Economic Assessment of water storage for adaptation to climate change in Sub-Saharan Africa

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Abstract

The development of water storage schemes in Sub-Saharan Africa is considered a major aid for agricultural regions with scarce water and anticipated climate change impacts. The selection of storage options is often conducted through monetary assessment of direct costs and benefits. Such an approach, although prompt and straightforward, 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 an outranking methodology designed with threshold systems and weighting values. Though based on the underlying principle of economic efficiency, the approach proposed avoids some crucial weaknesses of cost-benefit related analyses. The methodology has been evaluated to six case studies in Ethiopia and Ghana through the introduction of socioeconomic and environmental related indicators.

1. Introduction

The inclusion of welfare assessment in water storage schemes was recommended early in the 19th century (Hanley and Spash, 1998). It was not until 1936, however, that federal legislation in the United States of America required the evaluation of direct costs and benefits in all water resource projects. As a result, cost-benefit analysis (CBA) emerged between the 1950s and 1970s as the dominant economic tool for supporting decision-making on dam projects (Boardman et al, 1996). If the expected benefits of a dam were deemed to outweigh the predicted costs, the project went ahead. The relatively narrow nature of the technical and economic analyses undertaken did not necessarily mean that decision-makers who chose dams as a development option were unaware of the social and environmental costs. However, often the sacrifices were deemed acceptable in light of the economic benefits that would accrue.

It was also about the same time, where an attempt to include broader costs and benefits by increasing the emphasis given to environmental improvement was noticed. However, initially this was specifically in relation to outdoor recreation (Clawson and Knetsch, 1966). After a while, the social aspects of distribution and equality were also considered as a major parameter for the identification of optimal solution (Baumol, and Oates, 1988). Nowadays, the incorporation of environmental and social aspects is an imperative part of identifying the most suitable option for water storage (Bennet and Birol, 2010). It is no longer desirable to optimize dam operation on the basis of economic criteria alone. However, there is still considerable debate about the most appropriate way under which social and environmental aspects can be adequately incorporated into decision-making processes.

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 benefits analyses (World Bank, 2004). For the ease of writing, we will refer to the cost and benefit like analysis with the acronym CBA (Cost Benefit Analysis).

Increasingly the purpose of large dam construction is moving away from single objectives (e.g. simple irrigation or hydropower production) to multiple purposes and the inclusion of other socially related aspects becomes ever more important. For example, attaining poverty alleviation in conjunction with the direct water and energy needs is getting an aspiration of multi objective large reservoirs (WCD, 2000). The provision of sufficient agricultural water with complementary hydroelectric power generation or vice versa is often perceived as an integrated option for welfare improvement in African countries (Kumambala and Ervine, 2009). However, there are still many instances, where the use of a large reservoir solely for irrigation purposes still attracts the interest of international donors. In nearly all cases though, the identification of the appropriate site, the dam design and the operating regime are still largely governed by purely economic assessments, usually assessed through cost benefit like analyses (WCD, 2000).

On the other hand, the development of smaller water storage types (e.g. small tanks and ponds or *in-situ* water harvesting) is often planned and implemented by non-governmental organizations. The participation of local communities is encouraged but does not always occur. The economic assessment through CBA is again suggested for the selection procedure. However, the experience of applied small-scale project shows that although the consideration of costs and benefits is initially noticed, a coherent CBA is finally missing (Koundouri et al, 2003).

CBA like analyses are widely acknowledged as the most appropriate approach for selecting water storage options due to the straightforward valuation of marketed goods and services. In the absence of policy distortions and market failures, market prices are assumed to portray both individual and relative social values (Panayotou, 2003).

However, there are some cases where a CBA may be prone to errors or considered as an inappropriate tool due to complexities in assessment procedure. Significant problems can arise when prices are not adjusted to market conditions due to undefined related parameters or different values determined by various stakeholders. For instance, the common land property rights in an impending flooding area due to dam construction might provoke assessment errors in the estimation of the compensating amount to be given in landholders. In another case, the value attributed to a hunting area that will be flooded might be significant in economic terms for the local community but of little economic value for the entire country that will benefit from a hydro-electric plant.

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 assessed through the services provided by mechanical filtrations. However, the economic assessment of a mechanical filtration would undervalue the service due to the multiple uses offered by the natural process. Indicatively, the natural filtration would additionally contribute to fauna and flora improvement in river banks and surroundings beyond the purification effects. Furthermore, in the case of individuals' preferences where the research is often conducted through a survey, it is rather usual to have biases in the research design, the survey application and the analysis stage.

The biases arising from the valuation of environmental goods and services may be mitigated by the application of Environmental Impact Assessment (EIA) (Gilpin, 1995). The EIA tool has been drastically improved the recent years in a way to quantitatively assess the environmental impacts of anticipated water storage projects (Treweek, 1999). However, the interpretation of impacts in monetary terms for its inclusion in CBA often impedes to methodological constraints. It is not a few cases where the two assessments are acknowledged as complementally but incompatible for the attribution of the assessment findings (Wood, 1995).

The current paper addresses the need for reorientation of the decision-making process for the selection of water storage options in Sub-Saharan Africa. With this intention, additional economic, social and environmental related indicators are included and measured through an outranking based approach. Threshold values and weighting coefficients are introduced for the avoidance of complete trade-off conditions. The final ranking of the recommended options outlines the optimal solution to be offered by diversified indicators. Our methodology anticipates to better illuminate the debate about the appropriateness of water storage options in developing countries (WCD, 2000). The quantification of the study sites' findings are deemed to offer rigorous indications about the appropriateness of storage types in Sub-Saharan Africa given the relevant case specific constraints. The suggested methodology is applied through the elicitation of individuals' preferences with a survey analysis. Our approach is tested in three representative sites in Ethiopia.

In Section 2, the prevailing theoretical framework of cost benefit analysis (CBA) is initially exhibited. Further, the suggested outranking based approached is juxtaposed as a promising alternative or a supplemental tool to CBA. In Section 3, the criteria introduced for the outranking process are presented while the reasoning of its section is explained. Section 4 delineates the features of the three selected case studies in Ehiopia. In Section 5, the results of the applied methodology are presented while concise comments on the findings are placed. Finally, in Section 6, the discussion points and the concluding remarks are appended.

2. Theoretical framework

2.1 The Outranking based approach as an alternative to CBA

The proposed methodology is based on a multi-criteria outranking based approach (Roy, 1996). The suggested methodology assesses diversified indicators related to both economic performance and environmental impacts of water storage schemes. Our concept is based on the principles of decision aiding approaches, which could be mainly distinguished in the following classification (Roy, 1996):

a) methods based on the "use of a single synthesizing criterion without incomparabilities". This is the conceptual basis of CBA and of other similar methods relying on complete trade offs and optimization approaches.

b) methods based on the "synthesis by outranking with incomparabilities" where a relative comparability between the criteria allows the preservation of heterogeneity. However, the strong involvement of the analyst in the decision-making process may threaten the objectivity of the approach if strong intervention will occur.

c) methods based on the "interactive local judgments with trial-and-error iteration". There is not currently a specific technique to clearly represent the above approach. It should be mentioned however, that quite a few goal-programming approaches have attempted to incorporated trial-and-error iterations although still not sufficiently enough.

In another classification, Vincke (1994) distinguishes between "descriptive" and "constructive" approaches. A descriptive approach focuses on the elicitation of already preexistent preferences. This implies that whoever's preference is to be elicited, they are predefined and preexist in a stable state. The descriptive approach motivated the development of a simple and comparable System of Preference Relations (SPR) based on the strict preference and indifference conditions.

While the "strict preference" refers to the existence of clear reasons that justify significant preference in favor of one of the two actions, the "indifference" situation refers to the existence of clear reasons that justify equivalence between the two actions.

In the descriptive approach, the criteria should be assessed through complete trade-off processes for the attainment of the most efficient solution. This means that strong comparability and complete substitutability conditions must be applied among the criteria no matter which values these criteria represent. As occurred with the first category presented by Roy (1996), the descriptive approach again delineates the concept of optimization usually through a single criterion. The monetization of all results in CBA for the identification of the first best solution is a representative case.

However, over the last two decades, the difficulty of adequately comparing and quantifying heterogeneous criteria, such as the environmental and economic ones in water resource projects, has steadily increased (Munda et al, 1994). The response came from the development of the "constructive" approach. As Vincke (1994) states, "…in a constructive approach the dialogue-processing sequence is seen as a tool to help progressively develop compromise solutions, sorting or rankings". The actors should build their preferences along an elicitation process by aiming at the enrichment of System of Preference Relations (SPR) and a more sophisticated decision making process.

In this case, apart from the "strict preference" and "indifference" conditions, the "weak preference" and "incomparability" situations are introduced. In the "weak preference" situation, two possibilities could prevail in which one criterion is weakly preferred to another or vice versa. In turn, for the "incomparability situation", two alternatives could simple remain incomparable. Table 1 below offers a more explanatory picture of the four preference conditions.

Table 1. Preference conditions through a constructive approach (Vincke 1994, adjusted by authors)

Conditions	**Definition**
Strict Preference	Corresponds to the existence of clear and positive reasons that justify significant preference in favor of one (identified of the two actions)
Weak preference	Corresponds to the existence of clear and positive reasons that invalidate strict preference in favor of one (identified) of the two actions. The reasons are insufficient to deduce either strict preference in favor of the other action or indifference between the two actions, thereby not allowing either of the two preceding situations to be distinguished as appropriate
Indifference	Corresponds to the existence of clear and positive reasons that justify equivalence between any two actions
Incomparability	Corresponds to an absence of clear and positive reasons that justify any of the three preceding relations

The specific conditions occurring in the Ethiopian case studies did not require the incomparability condition for the operationalization of the constructive approach and thus only the strict, weak and indifference preferences were adopted.

The proposed methodology attempts to establish an outranking based approach for the avoidance of the inherent constraints met in CBA and the preservation of constructive concept. As noted in the relevant literature, the outranking-based approach could include a set of diversified criteria that are measured in interval and ordinal scale without loosing significant information in the assessment process (Greco, 2005).

2.2 The concordance and discordance principles

The operationalisation of an outranking-based approach through the constructive concept demands the introduction of specific relations and values. An exhibition of the essential components of the outranking approach would help in the clarification of the following relations as below:

a, b = Alternatives of a proposed project (e.g. a= big reservoir, b= small reservoir, c=borehole, d= dugout, etc.)
g_j = A number of j criteria proposed for the ranking of the examined alternatives (e.g. g_1 =revenues from farming activities, g_2=farmers' satisfaction for water quality etc.)
p = strong preference threshold, q= indifference threshold

By initiating from strict preference condition, a threshold value (p) ascertains that a strict preference occurs only when the difference between the examined alternatives is beyond the defined value. In mathematical format, and assuming a maximization criterion without lose of generality, this condition is expressed as below:

a**P**b (a is strongly preferred to b) ⇔, $g(a)-g(b) > p$ (1)

Next, the weak preference condition is represented through the introduction of another threshold value (q) which is added in the strict preference above. The condition is then presented through a double threshold model, where a binary relation measures weak preference as below:

a**Q**b (a is weakly preferred to b) ⇔ $q < g(a)- g(b) < p$ (2)

In effect the thresholds q and p comprise the lowest and highest values that could be ever taken between the two alternatives. The weak preference should be determined within the range of these two values.

Through the operationalisation of the two preference conditions, an outranking relationship (S) between any two alternatives a and b could be built. The outranking relation could be interpreted as ''a is at least as good a b (aSb)'' or "a is not worse than b". It should be mentioned that these relationships are applied to each of the g criteria; that is, aSjb means that "a is at least as good as b with respect to the jth criterion." (Buchanan and Vanderpooten, 2007).

The two equations exhibited above do actually represent the two following principles (Roy, 1991):

- A **concordance principle** which requires that a majority of criteria is in favour of the assertion aSb, that is the majority principle

- A **non discordance principle** which requires that within the minority of criteria which do not support the previous assertion, none of them is strongly against it; that is the respect of minorities' principle.

The two principles make use of the three above models developed for strict, weak preference and indifference situations for the structuring of a functional relationship as below:

$$c_j(a,b) = \begin{cases} 1 & g_j(a) + q_j \geq g_j(b) \\ 0 & g_j(a) + p_j \leq g_j(b) \\ \theta & q_j \leq g_j(b) - g_j(a) \leq p_j \qquad \theta = \dfrac{p_j + g_j(a) - g_j(b)}{p_j - q_j} \end{cases} \tag{3}$$

Where
$g_j(a)$, $g_j(b)$ = the performances of alternative scenarios *a* and *b* respectively for each criterion *j*
p_j, q_j = the preference and indifference thresholds respectively

The values of 0, 1 and θ presented in equation (4), decipher the following messages:

a) 1 = when the difference between the two alternatives *a* and *b* for jth criterion is smaller than the indifference threshold.
b) 0 = when the difference between the two alternatives *a* and *b* for jth criterion exceed the preference threshold.
c) θ= when the difference between the two alternatives *a* and *b* for jth criterion is between the indifference and preference thresholds.

2.3 Weighting and Ranking process

Many of the outranking-based approaches indirectly handle the distributional concerns with the introduction of multipliers, which are commonly known as weighting factors (DTLR, 2002). Indicatively, if specific criteria appear to better represent the unequal socio-economic conditions in an analysis, then a weighting factor could be employed for the attribution of higher importance to these criteria.

The weighting assumptions require that the analysts should wisely judge the significance of the criteria for the avoidance of biasing in the assessment process. In effect, it is often claimed that the introduction of multipliers in decision aiding increases subjectivity, which in turn distorts final results (Carson et al, 1995). However, weight factors are currently the most widely applied approach for the consideration of distributional aspects (Seager, 2004).

We then calculate the results of the outranking approach. In many of the outranking based approaches (Rogers and Bruen, 1998), a formula composed by the weighting factors and the concordance results is applied. Particularly, a fraction is designed with nominator as the multiplication of weights and concordance results, while the denominator represents the summation of the weights as below:

$$C(a,b) = \frac{1}{w}\sum_{j=1}^{n} w_j C_j(a,b) \tag{4}$$

2.4 Indicators and data

The economic performance of water storage in Ethiopia are defined through a set of diversified indicators divided in two different groups. For a better comprehension of the outranking approach presented above, we will acknowledge the indicators as input criteria.

In the first group, the criteria are related with the direct and indirect economic effects of water storage to agricultural (cultivation and livestock) and domestic water use. The second group refers to the level of satisfaction of farmers about water use in agriculture and domestic sectors. The set of the criteria are presented as below:

Table 1. Criteria of economic performance for water

Group 1 : Direct and Indirect economic effects (quantitative)	
Net revenues from agricultural produce	Ratio of net revenues from agricultural produce and water charges
Impact of Water Use on Health	Water for Domestic Use
Ratio of net revenues from agricultural produce and water consumption	
Group 2 : Farmers' preferences in water use (qualitative)	
Level of satisfaction in - water volume - water quality - water abstraction methods	In the fields of - crop cultivation - livestock - domestic use

A brief presentation of the adopted criteria is anticipated to illuminate the reasoning of their selection. In the prime group, the first criterion is related to the economic performance of each farmer through a break-even analysis. The average net revenue responding to each water storage is aspired to hint the potential influence of the different sources to the economic performance of farmers.

The second criterion is related to ratio of water costs and net revenues on an annual basis. The water costs in Ethiopia are usually defined by Water User Associations if the land is designated as irrigated. In case however of pumping from surface or groundwater sources, the pumping related costs are considered. Also, there are quite a few instances where farmers trade water in exchange of sharing the annual harvesting. To this purpose, surrogate market prices related with the crop values of the harvested amount shared, are used for the assessment of the water charges. For this criterion, the higher value implies a more effective use of the water source.

The third criterion exhibits the ratio of water consumption and net revenues. The amount of water use is estimated on hourly basis due to the difficulty to accurately measure the inlet of the volumetric amount from different water supply sources. The various means of water transfer as for instance, furrows, buckets, diesel/electric pumps and alike, prohibit the exact estimation of the volumetric amount of water to be used for irrigation and livestock purposes. Alike the previous indicator, the higher value implies a more effective use of the water source.

The fourth criterion refers to domestic water use and the economic effort required to fetch freshwater for the household. The performance of this indicator is measured trough a function composed by four attributes. Namely, the distance and time spent for water fetching, the mean for water transfer and the person responsible for the delivery. The economic value related with these attributes is assessed by the foregone benefits or otherwise the opportunity costs related with the water fetching. This is interpreted as the economic value, which could be gained by using the time, the mean and the person occupied for water fetching, to agricultural work instead. The lower the opportunity costs, the better the performance of the indicator.

Further, the fifth criterion depicts the potential impact on human health derived from water borne diseases because of water storage. This indicator is included in the economic performance of a water storage scheme due to the link between illness from water borne diseases and potential economic loss in rural income. For the assessment of human health costs, the labor days lost and the costs of medical treatment are contemplated. Again, for the assessment of the lost labor days, the opportunity cost approach is followed as in the previous criterion. The better performance is given by the lower scoring.

The second group, encompasses a set of qualitative criteria which are employed for the assessment of the level of satisfaction derived from quantity and quality levels of water use in agriculture, livestock and domestic sectors. Also, the satisfaction status from the water abstraction methods currently used is queried. For these indicators, a better performance is signaled with the higher level of satisfaction.

4. Description of study area

This study was conducted in two regions of Ethiopia, namely Oromia and Amhara, that lie in the Nile Basin. Three districts were selected as the case study sites - Tokee Kutaye in Oromia, Fogera and Mecha in Amhara region. Tokee Kutaye is found in West Shoa zone, while Fogera and Mecha are in South Gonder and West Gojam zone, respectively. Specific study sites covered are the Gomit dam, wetlands and deep wells in Quara kebele[1] (in Fogera district), Koga dam and watershed in Kudmy, Inquti, Merawe and Agiza kebeles (in Mecha district), and the Indris watershed and small scale irrigation sites in Birbirsa Dogoma kebele (in Tokke Kutaayee district) (Figure 1).

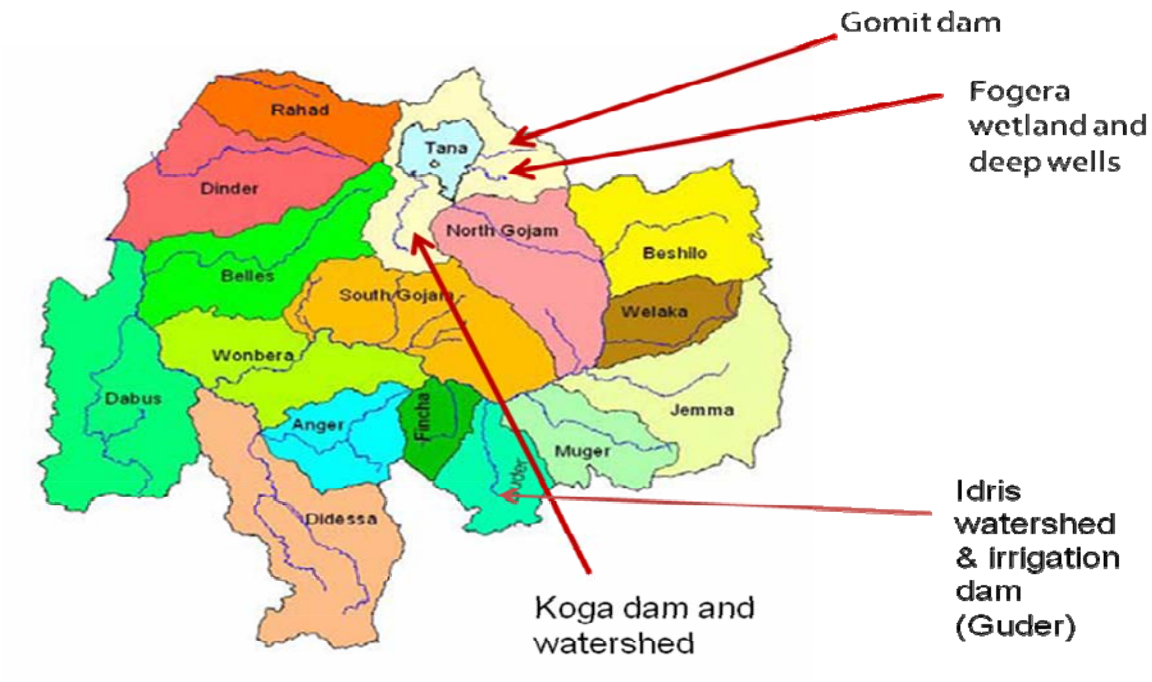

Figure 1: Study sites in the Ethiopian Blue Nile Areas

A survey of a sample of 500 farm households selected from the three study districts (table 7) was conducted in July 2010. The sampling was purposively stratified to capture a representative number of farmers practicing different water storage options.

[1] Kebele is the smallest administrative unit in Ethiopia which represents an amount of villages and settlements within an area

The three sites provided an opportunity to study the various indigenous and modern water storage types. The first site is located south of the Blue Nile river in West Shoa zone of the Oromia regional state. It is situated at about 130 km North-west of Addis Ababa, in *Toke Kutaye* district. The Guder-Idris small-scale irrigation uses water that originates from the Western central Shoa highlands and flow via Idris river. The area is situated in a medium altitude and relatively warm ecology that supports a smallholders farming system based on cereals and various vegetables. On the upper stream farmers practice a traditional water storage whereby water is diverted from the main river canal using local materials like wood, soil, crop residues, and mad as water canal. At the downstream water diversions were 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. Hence, only few cases of use of pumps for water abstraction was reported. A total of 130 farmer households where queried where 26% located in the upstream and sources by traditional water storage, 31% located in lowlands and irrigated by Idris dam and 45% located in both upstream and downstream and supply only by rainfall. The rainfed case was examined as a benchmark reference for a comparative analysis between the water storage options.

The second study site was a rural kebele called *Quahar Michael* selected from Fogera district. Fogera is located in South Gonder zone of the Amhara regional State and is part of the Tana Lake basin. The wetland in Fogera plain supports crop farming and livestock production. Lots of water storage and abstraction methods including hand dug-wells are practiced in this area. Small-scale irrigation is practiced using rivers that flow to the Tana lake. In addition, recession agriculture is used on the remnant moisture when the lake overflow and flood recedes in the early months after the main rainy season. Rice production is also becoming an emerging and prominent production system in Fogera plain.

For the quantitative survey and data collection, 170 farmers households were surveyed. The first water storage type examined is a small reservoir linked with cemented and soil canal water types. For a better understanding of the canal performance, 11% of cement canal connection users where queries while the other 89% where soil canal connections. This unequal distribution occurred due to the high prevalence of soil canal users which should be represented also in the sample. Also, a 12% of the sample belonged to well owners and the major 71% of the surveyed farmers consisted of pump users which is a very increasing trend in the area.

The third survey site is Koga irrigation dam located in *Mecha* district of the West Gojam zone in Amhara region. The dam site is only 40 km south of the regional capital of 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 and challenged in the system. As the construction work is nearing completion, some farming communities have now accessed water while others are waiting to get access to water. There are, however, some neighbouring rural communities that will not get opportunity to use the irrigation water at all. The quantitative survey in Koga dam area covered 200 farm households. These were selected from communities who already got water and irrigate their farms (35% of sample); from those farmers who did not yet get water and irrigate their farms but expect to get in the future (30% of the sample) and from those communities who will get no irrigation water (they are above the dam and canal area and water will not reach there) (35%).

In addition to the survey, qualitative study methods and tools (key informants interview and focus group discussions) were employed at the community level to get in-depth information about water storage practices, land and water management, production and livelihood and socio-economic aspects in the study areas.

The introduction of specific preference and indifference threshold values together with the weighting factors was required for each of the Ethiopian case studies. For the minimization of subjectivity factor, detailed research of relevant literature (Fülöp, 2008; Kumambala, 2009) and consultation with local experts was undertaken. The summary characteristics of the three case studies in Ghana and Ethiopia are presented in Table 2.

Table 2. Weighting factors for Ethiopian cases

Thresholds - Weights	Criteria					
	Net Rev ($)	Ratio Net Rev./Water Ch.($)	Ratio Net Rev./Water Cons.($/h)	Wat. Dom.($)	Imp.Health ($)	Pref. Cr.
Indif. Thrs.(q)	200	200	30	5	30	1
Pref. Thrs.(p)	300	300	60	10	60	2
Wgt.(w)	1.2	1.3	1.1	1	1	1

Note: Net Rev($)= Net revenue from agricultural produce ($) , Ratio Net Rev/Water Ch.($)= Ratio of net revenue from agricultural produce and water charges ($),Ratio Net Rev/Water Cons.($)= Ratio of net revenue from agricultural produce and water consumption ($/hr), Wat. Dom.($)= Water for Domestic Use , Imp.Health ($) = Impact of Water Use on Health ($),Pref. Cr.= The representation of the qualitative criteria

5. Results

The Ethiopian results indicate water storage options supplied by surface water from small reservoirs and river diversions predominate. The highest ranking score is attributed to the Guder upstream area supplied by river diversions through traditional water storage schemes made from local materials. The reason for the highest ranking could be attributed to the fertile land available in this area, the low health costs and the high satisfaction of farmers with their current water use.

Closely behind is the option of small reservoir in Gumera which is diverted to furrows made by farmers. In this case, the land is equally fertile, while large water volume is channelled to the furrows with nominal supply costs. A similar case occurs in the third placed ranking option where instead of furrows concrete canals are constructed. However, in this case there is considerable regulation of water supply resulting in less water being conveyed along the channels to the farmers furrows.

Of almost equal ranking is the Guder rainfed (i.e. no water storage) option which can possibly be attributed to the relatively productive land, the absence of water costs and the high farmer satisfaction with current water use. Surprising is the fact that the farmers irrigated from small reservoirs in the Guder area are below the rainfed farmers. This is possibly because insufficient water is provided by the dam and this in turn results in lower productivity. The farmers in Gumera who access water pumped from river diversion are slightly less satisfied probably because the high income from the increased produce is offset by equally high water supply and health costs linked with water related diseases.

At the bottom of the ranking scale are all the storage options related to the Koga dam and the groundwater derived from wells in Gumera. In effect, farmers who are unable to get connected to the irrigation scheme earn moderate net revenues and present low satisfaction with the current status of water quantity and quality. The well users in Gumera are probably at the lower end of the ranking because of the increased health costs and the relatively high expenditures required for well maintenance. Lastly, the farmers who anticipate that they will be connected and are already connected to the canals of the Koga dam, have the lowest ranking score, possibly because of the currently very low returns to investments made to date.

In table 3, the ranking performance of the storage options is presented while a more detailed presentation of the ranking analysis is exhibited in Appendix 1.

Table 3. Ranking results for storage options

No.	Ethiopian Options	Scoring
1	Guder Upstream (river diversion)	7.30
2	Gumera (furrows)	7.19
3	Gumera (Canal Cement)	6.63
4	Guder Rainfed	6.60
5	Guder Irrigated (small reservoir)	6.06
6	Gumera (pump-river diversion)	5.87
7	Koga (will not get connected)	5.52
8	Gumera (Wells)	4.65
9	Koga (to be connected)	3.34
10	Koga (connected)	3.03

6. Conclusion

The current research attempted to assess representative water storage options in Ethiopia through quantitative and qualitative criteria by minimizing information loss and still conforming to economic theory. It is acknowledged that not all the economic drivers that affect the performance of water storage options in the study areas were examined. Also, the ranking of the qualitative criteria, which is dependent on the knowledge and expectations of the farmers in each study site, can be debated (Louviere et al, 2000). Further, there are technical parameters which cause considerable effects in the criteria but which have only tentative relations to the type of water storage. For example, the presence of profitable and commercial crops instead of staple cultivation will significantly affect the agricultural income. Also, factors such as soil fertility and climatic factors are independent of storage but will significantly affect the performance of the economic criteria (Rogers and Bruen, 1998).

In an attempt to minimize the aforementioned constraints, the quantitative economic criteria were only selected after careful consideration of a range of options. The criteria chosen were identified through the relevant literature as being the most representative set of economic factors which are in a strong pursuit of the economic efficiency objective (Koundouri et al, 2003). In the case of the comparability conditions in the qualitative criteria, the relevant questions were accompanied by a follow-up query about farmers reasoning in relation to other water storage options.

The suggested method could substitute or supplement the currently dominant CBA application for water storage assessment in Sub-Saharan Africa. The application to case studies in Ethiopia were selected to capture as wide a range as possible of the water storage options used in many regions of Sub-Saharan Africa. It is however accepted that adjustment of the threshold levels and the weighting factors of the outranking method should be conducted if applied in a different country context.

Appendix 1. Ranking Analysis

No.	Options	1	2	3	4	5	6	7	8	9	10
1	**Guder Upstream (river diversion)**	-	0.854	0.918	0.514	0.795	0.788	0.932	0.445	0.452	0.795
2	**Guder Irrigated (small reservoir)**	0.932	-	0.918	0.452	0.726	0.863	0.932	0.452	0.452	0.795
3	**Guder Rainfed**	0.925	0.924	-	0.445	0.582	0.719	0.856	0.377	0.452	0.795
4	**Gumera (Wells)**	0.760	0.685	0.932	-	0.726	0.853	0.932	0.349	0.418	0.623
5	**Gumera (pump-river diversion)**	0.771	0.753	0.829	0.705	-	0.774	0.918	0.342	0.281	0.555
6	**Gumera (concrete canal-small reserv.)**	0.829	0.753	0.760	0.623	0.705	-	0.842	0.281	0.349	0.623
7	**Gumera (furrow- small reservoir)**	0.753	0.753	0.829	0.274	0.630	0.856	-	0.068	0.212	0.623
8	**Koga (connected-large dam)**	0.829	0.753	0.829	0.925	1.000	0.856	0.863	-	0.692	0.692
9	**Koga (to be connected-large dam)**	0.753	0.753	0.753	0.856	0.856	0.925	0.925	0.788	-	0.815
10	**Koga (will not get connected – large dam)**	0.753	0.685	0.753	0.377	0.651	0.788	0.925	0.377	0.486	-
	Total Score	**7.306**	**6.061**	**6.603**	**4.658**	**5.877**	**6.634**	**7.192**	**3.034**	**3.342**	**5.520**

Note: The numbers in the heading row represent the options sequenced as per the numbering order given in the first left column.

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