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Assessment of Water Allocation Strategies on Adequacy and Equity of Water Distribution at Tertiary Level of Geriyo Irrigation Project

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Abstract: In order to assess the water supply for the project to meet crop water requirement and to utilize the available water effectively, plot size water allocation strategies were used in which the water supply in the project were allocated during each irrigation schedule. Three boxes in which nine tertiary channels and nine farm plots with sizes designated as A (0.25 ha), B (0.50 ha) and C (0.75 ha) were used at the upstream, mid-stream and downstream of the experimental farm. Flumes of 100mm cutthroat flumes were installed in the upstream, mid-stream and downstream of the channel reach for this study to measure discharge during each irrigation season. Performance of the strategies were evaluated at farm plots and tertiary channel level relative to depth of water applied, adequacy and equity indicators during 2007/-08 and 2008/-09 irrigation seasons, using measured channel water discharges and the design water discharge of the channel obtained from Iirrigation works station.. The designed discharge was prepared according to the contact with the farmers and area of cultivation. The performance of the three studied strategies indicated that farm plot strategy (0.25ha) with the highest adequacy value of 0.95 and equity value of 0.03 performed better than farm plot strategy (0.50 ha) and (0.75 ha) during the 2007/-08 and 2008/-09 irrigation seasons.

Key words: Water allocation · Strategies · Adequacy · Equity · Geriyo

INTRODUCTION

Whenever the water available is less than the expected amount or the irrigation water requirements exceed the availability, the water shortage takes place even in the irrigated area. The issues of high irrigation water requirements are usually related to the adequacy and equity in water delivery and distribution. If appropriate water allocation strategy is adopted in the irrigation project, it can improve water shortage problem at more cost effectively than developing new water resources project to meet irrigation requirements. To maximize returns from irrigation development and from efficient on farm water application in developing countries, there is a need to know how water deficits and surpluses influence crop production, how to determine water requirements and the best methods and proper timing of irrigation applications [1]. More accurate measures of soil moisture content and crop water needs in determining application rates could increase adequacy, equity and efficiency in irrigation system [2]. In order to improve the water delivery, adequacy in application and the equity of water distribution among the head-and-end users, Royal Irrigation Department (RID) has developed various water allocation strategies including Water Management Systems (WMS) [3]. On the same purpose, Water Allocation Scheduling and Monitoring system strategy was developed to determine the required discharge of the canal section from long term average potential evapotranspiration(ETo), crop coefficient (Kc) and the cropping pattern of the area to be irrigated for the season. Besides, the actual water distribution in the canal system (at several key regulators) should be monitored on weekly basis in order to check field water delivery performance [4-8].

Another approach used to assess water saving and control of water logging and salinity through improved delivery and distribution systems included field studies

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and modeling adopting multi-criteria analysis. The importance of considering the joint effects of delivery schedule and operation performance is well identified by [9, 10] who show that without improving the delivery schedule any increase in systems efficiency may not be expected. Another strategy, a decision support system (DSS) model Sector Demand And delivery Model (SEDAM) was purposefully developed to simulate the demand and delivery at the Sector level with application of multi-criteria analysis to assess scenarios aimed at reducing the irrigation demand, improving delivery management and controlling related environmental impacts by considering simultaneously technical, environmental and socio-economic criteria [11].

The Geriyo Irrigation Scheme was a comparatively water-rich project in the past, but in the past few years the project faced problems of reduction in volume of water supply from the source that meet the requirement of crops in the area developed. Coupled with this is the absence of an allocation methodology with which to manage the little flow available. There are also weeds infestation and sedimentation of the channels. Canal breach, a situation in which farmers illegally break the channels to siphon water into their farm, while those at the downstream have little or no water which made many farmers to abandon their farms, is on the rise particularly among farmers at the upper reach. This situation increases the competition for water between farmers and necessitates a more efficient water allocation strategy to improve water distribution to the farm for crop use. Poor water allocation and distribution of the water in irrigation systems is a major factor leading to low efficiency and so there is a need to assess the extent to which present irrigation system in the area achieve their delivery and distribution goals. These shortfalls necessitate the assessment of water allocation strategies on performance of the system, both over the course of the irrigation season and also between the upstream and the downstream of the system. In this paper, water allocation strategies were assessed and evaluated to determine the effects of the strategies on adequacy and equity of water distribution at tertiary level of the Geriyo Irrigation system.

MATERIALS AND METHODS

Experimental Site: The Experimental site is located 2km North of Jimeta metropolis, Yola North Local Government Area, Adamawa State, within the savannah ecological zone of Nigeria. The locations lie between 12°21' to 22°18' E latitude and 9°16' to 19°19' N. longitude with altitude range of 150-180 m above the mean sea level. The area has two major seasons; the rainy and the dry season. The rainy season lasts from the beginning of May to the end of October with annual rainfall of 958.99mm, while the dry season lasts mainly from November to the end of April. The driest months are January and February when the average minimum relative humidity is 13%. This is mainly due to the prevalent dry and desiccating north-east trade winds. This season is favourable for the cultivation of many crops under irrigation as there is no rainfall during the period. The wettest months are August and September when depth of rainfall reaches up to 25% of total annual rainfall. The relative humidity of air rises in these months to about 81% from July to September. Temperatures in the area vary; the hottest month is April with monthly average maximum temperature of 39.7°C, while the coldest months are December and January with minimum average temperatures of 16°C [12].

The site has a total irrigation area of 350ha which were divided into three phases viz; phase I with developed irrigation area of 20 ha, phase II was divided into three with 2A(35ha), 2B(60ha)and 2C(45ha) making a total developed irrigation area of 140ha and phase III was also divided into two with 3A(140ha) and 3B(50ha) making a total developed irrigation area of 190ha.The experimental site is situated in phase II plot 2B of the project which is in the lower section of the irrigation system. The main water sources for the entire system are the lake situated in the project site and River Benue. Phase II system is served by the River Benue through a water pump installed at the bank of the river. The installed pump, pumps water to a box upstream which regulates the water on rotational basis to the farmers. The dominant soil type in the study area is clay-loam in texture.

Data Collection and Computation: The strategies were farm plots of different sizes in which the available water for irrigation in the project were allocated at each irrigation schedule. The strategies focused on allocation of water supply to the farm plot that resulted in improved performance of the system which subsequently increase crop yield. Three farm plots designated as A, B and C with plot sizes of A (0.25 ha), B (0.50 ha) and C (0.75 ha) were used as scenarios in which the water supply in the project were allocated during each irrigation schedule.

Scenarios are meant to test the strategies under the available water supply and then see how the strategies responses to the water supply. The best strategy would be recommended for possible adoption by the project managers. Scenario formulation requires information on stream size, time of irrigation and the irrigation efficiency of the scheme.

The Three Scenarios Were Formulated for Water Allocations as Follows:

- Allocate water when farm plot size is 0.25ha;In this situation, water is allocated to only farm plots of size 0.25 ha while other farm plots of 0.50ha and 0.75ha remain closed for the duration of irrigation.
- Allocate water when farm plot size is 0.50ha; Here, water is supplied to farm plots of size 0.50 ha only. Farm plots of sizes 0.25 ha and 0.75ha remain closed for the duration of irrigation
- Allocate water when farm plot size is 0.75ha; This is when water supply is allocated to farm plots of size 0.75 ha only, while farm plots of sizes 0.25 ha and 0.50 ha remain closed for the irrigation period.

The scenarios were simulated to ascertain their performances. Data related to duration of irrigations and irrigation efficiency of the scheme was obtained from irrigation works station. The strategies were evaluated in terms of the depth of water applied and the performance indicators of the channels that supplied the water for each strategy involved.

RESULTS AND DISCUSSIONS

Strategies and Depth of Water Applied: Table 1 shows the depth of water applied for each strategy involved in all the selected Boxes of the experimental farm for 2007/08 and 2008/09 irrigation seasons. Table 1 indicates that depth of water applied varied with each strategy involved in all the Boxes from upstream to downstream of the experimental farm. The result shows that when farm plot strategy of 0.25 ha was involved, higher depth of water applied were recorded at all stages of irrigation compared to farm plot strategies of 0.50 and 0.75 ha, respectively. This implies that the smaller the farm plot size, the higher the depth of water applied. When farm plot strategy of 0.50 ha was used, the results showed that the values of the depth of water applied were lower than that of farm plot strategy of 0.25 ha but higher than that of farm plot strategy of 0.75ha values. Farm plot strategy of 0.25ha had the highest depth of water applied, while farm plot strategy of 0.75ha recorded the lowest depth of water applied during the two irrigation seasons. However, there was no significant difference between means of the depth of water applied for each strategy during 2007/08 and 2008/09 irrigation season at 5% level of significance

Table 2 shows the farm plot strategies and mean depth of water applied for the two year irrigation seasons. Table 2 indicates that mean depth of water applied varied with the strategies in all the Boxes and at all stages of irrigation. Total depth of water applied of 762, 716 and 666mm were obtained in Box number 2, 6 and 10, respectively, when farm plot strategy of 0.25 ha was applied. Also, total depth of water applied of 290, 271 and 231mm were recorded when 0.50ha strategy was involved, while total depth of water applied of 160, 148 and 133mm were attained when strategy of 0.75ha was used in Box number 2, 6 and 10, respectively. The result revealed that the depth of water applied decreases from upstream to downstream even for the same strategy. This may be due evaporation and seepages as the water flow along the channel to the farm plots. Also, it was observed that there were significant differences between the depths of water applied obtained for each strategy involved. The result shows that for the water supply and time of irrigation as practice in the project, farm plot strategy of 0.25 ha performed better than farm plot strategies of 0.50 and 0.75 ha, respectively during 2007/08 and 2008/09 irrigation periods.

Table 1: Strategies and Depth of Water Applied (mm)

Stages of Irrigation									
		Early	Middle	Late	Total	Early	Middle	Late	Total
Box No.	Strategies (ha)	2007/08 season				2008/09 season			
2	0.25	248	268	228	744	266	264	250	780
	0.50	95.5	96.6	90.7	283	108	99.2	90.1	297
	0.75	50.6	53.2	46.9	151	63.2	56.2	49.7	169
6	0.25	241	238	211	690	260	248	234	742
	0.50	97.4	89.8	78.9	266	102	87.9	85.7	276
	0.75	48.2	50.3	43.3	142	52.5	57.6	44.2	154
10	0.25	225	216	207	648	249	223	210	682
	0.50	85.9	76.5	68.2	231	83.9	78.5	67.9	230
	0.75	41.5	42.3	41.2	125	46.1	51.8	42.5	140

Table 2: Strategies and Mean Depth of Water Applied (mm) for two irrigation seasons

Stages of Irrigation					
Box No.	Strategies (ha)	Early	Middle	Late	Total
2	0.25	257	266	239	762
	0.50	102	97.9	90.4	290
	0.75	56.9	54.7	48.3	160
6	0.25	251	243	223	716
	0.50	99.7	88.9	82.3	271
	0.75	50.4	54.0	43.3	148
10	0.25	237	220	209	666
	0.50	84.9	77.5	68.1	231
	0.75	43.8	47.1	41.9	133

Table 3: Performance Indicators of the Channels for Strategies during 2007/08 and 2008/09 Irrigation Seasons

Performance Indicators					
		Adequacy	Equity	Adequacy	Equity
		a	e	a	e
Box No.	Strategies(ha)	----------2007/08 season----------		----------2008/09 season----------	
2	0.25	0.96	0.01	0.96	0.02
	0.50	0.80	0.06	0.78	0.11
	0.75	0.70	0.07	0.70	0.12
6	0.25	0.96	0.06	0.96	0.04
	0.50	0.78	0.07	0.72	0.09
	0.75	0.67	0.09	0.68	0.09
10	0.25	0.93	0.02	0.94	0.04
	0.50	0.72	0.08	0.67	0.08
	0.75	0.65	0.06	0.65	0.03

Adequacy and Equity Performance of the Channels: Table 3 reveals that all channel outlets delivered adequate amount of water when farm plot strategy of 0.25 ha was applied in all the Boxes for 2007/08 and 2008/09 seasons. The most adequate deliveries were in the channels in which farm plot strategy of 0.25 ha was invoked compared to the results of the performance of the channels when strategies of 0.50 and 0.75 ha were used. The result reveals that involving farm plot strategies of 0.50 and 0.75ha did not perform well which resulted in inadequate delivery of water in the channels and to the farm plots which affected farmer's crop yields.

Table 4 gives the mean values of the indicators of the performance of the system's ability and equity of water allocation at the tertiary channel level in the irrigation system. Table 4 reveals that the average value of adequacy (a = 0.95) and equity (e = 0.03) was obtained when farm plot strategy of 0.25 ha was applied. Also, mean value of adequacy (a = 0.75) and equity (e = 0.08) was recorded when farm plot strategy of 0.50 ha was involved, while for a farm plot strategy of 0.75 ha, mean adequacy value of 0.68 and equity value of 0.0.07 were attained. The result indicates that the channels were able deliver 95% of the water with equity of 97% water distribution to the farm for crop use when farm plot strategy (0.25ha) was used.

Effects of Strategies on Adequacy and Equity of Water Allocation: Table 5 indicates that performance ratio and equity values varied from upstream to downstream of the experimental farm for each strategy involved. Table 5 reveals that for a farm plot strategy of 0.25 ha all the channels delivered more than 90% of the required amount to the farm plots in all the Boxes from upstream to downstream of the experimental farm. For channels of farm plot strategies of 0.50 and 0.75 ha, the result indicates that the channels could not deliver adequate amount of water which resulted in poor performance even though the channels were able to distribute the water available to the farm plots equitably. The result shows that the effect of the strategies influences the magnitude of performance and equity of water allocation in the system.

Table 4: The Combined Values of Performance Indicators of the Channels for Strategies

Strategies(ha)	Performance Indicator	
	Adequacy (a)	Equity(e)
0.25	0.95	0.03
0.50	0.75	0.08
0.75	0.68	0.07

Table 5: Effects of Strategies on Performance ratio and Equity

Box No.	Strategies (ha)	Perf/ratio	Equity	Strategies (ha)	Perf/ ratio	Equity
	2007/08 season			2008/09 season		
2	0.25	0.96	0.01	0.25	0.96	0.02
	0.50	0.80	0.06	0.50	0.78	0.11
	0.75	0.70	0.07	0.75	0.70	0.12
6	0.25	0.96	0.06	0.25	0.96	0.04
	0.50	0.78	0.07	0.50	0.72	0.09
	0.75	0.67	0.09	0.75	0.68	0.09
10	0.25	0.93	0.02	0.25	0.94	0.04
	0.50	0.72	0.08	0.50	0.67	0.08
	0.75	0.65	0.06	0.75	0.65	0.03

Table 6: Mean Effects of Strategies on Performance ratio and Equity

Box No.	Strategies (ha)	Performance ratio	Equity
2	0.25	0.96	0.02
	0.50	0.79	0.08
	0.75	0.73	0.10
6	0.25	0.96	0.05
	0.50	0.75	0.08
	0.75	0.71	0.09
10	0.25	0.94	0.03
	0.50	0.70	0.08
	0.75	0.65	0.04

Table 7: Statistical Analysis of the Effects of Strategies on Performance ratio and Equity

Strategies (ha)	Performance ratio	Equity
0.25	0.94a	0.95a
0.50	0.75b	0.82b
0.75	0.68c	0.91b
S.E	0.03	0.01
CV (%)	6.00	2.00
Box No.		
2	0.80a	0.94a
6	0.80a	0.93ab
10	0.76b	0.92b
S.E	0.03	0.01
CV (%)	6.00	2.00

Means within a column followed by the same letter(s) are not significantly different from each other at 5% probability level.

When farm plot strategy of 0.25 ha was used, the effect shows that performance ratio and equity of water distribution in the channels to the farms were good, however, when farm plot strategies of 0.50 and 0.75 ha were involved, the result indicated that their effects lead to poor adequacy performance and equity of water allocation in the system. This implies that the effect of strategy on performance of an irrigation system can increase or decrease the performance of the system depending on the severity of the strategy in the system.

Table 6 shows the combine effects of the strategies on performance ratio and equity of water in the channels of all the selected Boxes for the experiment. Table 6 indicates that adequacy and equity values varied in all the Boxes in line with the strategies invoked. When a farm plot strategy of 0.25 ha was applied, result showed that the channels were able to deliver 94-96% of the intended amount of water in all the selected Boxes for the experiment. On the other hand when farm plot strategies of 0.50 and 0.75ha were invoked, result revealed that the channels had poor water deliveries even though they had high mean equity values. A highest mean performance ratio and equity value of 0.96 and 0.02 was obtained in Box number 2 when farm plot strategy of 0.25 ha was applied.

The effect of strategies on performance ratio and equity of water allocation at tertiary level was analyzed using Statistical Analysis for Sciences (SAS) software

and indicates that the effects of strategies on adequacy and equity of water allocation at tertiary level was significant at 5% level of significance. Mean differences were tested using Duncan's Multiple Range Test (DMRT) (Table 7) which indicates that there were significant differences between the performance ratios of the strategies in the selected Boxes of the experimental farm.

CONCLUSION

Three Water allocation strategies (0.25, 0.50 and 0.75ha) were assessed relative to depth of water applied and performance indicators of the channels which indicated that strategy (0.25ha) had the highest depth of water applied, adequacy and equity performance values. The effects of water allocation strategies on the adequacy and equity of water distribution in the farms revealed that strategies influence the magnitude of the adequacy performance and equity of water allocation in the system. Also, application of appropriate strategy resulted in optimum adequacy performance and equity of water allocation which increased crop yields of the farmers. It is recommended that farm plot strategy of (0.25ha) be adopted for water allocation in the irrigation system of the project in order to improve the water allocation at tertiary level of Geriyo Irrigation Project.

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