Assessing Potential Land Suitability for Surface Irrigation using Groundwater in Ethiopia

Introduction

Although a detailed study on groundwater resources in Ethiopia is not available, a recent study by MacDonald et al. (2012) reported that the renewable groundwater storage in Africa is 100 times more than the annual renewable freshwater resources. An advantage of groundwater for irrigation of crops over surface water is its reliability and its tempered response to drought and variability in weather. Also, groundwater quality is typically better that surface water, requiring less treatment for human or livestock use. In Ethiopia, for example; groundwater is almost exclusively used for drinking water; and its use for irrigation of crops is limited. However, the need to increase food production in Ethiopia and other developing countries is reaching critical levels. It is important we more closely examine the groundwater resources in Ethiopia and suitability potential of land for irrigation using groundwater.

Approach

Potential land in Ethiopia suitable for irrigation using groundwater was identified using GIS-based Multi-Criteria Evaluation (MCE) techniques. The land suitability was determined by developing and assigning weight to the key factors that affect the irrigation potential of the land from groundwater using a 1 km grid. The factors used were identified from literature and from experts in the region (Akıncı et al., 2013; Chen et al., 2010; Mendas and Delali, 2012; Worqlul et al., 2015). Factors considered included physical land features (land use, soil and slope), climate characteristics (rainfall and evapotranspiration), and market access (proximity to roads and access to market). Factors were weighted using a pair-wise comparison matrix, reclassified, and overlaid to identify the suitable areas for groundwater irrigation. Groundwater data from the British Geological Survey were used to estimate potential groundwater availability and analyze the irrigation potential for dominant crops. The irrigation potential of groundwater was based on the ratio of groundwater availability to the total crop water requirement (CWR) of the dominant crop. Table 1 presents the source of input data, source, and respective spatial resolutions.

Table 1: Source and spatial resolution of input data used for the land suitability analysis.

Data	Source	Spatial resolution (m)
Land use	Land use Database of the World (LADA) from Food and Agriculture Organization (FAO), 2010	10,000
Land use	Spatial Production Allocation Model (SPAM), 2014	1,000
Soil	Africa Soil Information Service (AfSIS), 2015	250
Digital Elevation Model (DEM)	Enhanced Shuttle Land Elevation Data from United States Geological Survey (USGS), 2000 released in 2015	30
Population density	Global Gridded Population Database, 2000	1,000
Road network	Ethiopian Road Authority (ERA), 2006	--
MODIS potential evaporation (mm)	MOD16 Global Terrestrial Evapotranspiration Data Set (2000 – 2010)	1,000

Rainfall (mm/year)	Ethiopian National Meteorological Agency (ENMA) from 1996 to 2010	--
Groundwater depth (m)	British Geological Survey, 2012	5,000
Potential borehole yield (l/s)	British Geological Survey, 2012	5,000
Groundwater storage (mm)	British Geological Survey, 2012	5,000

Results and Discussion

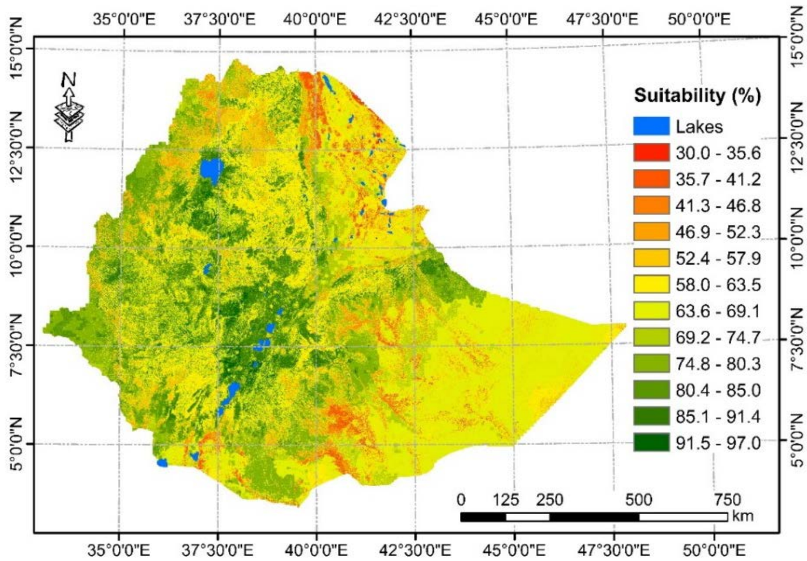
Preliminary Land Suitability for Surface Irrigation

Factor maps were compared one-to-one and scored using a scale of Saaty (1977). In the suitability analysis for irrigation, slope and rainfall deficit were found to be the most important factors, followed by population density and soil characteristics. Suitability classes were given weights using equal interval ranging technique. Preliminary suitable land areas were computed using the Weighted Overlay analysis in ArcGIS 10.2.2. The preliminary suitability map value ranges from 30 to 97%, where 30% indicates the least suitable land and 97% the most suitable land (Figure 1). A constraint map with a value of zero and one was used to exclude the unsuitable areas and to optimize with a user-defined threshold number. Figure 2 indicates the area of suitable land for a variable threshold number. Pixels with a suitability value of greater than 85% were identified as a suitable area. The result indicated thousands of suitable polygons with area ranging from 1 km^2 to 500 km^2. Nearly 5.3 %, approximately 60,025 km^2, of the landmass is suitable for surface irrigation.

Suitable land areas were categorized into the major river basins. Abbay basin (Blue Nile basin) has the largest area of suitable land (21,186 km^2), while the Rift Valley Basin has the highest percentage (20%) of suitable land for irrigation.

Groundwater Availability

Data from the British Geological Survey were used to determine the annual groundwater available for irrigation and the amount of resources need to irrigate suitable land. The groundwater storage volume for Ethiopia has a spatial variability ranging from 1,000 to 50,000 mm/year with a depth varying from 7 to 250 m below the surface. The storage map indicated 43% of the country has a groundwater storage potential in between 1,000 to 10,000 mm/year and 37% of the country, falls between 10,000 to 25,000 mm/year. However, only a fraction of this subsurface potential water is available for extraction from shallow wells with depths of 25 m or less. The aquifer productivity map, which has a spatial resolution of 5 km, indicates the groundwater yields in the country ranges from 0.1 to 20 l/s. The majority of the land (47%) has aquifer potential yield between 1 to 5 l/s; only 14% of the land has the highest aquifer potential yield between 5 to 20 l/s. The groundwater depth map indicates approximately 20% of the land has very shallow groundwater access up to seven meters from the surface. The majority of the land has a groundwater depth access 7 to 25 m below the ground surface.



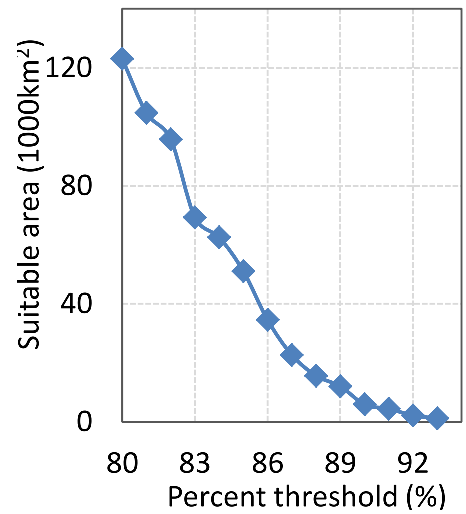


Figure 1: A preliminary suitable land for surface irrigation

Figure 2: Area of land suitability for a variable threshold number.

Areas Suitable for Irrigation versus Groundwater Availability

During the dry season in Ethiopia, from December through April, the MODIS global evapotranspiration (ET) ranges between 7.3 to 9.8 mm/day, total crop water requirement (TCWR) ranges between 1018 to 1953 mm, and potential groundwater availability ranges from 1,730 to 216,000 m^3. During the remainder of the year (June to September), rainfall is higher than potential evaporation and irrigation is not needed on a majority of the country's suitable farming land.

The ratio of available groundwater resources by volume and the total crop water requirement for the growing season provides an estimate of the irrigation potential from groundwater. Using this technique, we found that only a small proportion of the land in each grid was suitable to be irrigated using shallow groundwater. Out of 6 million ha suitable land, only 20,000 ha of land can be irrigated with from groundwater if lateral movement of water within the aquifer 5km grid is restricted. For Rift Vally Basin, 0.42 % of the suitable land, for Awash Basin, 0.35 % of the suitable land and for the Abbay Basin, 0.34 % of the suitable could be irrigation using groundwater within the grid. However, if lateral flow occurs within the aquifers the irrigation potential of the groundwater could increase significantly.

Conclusions

Approximately 6.0 million ha of land in Ethiopia is suitable for surface irrigation. A large portion of this suitable land is located in the Abbay, Rift Valley, Omo Ghibe, and Awash River basins, which all also have shallow groundwater access (<20m from the surface). The comparison between available groundwater and total crop water requirements indicated that current groundwater resources in the basins are not capable of irrigating all suitable land independently, but groundwater resources are a good option for supplementing current surface water resources in many regions. The study indicated that only 0.33 % of the suitable land could be irrigated with the groundwater within the grid.

Reference

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