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GIS BASED SITE SUITABILITY ANALYSIS FOR POND PRODUCTION OF NILE TILAPIA (*OREOCHROMIS NILOTICUS*) IN WEST SHOA ZONE, CENTRAL ETHIOPIA

Kebede, L.,* Kassahun, A. and Natarajan, P.

Ambo University, West Shoa, Ethiopia
**Email: lim.kebede@yahoo.com*

Abstract: The present study identifies and quantifies appropriate site for pond production of Nile tilapia in the West Shoa Zone, Central Ethiopia using remote sensing (RS) and geographical information system (GIS). In Ethiopia, Nile tilapia contributes to more than 60% of the annual total fish landings and it is the most preferred fish species. GIS and Remote Sensing are essential tools for planning aquaculture development. To identify areas which are suitable for inland pond Nile tilapia production in the region, two scenarios were considered. The first scenario was subsistence mode of production of Nile tilapia based on four major factors; water temperature, water availability, potential for pond construction (engineering) suitability and LULC. The second scenario was commercial mode of Nile tilapia production that by incorporating economic suitability factors on the four major factors in subsistence scenario. Finally, they were overlaid to produce suitability map and the results indicated that about 0.66% (9,621 ha),48.6% (712,909 ha), 50.3% (736,657 ha) and 0.44% (6,431 ha) total terrestrial boundary of West Shoa Zone were found to be most suitable, suitable, moderately suitable and unsuitable respectively for subsistence mode of production of Nile tilapia. Whereas, about 0.4% (5,887.38 ha), 52.86% (774,746.4 ha), 46.72% (684,692.8 ha) and 0.02% (291.42 ha) total terrestrial area in this zone was found most suitable, suitable, moderately suitable and unsuitable respectively for commercial mode of production of Nile tilapia.

Key words: Nile tilapia, mode of production, suitability classes, GIS & RS., ground truth

INTRODUCTION

Aquaculture has been the fastest growing food production sector in the world and now supplies more than half of the world's food fish (FAO, 2010). Excluding aquatic plants, aquaculture production reached 60 million tones representing a value of US$119 million in 2010 (FAO, 2012). Aquaculture is meeting the consumer demand of fish based products and protects wild fisheries. It can, moreover, solve conflicts between different activities, making rational use of the land (Hossain *et al.,* 2007). Despite the enormous potential for aquaculture and culture fisheries in the country, there has not been significant public and private sector investment in aquaculture development. Ethiopia lacks the requisite policy frameworks besides detailed information on site preferences for undertaking aquaculture. This forms one of the major constraints experienced by a large section of the people. Aquaculture in pond production of Nile tilapia *(O. niloticus*) was started in West Shoa Zone in 2007 (West Shoa Zone Livestock Agency). However, the aquaculture trials that are undertaken by different stake holders are not meeting the expected success due to the culture systems constructed are not scientifically designed or based on site suitability both in terms of soil and water quality. Site selection is a key factor in any aquaculture operation, because it decides its success and sustainability (Ashok *et al.,* 2014). The main problem in selecting suitable sites for tilapia farming is the lack of baseline information about physicochemical and topographic conditions, and existing land-use patterns (Hossain *et al.,* 2007). Currently, investors and government institution are demanding to identify potential aquaculture zones of pond production for Nile tilapia to enhance livelihood of local as well as national economies. Different tools are considered for the selection of site for undertaking aquaculture.GIS and RS are advanced techniques by which one can identify a suitable site for aquaculture. Therefore, conducting a specific study to bring to light the various factors suitable for aquaculture in West Shoa is essential. After GIS and RS data processed, reference points were selected for ground truth verification (Lardinois, 1992).

MATERIAL AND METHODS

The study area, West Shoa Zone, is 114 km a way west of Addis Ababa lying between latitude 8°31'46'' and 9° 93' 65'' N and longitude 37° 02' 02'' and 38° 68' 52'' E which occupies an area of 14,656.18 km^2 (Fig.1). The integration of computer hardware and software, ArcGIS 10 and ERDAS Imagine 2011 software were the primary ones used to provide meaningful information based on the intended purpose. For the analysis coincides with the geospatial aspects basic/crucial factors are identified and preparation were carried out based on the standard. Basically such kinds of information need to have a common spatial reference in order to carry out the overlay analysis. Therefore, all the data acquired were extracted and maintained in the same projection system (WGS_1984_UTM_Zone_37 N). Relatively good quality data which provided detailed and up to-date information were collected. After collecting all spatial data, weight and score were given according to their effect on Nile tilapia pond production to prepare data for ArcGIS weighted overlay. All parameters were categorized in to four suitability classes. The range of land characteristics was divided into four classes: most suitable, suitable, moderately suitable, and unsuitable (Kapetsky and Nath, 1997; FAO, 1997) on the basis of requirements for pond production of Nile tilapia.

This study focused on basic factors, twelve base layers (thematic maps) for Nile tilapia farming, namely: water temperature (maximum & minimum water temperature and elevation), water availability (perennial river, Lake and precipitation), potential for pond construction (soil texture and slope), and land use land cover (land-use type), economic factors (road, markets, population density). Weight was given according to the effectiveness of the criteria based on previous studies, experts' opinion and biology of Nile tilapia. Each classes was also given a score according to suitability, i.e. most suitable score 4, suitable score 3, moderately suitable score 2, and unsuitable score 1. The result of twelve parameters presented separately under five crucial factors and finally, in the two model scenarios.

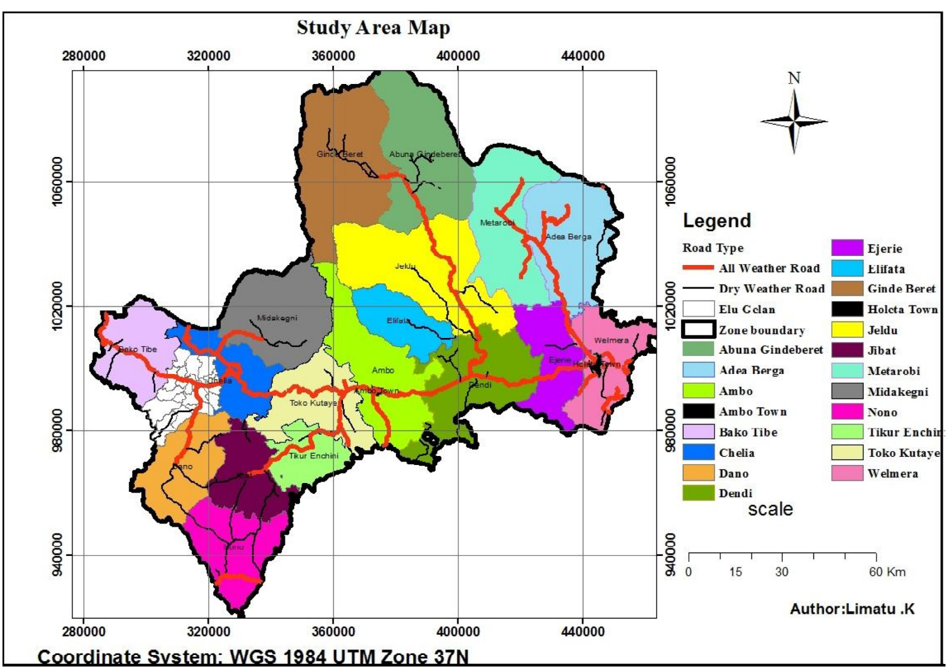

Fig. 1. Study area West Shoa Zone, west of Addis Ababa, Ethiopia

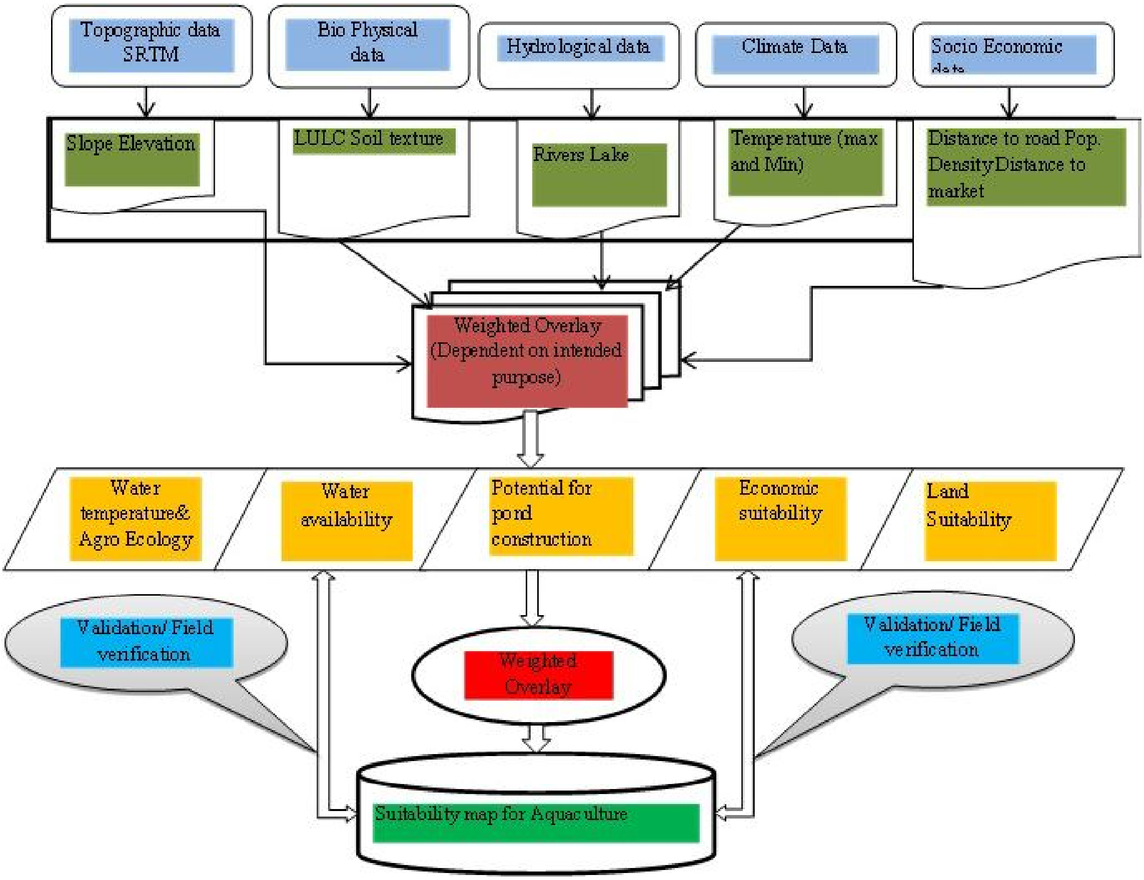

Fig. 2. The schematic overall of the Methodology

GIS Based Analysis

In present study twelve essential parameters categorized under five major factors were analyzed. The classifications of collected geospatial data were based on their specific necessity on the ArcGIS environment for the overlaid analysis. First of all, spatial data were clipped and extracted in West Shoa Zone context.

Buffer: Distance from the center of the parameters of the spatial data such as perennial rivers, lake, road and market were buffered by Multiple Ring Buffer.

Raster*:* In a raster GIS, space is represented by a uniform grid, each cell of which is assigned a unique descriptor depending on the coordinate system used. Model output can be exported to a gridded file, which in turn can be imported into raster systems for further classification and display (Kapetsky and Nath, 1997). Thus, perennial rivers, Lake, road, market, population density and land use land cover vector data were converted to raster. Slope and elevation were generated from DEM.

Raster Interpolation: Precipitation and temperature data interpolation done by spline.

Reclassification*:* Classification is an essential part of any data reduction process, whereby complex sets of observations are made understandable (Burrough, 1986). Therefore, all parameters data were classified in to four common scales.

Weighted Overly*:* To accomplish this, each source layer is first reclassified on to a common scale and then multiplied by a weighting factor (Aguilar-Manjarrez, 1996). The level of suitability parameters and threshold based on previous studies, experts' opinion and biology of the fish species.

Table 1. Interpretation of water temperature

Parameter	Most Suitable (4)	Suitable (3)	Moderately suitable (2)	Unsuitable (1)	Weight %
Elevation (m)*	<1400	1400-2000	2000-2600	>2600	20
Water T° max (^{0}C)**	25	24-25	23-24	<23	40
Water T° min (^{0}C)**	>8	5-8	4-5	<4	40

Source: (Giap & Yi, 2003)*; (Balarin & Haller, 1982)**

Table 2. Interpretations of water availability

Scale	Status	Precipitation (mm)*	Distance to Perennial Rivers(km)**	Distance to Lake(km)***
4	Most Suitable	>1400	<0.5	<5
3	Suitable	1200-1400	0.5-1	5-10
2	Moderately suitable	1000-1200	1-1.5	10-15
1	Unsuitable	<1000	>2	>15
Weight	%	80	15	5

Source; (Giap & Yi, 2003)* & **; (Eshete & Zemenu, 2012) ***,

Table 3. Potential pond construction suitability interpretation

Indicators	Most Suitable (4)	Suitable (3)	Moderately suitable (2)	Unsuitable (1)	Weight %
(Slope %)*	< 5	>5 – 8	>8 – 15	> 15	30
Soil texture (% clay)**	clay (light); silt clay; silt clay loam;	heavy clay; Sandy clay; Sandy clay loam;	Loam; loam sand Silt loam	silt/sand ; sandy loam	70

Source: (Eshete & Zemenu, 2012)*; (Hossain *et al.*, 2001; Pillay, 1996) **

Table 4. Interpretation of economic suitability

Scale	Status	Distance to Road (km)*	Distance to market (km)*	Population Density (per km^2)**
4	Most Suitable	<5	<5	>600
3	Suitable	5-10	5-10	300-600
2	Moderately suitable	10-15	10-15	200-300
1	Unsuitable	>15	>15	<200
Weight	%	25	35	40

Source; (Eshete & Zemenu, 2012) *; (Giap & Yi, 2003) **

Table 5. LULC and topography suitability interpretation

Indicators	Most Suitable (4)	Suitable (3)	Moderately suitable (2)	Unsuitable (1)	Weight %
Land use Types	Grassland Shrub land Woodland	Wetland/Afro-alpine	Cultivation	Natural Forest Plantation	100

(Source: Eshete & Zemenu, 2012)

RESULTS AND DISCUSSION

Figure 3 ‘a’ and ‘b’ show the final outcome of weight factor for subsistence and commercial mode of pond production of Nile tilapia respectively. According to this study, about 0.66% (9,621 ha), 48.6% (712,909 ha), 50.3% (736,657 ha) and 0.44% (6,431 ha) total terrestrial boundary of West Shoa Zone was found to be most suitable, suitable, moderately suitable and unsuitable respectively for subsistence mode production of Nile tilapia. Whereas, about 0.4% (5,887.38 ha), 52.86% (774,746.4 ha), 46.72% (684,692.8 ha) and 0.02% (291.42 ha) total terrestrial area of this Zone was found most suitable, suitable, moderately suitable and unsuitable respectively for commercial mode production of Nile tilapia. Only small areas were unsuitable in both commercial and subsistence mode production of Nile tilapia.

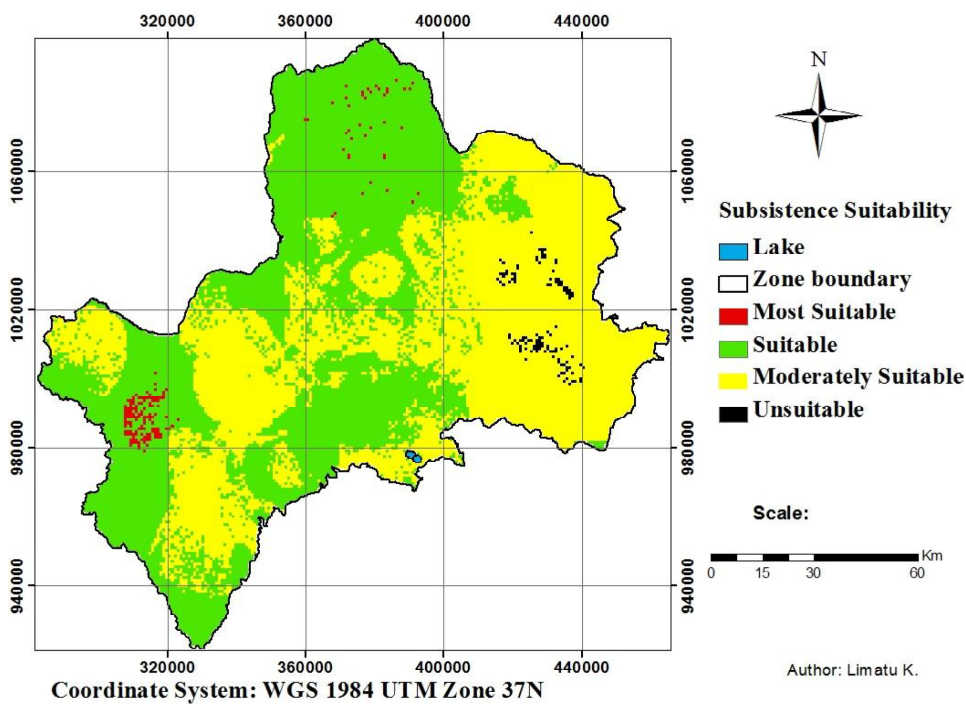

Fig. 3a. Subsistence mode of production of Nile tilapia

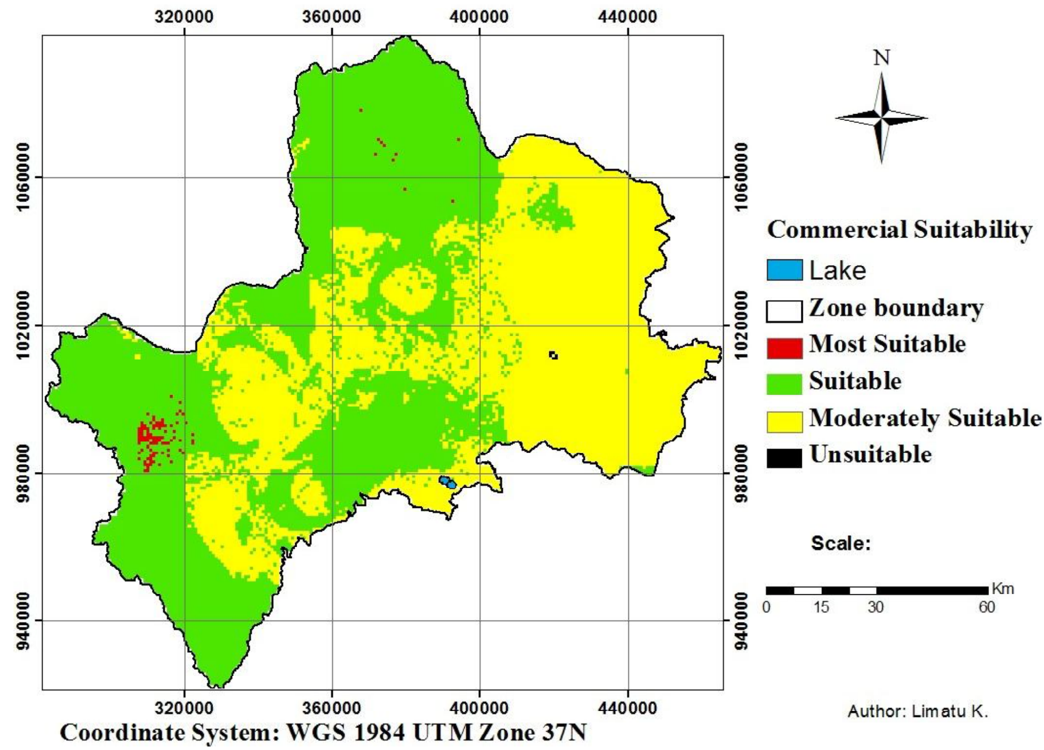

Fig. 3b. Commercial mode of production of Nile tilapia

In the present study, Geospatial data were analyzed, the geographical distribution of suitable and unsuitable sites were mapped, critical and limiting factors for the production of Nile tilapia were identified, and data on ground level truth gathered to confirm suitable sites for Nile tilapia pond production. Based on the results, it is concluded that significantly large part of the West Shoa Zone was found suitable and moderately suitable. Very small and negligible areas were found most suitable and unsuitable respectively. Water temperature and topography were the most limiting factors for Nile tilapia pond production in the Zone.

The model was verified by comparing predicted suitable sites with existing fish pond locations. Based on physicochemical parameters of water and soil, the selected woreda was categorized under most suitable class regarding to water and soil quality requirement for Nile Tilapia pond production.

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