IRRIGATION PERFORMANCE IN COMMUNITY-MANAGED SCHEMES: ASSESSMENT USING COMPARATIVE INDICATORS AND UTILITY ANALYSIS

PERFORMANCE D'IRRIGATION DES PROJETS GERES PAR LA COMMUNAUTE : EVALUATION A L'AIDE DES INDICATEURS COMPARATIFS ET DE L'ANALYSE D'UTILITE

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ABSTRACT

Community-managed irrigation systems are operated, managed and maintained by farmers themselves. Management activities by farmers include water diversion, conveyance, scheduling of water delivery, maintenance of infrastructure, sanctions for misbehaving, etc. These activities are in many cases carried out by institutions such as water users' associations. These schemes play significant role in addressing food security problems, particularly in least developed nations; and in most cases they are small to medium scale schemes demanding lower investment and operational costs thereby serving large number of beneficiaries. There have been significant investments on community-managed irrigation schemes in Ethiopia. Though they play a key role, these schemes suffer from poor water management and low water productivity problems.

This research is carried out at two community-managed irrigation schemes called Golgota and Wedecha located in central Ethiopia. The research aims to compare the performance of these two schemes using external comparative indicators and to find out the internal management practices which led to specific level of performance. Three groups of benchmarking (comparative) indicators have been used and fuzzy set concept has been applied to analyze farmers' utility of irrigation service. Golgota scheme has a higher level of

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performance over Wedecha with respect to both agricultural and physical indicators. With relative irrigation supply (RIS) of 1.49 and 1.34 for Golgota and Wedecha respectively, both schemes withdraw more water than demands. Utility levels are generally found to be higher in case of Golgota, except canal sedimentation problems. This shows that as volume of water diverted at Golgota is decided by water users themselves, farmers are more satisfied when they are responsible for managing their water resources. Recommendation for improving the water use efficiency and productivity are recommended in this study.

Key words: *Water productivity, comparative indicators, irrigation service, farmers' utility, fuzzy set theory.*

RESUME ET CONCLUSIONS

La performance globale et la durabilité des systèmes d'irrigation gérés par la communauté dans de nombreux pays les moins avancés est faible. En Ethiopie, l'un des pays les moins avancés dans la corne de l'Afrique, les régimes gérés par la communauté sont caractérisées par le faible niveau de la performance physique, opérationnelle et institutionnelle. Ainsi, l'évaluation des niveaux actuels de performance et les problèmes de performance d'adressage est un élément clé de la durabilité et l'économie des ressources en eau limitées. Dans ces périmètres d'irrigation, peu d'attention est accordée aux mesures de débit d'irrigation. Dans de nombreux cas, les structures de mesure de débit sont pas en place ou si elles existent elles ne sont pas utilisées adéquatement en raison d'un dommage ou un manque d'expertise par les utilisateurs d'eau à utiliser ces installations. Cependant, les méthodes classiques d'évaluation des performances dépendent principalement sur des données mesurées sur les livraisons d'eau d'irrigation afin d'évaluer la performance du système interne. Ainsi, une approche différente basée sur des données qualitatives doivent être utilisés dans de tels cas. Un de ces analyses est l'utilité des agriculteurs (FU), l'analyse des services d'irrigation utilisant l'approche des ensembles flous.

Cette recherche se concentre sur deux systèmes d'irrigation gérés par les communautés en Ethiopie, a appelé Golgota et Wedecha. Dans l'ancien régime, l'eau d'irrigation est détournée en utilisant une structure de gabion temporaire pour accroître le niveau d'eau dans la rivière, tandis que dans l'eau ce dernier régime est fourni à partir d'un barrage en remblai de petite taille. Gestion de l'eau dans les deux régimes est sous la responsabilité des usagers de l'eau eux-mêmes. Cependant, alors que dans le schéma Golgota la quantité d'eau à distraire est déterminé par les utilisateurs de l'eau, dans le schéma Wedecha elle est contrôlée par une autorité locale d'irrigation. Les deux régimes ont d'abord été évaluée à l'aide de critères sélectionnés et pertinents et associés des indicateurs comparatifs: Ensuite, les qualités internes des services d'irrigation (utilitaire) pour les utilisateurs d'eau ont été évalués à partir de données qualitatives en utilisant la théorie des ensembles flous.

Indicateurs comparatifs sont utilisés pour évaluer et comparer les résultats et les impacts des pratiques de gestion de l'irrigation avec d'autres régimes ou à l'intérieur du même régime sur une période de temps. Elles sont utiles pour comprendre la mesure dans laquelle les intrants et les ressources sont utilisées efficacement pour produire des extrants. Le but principal de l'utilisation d'évaluation comparative dans l'étude actuelle est que les deux régimes même si ils sont tous deux gérés par la communauté, ont typologie différente en termes de dérivation

de l'eau, répartition de l'eau et de la distribution, l'intensité des cultures, des situations taxe sur l'eau et des arrangements de gestion des eaux responsabilité. Ainsi, l'utilisation d'indicateurs relativement simples et bien acceptés permet l'analyse comparative meilleures pratiques de gestion interne d'un régime à un autre pour l'amélioration continue. Les deux régimes ont été évalués au moyen de trois groupes d'indicateurs de performance comparative, à savoir les indicateurs agricoles, les indicateurs de l'approvisionnement en eau et les indicateurs physiques. Comme les données mesurées sur les livraisons d'eau à des points clés n'est pas disponible, l'eau annuel total et les fournitures d'irrigation ont été déterminés en utilisant des mesures canal Parshall et les relations niveau-débit et ont été considérés pour évaluer les indicateurs liés à l'approvisionnement en eau.

Évaluer le fonctionnement interne et les pratiques de gestion et les niveaux de services des systèmes d'irrigation permettent de mesurer la performance actuelle par rapport aux objectifs opérationnels et chiffrés. Les indicateurs utilisés pour cette orientation effet sur la qualité des services d'irrigation tels que l'adéquation, l'équité et la fiabilité qui exigent mesurés de flux de données. Comme ce ne sont pas disponibles à des régimes à l'étude, l'évaluation qualitative de l'utilité des agriculteurs (FU) serait utile. Selon Sam-Amoah et Gowing (2001), l'utilité des services d'irrigation peut être décrit par la fiabilité (prévisibilité), traçabilité, le calendrier de l'offre, le débit et la durée de l'offre. Logique des ensembles flous est une méthode utile pour évaluer ces services à partir de données qualitatives en l'absence de données quantitatives sur les livraisons d'eau. Les évaluations des services publics ont été effectués pour trois emplacements physiques au sein des régimes (atteindre la tête, portée moyenne et atteindre la queue) pour comprendre la tendance dans laquelle l'utilitaire est en mutation. Trois facteurs principaux, à savoir, sa docilité, de discernement (confort) et de la prévisibilité et d'autres sous-facteurs ont été considérés dans l'analyse.

Les résultats de l'évaluation des performances comparatives indiquent à l'égard de deux indicateurs agricoles et physique, régime Golgota ont une meilleure performance au cours Wedecha. Plus d'irrigation intensive, la planification meilleure irrigation et la disponibilité de l'eau sont les raisons pour lesquelles les mêmes. En ce qui concerne l'eau indicateurs de l'offre, les deux régimes retirer beaucoup plus d'eau que leurs demandes et les déchets quantité d'eau considérable. Evaluation de l'offre d'irrigation relative (RIS) montre que l'efficacité globale de l'eau sont de 33% et 37% pour Golgota et Wedecha respectivement, ce qui pourrait être considéré comme très faible. Elle implique que les agriculteurs donnent peu d'attention à économiser l'eau et à appliquer autant d'eau que disponibles. En particulier au régime Golgota, le montant du détournement de l'eau est complètement décidé par les utilisateurs de l'eau et il n'ya aucun frais pour l'eau; donc de retirer trois fois de l'eau d'irrigation effectivement nécessaire dans le domaine. Introduction d'une taxe de l'eau est une solution pratique pour économiser l'eau au Golgota.

Analyse de l'utilité des agriculteurs indiquent qu'en ce qui concerne tous les sous-facteurs considérés d'utilité, les utilisateurs de l'eau Golgota régime sont mieux satisfaits des services d'irrigation, à l'exception des problèmes de sédimentation des canaux. Cela montre que les agriculteurs sont mieux satisfaits quand ils décident de leur eau eux-mêmes les fournitures et quand ils ne paient pas de taxe pour l'eau d'irrigation. Même s'il est très important que les agriculteurs doivent prendre part à l'activité de gestion de l'eau ensemble, quand ils sont entièrement en charge, le gaspillage et la mauvaise utilisation sont susceptibles comme cela a été prouvé par Golgota régime. Ainsi, un organisme d'irrigation doit être en place

pour introduire des droits et de se prononcer sur le retrait de l'eau. Analyse atteindre chef-milieu-queue n'a révélé aucune tendance significative de la variation des valeurs d'utilité à deux régimes.

Mots clés : *Productivité de l'eau, indicateurs comparatifs, service d'irrigation, utilité des agriculteurs, approche des ensembles flous.*

(Traduction française telle que fournie par les auteurs)

1. INTRODUCTION

Agriculture, consuming by far the largest share (more than 70%) of developed global fresh water resources, is the major source of livelihood in almost all least-developed nations. With up to 90% of the population in these countries depending on agriculture, the availability of water resources is crucial. In these countries, the technological advances in control, diversion, conveyance and distribution and field application of water for irrigation is very low; and more of traditional systems are dominant, even in the modern schemes in these nations. The nature of irrigation schemes in these nations are largely small to medium scale community-managed, dominated by small holder farmers.

Although availability of water for agriculture is a top priority to farmers in these countries, less attention is given for quality of irrigation services and efficiency of water utilization. Water is delivered to the fields without any sound assessment of irrigation demands and it depends on availability. This in turn causes non-uniform water distribution across the scheme water users. The degree of non-uniformity and inequity of water distribution depends on the nature of the schemes; in some cases more water delivery could be to head end users and in other cases it could be to tail end users.

In Ethiopia, only nearly 8% of the total irrigation potential has been developed so far. This shows that more and more new irrigation schemes need to be developed in order to utilize the water resources. However, the performance of existing schemes is also equally crucial. The government currently is undertaking several new irrigation developments, but the performance of existing community-managed schemes are given less attention. As a result, many schemes fail to meet the objective they are developed for. In many of these schemes, water management activities are performed by the farmers themselves but they lack the technical expertise to effectively manage their water. Failure of effective operation and management of the schemes result in lack of sustainability in many cases.

In Ethiopia community-managed schemes constitute more than 20% of the total area irrigated; and contribute a lot towards food security at national level. Golgota and Wedecha irrigation schemes, where this research is carried out are examples of those community-managed schemes. The irrigated areas for Golgota and Wedecha are about 1,063 ha and 200 ha, respectively. While in the former scheme, the amount of water diversion is totally decided by the water users themselves, in the later scheme, it is decided by a local irrigation authority. Moreover, water users of Golgota scheme do not pay any fees for the water they use since its developments, however at Wedecha, area-based irrigation water fees are applicable.

2. MATERIALS AND METHODS

2.1 Materials

The Irrigation schemes

This research was conducted at Golgota and Wedecha Community-managed irrigation schemes located in the central part of Etiopia in Awash River Basin. The source of water for Golgota is Awash River using temporary stone and gabion structure while for Wedecha water is provided from a reservoir created using embankment dam on Wedecha River. Water management and operational activities such as canal cleaning and maintenance, water allocation, irrigation scheduling, in both schemes is carried out by the water users. These activities are performed by water user associations (WUA's); except recently the amount of water diversion for Wedecha scheme is controlled by a local irrigation authority. The beneficiary households are 400 and 157, respectively, for Golgota and Wedecha while the corresponding currently irrigated areas amount to 1000 ha and 200 ha.

Questionnaire surveys

Conventional performance assessment methods require measured flow data of irrigation water deliveries. However, in community-managed schemes, such as the ones under consideration, less priority is given to flow measurement, and hence is not available. Consequently, a different approach using qualitative data was used to assess the level of irrigation services in these schemes. The degree of satisfaction of the water users (utility) was assessed using three factors: Tractability, Suitability and Expectedness. Under each of these main factors, sub-factors were considered. Farmers' opinions on the satisfaction of irrigation services were collected using questionnaire surveys. The water users were stratified as head, middle and tail users and the questionnaire was conducted for 10 randomly selected water users from each layer of farmers; totally 30 for each scheme.

Data from local irrigation authority and agricultural office

In order to assess the two schemes under consideration with comparative indicators, data related to amount of water used, irrigated and irrigable area, agricultural production and price of agricultural outputs and other related data were collected from district irrigation development and agricultural offices. The same data were also collected using questionnaire surveys from the water users. Data obtained from these two sources (offices and water users) were used in combination for comparative performance assessment.

2.2 Methods

Comparative performance assessment

There are large numbers of indicators proposed by different researchers to evaluate the performance of irrigation systems (Bos et al., 2005, Molden and Gates 1990, Nelson 2002). All performance indicators can however be broadly classified into internal or process indicators and external or comparative indicators (Renault et al., 2007). The purpose of comparative indicators is to evaluate outputs and impacts of activities related to irrigation management and interventions across different systems or within the same system over time, while process indicators are used to assess the actual irrigation performance in relation to system-specific management goals.

Malano et al. (2004) provided a summary of four groups of benchmarking (comparative) indicators. Under the current study, three groups of comparative performance indicators: agricultural (productive efficiency), water use (supply) and physical indicators were used to assess the performance of the two schemes under consideration.

Agricultural performance indicators

Four indicators were considered in order to evaluate the agricultural performance in this study.

Output per unit of irrigated land (US$/ha): is an indicator used to assess the value of annual agricultural outputs per unit of area actually irrigated.

$$Output\ per\ unit\ of\ irrigated\ land = \frac{GAVP}{cropped\ area}$$

Output per unit command area (US$/ha): is used to assess the value of annual agricultural outputs per unit of total area that can be irrigated.

$$Output\ per\ unit\ comand\ area = \frac{GAVP}{Total\ command\ area}$$

Output per unit of irrigation supply (US$/m^3): is used to assess the value of annual agricultural outputs per unit volume of total annual irrigation water supplied.

$$Output\ per\ unit\ irrigation\ supply = \frac{GAVP}{Annual\ irrigation\ supply}$$

Output per unit of water consumed (US$/m^3): This is used to assess the value of annual agricultural outputs per unit volume of total annual water consumed by evapotranspiration.

$$Output\ per\ unit\ water\ consumed = \frac{GAVP}{Annual\ water\ consumed}$$

Where GAVP is gross annual value of production at local markets (US$), cropped area is the area under crops (Renault, Facon et al.), total command area is the nominal area that can be irrigated (Renault, Facon et al.), annual irrigation supply is volume irrigation water diversion to the irrigated area (m^3), annual water consumed is volume of water actually consumed by the crop (m^3).

GAVP was determined first by collecting data on the area under each crop and the corresponding yield of the crops per hectare of land from both local agricultural development offices and through direct questionnaire. Data on the prices of the crops at local markets was collected from the offices and same was confirmed through interview with the farmers; thus GAVP was calculated as the sum of the value of each of each crop. Data on cropped and command areas were collected from the local agricultural development office for 2009/10 agricultural year. The same was also confirmed by field surveys.

The annual irrigation supply for 2009/10 agricultural year was determined by measuring the volume of irrigation water diverted. At Golgota scheme, a stage-discharge relationship was established on the main canal by using current meter for some flows in the canal. Stage readings were then continuously taken three times a day to find out average daily stage in the canal. Daily and annual flows were determined from the measured stages using the established rating curve. At Wedecha scheme, irrigation supply was determined using Parshall flume for measuring discharge. Similarly, stages at the flume were continuously taken three times a day. Daily volume of irrigation water diverted were determined from the same.

Annual volume of water consumed was determined using CROPWAT 8 program. Relevant meteorological data at stations located nearby the schemes were collected from National Meteorological Services Agency (NMSA). For known irrigation intensity, the cropping pattern along with areas under each crop was fed in the program. The crop water requirement for evapotranspiration is:

$$CWR = Kc * ETo \tag{1}$$

Where *ETo* is reference evapotranspiration and kc is the crop coefficient from FAO guidelines. The unit irrigation requirement (*l/s/ha*) was calculated by CROPWAT program for the given cropping pattern from the crop water requirements. The annual volume of water consumed was then determined based on the total area under irrigation and changing the discharge (l/s) into volumes (m^3).

Water use (supply) indicators

Relative water supply (RWS): This is an indicator to judge whether the amount of water supplied (irrigation + rainfall) is sufficient to satisfy the crop water demand or not. In other words, it is a measure of the adequacy of the water supply. It is expressed as:

$$Relative\ water\ supply = \frac{Annual\ water\ supply}{Annual\ CWR}$$

Relative irrigation supply (RIS): is a measure of the adequacy of the diverted irrigation water to meet the irrigation demand. While RIS value less than 1.0 depicts shortage, RIS greater than 1.0 indicates excess irrigation supply. RIS values near 1.0 are preferable than higher values for purposes of saving water and reducing environmental factors such as waterlogging (Molden, Sakthivadivel et al. 1998). Expressed as:

$$Relative\ irrigation\ supply = \frac{Annual\ rrigation\ supply}{Annual\ IR}$$

The annual water supply is the sum of annually supplied irrigation water and effective rainfall. The irrigation water supplied was determined from stage-discharge relations and using Parshall flumes. As these flow measurements were made at the main canals, losses in conveyance and distribution systems were considered. Effective rainfall was determined from monthly total rainfall with USBR method.

Physical indicators

Cropping intensity: is an indicator used to assess the degree to which irrigated crops are grown in the command area. It is determined as:

$$Cropping\ intensity = \frac{Annual\ cropped\ area}{Cultivable\ area}$$

More intensified cropping is indicative of more utilization of the available land resources for crop production. It is also related to availability of water for irrigation. In areas where irrigation water is scarce, values less than 100% are apparent; while in areas with excess water resources, much higher values are possible. In the current study, actual cropped area was determined for the agricultural year 2009/10 from the local agricultural office which was also supplemented by field interviews with sample farmers.

Irrigation ratio: is an indicator used to evaluate as to what portion of the irrigable area has been irrigated. A maximum value of 1.0 occurs when the whole irrigable part of the command has been irrigated.

$$Irrigation\ ratio = \frac{Irrigated\ area}{Irrigable\ area}$$

Sustainability of irrigated land: is related to loss of irrigated land as compared to the area initially irrigated when the system was developed.

$$Sustainability\ of\ irrigation = \frac{Currently\ irrigated\ area}{Initially\ irrigated\ area}$$

Irrigated area is the actual area irrigated in a cropping season, while irrigable area is the area that can potentially be irrigated. Availability of water resources and abandoning of agriculture business are some of the factors contributing to reduced irrigation ration and loss of irrigated land.

Utility analysis

Assessment of the performance of irrigation systems basically depend on measured flow data of irrigation deliveries. Clemmens and Bos (1990) mention that availability of quality data on water delivery is a key element for statistical evaluation irrigation water delivery systems. In community managed irrigation systems in least-developed countries, irrigation flow measurement is not a priority, and measured flow data is hardly available for longer periods. Thus, evaluation of the appropriateness of irrigation services may be evaluated based on qualitative data on the quality of the services collected from the water users. This gives attention to the water users who are the direct stakeholders in the irrigation system. Several researchers have applied a methodology of performance assessment of irrigation services with minimum data on water deliveries. Sam-Amoah et al. (2001) applied fuzzy set concept for analyzing the performance of irrigation systems from qualitative data (responses of water users) in the case of Dawhenya small-scale irrigation scheme, Ghana. Ghosh et al. (2005) also applied the same methodology to evaluate the performance of irrigation at Orissa, India from the perspective of farmers. In their study, they considered three main factors under which sub-factors were considered to assess the irrigation service Utility.

In the irrigation schemes considered in this study, flow measurement is not considered at all and no stakeholder is interested to measure it. So, the performances of these schemes were evaluated at two levels: first using comparative (external) indicators and then assessing the utility of irrigation service from farmers' responses. In the study, three main factors were considered as a measure of the utility of irrigation service: Tractability, Suitability and Expectedness.

i. *Tractability*: is the ease with which farmers can control and satisfactorily apply water to their land (Ghosh et al., 2005). Under this factor, three sub-factors were considered: volume of water supply, location of turnout and canal condition of canals (maintenance).

ii. *Suitability*: is the situation of water supply as preferred by water users. Three sub-factors: flow rate, duration of water supply and watering frequency were considered under this factor.

iii. *Expectedness*: is the degree of assurance with which the farmer rates future situations of water supply and irrigation services. Three sub-factors: knowledge of future water supply, ease of future planning and certainty of water availability were taken into consideration under this factor.

In order to assess the utility of irrigation service in this study, fuzzy set theory as was depicted by Sam-Amoah and Gowing (2001) and Ghosh et al. (2005) was used.

Utility assessment using Fuzzy set theory

Whenever data on water supplies to each farmer is not available, the overall utility or appropriateness of the irrigation services can be assessed based on the perception of the water users. The water users can be stratified based on the physical location within the schemes and describe their opinions regarding the irrigation service levels with linguistic statements. Fuzzy set concept can be used to aggregate the opinions of all sampled farmers regarding each sub-factor and to evaluate the importance of each sub-factor with respect to appropriateness (utility) of the water supply (Ghosh et al., 2005). This reduces the complexity of assessing the overall utility breaking down into smaller components. As such, fuzzy set concept can address fuzzy descriptions or judgments.

In the classical set theory, the degree of membership of an element of a set is either 0 or 1. This means that an element is either completely a member of a set or not. Unlike the classical set theory, in a fuzzy set an element can have a partial membership. The degree of membership of an element is designated by its support between 0 and 1. In this theory, fuzzy linguistic expressions and support functions for each variable is assigned. Let the range of likely members (universe) of a fuzzy set Z range from scale of 1 to 5, then it is expressed as:

$$Z=\{1/\mu(1),2/\mu(2),3/\mu(3),4/\mu(4),5/\mu(5)\} \quad (2)$$

Where *μ(1)* to *μ(5)* are support of the respective variables of the fuzzy set. One may select different support functions to represent a particular expression with fuzziness. However, the choice of the supports needs to be rational. Ghosh et al. (2005) state that the choice of a support function to represent a fuzzy linguistic expression may depend on the particular problem being taken into consideration. In the current study, a universe of U from 1 to 5 and supports as used by Sam-Amoah and Gowing (2001) and Ghosh et al. (2005) were employed. Fuzzy linguistic expressions with respective support functions used are given in Table 1.

Table 1: Fuzzy expressions and support functions (El-Awad, 1991)

Expressions	μ(1)	μ(2)	μ(3)	μ(4)	μ(5)
Very good/very high	0	0	0.01	0.25	1
Good/high	0	0	0.1	0.5	1
More or less good/more or less high	0	0	0.4	1	0.4
Medium	0	0.4	1	0.4	0
More or less bad/more or less low	0.4	1	0.4	0	0
Bad/low	1	0.5	0.1	0	0
Very bad/very low	1	0.25	0.01	0	0

Aggregation of opinions and linguistic approximation

As has already been stated earlier, in this study a sample of farmers were selected from head, middle and tail reaches of both schemes and asked to rate the irrigation services they receive with linguistic expressions shown in Table 1. The opinions given regarding the service quality by different farmers will be different. So, within each reach of the scheme, different opinions need to be aggregated. The same method as stated by Ghosh et al. (2005) is used in this study. According to this method of aggregation, the average support is calculated for each element of the set; it is added to the maximum support in the set and divided by 2. This gives the aggregated support of each element of fuzzy set.

The fuzzy set with aggregated support functions as discussed above may not have support functions that exactly fit the fuzzy expressions of Table 1. So, in order to use the selected linguistic expressions, the obtained fuzzy set can be approximated to the nearest expression. The method of best-fit as stated by Ghosh et al. (2005) is applied in this study. In this method, let Ai be the fuzzy expressions of Table 1 with i=1,2,3…,7 and B be the fuzzy set obtained by aggregation of the farmers opinions, the difference D is calculated, and then expression with the least difference is the one which approximates the set B.

$$D(B,A_i) = [\sum\{\mu B(X_i) - \mu A(X_i)\}^2]^{1/2} \quad (3)$$

Evaluation of farmers utility

The aggregated opinions of the water users regarding the irrigation services tell the degree of suitability of the services with linguistic expressions. However, it is more convenient for system managers and other stakeholders to use this measure of the level of service when it is converted into a numerical value on a scale 0 to1. El-Awad (1991) calls this numerical value as farmer utility (FU). Utilizing the same method as was used by Ghosh et al. (2005), the FU for a universe consisting of N elements shall be evaluated from:

$$FU = \{1/(N-1)\} * [\{\sum(i-1) * \mu_i\}/\sum \mu_i] \quad (4)$$

Where *FU* is farmer utility, *i* is possible values of the universe U and μ_i is the support of the element *i* of the fuzzy set.

3. RESULTS AND DISCUSSION

Assessment of the performance of Golgota and Wedecha community-managed irrigation systems was made at two levels. First the two schemes were evaluated using comparative indicators to assess the external performance. Next, the internal service levels (utility) was assessed using fuzzy set approach to identify the internal management practices leading to the given level of external performance.

3.1 Comparative performance assessment

Three groups of comparative performance indicators: agricultural (productive efficiency), water use (supply) and physical indicators were used to assess the performance of the two schemes in the current study.

Agricultural (productive efficiency) indicators

There are three main crops grown at Golgota scheme: onion, tomato and maize. The irrigated area is 1,063 ha and total command area is 1,500 ha. At Wedecha scheme, six crops were grown: onion, potato, tomato, lentil & chickpea, cabbage and maize. The irrigated area is 200 ha and the command area is 500 ha. The area allocation for each crop, intensity, productivity and annual value of agricultural production for the two schemes for agricultural year of 2009/10 are summarized in Tables 2 and 3.

Table 2: Crop area allocation, productivity and annual value of production for Golgota scheme

Crop type	Area, ha	% area	Intensity, %	Annual area, ha	Produ. ton/ha	Total prod., ton	Price, US$/ ton	Total annual value, US$
Onion	422	40	300	1,266	17	21,021	412	8,655,799
Tomato	266	25	200	532	30	15,811	294	4,650,306
Maize	375	35	200	750	4	2,900	176	511,765
Total	1,063	100		2,548				13,817,870

Table 3: Crop area allocation, productivity and annual value of production for Wedecha scheme

Crop type	Area, ha	% area	Intensity, %	Annual area, ha	Produ. ton/ha	Total prod., ton	Price, US$/ ton	Total annual value, US$
Onion	55	28	200	110	8.5	935	412	385,000
Potato	31	15	200	62	9.0	557	235	130,866
Tomato	3	1	200	6	18.9	104	294	30,561
Lentil & chickpea	66	33	200	132	1.2	158	882	139,709
Cabbage	21	10	200	41	8.5	351	588	206,168
Maize	6	3	200	11	6.0	66	176	11,616
Total	181	90		362				903,919

Agricultural performance indicators for the two schemes are shown in Table 4. The results of performance with respect to both land and water productivity indicate that Golgota scheme performs better. Higher land productivity values at Golgota are attributed to more intensive irrigation at the scheme. Although the amount of irrigation water supplied with respect to demanded is a bit higher at Golgota, the water productivity values are still higher at this scheme. The reasons could be attributed to other agricultural factors such as soil fertility and land suitability rather than purely water management.

Table 4: Agricultural indicators for Golgota scheme

Parameter/ Scheme	Output per unit of land cropped (US$/ha)	Output per unit command area (US$/ha)	Output per unit of irrigation water diverted (US$/m^3)	Output per unit of water consumed (US$/m^3)
Golgota	12,999	9,212	0.48	0.86
Wedecha	4,520	1,808	0.25	0.49

Water use (supply) indicators

Relative water supply (RWS) and relative irrigation supply (RIS) are the two indicators used to assess the water use performance. The volumes of irrigation water in this study were monitored in the main canal in case of Golgota and in secondary canal in case of Wedecha scheme. Apparently these are not the volumes of irrigation water supplied at field levels, as there are losses in conveyance and distribution systems. Various studies in other similar schemes in the past have shown that the average efficiency in conveyance and distribution is about 50%. Likewise, 50% of the measured flow was considered in evaluation of RWS and RIS at each scheme. Water supply/demand and water use indicators are shown in Table 5.

Table 5: Water use indicators of the two schemes

Parameter	Golgota	Wedecha
Total water supply, m^3	19,699,421	2,293,274
Crop water demand, m^3	14,961,599	1,832,930
Irrigation supply, m^3	14,352,531	1,809,907
Irrigation demand, m^3	9,614,709	1,349,563
Annual RWS	1.32	1.25
Annual RIS	1.49	1.34

The values of RWS and RIS in Table 5 are after accounting for the losses in the canal conveyance and distribution systems. With RIS of 1.49 and 1.34 for Golgota and Wedecha schemes respectively, excess irrigation water is supplied at both schemes. In comparison, the amount of irrigation water supplied with respect to the demand is higher in the case of Golgota. The main reason for more excessive supply at Golgota is the fact that at this scheme, the volume of water diverted is totally decided by the water users themselves, while at Wedecha it is controlled by a local irrigation authority. Moreover, at Golgota scheme irrigation water fee is absent and farmers use as much water as they can for free, which encourages excess water use.

If the flows measured are directly considered, efficiencies of water use becomes 33% and 37% respectively for Golgota and Wedecha. These figures obviously show that nearly three times of the water required at field levels are diverted for irrigation. It is evident that the water users give less attention to water saving issues and waste significantly large amount of water resources. Farmers feel that excess irrigation water application would result in increased yield, and divert the water to the schemes as long as it is available. Lack of sound irrigation scheduling, lack of knowhow on actual crop water requirements, absence of incentive for saving water (for Golgota), absence of technical intervention from concerned stakeholders, etc are some of the factors contributing to wastage of water.

As to the availability and supply of irrigation water to the schemes, at Golgota there is sufficient water supply at the scheme. However, water is used at the scheme with very low efficiency. Awash basin, where this scheme is located is intensively utilized for irrigation with diversions all along the river. In recent years there has been some water scarcity for irrigation in the basin. So, initiatives for saving water are essential. Introduction of irrigation water fee (based on irrigated are) by local irrigation authority or water users associations is recommended as an incentive. Moreover, revision of operation rules based on justifiable field demands is recommended.

At Wedecha scheme, though the volume of water released from the reservoir is controlled by an irrigation authority, still excess water is used. At the scheme, there is significantly large area that can be irrigated, but not irrigated so far. While some of this land could be irrigated with the diverted supply, farmers feel that they would face water shortage if they irrigate more land and leave the remaining land rainfed. Expansion of the irrigated land based on actual field water demand and water supply is recommended to be redesigned by concerned irrigation authority together with the water users association.

Physical indicators

Three physical indicators were used: irrigation ratio, sustainability of irrigation and cropping intensity. Data related to area of the land at the schemes is shown in Table 6.

Table 6: Data related to areas of land at the schemes

Parameter	Golgota	Wedecha
Currently irrigated land, ha	1,063	200
Irrigable (cultivable) land, ha	1,500	500
Initial irrigated land, ha	900	300
Annual area irrigated, ha	2,548	361
Cropping intensity	170%	72%
Irrigation ratio	0.71	0.40
Sustainability of irrigated land	1.18	0.67

The values of physical indicators for the two schemes are shown in Figure 1. The cropping intensity is a useful indicator to judge the degree of utilization of the available irrigable area. Burton et al. (2000) state that cropping intensity values from 100% to 200% are considered good, while an inferior figure is judged low. For Golgota scheme, a value of 170% is reasonably good, while for Wedecha a value of 72% is indicative of less utilization of the cultivable land for irrigated agriculture.

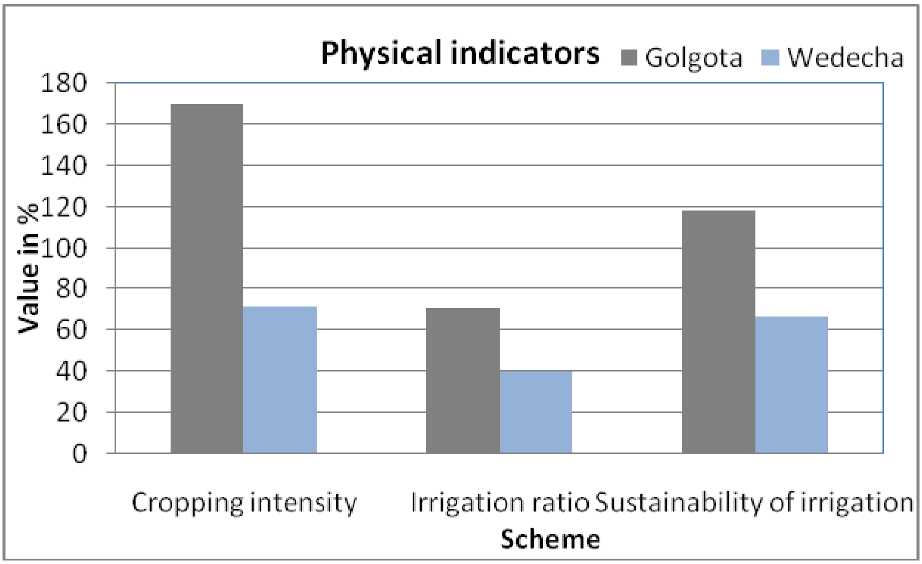

Fig. 1: Physical indicators at the two schemes

Irrigation ratio has also more or less similar purpose as that of cropping intensity' however this indicator considers only the area irrigated in one cropping season and not the cropping area on the same plot of land in a year. Values of 0.71 and 0.40 for Golgota and Wedecha show that 71% and 40% of the irrigable land has been irrigated. While Golgota scheme has a better performance, performance at Wedecha is lower. Lack of full control on the volume of irrigation water diversion at Wedecha and poor off-farm water management are possible reasons for lower performance. Sustainability of irrigation is indicative of whether the area under irrigation is contracting or expanding with reference to the nominal area initially developed. While the area under irrigation is expanding a little bit since its development in case of Golgota, there is a loss of irrigated land in case of Wedecha (Figure 1).

3.2 Utility analysis

Under each of the three main factors to measure the utility of irrigation service, three sub-factors were considered. The results on the utility for head, middle and tail reach water users for both schemes are shown in Table 7.

With regard to head, middle, tail reach utility values within the irrigation schemes, at Golgota utility values at the head reach are lower than middle and tail reaches for factors tractability and suitability. It shows that middle and tail reach users are more satisfied with the irrigation services with respect to these factors. It can be explained with fact that water runs to the tail reaches and head end users as the structures at offtakes are sluice gates with sensitivity less than 1.0. It is however worth to pay attention to certainty of water availability in the factor expectedness. The utility values are higher for head reach users. The possible reason for this is that head end users are located immediately next to the main diversion and feel that they are certain to get water whenever they need.

Table 7: Farmer utility values of the two schemes

Tractability						
Sub-factors	**Head**		**Middle**		**Tail**	
	Golgota	**Wedecha**	**Golgota**	**Wedecha**	**Golgota**	**Wedecha**
Quantity (volume) of water supply	0.68	0.72	0.73	0.65	0.75	0.72
Location of turnout	0.68	0.72	0.72	0.70	0.71	0.69
Canal maintenance	0.41	0.72	0.5	0.74	0.61	0.72
Suitability						
Sub-factors	**Head**		**Middle**		**Tail**	
	Golgota	**Wedecha**	**Golgota**	**Wedecha**	**Golgota**	**Wedecha**
Flow rate of water delivery	0.68	0.83	0.83	0.64	0.83	0.73
Duration of water supply	0.64	0.72	0.73	0.69	0.83	0.71
Watering frequency	0.65	0.71	0.83	0.68	0.72	0.69
Expectedness						
Sub-factors	**Head**		**Middle**		**Tail**	
	Golgota	**Wedecha**	**Golgota**	**Wedecha**	**Golgota**	**Wedecha**
Knowledge of future water supply	0.71	0.5	0.72	0.5	0.73	0.5
Ease of future planning	0.67	0.5	0.73	0.5	0.72	0.5
Certainty of water availability	0.71	0.5	0.66	0.5	0.65	0.5

For Wedecha scheme, the utility values for the sub-factors of tractability do not show appreciable trend/change for head-middle-tail reaches (Table 7). However, for the sub-factors of suitability, the utility values are consistently higher for the head end users than the middle users. This is due to the fact that the flows in the canals are relatively small, and head end users can easily control and use the water as per their demand. It is also interesting to see that the utility values for all the sub-factors of expectedness are 0.50 throughout the three reaches. The source of water for this scheme is water stored in an embankment dam whose operation is controlled by a local irrigation authority. With respect to the factor expectedness, there is no change in the utility values at Wedecha scheme; because water users have little power on the operation of the reservoir and thus have only limited knowledge of future events related to the water supply.

In addition to the head, middle, tail utility comparison within each irrigation scheme, it is also interesting to compare the average utility values of the two schemes. For this, the average utility was evaluated for each sub-factor for both schemes. It is the average utility of the head, middle and tail utilities for a particular sub-factor. Figures 2, 3 and 4 show the comparison of the average utility values at the two schemes for the three sub-factors of each main utility factor.

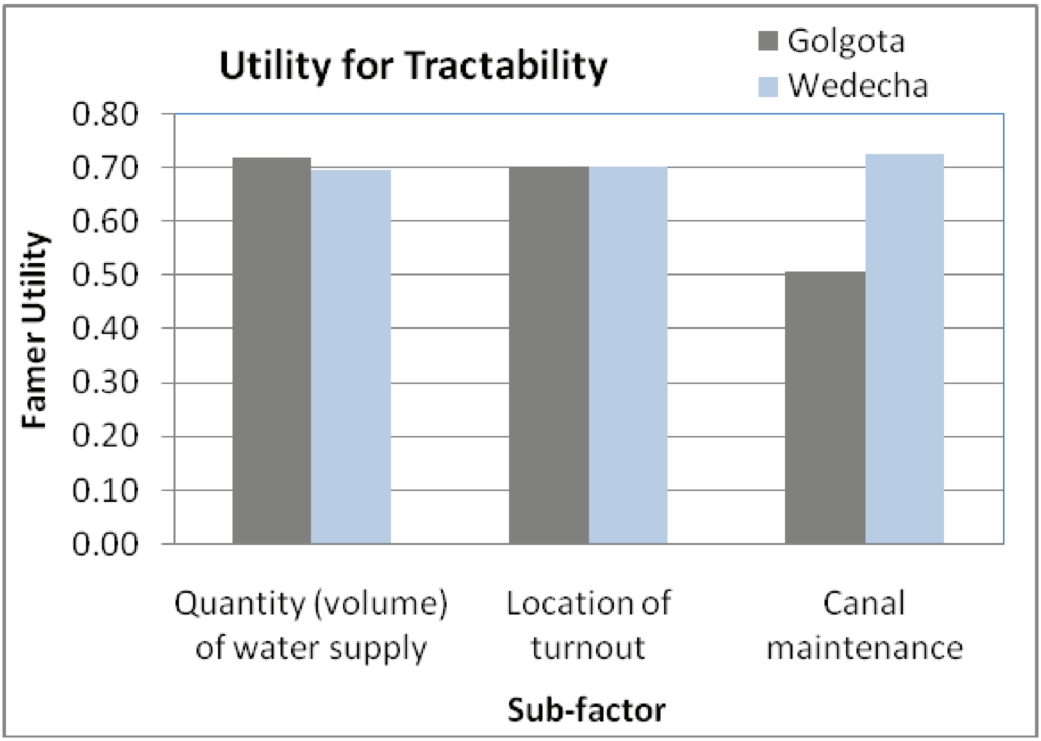

Fig. 2: Average utility values for Tractability

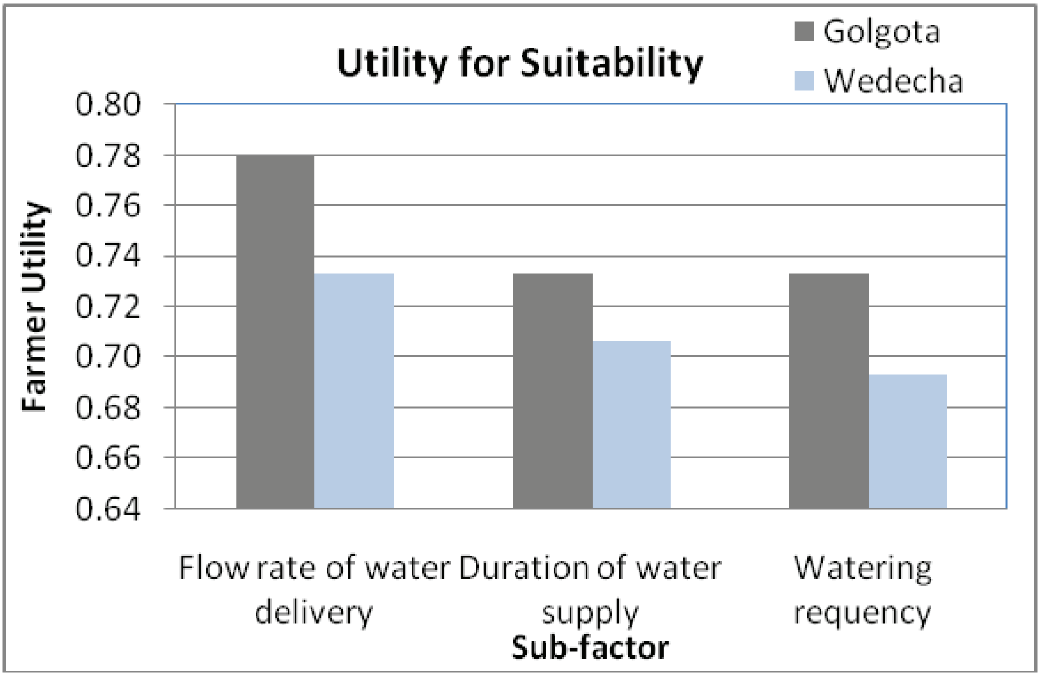

Fig. 3: Average utility values for Suitability

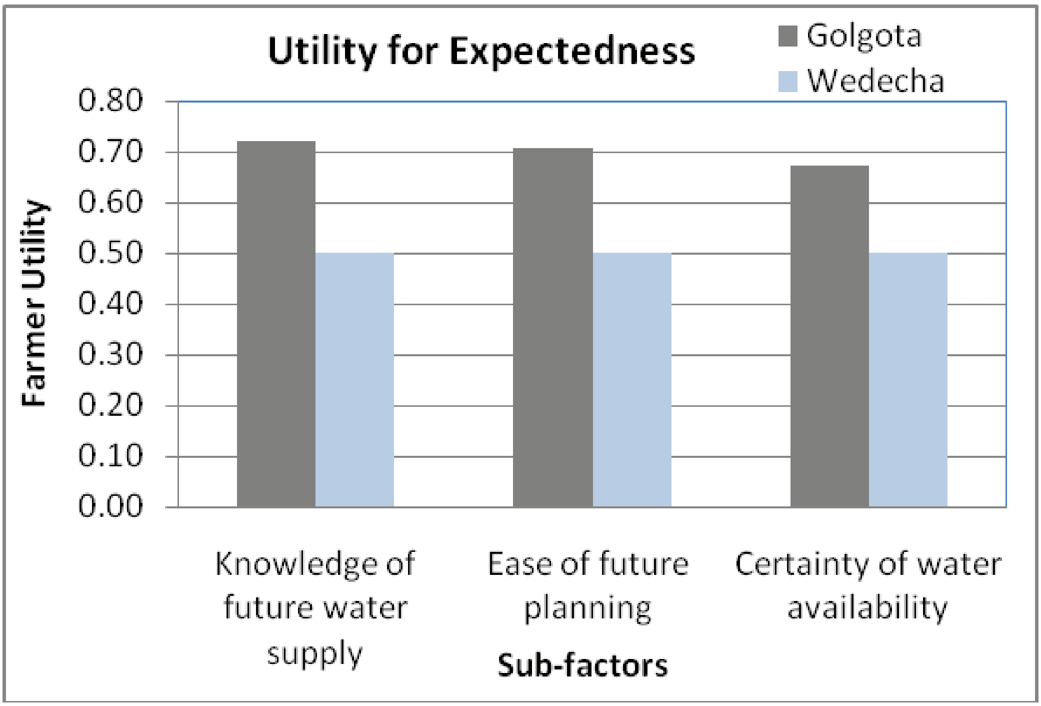

Fig. 4: Average utility values for Expectedness

It can be observed from the figures that the average utility values for all sub-factors are higher for the case of Golgota than Wedecha scheme, except canal maintenance. However, for canal maintenance levels, the utility values are higher for the case of Wedecha. The possible reason can be the fact that at Golgota, water diversion is using temporary gabion and stone structures which passes sediments directly into the main canal; whereas the headwork for Wedecha scheme is an embankment dam with piped outlet in which case there is no serious canal sedimentation.

As has been mentioned earlier, water delivery to Wedecha scheme is controlled by a local irrigation authority and farmers are responsible for off-farm and on-farm water management. So, higher utility values at Golgota indicate that farmers are more satisfied with the irrigation services when they themselves are responsible for all water management activities. The impact of the degree of satisfaction with the irrigation service is also reflected on the levels of external performance of the schemes. The comparative assessment result shows that Golgota performed better due to better irrigation service and satisfaction by the water users.

4. CONCLUSIONS AND RECOMMENDATIONS

In this study, the external performance of two community-managed irrigation schemes: Golgota and Wedecha were assessed using comparative indicators; and then the internal levels of service (utility) were assessed using fuzzy set theory. The comparative indicators used are useful to evaluate the degree of utilization of resources such as land and water in producing agricultural outputs; while utility evaluation is particularly useful to assess the levels of irrigation service from qualitative data whenever little quantitative data is available regarding water delivery.

The comparative indicators used are agricultural, water use (supply) and physical. The result has shown that Golgota scheme has better level of performance with regard to both agricultural and physical indicators. More intensive irrigation at Golgota makes it to have better land productivity. Moreover, as the whole water management is under the water users, they divert as much water as available to sustain the irrigated land area; hence higher physical performance. With regard to water use indicators, out of the total water diverted, only 33% and 37% are consumptively used in Golgota and Wedecha respectively; thus implying significant water losses in both schemes. However, the water loss at Golgota is higher for the fact that water diversion is fully under the control of the water users themselves unlike that at Wedecha scheme. Lack of expertise to determine actual field demands and failure to match supplies with demands make excess water diversion at Golgota. Moreover, there is no irrigation water fee at Golgota scheme; and thus there is no incentive for farmers to save water. Farmers divert water to their fields based on availability without due attention to actual field demands. Introduction of irrigation water fee is recommended as an incentive to save water at Golgota. At Wedecha scheme, the amount of water being used could command additional area; expansion of irrigated land with sound irrigation scheduling is recommended to reduce water losses.

The internal levels of irrigation services (utility) were assessed using three main factors and three sub-factors under each main factor. Head-middle-tail reaches utility assessment within each scheme and across the two schemes was made. The result of the assessment using fuzzy set concept implies that farmers at Golgota scheme are better satisfied with the irrigation services with respect to all sub-factors, except problems in canal maintenance. The fact that the main diversion at Golgota is a simple stone and gabion structure allows large sediment load to inter into the canal. This is attributed to the fact that: 1. farmers are responsible for the amount of water they divert; 2. they do not pay any fee for the water they use. It can be concluded that farmers are better satisfied when they decide on the amount of water they use and when they use irrigation water for free. It is good that water management is by water users themselves; however, as they lack most of the technical expertise, it would be better if there is an intervention from a local irrigation agency to put in place some guidelines to reduce wastage of water.

Water users at Golgota are responsible for the overall water management including maintenance of the main diversion and have not paid any irrigation water fee since they started irrigation. Rapid expansion of irrigation within Awash basin where this scheme is located cannot allow excessive water use and wastage in the next years. So, institutional reforms for water management at the scheme are essential. The water users association (WUA) would have to be strengthened and capacitated through training for efficient water management. The local irrigation authority is recommended to observe the activities of the WUA and assist them in implementing efficient water management and water saving strategies.

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