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Assessment of surface water irrigation potential in the Ethiopian highlands: The Lake Tana Basin

Abeyou W. Worqlul [a,b,c], Amy S. Collick [d,*], David G. Rossiter [a], Simon Langan [c], Tammo S. Steenhuis [a,b]

[a] Cornell University, Ithaca, NY, USA
[b] Bahir Dar University, School of Civil and Water Resource Engineering, Bahir Dar, Ethiopia
[c] International Water Management Institute (IWMI), Addis Ababa, Ethiopia
[d] Pasture Systems and Watershed Management Research Unit, USDA-ARS, University Park, PA, USA

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ABSTRACT

Although Ethiopia has a large potential to develop surface irrigation, only 5% of the 30 to 70 million hectares (ha) potentially available has been developed. To examine the underlying causes of this lack of irrigation development, this study evaluates the suitability of surface water irrigation for the Lake Tana Basin development corridor. Surface water availability and land potentially suitable for irrigation development were considered. Surface water potential was examined by analyzing long-term daily historical river discharges. Land suitable for irrigation was determined with a GIS-based multi-criteria evaluation, which considers the interaction of various factors such as climate, river proximity, soil type, land cover, topography/slope, and market outlets. The results indicate that nearly 20% of the Lake Tana Basin is suitable for surface irrigation. However, after analyzing 27 years of river discharge, less than 3% of the potential irrigable area (or less than 0.25% of the basin area) could be irrigated consistently with runoff from the river systems. Thus, the irrigation potential in the Lake Tana Basin can be met by increasing dry season flows, by improving upland infiltration, by supplying water from reservoirs, or by pumping water directly from Lake Tana.

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1. Introduction

The Ethiopian highlands are comprised of land resources, which are potentially suitable for irrigation. Irrigation would provide farmers with sustained livelihoods and improve their general well-being (Belay and Bewket, 2013; Hussain and Hanjra, 2004). However, the country's irrigable land has been underutilized, and only 4 to 5% of the potential area has been developed for irrigation (Awulachew et al., 2007). Consequently, the agricultural economy of the country is largely based on rainfed cultivation, but while employing 85% of the population, it only contributes 50% to the gross domestic product (Berry, 2003). Ultimately, increasing agricultural production using irrigation is one of the main drivers to end poverty caused by insufficient output from these rainfed systems. Therefore, the study investigates the causes of the underutilization of the land resources for irrigation.

According to the Ministry of Water, Irrigation & Energy of Ethiopia irrigation command areas can be classified into three groups (Awulachew et al., 2005). The first group is small-scale irrigation areas of less than 200 ha, medium-scale between 200 and 3000 ha and large-scale above 3000 ha. Consequently, we quantified both the potential land areas suitable for small, medium and large-scale surface irrigation; in addition, the available surface water potential for surface irrigation was identified by analyzing historical river flow data. This investigation focused on the Lake Tana basin situated in the Upper Blue Nile basin, which has been designated as one of the growth development corridors for economic development by the government of Ethiopia to end poverty.

2. Materials and methods

2.1. Description of study area

The study was carried out in the 15,000 km^2 Lake Tana Basin, of which the lake covers around 3000 km^2. The lake is located at 12°00′ N, 37°15′E in the northwest highlands of Ethiopia (Wale et al., 2009). The elevation of the watershed ranges from 1786 to 4107 m and the slope ranges from 0 to 167% with an average slope of 8.6%. The study area has a minor rainy season in April and May and a major rainy phase from June to September during which approximately 75% of the annual rainfall occurs. The mean annual rainfall is 1430 mm at Bahir Dar Station south of Lake Tana, and 1090 mm at Gondar Station north of the lake (Fig. 1). The average minimum and maximum temperatures are 20 °C and 7 °C at Debre Tabor station. The mean annual relative humidity from 1992 to 2006 at Bahir Dar is 58% and at Gondar 53%. It is

* Corresponding author at: Building 3702, Pasture Systems and Watershed Management Research Unit, USDA-ARS, University Park, PA 16802, USA.
E-mail address: amy.collick@ars.usda.gov (A.S. Collick).

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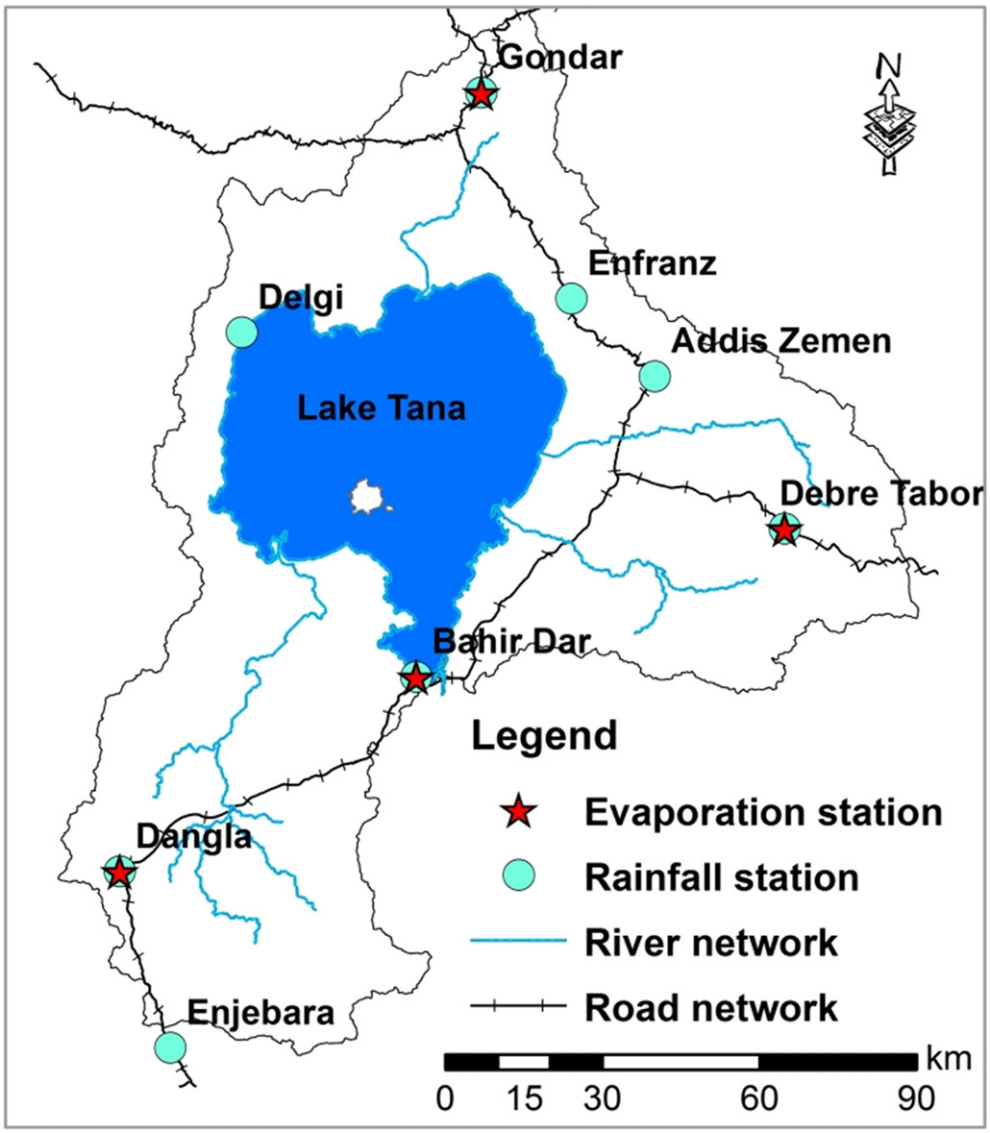

Fig. 1. Study area with major towns, rivers, climate stations, and paved road networks.

expected that future irrigation water availability due to climate change will increase (Dile et al., 2013).

Most farmers in the Lake Tana basin grow one crop per year during the rainy phase of the monsoon from June to September when 85% of the annual rainfall falls (Awulachew et al., 2007, 2010; Belay and Bewket, 2013). The major rainfed crops are teff, corn, sorghum, millet, barley, wheat, beans and rice. In addition *Eucalyptus* plantations are expanding rapidly (Chanie et al., 2013). Irrigated crops are usually of high value and include Khat, a mild narcotic leaf, onions, potatoes and vegetable crops. The acreage of irrigated crops in the Gilgil Abay basin one of the major sub-basins of Lake Tana is in the order of 1% (Enku et al., 2014) and it is in the same order as in the other basins in the Lake Tana. Both surface and groundwater are used for irrigation, with surface water irrigation dominant in the uplands and groundwater use in the plains around Lake Tana.

2.2. Source of data used

In this study, we have first identified potential land areas suitable for surface irrigation using a GIS based Multi-Criteria Evaluation (MCE) technique and then quantified the available surface water potential for surface irrigation by analyzing historical river flow data of the major rivers in the Lake Tana Basin. To achieve this, the following datasets for the Lake Tana watershed were collected.

2.2.1. Climate

Precipitation, temperature, wind speed, and relative humidity were collected from the Ethiopian Metrological Agency (EMA). Monthly long-term rainfall was available from 1992 to 2006 for eight stations (Fig. 1). For calculating evaporation with the Penman–Monteith equation (Monteith, 1965) the daily measurements of temperature, humidity, wind speed and sunshine hours were collected from four of the synoptic stations at Bahir Dar, Gondar, Dangla and Debre Tabor (Fig. 1).

2.2.2. Land features

Soil and land use data were obtained from the Ethiopian Ministry of Water and Energy (EMWE). The dominant soil groups according to FAO soil classification (Michéli et al., 2006) in the Lake Tana area are Haplic Luvisols (26%), Chromic Luvisols (20%), Eutric Leptosols (16%), Eutric Vertisols (15%) and Eutric Fluvisols (14%) (Fig. 2a). The land use map indicated that the study area was dominated by agricultural land covering approximately 74% followed by the lake itself accounting for approximately 22%, and bush and grassland at 6% (Fig. 2b). A 90 m resolution