CGIAR Challenge Program on WATER & FOOD

Nile Basin Focal Project

Soil Fertility Effect on Water Productivity of Maize and Potato in Abay Basin

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Introduction: Abay basin (Ethiopian part of Blue Nile) is characterized by a mixed crop-livestock rainfed farming system (Fig. 1). Agricultural productivity is low due to: high temporal and spatial variation in climate, sever land degradation, lack of appropriate technologies, poor infrastructure & limited extension services. Although rainfall is adequate, water productivity remains low due to poor crop, soil and water management practices. Soil fertility is a prime factor limiting crop water productivity in areas where rainfall is not limiting (Drechsel et al, 2004). This study investigated the effect of soil fertility (SF) levels on water productivity of maize and potato grown in sequence.

Methodology: The FAO AquaCrop model Version 3 (Raes et al., 2009; Steduto et al., 2009) was used to simulate the grain and biomass productivity of maize as well as the water balance of the system. Irrigation requirement and water productivity of potato planted following maize was estimated assuming the excess water during the rainy season is harvested for use as supplementary irrigation. Climate, soil and crop date obtained from the basin master plan and research centers located within the basin were input for model validation and simulation. The Reference Evapotranspiration was estimated using the ETo Calculator [Raes et al., 2009]. The Relative Root Mean Square Error (RRMSE) Equ.1 and Coefficient of Efficiency (E) Equ.2 were used to examine the robustness of the model,

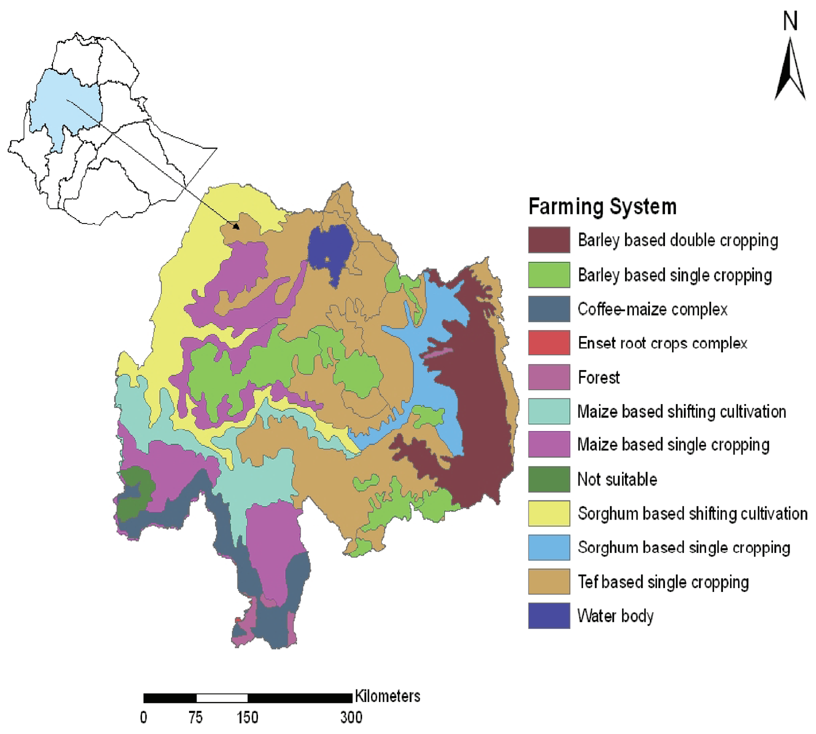

Fig. 1 :The major farming systems in Abbay Basin

$$\text{RRMSE} = \left(\frac{1}{N} \sum_{i=1}^{n} \left(\frac{E-O}{O} \right)^2 \right)^{1/2} \quad \text{Equ.1 and} \quad E = 1 - \frac{\sum_{i=1}^{N} (O_i - E_i)^2}{\sum_{i=1}^{N} \left(O_i - \bar{O} \right)^2} \quad \text{Equ.2}$$

Three soil fertility scenarios were considered:

1. **Poor-** representing the traditional no fertilizer use
2. **Near optimal-** representing use recommended rates of N and P
3. **Non-limiting-** representing use of recommended rates of N and P + other macro and micronutrients

Results: The RRMSE percentage was low (8.1%) and the model efficiency (E) was close to + 1, indicating that the model is robust enough to predict maize productivity in the area.

Simulated Productivity and Water Balance

Productivity of maize: Moisture availability was not limiting, but soil fertility was the main source of variation in productivity. About 39%, 75% and 100% of the potentially achievable biomass yield can be obtained under the poor, near optimal and non-limiting soil fertility conditions, respectively while the grain yield ranges between 2.5 t ha^{-1} and 9.2 t ha^{-1} under poor and non-limiting soil fertility conditions, with a corresponding increase in biomass and grain water productivity (Table 1). Assuming only 50% of the 3.03 million ha of Nitisols in maize based farming system in the basin is planted to hybrid maize, about 10 million ton and 14 million ton grain can be obtained with near optimal and non-limiting soil fertility conditions. That is, only row planting of hybrid seeds and applying recommended rates of nitrogen and phosphorus as practiced by research centres can increase productivity by three fold as compared to the current.

Table 1. Water productivity of maize as affected by soil fertility status

Soil fertility	Yield (t ha^{-1})		% Biomass in reference to		Water productivity (kg m^{-3})	
	Biomass	Grain	well watered	well fertilized	Biomass	Grain
Poor	7.5	2.5	100	39	5.1	1.7
Near optimal	14.3	6.4	100	75	5.3	2.4
Non limiting	19.2	9.2	100	100	5.4	2.6

Water Balance: SF levels affected water balance components, except runoff and infiltration. Of the 1450 mm rainfall received during the growing period, 60% infiltrates while the rest is lost as runoff. Of the infiltrated water, 276, 311 and 304 mm percolates under poor, near optimal and non-limiting SF conditions, respectively. The balance is either used as transpiration (T) or lost as evaporation (E). Improving SF decreased E and increased T (beneficial consumption) (Fig. 2). The reduction in E is due to better canopy cover under improved fertility, which attained its maximum in August. This corroborates Cooper et al. (1987) who suggested that application of fertilizers enhance crops' water use efficiency.

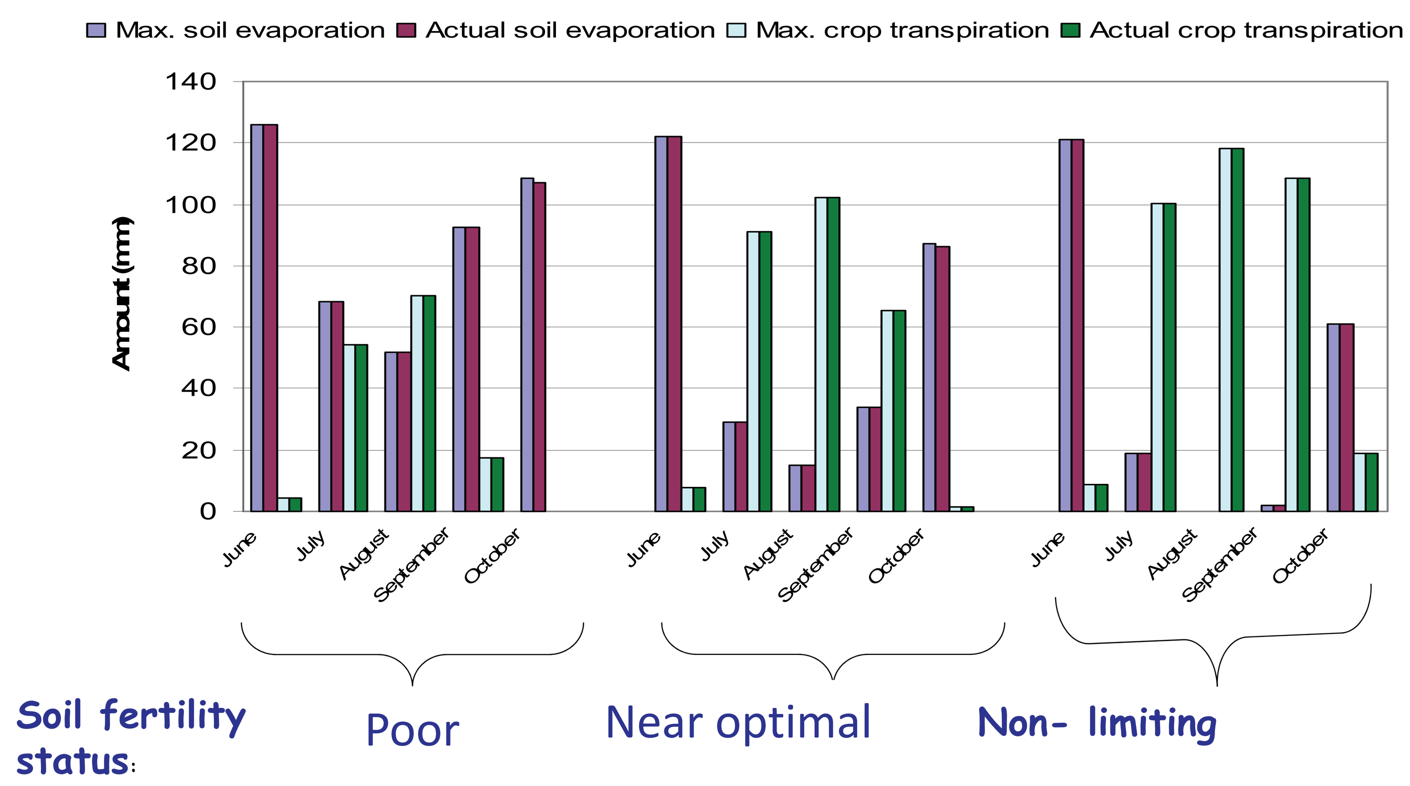

Fig. 2. Effect of soil fertility status on Evaporation and Transpiration

Water Harvesting: The runoff water can be harvested for use as supplementary irrigation of second crops. Potato planted 10 days after maize is harvested in October gives 4, 8 and 10 t ha^{-1} (dry weight) tuber yield under poor, near optimal and non-limiting SF, respectively (Table 2). Assuming 65% irrigation efficiency, growing potato under near optimal and well-fertilized conditions requires about 696 and 739 mm irrigation water , which is about 17 and 25% higher than the potentially harvestable water. Consequently, either less land area should be used or crops with less water requirement should be chosen. However, increasing irrigation efficiency to 80% can permit growing potato on the same area of land as maize.

Table 2. Productivity and Water Requirement of Potato grown after Maize

Soil fertility status	Productivity (ton ha^{-1})		NIR (mm)	GIR (at 65% IE) (mm)
	Dry biomass	Yield		
Poor	5.1	3.8	414	637
Near optimal	10.5	7.9	452	696
Non limiting	13.1	9.8	480	739

Conclusion: AquaCrop can reasonably predict the productivity of maize grown in Abbay river basin. Soil fertility and the use of high yielding varieties can significantly increase water productivity of maize and potato grown in the area. The increased water productivity of maize is achieved mainly by reducing evaporation and increasing transpiration. Harvesting the excess water during the main can allow the growing of a second crop with supplemental irrigation.

Reference:

Drechsel, P., Giordano, M. and Gyiele, L. 2004. Valuing nutrition in soil and water: concepts and techniques with examples from IWMI studies in developing world. IWMI Research Paper 82. International Water Management Institute (IWMI), Colombo, Sri Lanka

Cooper P. J. M., Gregory. P. J., Keatinge, J. D. H. and Brown S. C.1987. Effects of fertilizer, variety and location on barley production under rainfed conditions in northern Syria. Field Crops Res. 16, 67–84

Raes, D., Steduto, P., Hsiao, Th and Fereres, E. 2009. AquaCrop—The FAO crop model for predicting yield response to water: II. Main algorithms and soft ware description. Agron. J. 101:438–447

Steduto, P., Hsiao, T.C., Raes, D., Fereres, E., 2009. AquaCrop—the FAO crop model to simulate yield response to water. I. Concepts. J. Agron. 101, 426–437

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