Whole-system Efficiency of Small- and Medium-scale Reservoir-based Irrigation Schemes in Northern Ghana

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Background

Over 19,000 reservoir-based irrigation schemes have been constructed in Sub-Saharan Africa, with more than 1,000 small and medium-scale schemes in Ghana where 230 of them provide water for crop irrigation, livestock, fishery, and households in the Upper East region (UER) (Acheampong et al. 2014). The performance adequacy of these irrigation schemes is increasingly challenged due to changing climate and land use, population growth, and competing demands, besides the basic need for rehabilitation. Many previous assessments concentrated on field-level crop irrigation but information on the schemes as the whole considering their multiple water users remains scarce.

Objectives

To assess the performance of a small- and a medium-scale irrigation schemes in the UER by considering the whole irrigation system and competing water users. The specific objectives are to determine:

- the current storage capacity of reservoirs for overall scheme operations
- the efficiency of the conveyance and distribution networks
- the efficiency of water use at the field level.

Study area

- The UER (Figure 1) climate is characterized by rainy (April/May – September/October) and dry (November – April/May) season. Mean annual rainfall and temperature are 971 mm and 29 °C, respectively.
- This study covered a medium-scale Vea (VIS) and a small-scale Bongo irrigation schemes (BIS) which included the water reservoir, water conveyance and distribution network, cropping fields, and the management entity.
- The management of the BIS is community-based, whereas the VIS is operated by a parastatal Irrigation Company of the Upper Region (ICOUR).
- The storage capacity, dead storage, and irrigable area of the VIS are 17.27 MCM, 1.27 MCM, and 850 ha, respectively. In the BIS these values are 0.43 MCM, 0.0026 MCM, and 12 ha, respectively.
- The cultivated area per farmer in the dry season ranges between 0.01–0.10 ha with the common practice of tomato and rice monocropping, and leafy vegetable intercropping.

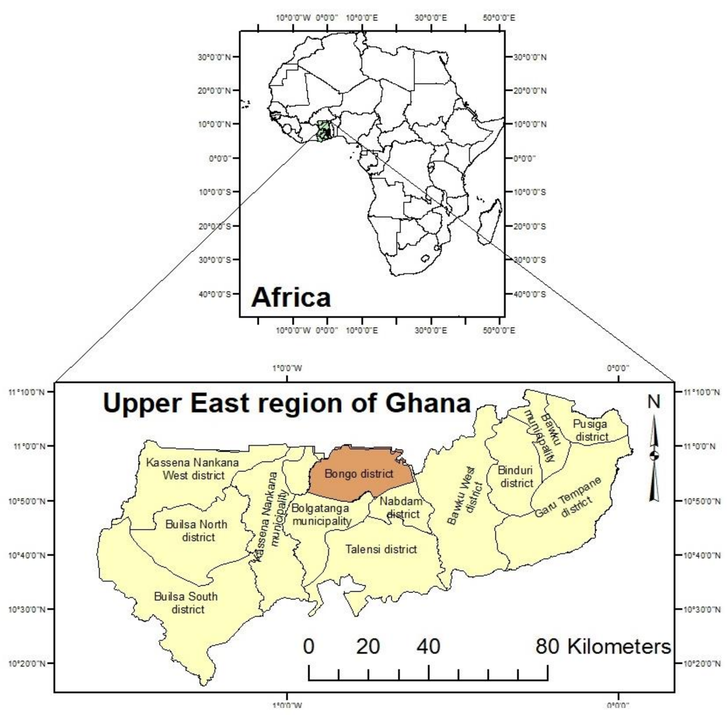

Figure 1. Area under consideration in the Upper East region (UER) of Ghana, West Africa.

Methodology

Measurements of the reservoir, water delivery, and environmental and agronomic parameters in 12 fields were conducted in the dry seasons from May 2014 to April 2016 (Figure 2) and used to calculate multiple performance indicators with relevance to water delivery and utilization as well as to agricultural production (Figure 3).

References

- Acheampong, E.N., Ozor, N., Sekyi-Annan, E., 2014. Development of small dams and their impact on livelihoods: Cases from northern Ghana. Afr. J. Agric. Res. 9, 1867–1877.
- García-Bolaños, M., Borgia, C., Poblador, N., Dia, M., Seyid, O.M.V., Mateos, L., 2011. Performance assessment of small irrigation schemes along the Mauritanian banks of the Senegal River. Agric. Water Manag. 98, 1141–1152.

Results and discussion

Reservoir performance

Water resources were underutilized (<40%) in the medium-scale VIS, whereas water demand approached the supply limit in the BIS (about 70%), resulting from the deteriorated water delivery infrastructure and wasteful water application at field level (Table 1).

Table 1. Gross water use in million cubic meters (MCM) and water availability index (WAI) for multiple users of the medium- (Vea) and small-scale (Bongo) irrigation schemes over two dry seasons

	Vea irrigation scheme		Bongo irrigation scheme	
Water use (MCM)	2014-2015	2015-2016	2014-2015	2015-2016
Initial storage	**11.05**	**13.72**	**0.076**	**0.286**
Drinking water demand	2.103	2.074	-	-
Crop irrigation amount	1.99	2.7312	0.0753	0.1891
Livestock demand	0.0521	0.0373	0.0259	0.0214
Fishery water use	0.0954	0.0954	0.0026	0.0026
Gross water use	**4.24**	**4.939**	**0.1037**	**0.2131**
WAI	**2.6**	**2.8**	**0.7**	**1.3**

Field application and overall system efficiencies

The field application efficiency ranged more widely, from 25 to 68%, in the small-scale scheme with an average of 46% across the seasons due to over-irrigation, than in the medium-scale scheme (52–58%) where it averaged 56%.

The overall system efficiency averaged 50% across the schemes and seasons. This was lower than the VIS management target of 65%.

Crop yield and water productivity

Similar seasonal ranges of tomato yields were observed in the irrigation schemes, between 34.3 and 49.2 Mg·ha^{-1} (BIS), and between 35.3 and 51.3 Mg·ha^{-1} (VIS). The varying degrees of over-irrigation led to a wide range of tomato water productivity values, from 1.5 to 8.4 kg·m^{-3}.

High variability was observed in leafy vegetable yields (2.3–37.5 Mg·ha^{-1}) and in water productivity (0.3–9.3 kg.m^{-3}), depending on crop type, observation season, and irrigation scheme.

The yield of rough rice (5.1 Mg.ha^{-1}) was in the upper range of values determined by in Mauritania (0.6-5.7 Mg·ha^{-1}). The water productivity of rice (0.9 kg.m^{-3}) was however higher similar to published (García-Bolaños et al. 2011).

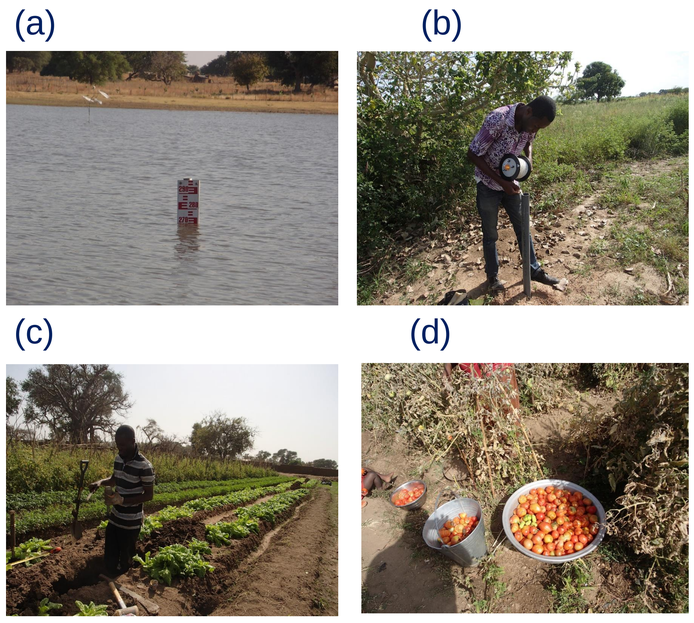

Figure 2. Monitoring of (a) reservoir storage in Bongo, (b) the depth to groundwater table in a well, (c) gravimetric soil moisture in a leafy vegetable field, and (d) tomato yield

Conclusions

- Either underutilized reservoir storage or insufficient water supply strongly undermine the performance of irrigation schemes.
- Maximum application efficiency achieved under current irrigations practices did not exceed 58–68%.
- Mean overall system efficiency ranged between 45 and 55% across schemes and could be increased by reducing water conveyance network losses and by eliminating over-irrigation of fields.

Take home message

The whole system approach considering all competing water demands is useful in the performance evaluation of reservoir-based irrigation schemes by revealing which of their components need to be prioritized for improvement.

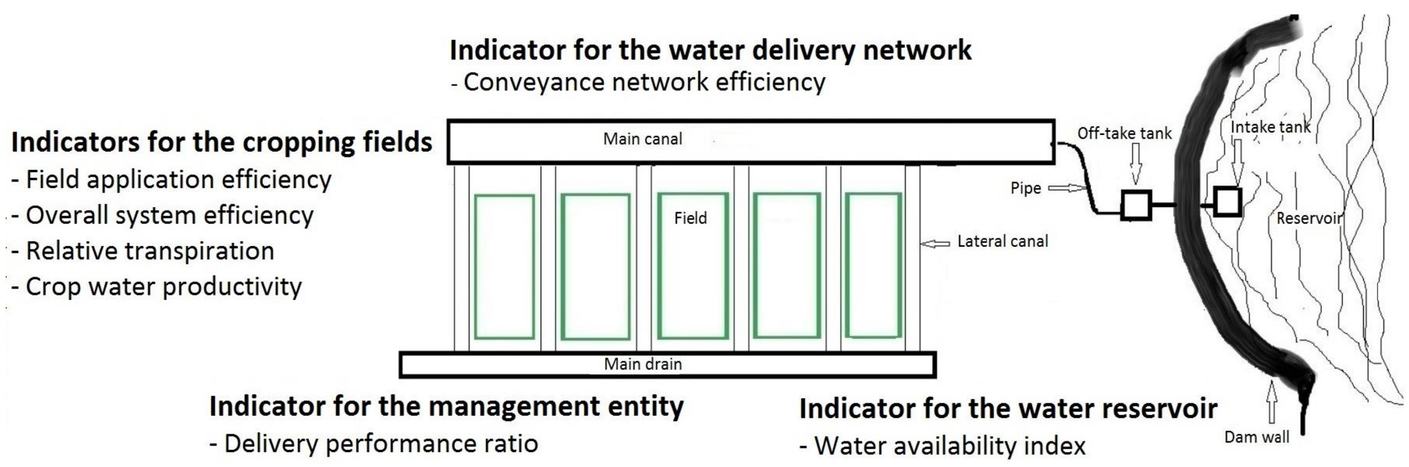

Figure 3. Schematic representation of the reservoir-based irrigation schemes and indicators for their performance evaluation in the UER of Ghana.

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WASCAL West African Science Service Centre on Climate Change and Adapted Land Use
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