Assessment of Irrigation Performance along the Canal Reach of Community Managed Scheme in Southern Ethiopia

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Abstract

This paper presents the results of irrigation performance assessment made along the canal reaches of community-managed Hare irrigation scheme in Southern Ethiopia. Field measurement, interview, group discussion and measurement of water supply were undertaken, and output performance indicators were assessed. Measurements of cropping intensity, irrigation interval and productivity show that there is a distinct difference in performance along the main canal. Upstream water users always have easy access to water, higher annual income and resource base than those in midstream and downstream. Disparity among users occurs due to lack of functional institutions and poor conditions of water distribution systems.

Keywords: *upstream, midstream, downstream, performance, access to water, productivity*

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Introduction

Evaluation of water distribution along canals in terms of performance has attracted the attention of many researchers in recent years (Abdullaev et al., 2009; Unal et al., 2004). Well operated water distribution systems often have multi-objectives such as equity, adequacy and timeliness (Santhi et al., 2000). These objectives are not always achieved in community-managed irrigation schemes where appropriate institutions, capacity and skills to manage water are often lacking. Generally, there is a common perception that water users located at the upstream of the irrigation system have more access to water than those located at the downstream of the system. Moreover, the irrigation activity of tail-enders is seriously affected in both water-scarce and water-abundant periods due to under and over irrigation, respectively. It is also common for the population in an area to increase following the establishment of an irrigation scheme, because people migrate from other areas to reap the benefits of an irrigation scheme. Land acquisition of new comers is most likely at the downstream of the canal within the system. These late settlers may not only become the victims of water shortage but the whole irrigation system can also be over-exploited as the initial designed capacity may not meet the increased demand through time. Unless available water and demand for water are continuously monitored and managed, competition for land and water could be a major cause of conflict among water users.

The Hare irrigation scheme near Arba Minch town in Southern Nations, Nationalities, and People's Regional State was used as a case study of irrigation performance, and to describe related problems. In Hare irrigation scheme, there are three diversion sites very close to each other that are planned to serve a wide range of users. Before the establishment of the scheme, irrigation practices were limited to a number of farmers living close to the water source, and irrigation methods employed were also traditional (Bruhl, 1996).

In Hare scheme, there are complaints among four peasant associations (*kebeles*) regarding unequal distribution of water among the users. Especially during dry seasons, Kolla Shara *Kebele* which is served by the up stream diversion structure diverts water without considering the share of the three other *kebeles* (Chano Dorga, Chano Chalba and Chano Mile) fed by two downstream diversions. This may ultimately affect productivity and disturb livelihood systems. Furthermore, the situation of landholding affects the productivity and income of the farming community. If water is sufficiently available, the direct benefits of irrigation, in terms of increased farm output, tends to accrue in proportion to the size of landholdings with large holders benefiting more than smallholders and smallholders benefiting more than the landless. With this background, the objective of this study was to assess the spatial variation of irrigation performance in Hare community-managed irrigation scheme in the southern region of Ethiopia, with the following specific objectives:

- To assess and capture the water distribution performance of the scheme
- To evaluate the effect of location from the upstream to downstream in terms of performance of agricultural production (intensification and productivity), income and resources base

Description of the Study Area

Location and Climate

Hare irrigation scheme was established in 1996 with the technical and financial support of the Chinese Government. It is found in the Southern Nations, Nationalities, and People's Regional State (SNNPR). It is located at about 10 km east of Arba Minch town. Astronomically, it is situated at 6^0 30′ to 6^0 38′ N and 37^0 33′ to 37^0 37′ E longitudes. The soil of the study area is characterized as sandy loam to clay loam.

The area is characterized by mean maximum and minimum temperatures of 30.3^0C and 17.4^0C, respectively. It has the annual rainfall of 843 mm and potential evapo-transpiration of about 1644 mm. Mean monthly distribution of these parameters are shown in Table 1. The rainfall distribution pattern is bimodal with first and maximum peak from April to March and second peak in October. The area is characterized by high potential evapo-transpiration rate that ranges from 112 mm in July to 180 mm in March. Except in April and May, the evaporative demand of the area is greater than the amount of natural rainfall. This means that there is a negative 'climatic water balance' in the area that calls for supplementary water application to the crop fields through irrigation to sustain crop production. The warmest months of the year are February and March, while the coldest are November and December.

The maximum flow hydrograph of Hare River, which is the source of water for the scheme, shows also two distinct peaks that occur in May (5.60 m^3/s) and October (4.53m^3/s). The low flow hydrograph between the two peak rainfall periods, i.e. from May to October, is almost consistent ranging from 1.26 to 1.62 $m^{3/}s$. The low flow declines from December to April.

Table 1: Mean monthly values of hydro-meteorological parameters: Hare (data: Ministry of Water Resources (MoWR), Ethiopia)

	Rainfall (mm)	PET (mm)	Temperature (^{0}C)		Hare River Flow (m^3/s)	
			Maximum	Minimum	Maximum	Low flow
January	28.1	139.5	31.7	16.3	1.31	0.69
February	27.9	140.0	32.9	17.1	1.49	0.64
March	64.0	179.8	33.0	18.3	1.95	0.63
April	144.1	141.0	30.8	18.2	4.06	0.85
May	140.5	136.4	28.9	17.9	5.59	1.33
June	63.1	120.0	28.1	17.9	3.79	1.25
July	43.4	111.6	27.7	17.9	3.81	1.26
August	53.2	124.0	28.5	18.0	3.54	1.31
September	78.1	135.0	30.1	17.8	4.26	1.33
October	110.6	136.4	29.8	17.7	4.53	1.62
November	59.3	138.0	30.6	16.0	2.65	1.16
December	31.1	142.6	31.1	15.7	2.13	0.93
Total/Mean	**843.2**	**1644.3**	**30.3**	**17.4**	**3.26**	**1.09**

Description of the Irrigation Scheme

Hare irrigation scheme encompasses three diversion systems - the upstream diversion with control gate, the midstream traditional diversion, and downstream diversion weir. These diversion points are respectively designated as D1, D2 and D3 (*1*). The upstream and midstream diversions and their delivery systems were established in the year 1993 while the downstream diversion weir was implemented in 1996. It was meant to serve four villages or *kebeles* visavis Kola Shara, Chano Dorga, Chano Chalba and Chano Mille. Figure 1 shows the diversion points and the canal systems delivering water to the respective *Kebeles*.

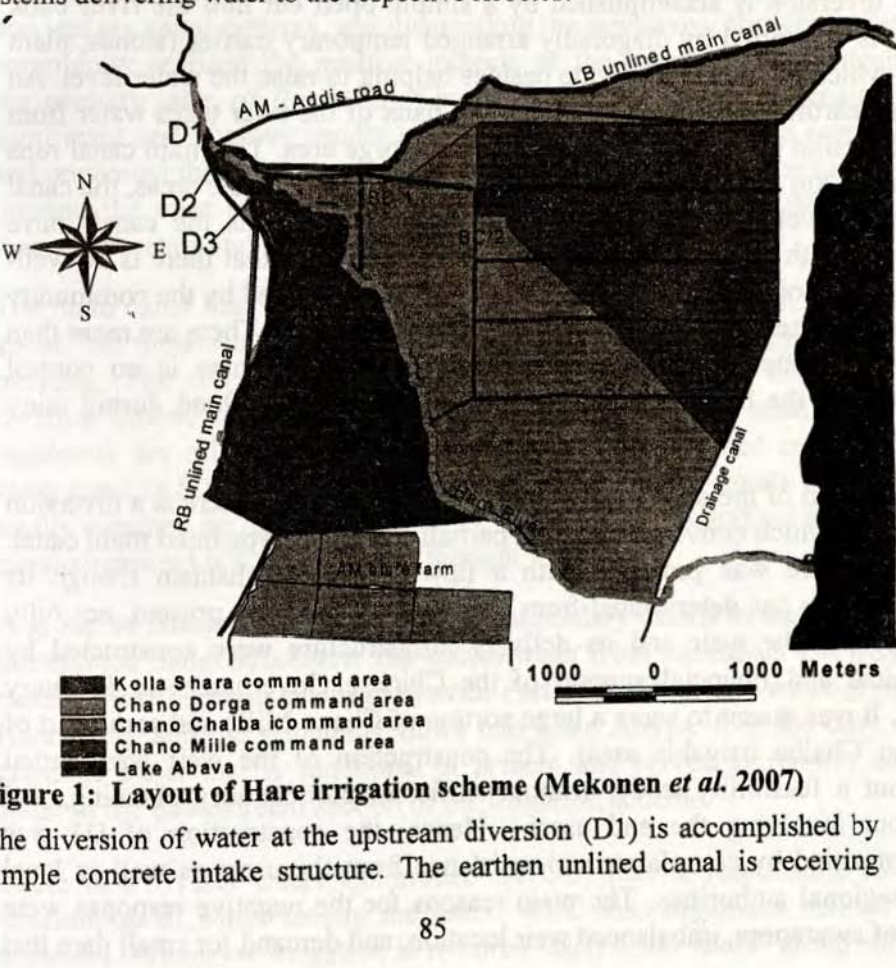

Figure 1: Layout of Hare irrigation scheme (Mekonen *et al.* 2007)

The diversion of water at the upstream diversion (D1) is accomplished by simple concrete intake structure. The earthen unlined canal is receiving water from the intake structure to irrigate Kolla Shara command area. The 6 km long main canal was initially trapezoidal in shape; however, it is now irregular due to lack of maintenance and damage caused by human and animal interferences. The canals pass through a series of settlements and are subject to damage by human and animals. Damage caused so far includes bank breaks, overtopping, weed growth, accumulation of silt, and disposal of wastes in the canals.

The midstream diversion (D2) is the point at which traditional diversion of water is practiced. This means that there is no headwork regulator, and water diversion is accomplished by a simple open cut into the river bank which is supported by diagonally arranged temporary barrier (stones, plant rests) which act as a wall divide besides helping to raise the water level. An unlined earthen canal running on the left bank of the river takes water from this diversion point (D2) to irrigate Chano Dorga area. The main canal runs over a 7.1 km distance and has got irregular shapes. In some areas, the canal bed has developed into gorges while in other locations the canals have shallow depth and wide surface areas. It is safe to say that there is no well-designed secondary canal. Hence, field channels arranged by the community take water directly to irrigate their corresponding fields. There are more than 60 major outlet points along the main canal. Since there is no control structure at the head, some farm fields are affected by flood during rainy seasons.

Downstream of the above mentioned intake points (D2), there is a diversion weir (D3) which conveys water to a partially masonry type lined main canal. The structure was provided with a flow control mechanism though its Performance has deteriorated from time to time and is, at present, not fully functional. The weir and its delivery infrastructure were constructed by technical and financial support of the Chinese Government in February 1996. It was meant to serve a large portion of Chano Mille and some part of Chano Chalba irrigable areas. The construction of the weir was started without a feasibility study, without sufficient participatory planning, and without involving the end users. Hence, the construction of D3 was accompanied by complaints and resistance from the users as well as local and regional authorities. The main reasons for the negative response were lack of awareness, imbalanced weir location, and demand for small dam that could ensure the balance between water supply and demand over the growing season. During the construction phase, the communities realized that the implementation of the system would bring about the dissections of their fields for delivery systems and for the access roads etc., and thus they grew more and more reluctant. In spite of this resistance, the Chinese contractors went along with the construction of the diversion weir.

While the construction work was in the final phase, some parts had started to give partial services but the discontented farmers started partly destroying the irrigation channels, particularly plowing over the secondary and tertiary canal systems, and dismantling the structures. But gradually, the community realized the positive impacts of the intervention. Particularly, the primary user of this weir, Chano Chalba is benefiting greatly with significant and positive results seen in livelihoods. Those who complained and prevented the irrigation canal from reaching their field at the time are, at present, the ones struggling to bring the water to their own field through their own means and as such are relatively poor.

The main canal that takes water from the weir is of two types. A length of about 100 meters is masonry rectangular canal and then trapezoidal stone pitching. The other irrigation infrastructure such as the turn outs, the division boxes, the road crossings, the drops, and the head and cross regulators are all constructed with masonry and reinforced concrete. The main canal is 5.33 km long. There are seven secondary canals which when totally summed up have a length of 12.95 km. The longitudinal slope of the canal alignment is 0.1 %, ensured through 13 drops.

A group of farmers take water from the secondary canals to their field plots through the outlet structures. The excess water from the canals and from the runoff joins the main drainage system. Part of the drainage water joins the Hare River and the remaining flows into Lake Abaya. It is the only main drainage canal that is functional at present and serves to remove excess water at the downstream section of the irrigation scheme.

There is a 'Water Users Committee' (WUC) that is responsible for fair distribution of water among the users. WUC also organizes maintenance activities. Whenever irrigation is required, each water users' group submits a request for water to the WUC. Once the request is made to the WUC, the committee then prepares a tentative time schedule upon which water distribution and irrigation can be made.

Prior to the construction of an irrigation scheme in the area, local farmers used to irrigate their lands, approximately 300 hectares, in traditional ways. After the implementation of first and second phase construction in 1993 and 1996, more than 1031 ha and 1336 ha of land respectively have been developed (Bruhl, 1996), see Table 2, greatly increasing the irrigated area. The number of beneficiaries has also increased. The principal crops grown in the command area are banana, maize, mango, avocado, sweet potato and cotton. Those farmers who have better access to water prefer growing banana as a cash crop mainly due to its marketability, a relative quick return on investment, non- intensive management and its role to the year round food security and income. The area is also suitable and known for fruits such as mango, avocado, and papaya in the central market. Farmers grow crops such as maize and sweet potato for their own consumption. Cotton is an alternative crop for tail-enders as it withstands water stress conditions.

Table 2: Demographic feature and irrigated areas of Hare irrigation scheme (data: Belete, 2006)

Name of Villages	Number of Households			Population			Irrigated area in 2006, ha
	Male	Female	Total	Male	Female	Total	
Kola Shara	800	164	964	2358	2474	4832	617
Chano Dorga	413	20	433	1403	1363	2766	242
Chano Chalba	751	175	926	2339	2713	5052	649
Chano Mile	821	102	923	3950	3074	7024	454
Total	2785	461	3246	10050	9624	19,674	1962

As per the information in 2006, the total number of beneficiary households is about 3,246 out of which 14% are female headed. The relative proportion of female and male of the total population in the command area is almost equal. More female households are found in the command areas of upstream and modern diversion canals viz. in Kola Shara and Chano Chalba commands.

Assessment Methods and Approach

Methodological framework followed to carryout the assessment is presented in Figure 2.

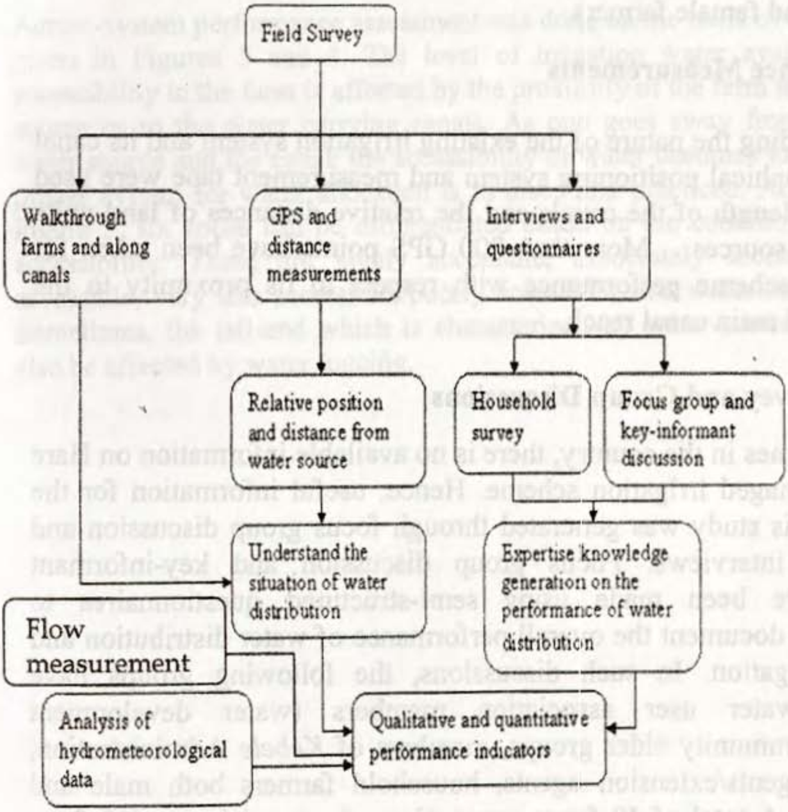

Figure 2: Methodological framework used for the assessment field observation of farms and canals

As there were no design documents that show canal layout and farm boundaries and units, the first activity of the researchers was to walk through the farms and along the canals to obtain an overview of the routes of water distribution and document the nature of landholdings and farming systems. The scheme was frequently visited to examine the operations, the conditions and functions of irrigation systems, agronomic practices of farmers, cropping patterns, etc. These visits were conducted with the accompany of different water users and operators group, vis-à-vis water development committee members, administrators, local elders, model farmers, male and female farmers.

GPS and Distance Measurements

After understanding the nature of the existing irrigation system and its canal network, geographical positioning system and measurement tape were used to measure the length of the canals and the relative distances of land units from the water sources. More than 800 GPS points have been taken for evaluating the scheme performance with respect to its proximity to the watercourse and main canal reach.

Household Survey and Group Discussions

Like other schemes in the country, there is no available information on Hare community managed irrigation scheme. Hence, useful information for the execution of this study was generated through focus group discussion and key-informant interviews. Focus group discussion and key-informant interviews have been made using semi-structured questionnaires to understand and document the overall performance of water distribution and outputs of irrigation. In such discussions, the following groups have participated: water user association members (water development committee), community elder groups, members of *Kebele* Administration, development agents/extension agents, household farmers both male and female headed. A total of 48 focus group discussion participants (12 from each *kebele*), and 150 household heads have been considered for interviews based on a 38-paged questionnaire. An attempt was made to understand the system and collect data necessary to measure the performance indicators.

Canal Flow Measurements

The main canal, the secondary canal, tertiary canals and field canals including the drainage lines of all the three schemes have been inspected. The capacities of the canal systems have been measured at different reaches. Measurements of flows in the canals have been conducted after the canals were maintained, i.e. after the removal of sediments, weeds and other barriers in the canals.

Across-system performance assessment was done on the basis of illustration given in Figures 3 and 4. The level of irrigation water availability or accessibility to the farm is affected by the proximity of the farm to the water source or to the water carrying canals. As one goes away from both the water source and the canal, the accessibility of water becomes low unless a proper system for water allocation is in place and practiced. According to Figure 3, six zones can be differentiated based on the condition of water accessibility. These are highly accessible, moderately accessible, less accessible, very less accessible, poorly accessible, and water-scarce areas. Sometimes, the tail-end which is characterized by water-scarce zone can also be affected by water logging.

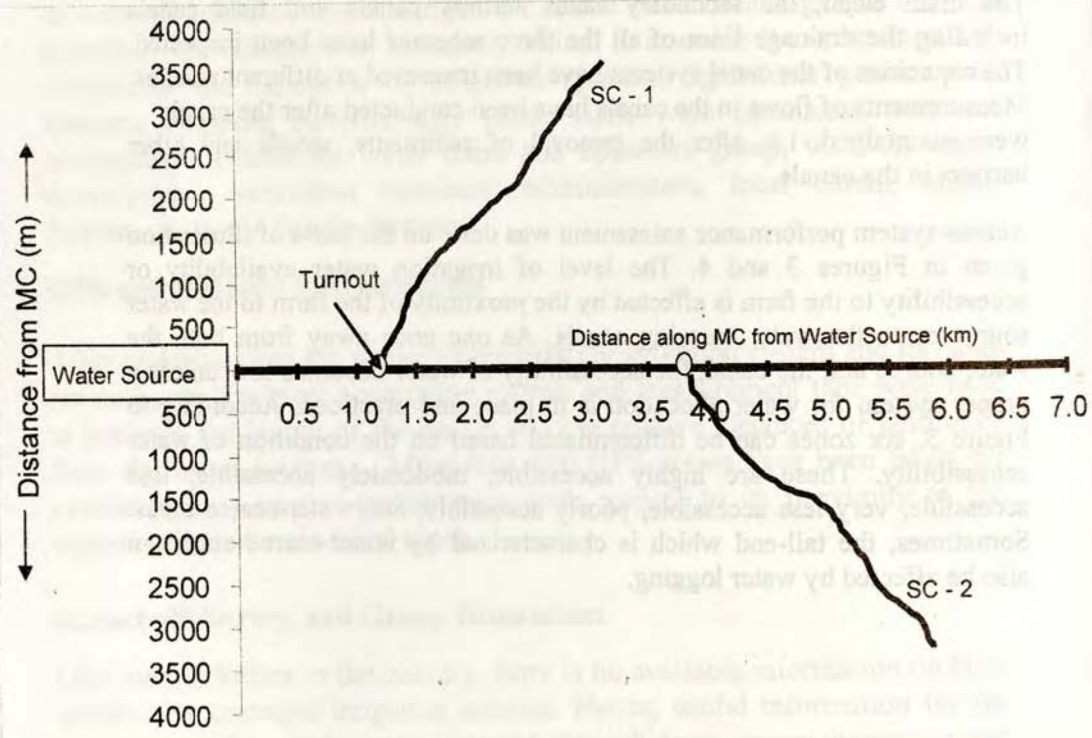

Figure 3: Simple illustration of the approach followed for the assessment

All relevant data were collected along the main canal (MC) and secondary canals (SC) that are functional during the season. Accessibility of water to a farm unit which is measured in amount and timely delivery is defined in this case with respect to proximity to water source that decreases from the head to tail end of the canal systems. The assessment was carried out following two directions (Fure 4*),* i.e., (i) along the main canal that receives water from the main source and (ii) along secondary canals that take water from the main canal. The hypothesis here is that the secondary canal 1 (SC-1) has more access to water than the secondary canal 2 (SC-2) due to its relative closeness to the water source along the main canal. Likewise, there are differences along the secondary canal itself as one goes from head to tail, see Table 3.

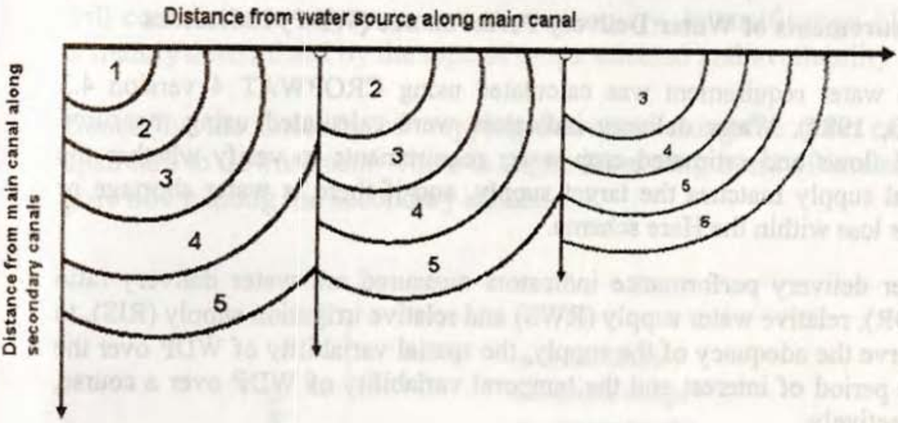

Figure 4: Simple conceptual illustration for different levels of water accessibility along the canal reaches

Table 3: Summary of information in Figure 4

Zones	Distance ranges along(in meter)		Water accessibility
	Main canal	Secondary canal	
1	0 – 500	0 – 250	High
2	500-1000	500-750	moderate
3	1000-1500	570-1000	less
4	1500-2000	1000-1250	Very less
5	2000-2500	1250-1500	Poorly accessible
6	2500-3000	1500-1750	Water scarce

Areas that fall in the regions of poorly available and water-scarce zone are characterized by critically limited water availability and hence depend more on rainfall. Water logged areas are located at the end of the systems. The owners of such land are suffering from shortage of water during irrigation and flooding during off-irrigation periods. These areas are covered by cotton which is relatively water stress resistant compared to common crops grown in the area. Irrigation performance has been assessed using performance indicators given by Molden and colleagues (1998).

Measurements of Water Delivery Performance (WDP) Indicators

Crop water requirement was calculated using CROPWAT 4 version 4.3 (FAO, 1989). Water delivery indicators were calculated using measured canal flows and estimated crop water requirements to verify whether the actual supply matches the target supply, and if there is water shortage or water loss within the Hare scheme.

Water delivery performance indicators measured are water delivery ratio (WDR), relative water supply (RWS) and relative irrigation supply (RIS), to observe the adequacy of the supply, the spatial variability of WDP over the time period of interest and the temporal variability of WDP over a course, respectively.

WDR relates the volume of water actually delivered by the canals to intended volume of water to be delivered. RWS is the ratio of total volume of water supplied to total volume of water demanded by crops. RIS is the ratio of total volume of irrigation water diverted to total volume of irrigation water demanded. The closer the values of these indicators to unity, the better are the water delivery performance.

Results and Discussions

General Practices

One of the most important problems that exist in and around the small- and medium-scale irrigation schemes in the country are discrepancies between design specifications of the systems and expectations from the same. No reference is usually made, if at all available, to the design documents while operating and managing the schemes.

With increasing population, the size of the landholdings in an area becomes smaller and smaller. This is exactly what is observed around successful irrigation schemes. The main advantages of irrigation practice lay on provision of opportunity for intensification of cropping. Under decreasing size of landholdings in irrigated agriculture, intensification of cropping coupled with productivity improvement is the way to enhance food production. There is no doubt that better access to inputs and technologies will contribute to improvement of productivity. Intensification of cropping is mainly determined by the type of crops selected and availability of water.

Generally, the intensity of cropping decreases along the main canals from upstream to downstream. There is slight decreasing trend of intensity as one goes down along the secondary canals.

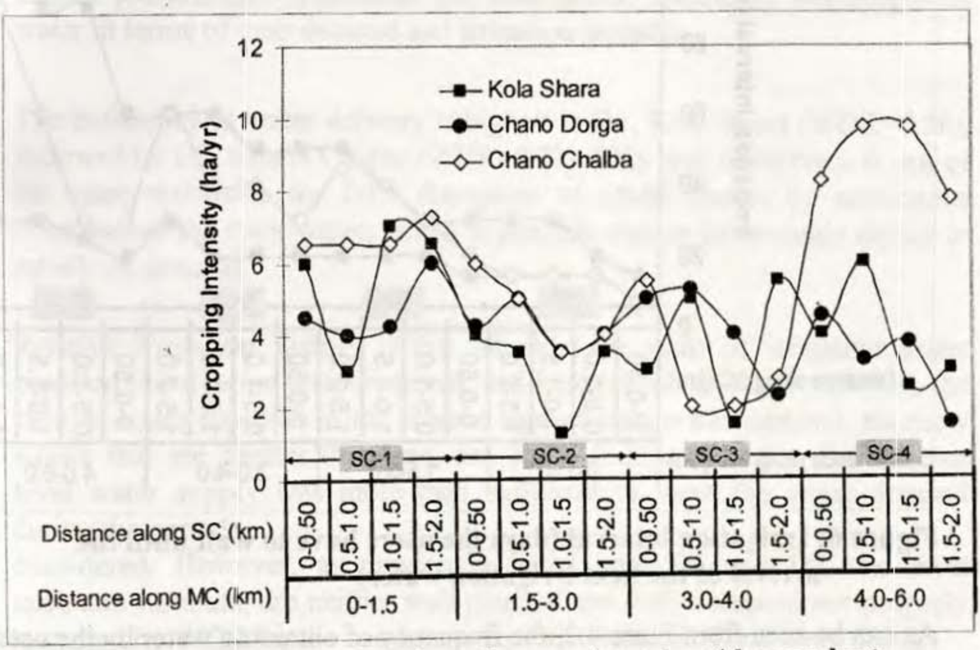

Figure 5: Cropping intensity along the canal reaches (the product of average area cultivated per season and frequency of harvest per season)

Under Chano Chalba condition, the trend of the curve coincides with the Kola Shara and Chano Dorga upto a certain distance beyond which rapid rise takes place. Farmers located here, i.e., 4 – 6 km away from the diversion point along this canal, are practicing higher crop intensification compared to those located in the middle and head regions of the canal.

These farmers are trying to convert the challenges of flooding and shallow groundwater depths in the tail regions of the canals into opportunities by adopting multi-cropping system or intercropping.

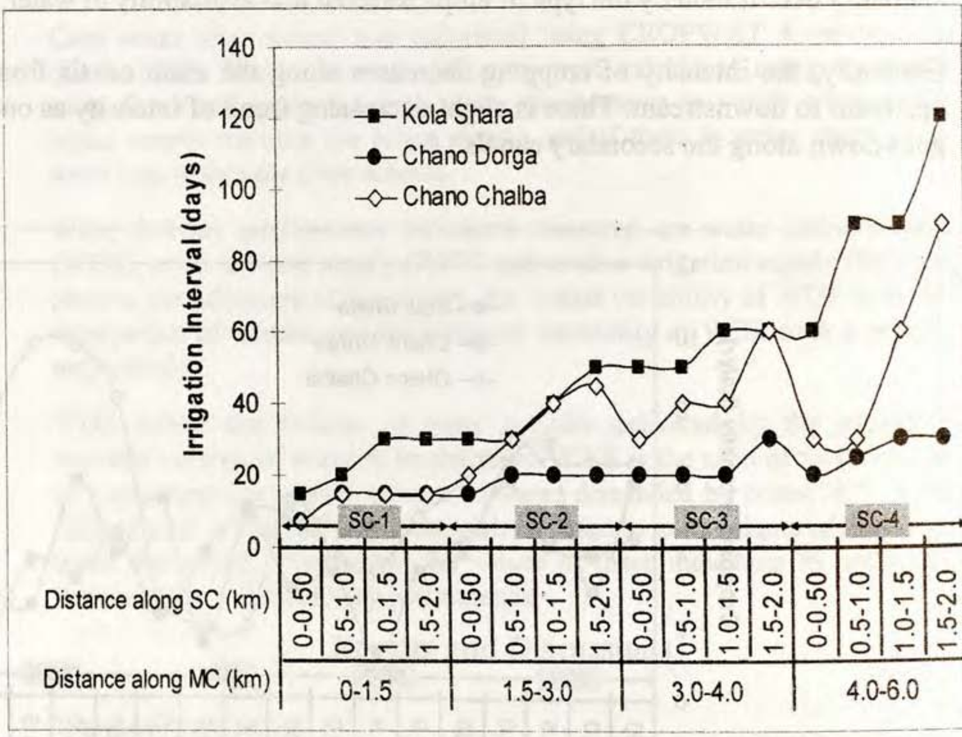

Figure 6: Irrigation interval (days the users have to wait until the arrival of the next irrigation water)

As can be seen from Fiure 4.2, the frequency of obtaining water by the users decreases from head to tail-ends of all canal systems. It varies from 7 – 30 days, from 7 – 90 days, and from 15 – 120 days in Chano Dorga, Chano Chalba and Kola Shara respectively. Irrespective of the location of diversion point with respect to each other, those users close to the water source have frequent access to water. The communities using traditional diversion obtain water frequently compared to Kola Shara and Chano Chalba that use simple diversion structures and diversion weirs respectively. As a result, it was observed that farmers located downstream are accustomed to growing water stress tolerant crops such as cotton, sweet potato etc., and have limited crop diversity.

Water Delivery Performance

The values of some performance indicators are given in Table 4. With regard to water delivery (WDR), Chano Dorga which is served by traditional diversion (D2) was found to perform better than the others. Chano Dorga, however, is also characterized by very high values of water supply performance indicators, i.e. RIS, RWS, indicating oversupply of water in terms of crop demand and irrigation demand.

The deficiency in water delivery is highest in D1, Kola Shara (WDR=0.56), followed by D3, Chano Chalba (WDR=0.71). This lack of delivery is one of the main rationales for D1's disruption of others shares by continuous diversion of the river water, which is possible due to its strategic ability to satisfy its demand.

Relative Irrigation Supply (RIS), which is the ratio of irrigation water supplied to irrigation water required, and Relative Water Supply (RWS), the ratio of water supplied to the scheme against crop water demand, all show values that are greater than one, see Table 4. This indicates that scheme level water supply was more than sufficient to meet the water demand during the period considered. However, as previously stated both D1 and D2, the most upstream turnouts, are neither well planned and well designed nor properly managed by WDC for the maximum expected demand. Thus, even though scheme level demand is supplied, most downstream users are not able to benefit from the irrigation scheme and remain victims of social imbalance and lowered standard of living. Deterioration in canal capacities due to lack of maintenance and heavy siltation is a serious problem that affects water distribution in the (Mekonen, et al., 2009).

Table 4: Values of water Supply performance indicators

Performance Indicators	Kola Shara	Chano Dorga	Chano Chalba
Water Delivery Ratio (WDR)	0.56	1.09	0.71
Relative Irrigation Supply (RIS)	1.40	2.70	1.78
Relative Water Supply (RWS)	1.18	1.79	1.36

The community in Kola Shara, Chano Dorga and Chano Chalba are served by the upstream, midstream and downstream diversions respectively.

Output Performance

Table 5 and Figure 6 show the output performances of irrigated agriculture across the system considered. The productivity of land and water was greater in Kola Shara, which is located upstream in the system followed by Chano Dorga, and the least was in Chano Chalba. Figure 4.3, shows that the productivity of banana decreases from upstream to midstream rapidly in Kola Shara and Chano Dorga command areas. From midstream to downstream, no decreasing trend both along the main canal and the secondary canals is observed; however, variations among the canals, in terms of productivity, are visible. The lower areas of tail enders are usually characterized by shallow groundwater tables (0.6 – 2 m below the surface), which are likely to contribute to the water requirements of perennial crops.

Table 5: Values of output performance indicators

Performance Indicators	Kola Shara	Chano Dorga	Chano Chalba
Output per Water Consumed (birr/m^3)	0.56	0.44	0.35
Output per Cropped Area (birr/ha)	4400	3464	2736

Large differences in the productivity of banana were observed over a 1.5km canal distance form the water source. In the midstream reach, the level and the variation of productivity are low. At the downstream regions, both the production and productivity rises. This may be due to shallow groundwater levels contributed by poorly drained downstream areas from which perennial crops such as banana could benefit.

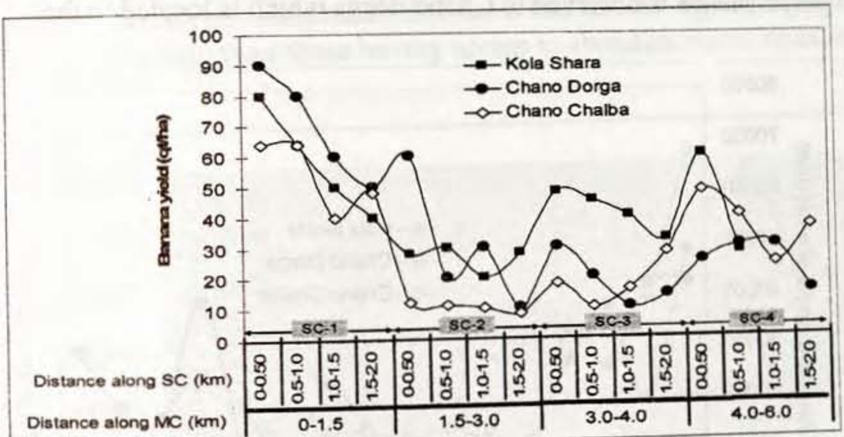

Figure 6: Productivity variation of banana along the canal reaches

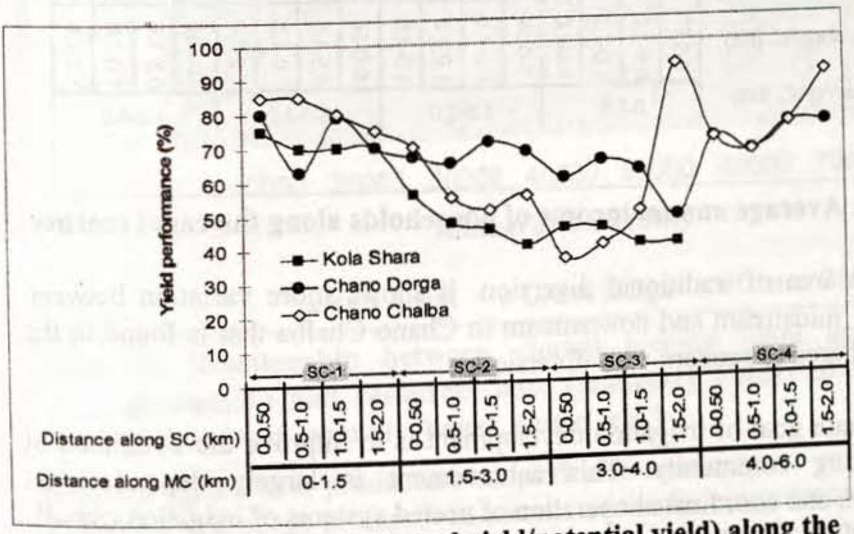

Figure 7: Yield performance (actual yield/potential yield) along the canal reaches

Yield performance which is the ratio of actually harvested yield to potentially harvestable yield of crop varieties can be an indication for how agronomic practices and other inputs (water and agrochemicals) were effective to exploit the yielding potentials of the crops selected. The indicator also shows a decreasing tendency towards midstream. Almost equal yield performance is observed in Chano dorga which is located in the

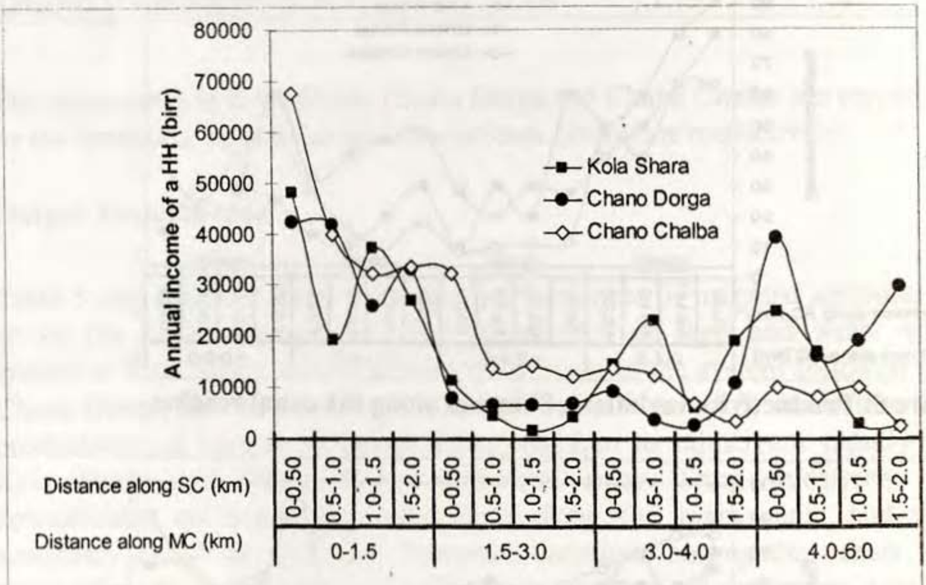

Figure 8: Average annual income of households along the canal reaches

command area of traditional diversion. It shows more variation between upstream, midstream and downstream in Chano Chalba that is found in the command area of modern weir diversion.

The ultimate goal of irrigation development is to improve the livelihood of the farming community. This achievement is largely dependant on integration and coordinated operation of nested systems of irrigation (Small *et al.,* 1992). As the production increases, the income of the farmers is likely to increase. Other factors such as marketability of the produce and market access influences the total income of the households. The annual income of households that have year-round access to water, be it from canal or groundwater, is greater than farmers with limited access to water (Figure 9). Annual income of households in Kola Shara and Chano Dorga command areas is variable irrespective of proximity to the canal. Most often, resources are efficiently and effectively utilized when they become scarce. Similarly, households that have less access to water tend to use it more efficiently than those having access to abundant water resources.

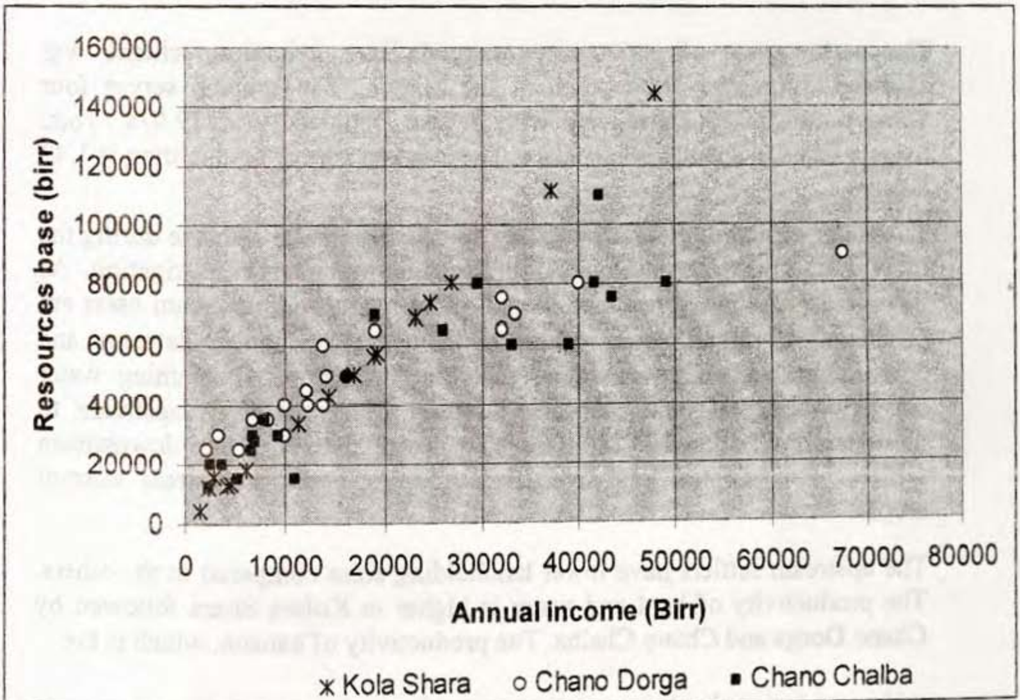

Figure 9: Relationship between annual income from agricultural production and resources base (monetary values of important possessions; example, house, cattle, etc.)

Improved agricultural production coupled with remunerative selling of the production will result in improved income of the farming community. This together with better social facilities enhances the welfare of the farmers.

Figure 4.6 shows how the resource base of a household improves with the level of income. There are farmers who have managed to construct houses

in the nearby towns, buy taxis and small transporters, etc. Annual income of households, and hence resource base that these households possess are highly variable among the households within the scheme.

Summary and Conclusions

The performance of community-managed Hare irrigation scheme was assessed across the canal reach of the system. The scheme serves four villages and 3,246 households with a total population of 19,674. Total irrigated area is about 1,962 hectare. The average size of landholding is 1.42 hectare.

The water availability is characterized by negative water balance during the months of mid September to April necessitating intensive irrigation. As there is no functional irrigation management institution, upstream users are privileged to divert more water to their canals than midstream and downstream users. It was found that the frequency of obtaining water (irrigation interval) and cropping intensity decreases from upstream to downstream. To cope with unreliable water delivery, the downstream settlers have adopted less diversified cropping and water stress tolerant crops.

The upstream settlers have lower landholding sizes compared to the others. The productivity of land and water is higher in Kolara Shara followed by Chano Dorga and Chano Chalba. The productivity of banana, which is the

widespread crop in the area, decreases when one goes from upstream to midstream. But it rises in downstream. This is mainly due to the contribution of shallow groundwater which lay 0.6 – 2 m below the surface.

The estimated average annual income of the household is higher in upstream and almost in equal range in midstream and downstream. Those areas that have year-round access to water, whether from surface or ground, have greater annual income than farmers with limited access to water. Most often, resources are efficiently used when they are scarce. Even though the water supply and delivery was not reliable for downstream users, they were found to use the available water more efficiently and produced outputs that are comparable to midstream users. However, it is evident that farmers that have access to water have higher annual income and resource base. Fair distribution of water among the users requires functional institutions and a well-maintained water distribution system which is not the case in Hare irrigation scheme.

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