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AGRICULTURAL LAND SUITABILITY ANALYSIS OF GANDHESWARI RIVER BASIN, USING MULTICRITERIA DECISION MAKING ANALYSIS (MCDA) AND GEOINFORMATICS

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Abstract: Agricultural land suitability refers to the ability of a portion of land to be fertile for crop production in a sustainable manner. This kind of analysis makes it possible to identify the main limitations agricultural production and enables decision makers to grow crops management capable of increasing soil productivity. The objective of this research is to identify and delineate the soil that can best support crops using a GIS-based and remote sensing multi-criteria evaluation technique of Gandheswari river basin in Bankura. The most suitable approach for spatial analysis of land suitability using Fuzzy-Entropy is the Multi-Criteria Decision Making (MCDM) concept. Several parameters of topography (slope, elevation), morphometric (drainage density), climatic (rainfall, temperature, evapo-transpiration), and soil parameters (sand, silt, clay, soil pH, NPK,) are selected to achieve this goal. All these data are normalized using fuzzification and entropy was used to determine relative importance of criteria and the resulting weights were used to construct the suitability maps using GIS software. The results of agricultural land suitability were extracted with respect to sub-basin level. The Study area has been classified into five categories of agricultural suitability (very high suitable, high suitable, suitable, moderately suitable and unsuitable). The model was tested with respect to its validity as the results were compared with the primary survey using Spearman rank correlation. The validity came out to be 0.98, which is most significant. The results of this research revealed that in the study area, 28.29% of the agricultural land is highly suitable,33.71% is suitable, 12.58% is moderately suitable 14.25% is marginally suitable and11.17% is not suitable for agricultural production. From the Spatial variation of suitability study, It can be shown that in the northern part and around the Susunia hill the not suitable land is found comparatively than the southern part and along the riverside area.

***Index Terms*—**Suitability Analysis, Fuzzy membership, Shannon entropy, GIS, Gandheswari River Basin

I. INTRODUCTION

The rapidly growing world population is putting considerable pressure on increasingly scarce natural resources, fueling the need develop more efficient and sustainable agricultural production systems to feed these growing populations (silva et al) The main thing is to choose suitable crops for specific soil and climate challenge and problems for farmers for a long time. Increased demand for food the scarcity of soil resources prompts the need for effective methods of soil suitability.(Dhadhichi) Food and The Agricultural Organization (FAO, 1976) defined a well-known suitability method analysis with respect to various parameters. There are various parameters like land land use/land cover, soil texture, slope, soil pH, soil salinity, soil sodicity, soil depth, soil drainage, groundwater quality and soil nutrients [nitrogen (N), phosphorus (P) andpotassium (K); NPK] and many climatic and agricultural factors such as rainfall,temperature, humidity, type of irrigation, etc. also affect crop development.These parameters helps to assess the farmland Capacity for the crop production. According to Collins et al.,(2001).Geographical Information System (GIS) is a significant tool for effective the mapping of land suitability and evaluation . Since in this study, various parameters are involved each parameter should be weighed based on their relative importance. The weight analysis was integrated into GIS technology and produced an accurate and reliable map of the suitability of cultivated land. In Bankura district the main food crops are Paddy,wheat.

Land suitability analysis has been proliferated during more than last three decades, after publishing the book of FAO (1976) the direction of new path has been evolved in this field. F Wang (1994), in his research paper "The use of artificial neural networks in a geographical information system for agricultural land-suitability assessment" used statistical pattern - classification method, and the Most-limiting characteristics methods and he had shown neural network are effective for agriculture land suitability assessment in the context of GIS. In another paper of Ahmed et. Al (2000), "GIS-based fuzzy membership model for crop-land suitability analysis" used Fuzzy (partial) membership classification, where he stated that GIS approach allows consideration of the spatial variability of relevant terrain as well as other parameters and consideration of partial membership to obviate the limitation of classical classification methods allowed by fuzzy membership approach. Silva and Blanco (2003), in their paper of "Delineation of suitable areas for crops using a Multi-Criteria Evaluation approach and land use/cover mapping: a case study in Central Mexico" used Principal component analysis (PCA), MCE of IDRISI (Eastman, 1997) and the method used here was adequate to integrate a climate, soil and relief database with different spatial and temporal resolutions in a GIS context. Bhagat et. al (2009), in the research paper "Land Suitability Analysis for Cereal Production in Himachal Pradesh (India) using Geographical Information System used GIS method to delineate suitable production areas for major crops (wheat, rice, maize and barley) in Himachal Pradesh" using the parameters of climatic (precipitation and temperature), topographic (elevation), soil type and land cover/land use. Duc, T.T,(2006), in his paper "Using GIS and AHP technique for landuse suitability analysis" used AHP and GIS techniques he stated The GIS technique provides greater flexibility and accuracy for handling digital spatial data. Jafari and Zaredar (2010), also used AHP process in his "Land Suitability

Analysis using Multi Attribute Decision Making Approach” and stated that AHP process is powerful support system to resolve land suitability analysis. In the paper of “Land Suitability Analysis for Different Crops: A Multi Criteria Decision Making Approach using Remote Sensing and GIS” by Mustafa et. al (2011) used Electrical conductivity (ECe),Organic carbon, Available nitrogen (N), Available phosphorus (P),Available potassium (K), Exchangeable sodium percentage (ESP), Base saturation (BS) and Cation exchange capacity (CEC),Soil texture Normalized difference vegetation index (NDVI), as parameters. Chandio et. al in his paper of “GIS- based Land Suitability Analysis Using AHP for Public Parks Planning in Larkana City” used Analytical Hierarchy Process (AHP),Weighted Linear Combination(WLC). Samanta et. al (2011) in his paper “Land Suitability Analysis for Rice Cultivation Based on Multi-Criteria Decision Approach through GIS” used MCDM technique and the parameters of Slope ,aspect ,soil texture, water holding capacity ,soil depth, soil pH, NPK ,temperature ,rainfall, and stated the inverse relationship between the percent of vegetation cover and rice land suitability predicted by index model**.**

Analytic Hierarchy Analysis (AHP) is an MCE method proposed by (Saaty 1994) investigating using a pairwise comparison matrix, which means that the two criteria are compared with each other at the same time. Analytic Hierarchy Process (AHP) is considered as a classic land suitability analysis procedure that helps to provide a systematic approach for making sound site selection decisions and also refers to the integration of a GIS-based land suitability model for site selection (Mendoza 1997).Maximum papers have used the AHP and WOA (weighted overlay analysis) AHP is mostly suitable to solve problems where the decision criteria can be organized in a hierarchical way into sub-criteria.(Zafari and Zaredar.,2010; Mustafa et al. 2011; Akıncı et al., 2013; Yalew et. al 2014; Zolekar and Bhagat 2015; Ahmed et al.,2016; Pramanik, M. K 2016; Ayehu et al., 2017; Parry et al., 2018; Akpoti et al.2019; Kadam et al. 2020; Tiwari and ajmera 2021; Kazemia, and Akinci 2018; Rajasekhar et al. 2020). Hwang and Yoon (1981) first described TOPSIS and in this field of land suitability analysis (Prakash 2003) and Bagherzadeh and Gholizadeh(2016) used TOPSIS along with AHP.

Here in the study of ALSA many researchers emphasized on the soil parameters like Soil texture Available nitrogen (N), Available phosphorus (P)Available potassium (K), as Soil reaction ,Electrical conductivity (ECe),Organic carbon, Exchangeable sodium percentage (ESP), Base saturation (BS) and Cation exchange capacity (CEC), Ahmed et al.,1999; Mustafa et al.(2011); Zolekar and Bhagat.,2015 AbdelRahman et al.,2016; Nath et al.,2021; where on emphasizing on the climatic factors F wang., 1994; Samanta et al.,2011; Kamau et a.,2015 revealed their papers. Silva and Blanco.,2003; Akıncı et al., 2013; Yalew et al.,2016; Pramanik, M.K.,2016; Bera et al., 2017;provide the importance on the topographical parameters such as slope, elevation, aspect. On the other hand many researchers have used the social factors of qualitative parameters of river proximity,well proximity, road proximity Romanao et al. 2015; Habibie et al.,2019;. Tiwari and Ajmera, 2021 only used the morphometric parameter of Drainage density with NDVI, NDWI. The objective of this research is to identify and delineate the soil that can best support crops using a GIS-based and remote sensing multi-criteria evaluation technique of Gandheswari river basin in Bankura.

II. Study area:

Gandheswari river basin is chosen for the present study of agricultural land suitability analysis. It is a left bank tributary of Darakeswar River. The river originated from north-western part of Saltora block and flow over the block of Gangajalghati, Chatna, Bankura and meet with Darakeswar River near Bankura town.

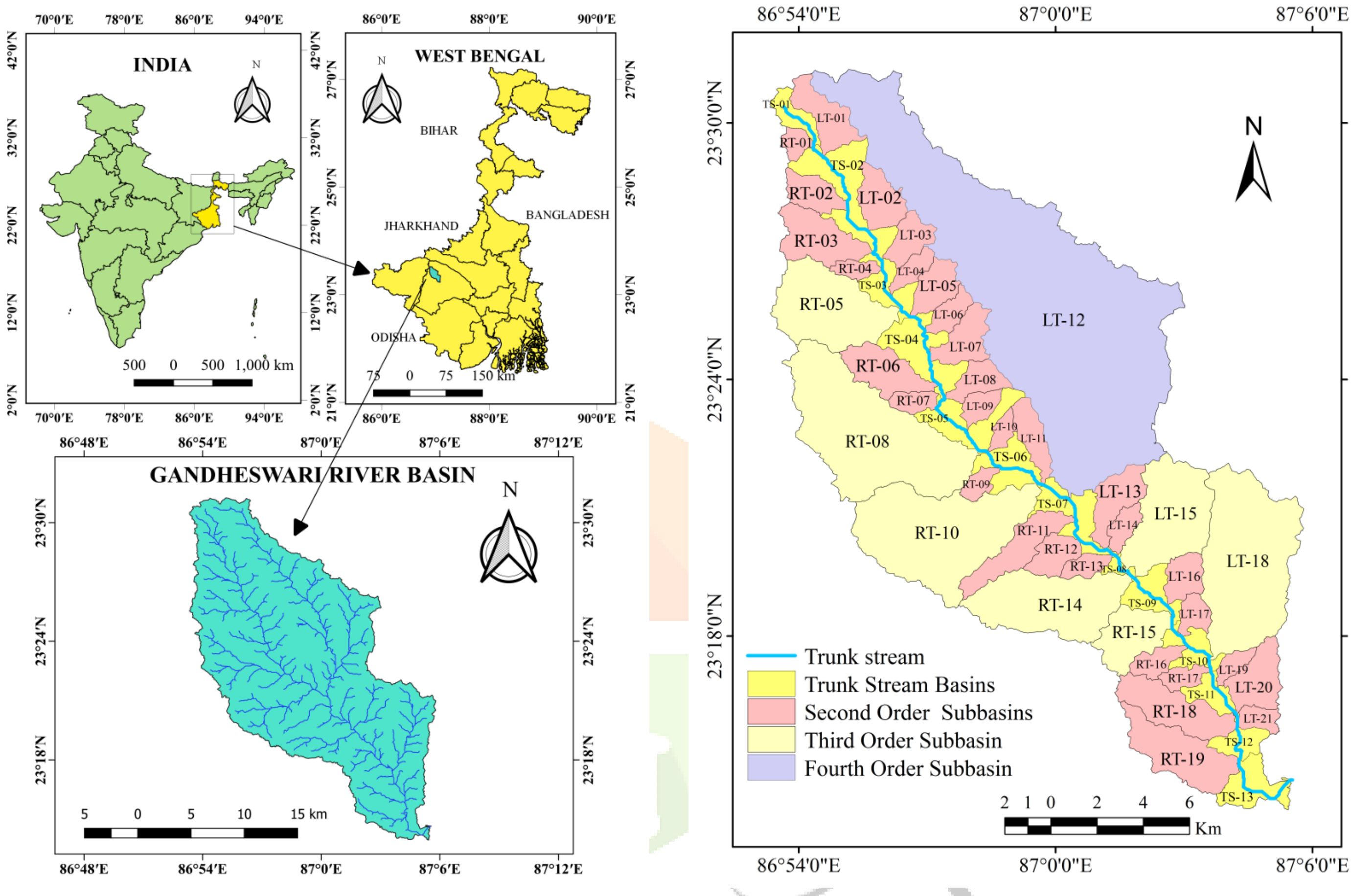


Fig 1: Location of the Study Area

The total length of Gandheswari River is 45km and is a 5th order stream. Geographically, the Gandheswari Basin is bounded by 23º14'36"N to 23º30'25"N latitudes and 86º53'13"E to 87º05'30" E longitudes and spreads across an area of about 348.693 km². The study area is subdivided into 53 sub-basins.

III. Materials and Method:

A. Materials:

In order to assess the land in the designated study area, various factors are considered such as soil parameters, climatic data, topographic data, and other relevant information. The data regarding the utilization and coverage of land were employed. The settings employed in the 'A comprehensive explanation of the study's scope is provided in the subsequent sections.

A high-quality digital elevation model (DEM) is usually suitable for assessing the characteristics and form of landforms. (Giannoni et al., 2005; Evans, 2012; Das et all (2016) etc. To conduct this research, DEM (Digital Elevation Model) data with a resolution of 30m was obtained from USGS earth explorer. The specific datasets used were n23 e086 1arc v3 and n23 e087 1arc v3. On 2000-02-11, the Shuttle Radar Terrain Mapper (SRTM) DEM was acquired. The Survey of India (SOI) provided topographic maps at a scale of 1:50,000. The basin, sub-watershed boundary, drainage network, and order were confirmed using Survey of India (SOI) topographical sheets numbers 73I/8 and 73I/12.

the properties of soil samples, including pH and NPK concentrations. The texture classes were supplied by the primary survey. Soil samples were taken in May 2022 from twelve different locations. The samples were collected at depths ranging from 0 to 30 cm and dried in the air to eliminate any grains and larger crop remnants. investigated in this study. Evaluated using a range of interpolation and geostatistical methods

The Rainfall data is acquired from the Indian Meteorological Department, whereas temperature and Potential evapotranspiration data are gathered from the grided system of the climatic research unit between 2016 and 2020. Subsequently, the maps are created using the IDW method.

B. Methods:

1) Watershed and drainage network extraction:

In this study of agricultural land suitability analysis, the Gandheswari Basin is selected as a study area. The Gandheswari drainage basin has been prepared from DEM (downloaded from USGS earth explorer https://earthexplorer.usgs.gov) in the ArcGIS 10.2.2 software. At first the downloaded two DEM's are mosaiced and then the mosaiced DEM's have been filled to clear the voids. The drainage accumulation matrix was calculated by the Flow Accumulation Command after the flow direction algorithm was performed using the D8 approach for determining the drainage network the threshold limit of 500 has been applied using raster calculator and then basin tool has used for delineating the Gandheswari basin and it has transformed into vector layer using conversion tools. Therefore, the stream ordering has been done after Strahler (1964) method. Order wise sub-basins have created by merging process. Gandheswari River is the 5th order stream, where from 32 2nd orders, 7 3rd orders, 1 4th order and 13 trunk streams and sub-basins are delineated.

2) Choosing of the parameters and preparation of maps:

The spatial information regarding selected criterion i.e. topographic parameters of slope, elevation, soil qualities like texture, potential of hydrogen (pH), and primary nutrients like nitrogen, phosphorus, potassium, the climatic parameters of rainfall, temperature, evapotranspiration and morphometric parameter of Drainage density (Horton,1945)were used for present LSA in this study.

Here the slope map has been prepared by SRTM DEM (30m resolution) and drainage density calculation has been performed by gridded system using the DEM and map has been prepared by IDW method. On the other hand, the rainfall data collected from IMD gridded data of 0.25×0.25 NetCDF file of 2016 to 2020, (Pai et al. 2014) has been prepared by interpolation. Temperature and evapotranspiration data collected from CRU gridded system; maps are prepared through interpolation (IDW) process by collecting the gridded data. The soil data of soil texture (sand, silt, and clay), macro nutrients (NPK), soil pH are collected from primary survey by collecting the data of 34 points located throughout the study area. These points are taken through gridded system using fishnet and tested in the laboratory. The sand, silt, clay, NPK, soil pH maps area prepared through interpolation (IDW).

3) Normalizing the data through fuzzification:

In this study of agricultural land suitability (ALS) analysis the different conditional factors work together to determine the ALS but these factors affect distinctly according to its different data ranges and unit. As for example, drainage density ranges between 0.01 to 3.639 km/km^2, slope varies from 0 to 40.019° so, it is very necessary to standardize the absolute value of each parameter to simplify the comparison, so the fuzzy membership method has been used to normalize the data. Fuzzy sets are not classes with the prominent boundaries (Zadeh 1965), the fuzzy membership ranges between 0.00 to 1.0 Burrough (1989), applied the fuzzy logic to land suitability evaluation for agricultural crops for the first time. The parameters which are recognized as the beneficial for land suitability like rainfall, temperature, drainage density, pH, Nitrogen, Phosphorus, Potassium, and silt are normalized by the MS Large Function using overlay tools (spatial analyst tools) and the non-beneficial parameters of slope, elevation, potential evapotranspiration are calculated under the environment of MS small.

The equation of MS large function (Luo and Dimitrakopoulous, 2003) is

$$\mathbf{f(x)}\begin{cases} \mathbf{1-\frac{bs}{x-am+bs}}, & \mathbf{x} > \boldsymbol{am} \\ \mathbf{0}, & \mathbf{otherwise} \end{cases}$$ Equation: 1

Where, f(x) is the fuzzy membership function, m = Arithmetic Mean, s = Standard Deviation of attribute x, a = Mean multiplier (taken as 1) and b = Standard Deviation multiplier (taken as 1)

With the help of the MS Small Membership function the non-beneficial parameters are fuzzified. The mathematical equation of MS Small function (Luo and Dimitrakopoulous, 2003).

$$\mathbf{f(x)} = \begin{cases} \mathbf{\frac{bs}{x-am+bs}}, & \mathbf{x} > \boldsymbol{am} \\ \mathbf{0}, & \mathbf{otherwise} \end{cases}$$ Equation:2

4) Multi-criteria decision-making technique (Entropy) for criteria weight calculation:

Here in this study of ALS Shannon entropy method is applied to evaluate the inhomogeneity among the indicators (Yang, et al., 2018). There must exist the relative importance of the parameters according to its variation of time and space, so each parameters have their individual weight according to its relative importance.

The calculation of Entropy presented as follows,

Considered as the matrix of the criteria value for each alternative,

$$\mathbf{X} = [x_{ij}]_{mn}, \quad \text{Equation: 3}$$

Step-1: The first step is to normalize the data, the normalized value for the criteria weights were evaluated by the following formula:

$$\mathbf{P_{ij}} = \frac{\mathbf{x_{ij}}}{\sum_{i=1}^{m} \mathbf{x_{ij}}} \quad \text{Equation: 4}$$

Let Pij is the normalized value of each criterion, xij be the significance of each criterion; and m is the number of hydrological units

Step-2:

$$\mathbf{e_j} = -\mathbf{k}\sum_{j=1}^{n} \mathbf{P_{ij}}\,\mathbf{lnP_{ij}}, \quad (\mathbf{i} = \mathbf{1}, \dots, \mathbf{m}) \text{ Equation: 5}$$

$$\boldsymbol{k} = \frac{\mathbf{1}}{\ln \boldsymbol{m}} \quad \text{Equation:6}$$

Where e_j = the entropy of the evaluation object, m is the number of evaluation objects, n is the number of attribute indexes,

Step-3: Entropy and inherent contrast intensity of each criterion were calculated as follows (Malekian and Azarnivand, 2015):

$$\mathbf{D_j} = \mathbf{1} - \mathbf{e_j} \quad \text{Equation: 7}$$

Where, (D_j) is criterion's degree of diversification or inherent contrast intensity of each criterion and Ej is the Entropy of the criterion

Step-4: Objective weights of the criteria (W_j) were determined as follows:

$$\boldsymbol{W_j} = \frac{\boldsymbol{D_j}}{\sum_{j=1}^{n} \boldsymbol{D_j}} \quad \text{Equation: 8}$$

Here , the entropy has been calculated through 53 points of the study area.

5) Generation of agricultural land suitability map using raster calculator:

The final agricultural land suitability map (ALSM) has been generated using the raster calculator environment in ArcGIS

$$\textbf{ALSM} = \sum P_j x W_j \qquad \text{Equation: 9}$$

Here P_j is value of normalized data, and W_j is weight of criteria

IV.Results and Discussion:

1. **Results:**

A. **Topographical Factors:**

Slope

The quality of land is affected by slope and it also determine the level of land suitability for crops (Zolekar and Bhagat 2015).The thickness of soil layer increases with decreasing slope and increases with decreasing slope (Atalay, 2006).The slope limits the soil depth, soil moisture, texture and availability of nutrients (Datye and Gupte, 1984). Soil erosion is controlled by the slope gradient (Koulouri and Giourga 2007).

It is shown in the study area of Gandheswari river basin the slope ranges from 0°-40°, with the mean value of 2.3378, where 99% places having the slope of 0°-10°.which is considered as suitable for agricultural crop production, and only 1% area in under the slope >10°. The high slope is mainly concentrated in Susunia hill situated almost at the center of the study area of river basin.

Elevation

Elevation control the temperature changes, thus in variation of plant cover, so it is considered as a vital factor affecting agricultural land suitability (Atalay 2006). Higher elevation is more affected by higher amount of rainfall (Bozdag˘ et al. 2016) and higher erosion is found due to steep slopes (Zolekar and Bhagat 2015).

Elevation in the study area of Gandheswari river basin ranged from 70 to 438 m with the mean value of 127.225. About 48% area is under 70m-115m, this area is mainly found nearer the Bankura town and extended toward north along the trunk river and ended at the south of the Susunia hill. On the other hand the elevation having 115m-225m acquire 51% area nearer to the source region of Saltora block and it extended towards south of the study area. Only 1% area is under 225m-438m concentrated in Susunia hill.

B. Morphometric Factors

Drainage Density

The drainage density (Dd) is the length of stream per unit area of the basin area (Horton 1932). Soil and rock properties (Kelson and Wells 1989), relief, climate and vegetation (Moglen et al. 1998), are related to drainage density.

There is a positive relation between drainage density and agricultural crop production. Agricultural crop Production increases with increase of drainage density. In the study area of Gandheswari Basin the value of drainage density ranged from 0.065 to 3.639 km/km^2 with the average value 0.9742 km/km^2**.** No spatial pattern in the distribution of the drainage density is observed in this basin. 84% of total area is under 0 to 1.5 km/km^2 whereas about 16 % area is characterized by a drainage density above 1.5 km/km^2.

C. Soil Factors

Clay

The concentration of clay in the soil has a significant impact on its maintenance and productivity (Davies et al. 1972). For various reasons, a very low clay soil can be as difficult to work as a high clay soil and generally a loamy soil with 15-25 percent clay with a particle size below 2 g and a higher proportion of silt particles of size. 2-60 g are most productive (Newman, 1987). By coordinating to such surface-sorbed polyvalent ions, soil organic matter is tightly bound to the clay component (Edwards & Bremner 1967). Too much clay can make the soil too stiff for plants to thrive. (national geographic)

In this Basin, It can be stated that the clay content is increasing from the west to east side of the basin. The clay ranges from 239 – 312.99 g/kg with an average value of 274 g/kg About 29% of the area is under of the range below 265 g/kg whereas 30 % of the area between the ranges of 265 – 280 g/kg and 41 % of the area is characterized clay value of more than >280 g/kg.

Sand

Sandy soils are characterized by less than 18% clay and more than 68% sand in the first 100 cm of the soil. In the World Reference Base (WRB) soil classification system (ISSS Working Group R.B., 1998) Sand has many negative impacts on the agricultural sector, higher sand content in soil reduced crop yields, slows down plant development, increases soil erosion and accelerates the process of land degradation and desertification. (Stefanski and Sivakumar, 2009). Presence of sand in soil affects the water holding capacity, which affect on agricultural production. it increases with the increase of amount of sand present in that soil and vice versa.(Yu et al. 2013)

In case of sand, it can be stated that the sand content is increasing from the south-eastern part of the basin towards north-western part. The sand ranges between 317 – 491.57 g/kg with an average value of 425.91 g/kg. About 44% of the area is under below 420 g/kg whereas 34 % of the area between the ranges of 420-450 g/kg and 22% of the area is characterized sand value of more than >450 g/kg.

Silt

Alluvial soil is usually more fertile than other types of soil, which means it is suitable for growing crop as silt promotes water retention and air circulation. (national geographic) silt is a granular material between the size of sand and clay. They are normally quite fertile and support a wide range of plant production.

The silt content in the study area lies between 241-337.995 g/kg with the average value of 299.67 g/kg. It is clearly seen from the map that silt is increasing towards northern part of the basin from southern part.41% of the total area occupied by the silt content value of more than 310g/kg, where 37% area is under 280-310 g/kg and 22% area is covered by the silt having value of <280 g/kg.

Soil texture determined the percentage of sand, silt and clay according to USDA system by Hydrometer method (Piper, 1942). Soil properties like EC, pH, buffering capacity, salinity, soil structure, nutrients i.e., SOC, N, P, K and biological elements i.e. microbial biomass are controlled with soil texture (Girvan et al., 2003; Mojid et al., 2009; Mustafa et al., 2011; Bhagat, 2014).

Soil pH

Soil pH indicates the presence of Hydrogen ions in liquid. The pH of a regular soil is determined as an indicator of its transferable cation's saturation (USDA, 1954). pH effects on nutrient availability, plant growth and productivity (Thompson and Troeh, 1973). Soil pH ascertains negative charges on soil particles and CEC, whereas CEC directly influence on Soil pH (sollins et al., 1988). Soil pH is most necessary content in soil suitability evaluation and management as it gives information about the solubility and thus control potential availability or phyto- toxicity of elements for crops and afterwards the soil suitability for specific crop. (Mustafa et al.)

In the Gandheswari basin the value of pH ranges from 6.1 to 6.5 (pH*10) with an average value of 6.27 (pH*10). This indicates a good productivity of crops. The increasing value of soil pH found from southern part to northern part of the river basin. About 79% area contained the pH value of <6.3(pH*10), the minimum area 21 % is under the pH value >6.3 (pH*10) of the total area.

Nitrogen

Nitrogen is playing an essential role for plant growth basically leaf and stem development and production (Chapin and Shaver, 1985), considered as one of the macro nutrients. SOC is one of the sources of N. the suitability of soil for plant growth decreases with decreasing the Nitrogen (Prasuna Rani et al.,1992 and Mustafa et al.)

In the Gandheswari basin, value of available Nitrogen content lies between 178-479.99 kg/ha with anaverage value of 361.85 kg/ha. About only 14% area is acquired by the nitrogen value of <300kg/ha, maximum area of 50% covered by the nitrogen value of 300-385 kg/ha, 36% area is under the range of >385 kg/ha of the total area. Nitrogen value is minimum around Susunia hill and high amount of nitrogen is found northern and southern pattern of the study area.

Phosphorus

Phosphorus is considered as an important macronutrient for crop cultivation (Halder,2013), playing an important role for root formation and growth, crop maturity, stimulate flowering, seed production, etc (Muindi 2019, Zolekar and Bhagat 2015). NPK macronutrients change over time depending on the type of crop grown. (Dadhich et al., 2017). According to (Muindi 2019) soil pH level, amount of clay, organic matter, iron, aluminum, calcium carbonate, and soil temperature determine phosphorus.

In the study area Phosphorus ranges from 18.65-74.25 kg/ha with a mean value of 47.199 kg/ha. About 25 % area of the basin depicts low (<40kg/ha) distribution of Phosphorus whereas, only 55% and 20 % area are encompassed by moderate (40-55 kg/ha) and high (>55 kg/ha) Phosphorus concentration, respectively.

Pottasium

Potassium is considered as the macro nutrient of soil. Soil mineralogy almost completely controls soil potassium status and distribution. (Fanning et al., 1989). The most important soil attribute is soil fertility, thus significantly affects crop productivity.(Dadhich et al., 2017).Deficiency of potassium losses plant's green color, turns yellow, the lower leaves fall off and reduces productivity and also It plays a vital role for many functions of plants like (1) photosynthesis activity, (2) adds stalk and stem stiffness, (3) disease resistance, (4) drought tolerance, (5) plumpness to grain and seeds, (6) firmness, texture, size and color of fruits, and (7) oil content in oil seeds (Zolekar and Bhagat 2015)

In the Gandheswari basin, it can be observed that the Potassium level increases towards the upper part from the lower part. The potassium (K) level ranges from 388-398 kg/ha with the average value of 394.57 kg/ha. Only 9.5 % of the area had a potassium value of less than 393 kg/ha and 90.5 % area had an potassium value >300kg/ha

D. Climatic Factors

Rainfall

Rainfall is the main source of water, which is essential for plant growth and development (Rana aand Randhawa,). The soil is also greatly affected by rainfall. If it is too wet or too dry, nutrients from the soil can drain away and not reach plant roots, leading to poor growth and overall health. Water in all its forms plays a vital role in plant growth and the production of all crops. It provides the medium through which food and nutrients are carried by the plant (Ayoade 2004), Ezedimma (1986) states that water is the vital component of physiological plant tissue and a reagent in photosynthesis. Water is essential for all metabolic reactions in a plant. moisture is the most important of all climatic parameters affecting crop production and yield, however, (Hodder, 1980). Moisture is primarily obtained from rainfall, which is cyclical and relatively reliable in the tropics (Ezedinma, 1986).

The annual rainfall varied between 121 cm and 130 cm per annum, from the map it can be observed that the intensity and amount of rainfall is decreasing from western part to eastern and south-eastern part of the studied basin. This amount of rainfall is favorourable for suitability of crop production in the study area

Temperature

Temperature effects on agriculture and plant growth. Crops are sensitive to climate change, including changes in precipitation and temperature, and increasing CO_2 concentrations in the atmosphere (Rosenzweig C, et al. 2014, Wheeler and von, 2013). Among the changes, an increase in temperature has the most likely negative impact on crop yields (Porter and Gawith; 1999, Ottman et al. 2012),

The mean annual temperature ranged between 26.05°C-26.22°C of the Gandheswari river basin, which helps in the agricultural production and map shown that the temperature is decreasing from south-eastern part to north-western part.

Evapotranspiration

An evapotranspiration is a very complex phenomenon comprising different aspect and processes (hydrological, meteriological, physiological, soil plant and others). Evapotranspiration forms an important component of the water flows of our hydrosphere and atmosphere (Conroy et al., 2003)

In the study area the potential evapotranspiration varies from 3.607- 3.616. Here the potential evapotranspiration work as negative factor for agricultural production.

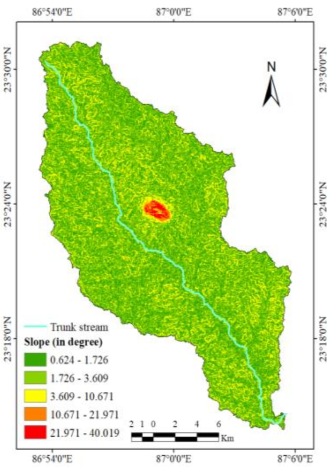


Fig 2: Slope Map

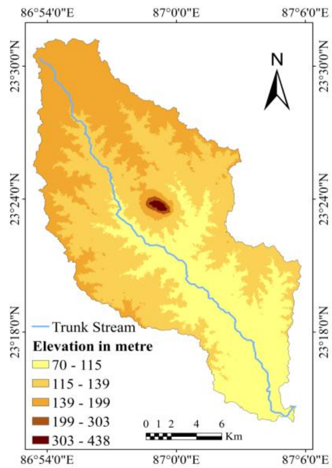


Fig 3: Elevation Map

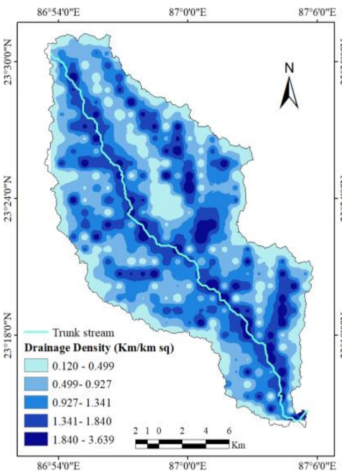


Fig 4: Drainage Density Map

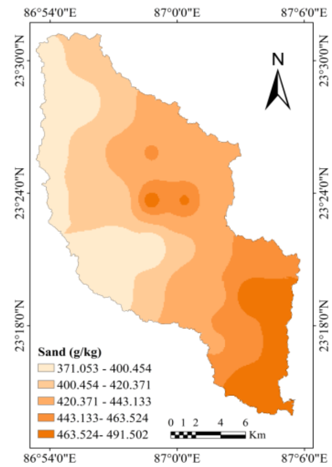


Fig 5: Sand Map

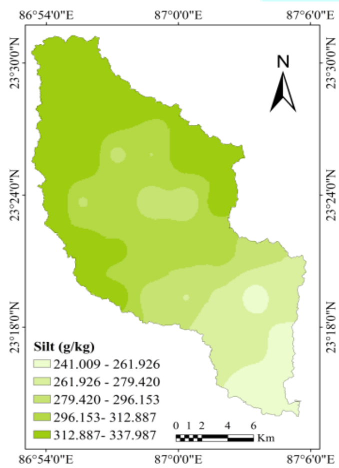


Fig :6 Silt Map

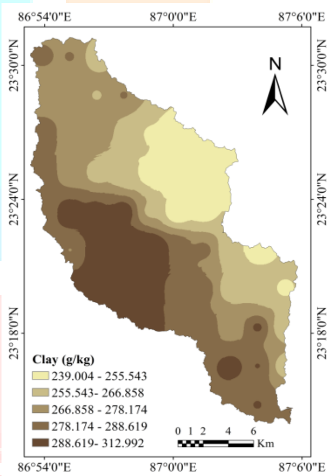


Fig 7: Clay Map

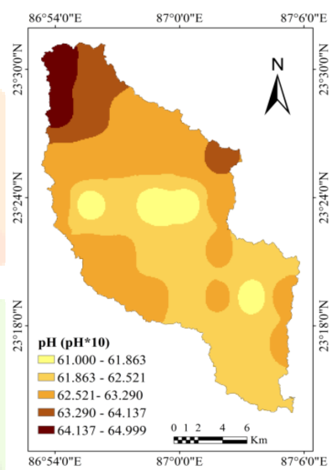


Fig 8: pH Map

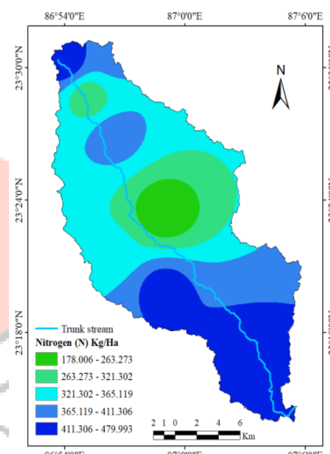


Fig 9: Nitrogen Map

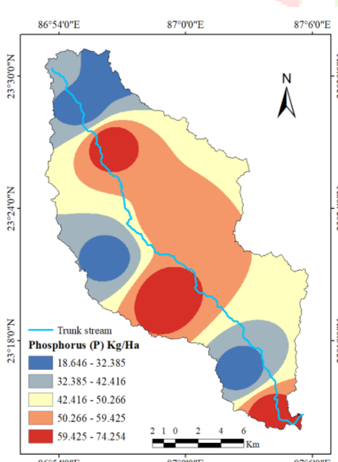


Fig 10: Phosphorus Map

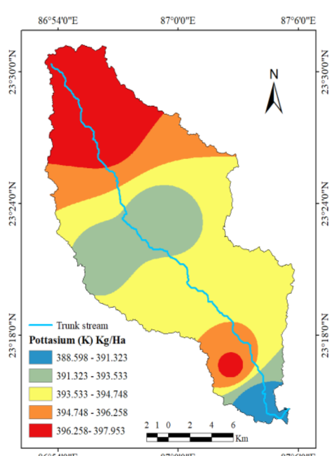


Fig 11: Pottasium Map

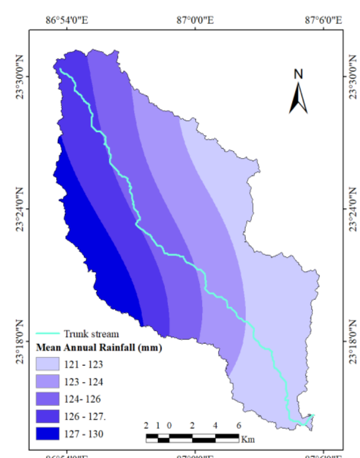


Fig 12: Mean Annual Rainfall Map

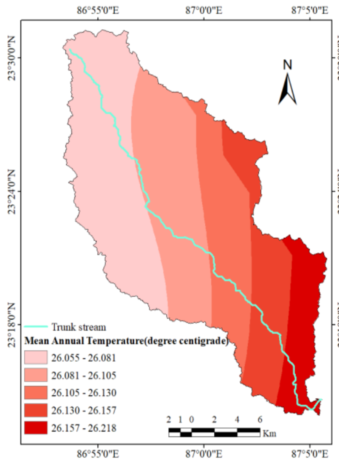


Fig 13: Mean Annual Temperature Map

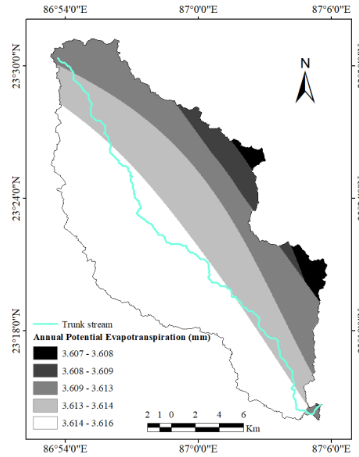
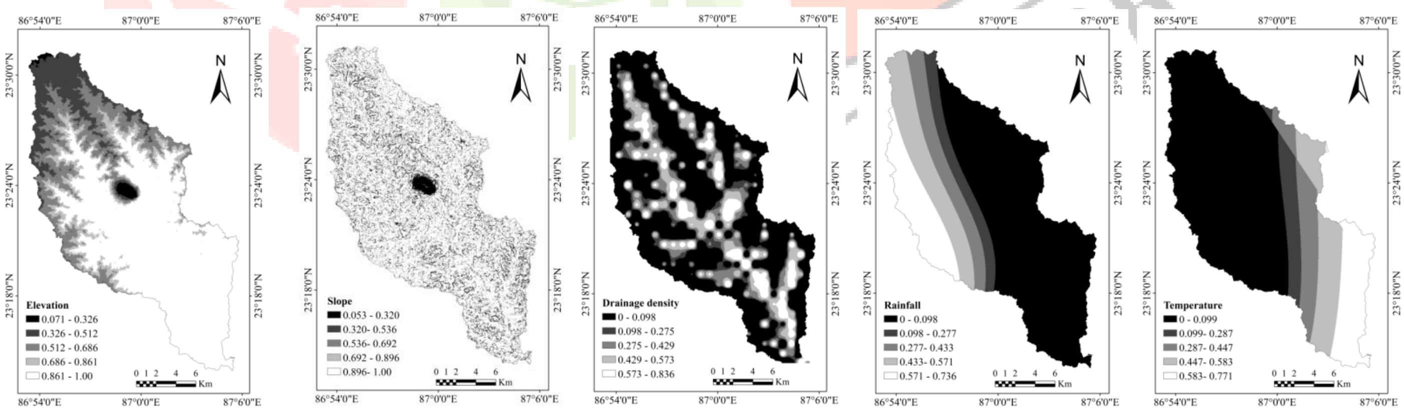


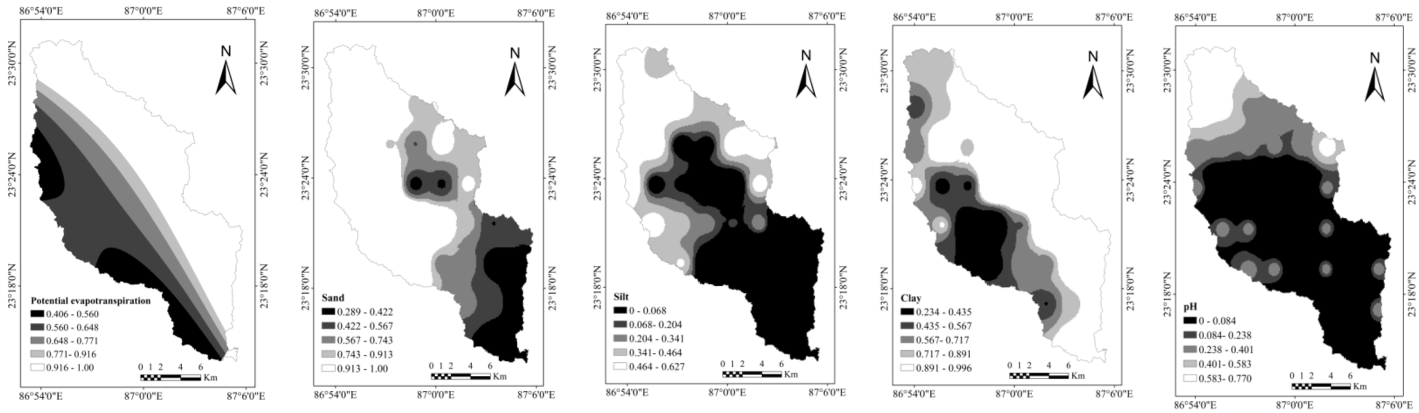
Fig 14: Mean Annual Potential Evapotranspiration Map

E. Calculation of LSA through the Fuzzy-Entropy Method

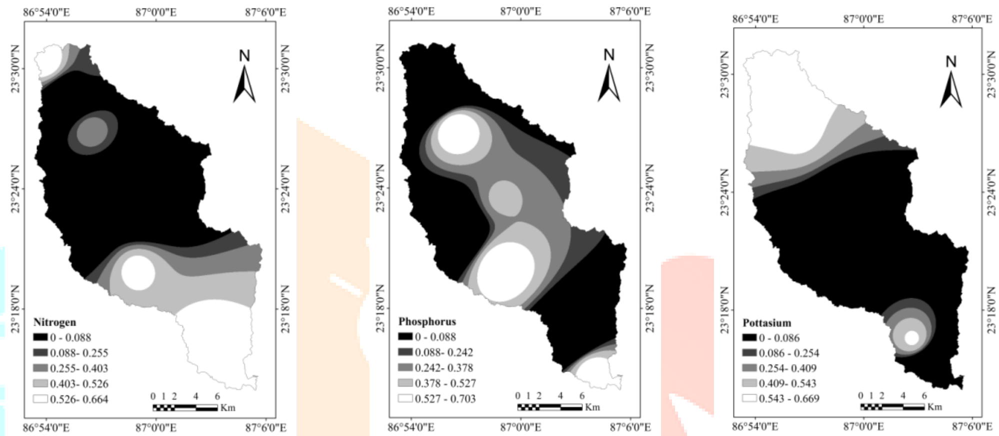
In this study, the fuzzy-entropy technique was used to assess the Land-suitability of Gandheswari River Basin. The parameters which are recognized as the beneficial for land suitability like rainfall, temperature, drainage density, pH, Nitrogen, Phosphorus, Potassium, and silt are normalized by the MS Large Function (equation:1) using overlay tools (spatial analyst tools) and the non- beneficial parameters of slope, elevation, potential evapotranspiration are calculated under the environment of MS small (equation:2). Subsequently, the Shannon's Entropy is employed to compute the objective weight of every conditional factor. Furthermore, the individual fuzzy maps are multiplied by their corresponding weight values obtained using the Entropy method (equation 4-8) with the help of the raster calculator in the ArcGIS environment.



(a) (b) (c) (d) (e)



(f) (g) (h) (i) (j)



(k) (l) (m)

Fig 15: Fuzzy Maps

(a)Elevation, (b)Slope, (c) Drainage Density, (d) Rainfall, (e) Temperature, (f) Potential Evapotranspiration (g) Sand (h) Silt (i) Clay (j) pH (k) Nitrogen (l) Phosphorus (m) Pottasium

Table:1 Calculation of Weight using Shannon's Entropy Method

Sl. no	Dem	Slope	DD	Rainfall	Temperature	PET	Clay	Sand	Silt	N	K	P	pH
1	86	1.02518	1.84586	123.069	26.164	3.61503	270.066	485.44	245.345	455.999	388.598	68.3789	62.0561
2	101	1.83982	1.35019	123.3	26.1405	3.61493	280.263	454.063	266.044	453	396.854	22.3635	62.1202
3	89	3.05393	1.34258	123.04	26.1594	3.61412	274.555	464.26	261.31	447.865	394.331	37.5462	62.2334
4	107	3.2388	0.365844	122.674	26.1792	3.61304	267.728	481.884	250.431	442.017	392.568	48.3821	62.7474
5	134	0.483315	0.354737	126.053	26.0881	3.61526	289.84	418.801	291.537	416.536	393.987	59.328	62.5922
6	128	4.84578	0.536859	124.879	26.1031	3.61516	284.412	433.997	281.945	418.114	394.202	53.8186	62.3303
7	118	2.18729	0.813974	124.045	26.1196	3.61482	282.752	441.728	275.643	424.236	394.701	43.4792	62.3248
8	87	2.66733	2.00355	123.444	26.1376	3.61422	277.603	452.808	269.486	431.969	395.02	37.5016	62.162
9	94	1.70831	1.48901	122.935	26.1563	3.61338	271.357	464.493	263.969	430.777	394.558	39.4811	62.1387
10	115	2.75326	0.065793	122.353	26.176	3.6123	266.324	470.948	262.672	425.595	393.867	43.768	62.5939
11	136	1.23205	0.539945	128.778	26.0672	3.61482	291.666	394.933	313.555	363.974	393.476	42.5353	62.7406
12	136	2.66733	1.0893	127.245	26.0772	3.61496	294.135	396.593	309.412	406.803	393.762	60.0652	62.7319
13	124	1.992	0.75377	125.976	26.0893	3.61493	293.353	411.703	295.049	449.998	393.96	74.2546	62.644
14	108	3.48102	0.747836	124.937	26.1034	3.61471	282.881	430.845	286.709	419.904	393.93	65.2184	62.2075
15	99	3.43057	1.69275	124.107	26.1192	3.61427	278.899	436.446	284.392	397.214	394.041	54.7273	62.5123
16	102	5.46227	1.40873	123.413	26.1364	3.61362	272.227	452.797	274.52	396.07	394.166	48.8128	62.1836
17	122	2.16048	0.688978	122.774	26.1544	3.61275	267.029	466.076	266.442	399.25	394.147	46.5437	61.889
18	117	1.02518	1.04714	122.078	26.1869	3.6084	261.938	464.473	273.501	400.746	394.017	46.2924	62.6674
19	132	0.00012	1.41006	129.16	26.0641	3.61484	278.89	398.789	322.345	339.099	393.222	30.4819	62.8161
20	137	0.683494	0.455871	127.83	26.0715	3.61488	291.668	392.777	315.895	336	392.774	22.2648	62.7057
21	120	1.08062	0.862829	126.597	26.081	3.61482	304.076	384.614	311.917	333.486	393.195	39.2302	62.6525
22	110	1.40884	1.58358	125.538	26.0923	3.61463	312.891	379.434	307.695	328.075	393.396	54.3111	62.0349
23	105	2.16048	0.592848	124.639	26.1055	3.61428	283.953	414.505	301.539	332.431	393.535	55.9333	62.031
24	119	3.14773	0.626349	123.895	26.1203	3.61376	264.054	430.858	305.035	344.045	393.758	53.6746	62.6611
25	115	2.89748	1.30291	123.251	26.1364	3.61305	260.568	444.72	294.617	357.28	393.957	51.0342	62.423
26	125	3.69162	0.419937	122.638	26.1666	3.60896	257.678	458.441	283.819	368.285	394.069	49.1077	62.1138
27	152	0.966561	0.131289	129.089	26.0629	3.6151	274.058	391.158	334.766	344.903	394.603	41.5578	62.9476
28	129	1.23205	1.48428	128.042	26.0687	3.61498	290.055	405.055	304.852	335.83	394.132	40.1203	61.6898
29	127	2.48651	0.573825	126.926	26.076	3.61483	288.859	408.252	302.886	317.56	393.709	41.0125	61.8931
30	122	4.36822	1.41947	125.855	26.0851	3.6146	283.911	415.493	300.611	252.854	393.097	49.9588	61.9804
31	185	11.2301	0.067174	124.927	26.0956	3.61427	244.794	466.5	288.704	178.006	392.305	56.1915	61.1867
32	125	3.67585	0.744443	124.161	26.1079	3.61381	253.876	461.386	284.725	234.597	392.949	53.999	61.203

33	111	1.36679	1.30831	123.565	26.1217	3.61322	252.368	432.246	314.771	294.534	393.634	51.9467	62.601
34	147	6.33127	0.302283	128.172	26.0657	3.61514	280.766	395.268	323.306	353.585	395.864	45.8096	62.9796
35	142	3.89071	0.906725	127.228	26.0719	3.61486	273.199	404.309	321.929	354.063	395.848	50.7109	62.8192
36	123	0.76416	1.30038	126.186	26.0794	3.61456	274.22	414.155	311.317	348.61	395.666	54.5424	62.7298
37	135	3.41359	0.967272	125.179	26.0882	3.6142	272.353	427.116	300.446	315.986	394.885	53.5004	62.6336
38	124	0.483315	1.43832	124.332	26.0982	3.61377	259.461	439.312	301.18	280.311	394.076	52.4932	62.6251
39	127	1.992	1.59564	123.689	26.1098	3.61324	252.373	430.241	317.329	284.272	394.009	51.4471	62.7137
40	126	3.05393	1.29288	123.271	26.1357	3.60942	249.061	431.643	319.182	306.62	394.235	50.0291	63.1475
41	154	3.81538	0.375928	127.641	26.0663	3.61481	281.053	391.706	326.84	351.442	396.88	41.4984	63.6893
42	141	3.07292	1.40213	126.7	26.073	3.61443	274.913	399.5	325.19	364.375	396.965	53.2903	63.4563
43	140	1.23205	1.07598	125.67	26.0807	3.61403	271.623	409.062	318.937	401	397.024	73.9799	63.2051
44	141	2.81598	0.758593	124.695	26.0894	3.61359	266.857	421.215	311.633	373.252	396.603	60.098	62.9825
45	137	0.76416	0.88438	123.91	26.0992	3.6131	258.795	431.148	309.938	347.485	395.895	50.9212	62.9363
46	148	1.23205	0.581798	123.376	26.1235	3.60932	254.094	428.907	316.907	335.944	395.403	48.0345	62.9258
47	158	2.4152	0.29529	127.302	26.0644	3.61408	284.48	383.7	331.741	344.913	397.477	30.5829	64.5382
48	146	1.70831	1.0487	126.362	26.0715	3.61365	278.296	394.442	327.141	272.002	397.99	19.6089	63.9722
49	149	2.07795	0.69388	125.365	26.0795	3.61321	272.626	402.413	324.605	337.635	397.334	33.5055	63.5119
50	149	0.76416	0.535708	124.445	26.0883	3.61275	265.658	411.843	321.976	360.454	396.899	39.7536	63.1503
51	169	3.69162	0.869402	126.999	26.0597	3.61297	278.874	398.178	322.938	479.994	397.42	40.9918	64.9269
52	172	1.52805	0.825572	126.117	26.0673	3.61254	276.962	404.895	318.108	398.95	397.285	30.2246	64.0758
53	162	3.69162	0.757415	125.206	26.0755	3.61212	275.059	406.465	318.376	378	397.13	18.6469	63.8581
Wj =	***0.032597294***	***0.503370626***	***0.33221569***	***0.000263***	***0.0000020883646***	***0.0000002206685***	***0.002915***	***0.004936***	***0.006719***	***0.033499***	***0.0000219948097***	***0.08330725***	***0.00015363***

2. Discussions:

The purpose of this study was primarily focused on identification of suitable land for agricultural crops of Gandheswari river basin of Bankura district using a geographic information system (GIS) remote sensing and entropy. The results of this research revealed that in the study area, 28.29% of the agricultural land is highly suitable, 33.71% is suitable, 12.58% is moderately suitable 14.25% is marginally suitable and11.17% is not suitable for agricultural production.

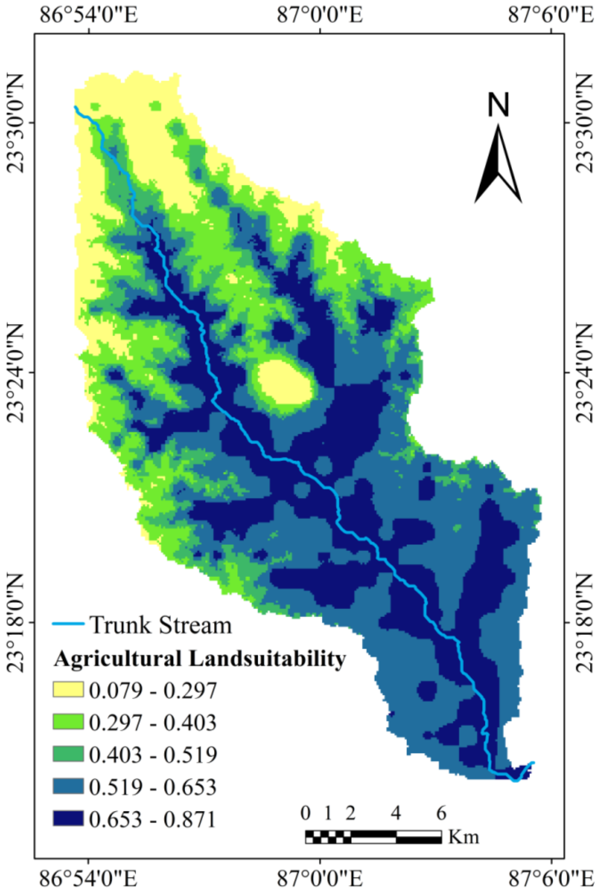


Fig 16: Agricultural Landsuitability of Gandheswari river Basin

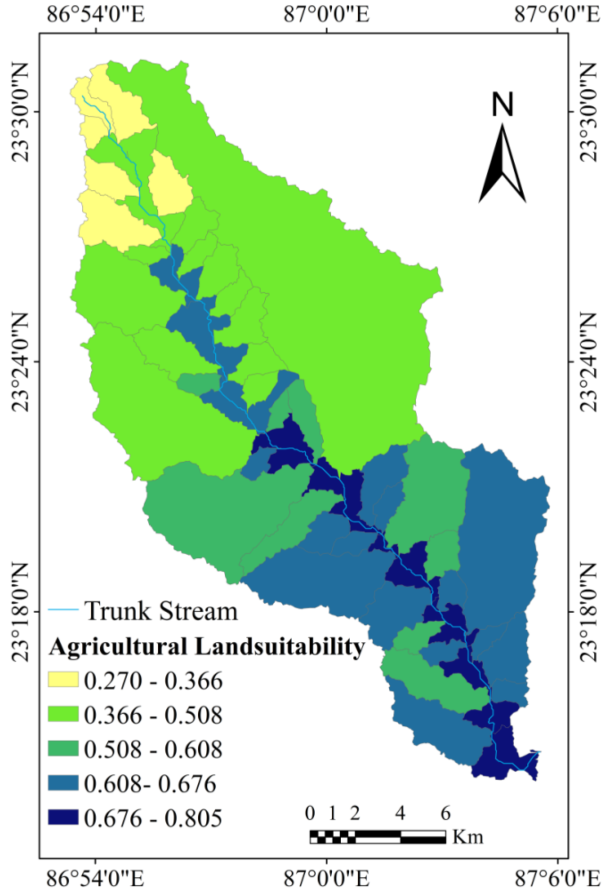


Fig 17: Subbasin level Suitability of Gandheswari River Basin

The low production mainly found in the upper part of the study area. In this part of Saltora block the low production caused by some geomorphologic process like high elevation not only that here the presence of rocky soil can be identified, the people of this area stated that there is more irrigation problem and this problem helps to decrease the agricultural production. On the other hand, in the southern part and the middle of the basin shows the suitable due to its low elevation and good availability of irrigation system. From the primary survey it has been noticed that this area has multiple water bodies of ponds and well also.

Table 2: Ranking and suitability zone of 53 sub-basins according to the mean value

Sub-basin Name	MEAN	Rank	Suitability Zone	Sub-basin Name	MEAN	Rank	Suitability Zone
LT_01	0.280256	5	not suitable	RT_06	0.482708	4	marginally suitable
LT_02	0.353337	5	not suitable	RT_07	0.579533	3	moderately suitable
LT_03	0.424876	4	marginally suitable	RT_08	0.484898	4	marginally suitable
LT_04	0.483269	4	marginally suitable	RT_09	0.61479	2	suitable,
LT_05	0.453954	4	marginally suitable	RT_10	0.546067	3	moderately suitable
LT_06	0.477381	4	marginally suitable	RT_11	0.599733	3	moderately suitable
LT_07	0.484286	4	marginally suitable	RT_12	0.637068	2	suitable,
LT_08	0.460428	4	marginally suitable	RT_13	0.664477	2	suitable,
LT_09	0.508496	4	marginally suitable	RT_14	0.630223	2	suitable,
LT_10	0.58062	3	moderately suitable	RT_15	0.631112	2	suitable,
LT_11	0.54777	3	moderately suitable	RT_16	0.587862	3	moderately suitable
LT_12	0.485234	4	marginally suitable	RT_17	0.632437	2	suitable,
LT_13	0.645507	2	suitable,	RT_18	0.606891	3	moderately suitable
LT_14	0.658071	2	suitable,	RT_19	0.620748	2	suitable,
LT_15	0.608527	3	moderately suitable	TS_01	0.28257	5	not suitable
LT_16	0.603904	3	moderately suitable	TS_02	0.437988	4	marginally suitable
LT_17	0.623887	2	suitable,	TS_03	0.651503	2	suitable,
LT_18	0.623513	2	suitable,	TS_04	0.656487	2	suitable,
LT_19	0.676065	2	suitable,	TS_05	0.618365	2	suitable,
LT_20	0.619887	2	suitable,	TS_06	0.705649	1	highly suitable
LT_21	0.664242	2	suitable,	TS_07	0.724979	1	highly suitable
RT_01	0.270077	5	not suitable	TS_08	0.74884	1	highly suitable
RT_02	0.326513	5	not suitable	TS_09	0.704332	1	highly suitable
RT_03	0.366217	5	not suitable	TS_10	0.709983	1	highly suitable
RT_04	0.496623	4	marginally suitable	TS_11	0.690419	1	highly suitable
RT_05	0.415525	4	marginally suitable	TS_12	0.717036	1	highly suitable
				TS_13	0.693849	1	highly suitable

V. Conclusion:

Validation is needed for making the predictive model reliable. Until and unless the predictions of model become reliable it is necessary to continue the research and find out the possible reason of its inaccuracy. So, it is necessary that the entropy-based agricultural land suitability analysis of Gandheswari river basin needs to be checked with respect to the actual production. So the estimated land suitability which is calculated by entropy method is validated to the people perception (data taken from the primary survey) with the help of 5 point Likert scale from that area using spearman rank correlation

$$r = 1 - \frac{6\{\sum d^2 + \sum (t^3 - t)/12\}}{n^3 - n} \quad \text{..............(21)}$$

(N G Das)

Where, r= Spearman Rank Correlation Coefficient, n = Number of individuals, t = number of individuals participating in a tie in the first or second series, d = Difference between the ranks of an individual in the two series

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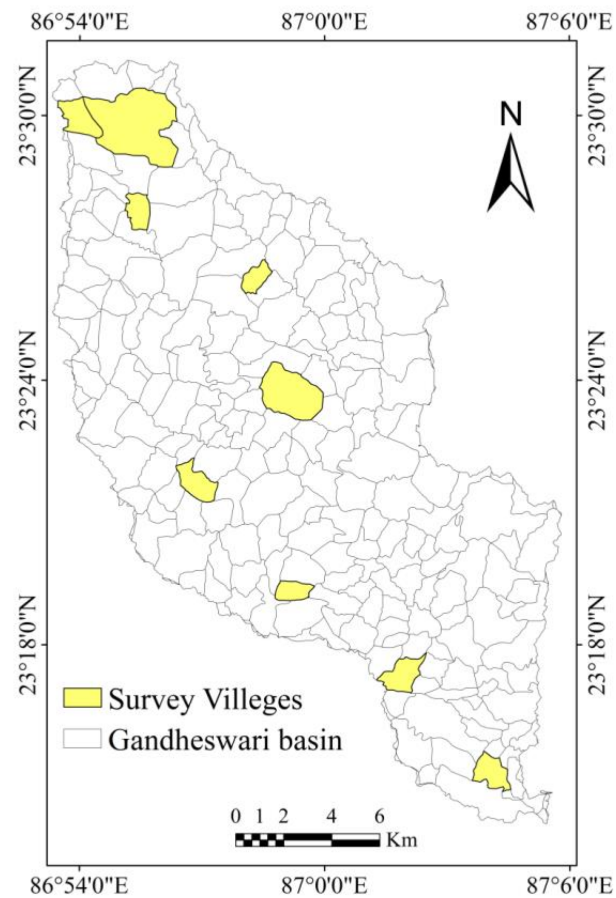

Fig 18:Surveyed villages of Gandheswari River Basin

The 9 villages of Shiarbedia, Ghoramurga, Nambad, Madhabpur, Susunia, Majhidi, Sarberia, Chaitali, and Junbedia have been surveyed. With the help of 5 point Likert scale (as the area is divided in 5 suitable zone) of 1-Highly suitable, 2- Suitable, 3-Moderately suitable, 4- Marginally Suitable, 5- Not suitable. From here with the help of questionnaire the agricultural production of that area, Soil quality, climatic condition, data have been collected. And from this perception survey the rank is given to the following villages (mentioned in table:2)

In case of secondary data with the help of mean value extracted from the agricultural land suitability final map the rank is given to the following villages, (mentioned in the table: 3)

Comparing the values from entropy to the observed values of primary survey it reveals high correlation. Here the nonparametric spearman's correlation method has been maintained to find out the value of ***r***. The values of correlation coefficient ***(r)*** is **0.986**

Table 3: Validation table; Entropy weight and primary survey weight of 9 surveyed villages

Villages	MEAN	Entropy weight (Rx) Secondary Sources	Survey weight (Ry) Primary Sources
Shiarbedia	0.279221	5	4
Ghoramurga	0.292317	5	4
Nambad	0.542275	2	2
Madhabpur	0.426384	3	2
Susunia	0.217243	5	5
Majhidi	0.484992	3	2
Sarberia	0.709489	1	2
Chaitali	0.563029	2	1
Junbedia	0.70141	1	1

Based on the objective of the work that is to find out the suitable land that ascertain the sustainable agricultural production, in highly suitable and suitable areas, southern part of the basin and along the trunk river large-scale agriculture can be practiced and appreciable production can be expected. In moderately suitable areas, irrigation method should be chosen carefully and soil management must be performed to develop soil fertility. In marginally suitable areas, a good farming is only possible with the improvement of soil quality, irrigation system. And in the not suitable zone the farming will be risky and should be limited. The study involves the physical properties (topographical properties, climatic, pedologic etc) only and need to incorporate social criteria and the parameters related to water availability for the farming generation. The results of this study accounting the rigidity of existing land use pattern and help us to identify the natural potentials and limitations of land for agriculture.

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