Data collection methods

2.2.2.1 Quantitative and qualitative data

During data collection both quantitative and qualitative research approaches were used to collect primary and secondary data. We used structured questionnaires as the main tools to collect primary (quantitative) data. Questionnaire items comprised questions mainly drivers/factors of water grabbing, socio-economic activities, types of water investors/grabbers, types of watershed services affected by water grabbing, crop yield before and after the coming of investors, environmental and socio-economic effects of water grabbing, to name just a few. We used different methods to collect qualitative data. Among others these methods include: group focus discussions, face to face interviews, informal and formal interviews. We also searched, and reviewed relevant literatures on irrigated agriculture and water use conflicts in the study area.

2.2.2.2 Data on population census

To collect data on population dynamics and increase in PRB, we visited the national library for Tanzania Bureau of Statistics in Dar es Salaam to collect population census. Normally population census in Tanzania is conducted after every 10 years. Therefore, we collated population census reports for six years i.e. 1957, 1967, 1978, 1988, 2002, and 2012. Thereafter, we extracted relevant information for PRB we converted them from analogue to digital format (Table 2).

Table 2: Population dynamics in Pangani River Basin, Tanzania

	Years and population					
Region	**1957**	**1967**	**1978**	**1988**	**2002**	**2012**
Kilimanjaro	476530	650533	902437	1108699	1376700	1640090
Tanga	375923	769504	1037767	1283636	1636280	2045210
Arusha	399866	601515	926223	1351675	1288090	1694310

2.2.2.3 Data on water and land deals

To collect secondary data, we reviewed literatures on land and water policy issues and document on land and water grabbing. For policy issue, we reviewed the National Water Policy (URT, 2002); Land Policy (URT, 1995); Land Act of 1999 (URT, 1999a), Village Land Act of 1999 (URT, 1999b), and Environmental Policy (URT, 1997). On land and water grabbing, we reviewed document such as Biofuels in Tanzania: Status, Opportunities and Challenges (Mshandete, 2011); Biofuels, land access and rural livelihoods in Tanzania (Sulle and Nelson 2009); Foreign land acquisitions in Tanzania: Global ideology and local perspectives (Larsen, 2002); Biofuel Industry

Study in Tanzania (Gordon-Maclean et al., 2008); and Accumulation by land dispossession and labour devaluation in Tanzania (Haki Ardhi, 2010).

2.3 Data analysis

2.3.1 Quantitative and Qualitative data.

We coded and cleaned the 170 structured questionnaires for final analyses. Thereafter, we used Statistical Package for Social Sciences (SPSS) version 20.0 to analyse quantitative data from structured questionnaires. Later on we carried out multiple responses to obtain frequency and percentages of responses from smallholder farmers. On the other hand, we analysed qualitative data with participants during group focus discussions through dialogue and intensive debates.

2.3.2 Population census data

We used a base map of 1:50,000 scale to locate topographic sheets for Arusha, Kilimanjaro and Tanga Regions. Thereafter, we scanned topographic sheets, geo-referenced and digitized into polygons using ArcGIS version 10.1. We then entered the data for each region (displayed in Table 2) in MS Excel and the attribute table of shapefiles for the three regions were edited by adding population data from the excel file.

We then chose different colours to represent the population data for the three regions. Thereafter, we created shape files and labelled administrative boundaries for regions, countries, lakes, rivers and the Indian Ocean. We shifted from data view to layout view in order to insert title, legend, north direction arrow, scale bar and the scale according to the paper size. Finally, we exported the output into JPEG images as population maps (Figure 3, 4 and 5).

With regards to statistical tests of crop yield before and after water grabbing, we used two-tailed t-test.

Null hypothesis: There is no significant difference in yield before and after water grabbing

Ho: $\mu_1 = \mu_2$, (i.e. $\mu_1 - \mu_2 = 0$)

Alternative hypothesis: There is significant different in yield before and after water grabbing

H1: $\mu_1 \neq \mu_2$, (i.e. $\mu_1 - \mu_2 \neq 0$)

To test and compare the means for the net loss in yield before and after water grabbing between villages and within villages, we had this hypothesis:

"There is no significant difference in net loss in yield before and after water grabbing".

We applied the one-way analysis of variance (ANOVA) to test this hypothesis. Thereafter, we carried out the Duncan Multiple Range test to separate the means.

3.0 RESULTS

3. 1 Effect of water grabbing on crop yield along PRB

The results in Table 3 indicate that mean yields and their respective standard deviations (STD) before water grabbing were higher than yields after water grabbing in all villages. This implies water loss due to water grabbing had negative effects on crop yield. Similarly, findings in Table 3 indicated that standard deviations for yield before water grabbing were higher than their means only in two villages (i.e. Mawala and Patanumbe).

Table 3: Maize means yield before and after water grabbing (kg/ha/season) in PRB, Tanzania

Village	Maize Yield (kg/ha/season)	Mean ± STD	Std Error Mean
Mawala	Before water grabbing	1479.8851 ± 2931.02378	544.27745
	After water grabbing	355.1724 ± 214.87831	39.90190
Patanumbe	Before water grabbing	846.2984 ± 1097.74824	167.40504
	After water grabbing	252.3643 ± 150.66079	22.97556
Valesca	Before water grabbing	1255.3075 ± 663.56007	95.77665
	After water grabbing	462.7629 ± 271.68247	39.21399
Ngasinyi	Before water grabbing	1067.5397 ± 503.81690	77.74064
	After water grabbing	480.0000 ± 237.95197	36.71679

Furthermore, we carried out a two-tailed statistical test to see the significance of the crop yield before and after water grabbing. We preferred two-tailed t-test because the assessment was from the same respondents for the two scenarios (i.e. yields before and after water grabbing). Results are summarized in Table 4 below.

Table 4: Statistical test for crop yield before and after water grabbing (kg/ha) in PRB, Tanzania

Village	Mean ± STD	Std Error Mean	t-value	Sig (2-tailed)
Mawala	746.13977 ± 1374.81908	108.01599	6.908	0.000***
Patanumbe	593.93411± 1060.42184	161.71282	3.673	0.001***
Valesca	792.54464 ± 527.68757	76.16514	10.406	0.000***
Ngasinyi	587.53968 ± 375.96060	58.01198	10.128	0.000***

*** = Significance at $P < 0.001$

As denoted in Table 4, the mean yield before and after water grabbing was statistically significant ($P < 0.001$). Thus we rejected the null hypothesis which stated that "there was no significant difference in mean yield before and after water grabbing".

Results from one way ANOVA on the net loss in crop yield are displayed in Table 5. While the standard deviation for the net loss in Mawala and Patanumbe villages were greater than their respective means, the situation was opposite in Valesca and Ngasinyi villages means were greater than their respective standard deviations.

Table 5: Net loss in crop yield in PRB, Tanzania

Village	N	Mean ± STD	Std Error	95% Confidence Interval for Mean	
				Lower Bound	Upper Bound
Mawala	29	485.0575 ± 704.21555	130.76954	217.1882	752.9267
Patanumbe	43	562.5388 ± 1044.37845	159.26622	241.1265	883.9510
Valesca	48	795.5208 ± 528.13319	76.22946	642.1669	948.8747
Ngasinyi	42	587.5397 ± 375.96060	58.01198	470.3821	704.6973
Total	162	624.1821 ± 708.38435	55.65593	514.2723	734.0919

Results on statistical test about the net loss between and within villages before and after water grabbing are displayed in Table 6.

Table 6: One-way ANOVA statistical test for net loss between and within villages in PRB, Tanzania

Villages	Sum of Squares	df	Mean Square	F	Sig.
Between villages	2190236.125	3	730078.708	1.468	0.225**NS**
Within villages	78600914.586	158	497474.143		
Total	80791150.711	161			

NS = Non statistical significance ($P > 0.05$)

It was revealed that $p = 0.225$. Therefore, $p > 0.05$ implying that there was no significant difference in yield net loss between villages and within villages. Based on these findings, we accept the null hypothesis.

3.2 Drivers for water grabbing

3.2.1 Drivers at (in PRB) local scale

Land and water grabbing are currently seen as the major problem to many poor families who rely solely on smallholder agriculture. In the PRB we identified a number of local drivers for water grabbing (Table 7). According to perceptions from smallholder irrigators, they include poor water governance (29.6%); corruption (27.7%); lack of transparency (19.8%); inadequate environmental impact assessment

(11.8); lack of integrated planning (10.5); and top-down management approaches (0.3%).

Table 7: Responses on local drivers for water grabbing in the PRB, Tanzania

Driver	Frequency	Percentage
Poor water governance	160	29.6
Corruption	150	27.7
Lack of transparencies in contracts/agreements	107	19.8
Inadequate environmental impact assessments	64	11.8
Lack of integrated planning	57	10.5
Top down management approaches	3	0.6

We found that poor water governance in the PRB is related to inadequate administration in water conservation authorities, insufficient approaches in information delivery, policy isolation in conservation issues, and funding constraints (Charbit, 2011), to name just a few.

As indicted in Table 7, we identified corruption (27.7%) as one of the drivers for water grabbing in the study villages. It was reported that some of unfaithful government leaders at national and local levels conspired with investors over investment contracts at the detrimental of smallholder farmers. Consequently, the situation led to water use conflicts and unnecessary loss of human properties and chaos. Furthermore, we identified Lack of transparency (19.8%) as one of the driver for water grabbing along PRB. It was reported that lack of transparent and democratic decision process accounted a lot for the loss of land with ample water to investors. The absence of negotiation with the local communities contributes a lot to resource use conflicts (Mbonile, 2005) and this was evident in the PRB. Findings by World Bank (2010); Cotula et al. (2009) and Rulli et al. (2013) reported similar sentiments that many land deals were done with inadequate local population involvement, inadequate compensation and without clear plans for new jobs and ecological integrity. Other contributing drivers identified in the study villages includes inadequate environmental impact assessments (11.8%), Lack of integrated planning (10.5%) and top down management approaches.

3.2.2 Drivers at global scale

Table 8 reveals drivers for water grabbing at international scale. Local communities' perceptions are that FDIs are new forms of neo-colonialism.

Table 8: Responses on global drivers for water grabbing

Driver	Frequency	Percentage
Climate change and variability	153	28.5
Global and local population growth	136	25.4
Shifting consumption patterns	134	25.0
Economic growth	113	21.1

Findings in Table 8 show that climate change (28.5%) plays a key role in global water grabbing. Climate change and persistent climate variability influence water (Boko et al., 2007) in some areas thus forcing multinational companies to shift their investments abroad.

Consequently, these investments affect water availability, accessibility, the normal water circle and daily economic activities of local communities in the area of destination.

We also found that an increase of global and local human population (25.4%) is to blame for the current water grabbing in the PRB. During field excursion we found different economic undertakings ranging from irrigation and ranching to mining. Some of these socio-economic activities were carried out by either foreign investors or Tanzanians but from different areas of the country. Furthermore, we found that the population increase in PRB was either natural (i.e. natural birth) or artificial increase (through population immigration). Therefore, the number of human population outpaced the land's carrying capacity, thereby, resulting into completion for land and water resources. Confiscation of water resources and water withdrawals along the PRB is mainly for irrigated agriculture. The situation result in irrigation water scarcity to the downstream smallholder irrigators, social unrest and resources use conflicts (Mbonile, 2005; The Oakland Institute, 2011).

The results of shifting consumer patterns (25%) are presented in Table 8. The combination of drivers such as climate change, economic growth and global and local population growth and have contributed to the shift of consumer preferences and change in production systems. These attributes when combined with the declining natural resources base result in poverty thereby exposing the rural poor in vulnerable situation. The situation is also evident in the PRB where change in consumer preference across the globe has driven FDIs investments. Changes in consumer behavior necessitate a deliberate transformation in the approach to development and a significant increase of investment in agriculture in the developing world. For quite some time, FDIs along the PRB are dealing with production of sugarcane, jatropha, flowers, vegetables and horticultural crops instead of cereals (e.g. wheat and rice) and coffee that used to be grown in the previous years.

Results of economic growth (21.1) as one of the global drivers for water grabbing are presented in Table 8. It is believed that once the economy flourish with super profit, it needs to be re-invested to generate more profit. The ideal area for this re-investment is in developing countries (the African continent) where there is ample fertile and virgin land.

3.2.3 Other ecosystem services affected by water grabbing

Table 9 present findings of other ecosystem services that are affected by the appropriation (water grabbing) of water resources in the PRB.

Table 9: Responses on ecosystem services affected by water grabbing in the PRB, Tanzania

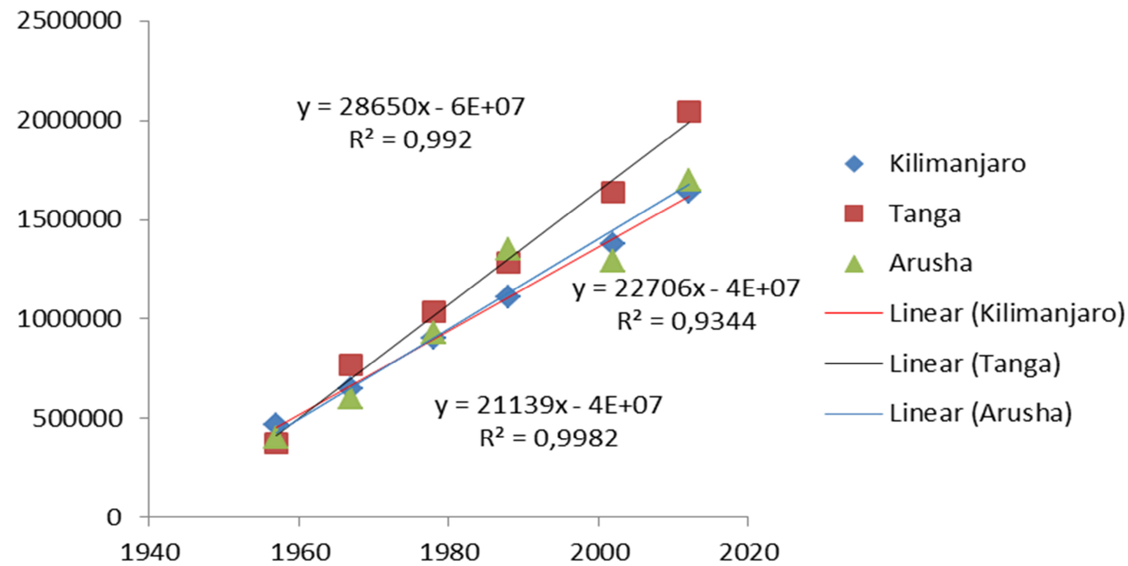
Ecosystem service	Frequency	Percentage
Disappearance of fish species	104	29.3
Water for HEP production	63	17.7
Water for livestock uses	62	17.5
Disappearance of birds	55	15.5
Water for domestic use	37	10.4
Disappearance of aquatic plants / trees	17	4.8
Reduced food crop harvest	9	2.5

Excessive water (abstraction) grabbing (29.3%) cause water fluctuation, change of river flow regime and affects the river health. Water decrease affects fish breeding and supplies of tilapia species. In recent years fishing activities have become seasonal due to water fluctuation accompanied by fish disappearance. Some parts of the river were no long perennial, some had fast flowing water, shallow areas and deeper runs with fish species adapted to living in fast flowing streams (e.g. *Garra dembeensis*) (PBWO and IUCN, 2007). Some of fish species endemic to the PRB include the *Oreochromis pangani*. Mwamila et al. (2008) found that the reduction in water flow affected negatively fish productivity, whereas higher flows result into swamp and floodplain formation. Normally, flooding conditions is necessary for fish spawning, feeding and growth of young fish species.

Table 9 reveals that hydroelectric power production (17.7%) is another crucial ES along the PRB which are affected by water grabbing. The NyM dam is the largest water body potential for hydropower production. Other hydropower plants affected by water grabbing along the PRB include Hale and Pangani. Other ES include along the PRB includes water for livestock uses (17.5%), disappearance of water birds (15.5%), water for domestic use (10.4%), and disappearance of aquatic plants / trees (4.8%). Aquatic tree affected by reduction of water flow include the fig trees (*Ficus ssp.*) which are adapted to surviving in dry areas due to their ability to reserve/store water and mangrove tree species. Other ES that affected by shortage of water flow is food crop harvest (2.5%) as elaborated in section 3.1 in Table 3, 4, and 5.

3.3 Population dynamics in PRB

Figure 2 shows the trend of population increase along PRB. Overall, Tanga Region had many people than Arusha and Kilimnajaro (Table 2). This is also testified by the alinment of the trend lines in Figure 2.



Figre 2: Population dynamics for 1957 – 2012 along Pangani River Basin Tanzania

According to population census 1957-2012 population increase was consistent in Tanga (R^2 = 99%) and Kilimanjaro (R^2 = 99.8%) Regions. The dramatic fall of population trend in Arusha Region in 2000 is due to the split of adaminiistrative units where Manya Region was chopped ot from Arusha Regions.

Findings from population maps are reveled in Figure 3, 4, and 5. The size of the dots represnts the size of number of population in earch region.

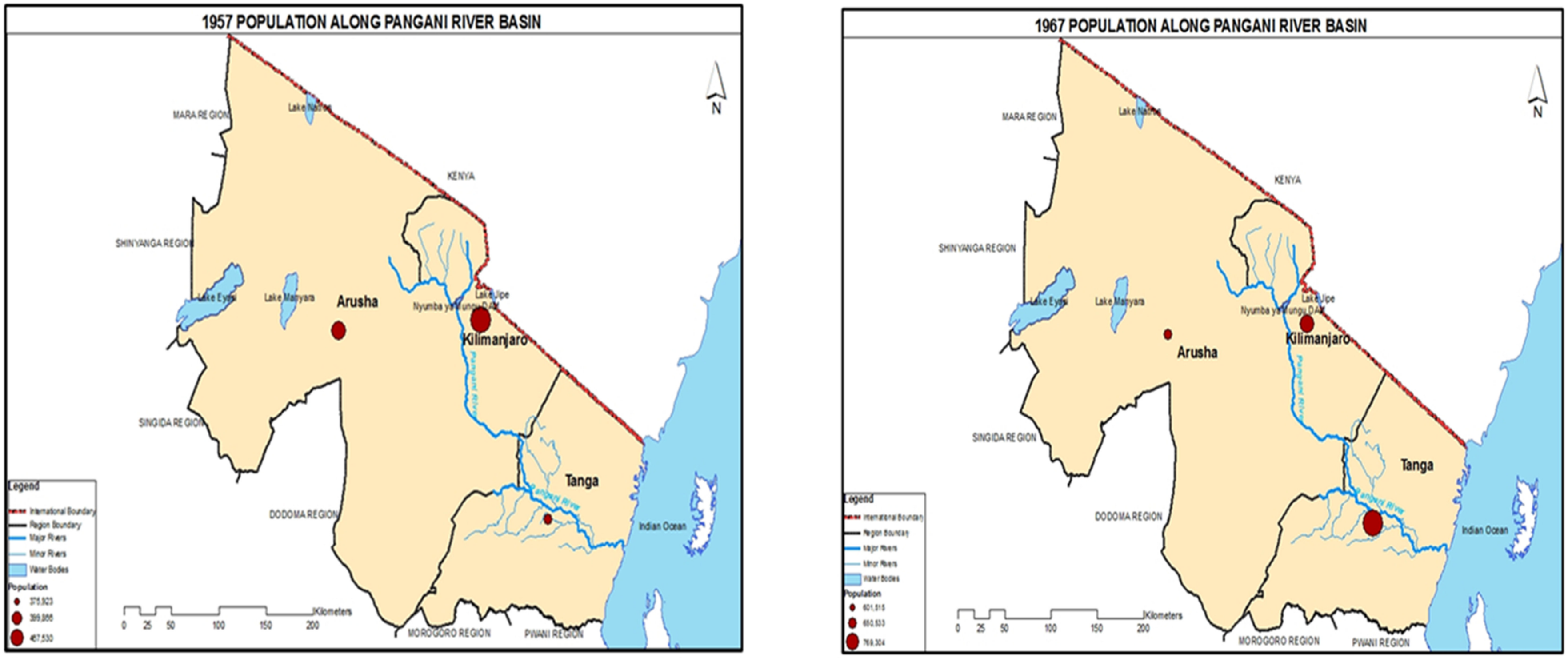
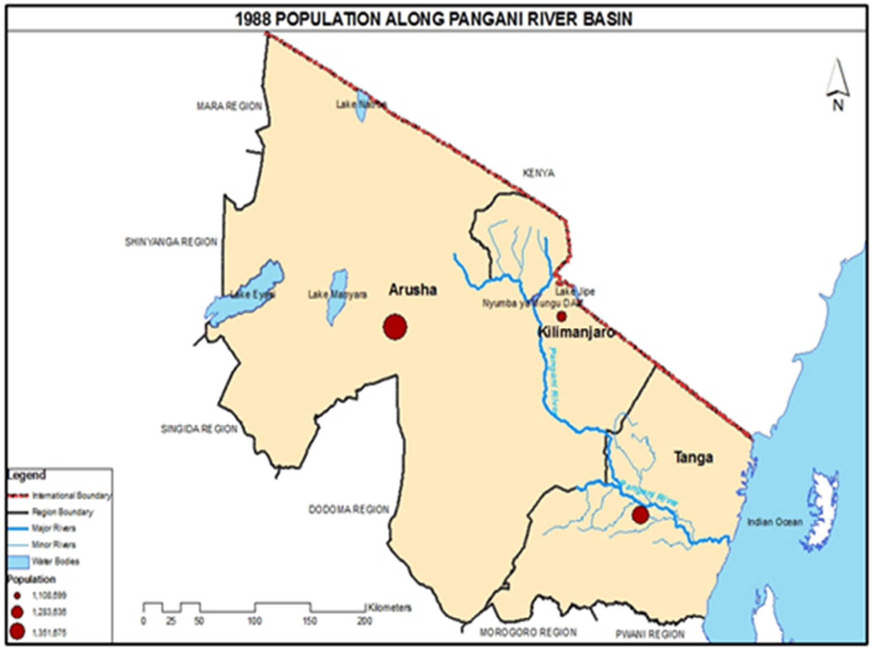
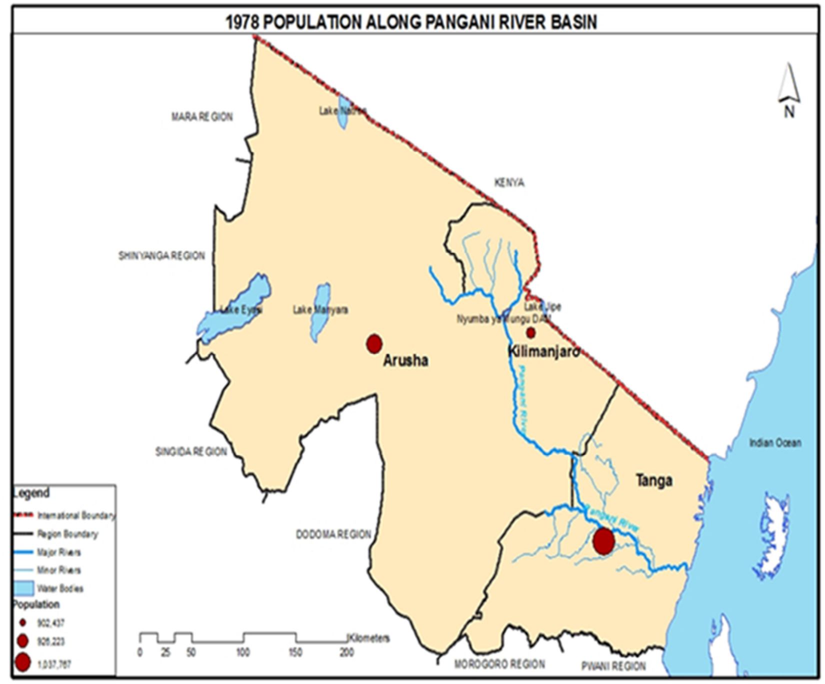


Figure 3: Population maps for 1957 and 1967 along Pangani River Basin Tanzania

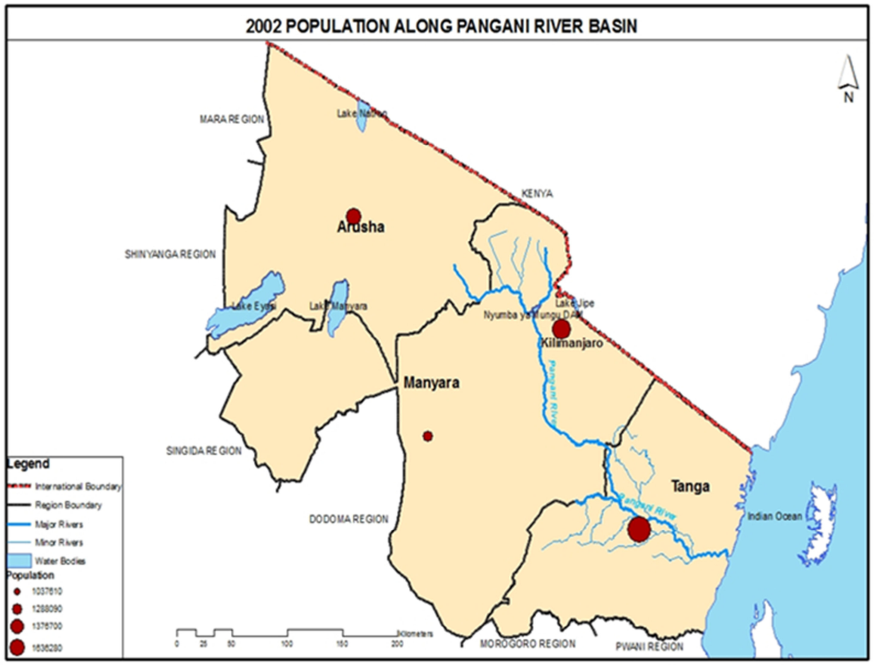




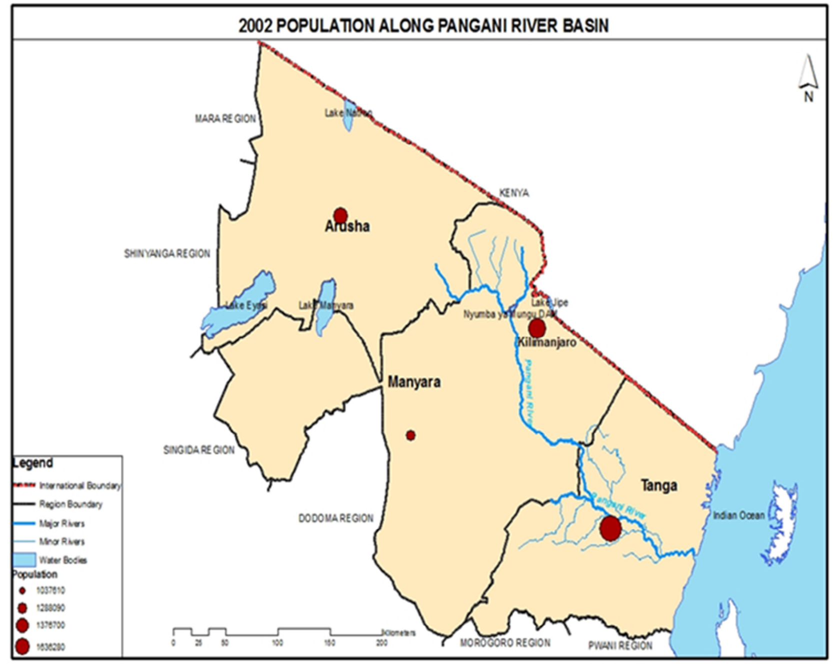
A

B

Figure 4: Population maps for 1978 and 1988 along Pangani River Basin Tanzania



A



B

Figure 5: Population maps for 2002 and 2012 along Pangani River Basin Tanzania

3.4 Land and water deals in Tanzania

Table 10 summarizes examples of land acquired by FDIs for biofuel plantations in Tanzania by end of 2010. During literature review, we realized that majority of FDIs were geared towards biofuel production for filling the void of energy demand. During the documentary review, we found that majority of FDIs engaged on large scale plantations of jatropha, sugarcane, Aloe vera, oil palm, flowers, white sorghum and *Croton megalocarpus*

Believers of the FDIs assert that these investments would have positive outcomes to agricultural production, add value to local products and markets and improve social services such as roads infrastructure, health facilities, clean water supply and education (Haki Ardhi, 2010). Experience, nevertheless, indicates that problems tied with FDIs outweigh the perceived benefits.

Table 10: Land grabbing status in Tanzania by 2010

S/N	Investor	Crop	Location	Land Requested (hectares)	Land Acquired (hectares)	Project Status
1	FELISA	Oil Palm	Kigoma	5,000	4,258	Land dispute in court for extra 350 ha obtained from 2 villages. No EIA done
2	BioShape	Jatropha	Kilwa, Lindi	82,000	34,000	400 ha pilot farm planted. Integrity of EIA questioned
3	Sun Biofuel	Jatropha	Kisarawe, Coast	50,000	8,211	8,211 ha of land formerly belonging to 12 villages transferred to general land; derivative title being finalised
4	SEKAB BT	Sugarcane	Bagamoyo, Coast	24,500	22,500	Seed cane planted and irrigation reservoir constructed
5	SEKAB BT	Sugarcane	Rufiji, Coast	400,000	0	In land acquisition process
6	Diligent Tanzania Ltd	Jatropha	Arusha; Babati, Manyara; Handeni, Tanga; Singida; Monduli, Arusha	n/a	n/a	Contracted over 4,000 farmers
		Croton megalocarpus		n/a	n/a	Collecting seeds from natural and planted forests
7	Donesta Ltd & Savannah Biofuels Ltd	Jatropha	Dodoma	n/a	2,000	200 ha planted
8	Trinity Consultants/Bioenergy TZ Ltd	Jatropha	Bagamoyo, Coast	30,000	16,000	Surveying land to be granted
9	Shanta Estates Ltd	Jatropha	Bagamoyo, Coast	n/a	14,500	Agreement with villagers signed
10	Tanzania Biodiesel Plant Ltd	Oil Palm	Bagamoyo, Coast	25,000	16,000	Land not surveyed; land granted by district but not by TIC

11	Clean Power TZ Ltd	Oil Palm	Bagamoyo, Coast	n/a	3,500	Project abandoned after realised high cost of doing land use plans
12	Agriculture Bio-energy Tanzania	White Sorghum	Bagamoyo, Coast	n/a	25,000	Land request approved but asked to do land use plans
13	ZAGA	Jatropha	Kisarawe, Coast	n/a	n/a	Applied for land
14	African Green Oils	Oil Palm	Rufiji, Coast	n/a	860	Planted 360 ha and financing land use plans in 7 villages
15	InfEnergy Co. Ltd	Oil Palm	Kilombero	n/a	5,818	Land lease pending. Cultivating rice while growing oil palm
16	Massive	Jatropha & Pangamia	Lindi	n/a	50,000	
17	JCJ Co. Ltd.	Jatropha	Mwanza Mara Shinyanga Tabora	n/a	n/a	Aimed to sensitize local communities but project abandoned due to alleged lack of government support
18	ABERC	*Croton megalocarpus*	Biharamulo, Kagera	n/a	20,000	No operational progress due to lack of funds
19	Prokon BV	Jatropha	Mpanda, Rukwa	n/a	10,000	Contract farming with 2000 smallholders; does not own any plantation land
20	Mitsubishi Corporation	Jatropha	Arusha Dar es Salaam Coast	n/a	n/a	Looking for land in these regions
21	Kapunga Rice Project	Jatropha	Mbarali, Mbeya	n/a	50,000	Planned to replant rice with jatropha; President recently ordered that rice cultivation patterns not be changed
22	DI Oils Tanzania Ltd	Jatropha			n/a	Abandoned plans for Tanzania
23	Kikuletwa Farm	Jatropha & Aloe Vera	Kilimanjaro	n/a	400	Growing Jatropha

Source: Adapted from Haki Ardhi (2010), Gordon-Maclean et al., (2008) and Sulle and Nelson (2009).

4.0 DISCUSSION

4.1 Effect of water grabbing on crop yield along

Investment in irrigated agriculture is one of the main means of achieving sustained crop yield. It is through sustained crop yield where food security and community welfare can be ensured at household level. On the contrary, irrigated agriculture is faced with water grabbing by FDIs (Table 3) something which leads to loss of crop yield. Sustainable agriculture and crop yield in the study villages is curtailed by foreign companies (located upstream) who abstract water for flower irrigation. Policy failures to enforce signed agreements (e.g. use of ground water) is a testimony on how the policy framework hasn't answered problems of water shortages faced by smallholder irrigators.

The influence of water grabbing on crop yield indicated in Table 4 is another indicator of the plight of water grabbing to irrigated agriculture. Results of statistical significance on mean yield before water grabbing ($P < 0.001$) confirms how bad water grabbing is. Given the current situation of the failure of rainfed agriculture due to climate change and climate variability in PRB, irrigated agriculture would have been the solution for boosting crop yield and community livelihoods through increased income and provision of ES (i.e. food). Similar observation is echoed by FAO (2002) that increased crop yield has extra benefits than just income increase. Sustainable irrigation creates on-farm employment, ensures food security and lowers food prices. Irrigated agriculture reduces poverty as well, because the poor normally spend 60–70 percent of their income on food (FAO, 2002).

4.2 Local and global drivers for water grabbing in PRB

4.2.1 Local in PRB

Water grabbing exists in PRB because local communities (majority of whom are small scale irrigators) have lost access to fertile land and ample water they used previously to support their living. Opinions from respondents suggest that poor water governance (Table 7) is the main driver for water grabbing in the study villages. Village and irrigation officers do not enforce the political, social, economic and administrative procedure articulated in the by-laws guiding water use and distribution. Majority of villagers don't participate fully during contract negotiations and decision making. Lack of full local community's involvement lead to poor and unfair decisions at the detrimental of local these communities. In the study villages, for instance, smallholder irrigators have no access to fertile land and water that they previously used to have the right to. In Arusha, large tracts of land are appropriated by foreign investors after signing with the government leaders. Local communities were poorly informed of the actual benefits and consequences of these land deals. As things stands they have little rights to stop the land acquisition and claim the land back (Sulle and Nelson, 2009). Furthermore, foreign companies located upstream divert large quantities of water (than the amount portrayed in the signed contracts) at the expense of downstream smallholder irrigators. This affects irrigation activities, provision of other ES (e.g. production of hydropower electricity) and the enhancement of ecological integrity along the river basin.

Corrupt leaders and lack of transparency are also key factors for water grabbing in the study villages. Responses from local smallholder irrigators revealed in Table 7 testify this existence. Decisions on who should be given a fertile land (and water) are corrupt oriented and are with low transparency and accountability. Findings from informal discussion with smallholder irrigators indicated that rampant corruption and absence of open village meetings are key to water grabbing in PRB. Consequently, once investment contracts are signed, environmental issues are not given special priority thus affecting the sustainable provision of ES and conservation of aquatic diversity within the river basins.

Inadequate environmental impact assessment; lack of integrated planning; and top-down management approaches associated with the current level of water grabbing and water use conflict in the study villages. Large scale investments on agriculture require a careful assessment of its environmental consequences before its initiation. FDIs of jatropha, sugarcane and flower plantations in Kilimanjaro and Arusha regions do not adhere to recommendation from scientists about adverse environmental impacts. In turn, there have been cases of water pollution caused by agro-chemicals and pesticides (Hellar and Kishimba, 2005; Hellar-Kihampa, 211; 2013) thereby affecting aquatic species, ES and human health. Sometimes, majority of these kind of investments are often negotiated at the highest level (e.g. national or regional level) neglecting the views of local leaders (at village levels) where investment are to take place. Moreover, important decisions on agricultural investment plans (poor planning) or integrated water resource management (IWRM) is always decided at ministerial level thereby leading to chaos and conflicts during implementation process. For example, uprooting natural forest in favour of large scale plantation (e.g. sugarcane and jatropha) affects biodiversity, water flow, river regime, nutrient cycling, and the and other ES necessary for human well-being.

4.2.2 Global drivers

Climate change and climate variability has already caused effects on production food at global scale especially in developing countries. These negative effects are felt more on provisioning ES where significant reduction of maize, wheat and rice yield have been reported (Howden and O'Leary, 1997; Hoogenboom, 2000; Gbetibouo and Hassan, 2005; Challinor and Wheeler, 2008).To feed the growing population in areas hit by climate change and climate variability and also fill the gap of global food shortages and demands, investments are carried out in developing countries (including in the PRB Tanzania). However, the way these investments are carried out (i.e. excessive water abstraction), seem have detrimental effects to the majority of native population and provision of ES. Water grabbing is depriving smallholder farmers' of irrigation water for thereby affecting the local economy.

Climate variability has accelerated the droughts, compromised rainfed agriculture and hence food shortages thereby necessitating irrigated agriculture. Land grabbing in the PRB is not just rush for fertile soil, rather it aims at fertile soil with ample water for irrigated agriculture. Thus the motive behind land's appropriation is water to carry out irrigated because rainfall is not reliable for rainfed agriculture. These views concur with the argument by Rulli et al. (2012) who asserted that irrigated agriculture will remain the largest user of water where it accounts for more than 80% of use in developing countries.

Population increase has an implication on the future of natural resources, utilization and conservation (Rulli eta l., 2012). This is also revealed by the responses on Table 8 where respondents in PRB indicated that the global and local population growth enhances water and land grabbing. According to Mbonile (2005) global and local population growth result in increased food demands and changes in food preferences thereby exerting pressure on the global land and water resources to satisfy those growing human needs. The global land and water resources are, therefore, under severe demands to satisfy the needs of growing human population (Gleick, 2000; Haki Ardhi, 2010; Molden and de Fraiture, 2010; Rulli et al., 2012). In recent years population increase has been accompanied with consumer preference on certain food types. Unfortunately, some of the preferred food types are not locally grown in European countries and in USA, thus necessitating overseas plunder through water and land grabbing (World Bank, 2010; White and Dasgupta, 2010; Borras et al., 2012). The change of food preferences are sometimes induced by health reasons (high blood pressure and diabetes), life style, indicator of income increase, or just effects of globalization. These changes influence types of manufacturing and processing industries, energy required and raw materials as well. Thus crossing the boundaries for water and land grabbing is a strategy to fulfil these consumers' requirements (Rulli et al., 2012) at the expense of ES at the area of destination.

As the economies tend to flourish, the need for re-investments arises for capital accumulation (Harvey, 2003). This in turn necessitates the exportation of surplus value (financial) for investment abroad. Therefore, economic growth (Table 8) is also a driver believed to have fuelled water and land grabbing globally in the PRB. Developed countries like The Gulf States, China, the Netherlands, USA, India, and South Korea are at the forefront of new investments in farmland abroad either for food or biofuel (von Braun and Meinzen-Dick, 2009). In economic terms, financial capital is re-invested where production costs are much lower and where land and water are more abundant. Unfortunately, these foreign funded biofuel and food plantations in PRB are causing environmental and socio-economic disaster through watershed degradation, forest and biodiversity abuse, water use conflicts and ecological, significant reduction of ES (water) and sustainability uncertainty along the PRB.

4.2.3 Other ecosystem services affected by water grabbing

Rivers requires a certain quantity of water and quality of riparian vegetation for ecological integrity and to support aquatic life (Baker et al., 2006; Kędziora, 2010; Randhir and Ekness, 2013) including fish species. The current water abstraction in the

PRB affect availability of ES and low water flow is a problem to aquatic plants and ecological integrity. As indicated in Table 9, opinions from respondents shows that low water flow affects existence of some fish species and aquatic plants. Low water level affects also hydroelectric power production at NyM dam, Hale and New Pangani falls power plants. Increase of FDIs upstream consumes a lot of water intended for downstream smallholder irrigators and for electricity generation. Low contribution of these three electricity plants to the national electricity network effect the country's economy. Furthermore, reduced water flow and water level affects water bird breeding grounds, the bird watching sub-economy and the tourist industry as a well. Therefore, excessive water diversions (by investors) affect the bird watching tourism along PRB due to low water in the breeding grounds. Thus, efforts need to be done in order to improve water availability for domestic uses, restore aquatic plants and water tree species and water availability for crop irrigated agriculture. Sustainability of these ES will ensure the welfare of communities residing along PRB.

4.3 Population dynamics in the PRB

The population dynamics in the PRB (Figure 2-5) is relatively in increasing trends. The increase has a clear implication to the supply of ES especially water for domestic and irrigated agriculture and more land for agriculture and settlement. But the timing of this increase is coinciding with influx of FDIs looking for fertile land and ample water for investments. Substantial amount of water is abstracted by foreign companies (large scale flower irrigators) that located upstream at the detrimental of smallholder farmers located far downstream.

Population growth along the PRB has resulted in increased number of irrigation farms, irrigation canals and other human activities that rely on water use. As a result, water is not enough to satisfy human demands and this water shortage is causing chaos and water use conflicts. Mbonile (2001; 2005) reported a number of water use conflicts along the PRB. They include conflict between communities and conservation organizations; upstream and downstream water users; hydroelectricity plants and other water users; farmers and livestock keeper; rural dwellers and urban communities; and communities and river basin authorities.

4.4 Land and water deals in Tanzania

Results on land and water deals presented in Table 10 are just indicative examples representing few cases of the major problem prevailing in the country. These examples focus much on biofuel and food crop investments. Other land deals in Tanzania (which are not in the table) focus on carbon sequestration projects under the umbrella of Reducing Emissions from Deforestation and Forest Degradation (REDD) and Clean Development Mechanism (CDM) initiatives.

Land and water grabbing highlighted in this study not only reveals a sign of poor knowledge of local communities over their resources, but it indicates the extent of corruption among our leaders. Some of the leaders responsible for safeguarding natural resources conspire with investors (FDIs) in order to violate regulations, guideline and laws that guide proper land and water utilization. In some case, even clauses stipulated clearly in the 2002 national water policy, 1995 Land policy, 1999 Land use Act and 1999 Village Land Use Act are bypassed in favour of FDIs. Land and water grabbing in Tanzania is an example of the validity of the applicability of classical economic theories (Harvey, 2003) on wealth appropriation through "primitive accumulation"

Primitive accumulation in the PRB involves depriving poor smallholder farmers off their fertile land in the name of boosting the local economy through capital investment (FDIs). Letting fertile land and water to foreign firms (Table 10) is a testimony of the operationalization of the Marxist theory of accumulation by dispossession (Harvey, 2003). In the PRB, there are transfers of factors of production (land and water) from the majority (poor Tanzanians) to the few (foreign companies). What is actually going on is the transfer of sources of income from smallholder farmers to few who claim themselves as investors. In economic terms this situation is like taking away sources of income from the majority (smallholder farmers) to the minority (FDIs) without creating new investment. Water and land grabbing in the PRB is like "the conversion of various forms of property rights into exclusive private property rights" (Larsen, 2012). In a nutshell, land and water grabbing in Tanzania is another form of capital accumulation through ne-colonialism dubbed as *"accumulation by deprivation"*. It is a new neo-colonial approach in disguise aimed at plundering natural wealth from developing countries.

5. 0 CONCLUSIONS

Foreign direct investments (FDIs) have potential contribution to development especially where the central government and private sector lacks sufficient capital and skilled labour. Nevertheless, the current study has demonstrated that FDIs are exploitative in nature and influence water grabbing along the PRB. The significant influence of water grabbing on crop yield before water grabbing is an indicator of the negative effects of FDIs to smallholder irrigators. This testifies that the perceived positive expectations from FDIs are outweighed by the actual negative outcomes.

The current study has revealed that drivers for land and water grabbing displayed are influenced by policy failures, poor governance, and lack of patriotism and among officers responsible for laws and regulations enforcement. Therefore, these negative outcomes and failure to oversee their responsibilities calls for enforcement of policies, laws and by-laws in order to off-set the drivers and negative effects of land and water grabbing. Contracts signed between the government and foreign investors doesn't adhered to clauses outlined in national policies are violated and corruption sums up the problems facing land and water deals. Adjusting land laws, policies, by-laws and enforcing them to benefit smallholder farmers would bring about a win-win situation between villagers and foreign investors. This would also remove features of ne-colonialism (e.g. land alienation, forced labour, bad working conditions and discrimination) which are witnessed in majority of large scale plantations along the PRB.

Investments involving land and water in Tanzania have so far created more problems (conflicts) than the expected benefits (such as employment and community welfare). Majority of FDIs has jeopardized the security of tenure and the national interest as well. Lack of transparency and accountability in contract negotiations has created loopholes for corruption. Based on the above results and discussions, we recommend enforcement of Land policy, Land use Act and the Village Land Act; implementation of investments aimed at improving food security; transparency in land acquisition; and investments that aim at ensuring the social security and remove vulnerability to water grabbing problems. Furthermore, we recommend FDIs to assist local communities to explore ground water, rainwater harvesting, and construction of water reservoirs.

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CHAPTER 6

Can irrigated agriculture work as adaptation strategy in climate stressed environment? Empirical evidence from Pangani River Basin Tanzania

This chapter is based on:

Lalika, M.C.S., Meire., P., Ngaga Y. M. and Chang'a, L. **(**Revised and submitted**).** Can irrigated agriculture work as adaptation strategy in climate stressed environment? Empirical evidence from Pangani River Basin Tanzania. ***Land Use Policy***.

ABSTRACT

Fresh water scarcity is a common problem in Pangani River Tanzania due to both irregular rainfall and increased annual mean temperature. Future increase in temperature will further exacerbate water scarcity and agriculture production. This study was carried out to determine trend of rainfall and temperature and analyze irrigated agriculture as adaptation option to water shortages. Data on population trend were collected from the National Bureau of Statistics and socio-economic data were collected in the study villages through questionnaires. Rainfall and temperature information for the period 1970 to 2008 were collected from Tanzania Meteorological Agency. The results indicate that the trend of population increase puts pressure on water demands. Both rainfall and temperature had positive and statistical significant ($P < 0.05$) influence on water flow. One unit of rainfall influenced the increase of water flow at the magnitude of 0.466 m^3s^{-1}. Irrigated agriculture is the principal socio-economic activity and is carried out as adaptation option due to unreliability of rainfall and failure of rainfed agriculture. A holistic approach for watershed conservation would enhance sustainable water flow. Drought resistant crops and short term seed varieties should also be promoted in order to deal with rainfall and water fluctuation.

Keywords: *Rainfall variability, Ecosystem services,* Smallholder irrigators, Rainfall, Water

1.0 INTRODUCTION

The sustainability of agriculture, industry and the natural environment depends largely on the supply of fresh water. Unfortunately, watersheds that provide freshwater for different ecological and socio-economic activities are under pressure due to climate change (CC) impacts, population increase and land use dynamics (Murray et al., 2012). Experience from different studies carried out across the globe shows that shortage of fresh water can lead to a poor supply of agricultural products and conflicts even at the international scale (Wolf et al., 2003). Rainfed agriculture is among the economic sectors that have been affected by the impacts of freshwater supply shortages. Therefore, understanding adaptation measures to water shortages and CC impacts is key towards solving problems of water scarcity. Irrigated agriculture is perceived.to be an ideal adaptation strategy in this case.

Climate change (CC) is currently considered as the most severe and devastating environmental catastrophe facing the globe (Wolf et al., 2003; Unmüßig et al., 2008; Berrang-Ford et al., 2011; Murray et al., 2012). It is the latest in a series of environmental drivers of global environmental change that have been identified following other environmental disasters such as drought, desertification, land degradation, failing water supplies, pollution, deforestation, fisheries depletion, and ozone depletion (Trabucco, 2008; 2012; Pearson et al., 2003; Bogale, 2013; Wolf et al., 2003; Boko et al., 2007; Brown et al., 2007; Murray et al., 2012). CC is expected to have adverse effects in developing countries mainly due to their geographic exposure, low income, greater reliance on climate-sensitive sectors and weak capacity to adapt to the changing environment (Bogale, 2013; IPFRI, 2012; Smit et al., 2003; Brooks et al., 2005; Boko et al., 2007; Bryan et al., 2009).

Africa is probably the most vulnerable continent to CC and climate variability not only because of the dependence of many of its economies on agriculture (Trabucco, 2008; 2012; Pearson et al., 2003, Bogale, 2013; Wolf et al., 2003; Boko et al., 2007) but also because of the presence of other environmental stresses besides CC (Mendelsohn et al., 2000; Hulme et al., 2001; Unmüßig et al., 2001, 2008; Boko et al., 2007; Matthews et al., 2007). These stresses include rapid population growth, land degradation, prevalence of human diseases and widespread poverty all of which have negative impacts on the sustainable management of ecosystems (IPCC, 2001; Mbonile, 2005; Notter, 2010; Boko et al., 2007). Rainfall irregularities coupled with rise in annual mean temperature have significantly affected smallholder farmers who depend mainly on agriculture (Kurukulasuriya et al., 2006) because CC deprives them from irrigation water. Previous studies on water resources in Africa (Vorosmarty and Sahagian., 2000) indicated a clear water stress (use exceeds renewable supply).

Along the Pangani River Basin (PRB) in Tanzania, a decrease in rainfall and an increase in temperature leading to a reduction in water flow are common characteristics and signals of CC (PBWO and IUCN, 2011; Munishi et al., 2009). In the PRB, CC is perceived to have reduced the capacity of watersheds to supply adequate water downstream where the majority of smallholder irrigators are located. Water is not only a finite resource, but also a key ES which is central to the socio-economic development and welfare of the people residing along the PRB. Reduced rainfall and low water quantities for agricultural sector are currently evident in the PRB. The current climate and rainfall variability are expected to persist and would worsen agricultural activities in the PRB. The prolonged rainfall decrease and increased temperature coupled with skyrocketing water demands has already aggravated the prevailing water scarcity situation along this basin. The recent low capacity of watersheds in Meru and Kilimanjaro mountains to release water downstream (Turpie et al 2005; Mwamila et al., 2008, Lalika et al., 2011) is linked with rainfall variability and temperature increase. Consequently, many streams and river valleys that contained large quantities of water in the past are now mostly dry and hardly contain any water during the rainy season. Meru and Kilimanjaro Mountains are no longer fulfilling their previous role of recharging ground and surface water through Kikuletwa and Ruvu rivers; small streams and river tributaries; and natural springs.

Furthermore, disappearance of the ice cap at the top of Mount Kilimanjaro has reduced the water flow along the PRB in recent years and the projection by climatologists is that it would completely disappear by the year 2020 (Notter, 2010, Ngana et al., 2010). Rainfall variability and uneven water flow have affected coffee and banana cultivation in the foothills and highland along the PRB. Smallholder farmers who used to make their ends meet through rainfed agriculture have been suffering from income poverty and food insecurity (Mbonile, 2005; Amani, 2006).

Irrigated agriculture is, therefore, a viable option and adaptation strategy against water reduction. It is also regarded as the ideal solution for ensuring food supply and security at household level during the dry season (Butler and Laurance, 2006; Conway et al., 2009). Irrigated agriculture has the potential to support smallholder farmers to harvest enough crops in environments already suffering from CC and could boost crop production in water stressed and marginalised areas (Song-cai, 2001; Gordon et al., 2010; Kandlinkar and Risbey 2000, Khan and Hanjra 2009, Hanjra et al., 2009a; 2009b; Molden et al., 2010). Despite the increased information on the evidence of the effectiveness and potential for agriculture as adaptation strategy to CC and water stress (Song-cai, 2001, Droogers and Aerts 2005, Hassan and Nhemachena, 2008; Rosenzweig et al., 2004; Munir et al., 2010), information on irrigated agriculture as adaptation strategy to water scarcity and CC is limited in PRB. Similarly, while there are enough data collected for nearly half a century on rainfall and water fluctuation in the PRB, this information has not been disseminated at a wider scale to decision makers. Objectives of this study were (i) To analyze population increase in the PRB (ii) to determine the trend of rainfall and temperature in the PRB; and (iii) to analyze irrigated agriculture as adaptation option to water shortages and impacts of CC and climate variability in the PRB.

2.0 MATERIALS AND METHODS

2.1 The study area

We conducted this study in eight villages, four (Kaloleni, Chekereni, Rau River and Mabogini) in Kilimanjaro Region and four (Lekitatu, Karangai, Msitu wa Mbogo and Kikuletwa) in Arusha Region (Figure 1). We carried out data collection between 2011 and 2103.

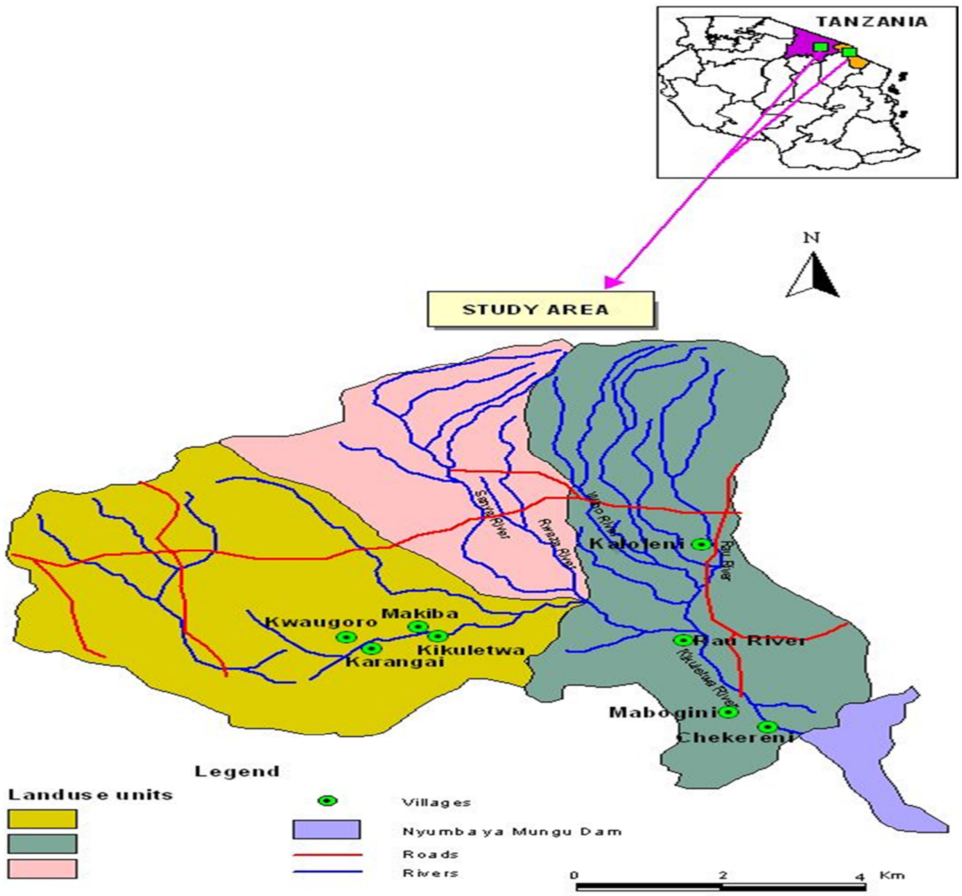


Figure1: Location of Pangani River Basin (PRB) Tanzania.

The PRB extends from the northern highlands to the north-eastern coast of the country and lies between latitude 03º 05' 00" and 06º 06' 00" South and longitude 36º 45' 36" and 39º 36' 00" East

2.2 Climate and drainage patterns

The upper parts in the slopes of Mt. Kilimanjaro and Mt. Meru receive 1200-2000mm rainfall per year, and the rest of the catchment area receives only about 500mm per year (Sarmett, 2005). There are two distinct rainy seasons, the short season (*vuli*) from mid-October to December (OND) and the long season (*masika*) from mid-March to May (MAM). The PRB faces water demand stress from different sectors, such as irrigation, hydroelectric power, domestic, industrial, and tourism. Such stress has created a drastic impact on the downstream users especially the national hydropower plants of Nyumba ya Mungu (NyM) Dam constructed early in 1969 with a capacity of 8 MW, Hale built in 1964 with (21MW, 1964), Old Pangani in 1934 with (17.5 MW,

1934) and New Pangani falls constructed in 1995 with a capacity of 68 MW (Shaghude, 2006).

The increase unreliability of rainfalls and other poor climatic elements coupled with human water demanding activities will further worsen the already precarious situation. The volume of the ice cap at the Kibo Summit of Kilimanjaro Mountain has been reduced by 82% since 1912, when the ice cap was thoroughly surveyed (IUCN, 2003; Mbonile, 2005). The glacial ice cap of Mount Kilimanjaro, towering over the basin, is estimated to disappear by 2020 and increased temperatures are expected to result in a 6-9% annual reduction in surface flows (URT, 2009; Kamugisha, 2009). The disappearing glaciers on Mt. Kilimanjaro are among the few clear signs of global warming.

Drainage pattern in the catchment varies considerably. The PRB comprises of several sub-catchments of widely different characteristics. The Pangani River (PR) has two main tributaries: Kikuletwa that originates from the slopes of Mt. Meru, and Ruvu on the slopes of Kilimanjaro which join to form the main PR. The PR drains to NyM dam, a man made wetland of 140km^2, and the uppermost dam for hydropower generation in the north eastern part of Tanzania (PBWO, 2007). Other tributaries from Pare and Usambara Mountain Ranges are Mkomazi and Luengera which join PR before reaching the Indian Ocean through Pangani a coastal town.

2.3 Data collection and analysis

Field visits were first carried out along the PRB for village identification and sampling purposes. A simple random sampling technique was used to select the sampling units in order to avoid bias. We used this sampling technique in order to give every member of the population an equal chance of being selected. The sampling frames for this study were the village registers containing the list of all household in the respective villages. We sampled 8 villages, 4 in Arusha Region and 4 in Kilimanjaro Region (Table 1).

Table 1: Interviewed respondents in the study villages

Region	District	Village	Total households	Respondents
Arusha	Meru	Lekitatu	250	25
		Karangai	480	48
		Kikuletwa	640	64
		Msitu wa Mbogo	420	42
Kilimanjaro	Moshi Urban	Kaloleni	490	49
		Chekereni	550	55
	Moshi Rural	Rau river	340	34
		Mabogini	430	43
Total			3600	360

In each village, we randomly selected respondents using a table of random numbers. The respondents were selected by matching their numbers in the register. We used both quantitative and qualitative methods in data collection.

For quantitative data, we used structured questionnaires as our main tool for collecting primary data. The structured questionnaire covered questions on water uses, types of water sources, types of irrigated crops, payment methods for water utilization, types of socio-economic activities; other goods and services available in the PRB; adaptation methods to CC and for water shortages, and other issues relevant to the study. During field work, one researcher and two research assistants administered the structured questionnaires in the study villages. As indicated in Table 1, a total of 360 respondents were interviewed in eight villages.

We divided the study in three phases. During the first phase we carried out a field excursion with the aim of familiarizing ourselves with the study area and selecting study villages. We also pre-tested questionnaires in order to assess questions for their validity and reliability in the sampled villages.

In phase two, we collected data using the structured questionnaires where a total of 360 respondents were interviewed (Table 1). We also collected qualitative data through informal and formal discussions. These discussions enabled us to enrich quantitative data collected through structured questionnaires. Group focus discussions were also carried out. We collected secondary data on population increase through literature search and review. We visited the Tanzania Bureau of Statistics for collecting data on human population increase. We gathered the national population census reports and information on population dynamics and increase were extracted from therein.

During the third phase, we collected time series data on rainfall and temperature in order to determine the impacts of CC on water flow. As mentioned in section 2.2, the PRB experiences two bimodal rainfall seasons i.e. MAM and OND. Our interest was on the later which is the period for smallholder farmers to carry out irrigated agriculture. Therefore, we collected mean monthly rainfall and temperature data for OND for the period 1970 to 2008 from selected synoptic stations to assess regional climatic trends along the PRB. The synoptic stations involved in this case include Tanga, Moshi, Same, Arusha and Handeni. The data were obtained from central Tanzania Meteorological Agency (TMA), a designated meteorological authority mandated to provide meteorological services for the United Republic of Tanzania.

Rainfall data were recorded from standard rain gauges for the interval of three hours. Standard rain gauges with special bottle were normally inserted on the ground for capturing rainfall drops. Thereafter, water from the bottle was taken to the laboratory for measuring its quantity in millimetres using a special measuring cylinder. At the gauging station, the total rainfall recorded was normally reported on the second day at 09:00. This means that we collected the cumulative data for daily rainfall from the first day at 09:00 in the morning to the next day at 09:00 in the morning.

2.4 Data analysis

We coded information from structured questionnaires, cleaned and wherever applicable data from open-ended responses were categorized and transferred to enable further analysis. All quantitative analyses were performed using Statistical Package for Social Sciences (SPSS) version 20.0. Time series data for the October, November and December (OND) season for rainfall and temperature were subjected to rigorous procedures to ensure data quality. Trend analysis for both rainfall and temperature for each of the station was then performed. For hydrological data, daily, monthly and seasonal flows were then used to compute average, minimum and maximum yearly flows in the PRB (Valimba, 2007; Ndomba et al., 2008). Thereafter, data were entered in MS excel where trend analysis was carried to draw figures.

To test the influence CC on water flow we had this hypothesis: rainfall and temperature influence the quantity of water flow. Our statistical test was based on probability level of 95% ($p<0.05$). Results of this analysis are displayed in Table 3.

The statistical analysis for CC effects on water flow was tested by using the ordinary least square method (OLS), i.e. the regression analysis. In this analysis we treated water flow as a function of different explanatory variables as indicated here under:

$$WF = f\,(RA, TM, EV, HU, WW, IR) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

Where: **WF** = Water flow

R = Rainfall

TM = Temperature

EV = Evaporation

HU = Humidity

IR = Irrigation

WW = Water withdrawal

Therefore,

$$WF = \beta_0 + \beta_1 R + \beta_2 TM + \beta_3 EV + \beta_4 HU + \beta_5 WW + \beta_5 + \ldots \beta_n X_n + e \quad \ldots\ldots\ldots\ldots\ldots\ldots 2$$

Where:

β_0 = a constant showing intercepts for regression equation

β_1 to β_n = independent variables coefficients

e = error term

However, due to the challenges that we faced during data collection including poor data management, we failed to get some data for running the model (e.g. data on evaporation, humidity, quantity for irrigation water, etc.). Therefore, we computed the model using only rainfall and temperature data.

$$WF = f\,(RA, TM) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3$$

Therefore, the model used for exploring the relationship between rainfall, temperature and water flow is:

$$WF = \beta_0 + \beta_1 RA + \beta_1 TM + \ldots \beta_n X_n + e \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 4$$

Lack of data for water withdrawn from rivers (for different socio-economic activities), data for evaporation, and population increase on yearly basis is a serious limitation that affected the model. For example, increase of population (including small holder farmers) increase water withdrawals. And as temperature increases, evaporation tends also to increase. Therefore, we didn't include those two crucial parameters in the model. We also carried out analysis to compare the means between yield with and without irrigation. Results are displayed in Table 4.

3.0 RESULTS

3.1 Socio-economic characteristics of respondents.

Socio-economic characteristics or respondents displayed in Table 2 focused much on water and irrigated agriculture. Our findings indicated that majority of respondents (98%) carried out irrigated agriculture as the main economic activity and source of household income.

Table 2: Respondent's socio-economic variables along the PRB, Tanzania

Variable		Frequency (n)	Percentage
Main source of income	Irrigated agriculture	354	98.3
	Employment	4	1.2
	Small scale trading	2	0.6
	Both (dry and rainy)	210	69.8
Irrigation season	Dry	57	18.9
	Rainy	54	11.3
	Climate change	214	70.6
	Population increase	51	16.8
Causes of water shortages	Abstraction by investors	24	7.9
	Watershed degradation	14	4.6
	Reduction of crop harvest	237	79.8
Main effects of water shortages	Hunger	48	16.2
	Loss of income	8	2.7
	Poverty	4	1.2
	Yes	339	95.8
Water right for irrigation water	No	15	4.2
	Don't know	1	0.9

Responses from respondents indicated that 70% of smallholder farmers carry out irrigation activities in both seasons (i.e. dry and wet season). This was contributed mainly by erratic rainfall which affected rainfed agriculture (Mkojera, 2009).

Perceptions regarding factors behind the current water shortages along the PRB are displayed in Table 2. According to respondents, CC accounted for 71%, human population increase (17%), water abstraction by investors accounted for 8% and watershed degradation (4%). We also found that water shortages affected respondents through reduced crop harvest (80%), hunger (16%), income loss (3%) and poverty (1%). With respect to irrigation water utilization, 94% had water user right granted by Pangani Basin Water Office (PBWO), the government agency responsible for water allocation, management and collection of water use fees from customers.

3.2 Population dynamics in PRB

3.2.1 Population increase in PRB for 1957 – 2012 censuses

Figure 2 indicates the trend of population dynamics in PRB since 1957 to 2012. Tanga region showed higher increase (R^2 = 99.7%) as compared to Kilimanjaro (R^2 = 99.3%) and Arusha (R^2 = 95.4).

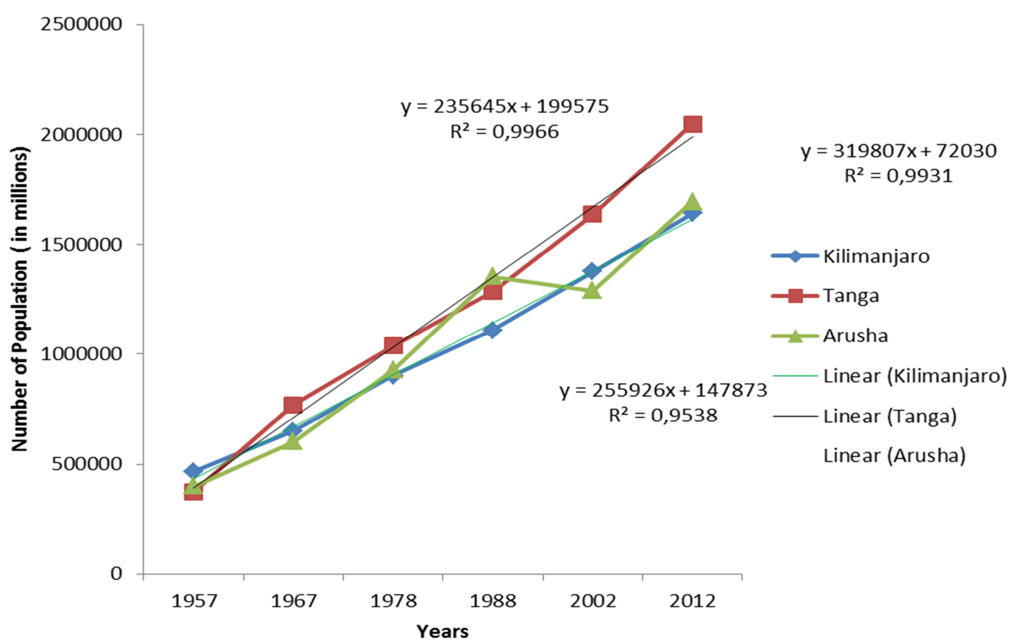


Figure 2: Trend of population dynamics along PRB, Tanzania

The population trend in the PRB (Figure 2) indicated similar population trend like that for population dynamics revealed in Figure 3 for the entire country from 1967 to 2012. For instance the coefficient of determination for population increases and population density were 97.7% and 97.5% respectively with a positive trend line. These population parameters at national level do not differ with large margin as compared to those in Figure 2. This population increase calls for increased ES, water in particular to cater for the rising rapidly growing population. In the context of the current study, the population growth in the wake of CC and climate variability calls for increased irrigation water (Murray et al., 2012; Yoffe et al., 2003; Wolf et al., 2003) for boosting crop production to feed the growing population.

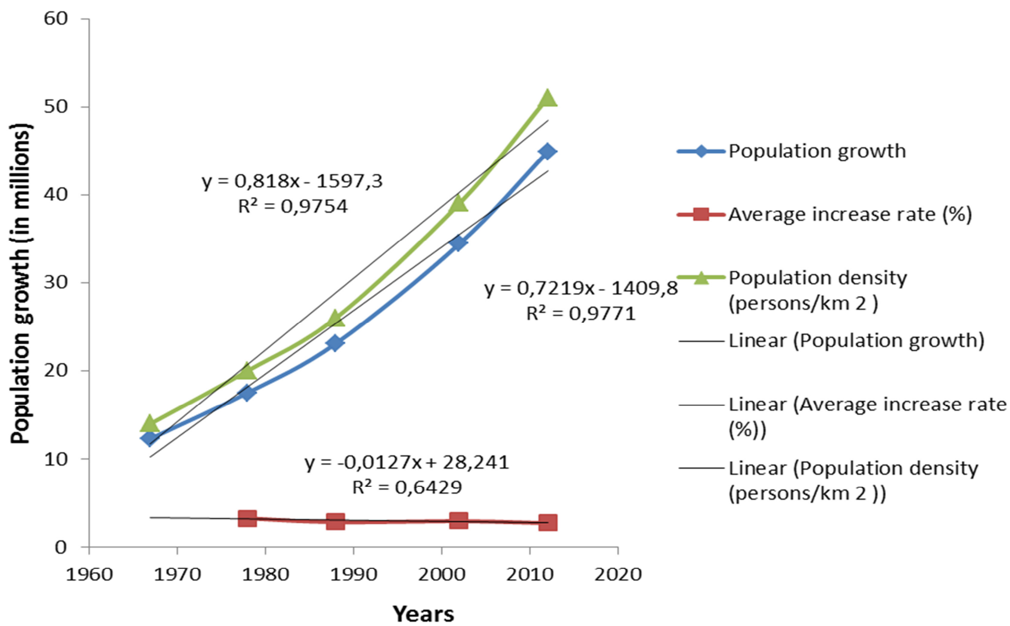


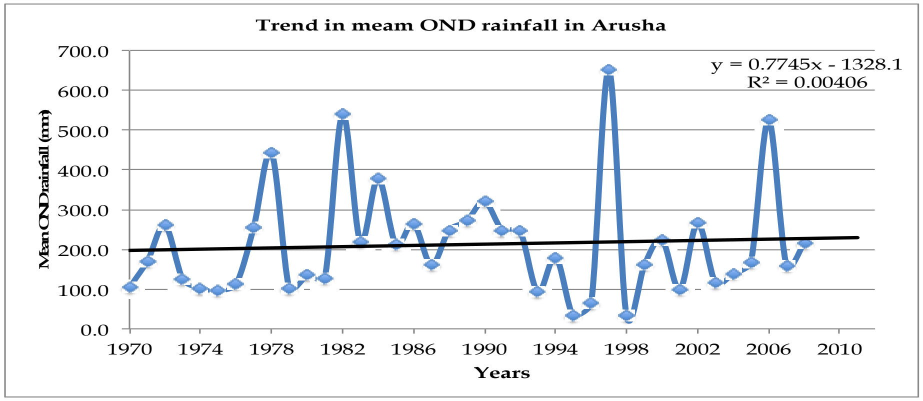
Figure 3: Trend of population dynamics at national scale for 1967 to 2012 census in Tanzania

Apparently, while the number of human population is increasing at an alarming rate along the PRB, watershed ecosystems essential for the provision of ES services (water in particular) are dwindling. The decline of the capacity of watersheds to provide ES is a worldwide problem. The study by Vörösmarty et al. (2000; 2010), based on anthropogenic and biodiversity indicators revealed that in 2000, 80% of human population across the globe was living in water stressed regions. Similar situation were reported by (Mbonile, 2005; Ngana et al., 2010) on water use conflicts along the PRB fuelled by rampant human population increase.

3.3 Rainfall and temperature patterns for in the PRB

3.3.1 Rainfall trend

Figure 4 shows a slight increase of mean rainfall in OND. This trivial increase in mean seasonal rainfall highlighted uncertainty associated with rainfall pattern (Suweis et al., 2012).



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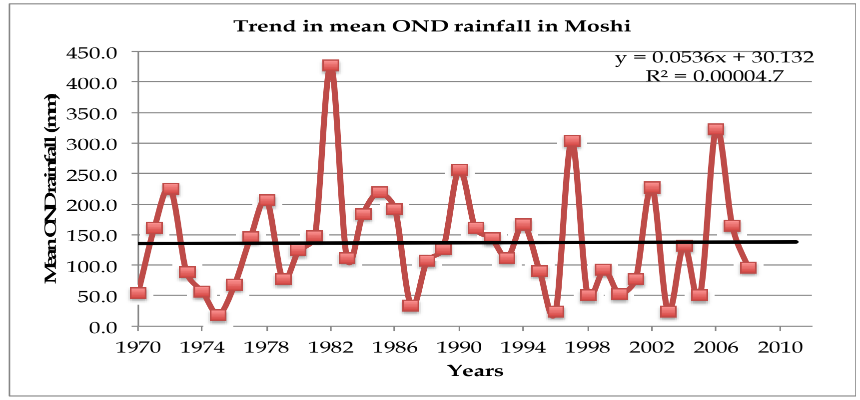

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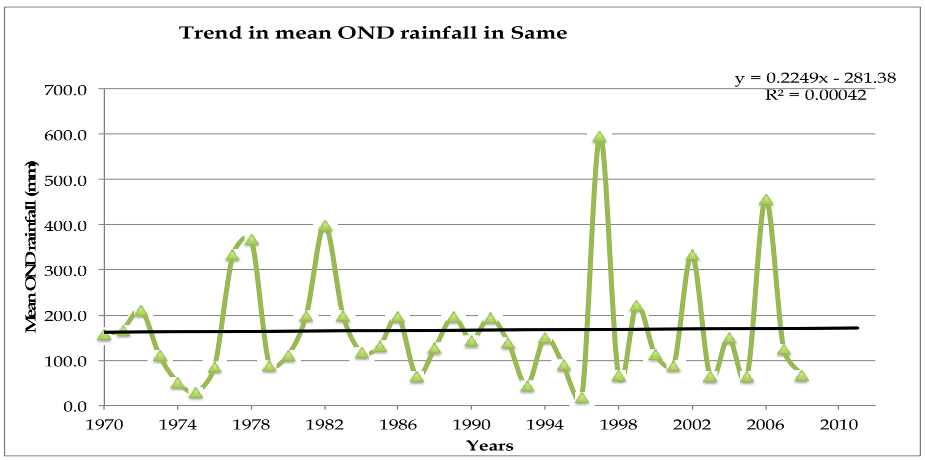

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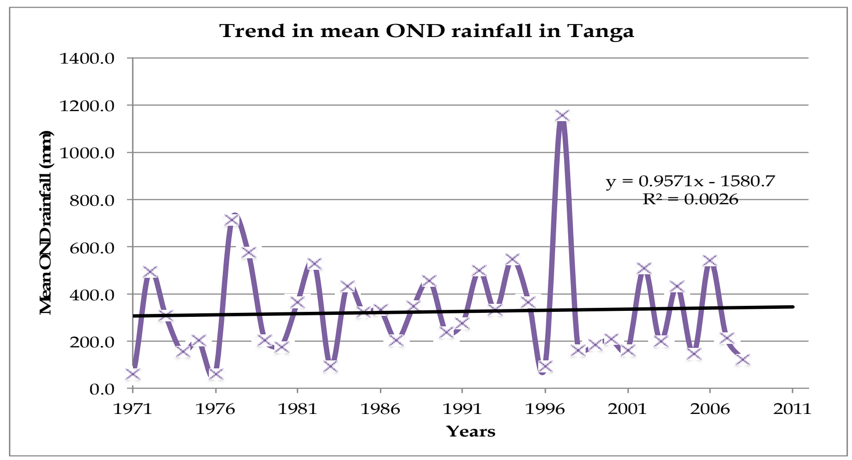


D

Figure 4: Trends in mean OND rainfall at four meteorological stations along the PRB, Tanzania

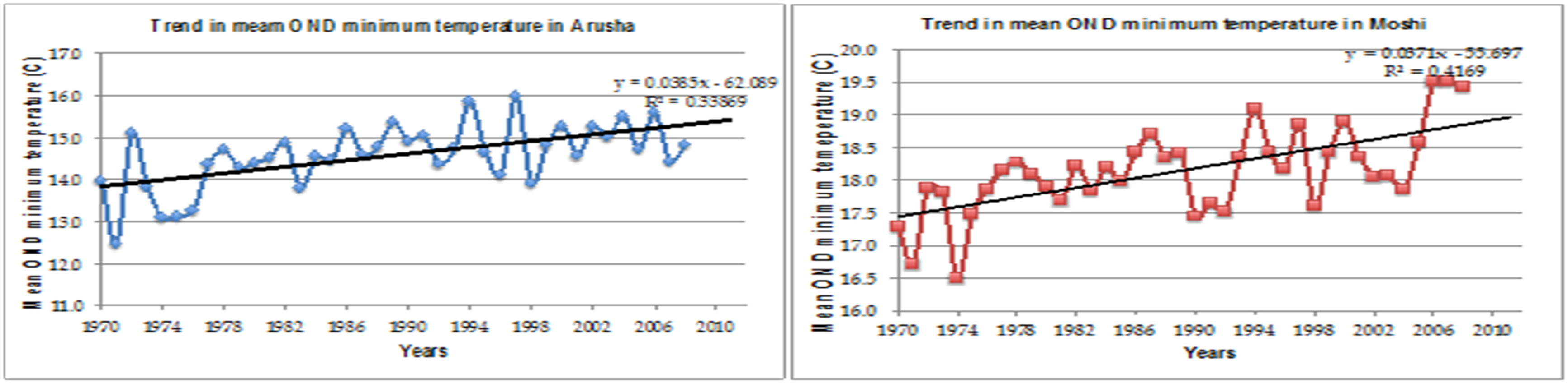
As indicated in Figure 4, rainfall increase is quite small in all four meteorological stations. The small increase seems not to have been influenced by CC, instead by climate variability (Zorita and Tilya, 2002). Therefore, CC may have little to do with water shortages along the PRB, rather water shortages is influenced by competing water demands for irrigated agriculture (the main economic activity) and demands driven to cater for the increased population.

Similarly, the small rainfall increase (Figure 4) is a huge setback for OND spell which are popularly regarded as "*short rains*" season. Few years back OND rainfall season has been quite instrumental for ensuring food security before the long season rainflall harvest. However, the recent rainfall trend aggravated by the effects of CC in Kilimanjaro and Meru Mountains has threatening efficiency of economic activities that depend on water the PRB.

Kilimanjaro and Meru Mountains are two highest peaks crucial for modifying microclimate, regulating rainfall and steady water flow (Valimba, 2007; Ndomba et al., 2008). The current slight rainfall increase (Figure 4) and predicability is threatening the OND rainfall season in such a way that some climatologists (Agrawal et al. 2003 ; Muamba and Kraybill, 2010) predict it may disappear in the next few years. The decline of OND rainfall season may noramally enhances failure of rainfed agriculture and food insecurity since it stretches the dry period (Devereux et al., 2008). Therefore, irrigated agriculture is the way forward towards food production and security and as an adaptation option to water shortages along the PRB.

3.3.2 Temperature trend

Figure 5 reveal results of temperature trends in OND for four meteorological stations along the PRB.



A **B**

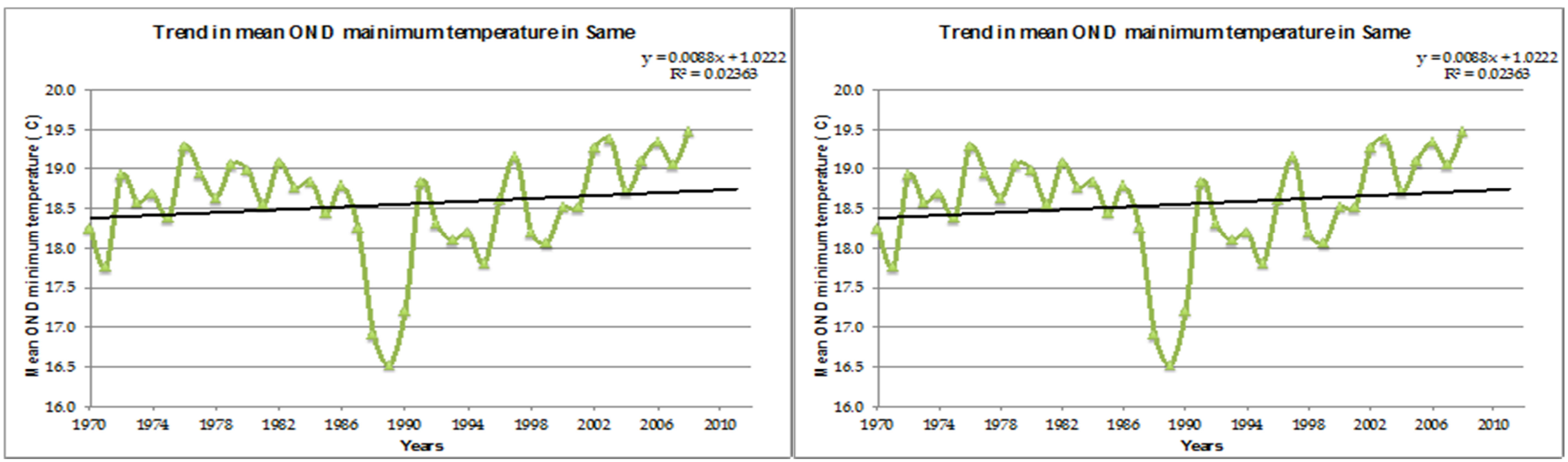


Figure 5: Trends in mean OND minimum temperature at four meteorological stations along the PRB, Tanzania

Figure 5 indicate increase in temperature in all four meteorological stations. However, the increase in temperature is a bit lower in Same station (Figure 5C) as compared to other meteorological stations along PRB. This observation is a bit strange because Same District is located in the leeward side of Pare and Usambara mountains ranges thus it experiences semiarid climate condition. This finding concur with findings by Munishi et al.(2009), who observed increase temperature patterns in 12 different climatic zones of Tanzania except Dodoma and Singida which are constitute semi-arid areas of Tanzania.

To assess the influence of rainfall and temperature on water flow we adopted regression analysis. Results are displayed in Table 3. Results indicated that both rainfall and temperature had positive and significant ($p < 0.05$) influence on water flow.

Table 3: Summary on the influence of rainfall and temperature on water flow in PRB

Variable	Standard error	Beta	t	Sign.
Rainfall	0.81	0.466	3.319	0.003*
Temperature	18.231	0.338	2.336	0.025*
R^2				0.237

Note: * $p < 0.05$

The beta value in Table 3 denotes that one unit of rainfall influences the increase of at water flow at the magnitude of 0.466 m^3s^{-1}. Likewise temperature had positive regression coefficient and significant ($p < 0.03$) influence on reduction of water flow. its influence on water flow was statistically not significant (Table 3). Nevertheless, the goodness fit of the regression model ($R^2 = 0.237$) was weak in the sense that it explained only 23.7% of the relationship between rainfall and temperature (i.e. explanatory variables) and water flow (i.e. the dependent variable).

Water withdrawals and illegal water abstraction for irrigated agriculture and other socio-economic activities affect enormously water flow along the PRB (PBWO and IUCN, 2011). As stated earlier in section 2.4 we didn't manage to get adequate data for these parameters for inclusion in the model. And this is one of the problems of data acquisition, storage, management inherent in developing countries. Water intake and irrigation canals were locally built without gauging meters. And this hindered irrigation canal managers to record the quantity of water withdrawn or abstracted (Figure 6).

Figure 6: Water intakes for irrigation canals along the PRB, Tanzania

Furthermore, we found that majority of irrigation canals had no concrete structures at the bottom, causing significant quantity of water to infiltrate before reaching the farm fields.

3.4 Irrigated agriculture as adaptation option to water shortage

3.4.1 Irrigated agriculture vs non-irrigated agriculture

Comparison in yield revealed that crop yield was higher in irrigated agriculture than in non-irrigated agriculture (Table 4).

Table 4: Crop yield between irrigation vs without irrigation per village

Village	Yield with irrigation(kg/ha/season)		Yield without irrigation(kg/ha/season)	
	Maximum	Mean ± STD	Maximum	Mean ± STD
Rau River	33333.33	2443.63 ± 5537.44	2000.00	638.40 ± 485.58
Chekereni	6000.00	1768.18 ± 1096.59	3500.00	648.50 ± 738.64
Mabogini	14000.00	2092.31 ± 2054.50	1600.00	878.62 ± 426.40
Lekitatu	9600.00	2858.67 ± 1662.08	15000.00	2379.33 ± 2971.03
Kikuletwa	8000.00	1017.36 ± 1163.42	10000.00	520.17 ± 1250.87
Karangai	16000.00	912.22 ± 2263.52	10000.00	445.56 ± 1431.88
Msitu wa Mbogo	28000.00	1836.11 ± 4235.78	6000.00	586.71 ± 960.56

Crops earmarked in this analysis were those with weight measurements (kg/ha/season) during harvest. They included maize, paddy, beans and cassava. As indicated in Table 4 both the mean and standard deviation of crop yield with irrigation were higher than that for without irrigation. This implies that irrigation is a viable option as adaptation strategy against the impacts climate variability, erratic rainfall and failure of rainfed agriculture) (Munishi et al., 2009).

Furthermore, we looked at types of crops irrigated along the PRB. Findings in Figure 7 indicate that maize and paddy are the main crops grown by majority of smallholder irrigators. As indicated in Table 2, majority of respondents carry out irrigated agriculture as the main economic activity.

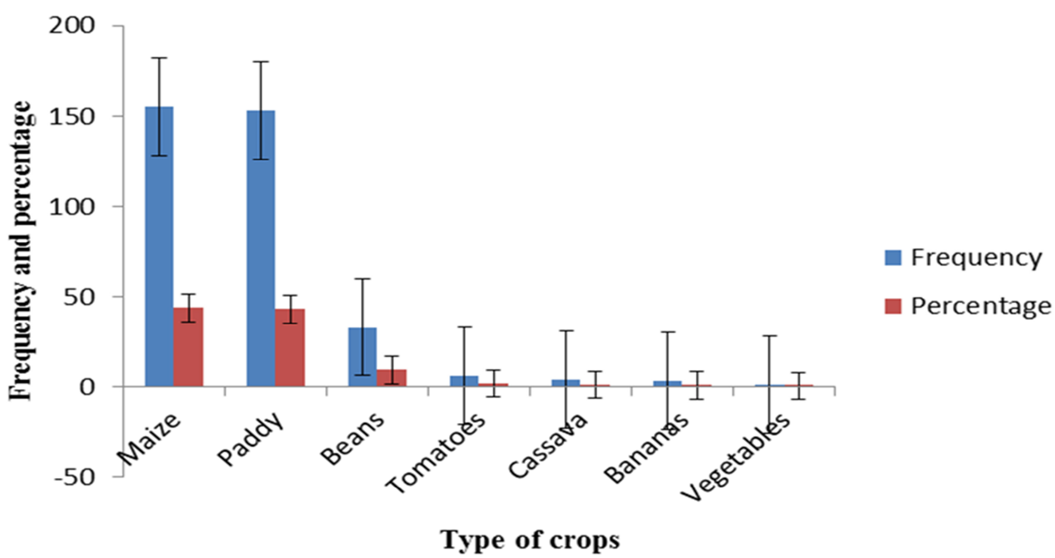


Figure 7: Type of irrigated crops in the Pangani River Basin, Tanzania

Other crops are grown in the PRB are just to spread the risk of the unforeseen failure of main crops. Furthermore, it is a kind of crop diversification due to water shortages. These crops incudes bean, bananas, tomatoes, cassava, and various vegetable types. Findings from formal and informal interviews indicated that maize and paddy are currently grown for commercial purposes contrary to the past where all cereal crops were regarded as food crops. The main reason behind (food crops being transformed to commercial crops) this situation is drought and skewed population increase which influence market forces of demand and supply. While in some parts there are plenty food, other areas face food shortages.

CC and climate variability has contributed to regional food shortage in such a way cereals are no longer food crops, rather they have become commercial crops across Sub-Saharan Africa (Amani, 2006; Brown et al., 2007; Ehui et al., 2010; Munir et al., 2010). This CC and climate variability has accelerated and drought in the Sahel Region (Chad, Sudan, North Kenya and Uganda, South Sudan, and Ethiopia) and entire Horn of Africa Regions (Somalia, Djibouti, Eritrea, and Somaliland) thereby necessitating adaptation options. On the other hand, paddy irrigation could also play a key role as carbon stock for the atmospheric carbon. Experiences from literature (UNW-DPC, 2008) have indicated that paddy cultivation also plays a key role in green economy by ensuring food production and enhancing carbon sequestration as well.

3.4.2 Socio-economic activities that contribute to water shortages CC and variability in the PRB

We revealed a number of drivers that play key role in the current CC change along the PRB. Some of them are displayed in Table 5.

Table 5: Opinions on socio-economic activities that contribute to CC and variability

Indicator	Frequency	Percentage
Deforestation	238	67.8
Unsustainable agriculture	52	14.8
Overgrazing	20	5.7
Lumbering	15	4.3
Charcoal making	14	4.0
Fire	12	3.5

Of all respondents, 67.8% indicated that human activities result in deforestation that brings about the current CC impacts. The operational definition for deforestation in this document is *"the permanent removal of a forest or stand of trees where the land is thereafter converted to a non-forest use"*. Examples of deforestation include conversion of forestland to agriculture; logging; cattle ranching; oil, gas and mineral extraction; or for human settlement use (Ogutunde et al., 2006). Deforestation evident in the PRB for the past few decades due to mineral extraction in Mererani Tanzanite deposits and gold mining in Usambara Mountains. Establishment of large farms (in Arusha and Moshi) claimed large tracts of forest stands in favour of growing flowers for exports in the United States of America and European markets.

Other opinions that we also document as drivers for CC and variability include unsustainable agriculture (absence of conservation farming such agroforestry and mulching) 14.8%, overgrazing (5.7%), lumbering (4.3%), charcoal making (4%) and wild fire (3.5%). These factors contribute to CC and variability through by reducing the forest cover (atmospheric carbon sink) on one hand, and by releasing below ground carbon to the atmosphere, on the other hand (Butler and Laurance, 2006). Moreover, deforestation, unsustainable agriculture, lumbering, overgrazing and fire has reduces the capacity of watersheds and other natural springs to release water, consequently causing water shortages for human activities and ecological functions.

4.0 DISCUSSION

4.1 Socio-economic variables

Agriculture remains the largest sector, the source of income, food security, a poverty alleviation strategy and employer of majority especially in rural areas of Tanzania (Maijo 2010; Mkojera, 2009). Nevertheless, large part of the country receives reliable rainfall for hardly three months (March, April and May) thereby subjecting problems to rainfed agriculture. As indicated in Table 2 irrigated agriculture is the main economic activity, source of income and probably the ideal answer for the current failure of rainfed agriculture. Nevertheless, population increase has led to the over utilisation of water resource and water shortages and is threatening the future availability of water ES along the PRB (Mbonile, 2005; Welling et al., 2012). In recent years, irrigation is carried out even during the rainy season in some of the study villages (e.g. Chekereni and Rau River). In the PRB, water shortage is influenced by incresed demands driven by population increase (Figure 2 & 3). Smallholder agriculture is among the sectors affected by water shortages and CC variability. Enhancing sustainable water flow and improving irrigation infrastructures would help to satisfy irrigation demands (Mkojera, 2009). This is possible through the enforcement of policy and institutional measures to improve water flow, water allocation, rationing and distribution for various socio-economic activities including irrigated agriculture. This could be implemented through financing watershed conservation programmes, transferring irrigation management systems from the government to smallholder irrigators associations, to name just a few (Mkojera, 2009).

On the other hand, carrying out irrigation even during rainy season is an indicator of how important watershed conservation is. It emphases the essential for the conservation to enhance sustainable water flow. In the past few years, the main objective of irrigation was to supplement failures of crop harvest occured during rainy season. However, the case has been different in recent years where change in rainfall patterns and climate variability have forced smalholder farmers to carry out irrigation in both seasons (i.e. rainy and dry season) (Table 2). Thus more emphasis is needed for watershed conservation in order to enhance water flow. As indicated in Table 2 CC and population increase are among the factors influencing the current water fluctuation and water demands in the PRB. Reduced rainfall and increased temperature are associated with CC and climate variability result in water fluctuation. Population influx along the PRB is accompanied by increased human demands (such as water) which lead to water abstraction, increased irrigations canals, conflicts over water uses [18]. Although, severe damage along the PRB is yet to be recorded as was the case for the Sahel and Horn of African region (in the last decade) (Brown et al., 2007) the fall of crop harvest at 80% (Table 2) is an indicator of how damaging would CC and climate variability do to crop production in the study villages.

The trend of population growth along the PRB and in the country (Figure 2) and (Figure 3) respectively has implication on water and ES as a whole. The coefficients of determination of population increase in Arusha, Kilimanjaro and Tanga Regions are indications of human increase and the urgent need for increase of ES (water in particular) to support the growing population. Population growth in the PRB is modifying the whole issue of water scarcity and allocation to difference economic sectors. The current population increase is far ahead of the capacity of the natural ecosystem to release water for various socio-economic activities especially to the downstream stallholder irrigators. The demand for water for irrigated agriculture is increasing significantly due to population growth and economic development. Water scarcity in the PRB is occurring because watershed ecosystems are no longer able to retain and release gradually adequate water to meet demand of the existing population. Furthermore, population growth is far ahead and cannot keep pace with the available water to support socio-economic development. This observation conforms to the theory of population growth and resource scarcity (Malthus, 1798).

This population growth is a clue about the urgent need for policy makers and development planners to develop comprehensive plans for safeguarding the ecosystems for sustainable provisioning of ES. Population growth pressure on ecosystem and their associated ES is realized mainly on their influence on water shortages and scarcity. Unfortunately, water scarce and water stressed areas in the PRB are typically those with few water resources, high population densities, and high population growth rates (Mbonile, 2005; Suweis et al., 2012). Population growth limits the amount of water available per person, drives people into marginal areas which are already water stressed and also into cities.

On the other hand population increase leads to demands for more space for urbanization and more space development of urban infrastructures to support the growing population. The case in point is in Moshi Municipality where settlement expansion led to the modification of urban water pathways through different networks such as roads and liquid waste system (Mbonile, 2005; Zorita and Tilya, 2002). Furthermore, population growth may result in urbanization thereby affecting the provision of ES, the water cycle, urban rivers and aquatic ecosystems integrity. According to Mhina et al. (2010), part of fertile land in Moshi Municipality which under irrigation was converted to Mabogini wastewater treatment ponds by Moshi Water Supply and Sewerage Authority (MUWSA). Prior to the establishment of these treatment ponds, this area has been under paddy irrigation for years providing food ES. As a consequence of this water treatment project, a number of smallholder irrigators have been deprived off their land.

The consequences of these Mabogini ponds include loss of case income, ground water pollution caused by liquid waste leakage, reduced supply of ES (food supply). Therefore, it is important to be aware of the adaptation options for the impending population growth in order to design mechanism for supporting the accompanied human needs without affecting ecosystems and associated ES. Proper planning for population growth also help to avoid resource use conflicts at local scale. Reported conflicts caused by population increase in the PRB includes that between local communities and conservation officers; upstream and downstream water users; hydroelectricity plants and other water users; local communities and investors; local communities and river basin authorities; to name just a few (Mbonile, 2005). One of the remarkable and interesting finding in this study is that the cause of population increase in the areas of destination is CC. (involving people running away from CC stress). It is high time to promote irrigated agriculture in CC stricken and water stressed areas either through rainwater harvesting (surface runoff) during rainy season and intensify ground water exploration as well.

4.3 Rainfall and temperature patterns in the PRB

Based on results in Figure 4, the slightly doesn't influence the quantify flowing down stream, rather the reduced water flow patterns is influenced by competing demands water related ES. Normally steady rainfall recharges and enhances the capacity of watersheds to retain and release water gradually. But this is not the case in the PRB where reduced water flow in rivers is associated with competing demands, excessive water abstraction and degraded watersheds which affects enormously their capacity to release water downstream. The situation has been the case in recent years along the PRB where the current watersheds degradation in Kilimanjaro, Meru, Pare and Usambara Mountains has significantly affected the recharge capacity of water aquifers (PBWO and IUC, 2011).

For instance, the combined effects degraded watersheds in Kilimanjaro and Meru Mountains and low water flow along river tributaries (including Nduruma, Malala, Tengeru, Sanya, and Kikuletwa Ruvu and Rau). Reduced water quantity affects the provisioning ES (e.g. water), production of hydroelectric power production at NyM dam, Pangani and Halle electricity plant (PBWO and IUC, 2011). In terms of ecological ES, reduced rainfall and water quantity along Pangani river affect nutrient cycling in Kirua swamp and fish catches.

The slight temperature increase in all four meteorological stations (Figure 5) is another factor influencing the capacity of watersheds to deliver ES along PRB. Normally, temperature increase escalates water flow reduction through increased evaporation. Although there is a small temperature increase at Same meteorological station (Figure 5C), the increase trend in other stations (i.e. Arusha, Moshi and Tanga) is by itself a testimony of how rivers could face water scarcity in the next couple of years (Conway, 2002; Hamandawana et al., 2007). Increasing temperature and decreasing rainfall in would seriously impact further the hydrological cycle and water flow along the PRB.

However, the influence of temperature on river flow regime (Table 3) is a signal of how important is water resources management is in the wake of the adverse impacts of climate variability and competing water demands due to population increase**.** A number of studies (Conway, 2002; Butler and Laurance, 2006, Hamandawana et al., 2007) reported similar sentiments that change in climate patterns and river flows in Africa display high levels of variability across a range of spatial and temporal scales, with important consequences for the management of water resource systems. Challenges with regards to water resources variability and management were further reported on balancing supply and demand for Nile water in Egypt (Boko et al., 2007) irrigation management in the Greater Ruaha River in Tanzania (Lankford and Beale, 2007), and hydropower generation in the Kafue and Lake Victoria basins (Tate et al., 2004).

Change in temperature along the PRB affect water flow in a number of ways. Temperature rise, for instance, trigger evaporation, water loss through infiltration, the availability of watershed ES and ecosystem functions (such as water for irrigation, domestic and industrial use, water for hydroelectric power generation, and water for regulation sediment load transport) (Boko et al., 2007). Given the current rainfall variability and failure of rainfed agriculture, irrigated agriculture could, therefore, revive farm productivity and ultimately harness new opportunities through water management along the PRB.

Nevertheless, water demands along the PRB are aggravated by increase of human population (Mbonile, 2005; Ngana et al., 2010). Apart from water loss through ecological processes (e.g. evaporation) other challenges with respect to water flow and management emanate from contradicting water use and conservation objectives among stakeholders. While conservation organizations (e.g. IUCN) have been in the forefront to conserve watersheds, there have been conflicting national sectoral policies over utilization and conservation. During group focus discussions, we realized a number of problems. For instance, poor irrigation infrastructures and ungauged intakes (Figure 6), water abstraction and excessive withdrawals (by water grabbers), poor policy and enforcement of water regulations and by-laws, to name just a few (Ngana et al., 2010). Water withdrawals are either carried out in favour of large scale irrigators (owned by foreign investors/water grabbers), allocation to farms owned by government or political leaders (e.g. Member of the Parliament; Ward Councilors) or water rationing triggered by corruption. For instance in Kikuletwa and Karangai villages, smallholder farmers are discontent about canal and water managers for unfair water allocation. In Kikuletwa village and Mabogini, and Msitu wa Mbogo villages there are signs of unfair water rationing and allocation based on corruption. Although we didn't quantity the level of water governance with respect to equitable water allocation, we water withdrawals, allocation and rationing within and between villages is corrupt in nature. With regards to irrigation water management property rights, our observations concur with that of Amani (2006) who asserted that despite the potential and importance of water resources, this common pool resource (i.e. water) were often inefficiently utilized and maintained poorly.

4.4 Irrigated agriculture as adaptation option

Historically, irrigated agriculture in the PRB was carried out to get surplus crop harvest. Majority of small holder farmers relied on rainfed agriculture by growing coffee, bananas and vegetables in the wetter slopes (Mbonile, 2005). Zero grazing and home gardens of agroforestry practices were part of this perennial rainfed agriculture (Munishi et al., 2009; Ngana et al., 2010). But in recent years irrigation is carried out as adaptation option in order to supplement crops water needs due to unreliability of rainfall for rainfed agriculture. Under such circumstances, irrigation with proper drainages gives greater crop yield and offers flexible choice of crops.

With the prevailing rainfall fluctuation and competition for water resources, irrigated agriculture is currently the priority and a survival strategy (Table 2). Majority of smallholder farmers, who relied on perennial crops (e.g. coffee and bananas) are currently carrying out irrigated agriculture (rice, maize and horticultural crops) downstream. Rainfall fluctuation, water stress and water scarcity has compelled smallholder farmers in the study villages to resort to irrigation (Figure 7).The amount of water flowing in the river system doesn't satisfy socio-economic and ecological demands. For instance, the little water flowing in the study villages is over-allocated for different uses (including irrigation activities) thereby creating conflict among water users (Mbonile, 2005). A number of factors contribute to reduced water shortages and flow including demand driven water uses caused increased population, water abstraction for industrial and domestic used, climate variability, degradation of water sources. Thus irrigated agriculture is a suitable adaption option and it can be implemented through equitable and fair water rationing.

Adaptation to CC and climate variability requires innovative measures to be shared, adopted and implemented among smallholder irrigators. The current rainfall fluctuation and water shortages along the PRB are tackled in a number of ways. For instance, in Kikuletwa and Chekereni villages and Mabogini, smallholder irrigators involved mainly on maize growing. And they grow short term maize varieties as adaptation strategy to the current rainfall and water flow fluctuation. This short term maize varieties include such as SEED CO *(e.g. SC 403)* and PANNAR *(e.g. PAN 4M-19, PAN 6 and PAN 63).* In villages where the intensity of water shortage is not that much big (e.g. Rau River, Lekitatu and Makiba) as compared to the previous villages, they grow short term rice varieties (e.g. *IR 64, IR 56, IR 34 and SARO*). Local rice varieties preferred as includes *"wahiwahi", "bawa la nzi" and "shingo ya mwali."* These short crop varieties help to stabilize food supplies during dry season and rainfall shortages. Short term crops stabilize the country's economy through food supply and food price fluctuation (Balirwa, 1990; Chemka, 1996).

Irrigated agriculture has a potential benefits in areas where crop yield is affected by droughts or in areas experiencing less rainfall due to climate variability. It is also an essential economic activity in drought prone regions because it outweighs crop yield from rainfed agriculture (Mkojera, 2009; Chemka, 1996). Apart from supplementing food production during drought seasons, irrigated agriculture makes use of even marginal land which otherwise would have been useless. In terms of crop yield in the PRB, irrigated agriculture is ahead of rainfed. For instance, with exceptional of few cases, Table 4 indicates that standard deviations for irrigated agriculture are higher than their respective yields without irrigation. Given this vivid example of yield comparison, small holder farmers have to invest more on irrigated agriculture. For farms located where irrigation water can't reach drought tolerant crops (e.g. sorghum, millet and cassava), improved crop varieties, and crop diversification (i.e. growing different types of crops on different land units) can be promoted as adaptation option.

4.5 Socio-economic activities that contribute to water shortages and CC in the PRB

As reveled in Table 5, respondent's opinions indicated deforestation is among the factors for the current water shortages and CC along the PRB. In the context of this study, we referred deforestation to the total removal of vegetation (forest/trees) at a certain locality for different purposes (e.g. mining, road construction, settlement building, plantation farming, etc.). In the PRB deforestation has been occurring through forest clearance in search for fertile land for agriculture and mining. In recent years deforestation has been severe due to land clearance in search for large tracts of land for biofuel plantations (e.g. jatropha and sugarcane), flower irrigation, etc. Deforestation is linked to CC in the sense that when natural vegetation are uprooted, land is deprived off its capacity to sequester carbon and in long run this intensifies carbon emissions. Furthermore, these kinds of investments are negatively received by the local communities and are regarded as new form of water and land grabbing. Majority of smallholder farmers were unhappy with this kind of foreign investment because the negative outcomes outweigh the prior perceived benefits.

Unsustainable agriculture involves cultivation along the slope thereby accelerating soil erosion, release of below ground carbon, etc. In addition, forest clearing in favour of large scale agriculture, it releases below ground carbon (to the atmosphere), thereby jeopardizing the ozone layer. This has been the case in the PRB where large land areas have been converted to agriculture plantations. Conservation agriculture (e.g terracing, agroforestry, cultivation of legumes, and mulching) is ideal for water conservation and reducing carbon emissions. Thus conservation agriculture would enhance performance of of ecosystem functions (including water and air purification, regulating microclimate, reducing soil erosion, nutrient cycling, etc.) thereby enhancing the availability of ES.

Keeping large herds (overgrazing) of animals (Table 5) has outweighed the carrying capacity along the PRB thereby leading to the current water shortages and CC. Historically, lowlands of the PRB was inhabited by pastoralists (Meru and Maasai) who relied mainly on livestock keeping. The population increase in the last few decades has resulted into reduced land for commercial and smallholder agriculture, settlements, industries, to name just a few. Consequently, the increase of land use along has marginalized pastoralists and agro-pastoralists in search a way they were pushed to overgraze in the same area. In turn, the situation has resulted into increased soil erosion, degradation of water sources, accelerated gully and wind erosion, thereby leading to water shortages and incidences of CC.

5.0 CONCLUSIONS

This paper demonstrates the environmental problems affecting ES along the PRB in Tanzania. The current problems brought by climate change and climate variability influence rainfall fluctuation thereby affecting agriculture, the main economic activity for majority of rural dwellers. Climate variability has changed the duration, timing intensity and distribution of rainfall within months, seasons and years thereby affecting the timing of cropping calendar. Furthermore, the trend of population increase along the PRB puts pressure on water resources because water availability does not keep pace with demands of the fast growing population, water for socio-economic development and for ecological integrity. This scenario conforms to the theory of population growth and resource scarcity that while resources were growing at arithmetic rate, on the contrary population was increasing at an exponential rate. Thus in the PRB population increase (through natural increase and emigration) has outpaced water availability especially for irrigated agriculture. Given that irrigation water has been decreasing over time, policy makers should integrate water management plans into their decision forums. Plans are also needed so as to develop strategies that would enable the growing population to have access to water in the wake of CC.

Although this study has not revealed scientifically the impact of CC on water stress and water flow, the slight rainfall increase and temperature rise is a signal of the impending CC and climate variability along the PRB. Furthermore, water withdrawals and climate variability contribute to water shortages along PRB thereby affecting downstream smallholder agriculture and ecological processes. Nevertheless, empirical research should be carried out so as to quantify the magnitude of water shortages in the study villages so as to give definitive solutions for the way forward. In addition, the current study serves as a stepping stone for finding solutions for problems related to the rainfall variability along other major river basins encountering similar problems like in the PRB. Moreover, the current fluctuation of rainfall and irrigation water along the PRB reveals the need for drought resistance and improved seed varieties as an adaptation strategy to suit the prevailing climate situation. Moreover, it is high time to strengthen the involvement of key stakeholders in water management decisions through the formation of effective water user groups and associations. This will enhance watershed conservation, sustainable water flow and efficient water distribution.

Ground water exploration and rainwater harvesting should also be promoted as options to deal with the current water fluctuation along the PRB. With respect to new initiatives, we recommend targeting actions aimed at improving irrigated agriculture through simple, improved and affordable irrigation technologies. These initiatives should also integrate environmental protection, ecosystem restoration and CC adaptation actions. And efforts to enhance agricultural productivity should take into considerations frameworks and strategic plans from other sectoral policies (e.g. forestry, water, land, wildlife, to name just a few) in a holistic manner. It is through these processes, watershed conservation, adaptation to CC and water shortages would be realised as such.

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CHAPTER 7

Understanding Watershed Dynamics and Impacts of Climate Change and Variability in the Pangani River Basin, Tanzania

This chapter is based on:

Lalika, M.C.S., Meire., P., Ngaga Y. M. and Chang'a, L. (2015). Understanding Watershed Dynamics and Impacts of Climate Change and Variability in the Pangani River Basin, Tanzania. ***Ecohydrology and Hydrobiology*****, 15 (1): 26 – 38.**

ABSTRACT

Watersheds and rivers are vital ecological features for the provision of hydrological services for the health, welfare and prosperity of human communities. Nevertheless, anthropogenic activities coupled with climate change and climate variability are blamed for degrading watersheds and rivers and decreasing their capacity to irrigate. To address the situation, it is important to understand why and how water shortages are occurring. This paper reports findings of a study carried out to identify and assess drivers of water shortages and adaptation strategies to climate change and variability in Pangani River Basin of Tanzania. To assess the influence of climate change and variability on hydrological flow and water shortages, time series data on rainfall and temperature were compiled from the Tanzania Meteorological Agency. We also used structured questionnaires to collect data on villagers' perceptions about the drivers of water shortages and adaptation strategies. Results indicated a decreasing trend of water flow ($p < 0.05$) at Kikuletwa-Karangai gauging station along Pangani River Basin. Trend analysis indicated a slight decrease of rainfall and increase of temperature. Although there is no empirical evidence to associate climate change with the decline of rainfall and water flow, adaptation measures need to be put in place in order to mitigate against increasing climate variability, reduced water flow, and projected climate change. Therefore, watershed conservation strategies should also focus on improving the welfare of local communities. Additionally, involvement of stakeholders in the entire PRB is crucial towards watersheds conservation for steady flow of hydrological services.

Key words: *Water, Ecosystem services, Watershed degradation, Climate change, Pangani River Basin*

1.0 INTRODUCTION

Watersheds and rivers are vital ecological factors for the provision of ecosystem services (ES) for human consumption and ecological integrity (Costanza et al., 1997; Daily, 1997; De Groot et al., 2002; Landell-Mills and Porras, 2002; MEA, 2005). Providing water is an essential service by virtue of its integral role for domestic uses, hydro-power generation, industrial use, irrigation, and livestock production, among others (Brauman et al., 2007**;** De Groot et al., 2010). Sustainable water flow depends largely on the health and integrity of the watersheds from which the services originate. To maintain watershed health and sustainable water flow, integrated water resources management (IWRM) approaches (i.e. existence of a coordinated development and management of water, land, and related resources) should be in place (Solanes and Gonzales-Villareal, 1999; Jewitt, 2002; McDonnel, 2008). IWRM maximizes economic and social welfare without compromising the sustainability of vital environmental systems through the guidance of Dublin Principles. These principles states that: (1) Freshwater is a finite and vulnerable resource, essential to sustain life, development and the environment; (2) Water development and management should be based on a participatory approach, involving users, planners and policy makers at all levels; (3) Women play a central part in the provision, management and safeguarding of water; and (4) Water has an economic value in all its competing uses and should be recognized as an economic good (Solanes and Gonzales-Villareal, 1999; Jewitt, 2002; McDonnel, 2008).

Understanding the capacity of a watershed to provide water is complicated due to various hydrologic components distributed heterogeneously within the watershed (Isik et al., 2013). Among the key characteristics that determine this capacity include the topography, forest cover and land use types, and more importantly, the climate of the particular watershed (Brauman et al., 2007; Isik et al., 2013).

Climate is a key factor in water supply planning and rainfall availability. To a great extent, climate influences the amount of water flowing through the water cycle (Middelkoop et al., 2001; Changnon, 2003). In addition to climatic factors (such as rainfall and temperature), watershed runoff depends on the topology, soil, underlying geology, and land use/cover of the watershed. In general, the higher the rainfall, the more water is available. Low precipitation and droughts reduce the availability of water supply. Temperature influences water availability and other watershed services. The higher the temperature, the greater the amount of water lost from the Earth's surface and returned to the atmosphere through evapotranspiration (Middelkoop et al., 2001; Christensen, 2004; Mwamila et al., 2008). Climate and hydrological records are used as a firmer basis for quantifying relationships between climate change (CC) and the amount of water available in rivers and aquifers (Arnell, 1998; 2004; Middelkoop et al., 2001; Christensen, 2004; Mwamila et al., 2008).

A few studies (Zorita and Tilya, 2002; Yanda and Munishi, 2007; Munishi et al., 2009) completed so far in Tanzania indicate enormous variability in terms of climatic variables such as rainfall, temperature, and stream flow or levels. Current trends in major river basins indicate a decrease in runoff of about 17% over the past decade (Munishi et al., 2009). Hydrological studies carried out in the country (Valimba, 2005; 2007; Yanda and Munishi, 2007; Ndomba et al., 2008) have shown a decreasing trend in the dry season flows for some of the perennial rivers, possibly implying a decrease in the annual rainfall in the area or increased evapotranspiration resulting from increasing temperatures and CC impacts.

In recent years, CC has posed a serious threat to human beings and the environment. Its adverse impacts are also felt in the Pangani River Basin (PRB), where the amount of water availability has declined in recent years (Kulindwa, 2005; Mwanyoka, 2005; Notter, 2010; Lalika et al., 2011). A reduction in rainfall, mean annual run-off, and the seasonality of freshwater flows has also affected sediment transport to the Pangani estuary, consequently reducing water quality (Shaghude, 2006; Sotthewes, 2008). This reduction is attributed to a decrease in dissolved oxygen and an increase in inorganic nutrients in the water (Hellar-Kihampa, 2013). Changes in water flows along the PRB have had a serious, negative impact on the abundance and diversity of flora and fauna in the system, including aquatic resources used for people's livelihoods (Newmark, 1998; Notter, 2010; Lalika et al., 2011). Other ecological effects associated with low water flow include the disappearance of fish species, loss of aquatic plants, water pollution caused by heavy metals (Hellar-Kihampa, 2013), lower capacity for nutrient cycling, and intrusion of saline water (Sotthewes, 2008).

Reduced rainfall in the PRB that supported rain-fed agriculture for quite some time has compelled small and large-scale farmers to turn their attention to irrigated agriculture and other activities. Currently, irrigated agriculture is the main economic activity in the PRB. Unfortunately, some cultivation techniques, irrigation practices, and land uses contribute further to the degradation of watersheds and water pollution (Hellar-Kihampa, 2011; 2013). Anthropogenic activities, for instance, have a strong influence on the quality of the river catchment related to differences in their micro-contaminants (Hellar and Kishimba, 2005; Terrado et al., 2006; Li et al., 2008; Hellar-Kihampa, 2013). According to Brodie and Mitchell (2005) and Buck et al. (2004), croplands, horticulture, gardening, and livestock-keeping contribute to high concentrations of nitrogen and phosphorous, along with pesticide residues and enrichment of some major elements (Cl, Na, Ca, and Mg). Furthermore, urban land uses has been associated with elevated concentration of trace elements (As, Cu, Cr, Zn, Cd, Mn, Pb, Ni and V) (Hellar-Kihampa, 2011; Hellar and Kishimba, 2005), and nutrients ($NH4^{+}$, $NO3^{-}$, $NO2^{-}$, $PO4^{3-}$ and $SO4^{2-}$), both in water and sediments (Butler and Davis, 2004; Fitzpatrick, 2007).

Apart from using irrigated agriculture as an adaptation strategy in response to low rainfall, other local communities have reverted to gold and tanzanite mining in Usambara Mountains and Mererani deposits as alternative livelihood options after the failure of rain-fed agriculture. However, mining activities contribute to water pollution through the release of heavy metals such as As, Hg, Zn, and Pb (Angelo et al., 2006; Donkor et al., 2006; Sampaio da Silva, 2009). Therefore, the concern over the impacts of CC is linked not only with associated water scarcity, but also is driven by water pollution along the PRB (Hellar-Kihampa, 2011). Accordingly, better strategies for the sustainable watershed management and adaptation to water shortages and rainfall fluctuation across the entire PRB are required in the face of increasing demand for water. Although efforts to tackle the challenges of water availability and watershed conservation at the river basin scale has been increasingly recognized since the 1990s (Ngana, 2001; Kulindwa, 2005; Notter, 2010; Msuya, 2010; Turpie et al., 2005; 2007; Ngana et al., 2010; Lalika et al., 2011), limited information exists to establish a link between CC and its adverse impacts on water availability in the PRB. Moreover, the manner in which the natural environment responds to CC and variability is critically important to human well-being and for designing adaptation strategies.

Understanding these links should help policy makers come up with definitive solutions to the problems of water scarcity and adaptation strategies to the adverse impacts of CC in PRB. The objectives of this paper are to analyze changes in stream flow in Kikuletwa River and water levels at Nyumba ya Mungu (NyM) Dam and rainfall and temperature trends in PRB, as well as to examine adaption strategies to water shortages and CC in PRB.

2.0 MATERIALS AND METHODS

2.1 Description of the study area

2.1.1 Location

This study was conducted between 2011 and 2013 across 8 villages, namely Kaloleni, Chekereni, Rau River, and Mabogini (in Kilimanjaro Region) and Lekitatu, Karangai, Msitu wa Mbogo, and Kikuletwa (in Arusha Region) along Tanzania's Pangani River Basin (Figure 1).

The PRB extends from the northern highlands to the north-eastern coast of Tanzania. It lies between latitude 03º 05' 00" and 06º 06' 00" South and longitude 36º 45' 36" and 39º 36' 00" East. PRB, the largest river basin within Pangani Basin (PB) and covers an area of about 43,650 km^2 and 3, 900 km^2 (IUCN, 2003). The terms "PRB" and "PB" have different meanings.

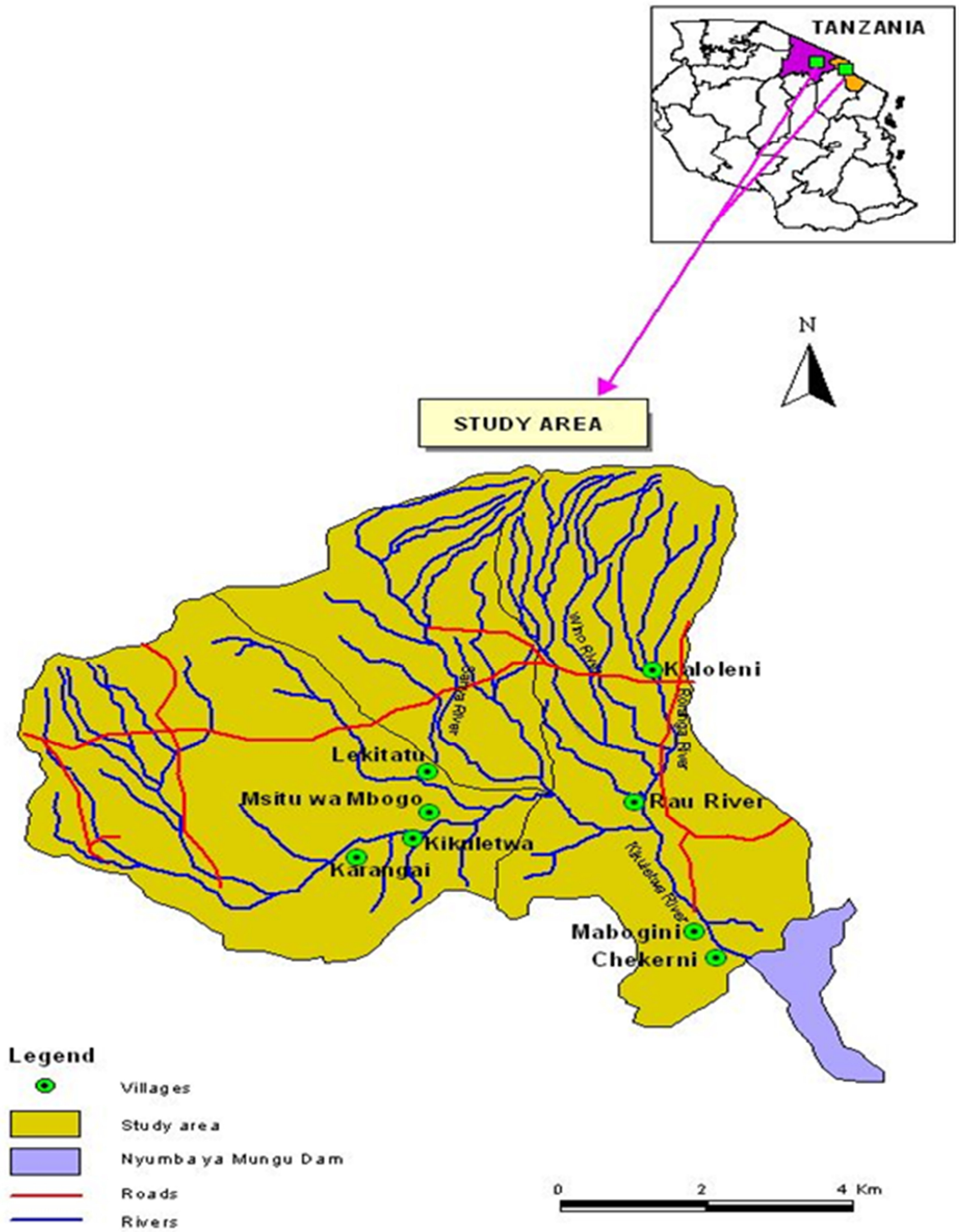


Figure 1: Location of the study area along Pangani River Basin, Tanzania

The former refers to the basin where the Pangani main river and its river tributaries whereas the latter incorporates the PRB and other three smaller basins i.e. Umba, Zigi-Mkulumuzi Coastal and Msangazi Rivers catchments (Figure 2) (IUCN and PBWO, 2008). PB is also a shared transboundary resource between Tanzania and Kenya.

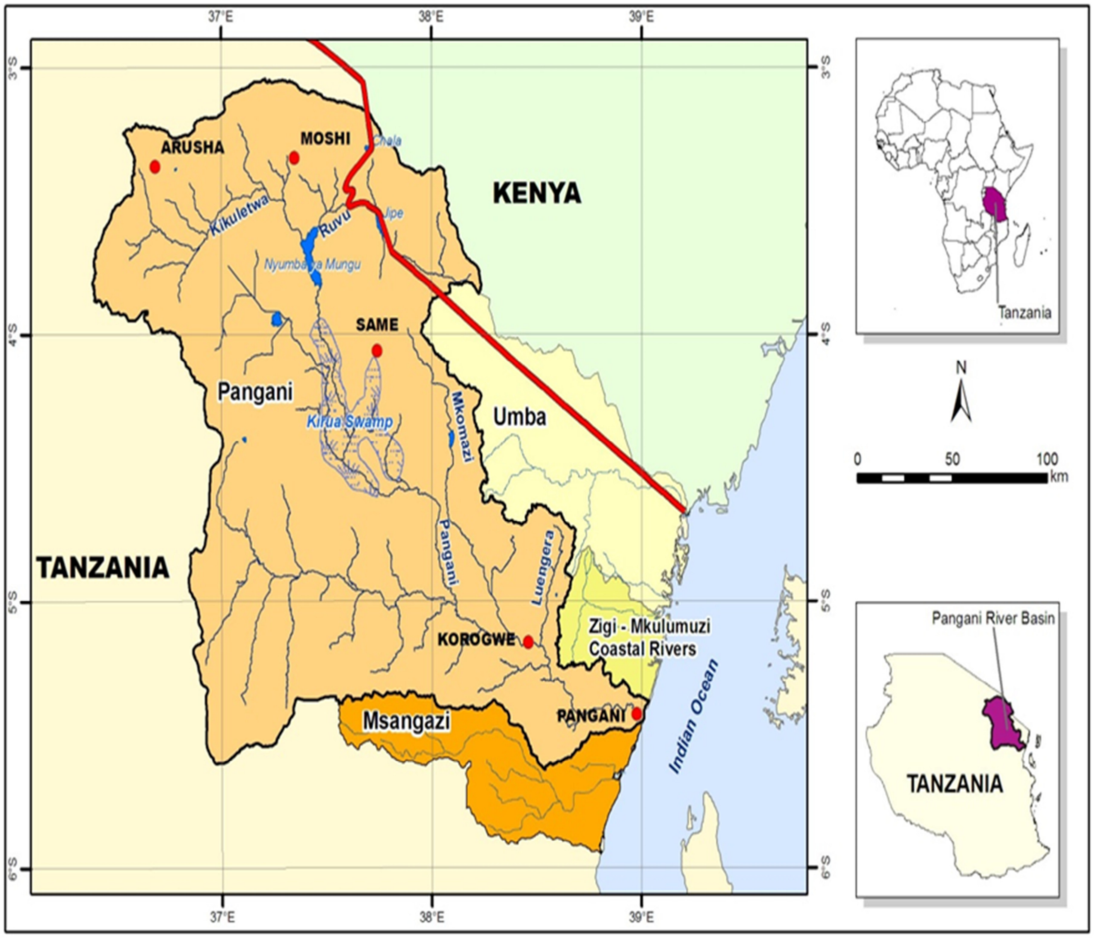


Figure 2: Location of Pangani River Basin and Pangani Basin, Tanzania

2.1.2 Hydrology and drainage pattern

The hydrology and drainage pattern in the PRB catchment varies considerably. The PRB comprises of several sub-catchments of widely different characteristics. The Pangani River (PR), which is referred to (in other publications) as Pangani Mainstem, rises as a series of several small streams and springs on the southern sides of the Africa's highest peak, Mt. Kilimanjaro, and on Mt. Meru (IUCN; 2007; IUCN and PBWO, 2008). These streams (Nduruma, Tengeru, Sanya, Malala, etc.) create the Kikuletwa and Ruvu Rivers (Himo, Muraini, etc), which drain further downstream into the Nyumba ya Mungu Dam (NyM) (Faraji, 2007; IUCN; 2007; IUCN and PBWO, 2008; 2011). Other river tributaries from Eastern Arc Mountatins (i.e. Pare and Usambara mountain ranges), namely Mkomazi and Luengera, join the PR before reaching the Indian Ocean through Pangani estuary.

2.1.3 Nyumba ya Mungu (NyM) dam

Nyumba ya Mungu (NyM) Dam (with catchment area of 9,320 km^2) is a wetland of ecological and economic importance along PRB. The overflow of the dam, the PR, flows for 432 km before emptying into the Indian Ocean at Pangani estuary. The NyM Dam is the largest water body in the PRB. The dam was constructed in 1965 to enhance river flows for hydropower generation; however, in later years, irrigation potential was recognized and incorporated into plans (Mulungu, 1997; Ndomba et al., 2008). The current decrease in rainfall and temperature increase has resulted in water scarcity for irrigation water (upstream of the dam), thereby creating water use conflict between the irrigation sector and hydropower generation. During construction, the maximum depth of the dam was 29 m and live storage capacity was 871.5 m^3.

As stated in the Water Master Plan of Kilimanjaro Region, the dam was designed mainly for water regulation (Mulungu, 1997). Besides the power station at NyM Dam, there are two power plants downstream at Hale and New Pangani Falls (NPF). Apart from its irrigation and power production potential at the proceeding hydropower stations, water discharged from NyM Dam is essential for regulating services, including nutrient cycling, at Kirua Swamp (which is located downstream) and enhancing ecological processes (e.g., hindering salt water intrusion and coastal erosion) at the estuary mouth in Pangani Town (Sotthewes, 2008; Shaghude, 2006).

2.1.4 Forest and vegetation types

Variation in vegetation in the PRB range from forests on mountain slopes to semiarid grasslands (IUCN, 2003). Major vegetation includes forests, woodlands, and bushland, along with grassland thickets and plantation forests (Turpie et al., 2005). Plantation forests have replaced natural forests in the highlands, and the larger part of the lowlands is composed of woodland, bushland, grassland, and thicket. Forests perform vital hydrological functions in the PRB, including the regulation of run-off, prevention of soil erosion, storage of water, and improvement of water quality (IUCN, 2003; Msuya, 2010). According to IUCN (2003), types of dominant forest types in the PRB include: *mangrove forests* (located at the confluence of the Pangani River and the Indian Ocean protecting the coastlines, protecting soft sediment shorelines from erosion, trapping sediments, and recycling nutrients); East *African coastal forests* (containing remarkable biodiversity and endemism); *afromontane forests* (playing key part in hydrological functions); and *riverine forests* (controlling erosion along the river banks). Research and previous studies on forest health conducted in the PRB shows that between 1952 and 1982, catchment forests in the PRB declined at a fairly high rate of 3.8% of forest cover per year (Kaoneka, 1993; Newmark, 1998; Lambrechts et al., 2002).

2.1.5 Population and economic activities

By 2007, the PRB contained an estimated 4.5 million people, the population density of which varied between highlands and lowlands. About 90% of the basin's population resides in the highlands with some 900 people per km^2, while lowland densities are around 65 people per km^2 (IUCN, 2003). The main causes of forest degradation and deforestation include encroachment for settlement and agriculture, as well as increasing demand of forest products (mainly timber and fuelwood) (IUCN, 2003). In terms of human population, the PRB is a densely populated area in Tanzania, posing serious challenges to sustainable watershed management (Msuya, 2010).

2.1.6 Climate

Variations in the local climate in the PRB are mostly related to topography. The flatter, lower-lying south-western half of the Basin is arid and hot, while the mountain ranges along the northern and south-eastern catchment boundaries have cooler, wetter conditions. The high-altitude slopes above the forest line on Mt. Meru and Mt. Kilimanjaro have an Afro-Alpine climate and receive more than 2500 mm of rainfall per year. Mean annual rainfall increases in a southerly direction along the mountain ranges, and varies from about 650 mm per year in the North and South Pare Mountains to 800 mm per year in the Western Usambara Mountains, and 2000 mm per year in the Eastern Usambara Mountains.

2.3 Data collection and analysis

2.3.1 Sampling procedures

For hydrological, rainfall, and temperature data, we earmarked the main hydrological and weather stations in Arusha, Moshi, Same, and Tanga. For socio-economic data (questionnaire surveys), we sampled villages located along the PRB. Within each of the identified eight villages, a random sampling technique was adapted to identify respondents, and 10% of the total households in each village were selected for interviews. Each household head was numbered in the village register books, and the households we selected corresponded to those we identified through using a table of random numbers. Household heads were interviewed, but wherever the heads of the household were not around, we randomly chose a member within that particular household who was 18 years or older. According to Tanzania regulations and laws, anyone 18 years or older is regarded as mature person.

2.3.2 Data collection methods

2.3.2.1 Data on rainfall and temperature

We used mean monthly rainfall and temperature data for the period between 1970 to 2012 from selected synoptic stations along the PRB to assess regional climatic trends. The synoptic stations involved in this case include Arusha, Moshi, Same, and Tanga (Table 1).

Table 1: Location of weather stations along Pangani River Basin, Tanzania

Station	Latitude	Longitude
Arusha	5^{0}08′ S	39^{0}07′E
Moshi	3^{0}37′ S	36^{0}63′ E
Same	4^{0}08′ S	37^{0}73′ E
Tanga	3^{0}43′ S	37^{0}06′ E

We obtained data from Tanzania Meteorological Agency (TMA), the designated meteorological authority in Tanzania mandated to provide meteorological services for the United Republic of Tanzania.

We collected data for the two bimodal rainfall seasons, i.e., data for October, November, and December (OND) as one cluster and March, April, and May (MAM) as the second cluster. Our preference for the two bimodal seasons was based upon the increased likelihood of retrieving reliable data. Rainfall data were recorded from standard rain gauges for the interval of three hours for the period from 1970 to 2012. When recording rainfall data, standard rain gauges affixed with a special bottle are normally inserted in the ground for capturing rainfall drops. Afterwards, water from the bottle is taken to the laboratory for measuring its quantity (in millimeters) using a special measuring cylinder. At the gauging station, the total rainfall recorded is normally reported on the second day at 0900. As a result, we obtained cumulative data for daily rainfall collected from the first day at 0900 in the morning to the next day at 0900 in the morning.

2.3.2.2 Data on hydrological flow

For data on hydrological flow, two types of information were collected: data for water flow at different agro-ecological zones along Kikuletwa River, and water levels at NyM Dam (Table 2).

Table 2: Location of gauging stations along Pangani River Basin, Tanzania

Station code	River/ Dam	Location/zone	Latitude	Longitude	Catchment size (km^2)
1DD55	Kikuletwa	Karangai	3^0 26′S	36^0 51′S	245
1DD54	Kikuletwa	Power station	3^0 27′S	37^0 17′S	2220
1DD1	Kikuletwa	TPC	3^0 31′S	37^0 17′S	2849
1D8C	NyM Dam	NyM	3^0 48′S	37^0 30′S	9320

To measure water level, data were recorded using a graduated vertical staff gauge and automatic water lever. Water levels were measured and recorded in the daily gauge record (DGR) form (H3) and in writing pads. These measurements were taken twice a day in the morning and in the afternoon. Later on, the data were transferred to MS Excel for mathematical computation and figure drawing.

2.3.2.3 Socio-economic data

We used both quantitative and qualitative methods in primary data collection. For quantitative data, structured questionnaires were the main tool of collection. The structured questionnaire covered questions on water utilization, adaptation methods in response to CC and water shortages, type of crops irrigated, payment methods for water utilization, and other issues. Before commencing field work, questionnaires were pretested to eliminate ambiguities or correct for omissions. During field work, one researcher and two research assistants administered the structured questionnaires in the study villages. A total of 360 respondents were interviewed in eight villages as indicated in Table 3.

Table 3: Interviewed respondents in the study area

Region	District	Village	Total households	Respondents
Arusha	Meru	Lekitatu	250	25
		Karangai	480	48
		Kikuletwa	640	64
		Msitu wa Mbogo	420	42
Kilimanjaro	Moshi Urban	Kaloleni	490	49
		Chekereni	550	55
	Moshi Rural	Rau river	340	34
		Mabogini	430	43

For qualitative data, we carried out informal and formal interviews. This enabled us to to supplement quantitative data and triangulate on findings collected by other means. Additionally, we used a checklist of questions to collect information from key informants. A key informant in this study was defined as a person knowledgeable in a specific area of specialization. Moreover, we undertook a literature review and collated relevant unpublished documents for secondary data collection.

2.3.2.4 Data analysis

Rainfall and temperature time-series data for the March–May (MAM) season were aggregated on a daily, weekly, monthly, and finally yearly basis. Trend analysis for both rainfall and temperature for each of the stations was then performed. For hydrological data, daily, monthly, and seasonal flows were then used to compute average, minimum and maximum yearly flows in the PRB (Valimba, 2005; 2007). Afterwards, data were entered in MS Excel, where linear regression analyses were conducted to determine possible trends. The 360 structured questionnaires were coded, cleaned, and wherever applicable, data from open-ended responses were categorized and transferred to enable further analysis. All quantitative analyses were performed using Statistical Package for Social Sciences (SPSS) version 20.0.

3.0 RESULTS

3.1 Water level trends and water flow in PRB

The trend from early 1970s to late 1990s in Nyumba ya Mungu (NyM) Dam indicated that the highest level was 689.7masl in 1990, whereas the lowest level was 684masl in 2000 (Figure 3). As depicted by Figure 3, water levels in NyM have been in decline (with exceptions from 2001) since its establishment in mid 1960s.

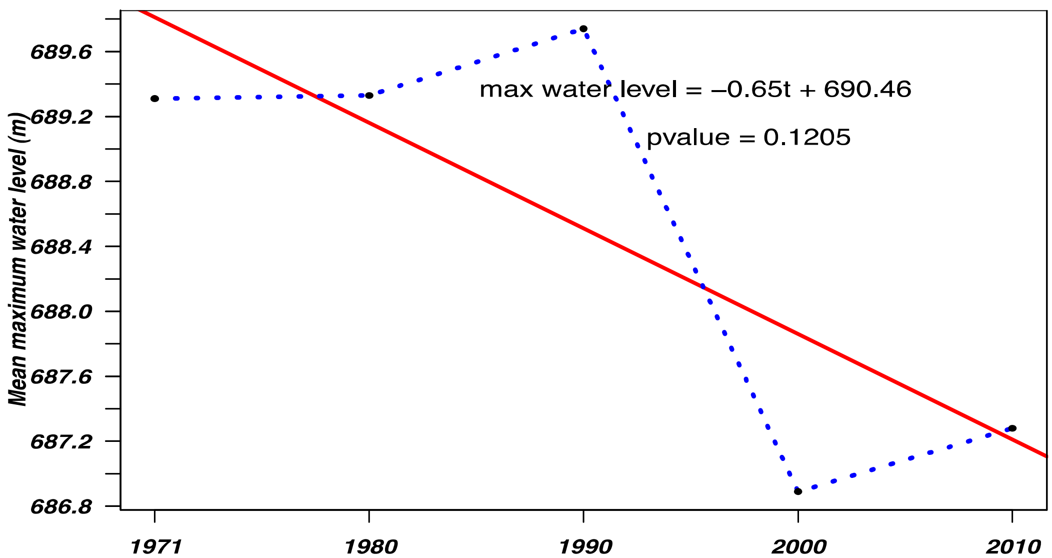


Figure 3: Trend of water level at Nyumba ya Mungu dam in PRB, Tanzania

Figure 4 shows the annual maximum and annual mean flow for the Kikuletwa River at Karangai gauging station, Tanzania. Both the maximum and mean flows show a statistically significant downward flow. The statistical significance and R^2 values are given in Table 4.

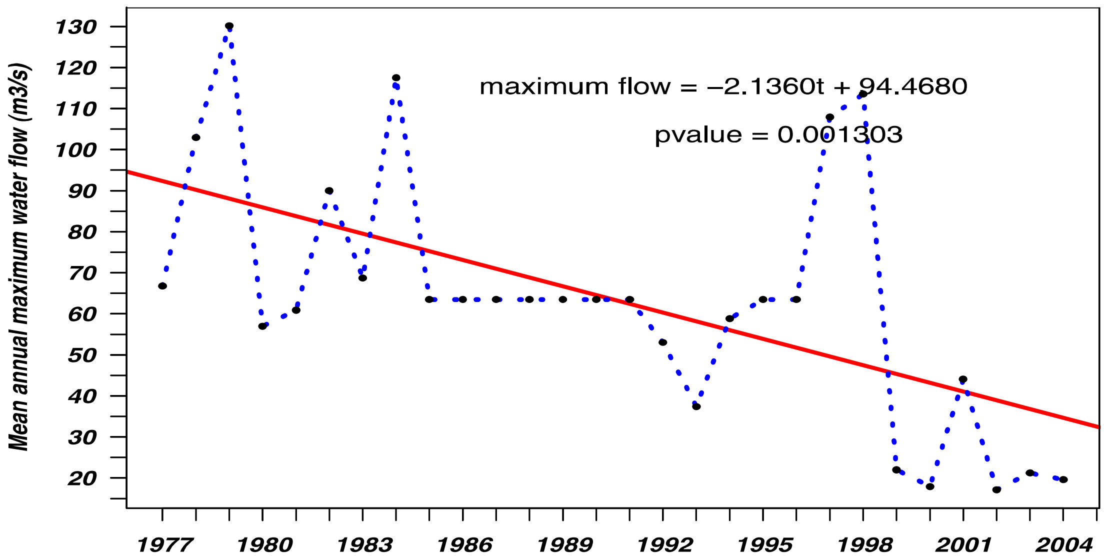
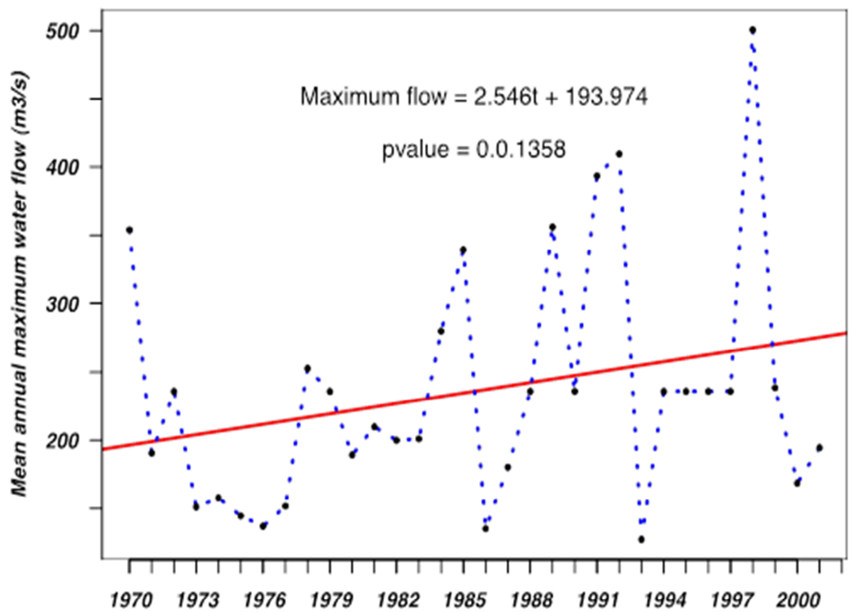


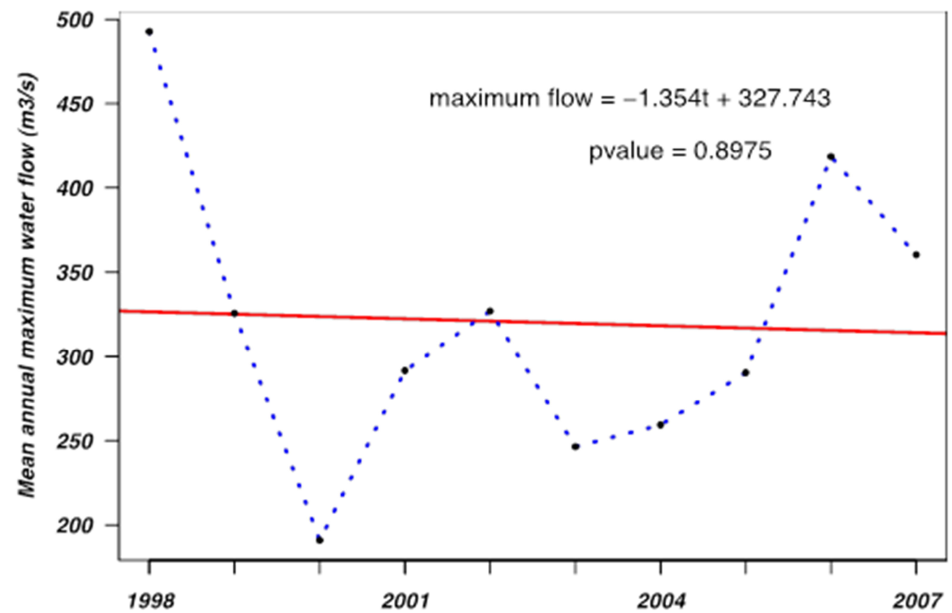
Figure 4: Maximum and mean water flow in Kikuletwa River at Karangai gauging station, Tanzania

Normally, the PRB region experiences a high/long rainfall season (*masika*) during March, April and May (MAM). This season influences the maximum and mean flow as revealed in Figure 4. For example, Valimba (2005; 2007) found that the flow increased with the onset of rains in March and that high rainfall during the long rains *(masika)* upstream of NyM reservoir contributed to highest flows in April and May.

Figures 5a and 5b show the annual maximum and annual mean flow for the Kikuletwa River at the Power gauging station and the TPC station. A linear regression analysis was performed on these flows, but the trends were not statistically significant. The statistical significance and R^2 values are given in Table 4.



a



b

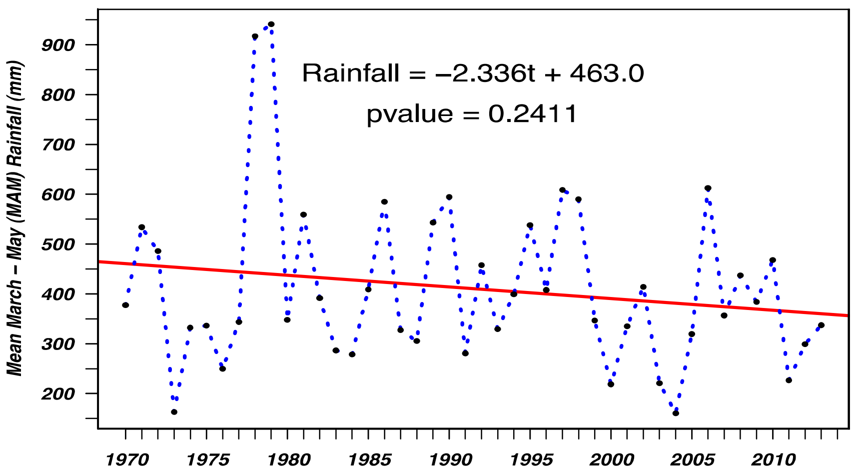
Figure 5: Maximum and mean water flow at Power gauging station Tanzania

Figure 5: Maximum and mean water flow at TPC gauging station, Tanzania

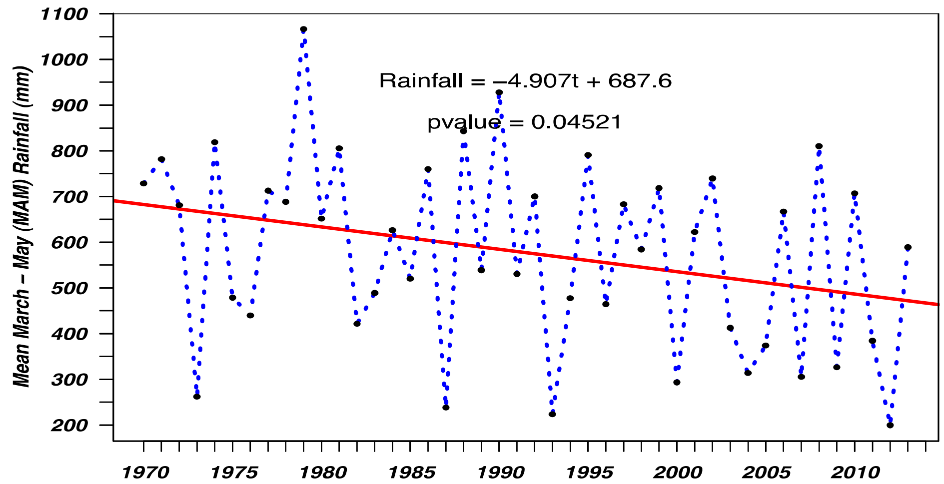
3.2 Trend analysis for rainfall and temperature patterns in PRB

3.2.1 Rainfall trends

In the PRB, the long rain season (*masika*) is experienced between March and May (MAM), while the short rain season (*vuli*) is normally experienced between October and December (OND). The *masika* is more important for agriculture activities than the *vuli*. Trend analyses for mean MAM seasonal rainfall at four meteorological stations in PRB are presented in Figure 6. The MAM rainfall for Moshi shows a statistically significant downward trend at the 95% level. The other stations show a slight decreasing rainfall trend, but are not statistically significant.


Rainfall = −2.336t + 463.0
pvalue = 0.2411
Mean March – May (MAM) Rainfall (mm)
900
800
700
600
500
400
300
200
1970
1975
1980
1985
1990
1995
2000
2005
2010

a


Rainfall = −4.907t + 687.6
pvalue = 0.04521
Mean March – May (MAM) Rainfall (mm)
1100
1000
900
800
700
600
500
400
300
200
1970
1975
1980
1985
1990
1995
2000
2005
2010

b

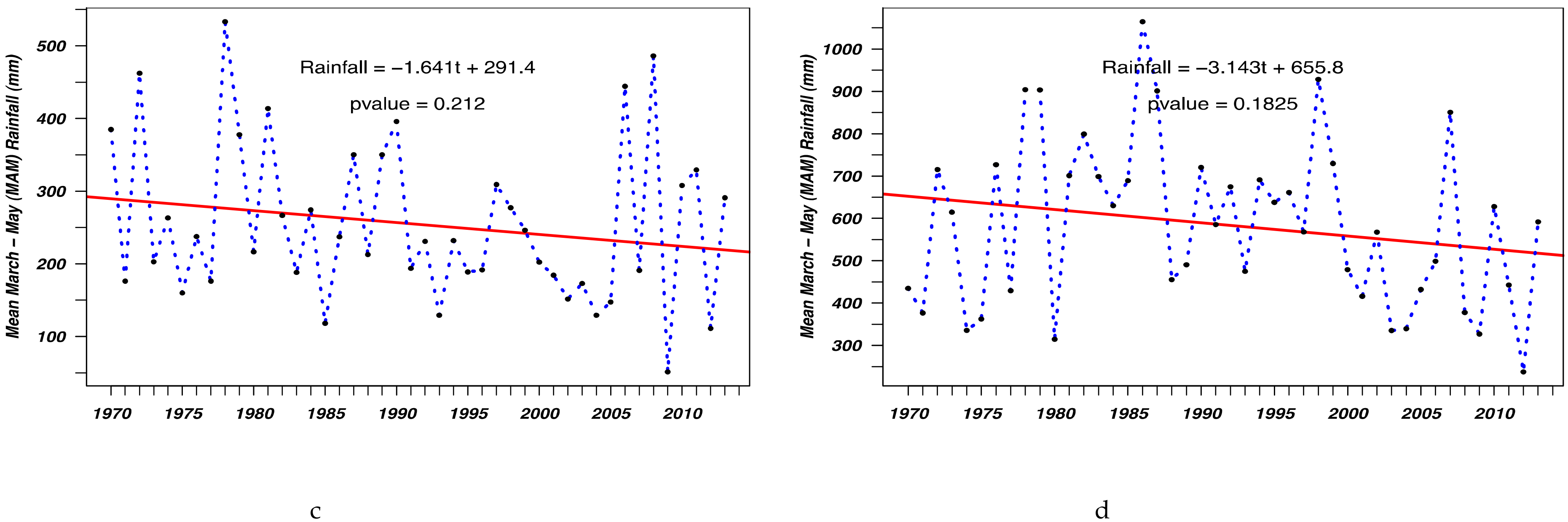


Figure 6: Trend in mean MAM rainfall at four meteorological stations in the PRB, Tanzania

Results in Table 4 indicate a statistically significant ($p < 0.05$) and negative trend for both mean and maximum flow for the Kikuletwa River at the Karangai gauging station. The flow trends at the other two gauging stations were not statisticall significant at $p < 0.05$.

Table 4: Summary of the trend of mean and maximum water flow in Kikuletwa River along PRB Tanzania

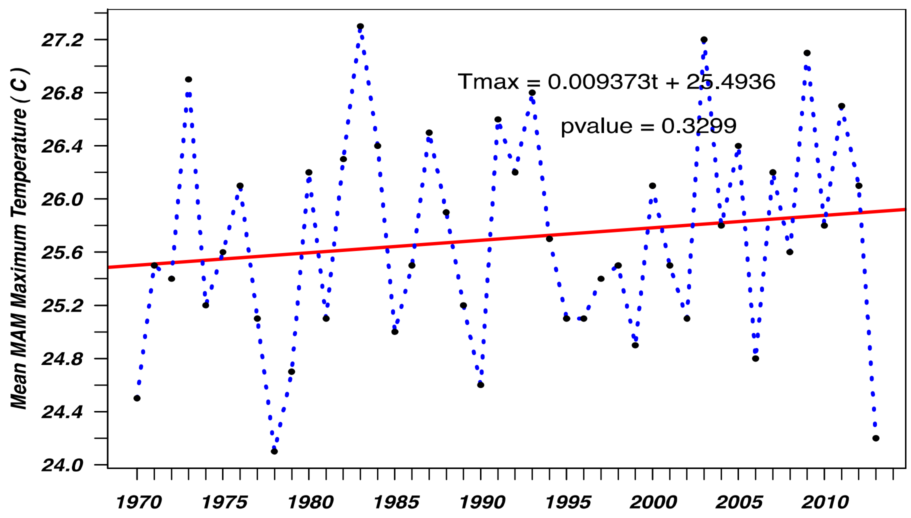
Station	Dependent variable	Independent variable (number of years)	Intercept	Slope	R^2	p-value	Lower 95% confidence	Upper 95% confidence
	Mean Flow	19	2819,9	-1,3957	0,266	0,02**	-2,58	-0,21
Karangai at gauging station	Maximum flow	19	4628,9	-2,2931	0,357	0,01**	-3,87	-0,72
Karangai at Power station	Mean Flow	25	119,68	0,02	0,00	0,98*	-4,98	5,07
	Maximum flow	25	-3723,5	0,61	0,015	0,57*	-4,98	8,82
Karangai at TPC station	Mean Flow	10	8820,17	-0,57	0,03	0,57*	-12,59	13,01
	Maximum flow	10	3032,17	-0,13	0,00	0,89*	-24,84	22,13

Note: ** = Significant at $p < 0.05$

* = Non-significant at $p < 0.05$

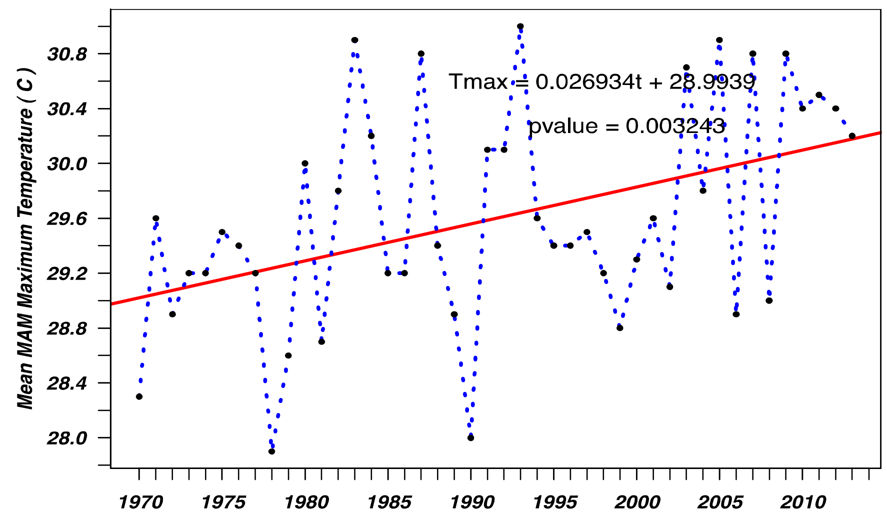
3.2.2 Temperature Trend

Figure 7 shows the mean MAM maximum temperature for Arusha, Same, and Tanga meteorological stations and the mean MAM minimum temperature for Moshi meteorological station. Temperatures show an increasing trend at all four stations, but only records from Moshi and Same are statistically significant at the 95% significance level.



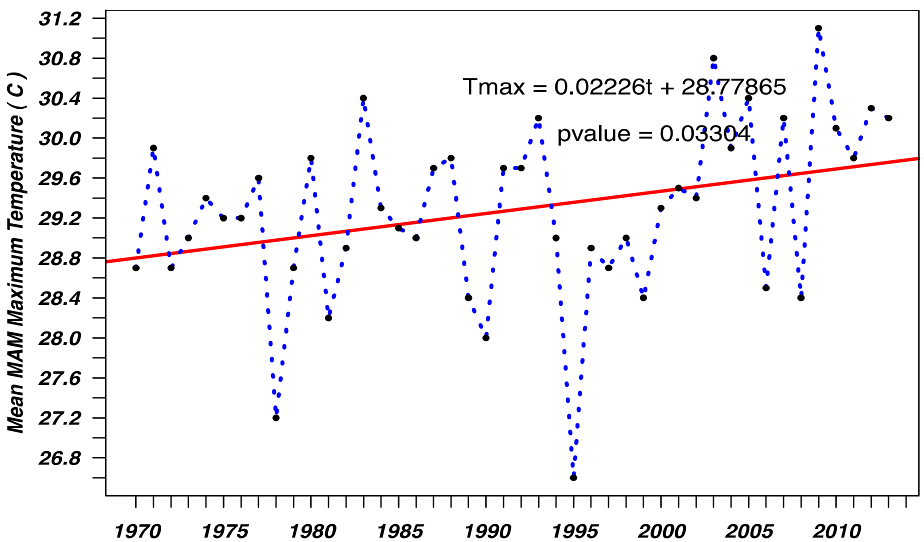
Tmax = 0.009373t + 25.4936
pvalue = 0.3299
Mean MAM Maximum Temperature (C)
27.2
26.8
26.4
26.0
25.6
25.2
24.8
24.4
24.0
1970
1975
1980
1985
1990
1995
2000
2005
2010

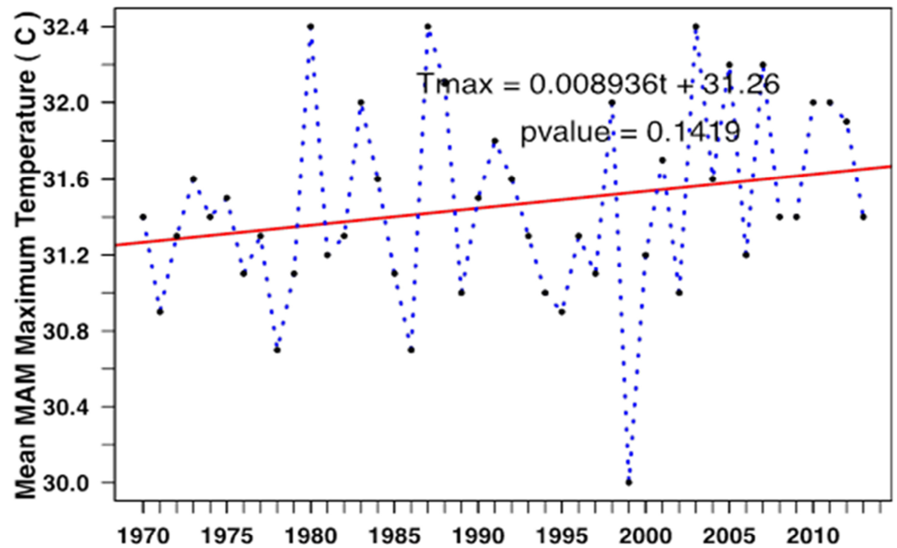
a



Tmax = 0.026934t + 28.9939
pvalue = 0.003243
Mean MAM Maximum Temperature (C)
30.8
30.4
30.0
29.6
29.2
28.8
28.4
28.0
1970
1975
1980
1985
1990
1995
2000
2005
2010

b





c

d

Figure 7: Trend in mean MAM maximum temperature at four meteorological stations in PRB, Tanzania

3.2 Socio-economic characteristics of respondents

The vast majority of respondents (98.2%) were involved in agriculture, whereas 1.8% of them were employees. Irrigated agriculture was the main socio-economic activity, and the main water sources for irrigation include rivers, springs and bore holes. The majority of respondents (84.1%) had primary education, 8.8% never went to school, and 7.1% had secondary education. In terms of marital status, 79.3% of respondents were married, 11.7% widowed, 3.6% separated, 2.7% singles and 2.7% were divorced. Of respondents, 62.3% were males and 37.7% females. Given the fact that majority of respondents engage in agriculture, the socio-economic characteristics of the people in the study have important implications to resource management and water utilization as a whole.

3.2 Main drivers of water reduction in PRB.

Water reduction is attributed to a number of factors ranging from natural to human-made. Some of the reported drivers are presented in Table 5.

Table 5: Drivers of water reduction in PRB, Tanzania

Driver	Counts	Percentages
Climate change	65	58.6
Population increase	36	32.4
Watershed degradation	8	7.2
Water abstraction by investors	2	1.8

Of all respondents, 58.6% recognized CC as the main driver of water shortages and reduction in PRB. Increase of human population (32.4%) was given as another reason for the water shortages in PRB. Two factors were found to account for the population increase in the study villages: natural increase (through birth) and population movement due to displacement and in-migration (Maro, 1975; Mbonile, 2005; 2001; 1999a; b; Maddox et al. 1996). Among others, reported effects of water reduction in PRB included poor crop harvest, hunger, and income reduction.

3.3 Adaptation strategies to water reduction in PRB

A number of adaptation strategies are in place as a response to PRB water scarcity (Table 6). Smallholder farmers spent their time abstracting water during night hours.

We found that almost 35% (Table 6) of smallholder farmers irrigate their farms during the night. Although this method would reduce the amount of evapotransipiration, the strategy could prove dangerous since farmers from nearby villages looking for irrigation water might be more likely to attack at night. Similarly, dangerous animals such as snakes are less visible at night, making attacks harder to avoid. With respect to social life, abstracting water during the night is a loophole for some individuals to involve themselves in illegal practices (e.g., theft) and spousal infidelity.

Growing crops that tolerate drought condition is the recommended coping strategy for dealing with water reduction. Given the probability of less rainfall, some of the smallholder farmers opted to grow maize, sorghum, vegetables, and legumes instead of paddy. Of all respondents, 21.1% (Table 6) indicated that they were obliged to shift from paddy irrigation to other crops due to the scarcity of irrigation water.

Table 6: Adaptation strategies against water shortages

Strategy	Counts	Percentages
Abstracting water during the night	38	34.9
Switching to drought resistant crops	23	21.1
Guarding water over night	20	18.3
Shifting to other economic activities	14	12.8
Water rationing	8	7.3
Using bribes	6	5.5

We also found that in the case of extreme water scarcity, smallholder irrigators spent their nights guarding water from illegal abstraction. Similarly, a shift to other economic activities and even water rationing were also used as adaptation strategies against water shortages in the villages studied. Petty trading, small scale mining, and working as casual laborers are a few of these alternative socio-economic activities.

4.0 DISCUSSION

4.1 Influence of rainfall and temperature on hydrological flow

Water level in NyM Dam has been in decline in recent years, although this trend is likely not solely caused by rainfall fluctuation, temperature increase, or climate change and variability. The downward trend in water level and reduced water flow at the

Karangai gauging station may be due to a combination of factors. These factors may include: type of land uses adjacent to water sources in the watersheds, rainfall variability, excessive water withdrawals by large scale users who are located upstream, illegal water abstraction, and poor irrigation farming methods. While reduced rainfall affects rain-fed agriculture, water flow fluctuation affects the majority of smallholder irrigators who depend on water flowing downstream for irrigation purposes.

Fluctuation and change of river regime (i.e. day to day, season to season and year to tear) play a decisive role in determining river health and ES. Reduced rainfall and increased temperature have both contributed to the reduction of water flow along Kikuletwa River, consequently affecting the water level and ecological functions. Anthropogenic climate change may not be the cause of decreased rainfall (Figure 6). Variation of rainfall might have been due to natural climate variability over time and space. With regard to temperature, slight increases (Figure 7) may have led to increased evapotranspiration, which could lower water levels in NyM Dam or reduce runoff and water flow in Kikuletwa River.

The observed declining trend in water level (Figure 3) and water flow (Figure 4) have adverse impacts on the provision of ES, environmental flow, and ecological process along PRB. Mwamila et al. (2008) found that the reduction in high-flow occurrences has great negative impacts on fish in terms of productivity, whereas higher flows led to swamp and floodplain formation and flooding conditions necessary for fish spawning, feeding, growth of young fish species and flushing through of nutrients from floodplains into the river, thus increasing reproduction and fish population. Apart from ecological consequences, reduced water level in NyM Dam affects the country's economy (production of hydroelectricity) and the livelihoods of smallholder farmers across the PRB who depend on the outflow for irrigation activities (Msuya, 2010; Notter, 2010). In addition, unsustainable land use practices (that stimulate soil erosion and sedimentation) have major effects on natural ecosystems. Reduced water levels in NyM Dam (Figure 3) in recent years (Lugomela et al., 2009; Ndomba et al., 2008) have negatively impacted hydropower production, fish catches, and other and ES (IUCN and PBWO, 2007). This is further confirmed by the fact that the full capacity of the water supply in NyM Dam (1, 134.8 million m^3, which includes an inactive storage volume of 260.3 million m^3) is no longer attained as it was in the past

(Valimba, 2007; Ndomba et al., 2008). When the volume of water in storage drops below 553.5 million m^3 (just less than 50% of the full supply volume), releases from the dam are reduced to 57% of the downstream demand (Valimba, 2007). This situation compromises the maintenance of ecological functions and provision of ES (water) downstream. Rises in temperature (Figure 7) are contributing factors, together with the melting of the ice caps in the Kilimanjaro Mountains, thereby jeopardizing the sustainable water supply and other ES in future.

Reduced water volume at NyM Dam has affected human activities that used to provide livelihoods to the local communities living around it. For example, fish breeding and fish supplies, such as tilapia species (*i.e. pangani*, *zili* and *jipe*) and catfish (*kambale*), are no longer as bountiful as they were in the past (Valimba, 2007; Ndomba et al., 2008; Turpie et al., 2007). Due to a recent water volume fluctuation in Kikuletwa River and NyM Dam, the fishery activities have become seasonal, with fisheries being most active from March to June. The plausible explanation is that this is a period of high rainfall, with large amounts of water enhancing fish breeding.

Similarly, lower water volume in NyM Dam would reduce reservoir releases, discharge, and the ecological processes in Pangani (Mainstem) River, such as fish breeding, nutrient cycling, and sedimentation processes in Kirua swamp, which depends greatly on the outflows from NyM Dam. Pangani Basin Water Office (PBWO) and International Union for Conservation of Nature (IUCN) (2011) indicated that different parts of the river flow regime have different effects on the health status of the river and its associated hydrological services downstream. For instance, when NyM Dam receives an influx of water from its main inlets (Kikuletwa and Ruvu Rivers), it releases water (outflows) into Pangani Mainstem, which eventually causes flooding downstream at Kirua Swamp. This process enhances fish breeding, migration, and ample flood plain for fish feeding. However, lower rainfall and increased temperature negatively affects these ecological and biological processes.

4.2 Socio-economic characteristics of respondents

Based on findings presented in section 3.1, agriculture could be not only an opportunity for local communities to make their ends meet and improve their living standards, but could also be a serious threat to the future provision of watershed services. If 98.2% of the respondents rely on agriculture for their livelihood, there is a risk that watershed areas would be degraded in search for fertile land and irrigation water at the expense of nature conservation. We feel that although agriculture provides ES like food, expansion of agricultural would undermine the capacity of the watershed to provide other ES in the future such as water provision, climate regulation, soil erosion control, and biodiversity conservation (Costanza et al., 1997; De Groot et al., 2002). Similar observations were echoed by Kedziora (2010), who found that many weaknesses in agriculture activities in the past resulted in the deterioration of landscape functions and loss of ES.

Given that current agriculture activities in PRB are influenced primarily by the rainfall availability, erratic rainfall caused by CC threatens food supply in the area. With rain-fed agriculture being carried out up to the edges of watershed areas, this is an indication of future problems with respect to the sustainability of watersheds and their associated ES (Kulindwa, 2005; Notter, 2010; Lalika et al., 2011; Ngana et al., 2010).

With decreasing rainfall coupled with increased temperature, switching to irrigated agriculture could serve as an adaptation strategy, but it could also lead to worsening water shortages in PRB. Given the presence of considerable large-scale commercial irrigation (e.g. sugar and flowers), we think that this strategy would also lead to significant water reduction to the downstream smallholder farmers who engage in smallholder irrigation. Similarly, we feel that water abstraction for large-scale irrigation could further reduce water used for ecological functions downstream. These ecological functions include nutrient cycling and water regulation essential for i) aquatic life, ii) controlling the salt water intrusion at the Pangani estuary (Notter, 2010, Sotthewes, 2008; Mwamila et al., 2008), and iii) reducing the impacts of water pollution (Hellar-Kihampa, 2011; Hellar-Kihampa, 2013; Hellar and Kishimba, 2005).

4.3 Main drivers of water reduction

Opinions from respondents (Table 5) revealed that CC was ranked first among the drivers preventing watersheds from performing their vital ecological functions, including hydrological services. Watersheds in the upper basin at Mounts Meru and Kilimanjaro have played an important role in regulating steady water flow and erosion control for many years. However, CC has contributed to the current ice cap melting at the summit of Mount Kilimanjaro, a situation which is threatening the maintenance and sustainability of water flow and the availability of multiple ES along PRB. Due to recent extremes in climate conditions, the delivery of hydrological ecosystem services in the PRB varies significantly over time. The capacity of Mounts Meru and Kilimanjaro (the water towers in PRB) to provide water to their immediate surroundings and downstream are the most affected. CC in PRB has affected rainfall and the availability of water for irrigation. A decline in rainfall, along with an increase in temperature in the study area (as supported by Figure 6 and 7), has increased pressure for water utilization.

As described by Mbonile (2005), population movement is another factor that contributes to the degradation of watersheds and subsequent reduced water flow along PRB. This statement was echoed by our study, in which 32.4% (Table 5) of respondents gave their views that population increase was among the drivers for water reduction. The current study revealed that massive population displacement and migration resulted in high water demands to satisfy the incoming population. In this study, we viewed water shortages caused by population increase in two parallel fronts. First, we found that people who migrated upstream established farms near watershed areas, thereby degrading water sources and other critical zones for watershed conservation. Secondly, we viewed water shortages as a function of population increase beyond the capacity of the watersheds to provide water for the rapidly growing population. Thus, population increase reduces the capacity of these watersheds to provide water and other ES. Policy measures (e.g., equal distribution of social services, targeting marginalized communities, and provision of livelihood opportunities in the area of origin) could stop these human population movements, thereby safeguarding watersheds.

4.4 Adaptation strategies to water reduction

Since the watershed has been degraded and failed to mitigate CC change, we feel that adaptation is the final strategy and best way forward. For instance, in the past it was unusual for smallholder farmers to stay overnight abstracting irrigation water. But due to watershed degradation coupled with the impact of the CC, these farmers are now sometimes obliged to spend hours during the night irrigating their farms, which is unusual as well as dangerous. In some villages (e.g., Mabogini), irrigation officers forced smallholder farmers to grow maize instead of paddy as adaptation strategy in response to water shortages. In addition to overall switching to maize from rice, some of the smallholder farmers adapted to short term rice varieties (e.g. *Saro, IR 54 and IR 64*) and short term maize varieties such as SEED CO *(e.g. SC 403)* and PANNAR *(e.g. PAN 4M-19, PAN 6 and PAN 63).* Water rationing was also a well-known and widely used strategy across the study villages. Although water abstraction during the night was favored by the majority of smallholder farmers, we think that growing drought-resistant crops, switching to less water-demanding crops, and water rationing are the best alternatives that should be applied elsewhere in areas with similar problems.

With respect to adaptation through water rationing, the application of the concept of IWRM was well established in the study villages where PRB catchment and its sub-catchments were treated as basic management units (Jewitt, 2002; McDonnel, 2008). Along the Kikuletwa River Sub-Catchment, for instance, water rationing was based on geographical characteristics, such as topography, location, distance from the water intake and proximity to the river and irrigation canals. Canal irrigation managers and river basin committees had regular set down meetings for supervising water rationing and monitoring water flow along their respective sub-basins in an integrated way. IWRM represents a paradigm shift towards water management in PRB and, if maintained, it could bring about a lasting solution for watershed conservation, integrity and functioning of ecosystems, and sustainable flow of water (Jewitt, 2002; McDonnel, 2008; Solanes and Gonzales-Villareal, 1999).

5.0 CONCLUSIONS

This study has determined that agriculture is the main socio-economic activity in the study region, playing a key role for providing food (provision ecosystem services) and enhancing the income of smallholder farmers along PRB. As a consequence, the major concern should be management of scarce water resources, which are currently under increasing stress because of increased use in various socio-economic activities, especially irrigated agriculture. Although there is no scientific evidence to support the effect of CC and climate variability on reduced rainfall and water flow, adaptation measures need to be in place in order to overcome water stress problems.

The population influx in PRB has increased demands for ES from watersheds. Therefore, there is a pressing need to design a holistic approach for sustainable utilization of ES and conservation of watershed resources for improving their capacity to retain and release water gradually, as well as enhancing the welfare of the local communities near the watersheds. Furthermore, opinions from respondents indicated that CC and population increase play key roles in water shortages and watershed degradation in PRB. Even if we didn't prove this speculation scientifically through evidence-based empirical experimentation, CC and climate variability have widely been held responsible for detrimental effects on rainfall and water flow reduction along PRB. Given that watersheds and rivers have already been degraded, emphasis should be placed on adaptation measures as the way forward in response to the current rainfall and water scarcity problems.

The current study has also indicated the temporal variable patterns of seasonal flow variations, with the maximum peak during the months of March, April and May. Over the period between 1970 and 2012, the study illustrates changes of water flow, water level fluctuation and reduction of rainfall. Thus, in order to enhance sustainable water flow, joint efforts and holistic approaches among stakeholders dedicated to watershed conservation are fundamental. Moreover, we propose the implementation of integrated water resource management (IWRM) for enhancing the sustainability of water flow along PRB. This is one way of abiding by the Dublin Principles that advocate sustainability through *environmental integrity, economic wealth, and social justice*, that is, the way of promoting economic and social wellbeing of the local communities who are the primary beneficiaries and guardians of ES from watersheds.

Adaptation strategies developed in response to CC and climate variability require innovative measures to be shared, disseminated and implemented at a wider scale among stakeholders along river basins. Therefore, the current study is one of such means to share research knowledge and disseminate to the widest extent possible for enhancing conservation goals and sustainable use of ES.

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CHAPTER 8

Exploring watershed conservation and water governance along Pangani River Basin, Tanzania

This chapter is based on:

Lalika, M.C.S., Meire., P. and. Ngaga Y. M. (2015). Exploring watershed conservation and water governance along Pangani River Basin, Tanzania. ***Land Use Policy*, 48: 351–361.**

ABSTRACT

Increased illegal water abstractions coupled with low water flows from watersheds has resulted in severe water scarcity to downstream users. The problem is worsened by policy failures to enforce water governance and watershed conservation. Consequently, it has curtailed the capacity of watersheds to release hydrological services, water in particular. We carried out this study to explore approaches for watershed conservation and investigate water governance challenges in Pangani River Basin, Tanzania. We collected data by using structured questionnaires and meetings with different actors in the study area. We found that retaining riparian vegetation is the appropriate strategy for watershed conservation and sustainable water flow. Water governance challenges include ineffective and uncoordinated water governing institutional structures; and untrustworthy financial management. Building the capacity of water users association could bring about positive outcomes for both watershed conservation and water governance. We recommend that strategies and policies aimed at improving the flow of hydrological services should also focus on improving the welfare of the local communities, who are the primary beneficiaries of water from watersheds.

Key words: *Water abstraction, Hydrological services, Ecosystem conservation, Catchment forest, Water association*

1.0 INTRODUCTION

Watershed ecosystems are key natural wealth for economic growth, ecological integrity and other hydrological services (Barbier and Thompson, 1998; Bennett et al., 2005; 2009; Boelee and Madsen, 2006; Boelee, 2011). Watersheds play a crucial role in the delivery of many ecosystem services (ES), including provisioning services, cultural, regulatory and supporting services (Miranda et al., 2003; MA, 2005; Brauman et al., 2007). In recent years, however, watersheds have been degraded beyond provision of water in a sustainable way (De Groot et al., 2012). Water is a finite and exceptional ES as it can be a cultural provisioning, regulating and a supporting service (SafMA, 2004). Thus for ensuring the availability and sustainable supply of this unique ES, it is essential to improve watershed conservation through water governance and strengthening water user associations (WUAs).

Reduced water flow from watersheds and catchment forest degradation are mainly due to failures in watershed governance (Brandes, 2005; Yong et al., 2002; Franks et al., 2011). Fragmented management structures, uncoordinated integrated water management policies are few among factors which contribute to water governance gaps. Poor governance is threatening water resource management more than the degradation of the resource base itself (Tropp, 2005; Franks et al., 2011). hus, understanding how watershed governance works is vital towards sustainable water flow.

In Tanzania, watershed governance problems are key obstacles towards sustainable water flow along many rivers including the Pangani River Basin (PRB). Governance is confronted with little responsiveness and accountability to actors, lack of effective institutional set-up, poor accounting and valuation of ES from watersheds (Brandes, 2005, Costanza et al., 1997, Lopa et al., 2011). Fragmented (sectoral) water management approaches speak a lot for the current failure of the watershed conservation intervention strategies (Msuya, 2010; Mombo, 2013). The future existence and sustainability of watershed management options depends largely on the presence of both formal and informal institutions (Mbeyale, 2009; Lopa et al., 2011). While formal institutions provide constitutional framework where organizations and individuals are brought together in a positive manner, the informal organizations offers norms and informal sanctioning mechanisms to govern the ways of doing things (Blomquist and Schlager, 2005; Msuya, 2010; Ngana et al., 2010).

Responding to the international strategy on water and watershed governance i.e. moving away from conventional to integrated / holistic approaches, watershed management in Tanzania has undergone a major paradigm shift by letting the power go to the local communities (Blomquist and Schlager, 2005; Mbeyale, 2009; Msuya, 2010). Along PRB the integrated water resource management (IWRM) has been in place for quite sometime through river basin management approaches and WUAs (Blomquist and Schlager, 2005; Lein and Tagseth, 2009; Msuya, 2010; Notter, 2010; Lalika et al., 2011).

However, enforcement of policies, regulations, guidelines and local by-laws are handicapped with poor governance. For instance, research on how to bring together institutions working on water management (Sehring, 2009; Van der Zaag and Bolding, 2009) showed that local water management efforts were not often fully integrated into government water sector institutional reforms. Consequently, the situation resulted into mismatches between the new institutions and locally evolved ones. While (Van der Zaag and Bolding, 2009) argued that for any new water institution to be effective, it must be consistent with both the government and local-level institutions, (Komakech and van der Zaag, 2011) advocated that understanding the interface between locally developed water institutions and those created by the central government could add insight into the development of integrated catchment management institutions. Therefore, integration of water governance and watershed conservation by strengthening WUAs could enhance sustainable watershed conservation and water flow increase in the PRB.

However, the lack of effective water governance for water use fees collection is one of weaknesses of WUAs in PRB (Lein and Tagseth, 2009). Similarly, there is lack of information and transparency on how fees paid by downstream water users are used to support watershed conservation for sustainable water flow. Moreover, there is limited information on how Pangani Basin Water Office (PBWO), the institution accountable for collecting water use fees within Pangani River Basin enforces water regulations and by-laws. Understanding these procedures and water governance dynamics would enhance watershed conservation for sustainable water flow. The information could also be useful to policy makers for watershed conservation planning. The objectives of this study were to: i) identify methods for watershed conservation in PRB; ii) identify water user associations and determine their water right and water use fee for irrigation water in PRB, and iii) identify and examine gaps in watershed conservation and water governance.

2.0 MATERIALS AND METHODS

2.1 Description of the study area

2.1.1 Location

This study was conducted in four villages, i.e. Kaloleni and Chekereni villages in Kilimanjaro Region and Karangai and Kikuletwa villages in Arusha Region along PRB, Tanzania (Figure 1).

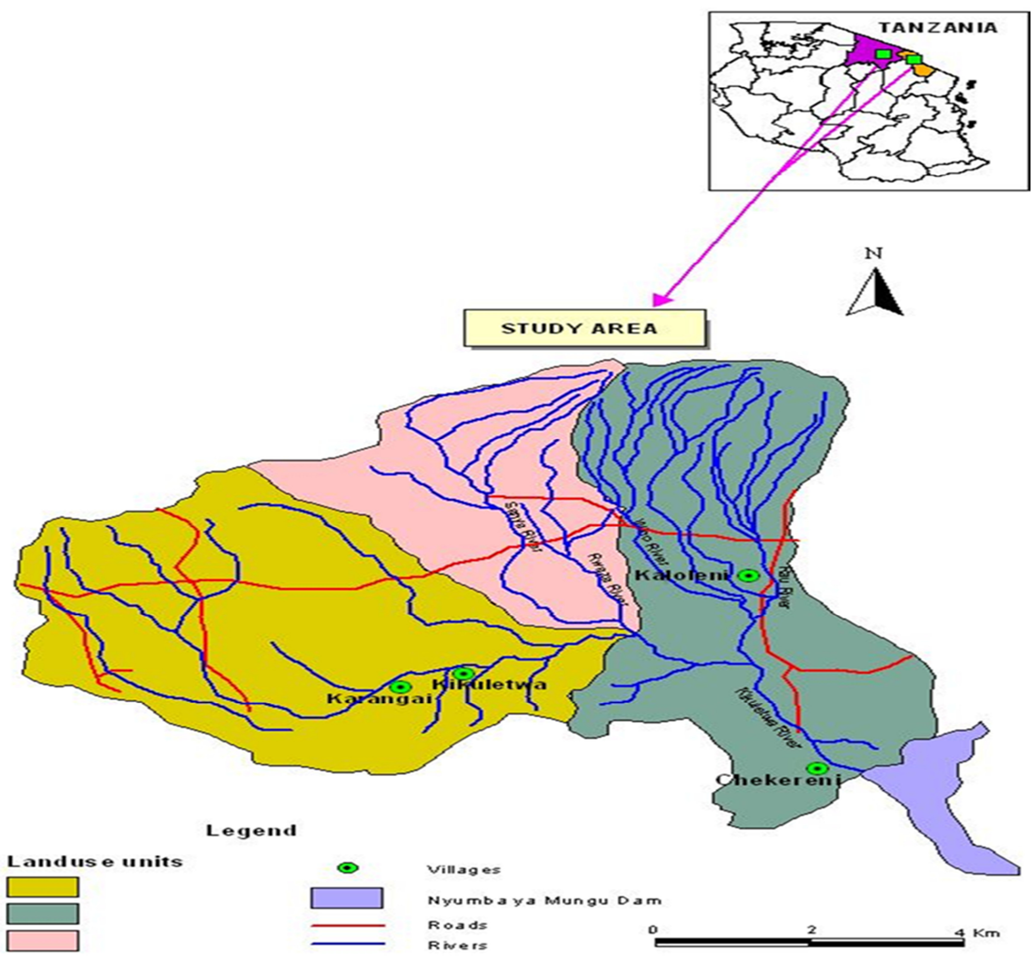

Figure 1: Location of the study area along Pangani River Basin, Tanzania

The PRB drains the southern and eastern sides of Mt Kilimanjaro (5,985 m) as well as Mt. Meru (4,566 m), then passes through the arid Maasai Steppe in the west, draining some of the Eastern Arc Mountains (Pare and Usambara Mountains) which are the World biodiversity hotspots before discharging to the Indian Ocean at Pangani town. PRB an estimated 3.8 million people 80% of who rely directly or indirectly on irrigated agriculture for their livelihoods (IUCN, IUCN and PBWO, 2008; Kamugisha, 2009).

2.1.2 Hydrology and drainage pattern

The hydrology and drainage pattern in the PRB catchment varies considerably both in space and time. PRB comprises of several sub-catchments with widely different characteristics. The Pangani River (PR) which is referred (in other publications) as Pangani Mainstem rises as a series of several small streams and springs on the southern sides of Africa's highest peak, Mt. Kilimanjaro, and Mt. Meru (IUCN, 2007; IUCN and PBWO, 2008). These streams (Nduruma, Tengeru, Sanya, Malala, etc.) they create the Kikuletwa and Ruvu Rivers (Himo, Muraini, etc) which drain further downstream into the Nyumba ya Mungu Dam (NyM) (IUCN, 2007; IUCN and PBWO, 2008). NyM is a man-made water body of ecological and economic importance along PRB. The overflow of the dam (outlet) is known as Pangani River Maistem and flows for 432 km before emptying into the Indian Ocean at Pangani estuary. The NyM dam is the largest water body in the PRB and was constructed in 1965 to enhance river flows for hydropower generation, however, in later years irrigation potential was recognized and incorporated into plans (Mulungu, 1997; Ndomba et al., 2008). Besides the power station at NyM dam, other hydropower plants along PRB include Hale and New Pangani Falls. Apart from its irrigation and power production potential, water discharged from NyM dam is essential for regulating services such as nutrient cycling at Kirua Swamp and enhancing ecological processes (e.g. hindering salt water intrusion and coastal erosion) at the estuary mouth in Pangani Town (Ndomba et al., 2008; Sotthewes, 2008). Other river tributaries from Eastern Arc Mountains (i.e. Pare and Usambara mountain ranges) namely Mkomazi and Luengera join PR before reaching the Indian Ocean through Pangani estuary.

2.1.3 Forest and vegetation types

Vegetation in the PRB range from forests on mountain slopes to semiarid grasslands (IUCN, 2003). Major vegetation includes forests, woodlands, bushland, along with grassland thicket and plantation forest (Shaghude, 2006). Forest plantatins have replaced natural forests in the highlands, and the larger part of the lowlands is composed of woodland, bushland, grassland and thicket. Forests perform vital hydrological functions in the PRB including the regulation of run-off, prevention of soil erosion, water storage and improvement of water quality (IUCN, 2003; Mehari eta l., 2009). According to (IUCN, 2003) dominant forest types in the PRB include: *mangrove forests* (located at the confluence of the Pangani River and the Indian Ocean protecting the coastlines, protecting soft sediment shorelines from erosion, trapping sediments and recycling nutrients); *East African coastal forests* (containing remarkable biodiversity and endemism); *afromontane forests* (playing key part in hydrological functions); and *riverine forests* (controlling erosion along the river banks). Previous research on forest health conducted in the PRB shows that between 1952 and 1982, catchment forests declined at a fairly high rate of 3.8% of forest cover per year (Kaoneka, 1993; Newmark, 1998; Lambrechts et al., 2002; Turpie et al., 2005).

2.1.4 Population and economic activities

In 2007 the population size in the PRB was estimated at 4.5 million people, the densities of which varied between highlands and lowlands. About 90% of the basin's population resided in the highlands with some 900 people per km^2, while lowland densities were around 65 people per km^2 (IUCN, 2003). The main causes of forest degradation and deforestation include encroachment for settlement and agriculture as well as increasing demand of forest products (mainly timber and fuel wood) (IUCN, 2003). In terms of human population, the PRB is a densely populated area in Tanzania, posing serious challenges to sustainable watershed management.

2.1.5 Climate

Variations in the local climate in the PRB are mostly related to topography. The flatter, lower-lying south-western half of the Basin is arid and hot, while the mountain ranges along the northern and south-eastern catchment boundaries have cooler, wetter conditions. The high altitude slopes above the forest line on Mt Meru and Mt Kilimanjaro have an Afro-Alpine climate and receive more than 2500 mm of rainfall per year. Mean annual rainfall decreases in a southerly direction along the mountain ranges, and varies from about 650 mm per year in the North and South Pare

Mountains, to 800 mm per year in the Western Usambara Mountains, and 2000 mm per year in the Eastern Usambara Mountains.

2.2 Data collection

2.2.1 Sampling procedure

We adopted purposive sampling procedure where four villages were earmarked for the questionnaire survey (two in Arusha and Kilimanjaro regions respectively). Our decision on the location of the villages was based on their proximity to rivers and the reliance of the local communities on water for irrigation. Based on these two criteria, our main target was smallholder irrigators. Within each village, we selected respondents using a table of random numbers that corresponded to the household numbers in the village register. Household heads were the target for interview, but wherever the head of the household was not around we randomly picked any household member within that particular household who had 18 years and above. According to Tanzania regulations and laws, any one at 18 years and above is regarded as mature person. We adapted the 10% sampling intensity giving a total of 216 respondents were interviewed (Table 1).

Table 3: Interviewed respondents

Region	Village	Total households	Sample size
	Kaloleni	490	49
Kilimanjaro	Chekereni	550	55
	Kikuletwa	640	64
Arusha	Karangai	480	48
	Total	**2160**	**216**

2.2.2 Data collection methods

During data collection both quantitative and qualitative research approaches were used to collect primary and secondary data. We used structured questionnaires as the main tools to collect primary (quantitative) data. Questionnaire items comprised questions mainly on water utilization, types of water sources, types of water associations (WUAs), amounts paid by individual irrigators to canal managers for water uses, amounts of water right paid by WUAs to PBWO, methods used for watershed conservation, to name just a few.

To collect qualitative data, we carried out a series of in-door and open consultations with individuals and different committees in order to collect data on watershed conservation and water governance. Summary of the methods used to collect data for each objective are presented here under in Table 2.

At the Regional and District levels, we consulted the Water Officer (the head of the PBWO in Moshi), the IUCN Water and Nature Initiative (WANI) officer in Moshi, the District and Municipal irrigation officers (in Meru, Moshi Urban and Moshi Rural). At the local (field) level, we carried out group focus discussions and meetings with Ward and Division agriculture extension officers, chairmen and secretaries of different water associations (WUAs) within PRB (i.e. Kaloleni, Shamima, Mbukita, Kitamaka and Kammmama), canal irrigation managers, canal irrigation treasurers and influential smallholder farmers.

Table 2: Summary of data collection methods and target groups

Objective	Method	Target group
i)To identify methods for watershed conservation	Structured questionnaires	Smallholder irrigators
ii) To identify water user associations and determine their water right and water use fee for irrigation water	Structured questionnaires, group focus discussions, in-door and open consultations, and literature reviews	Smallholder irrigators, irrigation engineers, extension officers, canal managers, leaders of WUAs, irrigation committees and influential farmers,
iii) To identify and examine gaps in watershed conservation and water governance.	Face to face interviews, informal and formal interviews, methodology and framework used by OECD and literature reviews.	Smallholder irrigators, influential farmers, and committees responsible for water management, allocation, rationing, enforcement, collecting water right and water use fees.

Moreover, we held discussions with water management committees, water allocation and rationing committees, and committees responsible for enforcing water utilization by-laws, and committees responsible for collecting water right and water use fees. The aim was to solicit information on governance gaps with respect to accountability, transparency and effectiveness of the prevailing water management structures. In order to achieve this aim, we carried out face to face interviews and informal and formal discussions. Furthermore, we adapted the methodology and framework used by Organization for Economic Co-operation and Development (OECD) (OECD, 2009). Key issues during these discussions were: administrative matters, accessibility to information, policy relevance, staff capacity, funding constraints, conservation objectives, and level of accountability of staffs. Results are presented in Table 4. In addition, we discussed about policy instruments with regards to watershed and water governance along PRB. Policy tools that we focused much on includes: technical, economic, administrative, legal, institutional and social/participatory tools (Plummer and Slaymaker, 2007). Summary of findings these discussions are displayed in Table 5.

Furthermore, we visited different libraries, offices and internet links in order to collect secondary data. We searched, collated and reviewed relevant literatures on watershed conservation, water utilization, water governance and irrigated agriculture.

2.3 Data analysis

The 216 structured questionnaires were coded and cleaned for final analyses. We used Statistical Package for Social Sciences (SPSS) version 20.0 to analyse all quantitative data from questionnaires. There after we carried out multiple responses to obtain frequency and percentages of responses from smallholder farmers For qualitative data on governance, we adapted the Multi-level Governance Framework (MGF) tool (Akhmouch, 2012) to diagnose water governance challenges, governance gaps, transparency and accountability in PRB. Also, participants during group focus discussions and on-door meetings assisted us to analyse qualitative data through dialogue and intensive heated debates. It is from these hot dialogues and debates that we extracted key information which is summarised in Table 4 and 5.

3.0 RESULTS

3.1 Methods for watershed conservation in PRB

Results on watershed conservation methods indicated two categories of approaches for watershed conservation in PRB and they are based on responses from the 216 household questionnaires. The first one is retaining riparian (*in situ* conservation) vegetation around water sources, and the second one involved applying human interventions (e.g. planting trees). Other approaches encompass building concrete canals, cleaning water canals and removing silt in both water intakes (springs) and irrigation canals (Figure 2).

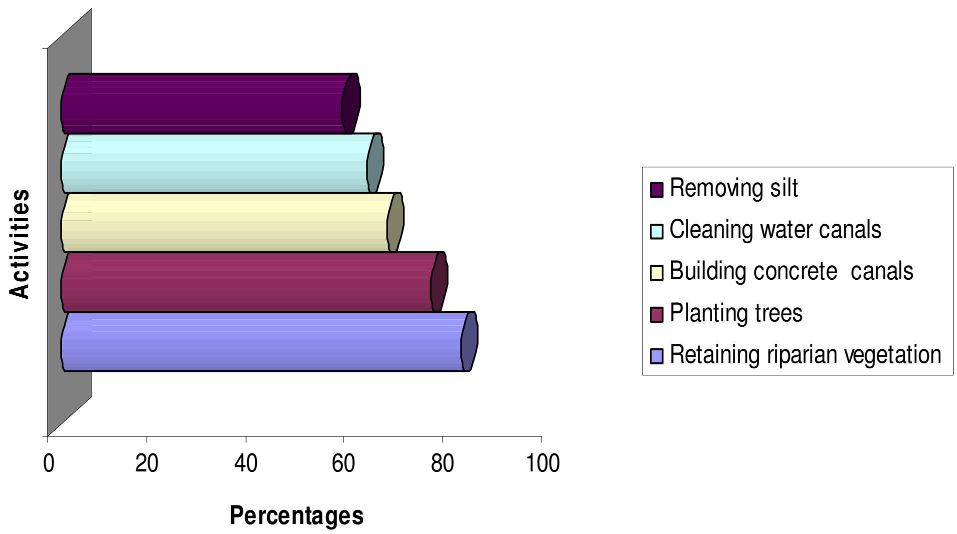

Figure 2: Responses on methods used for watershed conservation along PRB, Tanzania

As indicated in Figure 2 above, retaining riparian vegetation was preferred by majority of smallholder farmers (the 216 respondents) as the best approach as compared to other approaches. Some of the trees that we identified that were conserved in their natural habitats include *Rauvolfia caffra*, *Melicia excelsa* and *Ficus sycomorus* and varieties of herbs species. From conservation point of view, retaining natural vegetation (*in situ*) is the better than other approach over others due to its multiple benefits. These multiple benefits include ecosystem functions and services such as: climate regulation, soil erosion control, air purification, water regulation, carbon sequestration and biodiversity conservation, to name a few. Approaches that involved human interventions are tree planting around water sources, building concrete canals (to reduce water loss through infiltration and retard sedimentation), cleaning water canals, and removing muds and silt in the canals (Figure 2). These human interventions are mainly enforced by WUAs.

3.2 Water user associations and fees for irrigation water

3.2.1 Water user associations in PRB and water rights

In this paper, we referred WUAs as the consolidated group of smallholder farmers sharing common interests with respect to irrigated agriculture. We identified seven WUAs in the study area. They includes: KALOLENI Irrigation Scheme; Lower Moshi Irrigation Association (LOMIA); *Shango Migungani and Madukani* (SHAMIMA); *Mbuguni, Kikuletwa and Kambi ya Tanga* (MBUKITA); *Kikwe, Taran, Maweni and Karangai* (KITAMAKA); and Karangai, Msitu wa Mbogo, Marurani and Majimoto (KAMMMAMA) (Figure 3).

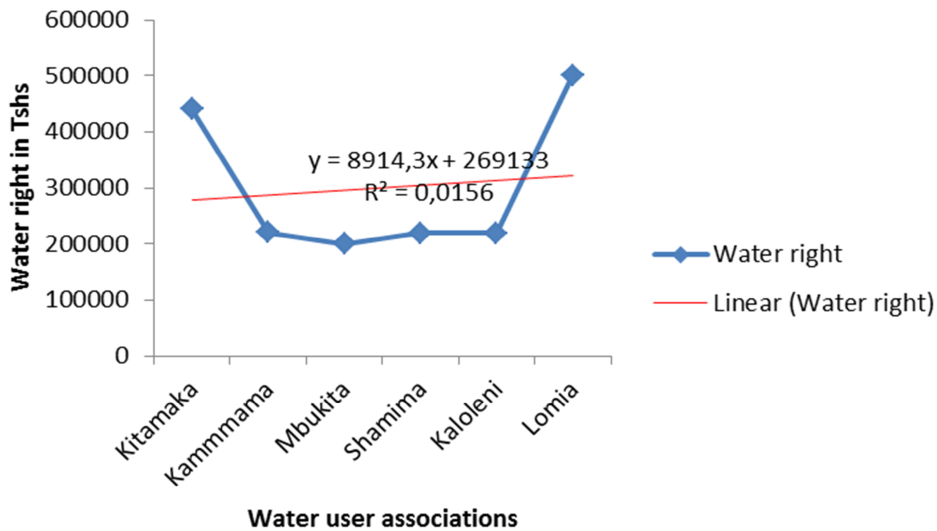

Figure 3: Water user associations in PRB Tanzania

WUAs were established in PRB to bring together smallholder farmers in their quest for improved irrigation supply. It was, however, reported that MBUKITA has recently disintegrated due to corruption and unfair water rationing.

Generally, WUAs are quite essential for facilitating water resources governance at local level (Komakech et al., 2011). In PRB, WUAs facilitated water management decisions (water allocation and rationing), by-laws formation, supervision and development of water resources infrastructures (e.g. establishment new irrigation canals). Moreover, we found that other objectives behind the formation of these WUAs in PRB were enhancing equitable allocation for irrigation water, water rationing, and collection of water use fees from small holder farmers. Related findings were reported by (Komakech et al., 2011) that river committees (RCs) were important local institutions for managing water allocation and solving water use conflicts between water user actors in Themi River Sub-Catchment in PRB.

We also noticed differences in the amount of water right fees paid to PBWO. Among the six WUAs that we investigated, *Kitamaka* (i.e. Tshs 441,000.00) and *Lomia* (i.e. Tshs 500,000.00) paid the higher fees as compared to other WUAs. As depicted in Figure 3 associations located at the extreme ends (upper and lower parts) paid higher water fee than those found in the middle part of rivers. The plausible explanation for the variations is that upstream villages have plenty water so they pay much in the view that the amount would cater for watershed conservation for sustainable water flow. On the other hand lower stream villages were motivated to pay higher amount of water right in view of financing water infrastructures. Water rights for other WUAs are Tshs 220,000.00 (for both *Kaloleni* and *Shamim*a), Tshs 221,000.00 (for *Kammmama*) and Tshs 200,000.000 (for *Mbukita*). According to interviews with irrigation and PBWO staff, however, the differences in the amount of water right fees depended on the original contracts signed during the establishment of each WUA. Other factors include the total number of smallholder irrigators per each WUA, revenues from crop sales, willingness of farmers to contribute water use fees, water availability for irrigated agriculture, transparency and efficiency fees collection.

3.2.2 Water use fees for irrigation water

We determined two categories of water use payments. First, fees for water utilization from smallholder farmers to WUAs, and secondly the cumulative yearly payment by WUAs (water right) to the PBWO (Table 3). Table 3 reveals standard deviations (STDs) for fees paid by smallholder farmers to WUAs (Tshs/season). The following are the results in descending order: Tshs 12, 852.90 (in Kikuletwa village), Tshs in 10,926.20 (in Chekereni village), Tshs 8,743.00 (in Rau River village), Tshs 7,098.00 (in Karangai village), and Tshs 4,962.40 (in Kaloleni village).

Table 3: Water user fees for irrigation water in PRB

Region	Village	Attribute	Fees paid by irrigators to WUAs (Tshs)/season	Water right paid by WUAs to PBWO (Tshs)/year
		Mean	3002.30	
	Kaloleni	Maximum	35000.00	220000.00
		STD	4962.40	
		Mean	24005.50	
Kilimanjaro	Chekereni	Maximum	70000.00	500000.00
		STD	10926.20	
		Mean	44250.80	
	Kikuletwa	Maximum	600000.00	220000.00
		STD	12852.90	
Arusha		Mean	12222.20	
	Karangai	Maximum	36000.00	441000.00
		STD	7098.00	

We also investigated the payment structure for water (permit) right and irrigation water. The payment hierarchical structure is displayed in Figure 4.

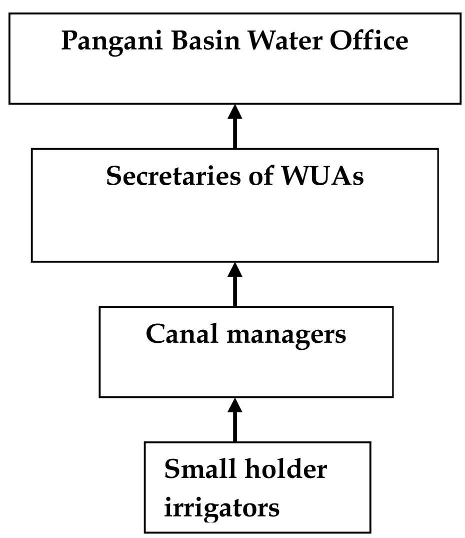

Figure 4: Water use payment structure in PRB, Tanzania

Under the systematic payment order displayed Figure 4, small holder farmers paid the water use fees to their respective canal irrigation managers. Then these canal irrigation managers handed over the fees (collected from smallholder farmers) to the higher authority (i.e. to the secretaries of WUAs). Finally, secretaries of different WUAs submit the money collected to the final destination (i.e. PBWO). Normally the collected water use fees were meant to cater for rehabilitating irrigation (canals) infrastructures and financing other water management operations (Lein and Tagseth, 2009).

3.3 Gaps in watershed conservation and water governance in PRB

We examined watershed conservation and water governance challenges by adopting seven factors from (Charbit, 2011).They includes administration, information, policy, capacity, funding, objectives and accountability. Results of our analysis are presented in Table 2.

As explained in **Table 4** river basins are shared nature resource base that requires integrated management strategies. We also found that weaknesses in information dissemination, policy constraints and low capacity of technical staff were undermining watershed management and water governance in Pangani River Basin. Moreover, lack of adequate funds for financing watershed conservation; contradicting objectives for watershed conservation and lack of accountability and transparency were equally reported as among the challenges contributing to uncertain future of watersheds and their capacity to release water in a sustainable manner.

Table 4: Watershed conservation and governance gaps in PRB, Tanzania

Governance gaps	Findings
Administrative gap	We found that it is a bit tricky to manage a watershed and its river tributaries because it is a common pool resource with no political or administrative boundaries. In PRB rivers, natural springs, and ground water are natural resources that have no administrative rather had ecological boundaries. Thus management of such kind of key resources is difficult and controversial. During the meetings, it was even difficult to tell exactly the sources of the rivers, who was responsible for management, and who the upstream and lower stream actors were. These in turn poise difficulties about its management options.
Information gap	We found that crucial information with regards to water governance is not shared adequately among key actors and players. For instance PBWO does not share crucial information with other water users and authorities. For instance, information on how much is collected as water user fee, how much is paid to PBWO as water right, and how much is given as subsides for water infrastructure rehabilitation does not go as far as to the local authorities. In turn, it prohibits policy makers and researchers to access crucial information for planning and decision making.
Policy gap	We noticed that there was a lack of concrete integrated (joint) water management plans between different policies dealing with natural resources management across PRB. For instance, we identified a lack of coherence among ministries and sectors (e.g. forest, water, mineral and agriculture) related to ES management. Respective sectoral ministries lacked effective joint action plans and strategies with regards to watershed management.
Capacity gap	Like in other river basins in Tanzania, we identified that PRB faced a lack of competent staff for shouldering high administrative, technical, information dissemination and coordination responsibilities. At the local level, we found a lack of competent officers for ensuring water allocation, equitable water distribution and rationing. We also identified weaknesses in collecting water use fee. There were no well trained staff for handling financial matters, in turn, smallholder farmers were extremely sceptical about their financial contributions.
Funding gap	We found that government funds were geared towards the provision of social services (i.e. health, education and road construction) at the detrimental of nature conservation. Our observation indicated that watershed conservation of sustainable water flow seemed to be the responsibility of conservation institutions like (WWF and CARE international) and local conservation Non-Governmental Organisations (NGOs). Even municipal authorities seemed to care less about setting aside funds for conservation, ultimately undermining the entire governance aspects with regards to water supply and allocation.
Objective gap	We identified contradicting interests between conservation (sustainability) and livelihoods (water utilization) objectives. While conservation organisations (WWF and the forest sector) are dedicated to nature conservation and sustainable use, on the contrary, water abstractors (e.g. Arusha and Moshi Urban Water and Sewerage Authorities focused much on water distribution regardless of the status of the watershed where water originated. We noted further that, in some instance, politicians seemed to fight for equitable water allocation (for political gains) without considering the integrity of the sources and the capacity of the watershed to release water downstream.
Accountability gap	We also documented conflicts over unfair water allocation caused by lack of transparency, responsibility and corruption. It was reported that some of (canal) irrigation officers had personal hidden agendas for personal gains in water rationing. These officers conspired with foreign investors (flower irrigation companies) over unfair water allocation at the detrimental of smallholder farmers. Similarly, transparency in revenue collection and expenditure was a case in point with regards to accountability and transparency.

Source: Adapted from OECD methodology presented in (Charbit, 2011).

We also identified policy instruments for water governance in Pangani River Basin. Results of our assessment (based on technical, economic, administrative, legal, institutional and social) are presented on Table 5.

Table 5: Policy instruments for water governance in PRB Tanzania

Policy instruments	Findings
Technical	We found that water allocation and rationing are governed by different authorities. Canal irrigation managers and WUA secretaries were the key people responsible for by-law enforcement for equitable and fair allocation and rationing in their respective water gates, canals and administrative locations. Water shortages in water sources, however, caused a lot of complains and loss of faith among smallholder farmers.
Economic	Our findings with regard to economic instruments indicated substantial reduction of subsidies and financial assistance from PBWO, political leaders and research institutions. There was lack of financial support from Legislators and Members of the Parliaments. We, however, found clues of supports from religious and academic institutions, international and local non-governmental organisations undertaking conservation projects in PRB.
Administrative	We documented that administration failures increased water use conflicts in PRB. The existing administration structures were ineffective, scrappy and uncoordinated with poor water governing institutional structures. Leaders of water WUAs had no power to deal with political leaders (Ministers, Members of the Parliaments, Councillors and Civil servants) who had irrigation farms within their administrative areas.
Legal	We found a clear violation of laws and by-laws with regards to water utilization guidelines. Illegal water abstractions and diversion were reported in almost every meeting that we carried out. According to the guideline for water permit issuance by the Water Ministry, water is supposed to be used according to "Water Resources Management Act, 2009" (URT,2002) Unfortunately, it was reported that some of these illegal water abstractors were senior government leaders whose tasks was to enforce equitable and equal water allocation and distribution.
Institutional	We identified problems related to ineffective local institutions, lack of clarity of roles and responsibilities with respect to water and watershed management. Furthermore, division of tasks were rather weak and this fuelled conflicts of interest and tug-of-war over power within WUAs. Other shortcomings include questionable resource allocation and untrustworthy financial management.
Social/Participatory	Majority of smallholder irrigators were aware of the existence of "water use permit" initially called "water use right". But it was extremely difficult for them to mention even a single sentence about their right. Smallholder farmers were relatively aware of water management but their effective involvement in planning for watershed conservation and financing water infrastructures was rather low.

Source: Adapted and modified from (Plummer and Slaymaker, 2007)

4.0 DISCUSSION

4.1 Methods for watershed conservation in PRB

From a conservation point of view, riparian vegetation is an ideal approach for sustainable watershed conservation and supply of multiple ES. Natural vegetation such as trees, herbs and climbers within natural habitats (*in situ* conservation) enhance multiple ecological functions (Costanza et al., 1997; de Groot et al., 2012) Like in Moshi where natural trees are conserved around Kilimanjaro Mountain National Park, Goa and Miwaleni springs, in the Arusha region riparian vegetation around River Nduruma water source facilitate provisioning service by filtering and maintaining water balance at the source. Apart from being the home of biodiversity, riparian vegetation in Meru and Kilimanjaro Mountains are the water towers in PRB, thus promoting watershed conservation would guarantee sustainable water flow and water quality improvement as well (Mwamila et al., 2008).

Tree planting offers multiple socio-economic and ecological benefits as well. In PRB planted trees along the mountain slopes has been instrumental in soil erosion control, retarding sedimentation, siltation and restoration of degraded forest catchments (Msuya, 2010; Notter, 2010; Ngaga et al., 2010). Tree planting along Meru and Kilimanjaro Mountain is carried out by the Ministry of Natural Resources and Tourism through the Forestry and Beekeeping Department, non-governmental institutions, private firms and individuals. However, forests contributions to sustainable water resources management is still a debatable topic. Problems have often arisen from a failure both to communicate results effectively to policymakers and planners, and to challenge entrenched views, and new approaches.

4.2 Water user associations and fees for irrigation water

Water user associations (WUAs) are important vehicles for irrigation enhancement along PRB. However, the challenges mentioned in section 3.3 contribute enormously to the failure of WUAs to achieve their missions and targets. For instance enforcement of actions and by-laws has been a stumbling block for quite sometime. Although, there is water scarcity in PRB, poor governance and weak WUAs are to blame for the current skewed water distribution and allocation of irrigation water. Corruption and failure of WUAs to mediate water use conflicts are among the poor water governances across the PRB. The weakness and failure of WUAs is exemplified by the collapse of MBUKITA due to lack of accountability and transparency in revenues and expenditures. Corruption in water allocation and rationing has further aggravated the situation.

Thus deliberate measures need to be enforced so as to get away from the current weakness related to poor water governance. Water supply irregularities due to illegal abstraction by investors (companies mainly from USA and Western Europe engaging on horticulture irrigation) are features of the failures of WUAs to enforce fair water allocation and rationing in PRB. Similar sentiments along these aspects were reported by (Komakech and van der Zaag, 2011) who found that RCs were ineffective to downstream users because enforcement of the water allocation schedule was a problem due to bribes for water use outside the legal hours. Given that misallocation and corruption is a governance problem, something has to be done for the future efficiency of WUAs and sustainability of water flow (Mehari et al., 2009).

Smallholder farmers are quite aware of the need for paying for irrigation water. As revealed in Table 3, the STDs for Kikuletwa and Chekereni are higher as compared to STDs for Karangai and Kaloleni villages. Higher STDs implies that the marginal utility or intrinsic value of water to smallholder farmers Kikuletwa and Chekereni villages is higher (Tshs 12, 852.90 and in 10,926.20 respectively) than in Karangai and Kaloleni (Tshs 7,098.00 and 4,962.40 respectively). Kikuletwa and Chekereni villages are located at the far downstream part (Figure 1) where water demand and competition is higher than in Karangai and Kaloleni villages. Thus being located upstream, Karangai and Kaloleni villages experience water as abundant and the competition is a bit lower as compared to Kikuletwa and Chekereni. So there is a need for regulating equal and fair water allocation and rationing between upstream and downstream villages. Similarly, equal distribution of water for smallholder farmers within villages is essential and could motivate smallholder farmers to increase their payment for unit increases of irrigation water.

4.3 Gaps in watershed conservation and water governance in PRB

As indicated in Table 4, fragmented, antagonistic interests and priorities of sectoral policies are hindrance to watershed conservation and governance. Shortage of competent technical staff, corruption, lack of accountability and transparency are key constraints precluding irrigated agriculture in PRB. From the analysis on seven parameters displayed in Table 4, corruption and lack of transparency affect negatively the fair and equal water allocation and rationing. Rich people bribe water canal irrigation managers for illegal water allocation contrary to the set-down bylaws. Some of canal irrigation managers and secretaries of WUAs are bribed by foreign investors for illegal water abstraction and allocation. Water abstraction and excessive withdrawals affect water flow, economic activities and ecological processes downstream. Our discussions during on-door meeting indicated that foreign firms/investors are no longer perceived as investors, rather they are enemies of smallholder farmers and water grabbers (Matthews, 2012, 50, 51, Woodhouse, 2012; Duvail et al., 2012; Williams et al., 2012). Thus, our opinion is that we should invest on capacity building by governing people first. It is through investment on capacity development that watershed conservation and water governance would be achieved. Similar views are reported by (Plummer and Slaymaker, 2007) who advocate that strong and effective capacity building is vital for sustainable water management programmes.

In this connection, capacity building should target first the irrigation engineers and irrigation extension workers who are the key actors in enhancing water utilisation along PRB. Once the extension officers are empowered, it would be easier for them to create smallholder farmers' knowledge on water user right (permit) and other shortcomings identified in Table 4. It is against this background that deliberate measure should be put in place in order to build the capacity of water users and other stakeholder along PRB. Once stakeholders are aware of watershed conservation approaches and water governance dynamics, then it would be easier for them to understand their roles, responsibilities, knowledge on water use by-laws, to mention a least.

Similarly, the current study attempted to link water governance gaps with policy instruments. As revealed in Table 5 the disjoint between theory and practice is among the challenges for water governance in PRB and most of river basin management in developing countries (Calder, 2007; Mehari et al., 2009; Franks et al., 2011). For instance, to get a water (permit) right in Tanzania, any WUAs is required to be aware of the following special requirement: **i)** That your abstraction is subject to inspection by the Pangani Basin Water Office at least once annually; **ii)** That the annual water abstraction charges shall be paid as prescribed in Water Resources Management Act No. 11 of 2009 made under Section 96; **iii)**That in case of drought or any Public interest your Water Permit will be subjected to review; **iv)** That the water after use in the farm shall not be retuned in the river or any other source in a polluted state; **v**) That the grantee shall always allow water to flow downstream; **vi)** That the grantee shall install a water flow measuring device at the intake before putting water into use and keep records of daily amount of water abstracted; **vii)**That the grantee shall submit the records when required; and **viii)** That the grantee shall be a member of the Water User Association of their respective area.

Unfortunately, majority of smallholder farmers didn't know exactly what this water right (water use permit) was all about and were not aware of the above stated conditions. Surprisingly enough, even the WUAs leaders didn't know the whereabouts of this important document. It is from this background, we feel that awareness creation should be a priority for if water governance is to be achieved. Once smallholder famers are aware and well informed about it, it would be easier for them to translate issues from theory to practises.

On the other hand smallholder farmers have no problem with the current structure of payment for irrigation water (Figure 4). This payment structure is convenient and even easier to them. But their doubts are those individuals (people) who misuse water use fees. The operationalization of this payment setup faces a lot of governance shortcomings including corruption, lack of accountability, transparency and administrative failures as elaborated in Table 4.

5.0 CONCLUSIONS

The present study has indicated that retaining riparian vegetation in their natural habitat is the recommended approach for conservation of watersheds in PRB. This is an important lesson especially to ecologists and communities residing along river basins facing similar problems like in PRB. The potential and usefulness of riparian vegetation lies in the fact that they have multiple benefits. Apart from enhancing water flow, riparian vegetation enhances ecological functions and provision of multiple ES. Nevertheless, despite a number of scientific reports linking conservation of riparian forest and water flow, a lot is yet to be researched in order to verify the clear link.

Enhancing smallholder farmers to form and strengthen existing WUAs along PRB is essential for sustainable watershed conservation and water flow as well. The presence of WUAs in the study area is a testimony of the implementation of the Dublin Principles (Lein, and Tagseth, 2009) on public involvement and decentralization of resource base conservation at local level scale. Devolution of power al the lowest local level (Dublin Principles) is also echoed by the study by (Komakech and van der Zaag, 2011) who found that formation of RCs were key towards lessening water use conflicts and sustainable water management along PRB. Despite the prevailing challenges facing WUAs, findings of the current study are key for policy makers on the urgent need of letting the power go to the lowest level (Ostrom, 1990; Ostrom and Schlager, 1996; Ostrom et al., 1993). The weaknesses and challenges facing WUAs would form the basis for sustainable watershed conservation, water governance, and hence sustainable water flow along PRB.

Watershed conservation and water governance are among the contemporary challenges of our time across the globe. Watershed conservation and challenges facing water governances reported in this study indicates clearly why we need to increase efforts in the quest for nature conservation. Thus, dedicating our efforts to governance improvement would bring about the desired outcome. Improving watershed conservation and water governance should go hand in hand with efficient, effective and transparency in water use fees collection, handling and utilisation. It is through good water governance that smallholder farmers would be motivated to contribute more water utilisation.

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CHAPTER 9

Willingness to Pay for Watershed Conservation: Are we applying the right paradigm?

This chapter is based on:

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ABSTRACT

The values of watershed services from watersheds has for many years been neglected, underestimated and not factored in land use decisions for sustainable management. The problem is profounding in developing countries which are characterized with constrained budget for financing conservation programs. To resolve this problem attention has moved to market based instruments such as payment for watershed services (PWS). However, the approach to elicit the necessary information for PWS to kick off is still lacking. This study investigated small holder farmers' willingness to pay (WTP) for watershed services in Pangani Basin. A contingent valuation method was employed to elicit the willingness to pay for watershed conservation. A probit model was used to determine respondents' response to WTP and factors conditioning the maximum amount they are WTP. Findings indicates that majority of respondents are willing to pay for watershed services. Similarly, result reveals that marital status, household size and distance from the water source positively influence smallholder farmers' WTP and the maximum amount to be paid. Equally important occupation, household size, income from irrigation, and amount paid for irrigation were found to negatively influencing smallholder farmers' WTP. The result also revealed that education level, total land size and yield from irrigated farm plot positively influence smallholder farmers' WTP. These results therefore, indicate that establishment of PWS is feasible.

Key words: *Contingent valuation, Ecosystem services, Watershed ecosystem, Tanzania*

1.0 INTRODUCTION

1.1 Watershed conservation and ecosystem services supply

For decades watershed ecosystems have been taken for granted and the ecosystem services (ES) from therein have been regarded as free resources (Tietenberg, 2002) and sometimes considered as common (pool) property resources (Mbeyale, 2009; Ostrom et al., 1993; Ostrom, 1990). Watershed ecosystems have the potential for the provision of ES ranging from provisioning, regulating, supporting to cultural services (Costanza et al, 1997; De Groot et al., 2002; MEA, 2005). However, their socio-economic and ecological significance have subjected them to severe threats in such a way that their potential to release watershed services has been dwindling (Tietenburg, 2002; Liquete et al., 2011). Analysis from the Millennium Ecosystem Assessment indicated that 60% of ES are under unsustainable use (MEA, 2005). Drivers for the degradation of watershed ecosystems include anthropogenic activities (such as unsustainable agriculture, excessive harvesting of forest products, mining activities and overgrazing) and natural drivers such as climate change and variability. This degradation has altered their long-term capacity to provide provisioning, regulating, supporting and cultural ecosystem services at levels that can sustain welfare of the current and future generations (Calder, 2007; Stanton et al., 2010; Liquete et al., 2011).

The Pangani River Basin (PRB) presents a compelling case for analysis of the feasibility of payment for watershed services (Kulindwa, 2005; Lalika et al., 2011). Kilimanjaro and Meru Mountains are regarded as the water towers because they are the catchments where Pangani River originates (IUCN and PBWO, 2008). The two catchments play an important role in providing fresh water to communities downstream. Their capacity to reduce run-off, percolate and slowly release water downstream has made the basin to become productive throughout the year. The watershed provide water for large and small scale irrigation, domestic and industrial use, hydropower production (at Nyumba ya Mungu Dam); for ecological processes along Pangani River and for nutrient cycling at Kirua Swamp (Mwamila et al., 2008). Nevertheless, the increase of the population along the PRB (Mbonile, 2005) triggered the change of prior land uses to new ones in search for ES to support the growing population. Rampant population influx in PRB accelerated urbanization which called for more area for human settlement, agriculture and supply of water for the increased domestic and industrial uses. Consequently, the change of land use in search for watershed services has accelerated degradation of the watershed, hence reduction of water flow along the PRB.

To reverse the harm done on the watershed an integrated conservation approach which brings together upstream communities and downstream water users is deemed important to complement the traditional command and control policy instruments (MEA, 2005; Pagiola, 2004a; 2008; Porras et al., 2008). Marked-based approaches for conservation have been tipped as ideal policy tools for watershed conservation (Pagiola et al., 2004b; Locatelli and Vignola, 2009; Okurut, 2011; Khanal and Paudel, 2012). The economic logic behind this argument is that the later instruments acting on their own have not been sufficient to address the problems facing the management of watersheds (Dobbs and Pretty, 2008). In particular, command and control instruments have not exploited the potential of upstream land holders and downstream ecosystem services beneficiaries in achieving conservation goals. Market based instruments provide incentives to upstream land holders to manage the catchment in a manner that ensure continued supply of services to downstream users (Pagiola et al., 2004b; Pagiola et al., 2005; Turpie et al., 2008). Equally important, market based instruments are considered important as they will motivate upstream land holders to take into account the effects of their actions when making decisions about their own land use (Okurut, 2011).

However, some key empirical analysis of downstream users who are willing to pay (WTP) for the services provided to upstream land holders is crucial before establishing the downstream-upstream market link (Whittington, 2002; Locatelli and Vignola, 2009; Mohamed et al., 2012; Calderon et al., 2005). The actual values of watershed services has for many years been neglected, underestimated, not captured in the national income accounting and not factored in land use decisions for sustainable management along PRB (Lalika et al., 2011). Thus undertaking a study on WTP for watershed conservation is crucial.

1.2 Willingnes to pay (WTP) and valuation of ecosystem services (ES)

Watershed ecosystems provide innumerable ecosystem goods and services to the society (Locatelli and Vignola, 2009). Human beings depend of ES from different ecosystems and a sustainable flow of ES depends much on well-functioning ecosystems. For quite some time, ecological economists have been researching in order to better understanding how these ES are valuable to human being and in the production process (Pattanayak and Kramer, 2001; Costanza et al., 1997, Heal et al., 2005). Unfortunately, the economic value to society of these ES are frequently undervalued and sometimes not captured along the PRB because of lack of knowledge regarding the role that watershed ecosystems play in offering ES or because these ES are indirect and therefore, difficult to quantity. Thus researches to ensure that watershed ecosystems along the PRB are carefully conserved to ensure sustainable supply of ES and that these ES are properly documented and quantified are crucial. More importantly, it is high time to carry out empirical studies so as to document the people's WTP for watershed conservation.

Across the globe, ecological economists have been using individual preference based approaches for estimating the demand for ES in order to cope with challenges of values / prices of ES in the absence of market prices (Champ et al., 2003). Contingent Valuation Method (CVM) is among the most preferred approach for achieving this purpose. CVM is advocated by a majority because it presents individuals with a theoretical market for a change in quality or quantity of ES by asking them to state and /or rank their WTP. Therefore, their preferences of a certain ES is determined or indicated by the amount of money assigned by their WTP (Voltaire et al., 2013).

There are a number of economic theories and school of thoughts about individual preferences on WTP. For instance, the microeconomic theory of consumer behavior assumes that any choice by individuals have a well-defined preference for that particular choice (Pindyck and Rubinfeld, 2005). For valuation purposes of ES, individuals are capable of indicating their preferences (in financial terms) by stating an exact WTP for any change in the provision of ES. According to Bateman et al. (2005), and Hanley et al. (2009), at some instance some individuals fail or feel uncertain to asign a value to a specific ES during valuation studies.

Understanding of the values that people place ES is critical to making sound management and economic decisions. In many cases, markets provide an easy way for people to reveal value through their decisions to buy and sell ES. But in other cases, markets fail to accurately reflect actual values. Whether it's because the ES being valued does not have a market, or existing markets fail to reflect the full value of the ES, non-market valuation methods are needed to fully measure the costs and benefits of ES (Haab and McConnell, 2003; Awad and Holländer, 2010). Therefore, this doctoral study (based on the CVM) was carried out to elicit people's WTP in order to gather information for designing and establishment of PWS scheme along the PRB, Tanzania. CVM was preferred in this doctoral study because it is widely applied to the problem of estimating economic values of ES that are not traded in markets and for which no economic behavior is observable (Pattanayak and Kramer, 2001; Heal et al., 2015). Furthermore, CVM was applied in this research because these non-markets characteristics are normally present when the ES in question is in the form of an environmental amenity.

Therefore, CVM was preferred and applied in this study so as to elicit the willingness of a household to pay for water flow that will produce benefits for that particular household. CVM has the ability estimate the total WTP based on people's direct statements of their preferences. Specifically the study (i) Identified respondent's socio-economics characteristics and their perceptions on the market based arrangement for watershed conservation; (ii) Identified socio-economic drivers and marginal effects for WTP for watershed conservation; (iii) Determined the factors influencing the maximum amount for WTP for conservation.

2.0. MATERIALS AND METHODS

2.1 Description of the study area

2.1.1 Location

This study was conducted in eight villages; four (Kaloleni, Chekereni, Rau River and Mabogini) in Kilimanjaro Region and the other four (Lekitatu, Karangai, Msitu wa Mbogo and Kikuletwa) in Arusha Region the Pangani River Basin (Figure 1).

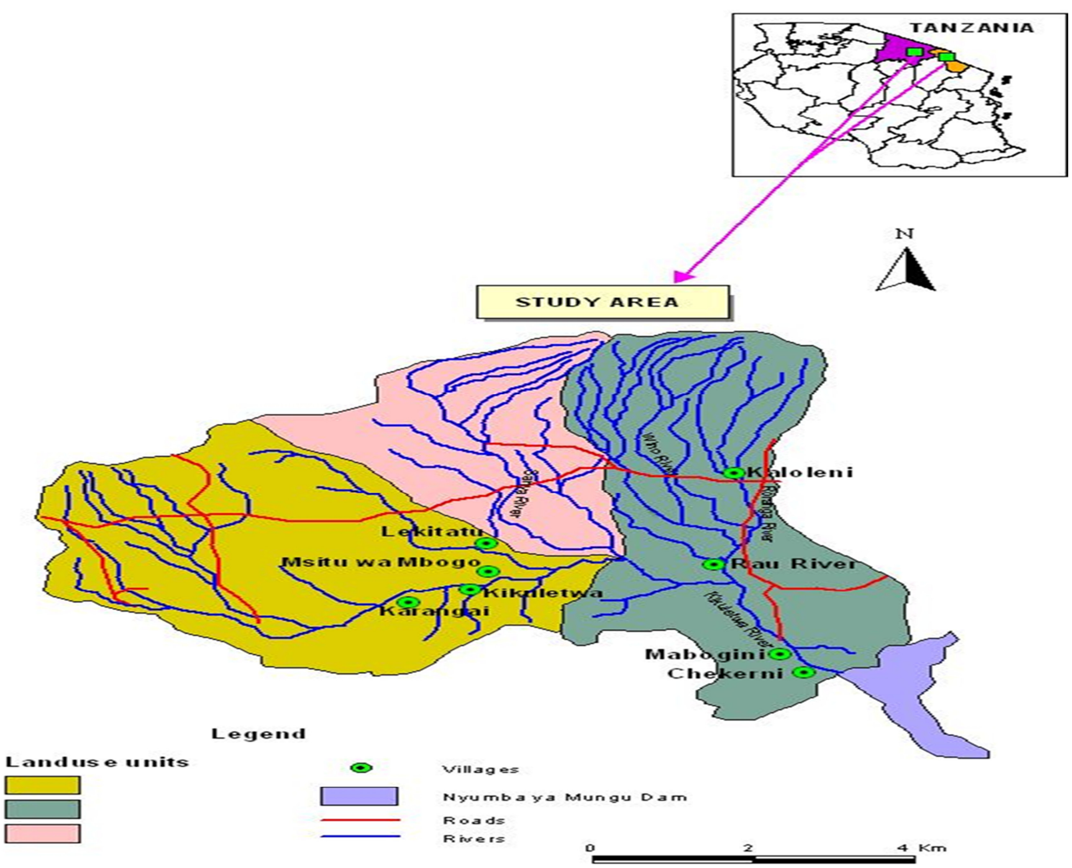

Figure 1: Location of the study area along Pangani River Basin, Tanzania

The PRB is located at latitude 03º 05' 00" and 06º 06' 00" South and longitude 36º 45' 36" and 39º 36' 00" East. It drains a large catchment in the northeastern part of the country along the border with Kenya, extending from Mount Meru and Kilimanjaro down through the Pare and Usambara Mountain ranges (IUCN and PBWO, 2008).

The basin has a total catchment area of about 43,650 km^2 with about 3,914 km^2 lying in Kenya (IUCN, 2007). Pangani River Basin is unique in the fact that it begins from the highest pick of mountain in Africa, Mount Kilimanjaro (which is 5895 m asl) and Mount Meru (which is 4565 m asl) through the Pare and Usambara Mountains to the north and north-east respectively to the low lands of about 900 m asl and 0 m asl. The low lands make up about 50% of the basin (Valimba, 2005).

2.1.2 Hydrology and drainage pattern

The hydrology and drainage pattern in the PRB catchment varies considerably. The PRB comprises of several sub-catchments of widely different characteristics. The Pangani River (PR), which is also referred as the Pangani Mainstream, rises as a series of several small streams and springs on the southern sides of the Africa's highest peak Mt. Kilimanjaro, and on Mt. Meru (IUCN and PBWO, 2008; IUCN, 2007). These streams (Nduruma, Tengeru, Sanya, Malala, etc.) create the Kikuletwa and Ruvu Rivers (Himo, Muraini, etc.) which drain further downstream into the Nyumba ya Mungu (NyM) dam (IUCN and PBWO, 2008; 2011; IUCN, 2007). The Nyumba ya Mungu dam has created a man-made water reservoir of ecological and economic importance along PRB. The overflow of the dam (outlet) is known as the Pangani River Mainstream and flows for 432 km before emptying into the Indian Ocean at the Pangani estuary.

The Nyumba ya Mungu reservoir is the largest water body in the PRB and was constructed in 1965 to enhance river flows for hydropower generation. It was later incorporated into irrigation plans (Mulungu, 1997; Ndomba et al., 2008). Besides the power station at the outlet of this dam, other hydropower power plants in the PRB are located near Hale and New Pangani Falls. Water released from the Nyumba ya Mungu dam supply ecosystem services downstream. These include nutrient cycling at Kirua Swamp and enhancement of ecological processes (e.g. hindering salt water intrusion and coastal erosion) at the estuary mouth in Pangani Town (Ndomba et al., 2008; Shaghude, 2006; Sotthewes, 2008; Valimba, 2005; 2007). Other river tributaries draining in the PRB are Mkomazi and Luengera from the Pare and Usambara Mountains ranges respectively.

2.1.3 Forest and vegetation types

Forest and vegetation in PRB range from forests on mountain slopes to semiarid grasslands (IUCN, 2003). The main vegetation types include forests, woodlands, bushland, along with grassland thicket and plantation forest (Turpie et al., 2005). Plantation forests have replaced natural forests in the highlands, and the larger part of the lowlands is composed of woodland, bushland, grassland and thicket. Forests perform vital hydrological functions in the PRB including the regulation of run-off, prevention of soil erosion, water storage and improvement of water quality (IUCN, 2003; Msuya, 2010). According to IUCN (2003), dominant forest types in PRB include: *mangrove forests* (located at the confluence of the Pangani River and the Indian Ocean and protecting the coastlines and soft sediment shorelines from erosion, trapping sediments and recycling nutrients); *East African coastal forests* (containing remarkable levels of biodiversity and endemism); *afromontane forests* (playing a key part in hydrological functions); and *riverine forests* (controlling erosion along the river banks). Research and previous studies on forest health conducted in the PRB shows that between 1952 and 1982, catchment forests in the PRB declined at a fairly high rate of 3.8% of forest cover per year and 83% of the forest cover lost from deforestation for other land uses such as farmlands and settlements (Lambrechts et al., 2002; Newmark, 1998).

2.1.4 Climate

Variations in the local climate in the PRB are mostly related to topography. The flatter, lower-lying south-western half of the Basin is arid and hot, while the mountain ranges along the northern and south-eastern catchment boundaries have cooler, wetter conditions. The high altitude slopes above the forest line on Mt Meru and Mt Kilimanjaro have an Afro-Alpine climate and receive more than 2,500 mm of rainfall per year. Mean annual rainfall increases in a southerly direction along the mountain ranges, and varies from about 650 mm per year in the North and South Pare Mountains, to 800 mm per year in the Western Usambara Mountains, and 2,000 mm per year in the Eastern Usambara Mountains.

2.1.5 Population and economic activities

The PRB is estimated to have 4.5 million people (data from 2007) and population densities vary between highlands and lowlands. About 90% of the basin's population resides in the highlands with some 900 people per km^2, while lowland densities were around 65 people per km^2 (IUCN, 2003). The main causes of forest degradation and deforestation include encroachment for settlement and agriculture as well as increasing demand of forest products (mainly timber and fuel wood) (IUCN, 2003). In terms of human population, PRB is a densely populated area in Tanzania, posing serious challenges to sustainable watershed management (Msuya, 2010).

2.2 Sampling procedure

Field visits were first carried out along the PRB for village identification and sampling purposes. A simple random sampling technique was used to select the sampling units (i.e. households) in order to avoid bias. We used this sampling technique in order to give each household in each village and every member of the household (aged 18 years and above) an equal chance of being selected. The sampling frames for this study were the village register books containing the list of all households in the respective villages.

We sampled 8 villages, 4 in Arusha Region and 4 in Kilimanjaro Region and in each village we sampled 10% of the total households as indicated in Table 1.

Table 1: Interviewed respondents in the study villages

Region	District	Village	Total households	Respondents
Arusha	Meru	Lekitatu	250	25
		Karangai	480	48
		Kikuletwa	640	64
Kilimanjaro	Moshi Urban	Msitu wa Mbogo	420	42
		Kaloleni	490	49
	Moshi Rural	Chekereni	550	55
		Rau River	340	34
		Mabogini	430	43
Total			3600	360

In each village, we randomly selected respondents using a table of random numbers. The respondents were selected by matching their numbers in the village register books. We used both quantitative and qualitative methods in data collection.

2.3 Questionnaire design and bid amounts

The household questionnaires for this survey were constructed and designed with the purpose of collecting all necessary information to answer research questions of this doctoral research. Key sections includes: socio-economic characteristics of the household/respondents; household income and sources; different water uses; and villager's perceptions towards changes in watershed services.

The questionnaire had the following sections: i) The valuation scenario (i.e. where we introduced the respondents the mission of our survey, types ES delivered by watersheds, why they should be conserved and paid for, etc.); ii) The status of watersheds (i.e. they are degrading and that continued degradation will result in significant reduction of ES and if they think conservation would restore the situation); iii) Initiatives set by the government and donor agencies on watershed conservation (i.e. if they are willing to contribute for increased unit of water flow; bids and payment methods); iv) If they are willing or unwilling to pay and why?; v) Certainty of their willingness and unwillingness to pay; vi) Their willingness to wait for longer periods in order ES to flow as a result of their payments and their opinions if they think PWS would enhance watershed conservation).

Including the above questions in the questionnaire was important for capturing different information related to socio-economic status and WTP for watershed conservation. This methodological approach conforms to research carried out by Loomis et al. (2000), Zhongmin et al. (2003), and Herrera et al. (2004), who contended that a clear explanation of CV variables to be studied is crucial in valuation studies because it gives a better understanding of the variables that affect the household's WTP, which is an important key to identify the hypothetical situation; it help to elicit the range of amount / values of WTP through binary (close ended) choice questions; and by ensuring accurate benefit estimates of the ecosystem good and services under study.

In this regard, we set questions in the form of binary/dichotomous, i.e. respondents had two options (1= yes and 0 =No). We designed bids amount in a form of payment cards assigned values ranging from Tanzanian shillings 0 – 75,000 where respondents were required to mention or circle the amount they were willing to pay. These bids were finally set after a careful pre-testing and feedback from smallholder farmers along the PRB.

Before actual interviews (data collection), we trained research assistants on the appropriate way to administer CV questions. We introduced them about the meaning of ecosystem services, willingness to pay for ecosystem services, watershed degradation, standard description on the CV scenario, to name just a few. Furthermore, we trained research assistants on several issues related to the CV questionnaire including opinion questions aimed at reminding respondents the benefits and constraints of watershed degradation. In the CV questionnaire, we selected payment vehicle as the water use fees. Respondents were also asked if they would be WTP for monthly or annual fee for watershed conservation. Based on the respondent's previous answer, research assitants were also trained on how to ask follow-up questions for lower or upper amounts of water use fees.

2.4 Data collection

For quantitative data, we used structured questionnaires (with the CV scenario) as the main tool for collecting primary (quantitative) data. The structured questionnaire covered questions on water uses, types of water sources, payment methods for water utilization, types of socio-economic activities; other goods and ecosystem services delivered by the PRB; and questions on WTP. As indicated in Table 1, a total of 360 respondents were interviewed in eight villages, i.e. four (4) villages in Arusha and Kilimanjaro Region respectively.

We divided the study in two phases. During the first phase we carried out a field excursion with the aim of familiarizing ourselves with the study area and selecting study villages. We also pre-tested questionnaires in order to assess questions for their validity and reliability in the sampled villages.

In phase two, we carried out the actual survey (i.e. we administered structured questionnaires) where a total of 360 respondents were interviewed (Table 1). We also collected qualitative data through informal and formal discussions and interviews. These discussions and interviews enabled us to enrich quantitative data collected through structured questionnaires. Furthermore, we also carried out group focus discussions (GFD) to supplement information collected through other methods.

2.5 Data analysis

2.5.1 Quantitative and Qualitative data

We coded and cleaned the 360 questionnaires for final analysis. We used Statistical Package for Social Sciences (SPSS) version 20.0 to analyze data. There after we carried out analysis to obtain frequency and percentages of responses from smallholder farmers who were willing or not willing to pay for watershed services. On the other hand, we analyzed qualitative data with the help of participants during group focus discussions through dialogue and intensive debates.

2.5.2 The empirical model

The study employed the CVM which is a hypothetical value based method used to estimate smallholder farmers' WTP for ecosystem services obtained from a watershed for sustainable management of the ecosystem. The approach was selected for this study because of its ability to assign a market value to ecosystem services which have no market values or cannot be assessed by market mechanisms (Bateman et al., 2002; Amponin et al., 2007).

To achieve the objective of the study, we therefore, employed un-observed latent variable as an underlying propensity to WTP. To get consistent results, the survey data were analyzed using probit model as suggested by Green et al. (1995), to examine more rigorously whether or not small holder farmers in Pangani Basin are different between the two lines of choices.

The model used takes the following form:

$$y_i = \begin{cases} 1 \text{if } y_i^* > \tau \\ 0 \text{if } y_i^* \leq \tau \end{cases} \qquad (1)$$

Where: τ is the threshold of being different between the two lines of choices, and y^* is the latent variable.

As revived by Green (2003) the latent variable $(y_i^*)$is assumed to be linearly related with observed variables $(x's)$ in the structural model and is presented as:

$$y_i^* = x_i\beta + \varepsilon_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$

Where; $x$is a vector of variables is hypothesized to influence WTP; β is a vector of parameters estimated; and ε_i is the random error assumed to be normally distributed with zero mean and unit variance (i.e. $\varepsilon \cong N(0, \sigma = 1)$.

The probability of observing a small holder farmers saying 'YES' (i.e. $y = 1$) is expressed as suggested by Long (1997)

$$\Pr(y_i = 1|x_i) = \Pr(y_i^* > 0|x_i) \Rightarrow \Pr(y_i = 1|x_i) = \Pr(x_i\beta + \varepsilon_i > 0|x_i) \ldots\ldots\ldots \text{(3)}$$

As mentioned in above, the probability of an individual to be willing to pay for watershed services was estimated by using logit model such that;

$$\Pr(y=1) = \frac{\exp(x_i\beta)}{1+\exp(x_i\beta)} = \frac{1}{1+\exp(x_i\beta)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(4)}$$

The parameter estimated were interpreted as marginal effects, which indicates the effects of a marginal change of the variables conditioning willingness to pay for watershed services on the probability of saying 'yes'. Therefore, the marginal effects were estimated as follows;

$$\frac{\partial \Pr(y=1|X)}{\partial X_i} = \phi(x_i\beta)\beta_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(5)}$$

Where: Y= is WTP taking values 0 and 1, X= is a vector of factors that condition individual WTP, and β= is a vector of variables estimated (Griffiths et al., 1993; Wooldridge, 2003; Sanga et al., 2013).

Note: that Y is censored at zero for the sub-sample of smallholder farmers that gave valid responses. Thus, to get consistent and robust results, the two-limit probit model as suggested by Rosett and Nelson (1975) was used to allow both upper and lower censoring to be captured in estimating the likelihood function for the model (see eqs. 6 and 7 respectively).

$$y = \begin{cases} \tau_L & \text{if } y^* \le \tau_L \\ y^* = x\beta + \varepsilon_i & \text{if } \tau_L < y^* < \tau_U \\ \tau_U & \text{if } y^* \ge \tau_U \end{cases} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

The likelihood function was estimated as follows:

$$\ln L = \sum_{\text{Lower}} \ln\Phi\left(\frac{\tau_L - x\beta}{\sigma}\right) + \sum_{\text{Uncensored}} \ln\frac{1}{\sigma}\phi\left(\frac{y - x\beta}{\sigma}\right) + \sum_{\text{Upper}} \ln\Phi\left(\frac{x\beta - \tau_U}{\sigma}\right) \ldots\ldots\ldots\ldots\ldots\ldots (7)$$

2.5.3 Description of variable and model specification

As explained in section 2.3 above responses on WTP was denoted by binary answers (dummy variables) where the response of respondents was "yes" denoted by the 0 value and "no" for 1. Respondent's WTP for watershed conservation were hypothesized to be conditioned by a number of socio-economic drivers. They include: water use fee; gender; marital status; education level; occupation; household size; number household members engaged in income generating activities; total annual income; irrigation income; household water sources; distance from the water sources; amount of water from other sources; water for different uses (e.g. cooking, drinking washing clothes, dishes, toilets, bathing, etc.); price for water; total land size; amount paid for irrigation; quantity of crop yield with and without irrigation; and water use for irrigation.

It was hypothesized that variables denoted by positive (+) and negative signs (-) (Table 2) could influence positively and negatively people's WTP respectively. Moreover, some variables were assigned dummy (binary) values i.e. 0 for "yes" and 1 for "no".

Table 2: Hypothesized direction opinion of socio-economic variables on WTP

Independent Variable	Description	Measurements	Hypothesized direction of opinion
H2OUSEFE	Water use fee	Tanzania shillings	-
GENDER	Gender	Male (0) or Female (1)	+
MARITALS	Marital status	Married(0) or otherwise (1)	+
EDUCAT	Education level	Number of years spend in education	+
OCCUPAT	Occupation	Employed (0) or not employed(1)	+
HHSIZE	Household size	Total number of those who generate income (0) and those who doesn't (1)	+
PROPTHHE	Number hh members engaged in income generating activities	Family members above 15 years old	+
TOTANNUA	Total annual income	Tanzania shillings	+
IRRIINCO	Irrigation income	Tanzania shillings	+
NHHSOURC	Household water sources	Tap water (0) or other sources (1)	-
DISTASOU	Distance from the water sources	In kilometres	+
AMOH2OSO	Amount of water from other sources	Number of buckets of 20 litres	-
AMOH2OCO	Water used for cooking	Number of buckets of 20 litres	+
AMOH2ODR	Water used for drinking	Number of buckets of 20 litres	+
H2OUSWAS	Water used for washing clothes	Number of buckets of 20 litres	+
H2OUSEDW	Water used for washing dishes	Number of buckets of 20 litres	-
H2OUSEDT	Water used for toilets	Number of buckets of 20 litres	-
PRICEH2O	Price for water	Tanzania shillings	-
SIZELAND	Total land size (ha)	Number of hectares	+
AMOPAIDI	Amount paid for irrigation	Tanzania shillings	+
YIELDIRR	Yield with irrigation	In Kilograms	+
YIELDNON	Yield without irrigation	In Kilograms	-
H2OUSERI	Water use for irrigation	In litres	-

For instance, for gender, males were assigned a 0 value and 1 for females; for marital status, married respondents were denoted by 0 value and 1 for not married with; for occupation, employed respondents were given a 0 value and 1 for those not employ; for household composition, adults were assigned a 0 value and 1 for children; for household water sources, tap water was given a 0 value where as other water sources were denoted by 1 value (Table 2).

The negative sign of the direction for water use fee was hypothesized that increase of water use fee was expected to reduce people's WTP. This is supported by economic theories that price influences the demand for good. Thus as the amount water use fee goes up it means demand for water decreases, and then the WTP for watershed conservation decreases. Education level was expected to increase WTP because many years of education improves awareness and civilization for an individual to contribute for conservation initiatives. Total annual income and income from irrigation were expected to influence positively WTP. Rise of income signifies the increase ability for an individual's WTP. Therefore, the full empirical model was specified as:

$$
\begin{aligned}
WTP = {} & \beta_1(H2OUSEFE) + \beta_2(GENDER) + \beta_3(MARITALS) + \beta_4(EDUCAT) + \beta_5(OCCUPAT) \\
& + \beta_6(HHSIZE) + \beta_7(PROPTHHE) + \beta_8(TOTANNU + \beta_9(IRRIINCO) + \beta_{10}(NNHSOUC) + \\
& \beta_{11}(DISTASOU) + \beta_{12}(AMOH2OSO) + \beta_{13}(AMOH2OCO) + \beta_{14}(AMOH2ODR) + \beta_{15}(H2OUSWAS + \\
& \beta_{16}(H2OUSEDW) + \beta_{17}(H2OUSEDT) + \beta_{18}(PRICEH2O) + \beta_{19}(SIZELAND) + \beta_{20}(AMOPAIDI) + \\
& \beta_{21}(YIELDIPP) + \beta_{22}(YIELDNON) + \beta_{23}(H2OUSERI) + \varepsilon \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)
\end{aligned}
$$

Where:

WTP = Willingness to pay for watershed conservation;

H2OUSEFE = Water use fee; GENDER = Gender; MARITALS = Marital status;

EDUCAT = Education level; OCCUPAT = Occupation; = HHSIZE = Household size;

PROPTHHE = Number household members engaged in income generating activities;

TOTANNUA = Total annual income; IRRIINCO = Irrigation income; NHHSOURC = Household water sources = DISTASOU = Distance from the water sources; AMOH2OSO = Amount of water from other sources; AMOH2OCO = Water used for cooking; AMOH2ODR = Water used for drinking; H2OUSWAS = Water used for washing clothes; H2OUSEDW = Water used for washing dishes; H2OUSEDT = Water used for toilets; PRICEH2O = Price for water = SIZELAND = Total land size; AMOPAIDI = Amount paid for irrigation;YIELDIRR = Yield with irrigation; YIELDNON = Yield without irrigation = and H2OUSERI = Water use for irrigation.

2.5.4 Strengths of CVM approach

CVM approach is preferred over other valuation methods due to the following arguments:

- CVM is enormously flexible (i.e. it can be used to estimate the economic value of various ES
- It can be used to recover existence (nonusage) values that can't be assessed through market approaches
- CVM method can produce estimates that are sufficiently reliable to be the starting point for administrative and judicial determinations
- CVM studies allows elicitation of beliefs and opinions that underlie preferences that determine values
- CVM has great flexibility that can allow valuation of a wider variety of nonmarket ES than all the indirect valuation techniques
- CVM is the most commonly used approach used to estimate the non-use value of the environment (including existence, bequest, and option value) through directly surveying respondents on their WTP
- CVM can be utilized in both, policy analysis and academic research.

2.5.5 Limitations of CVM approach

Despite the strengths and usefulness of CVM methods in capturing non-marketed ES, there are a number of weaknesses (Carsonet al., 2001). They include:

- The method is based on people's opinions as opposed to observing their actual behavior
- The validity and accuracy of a CVM study is enhanced if people are familiar with the ES to be valued
- It is complicated to design a CVM scenario appropriately on ecological studies especially to accurately elicit the values for the ES without information and interviewer bias (es)
- The CVM can provide useful and reliable information, but it needs to be applied carefully

3.0 RESULTS

3.1 Socio-economic characteristics of respondents on WTP

As expected prior to this study, we found that majority of the respondents (79%) were willing to contribute for watershed conservation (Table 3). As indicated in the table below, majority of them preferred to pay between 6 (33.6%) and 12 (37.8%) months. These preferred time scale for payment links well with harvesting seasons where smallholder farmers in PRB have two farming and harvesting seasons.

Table 3: Responses on perceptions on WTP for watershed conservation

Variable		Counts	Percentages
Contribution for conservation		**(n=360)**	
	Willing	286	79
	Not willing	74	21
		n=259	
Time frame for payment	12 months	136	37.8
	6 months	121	33.6
	1 month	2	0.6
		n=285	
Certainty about WTP	1-5 Very/certain	258	90.5
	6-10 Very/uncertain	27	9.5
		n=277	
Reasons for WTP	Dependency on water for household and irrigation uses	134	48.4
	Sustainable water flow for future generations	130	46.9
	Watershed conservation for flow of ES	8	2.8
	Conservation to enhance ecological processes	5	1.8
		n=345	
WTP for marginal conservation effects	Willingness to wait	269	78
	Unwillingness to wait	76	22

Furthermore, we found that the majority of smallholder farmers (90.5%) were confident of their decision and ability to pay WTP. Reasons for their certainty for WTP include: their dependency on water for household and irrigation uses; sustainable water flow for future generations; watershed conservation for flow of ES; and watershed conservation to enhance ecological integrity. With regards to the marginal effects of conservation programmes, majority of respondents (78%) were willing to wait for a unit increase of water flow as an output of their payment for watershed conservation (Table 3).

3.2 Socio-economic drivers and marginal effects on water users' WTP

Table 4 reveals drivers and their corresponding marginal probabilities for farmer's WTP where six variables indicated statistical significance on WTP at 1% ($p < 0.001$)

probability level. They includes: marital status (MARITALS), education level (EDUCAT), household size (HHSIZE), total annual income (TOTANNUA), distance from the water sources (DISTASOU) and total land size (SIZELAND).

Table 4: Marginal probabilities for small holder farmer's WTP for watershed services

Variable	**Marginal probability** $(\partial y / \partial x)$	**Standard error**	**z**	**P (|z |>z)**
Water use fee	-0.325e-06*	0.190e-06	-1.714	0.0866
Gender(1=female)	-0.166e-01	0.496e-01	-0.335	0.7380
Marital status (1=married)	0.135e-03***	0.038e-03	3.501	0.0012
Education level	-0.731e-02***	0.336e-01	-2.178	0.0263
Occupation	0.729e-01*	0.408e-01	1.787	0.0739
Household size	0.151e-01***	0.074e-01	2.036	0.0282
Number of hh members engaged in income generating activities	-0.295e-03*	0.161e-03	-1.831	0.0672
Total annual income	-0.923e-07***	0.334e-07	-2.762	0.0058
Irrigation income	0.450e-07**	0.234e-07	1.925	0.0505
Household water sources	-0.128e-03*	0.081e-03	-1.572	0.0946
Distance from the water sources	0.171e-03***	0.760e-04	2.247	0.0247
Amount of water from other sources	-0.112e-03	0.836e-04	-1.335	0.1819
Water used for cooking	0.207e-02	0.533e-02	0.388	0.6978
Water used for drinking	0.114e-01	0.294e-01	0.386	0.6997
Water used for washing clothes	0.205e-01	0.153e-01	1.342	0.1795
Water used for washing dishes	-0.357e-01	0.299e-01	-1.193	0.2330
Water used for toilets	0.144e-03	0.146e-03	0.988	0.3234
Price for water	-0.257e-05	0.932e-05	-0.276	0.7826
Total land size (ha)	-0.622e-04 ***	0.225e-03	2.761	0.0059
Amount paid for irrigation	0.180e-06 *	0.107e-06	1.684	0.0847
Yield with irrigation	0.102e-04*	0.581e-05	1.760	0.0685
Yield without irrigation	-0.152e-05	0.919e-05	-0.166	0.8683
Water use for irrigation	-0.218e-03*	0.143e-03	-1.522	0.0984

Number of observations (N) = 360
Log Likelihood= -219.63367
LRChi2=3.41964
Prob-Chi2= 0.8238571e-04

Notes: ***, **, * indicates significance at 1%, 5%, and 10% levels of significance respectively

As expected in the hypothetical direction of the respondent's opinion (Table 2), marital status (MARITALS), household size (HHSIZE), and distance from the water sources (DISTASOU) influenced positively respondent's WTP for watershed conservation. The positive sign for marital status (MARITALS) implies that the WTP for watershed conservation increseas as one get married. It is hypothesized that married couples are likely to have higher WTP because of the increase in water use in their household and also the expectation to have other members in the family (i.e. children). Similarly, the positive sign for household size (HHSIZE) means that as the number of household members increases, the probability of WTP for that household increases as well. Moreover, the positive sign for the distance from the water sources (DISTASOU) implies that, as the distance from the water sources increase, it increases the probability of people's WTP for the construction of nearby water sources. The positive direction of these variables concurs with the theoretical expectation hypothesized in Table 2.

On the other hand, the education level (EDUCAT) and total annual income (TOTANNUA) had negative signs thereby reducing respondent's probability WTP for watershed conservation. These results are contrary to the hypothesized sign in Table 2 and the expectation of the theoretical model. The negative sign of the education level (EDUCAT) implies that education level reduces respondent's probability for WTP for watershed conservation. Also the negative sign of the total annual income (TOTANNUA) implies that total annual income (TOTANNUA) reduces respondent's probability for WTP for watershed conservation. These findings are contrary to the hypothesized opinion direction in Table 2, the theoretical model is contrary to the study by Amponin et al. (2007) and Farolfi et al. (2007), who found that income increase influenced people's WTP for watershed protection for domestic water supply in (Tuguegarao City) Philippines and Swaziland respectively.

3.3 Determinants of the amount for WTP for the watershed conservation

Table 5 reveals factors that determine the amount that smallholder farmers are WTP. Factors that determined significantly this amount includes: education level, occupation, household size, irrigation income, water used for washing dishes, total land size (ha), amount paid for irrigation and crop yield with irrigation.

Table 5: Maximum amount small holder farmer's WTP

Variable	Coefficient	Standard error	b/St.Er	P[|Z|>z]
Willingness to pay	22261.83038***	10520.5486	2.116	0.0183
WTP certainty	3.670318282**	1.9170822	1.915	0.0556
Water use fee	-3.05E-04	5.16E-03	-0.059	0.9528
Gender (1=female)	-6527.65341***	1465.0761	-4.456	0
Marital status	17.379702***	4.9702078	3.497	0.0005
Education level	4511.653016***	1594.595	2.829	0.0047
Occupation	172.3448633***	81.62695	2.111	0.0094
Household size	-121.119996*	67.44146	-1.795	0.0693
Number hh members engaged in income generating activities	1.442747865***	0.6407413	2.252	0.0217
Total annual income	1.36E-04***	6.56E-05	2.079	0.0098
Irrigation income	1.93E-04	6.66E-04	0.29	0.7719
Household water sources	-9.11648574**	4.7719495	-1.91	0.0561
Distance from the water sources	8.84E-02	2.1981903	0.04	0.9679
Amount of water from other sources	-6.32423857***	2.6047383	-2.428	0.0152
Water used for cooking	1.93E-04	6.66E-04	0.29	0.7719
Water used for drinking	419.3810105	791.71684	0.53	0.5963
Water used for washing clothes	870.0716956*	480.05976	1.812	0.0699
Water used for washing dishes	-12.2853168	10.825056	-1.135	0.2564
Water used for toilets	5.477136869	5.7441356	0.954	0.3403
Price for water	-1.01E-02	2.44E-01	-0.041	0.967
Total land size (ha)	1.557890715*	0.95378501	1.633	0.0743
Amount paid for irrigation	-3.78E-02***	1.48E-02	-2.557	0.0056
Yield with irrigation	0.617585859	2.71E-01	2.275	0.0187
Yield without irrigation	-9.54E-01*	6.17E-01	-1.545	0.1223
Water use for irrigation	-2.89293972	5.527303	-0.523	0.6007

Number of observations (N)=360
Log-L= -1290.48
Threshold values for the Model: Lower=.000 Upper=+∞
LM test [df] for tobit= 94.576
ANOVA based fit measure = 13.636318
DECOMP based fit measure = 0.473343

Note: ***, **, * indicates significance at 1%, 5%, and 10% levels of significance respectively

The positive sign for education level, water used for washing dishes, total land size and crop yield with irrigation implies that these factors influenced positively on the probability of the amounts that respondents are WTP for watershed conservation. On the other hand negative sign for occupation, household size, irrigation income and amount paid for irrigation implies that influence negatively on the probability of the maximum amount that respondents are WTP for watershed conservation.

However, overall as indicated in Table 5, the WTP had positive influence and statistically indicated a significant influence at 1% ($p < 0.000$) probability level. In addition, the goodness fit of the linear model explained 0.62 (i.e. 62%) variation of the variables used in the computation. The rest, i.e. 38% may have been affected by external factors (i.e. some errors) during data acquisition, handling, processing and analysis.

4.0 DISCUSSION

4.1 Socio-economic characteristics of respondents on WTP

Overall, smallholder farmers have high level awareness on watershed conservation along the PRB. This has been testified by their willingness to contribute (76%) for watershed conservation (Table 3). Respondent's willingness to contribute for watershed conservation may be due to the high demand of watershed services (water) they need from therein. Due to climate change and climate variation, smallholder farmers depend much on irrigated agriculture, and this justifies their awareness and willingness to contribute for watershed conservation.

Smallholder farmers along the PRB seem to be embracing the concept of sustainable development. The fact that they are WTP for watershed conservation in order to enhance sustainable water flow and for increased flow of ES and ecological integrity, is in itself a testimony of their awareness on watershed conservation (Calderon et al., 2005). Normally conservation schemes take a considerable long time in order to yield lasting results. Respondents seem also to know this that's why they are willing to wait for the output of this conservation initiative.

4.2 Socio-economic drivers influencing water user's WTP

The level and spirit of respondents to be WTP for watershed conservation (Table 3 and 5) is an encouraging indicator for the sustainability of watershed ecosystem. Majority of smallholder farmers in the PRB are willing to contribute for financing watershed conservation in order to ensure the sustainability of water flow. However, the direction of the hypothesized model in Table 2 differs with the influence of some of the variables displayed in Table 4.

Normally, education determines the level of awareness and willingness to participate and contribute for conservation initiatives. It is perceived that an educated person is civilized and can make wise decisions driven by accumulated knowledge through education (Mohamed et al., 2012). On the contrary, findings of this study indicated that education had negative influence on respondent's WTP (Table 4). The negative sign means that the more an individual is educated the less that person is WTP for watershed conservation. In developing countries like Tanzania, majority of people with better education reside in urban areas. It is likely that they have more / alternative income sources which enable them to access water from other sources (e.g. bottled, tap water and from private boreholes). For this reason, they may have little interest on watershed conservation. This observation differs completely with the theoretical assumption on education (Table 2) and the observation by Samdin et al. (2010), who asserted that *"in normality, decision making made by educated communities are more fundamental due to knowledge advantages they owned. Therefore, their decisions towards WTP are influenced by their developed knowledge rather than emotion driven decisions*".

As indicated in Table 2, the variable income indicated positive and statistical influence on WTP. Normally, income level is a crucial determinant for one's ability to contribute or participate in conservation activities. The positive sign of income level implies that as the income raises the household's WTP for watershed conservation. In other words the household's WTP increases with increase in income level (Day and Mourato, 1998;

Fujita et al., 2005; Park and Turker, 2006; Ghorbani and Hamraz, 2009; Sathya and Sekar, 2012). Generally, communities with enough income can be able to finance human basic needs (i.e. food, clothing and shelter) and spare surplus for investing in conservation activities. This observation in Table 2 concur with the findings by Farolfi et al. (2007), who found that income level had a positive and statistically significant impact on WTP for domestic water supply in Swaziland.

The positive sign and statistical significance for the distance from the water source indicated in Table 4 confirms the assumption put forward earlier in Table 2. Usually it is expected that the longer the distance a household is located from water sources, the higher the WTP would be for that particular household for financing the establishment of a nearby water sources (Marrett, 2002). People who walk longer distances looking for water are likely to be WTP for construction of a new water source that would reduce their walking distances. Therefore, local communities are WTP for watershed conservation in the sense that their financial contributions are likely to restore degraded watersheds, enhance water flow along rivers and finally enable installation of more standing tap water.

4.3 Factors influencing the amount smallholder farmers' WTP

As indicated in Table 5, education level, water used for washing dishes, total land size and crop yield with irrigation influence positively the maximum amount that smallholder farmer's are WTP. The positive sign for education level implies that the maximum amount that a respondent is WTP for watershed conservation is determined by the number of years spend in education. In other words, the WTP for watershed conservation increases with the increase level of education. This implies that many years in education create awareness on environmental conservation.

The positive sign for the total land size determines the amount for maximum WTP. Large land size increases the possibility of getting many bags of crop harvest contrary to the one with small land size (given that factor such as mechanization and capital investments are held constant). Therefore, the positive sign for this variable means that as the size of land for agriculture increases, the maximum amount for WTP increases as well because smallholder farmers are motivation by the quantity of crop harvest. This interpretation applies also to other factors with positive sign.

On the other hand occupation, household size, irrigation income, and amount paid (fee) for irrigation influenced negatively the maximum amount for WTP. The negative sign for occupation implies that the WTP for watershed conservation for a particular household is reduced with occupation type. Some occupations have higher payments/returns with surplus income for contributing to conservation activities.

Therefore, occupation type determines respondent's WTP and the amount to pay. In the PRB the income level is normally determined by type of employment or occupation. A person who is employed in a lowly paid position is likely to be less WTP for watershed conservation because the low paid income is likely to be allocated to expenditures on subsistence needs. Therefore, the negative sign for occupation implies that poor paid jobs are likely to discourage an individual to contribute higher amount for conservation as opposed to employee who are holding positions with higher salaries.

The same case applies to the household size, irrigation income and amount paid for irrigation. The negative sign for household size implies that increase of household members reduces the WTP of that household for watershed conservation. Therefore, large household sizes increases expenditure on water thereby, reducing its maximum amount for WTP for watershed conservation. The same case applies to the amount paid for irrigation. The negative sign for irrigation income means that increase of water use fees for irrigation water, reduces the maximum amount that smallholder farmer' are WTP for watershed conservation. In other words, the higher the cost of irrigation water, the less is the amount that irrigators are WTP for watershed conservation.

5.0 CONCLUSIONS

The study reveals local community awareness and their enthusiasm for contributing their income for financing watershed conservation for sustainable water flow. Furthermore, the study reveals the potential for CVM as a policy tool for soliciting conservation funds from water users. It testifies how water use fees could be a potential and reliable revenue source for financing nature conservation programmes instead of relying on donor funding. Apart from uncovering the possibilities of accumulating funds from local sources for conservation, this study reveals the potential for generating funds from downstream water users to support upstream communities who would be willing to implement watershed conservation practices.

Although CVM studies are normally hypothetical in nature, i.e. they depend on people's opinions (Carsonet al. 2001), they are quite useful and have been extensively used in different parts of the world. Specific to this study, CVM results shows how socio-economic factors can influence people's WTP and the amount that they are WTP for watershed conservation. Results from this study would be a basis for resource valuation in other areas in Tanzania facing similar problems like in the PRB.

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CHAPTER 10

GENERAL DISCUSSION AND CONCLUSIONS

Delivery of water for different uses is a crucial and unique ES from watersheds. Apart from supplying water, ecosystems within a watershed provide a large number of ES associated with human benefits and community wellbeing. Despite being instrumental in providing water and other ES, watersheds are under pressure from human populations in PRB in search for livelihood opportunities. This thesis is an output of a study undertaken to investigate the potential for payment for watershed services (PWS) and climate change adaptation along the Pangani River Basin (PRB), Tanzania.

Pangani River Basin (PRB) is the largest river basin along Pangani Basin (PB). The PRB is located in the northern part of Tanzania, the busy tourist circuit in this the country. Although some parts of this basin are water stressed (e.g. Same and Mwanga Districts), the favourable climate condition, fertile soils, availability of National Parks (e.g. Kilimanjaro Mountain and Mkomazi National Parks), and Kilimanjaro Mountain (the highest peak in the African continent), attract human population influx in the area. However, influx of human population (Mbonile, 2005; Lalika et al., 2015a) in the PRB in search for ES has had detrimental effects on Kilimanjaro and Meru mountains, the two water towers for many rivers along the PRB. Increase of human population within the basin called for more land for agriculture (food production) along the foot hills of the two mountains, more water to cater for the rapid increasing population, more cooking energy (wood fuels) at the expense of watershed ecosystems. Among others, these resulted in competition for natural resource and water use conflicts among stakeholders within the river basin. Increase of these anthropogenic activities coupled with the impacts of climate change and variability (Lalika et al., 2015b) are threatening the future of the ice caps at the top of Mount Kilimanjaro.

Overall, ES delivered by PRB range from direct benefits supporting people's livelihoods to ecological ones that regulate the flow of the former category. Few years back, smallholder's farmers along the PRB were used to derive their livelihoods through rainfed agriculture. However, in recent years, the PRB has become a water stressed area and majority of these farmers are nowadays relying on irrigated agriculture as adaptation option to water shortages and CC and climate variability. Some of the crops grown includes drought resistant crop varieties such as *Saro, IR 54 and IR 64* and short term maize varieties such as SEED CO *(i.e. SC 403)* and PANNAR *(i.e. PAN 4M-19, PAN 6* and *PAN 63).*

Furthermore, the delivery of water related ecosystem services from watersheds along the PRB and the country at large is faced with a number of challenges. In chapter 1 I analyzed the essence of freshwater scarcity, watershed degradation, and water resources distribution in the country. For management purposes, water resources in Tanzania are divided into nine river basins, PRB being one of them. Despite the demarcation of these river basins for effective management purposes (URT, 2012; Msuya, 2010) water resource management challenges still exists. These challenges are due to conventional management approaches, lack of integrated management methods, sectoral management policies, and mismatch between administration levels (i.e. country, basin, local levels) and conflicting management objectives (utilization vs conservation).

Watershed and river basin conservation guidelines and regulatory instruments have provisions for sustainability, conflict resolution, good governance and IWRM indicators including accountability, participation, effectiveness and efficiency, holistic approach, and inter-sectoral and cross-sectoral coordination and integration (Mazvimavi et al., 2008; Jewitt, 2002; UNEP, 2012a; b; Evers and Nyberg, 2013; Cashman et al., 2014). Despite these provisions, the current study has revealed some institutional lapses such as lack of proper enforcement and poor institutional performance in watershed management of some of these provisions (Mbeyale, 2009; Msuya, 2010; Notter, 2010; Ngana et al., 2010). These institutional issues have caused a number of problems along the PRB including conflicts over water uses and reduction of the capacity of watersheds to offer diferent ES, notably those ecosystem services related to water.

Although the current study didn't document biodiversity related ES services, the review of literature in chapter 2 highlighted typologies of ES case studies for PWS implementation across the globe. This updated literature according to the Economics of Ecosystem and Biodiversity (TEEB) include prorovisioning services, regulating services, habitat services and cultural and amenity services (TEEB, 2008; 2009; De Groot et al., 2010). These ES are also found along the PRB, although this doctoral study didn't zero down on habitat services (such as hosting animal and plant species). The new classification typlogy accommodate aspects of economics of ecosystem change which was left out in the former categories of ES by the Millenium Ecosystem Assessment (MEA, 2005). Under this new typology of ES, there are four key variables which guided the updated classification. They include ecology, economics, biodiversity and ecosystem service valuation (TEEB, 2008; 2009; De Groot et al., 2002; 2010; Ring et al., 2010).

Results from the reviewed PWS schemes indicated that the majority of these inititives (Table 2 in chapter 1) aimed at watershed conservation for water quality improvement. They include the Equitable Payments for Watershed Services: Payment for Drinking Water in Tanzania (Lopa et al., 2011); the Vittel (Nestlé Waters) Payment for Water Quality in France (Johnson et al., 2002); The Quito Water Fund (FONAG) in Equador (Echavaria, 2004); Water Producers Program in Espirito Santo State in Brazil (Perrot-Maître and Davis, 2001); FONAFIFO Program: Program for fund mobilization for forest catchment protection, in Costa Rica (Pagiola, 2004; Zbinden and Lee, 2004); Catskills project: Payment for Drinking Water Management Programme, in USA (Perrot-Maître and Davis, 2001); Los negros programme in Bolivia (Asquith et al., 2008), and

Pimampiro payments for watershed services scheme (Echavarria, 2004; Pagiola, 2004; Wunder and Albán, 2008).

Among the reviewed PES schemes, concrete examples of implementation are found mainly in some countries in South America (e.g. Bolivia, Costa Rica, Equador, Guatemala, etc.) and parts of South-East Asia (Pattanayak et al., 2010) differing in the magnitude of implementation and results. On the African continent majority of PES initiatives are in the pilot stage relying heavily on donor funding (e.g. World Bank) (Ferraro, 2009) and NGOs (e.g. Care International and WWF) (Lopa et al., 20111). For instance the PWS pilot project in Uluguru Mountains in Tanzania is not self-sustaining financially and technically, and worse still it lacks adequate monitoring mechanisms to ensure compliance. Furthermore, the review has indicated that sustainability of this pilot initiative is questionable as it lack conditionality and monitoring mechanisms to ensure the ES is delivered are operationally similar to ICDPs whose initial popularity ended when expensive pilot projects were shown to deliver few conservation or livelihoods outcomes (Ferraro and Kiss, 2002; McShane and Wells, 2004; Burgess et al., 2010, Clements et al., 2010).

Despite the positive outcomes of PWS achieved so far in different countries, there are a number of challenges precluding their smooth progress. They include reliance on donor funding, lack of exclusive rights for land ownership, dependency on watersheds for subsistence, and income poverty among the local communities (Porras et al., 2008). Moreover, majority of smallholder farmers were not sure of the sustainability of these initiatives without donor funding. Despite these problems, PWS schemes serves as key conservation initiatives for scaling up in other areas facing similar problems.

PWS could also be applied in Uper Kikuletwa Sub-Catchment where there is potential for crop production through irrigation. Paddy and maize irrigation is carried out for both food and cash. However, water shortages along both sides of Kikuletwa River caused water use conflicts and reduction of crop harvest. The comparative analysis of crop yield (reported in chapter 3) between and across villages indicated no significant different implying that despite their locations and agro-ecological zones, the villages share similar characteristics. Furthermore, results from on-way Analysis of Variance (ANOVA) indicated that yields between the villages located in Eastern and Western Kikuletwa had no significant variations. Based on these findings, any agriculture intervention (e.g. mechanization or use modern agriculture practices) could be suitable in both locations. Similarly, the same conservation approach for watershed and river basin conservation could be instituted in both sides of the Kikuletwa River. For instance, government funding and provision of subsides could also be useful to smallholders of both locations.

For quite sometime, government funding in conservation activities has not been sufficient. This is clearly reflected in chapter 4 where commitment of government institutions in financing (budget allocation) watershed conservation is quite low as compared to projects. In some instances, this doctoral research has indicated that the level of commitment for conservation activities is low in the sense that the actual money allocated for conservation is little when compared to the approved budget. Government priorities seem to be on social services such as health, education, water supply, social infrastructures, and community development, to name a few.

Although conservation activities are spearheaded by various government organs such as the Ministry of Natural Resopurces and Tourism (Forestry and Wildlife Authorities), the Ministry of Water and Irrigation, The Vice President's Officice and Prime Minister's Office (Division of Environment); and some government parastatals such as the National Environment Management Council (NEMC) and Tanzania National Parks (TANAPA); government commitment and financial contributions for conservation initiatives has been quite discouraging. Majority of conservation activities have been left out to the donor community / development partners. For instance, conservation activities including PWS pilot projects in Uluguru Mountains are carried out under the financial support from donor international conservation organizations such as Wild Wide Fund for Nature Conservation (WWF) and Care International through the World Bank funds (Lopa et al., 2011). This reliance on donor funding jeopardizes the sustainability of PWS pilot scheme and other conservation activities along Uluguru Mountains in Tanzania. Therefore, government funding and involvement in nature conservation could ensure the sustainability of watersheds and flow of ES, notably water.

Investments on water ES related firms is among the lucrative business along the PRB. Acquisitions of areas with ample water and fertile land for flower, food and energy production is increasing rapidly in the study area. Majority of these investments are private firms (e.g. Diligent Tanzania Limited, Dekker Bruins Limited, Maua Tanzania, Tanzania flowers, etc) that use this ES for watering flowers. As indicated in chapter 5, these companies abstract water in large quantities in such a way it causes water shortages to people who live far downstream. Water (grabbing) abstraction affects negatively crop production along the PRB. The fact that the mean yields before water grabbing were statistically ($P < 0.001$) higher than yields after water grabbing is a testimony of these FDIs. Although FDIS are useful in developing countries particularly those handicapped with financial resources and technology, findings from this doctoral research testify that they have negative impacts to the local people especially those whose mainstay depend solely on irrigatd agriculute. Furthermore, water grabbing along the PRB not only affects irrigated agriculture, but also it reduces significantly the quantity and quality of water flow for enhancing ecological integrity downstream. However, climate change (CC) and variability are driver for reduced water flow apart from water (abstraction) grabbing.

Climate change (CC) and variability is among the pressing environmental problems of our time (Lalika et al., 2015). Their effects are felt along PRB as wel where signs of reduced rainfall and incresead temperature are have been evedent for quite sometime.

Reduced water flows along rivers within the PRB are partially attributed to these drivers. Chapter 6 and 7 revealed the effects of CC and variability ES (water), watersheds dynamics and its link with changes of watershed services and problems faced by communities living in the PRB. The melting of Ice Cape at the summit of Kimanjaro Mountain is attributed to CC and variability.

On the other hand on the influence of CC on water flow indicated that both rainfall and temperature had positive and statistical significant influence ($P < 0.05$) on water flow. The statistical analysis implies that one unit of rainfall influenced the increase of water flow at the magnitude of 0.466 m^3s^{-1}. Generally, the influence is also due to climate variability along the PRB. This variability affects rainfall distribution, rainfed agriculture and the quantity of crop harvested. In some cases, watershed degradation causes the capacity of watershed ecosystem to offer ES (water) to be low. This degradation may be due to institutional failures as explained in chapter 8. Watershed problems are attributed to ineffective, uncoordinated water governing institutional structures, lack of transparency and accountability and untrustworthy financial management. It is also crucial to integrate these institutional issues with economics by valuing ES services through stated preference approaches.

In order to fulfil this, we determined peoples' willingness to pay (WTP) for watershed services using contingent valuation method (CVM) in chapter 9. Results from socio-economic data indicated that majority of smallholder farmers were WTP for watershed conservation. Their WTP is based on the assumption that their payment would increase a unit increase of water flow. Although CVM studies seem to be theoretical in nature, they have been used extensively around the World for setting PWS schemes and determining the amount that communities are WTP (Whittington, 2002; Calderon et al., 2005; Amponin et al., 2007; Mohamed et al., 2012; Calderon et al., 2013).

RECOMMENDATIONS

Based on the research findings, discussions and conclusions of this doctoral research, the following are the recommendations:

FOR POLICY MAKERS

- Policy makers should create enabling environment for integrated water resources management approach along the PRB:

- It is crucial to for the government and conservation organisations to establish a self-revolving fund to care for a sustainable conservation fund for financing PES scheme / activities.

- All practioners /technical staff from different government conservation departments should come together and implement conservation activities along the PRB as a single unit in an integrated / holistic approach.

- The government has to design a strategy to make sure that some funds raised from the tourist sector is factored in waterhed conservation.

- The PBWO and Regional and District water authorities should make sure that all obsolete water pipes are replaced so as to curb water leakages. In addition, transparency in the utilization of the collected revenues from water users should be ensured.

- With regards to water grabbing, the responsible authorities should enforce policies, regulation, laws and by-laws in order to off-set the drivers and negative effects of land and water grabbing and the signed contracts. This would bring about a win-win situation between villagers and foreign investors.

FOR FARMERS

- To deal with climate change and variability, and dependency on rainfed agriculture, smallholder farmers should adapt irrigated agriculture by cultivating short term and drought resistant crops.

- To strengthen the involvement in water management decisions and water utilization, smallholder farmers should be involved effectively in the formation water user associations. This will enhance watershed conservation, sustainable water flow and efficient water distribution and utilization of water user fees.

FOR ACADEMICIANS /AREAS FOR FURTHER RESEARCH

- In-depth studies should be undertaken in order to validate the positive outcomes of PWS initiatives. Also more researches are needed so as to document the the amount paid to improve the income status and the livelihoods of upstream communities.

- More imperical research should be carried out so as to establish suitable ways for effective PES implementation. This is crucial in order to eliminate uncertainties for their sustainability especially after phasing out the donor funding.

- A cost benefit analysis study should be undertaken (to campare PES vs other land uses) before the establishment of any PES scheme. Cost benefit analysis studies are useful for ensuring the opportunity costs for changes former land use to PWS initiatives.

- Furthermore, more research on ground water exploration, rainwater harvesting, and construction of water reservoirs has to be done so as to eliminate the dependency of surface water and rainfed agriculture.

- More research on frameworks and strategic plans for integrating sectoral policies (e.g. forestry, water, land, wildlife, etc.) should be ndertaken in order to enhance watershed conservation, adaptation to CC and water shortages.

- More research should be done so as to establish, validate and verify the link between conservation watershed and water flow.

- A research is certainly needed on the 'willingness to provide' and the negotiation and elaboration of a viable institutional set-up in which conditional PES payments can be integrated.

- Before the estblishement of any PWS scheme along the PRB, a research to establishe answers for the following questions should be carried out: how to take care of trade-offs between conservation and community welfare? How to address the problem of "free riders"? How to determine buyers and sellers of watershed services? and how to convince local communities that PWS schemes are not another form of " land grabbing in disguise".

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