Economic Assessment of Water Storage in Sub-Saharan Africa

Stefanos Xenarios[a], Matthew McCartney[a] and Berhanu Adenew [b]

[a] International Water Management Institute, East Africa& Nile Basin Office
[b] Ethiopian Economic Association, Addis Ababa, Ethiopia

Abstract

The development of water storage schemes is considered a major aid for agricultural regions in Sub-Saharan Africa with scarce water. The selection of storage options is often conducted through the valuation of direct costs and benefits. Such an approach, based solely on monetary values, often leads to reductionism in the assessment process and loss of valuable information. This in turn can result in less than optimal decision-making. Against this background, this paper proposes an alternative approach based on a range of different criteria. Though based on the underlying principle of economic efficiency, the approach proposed avoids some of the weaknesses of simple cost-benefit analyses. The new approach has been evaluated through application to case studies in Ethiopia.

1. Introduction

The recent interest of international funding organizations for financing large water storage schemes in Africa has revived the debate on welfare assessment through cost and benefit analyses (CBA) (World Bank, 2004). CBA related analyses are widely acknowledged as the most appropriate approach for selecting water storage options due to the relatively straightforward valuation of marketed goods and services (Panayotou, 2003).

However, there are some cases where a CBA may be prone to errors due to complexities in assessment procedure. For example, significant problems may arise when prices are not property adjusted to true market conditions. When the market conditions are inferred though surrogate markets or individuals' preferences they are equally prone to errors (Panayotou, 2003). In the case of surrogate markets for instance, the natural water filtration in riverine ecosystems is usually valued by comparison with mechanical filters. However, this tends to undervalue the other natural services provided by riverine ecosystems, such as the values associated with biodiversity and aesthetics. In the case of individuals' preferences, where the research is often conducted through a survey, it is common to face biases in the research design, the survey application and the analysis stage.

The current paper addresses the need for re-thinking economic assessment in the selection of water storage options in Sub-Saharan Africa. With this intention, an outranking approach enhanced with diversified economic related criteria has been developed. The proposed methodology has been applied through the application of a survey and subsequent analyses. The approach is proposed for Sub-Saharan countries, with a particular focus on Ethiopia where the survey was tested.

2. Methodology

It is common that the procedure for water storage selection adopts a form of CBA for the identification of the most appropriate option. The purpose of CBA is to facilitate the more efficient allocation of resources by identifying the most efficient economic solution for water storage (Bann, 1997). However, in cases where imperfect market conditions occur and non-market goods and services appear, CBA may lead to incorrect results.

The first weakness of CBA arises from the prevalence of the strong comparability principle which occurs through the monetization of heterogeneous goods and services (O'Connor and Spash, 1998). The monetization of all elements inevitably leads to reductionism and loss of information about the nature of each factor (Munda, 1996). Second, the assumption of absolute substitutability among goods and service (i.e. complete trade off conditions) also tends to cause errors(Munda, 1996). For instance, the revenues derived from the electricity produced by a hydro-energy plant can outweigh the financial costs arising from the displacement of communities and the flooding of age-old forests. Another major constraint is the irreversibility of conditions that may occur through the development of a project. For example, the construction of a hydropower dam usually entails soil erosion due to clear-felling, which results in siltation of downstream areas and loss of wildlife (Hanley and Spash, 1998). These impacts will irreversibly affect the surroundings of the dam site without offering a replacement option.

The issue of ecosystem complexity is another major issue poorly handled by CBA methods. For example, the climate change projections for Sub-Saharan countries highlight the likely increase in rainfall variability (IPCC, 2007). Such changes, may drastically affect the costs and benefits over the lifespan of a planned water storage project. Further, institutional capture is largely considered as an impediment for the CBA concept. The discount rate to be introduced for future estimations and the distributional aspects (i.e who gains and who losses) are not well handled in CBA (Söderbaum, 2005).

To overcome the aforementioned constraints, the methodology proposed suggests the introduction of an outranking approach based on diversified criteria related to economic efficiency in water storage selection. For this, the Borda's rule was adopted as an appropriate outranking assumption (OECD, 2008). The suggested Borda's rule adopts a weak comparability condition through the application of a pairwise procedure (Young, 1974). The first best solution is determined by the prioritization given to each criterion. Points are attributed to each criterion according to the anticipated benefits. The number of points given to each criterion is determined by the number of options available in the assessment process (Brian, 2008). In the simplest form, if there are three options then a component will receive three points each time it is ranked first, two each time it is ranked second and one each time it is ranked third.

The institutional constraints occurring in CBA are in part managed in this approach. In particular the discount rate is not an applicable measure since a non monetary solution is proposed. Further, the distributional aspects can be handled by the establishment of a weighting scale (DTLR, 2002). Initially, in the case of water storage selection the target groups to be acknowledged as the most vulnerable, should be identified. For these groups, a weighting factor could be introduced to attribute more gravity in the groups who are related with the selected criteria (Bann, 1997). For example, we may have a criteria related to the costs required for irrigation purposes and another one related to the willingness to pay for a good water quality status. If we chose to attribute significance to economically weaker farmers we may introduce a weighting factor to this sub-group (weaker farmers) related to these specific criteria. For example, we assume that we have
$g_1(a), g_2(a)$

where
$g_1(a)$ = criteria related to the costs required for irrigation purposes
$g_2(a)$ = criteria related to willingness to pay for a good water quality status
a= a finite set of N alternative options related to water storage

we can then define a specific subset of economically weaker groups where a weighting factor will be introduced as below:

$$w_l g_{1k}(a), w_2 g_{2k}(a)$$

where

w_l = the weighting factor for $w_l = (l = 1,2....n)$ and $w = \sum_{l=1}^{n} wl \; g_{1,2k}(a)$ = the subset of criteria and k = 1,2…..n represent selected weak stakeholder groups

For the estimation of the final points to be to be attributed to all the criteria the weighting factors of all the subsets should be accounted as below:

$$A_p = \{ w_1 g_{1k}(a), w_2 g_{2k}(a).....w_n g_{nk}(a)\}$$

Where, A_p = the Option A with the weighted average points.

Finally, the constraints of irreversibility and ecosystem complexity are handled by the introduction of pseudo – criteria, usually introduced as thresholds (DTLR, 2002). More often than not, it is the outranking methodologies based on the incomparability concept that introduce such approaches (Seager, 2004). In practice, we initially set a veto threshold for the comparison among two alternatives. In case the difference between the two options is above the determined threshold then the comparability among the options cannot proceed. Otherwise, the outranking process continues until the final ranking is completed (Kangas et al, 2001). If we want to describe mathematically the threshold in the criteria of irrigation costs and water quality as adopted above, the following relation will be developed:

$$D_{ik} = 0 \; if \;\; g_1(a) - g_2(a) < v_j \;\; or$$
$$1 \;\; if \;\; g_1(a) - g_2(a) > v_j$$

Where
D_{ik} the condition with i criteria and k options
v_j = the veto threshold

Criteria of economic efficiency

The criteria for economic efficiency were selected for two purposes. Initially, the crucial aspects of economic efficiency related to both agricultural and domestic water use were identified. This first objective was achieved through the derivation of eight criteria.

The second objective investigates farmers' perceptions towards water and soil conservation practices. In this case, the economic efficiency is estimated according to users' preferences on practices related to water storage options. Six criteria were derived.

A concise description of the criteria for both objectives is presented. For the economic efficiency, the first criterion is related to the revenues raised by farming and livestock. The second criterion relates to the costs of the same activities. The analysis does not include the capital costs of land possession due to the highly intertwined property status in the two examined countries[1]. The third criterion relates to the water charges set by surface irrigation networks, groundwater sources and potential water trading. The intention is to isolate water costs from the other cost function attributes. The fourth criterion refers to domestic water use and the economic effort required to fetch freshwater for the household. Further, the fifth criterion relates to the potential impact on human health derived from water borne diseases related to water storage.

For the sixth criterion an informal choice experiment approach through contingent ranking is used to test the relevance of major attributes of water and land use. As Pearce and Ozdemirolou (2002) note "Choice experiments present respondents with a baseline scenario corresponding to the status quo and several alternative options in which specified attributes are changed in quantity." The chosen attributes, which construct the scenarios, represent the most important parameters plus a direct or implicit money value. The seventh criterion provides additional insights into farmers' preferences on water pricing and the qualitative and quantitative status of the water. A Willingness to Pay (WTP) technique is introduced and the reasons of abstaining from the hypothetical contribution are explored. Finally, the level of satisfaction associated with both the quantity and quality of water (i.e. its general status) as well as the methods of abstraction is dealt with by the eight criterion. The eight criteria are summarized in Table 1.

Table 1. Criteria related to economic efficiency in agricultural and domestic water use

Revenues from Agriculture (Cultivation &Livestock)	Cost from Agriculture (Cultivation &Livestock)
Cost of Water Use for farming	Water for Domestic Use
Choice experiment on different water storage options	Impact of Water Use on Health
Willingness to Pay for water quality and quantity status	Level of Satisfaction of quantitative and qualitative water status in agricultural and domestic sectors

For the economic efficiency related to water and soil conservation practices, the first criterion relates to the potential improvements stemming from investments in these practices over a time period of five years[2]. The second criterion relates to the level of difficulty of installing water and soil conversation schemes. The third and fourth criteria pertain to the potential investments and the level of difficulty related to these investments in water and soil practices. Finally, the fifth and sixth and criteria relate to farmers' perception about the technical and economic performance of water and storage options. The six criteria are presented in Table 2.

Table 2. Criteria related to water and soil conservation practices

Investment on Water Conservation practices	Investment on Soil Conservation practices
Level of improvement from Water and Soil Conservation practices	Level of difficulty from Water and Soil Conservation practices
Technical efficiency of water and storage types	Economic efficiency of water and storage types

[1] For instance, as regularly occurs in Ethiopia, land is long-lastingly leased from public authorities for a nominal amount (Weldesilassie, et al 2009). In some other cases, farmers apply shareholding practices where land is provided in exchange of a portion of the harvest. Although the absence of capital land costs might cause some deviation from the accuracy of the results, however its inclusion would distort more the cost related findings

[2] The five years period is selected as an appropriate time horizon to discern the effects of water and soil conservation practices to farmer's produce.

The responses are determined in a percentage ratio while the reference year responds to the time the survey is undertaken.

Case Studies in Ethiopia

The research was based on a detailed survey conducted in three selected sites in Ethiopia. The three sites provided an opportunity to study various indigenous and modern water storage types.

The first site is located to the south of the Blue Nile river in the West Shoa zone of the Oromia regional state. It is situated at about 130 km North-west of Addis Ababa, in *Toke Kutaye* district (woreda). The Guder-Idris small-scale irrigation scheme uses water that originates from the Western central Shoa highlands and flows in the Idris river. The area is located at a medium altitude and with a relatively warm ecology that supports smallholder farming systems based on cereals and various vegetables. On the upstream side of the scheme farmers practice traditional water storage whereby water is diverted from the main river canal using local materials like wood, soil, crop residues, and mud as water canal. In the downstream area, water diversions are made at two locations using cement materials. Besides the traditional smallholders systems, there are few emerging small-scale private commercial activities in horticultural production. The use of water for irrigation is not yet intensified and in only a few cases pumps are used for water abstraction. However, in recent years, the introduction of small-scale pumps has been supported by the regional government and it is anticipated that an increased number of pumps will intensify production. A total of 130 farmer households (50% from the upstream and 50% from the downstream (i.e. below the dam and irrigation user community) were selected for the quantitative survey. The study was conducted in *Birbirssa* Kebele.

The second studied site is a rural kebele called *Quahar Michael* located in the Fogera district. Fogera is located in the South Gonder zone of the Amhara regional State and it is part of the Tana Lake basin. Lots of water storage and abstraction methods including hand dug-wells are used in this area. Small-scale irrigation is undertaken using water from streams which flow to Lake Tana. In addition, recession agriculture is undertaken on the remnant moisture when the lake overflow and flood recedes in the early months after the main rainy season. Rice production is becoming an emerging and prominent production system across the entire Fogera plain. For the quantitative survey and data collection, 170 farmers households (30% from hand dug well users, 30% from water pump (motor) users and 40% from other kind of users (i.e canal, geo-membrane, springs etc.) were selected and interviewed.

The third survey site is Koga irrigation dam located in the *Mecha* district of the West Gojam zone in Amhara region. The dam site is 40 km south of the regional capital, Bahir Dar. The Koga dam is a large-scale irrigation investment implemented by the Federal government of Ethiopia. The potential irrigable land of about 6000 ha is to be developed using the water stored in the system. As the construction work is nearing completion, some farming communities have now accessed water while others are waiting to be connected. There are however some neighbouring rural communities that will not have the opportunity to use the irrigation water at all due to gravitational reasons. The quantitative survey in the Koga dam area covered 200 farm households. These were selected from communities who already have water and irrigate their farms (35% of sample); from those farmers who haven't yet received water but expect to get in the future (30% of the sample) and from those communities who will not get any irrigation water (they are above the dam and canal area and water will not reach them (35% of the sample).

The survey in the three selected sites was undertaken using a semi-structured questionnaire that was applied to 500 households in total. In addition, a more qualitative survey using key informants and community level foal group discussions (FGD) was also undertaken.

Although the analysis is still ongoing, we present some very preliminary results as inferred from the findings of few processed questionnaires from the three case studies. The water storage options of small reservoirs in Guder-Idris, multiple storage in Fogera and large reservoir in Koga are examined. The criteria of the two groups are initially measured in individual metric units and thereafter are standardized in a ranking order through the points systems referred in Borda's rule. In turn, weighting factors are introduced for the landless and marginal landholders while a threshold value between the criteria of Choice Experiments and Willingness to Pay is entered.

Table 3. Ranking Process from preliminary results

Options	**Small Reservoir**		**Multiple Storage**		**Large reservoir**	
	Units/Year	**Rank**	**Units/Year**	**Rank**	**Units/Year**	**Rank**
First Group (Criteria related with agricultural and domestic water use)						
Agric. Revenues	130 $/ha	1	125$ /ha	2	80$ / ha	3
Agric. Costs	20 $ / ha	3	15$ /ha	1	18$/ha	2
Water Costs	60 $ / ha	3	20$ /ha	2	15/ha	1
Cost Domestic water use	0.2$/time	1	0.3$/time	2	0.4$/time	3
Cost water borne diseases	8$/iln.	2	5$/iln.	1	10$/iln.	3
WTP Qual.& Quant.	5$/yr	2	4$/yr	3	9$/yr	
Choice exper. Water&land	5$/ha/yr-4hrs/week	2	7$/ha/yr-5hrs/week	1	2$/ha/yr-4hrs/week	3
Satisf. From water Qual (QLT), Quant (QT)& Abstr.(ABS)	+50 (QLT), +25 (QT), Satisf (ABS)	2	+25 (QLT), +25 (QT), No Satisf (ABS)	3	+75 (QLT), +75 (QT), Satisf (ABS)	1
Second Group (Criteria related with water and soil conservation practices)						
Invest. Water Cons.Practices	N/A	N/A	300$	1	150$	2
Invest. Soil.Practices	50$	3	60$	2	100$	1
Impr. from water & soil cons.	High Impr/1,3,5 yrs	1	No Impr./1,3,5 yrs	3	High Impr/1yr-Little Impr./3yr	2
Diffic. from water & soil conserve.	High Diff./1,3,5 yrs	3	No Diff./1,3,5 yrs	1	High Diff./1yr-Little Diff/3yr	2
Techn. Effici. Stor.types	1st /choice	1	3st /choice	3	2st /choice	2
Econ.Effic. Wat. Stor.types	3rd /choice	3	2nd /choice	2	1st /choice	1
Weighting Factor : 0.1 (for landless) and 0.05(for marginal landholders)						
Threshold Value : Threshold value is entered between Choice Experiment and WTP criteria						

Thereafter, the percentage of landless and marginal farmers who participated in the survey process is estimated while the activation of threshold value between the selected criteria is examined.

Table 4. Finalisation of ranking Process

Cr.	**%**		**Cr.**	**%**		**Cr.**	**%**		**Points**
5	**Landless**	**Marginal**	**4**	**Landless**	**Marginal**	**4**	**Landless**	**Marginal**	
C *	20	20	A	10	10	B	20	20	3
B	10	15	A	30	5	C	10	15	2
A	20	20	B	15	25	C*	15	10	1
** There is a threshold value between the Choice Experiment and WTP criteria because Low Fees Preference and High WTP bid are presented. Thus these two criteria are excluded from the counting*									
Options : A= Small reservoir B= Multiple Storage C= Large reservoir									
Calculations									
5 Criteria			**4 Criteria**			**4 Criteria**			
C	**4* (3*0.6+3.1*0.2+3.05*0.2)**		A	**4* (3*0.85+3.1*0.1+3.05*0.15)**		B	**4* (3*0.6+3.1*0.2+3.05*0.2)**		

B	**5* (2*0.85+2.1*0.1+2.05*0.15)**	A	**4* (2*0.6+2.1*0.2+2.05*0.2)**	C	**4* (2*0.75+2.1*0.1+2.05*0.15)**
A	**5* (1*0.6+1.1*0.2+1.05*0.2)**	B	**4* (1*0.85+1.1*0.1+1.05*0.15)**	C	**3* (1*0.85+1.1*0.15+1.05*0.1)**
Points					
5 Criteria		**4 Criteria**		**4 Criteria**	
C	**12.12**	**A**	**13.27**	**B**	**12.12**
B	**11.087**	**A**	**8.12**	**C**	**8.07**
A	**5.15**	**B**	**4.47**	**C**	**3.36**
Ranking: B(27.67)> A(26.54)>C (23.55)					

The very preliminary results reveal that the multiple storage option is more appealing to the sample with slight difference from small reservoirs and moderate difference from large schemes. However, it is underlined that the findings are still premature since only very few responses have been processed.

3. Conclusion

This paper attempted to assess economic criteria, which affect the valuation of water storage options in Sub-Saharan Africa, with specific reference to Ethiopia. There are some limitations to the method proposed. For instance, Borda's rule can be subject to tactical manipulation in cases where the respondents are predisposed to one specific option in preference to others. We attempted to eliminate this methodological constraint by avoiding group surveys and the biases of preoccupied respondents. Furthermore, in cases where a strong inclination towards a specific water storage option was presented, further explanation for this preference was always requested. We also omitted the outliers from the statistical analysis derived from open ended questions. This enabled us to better screen the real situation in the case study areas (Osborne and Overbay, 2004).

Also, the criteria developed for both the data extraction and for ascertaining farmers perceptions' could be described as inappropriate or of limited applicability in some instances. It is understood that the suggested approach cannot capture all the aspects of economic efficiency applicable for water storage options in an area as large as Sub-Saharan Africa. Consequently, we attempted to design those most applicable to the conditions occurring in Sub-Saharan countries. Nevertheless the framework could undoubtedly be further improved using the feedback obtained from the surveys.

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