Irrigation Area Suitability Mapping by Multi-criteria Evaluation Technique for the Case of Lake Tana Basin, Ethiopia

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Introduction

The water resource development of Ethiopia is under utilized, out of 3.35 million hectares irrigation potential only 4 to 5 percent has been developed. The study area, the largest lake in Ethiopia, has a developmental potential, but until recently, there has been only one water resource development to control the outflow for harnessing hydroelectricity down stream on the Blue Nile River.

Recently, the government of Ethiopia is committed to solving this paradox through an agricultural led development program that includes irrigation development as one of the strategies. The Lake Tana basin is currently considered as a development corridor of the national and regional government Plan for Accelerated and Sustained Development to End Poverty (PASDEP).

Objective

The study, is aimed at identifying the land suitability for surface irrigation by employing a GIS-based Multi Criteria Evaluation (MCE) analysis of spatial data. The main objective is to identify suitable medium scale (between 200 and 3000 ha) and large scale (greater than 3000 ha) irrigation areas in the basin by considering factors, such as meteorological information (temperature, humidity, rainfall etc), river proximity, soil type, land cover, topography/slope and market outlets.

Study area description

Lake Tana is the beginning of the Blue Nile River and has a total drainage area of approximately 15,000 km^2, of which the lake covers 3,060 km^2 at an elevation 1,786 m (Figure 1).

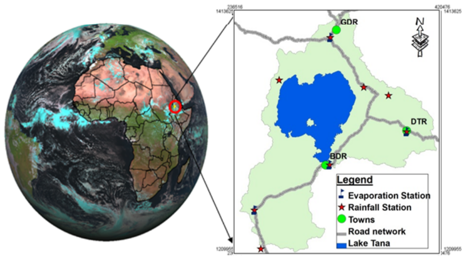


Figure- 1: Location of Lake Tana Basin north-west highlands of Ethiopia

(Left side first MSG satellite image received March 12, 2011 at 09:35 UTC and right spatial distribution of weather stations, major road network and towns

The elevation of the watershed ranges from 1781 to 4107 m amsl and the slope ranges from 0 to 167% with an average slope of 47%.

Methodology

The suitability was evaluated by mapping the major decision factors (Figure 2). Using the daily metrological data from 1992 to 2006, the long-term average rainfall and potential evaporation raster map was computed through interpolation based on Thiessen polygons. The monthly rainfall deficit map (rainfall-evaporation) was aggregated to the annual rainfall deficit map. The major perennial river network segment map and slope raster map was derived from SRTM DEM of the basin, and then the drainage network map was interpolated using the Euclidian distance tool in ArcGIS. Major potential marketing towns and the main paved road were digitized manually from Google Earth and interpolated. The interpolated maps were reclassified into four groups of suitability by an equal interval ranging technique. The soil and land use map collected from the Ethiopian Ministry of Water and Energy (EMWE) was reclassified to four major classes of FAO land suitability.

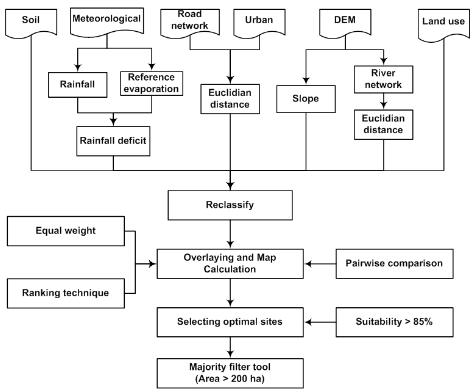


Figure 2: General flowchart of the methodology SPOT-VGT

Land suitability classes

Suitability classes are based on FAO (1976 and 1981) framework, land suitability map is classified into two classes: *suitable and not suitable* (see Table 1 a slightly modified version of FAO land suitability classification). In this study the Permanently Not Suitable land use group in the FAO suitability framework is considered as a constraint.

Table 1: Land suitability classes FAO (1976 & 1981)

Highly Suitable: S1	Land without significant limitations.
Moderately Suitable: S2	Land that is clearly suitable but which has limitations
Marginally Suitable: S3	Land with limitations so severe that benefits are reduced
Currently Not Suitable: S4 (N1)	Land that cannot support the land use on a sustained basis.

Weighing of factors

Weighting of the decision factors was accomplished by comparing three approaches:

Equal importance: the same weight is assigned to all factors assuming that the criteria's have the same degree of importance.

Ranking technique: involves ordering of decision factors in their relative order of importance (Table 2).

Pairwise comparison: each factor will be matched head-to-head (one-to-one) with each other and a comparison matrix is prepared to express the relative importance (Table 3).

Results

Table 2: Weighting by ranking technique

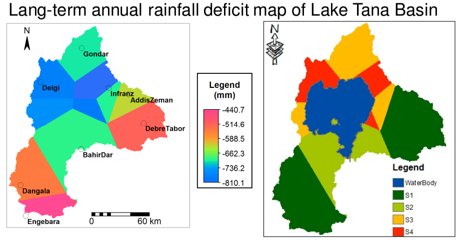
Scale reference	Definitions	Factors	Weight
Very important	Most relevant point	River proximity	20
	First order priority	Road proximity	18
		Slope	17
Important	Is relevant to the issue	Soil	15
	Second order priority	Rainfall deficit	14
Moderately Important	May be relevant to the issue	Urban proximity	9
	Third order priority	Land use	7

Table 3: Weighting by pairwise comparison technique

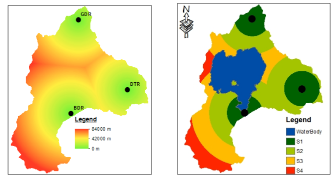
Factors	SO	LU	RiP	UP	RoP	RD	SL	Weight
Soil (SO)	1	4	1/3	4	1/2	2	1/3	12
Land use (LU)	1/4	1	1/7	1/2	1/6	1/3	1/5	3
River Proximity (RiP)	3	7	1	6	2	4	2	32
Urban Proximity (UP)	1/4	2	1/6	1	1/5	1/2	1/4	4
Road Proximity (RoP)	2	6	1/2	5	1	2	2	22
Rain deficit (RD)	1/2	3	1/4	2	1/2	1	1/3	8
Slope (SL)	3	5	1/2	4	1/2	3	1	19

Reclassified weighted factor maps

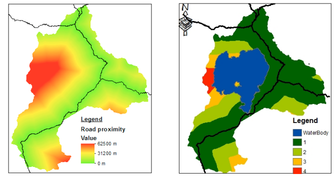
Lang-term annual rainfall deficit map of Lake Tana Basin



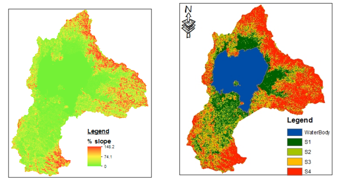
Proximity map to major towns and reclassified by equal interval ranging technique



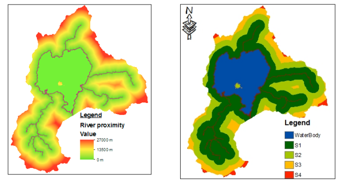
Proximity map to paved road network and reclassified by equal ranging technique



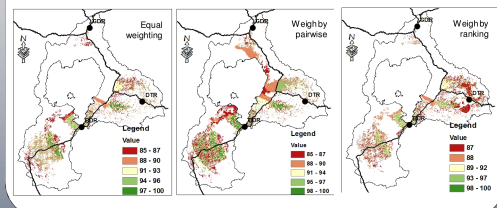
Percentage slope map and FAO slope classified map



Proximity map to major perianal rivers and reclassified by equal interval ranging technique



The preliminary suitability map is computed by Weighted Overlay tool of ArcGIS Spatial Analyst toolbox, and optimized by a threshold number greater than 85%. The optimized map indicated a total suitable area of 84,617 ha, 117,251 ha and 60,748 ha by equal, pairwise and ranking weighting technique, respectively.



Conclusion

The result of the study has indicated the sensitivity of Multi-Criteria Evaluation with respect to the weighting approach. The basin has a good irrigation potential for medium and large scale approximately 10%, 7% and 5% of the basin is suitable for surface irrigation according to the pairwise, equal weighting and ranking technique, respectively. The weighting by pairwise comparison has reduced the biasness associated within and it is close to the previous estimation by Seleshi et al. (2007).