Exploring the potential for watershed conservation for enhancing water quantity and quality: Upstream-downstream linkages

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Abstract

Watersheds are confronted with environmental degradation due to lack of sustainable mechanism for rewarding upstream communities for their conservation endeavors. Consequently the degradation leads to reduced water flow and poor water quality. Payments for watershed services (PWS) schemes are being developed worldwide as responses to these environmental challenges. This study was carried out to explore the potential for payment for watershed services along Pangani River Basin, Tanzania. Structured questionnaires were the main tools for data collection. To collect data for the willing to pay (WTP) for watershed conservation we used payment cards. We applied SPSS software version 20.0 to analyse data collected through questionnaires. Thereafter we applied probit model to estimate people's willingness to pay for watershed conservation. Findings indicated that direct cash, payment in-kind and payment by offering labour are the key payment methods. Results from probit model indicated that certainty for WTP, income size, participation in irrigation, yield with and without irrigation, and membership in irrigation association had positive and significant influence ($p < 0.001$) on the maximum amount that people are WTP for watershed conservation. PWS schemes are essential for motivating upstream communities to conserve watersheds for increased environmental flow. The Pangani Basin Water Board should assist the formulation of payment schemes to ensure effective collection of fees from downstream water users.

Keywords: Ecosystem services, environmental flow, willingness to pay, smallholder irrigators, water

[1] Introduction

Freshwater is a basic ecosystem service (ES) which sustains life and provides various socio-economic and ecological needs (Costanza et al., 1997; De Groot et al., 2002; MEA, 2005). Freshwater is arguably the most precious and finite ES from watersheds. It is an integral part of the environment whose quantity and quality determine how it can be used (Brauman et al., 2007; De Groot et al., 2010). Despite the importance of water and its implications to the ecological integrity, watersheds which provide this vital ES are currently deteriorating due to various drivers including anthropogenic activities and climate change and variability (Lalika et al., 2015a).

Payments for ecosystem services (PES) schemes are being developed largely as a response to the challenges and constraints that are facing regulatory mechanisms for the management of watersheds and ES they offer (Costanza et al., 1997; De Groot et al., 2002; Kremen, 2005). Payments for watershed services (PWS) are thus sub-sets of PES and specifically seeks to establish causal relationships between water users who are normally found at the downstream of rivers and upstream land managers who are basically regarded as the poor and guardian of watersheds (Landell-Mills and Porras, 2002; Pagiola, 2008; Turpie et al., 2007). Globally, there are a number of PWS schemes at various stages of maturity. However, their contribution to environmental flow (i.e. quantity, quality and timing of water flow) and benefits to upstream poor communities remain relatively unclear.

In Tanzania, for instance, there are PWS pilot projects in place (Lalika et al., 2015b). In East Usambara Mountains there is a PWS project aimed at conserving Sigi / Zigi River, the main source of domestic water supply for Tanga City (Mwanyoka, 2005). In Uluguru Mountains in Morogoro region there is a pioneering

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PWS pilot project known as "Equitable Payment for Watershed Services" implemented by CARE International in collaboration with World Wildlife Fund - Tanzania Country Office (WWF-TCO) (Lopa et al., 2011) aimed at supplying water for domestic use in Dar es Salaam City. Similarly, there is another PWS pilot project around Mindu catchment (water reservoir) aimed at providing water for domestic water supply in Morogoro Municipality. Despite the potential for PWS (Pagiola et al., 2002; Schösler and Riddington, 2006), information on how can PWS projects be designed in such a way that they benefit upstream communities along the PRB is lacking. For instance, it is not known how long benefit term for local communities, watershed conservation, and sustainable financing mechanisms will be in place after the initial establishment of these schemes. This study was carried out to bridge this information vacuum. The general objective of the study was to explore the potential for alternative approach to payments for watershed services in Pangani River Basin, Tanzania.

[2] OBJECTIVES

2.1 General objective

To explore the potential for payment for watershed services (PWS) for enhancing environmental flow along the Pangani River Basin (PRB), Tanzania.

2.2 Specific objectives

i) To evaluate the existing payment methods for water uses in PRB;
ii) To assess types of water uses and their effects on water quantity and quality along the PRB; and
iii) To examine factors affecting peoples' willingness to pay (WTP) for watershed conservation.

[3] MATERIALS AND METHODS

3.1 Location of the study area

This study was carried out in Oria, Mandaka Mnono and Mijongweni villages in Kilimanjaro region and Makiba, Kwaugoro and Manyata villages in Arusha region along the PRB (Figure 1-Appendix A).

Figure 1: Location of the study area in Arusha and Kilimanjaro Regions, Tanzania

The PRB covers a total area of 58,800 km^2 (about 5% of which is in the Republic of Kenya) and includes the Msangazi, Pangani, Umba, Zigi, Mkulumuzi, and small Coastal River Basins in north-eastern Tanzania. Lakes Challa and Jipe are the part of the Pangani Basin (IUCN, 2007). The hydrology and 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 Mountain. Both tributaries drain into Nyumba ya Mungu Dam (NYD), a reservoir of 140km^2, and the uppermost dam for hydropower generation in the north eastern part of Tanzania (IUCN, 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 (Figure 2-Appendix A-1).

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

3.2 Data collection methods

Structured questionnaires were our main method for data collection. We administered questionnaires in six (6) villages as indicated in Table 1 hereunder:

Table 1: Interviewed respondents in the study villages

Region	Village	Total	Sample size	Sampling Intensity

		households		(%)
	Oria	500	50	10
Kilimanjaro	MandakaMnono	460	46	10
	Mijongweni	470	47	10
	Makiba	660	66	10
Arusha	Kwaugoro	640	64	10
	Manyata	410	41	10
	Total	**3140**	**314**	**10**

We collected other information through formal and informal interviews and focused group discussions.

3.3 Data analysis

We used statistical packages for social sciences (SPSS) software to analyse data collected through structured questionnaires. For the empirical model we used the contingent valuation method (CVM) which is a hypothetical value based method to estimate smallholder farmers' WTP for watershed conservation (Bateman et al., 2002; Green et al., 1995).

We used the model in the following form:

……………..……………..……………………………………………… (1)

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

As revived by Green (2003) the latent variable is assumed to be linearly related with observed variables in the structural model and is presented as:

………..……………………………………………………………………… (2)

Where; is a vector of variables is hypothesized to influence WTP; is a vector of parameters estimated; and is the random error assumed to be normally distributed with zero mean and unit variance (i.e. .

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

.... (3)

As mentioned above, we estimated the probability of an individual to be willing to pay for watershed services by using probit model such that:

.........................…………………………… (4)

We interpreted the parameter estimated 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 'yes'. Therefore, we estimated the marginal effects as follows:

………………...………………..……………………………… (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).

The full empirical model was specified as:

4. RESULTS AND DISCUSSIONS

4.1 Existing payment methods for water uses

Three payment methods for water uses were identified. They include: i) direct cash; ii) in kind payment; and iii) by offering labour (physical participation in canal cleaning) (Figure 3).

Figure 3: Payment methods for water uses in Pangani River Basin, Tanzania.

Payment through hard cash was preferred by majority of respondents because it is convenient, easy, and reliable. However, for the few who were against this method said that it can enhance fraud, armed robbery and other types of money loss. Payment in kind involved donation of cement, stones, gravel, expertise (for masonry), etc. For those few people who participated physically by cleaning irrigation canals were exempted from the other two payment models. Payment through cash, nonetheless, remains to be the convenient and reliable for smallholder irrigators to participate fully in conservation of watershed in PRB.

4.2 Types of water uses and their economic benefits in PRB

Figure 4 reveals the main water uses in the PRB. They include irrigation, domestic uses and livestock. Others include hydroelectricity power generation (HEP) and fishing.

Figure 4: Types of water uses in the PRB, Tanzania

Figure 4 indicates that irrigation, domestic and livestock uses are the main water uses in the PRB. Irrigated agriculture, for instance, is not only a key economic activity in the area, but also a principal source of income and the mainstay of smallholder famers. Given that the PRB is faced with climate change and variability (Lalika et al., 2015a) irrigated agriculture is essential as opposed to rainfed agriculture. In the PRB water is used as a principal input in enhancing food production, irrigated agriculture being a well-established method of improving crop yield (MEA, 2005). Water is a key driver for several ecosystem functions such as crop yields as well as various supporting and regulatory ecosystem services. Along the PRB we identified two scenarios of agriculture i.e. irrigated and rainfed agriculture. Currently, rainfed agriculture is not performing well, therefore smallholder farmers are using irrigated agriculture.

However, the use of industrial fertilizers, pesticide and herbicides results into water pollution which is dangerous for public health. Furthermore, surface runoff and infiltration of industrial fertilizers to the surface water and ground water, consequently causing water pollution in form of eutrophication (Figure 5-Appendix A-2). Water enrichment by of industrial fertilizers (eutrophication) result into poor water quality for domestic uses, impairment and extinction of aquatic plant and animal species.

The call for conservation of watersheds is basically due to the current environmental problems in the PRB which result in water shortages and poor quality

Figure 5: A photo showing water pollution caused by water hyacinth

4.3 Factors influencing WTP for the improved watersheds management

Willingness to pay (WTP) for watershed management is influenced by factors displayed in **Table 2 (Appendix A-3**

Table 2: Determinants of small holder farmer's WTP along the PRB, Tanzania

Overall, **Table 2 (Appendix A-3)** reveals that certainty for WTP, income size, participation in irrigation, yield with and without irrigation, and membership in irrigation association had positive and significant influence ($p < 0.001$ at 1 % probability level) on the maximum amount that people are WTP for watershed conservation.

Table 2: Determinants of small holder farmer's WTP along the PRB, Tanzania

Furthermore, the goodness fit of the model explained 65% (0.65) variation of the variables included in the model. The rest, i.e. 35% may have been affected by external factors such as data collection, coding, cleaning and analysis

5. Conclusions

The study has indicated that direct cash is the main payment mechanism for watershed services and will continue to prevail in the PRB despite the associated shortcomings. However, deliberate efforts should be done so as to enhance sustainable water flow and provision of ecosystem services. Also PWS will be useful if money paid as water user fee will get back to upstream communities.. The flow of watershed services from the PRB will stand a test if a feasible and sustainable PWS is established and properly executed. PWS is also likely to enhance sustainable environmental flow and ensure improved water quality. People's WTP in this study is an indicator of how important is the conservation of watersheds in PRB. Thus, working off the negative externalities for watershed conservation will ensure sustainable flow of ES and community wellbeing. However, it is important to workout the problems of identifying *"free riders"* before the establishment of any PWS initiative in PRB. In addition, the PBWO should assist in the formulation of PWS that will ensure water user fees get back to upstream local communities who are the principal watershed guardians. Furthermore, experts from all sectoral ministries responsible for natural resources management (e.g. Forestry, Water, Wildlife, Beekeeping, Land, Environment, etc.) and other actors (e.g. conservation organisations, local communities, small and large scale water users, etc.), should come together and design an integrated management approach for the conservation of degraded watersheds and equitable water uses among actors in PRB.

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LIST OF APPENDICES

APPENDIX A.

Figure 1-Location of the study area.

Appendix A-1

Figure 2: Location of Pangani Basin and Pangani River Basin

Appendix A-2: Water pollution in form of eutrophication

Figure 5: Water pollution caused by water enrichment (hyacinth)

Appendix A-3: Determinants of small holder farmer's WTP

Table 3: Determinants of small holder farmer's WTP

Variable	Coefficient	Standard error	t-ratio	P[|T|>t]
Willingness to pay certainty	0.8355373903E-04***	0.22592899E-04	3.698	0.0001
Age	0.6331709565E-01*	0.38339350E-01	1.651	0.0624
Gender	-0.1117108220	0.07742392	-1.443	0.1568
Marital status	-0.1369344220E-02	0.12315612E-02	-1.112	0.3416
Education level	0.8378811167*	0.48734815	1.719	0.0578
Occupation	-0.1440337976**	0.06214383	-2.318	0.0241
Household size	0.8567949288*	0.53880071	1.590	0.0782
Income size	0.7754394000***	0.26953886	2.877	0.0023
Livelihood activity	0.5540074470	0.43545887	1.272	0.5382
Household income sources	-0.2948456682**	0.13853297	-2.128	0.0306
Irrigation income	0.1609784104E-05***	0.03474566E-05	4.633	0.0000
Household annual income	0.4748479891E-04	0.41752677E-04	1.137	0.6732
Engaging in irrigation	0.2843533146***	0.10483395	2.712	0.0034
Total land size	0.6548514083E-04*	0.36652123E-04	1.787	0.0710
Yield with irrigation	0.1343656908E-01***	0.05360211E-01	2.507	0.0035
Yield without irrigation	-0.8198445094E-01***	0.34642674E-01	-2.367	0.0048
Irrigation association membership	0.3614107563E-02***	0.10367268E-02	3.486	0.0002
Watershed service	0.5736102297E-01***	0.11678940E-01	4.911	0.0000
Number of observations (N)= 314				
R-squared= .65				
Degree of Freedom = 296				
Log-L= -8.241962				

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