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AGRICULTURAL LAND SUITABILITY ANALYSIS OF BANKURA DISTRICT OF WEST BENGAL USING AHP AND GIS TECHNIQUES

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ABSTRACT

Agriculture is the prime economic activity for people of Bankura district, West Bengal but due to some specific land characters, agricultural productivity is not satisfactory. Therefore, it is mandatory to judge the quality of land for better output of agricultural production as well as maintain the sustainability of land uses. Land suitability analysis is an important assessment for identifying proper land uses to get more benefits from the land. The present study evaluated the level of suitability for agriculture of the district. The analysis of agricultural land suitability has been done on the basis of multiple land characteristics and climatic variables. We have used the AHP (Analytic Hierarchy Process) technique to evaluate the land characteristics using elevation, slope and aspects of land; type, texture, depth and moisture of soil; land use/land cover and rainfall as influential factors for the agriculture and GIS (Geographical Information System) tools have also been used for overlay weighted calculation, mapping and final output of the agricultural land suitability analysis. Results indicated that the 3.44% area of Bankura district is not suitable for agricultural activities. On the other hand, the area highly suitable for agricultural production is found to be 5.26 % of the district. However, 56.26 % and 35.05 % area are found to be moderately and marginally suitable, respectively which need to be further managed for the sustainable agriculture. The techniques and results of the study can be useful in assessing the suitable land for agriculture for sustainable agriculture management.

Keywords: Agricultural Land Suitability Analysis, Analytic Hierarchy Process, Geographical Information Systems, Sustainable agriculture management.

In the present time, the rapid growth rate of the population has pressurized the natural resources especially agricultural land which are either converted or depleted due to the expansion of the human habitat area. As a result, the suitability or availability of land for agricultural production has decreased and has induced encroachment for another marginal land for agriculture without knowledge of the inherent capacity of the land. It was estimated that a total of 250 million population of the world is affected by land degradation and 1 billion people have risks (WMO, 2005). About 14.9% and 1.4% of people are suffering from hunger as well as malnutrition in developing and developed countries respectively (FAO, 2012). As on a report of Indian Council of Agricultural Research (2010), about 120.40 million hectors land of India has been affected by land degradation and as a result, the uses of the non-agricultural area increased by 11 % in the last decade whereas the area of cultivated land declined by 0.8% and the net sown area declined by 0.7% (Agricultural Census, 2012-13).

About 22% of the population in India has been suffering from malnutrition and 36% population do not get their optimum food. The improvement of agricultural activities is the only solution to overcome the scarcity of food (FAO, 2012). Therefore, discovering the land with the increasing demand and the land evaluation is an essential way to re-establish the capability of land (Bandyopadhyay *et al.,* 2009), and also it goes towards the high production of agriculture from the land.

Land suitability analysis is a key to detect the inherent capacities, potentiality, and suitability of a specific area for particular land use which is considered the multiple criteria based on environmental, social, and economic factors. It measures the requirements that how well the qualities of the land unit fulfilled the needs of specific land uses (Akinci *et al.*, 2013, FAO, 1976). The appropriate use of land can be determined with the comprehensive study of natural as well as social factors that influence the suitability of land.

Recently, the new method has been applied for the suitability level analysis of agricultural land that deals with Multiple Criteria Evaluation (MCE) and a large set of data from Remote Sensing techniques and Web base application which would support the appropriate analysis of land (Tayyebi *et al.*, 2016). Karimi *et al.* (2018) undertook a study on GIS and multi-criteria analysis techniques for the evaluation of land suitability of wheat cultivation using the Analytic Hierarchy Process (AHP). Recently, many researchers have used the AHP method of multiple criteria for land suitability analysis in reference to increasing efficiency

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of agricultural production (Kazemi and Akinci 2018; Ostovari *et al.*,2019).

The major part of the Bankura district is known for undulating topography and low fertility of the soil. In the Bankura district, more than 82% of the population is engaged in agriculture as the main occupation and due to high utilization, the agricultural land decreases the quality of land which has an impact upon the production rate. Since most of the soil in Bankura district has lost the productivity rate by indiscriminate interference to nature which results in a low rate of agriculture (NBSS, 2013). This region has not been taken in any research for the land evaluation on the basis of the nature of the lands. So, it has great relevance to do work on Agricultural Land Suitability Analysis (ALSA) as proper prosperity and proper management for sustainable agriculture and also this research provides information at a local level that can be used by the farmers for proper planning in accordance with suitability analysis. Therefore, the major objective of the present study is to analyse the land capabilities for finding the suitable site for agriculture through the evaluation of physical factors of land using AHP and GIS techniques.

MATERIALS AND METHODS

Study area

Bankura district is located on the western side of the state of West Bengal and extends between 22°38' and 23°38' North and between 86°36' and 87°46' East. The district is divided into two physiographic divisions i.e., vast alluvial plain in the east and denuded spurs of Chhota Nagpur plateau in the west. The eastern part is marked by flood plains and interfluves while in the west the elevation gradually raises to isolated hillocks, broken low ridges interspersed with valleys. The prominent hillocks are Biharinath (447.8 m above MSL) and Susunia (439.5 m above MSL). Besides, there are a number of sporadic hillocks and mounds ranging in elevation from 61 to 122m above MSL. The district is located on the marginal fringe of the undulating surface on the western portion and alluvial plain on the eastern portion of the West Bengal (Nandi, 2019). The poor drainage condition of soils, less fertility, soil erosion, heavy irregular rainfall, high pressure on agricultural land, etc. are unwanted problems for agriculture in this region. Bankura, as a backward district where about 82 % of the total population is engaged in agriculture, has to improve the quality of agriculture for improving the standard of living of people of this district (Fig.1).

Database

The agriculture suitability map has been prepared with the help of spatial distribution of various physical criteria influencing agriculture like slope, aspect,

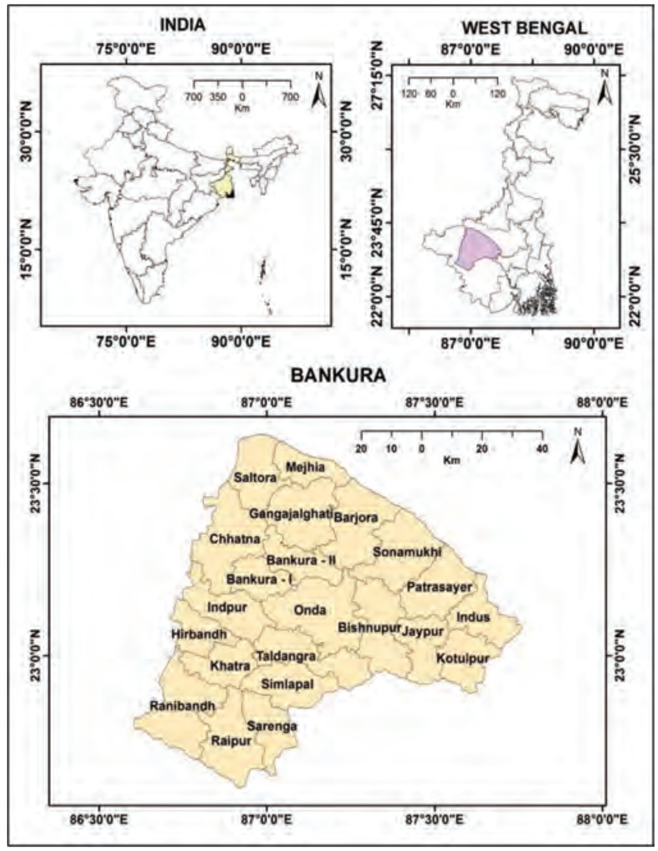

Fig. 1. Location map of the study area

elevation, rainfall, land cover categories etc. The slope, aspect and elevation maps were prepared by using the Digital Elevation Model (DEM) of Shuttle Radar Topography Mission (SRTM) which was downloaded from the Open Topography (https://opentopography.org/). Soil textures and soil depth map were prepared by using the data from Bhuvan (https://bhuvan.nrsc.gov.in/bhuvan_links.php#). The soil type map has been adapted from Nandi (2019). The rainfall data have been collected from the Centre for Hydrometeorology and Remote Sensing (CHRS) Data Portal (https://chrsdata.eng.uci.edu/). Land Use Land Cover (LULC) and Normalized Difference Water Index maps (NDWI) were prepared by using Landsat- 8 Operational Land Imager (OLI) data in 2020 which were downloaded from USGS website (https://earthexplorer.usgs.gov/).

Methodology

The present study has been carried out by the analysis of multiple criteria which directly or indirectly influence the agricultural activities. The AHP tool and GIS software was used. It has been done by given weighted value to each factor and score to each sub factor according to the importance. The whole methodology of the present study has been discussed within the following subsection (Fig. 2).

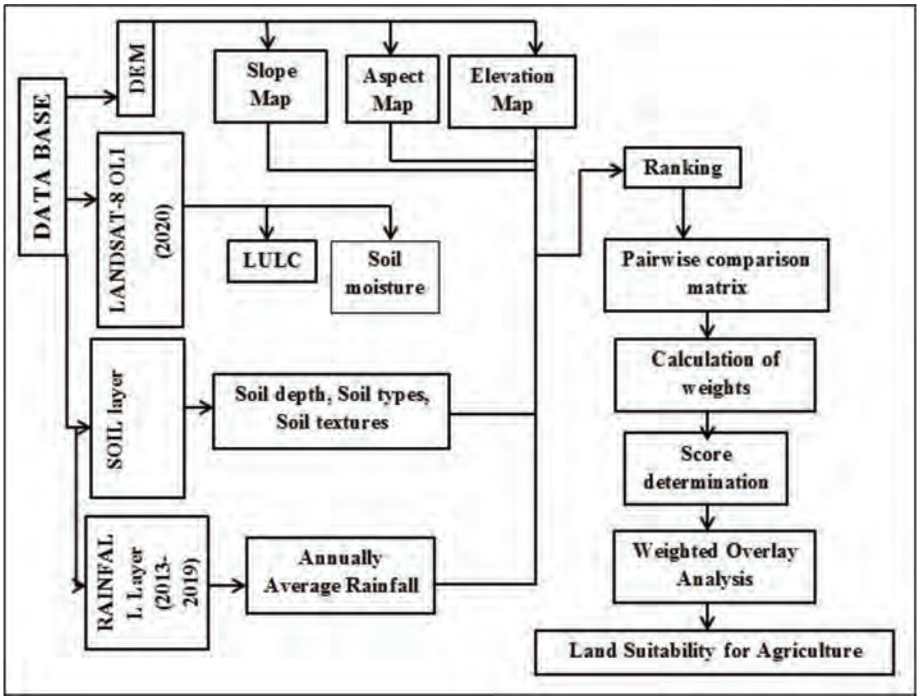

Fig. 2. Flow chart of agricultural land suitability analysis

Criterion

The present study aims at assessing the land suitability for agriculture and therefore, the criteria i.e., soil type, soil texture, LULC, soil depth, slope, aspect, elevation, soil moisture, and rainfall were selected.

Slope

The slope of the present study area is ranging from 0º to 35º and the maximum area comes under the 0º to 1º and 1º to 2º ranging of slope (Table. 1). Some upland hills are found in northern and southwestern of the study area (Fig. 3).

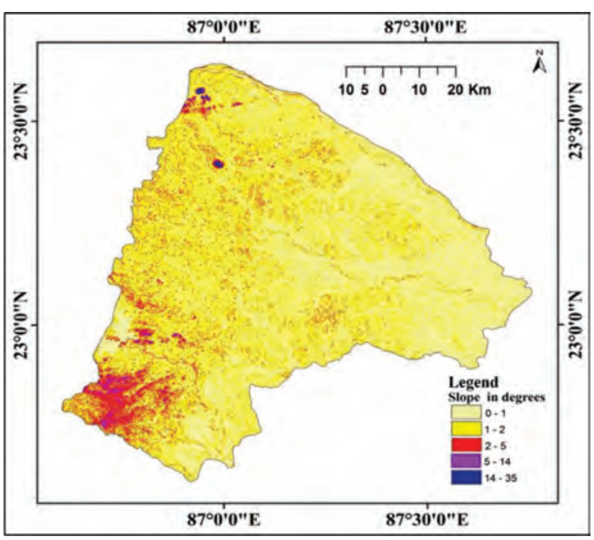

Fig. 3. Slope map of the study area

Land use land cover (LULC)

In the study area, eight land-use types were identified which are cultivated land, deep vegetation, sparse vegetation, settlement, rocky area, fallow land by using the combined method that is supervised and unsupervised classification techniques (Fig. 4).

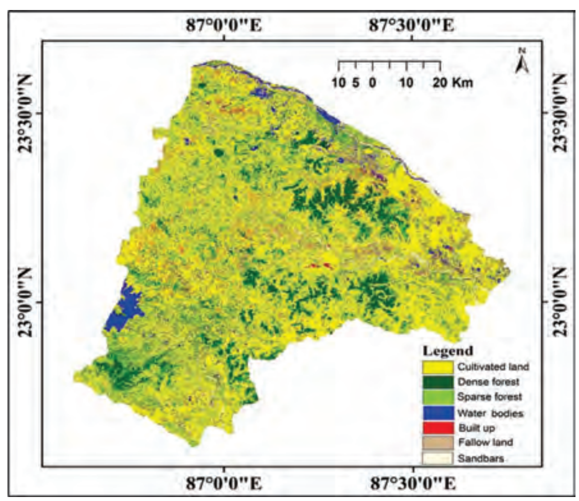

Fig. 4. LULC map of the study area

Soil types

The soils are grouped into five categories i.e., new alluvium, old alluvium, lateritic, red and yellow soil, red and gravelly soil (Fig. 5).

Table 1. **Areal and percentile distributions of the main and sub-criteria parameters in the study area**

Main criteria	Sub-criteria	Area (ha)	Area (%)
Slope(º)	0-1	341032.00	49.09
	1-2	262643.00	37.81
	2-5	82852.00	11.93
	5-14	7465.00	1.07
	14-35	676.00	0.10
LULC	Cultivated land	403951.00	58.15
	Dense forest	134993.00	19.43
	Sparse forest	31507.70	4.54
	Water bodies	49459.30	7.12
	Built up	26660.40	3.84
	Fallow land	41020.30	5.91
	Sandbars	7047.27	1.01
Soil depth(cm)	25-50	62888.02	9.05
	75-100	436.59	0.06
	100-150	585578.00	84.30
	150-200	45721.40	6.58
Soil type	Red Gravelly	16244.30	2.34
	Red Sandy	48160.10	6.93
	Old Alluvium	177910.00	25.61
	New Alluvium	37784.60	5.44
	Lateritic	196764.00	28.32
	Red and Yellow	217830.00	31.36
Soil texture	Clay-loamy	100331.90	14.44
	Clay	69049.53	9.94
	Loamy-clay	167890.00	24.17
	Loamy	357358.10	51.45
NDWI	-0.26-0.03	17933.85	2.58
	0.03-0.13	126005.80	18.14
	0.13-0.18	323626.10	46.59
	0.18-0.26	187821.00	27.04
	0.26-0.46	39251.52	5.65
Rainfall(mm)	1806-1885	81953.10	11.78
	1885-1931	133832.80	19.24
	1931-1971	169233.30	24.33
	1971-2018	282157.10	40.57
	2018-2083	28286.73	4.07
Aspect	Flat, SW, SE, S	322633.53	46.45
	W, E	203808.33	29.34
	NE, NW	76669.47	11.04
	N	91509.66	13.17
Elevation(m)	19 - 71	191645.44	27.70
	71- 115	299554.30	43.30
	115 - 174	178607.00	25.82
	174 - 425	24832.80	3.59

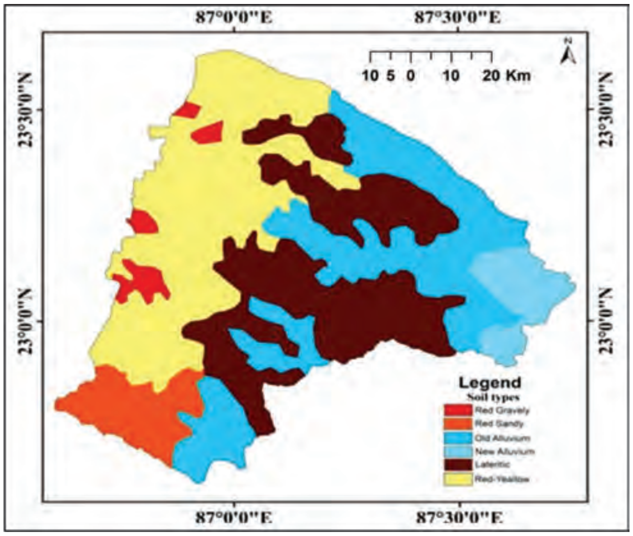

Fig. 5. Soil types map of the study area (after Nandi, S., 2019)

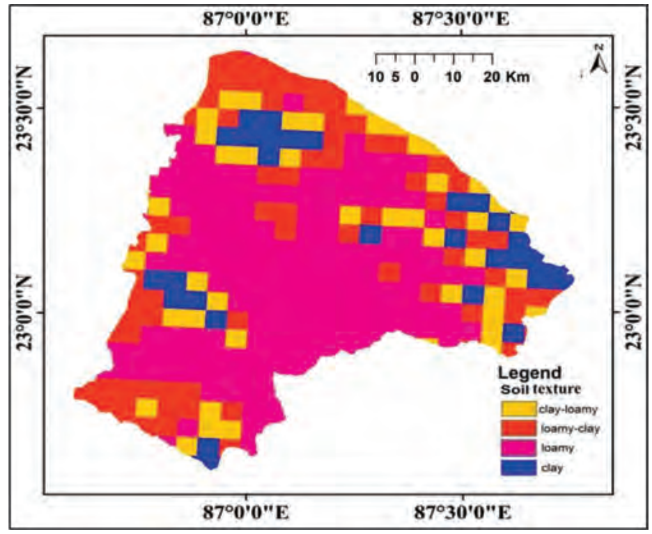

Fig. 6. Soil texture map of the study area

Soil texture

The soil texture data is collected as in different raster layers from the Bhuvan web site and a soil textured map was prepared using the GIS tool. According to texture, the Bankura district has mainly loam soils and clay loam types (Fig. 6). According to the importance of agricultural suitability, the weighted value has been given to the texture sub-classes.

Soil depth

Most of the areas have 100 to 150 cm soil depth and the soil depth of the western part is varying between 25-50 cm and 75-100 cm (Table 1, Fig. 7).

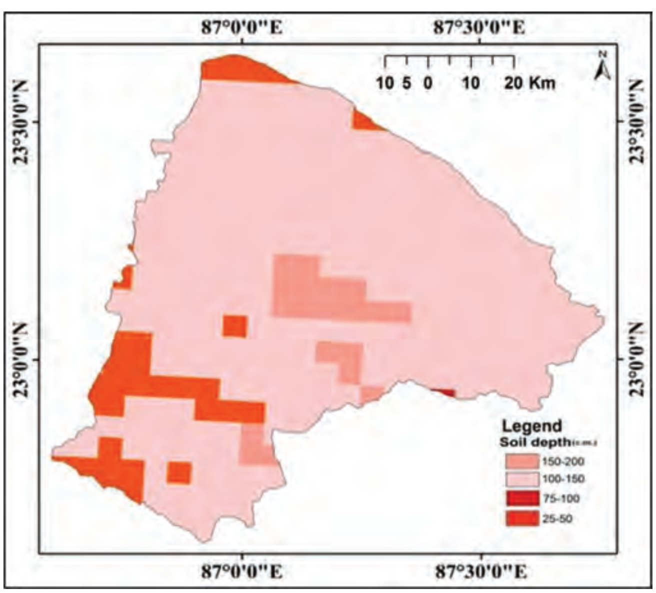

Fig. 7. Soil depth map of the study area

Soil moisture

NDWI is a good indicator to recognize the moisture condition of the soil and also find out water stress of vegetation. This is calculated from the following equation (Zolekar and Bhagat, 2015).

$$\text{NDWI} = \frac{\text{IR-G}}{\text{IR+ G}}$$

Where, IR = Infrared band and G = Green band

NDWI is a dimensionless and value is between -1 to +1, depending on the leaf water content. High values of NDWI pointed out the high vegetation water content, low NDWI values indicated to low vegetation water content and negative values indicate dry areas. The calculated values on the basis of vegetation water content level were broadly grouped into five soil moisture classes for the analysis of agricultural land suitability of the study area (Fig.8).

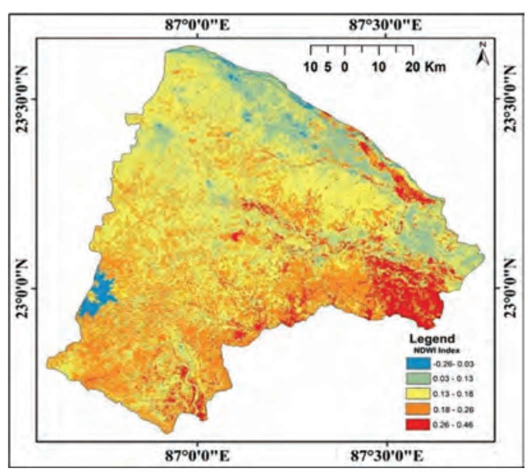

Fig. 8. Soil moisture of the study area

Rainfall

The amount of rainfall influences the agricultural activities spatially and temporally. The annual amount of rainfall varies from 18 cm to 21 cm which is calculated from the six (2013-2019) year average rainfall of the study area (Fig. 9). The study area is under the semi-arid region and therefore a high amount of rainfall is considered high suitability for agriculture according to the demand of particular crops.

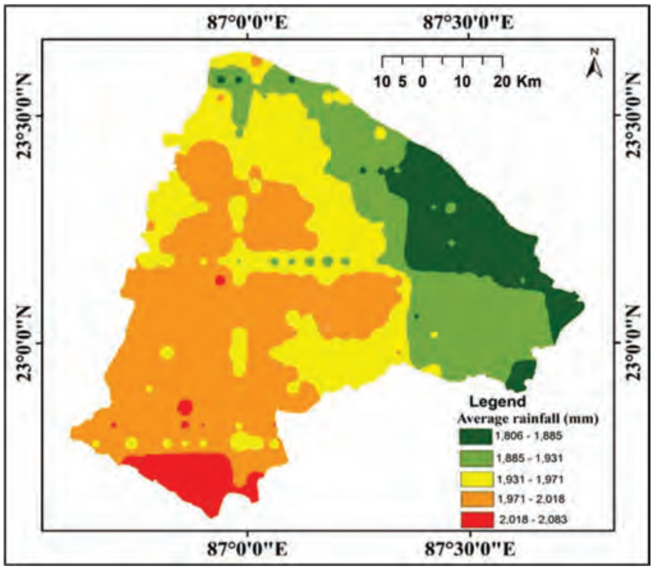

Fig.9 Annual average rainfall of the study area

Aspect

In the present study area, south, southeast, southwest, and flat areas have been chosen as a 'highly suitable' for agriculture in terms of receiving sunlight (Fig. 10).

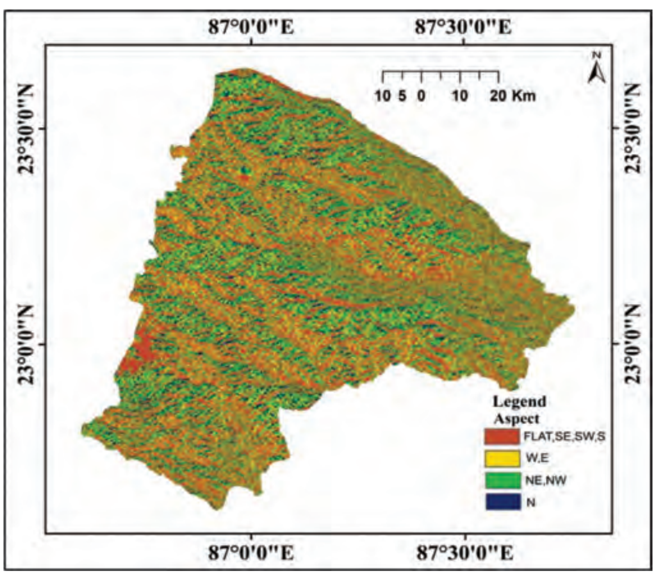

Fig. 10. Aspect map of the study area

Elevation

The elevation has also influenced the suitability of agricultural land due to decreasing temperature with high elevation. On mountains, the rising of elevation in every 100 m., the time of vegetation bloom is late by 4–6 days (Bozdag *et al.*, 2016). So, it adversely affects plant diversity to be selected for agricultural production. The elevation of the present study area varies from 18m to 425 m. In the southwestern portion of the study area, the elevation is greater than 170m. and the eastern portion has lower elevation which ranges from 19 m to 71m (Fig. 11).

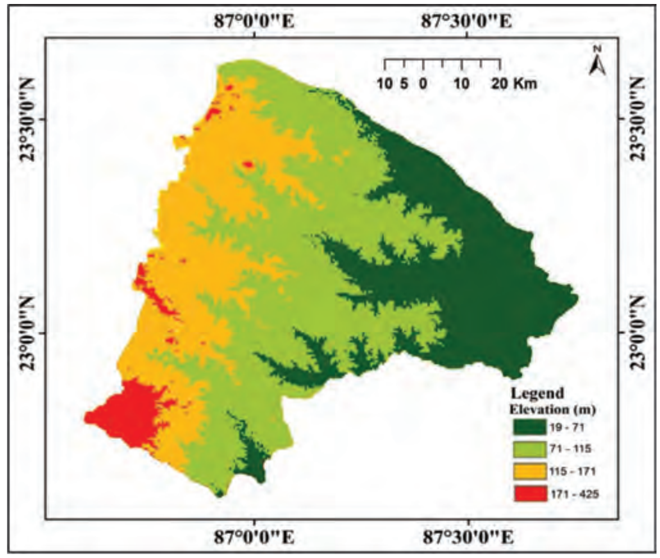

Fig. 11. Elevation map of the study area

Analytic Hierarchy Process (AHP)

AHP is a mathematical method that is applied to analyse the high complex decision-making problems with multiple criteria and factors and it is a powerful decision-making process that considers the problems of both quantitative and qualitative (Saaty, 1977; Weerakoon, 2014). By the analysis of relative importance of multiple criteria in a pairwise way, the weighted value for each criterion has been estimated.

Determination of ranks

In the present study area, a total of nine criteria have been taken for the analysis and these criteria represent rank wise to evaluate the importance of the criteria. Here, slope, LULC, and soil depth have more influence on selection the suitable land for agriculture in this region because these criteria effect more on the development of agriculture in specially plateau as semi-arid areas and ranked 1–3, respectively. And other criteria like soil type, soil texture, soil moistures, and rainfall influence moderately because these factors do not vary considerably for the small study area and were

Table 2. The fundamental scale for pairwise comparison matrix (Saaty 1980)

Criterion	Slope	LULC	Soil Depth	Soil Type	Soil Texture	Soil Moistures	Rainfall	Aspect	Elevation
Rank	1	2	3	4	5	6	7	8	9

ranked 4-7. Aspect and elevation show comparatively less significance for agricultural activities and these criteria ranked least (8-9) (Table 2).

Pairwise comparison matrix (PCM) and calculation of weights

The pairwise comparison matrix helps to take the decision to assign relative importance of the different factors which are involved in suitability analysis (Elaalem, 2012) and this is prepared to determine the weights of criteria as AHP. By taking the *Eigenvector* with the maximum important *Eigenvalue* of the matrix, the weighted value for each of the criteria is calculated by using the pairwise comparison matrix (Table 3). The pairwise comparison matrix is described in the following format.

$$A= \begin{vmatrix} a_{11} a_{12} \dots & \dots a_{1n} \\ a_{21} a_{22} \dots & \dots a_{2n} \\ \dots \ \dots \dots \ \dots \ \dots \ \dots & \dots \\ \dots \ \dots \dots \ \dots \ \dots \ \dots & \dots \\ \dots \ \dots \dots \ \dots \ \dots \ \dots & \dots \\ a_{n1} a_{n2} \dots & \dots a_{nn} \end{vmatrix}$$

Then, using the eigenvector method the vector of weights, w = (w1, w2, w3…wn) is determined (Saaty, 1980) and normalizing each criterion by using the Eq. 1(Table 4). Finally, the weights are computed by Eq. 2.

$$A_{ij} = \frac{\mathbf{aij}}{\sum_{\mathbf{j=1}}^{\mathbf{i}} \mathbf{aij}} \quad (1)$$

$$W_{i} = {}_{j}\frac{\sum_{j=1}^{i} aij}{n} \quad (2)$$

Where, i, j = 1, 2, 3….n.

The pairwise comparison matrix value has been judged by the *Consistency Ratio* (CR) which is calculated from the following formula (Chen *et al.*, 2010).

$$CR = \frac{CI}{RI} \quad (3)$$

$$CR = \frac{\lambda max - N}{N–I} \quad (4)$$

Where, RI is the average value of consistency index (CI) and λmax = the largest or principal Eigenvalue (Weighted value) of the matrix, n= the order of the matrix. The CR value of 0.10 or less indicates the logically consistent weighted value among the selected criteria (Saaty, 1977, Park *et al*., 2011) and it has been frequently used to measure the consistency of multiple factors in the AHP application (Chen *et al*., 2010). In the present analysis, the calculated CR value is Zero and that is accepted for the consistency of selected weights of criteria for the LSA. These weights are converted into a percentage for weighted overlay analysis in GIS.

Determination of score

The agricultural land suitability analysis has been made on the influences of sub-classes among the main criteria by putting the score to each sub-criterion. The score one point to ten point has been assigned to the sub-criteria on the basis of positive and negative impact on agricultural practices. The higher score and lower score were ascribed to high and low influence, respectively of land suitability for agriculture (Bandyopadhyay et al, 2009, Akinci *et al.*, 2013).

As mentioned by Akinci *et al.* (2013), the slope has a negative relation with soil qualities and agriculture productivity. In our present study, the maximum score ten point has been given to the minimum slope or gentle slope (0-1 degrees) and score one point has been assigned to (14 – 35 degrees) the high slope respectively (FAO, 1976) because the gentle slope or low land has no restriction and the high slope or high land is unfavourable for the agricultural practice (Table 5).

By the field observation, the score has been assigned for the LULC subclasses (Zolekar and Bhagat, 2015). For instance, fallow land has the capacity for extensive agricultural practice and it is assigned eight points score. The sparse forest area has moderate suitability for agriculture, and has been assigned six points score. Other classes like cultivated land, built-up area, Dense Forest, water bodies, sandbars have been assigned the score ten, one, zero, zero, and one point, respectively. Water bodies and the dense forest have been restricted for cultivation.

Soil depth is positively related to the growth and development of plant roots because the deep soils have a higher supply of nutrients and minerals. The maximum score ten points was given to deep soil and a lesser score one point to the thin soil (Bandyopadhyay *et al.*, 2009, Akinci *et al.*, 2013). Moderately and marginal soil depth assigned a score of six and three points (Table 5).

Table 3. Pairwise comparison matrix for multi-criteria decision analysis

Criteria	Slope	LULC	Soil Depth	Soil Type	Soil Texture	Soil Moisture	Rainfall	Aspect	Elevation
Slope	1/1	2/1	3/1	4/1	5/1	6/1	7/1	8/1	9/1
LULC	1/2	2/2	3/2	4/2	5/2	6/2	7/2	8/2	9/2
Soil Depth	1/3	2/3	3/3	4/3	5/3	6/3	7/3	8/3	9/3
Soil Type	1/4	2/4	3/4	4/4	5/4	6/4	7/4	8/4	9/4
Soil Texture	1/5	2/5	3/5	4/5	5/5	6/5	7/5	8/5	9/5
Soil Moistures	1/6	2/6	3/6	4/6	5/6	6/6	7/6	8/6	9/6
Rainfall	1/7	2/7	3/7	4/7	5/7	6/7	7/7	8/7	9/7
Aspect	1/8	2/8	3/8	4/8	5/8	6/8	7/8	8/8	9/8
Elevation	1/9	2/9	3/9	4/9	5/9	6/9	7/9	8/9	9/9

Table 4. Normalized matrix for multi-criteria decision making

Criteria	Slope	LULC	Soil Depth	Soil Type	Soil Texture	Soil Moistures	Rainfall	Aspect	Elevation	Weight
Slope	0.353	0.353	0.353	0.353	0.353	0.353	0.353	0.353	0.353	0.353
LULC	0.177	0.177	0.177	0.177	0.177	0.177	0.177	0.177	0.177	0.177
Soil Depth	0.118	0.118	0.118	0.118	0.118	0.118	0.118	0.118	0.118	0.118
Soil Type	0.088	0.088	0.088	0.088	0.088	0.088	0.088	0.088	0.088	0.088
Soil Texture	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071
Soil Moistures	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059
Rainfall	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
Aspect	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044
Elevation	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039

Alluvial soil has high potentiality for agricultural production, and so ten points score was given to new alluvium and nine to old alluvium. The other soil types, which limit the diversity of the cultivable species, were scored in light of the restricting factors (Table 5). In this respect, the lowest points were given to red gravelly and lateritic soil because of their inadequacies in terms of porosity and organic matter content (Akinci *et al.*, 2013).

From the soil texture point of view, FAO (2006) and Isitekhale *et al.* (2013) have estimated that loam soils are highly suitable and clay loam soils are moderately suitable for agriculture. Therefore, the maximum score (ten) was given to loam soils and a moderate score (six) was assigned to loamy clay soil. Four points were assigned to clay loamy soil and score three points were given to clay soil texture (Table 5).

Generally, good soil moisture indicates that the land is highly suitable for agriculture (Zolekar and Bhagat, 2014). The score one point assigned to the class of -0.26 to 0.03 of NDWI value due to dense forest, and also water bodies that both are not suitable areas for agriculture. The NDWI classes of 0.03-0.13, 0.13-0.18, and 0.18-0.26 were given a score of three, seven, and four points, respectively. As does soil moisture, rainfall influences the crop productivity, and the diversity of crops depends upon the variability of rainfall amount. Therefore, scores were given according to the high to low classes of rainfall having a high value for high rainfall (Table 5).

The areas with southern, southwestern, south eastern and flat aspects allow the cultivation of more products because these conditions receive sunlight for a long duration and those areas were scored with eight points. In contrast, as receiving insufficient daylight is a factor that limits the diversity of cultivable crops, areas with a northern aspect were scored with two points (Table 5). The diversity of crops is being affected by the elevation and low elevated areas (19 to 71 m.) was assigned eight points score and high elevated areas (174 to 425 m) was given two points score.

Weighted overlay analysis

The weighted overlay analysis method is very useful to solve any complex spatial problem in case of site selection or suitability based on dissimilar criteria (Kuria

Table 5. Weights of the criteria and scores of the sub-criteria

Main criterion	Weight	Influence	Sub-criteria	Score
Slope	0.35	35	0-1	10
			1-2	8
			2-5	5
			5-14	3
			14-35	1
LULC	0.18	18	Cultivated land	10
			Dense forest	1
			Sparse forest	6
			Water bodies	0
			Built up	1
			Fallow land	8
			Sandbars	1
Soil depth(cm)	0.12	12	25-50	1
			75-100	3
			100-150	6
			150-200	10
Soil type	0.09	9	Red Gravelly	2
			Red Sandy	3
			Old Alluvium	9
			Young Alluvium	10
			Lateritic	3
			Red and Yellow	6
Soil texture	0.07	7	Clay-loamy	4
			Clay	3
			Loamy-clay	6
			Loamy	10
NDWI	0.06	6	-0.26-0.03	1
			0.03-0.13	3
			0.13-0.18	7
			0.18-0.26	4
			0.26-0.46	1
Rainfall(mm)	0.05	5	1806-1885	2
			1885-1931	3
			1931-1971	4
			1971-2018	5
			2018-2083	7
Aspect	0.04	4	Flat, SW, SE, S	8
			W, E	7
			NE, NW	5
			N	2
Elevation(m)	0.04	4	19 - 71	10
			71- 115	6
			115 - 174	5
			174- 425	2

et al., 2011). To find out the influential level of given inputs, the AHP technique is used and the accumulated result is extracted from all those factors according to their given weighted values. Therefore, by using the weighted overlay, all the raster layers were integrated with each other in a GIS environment and those were overlaid by converting their cell values to a common scale with the assigning weight and score (Ajim and Ahmad, 2018). The cell values of each raster layer were multiplied by their weighted values, and the final output raster map was calculated by the following equation which was given by Cengiz and Akbulak (2009).

$$S = \sum_{i=1}^{n} wi\ xi$$

Where, S = total LSA score, wi = weight of LSA criteria, xi = sub-criteria score of i LSA criteria, n = total number of LSA criteria.

RESULTS AND DISCUSSION

The agricultural land suitability of the Bankura district has been grouped into four classes according to suitability level like highly suitable, moderately suitable, marginally suitable, and not suitable zones. The results show that the area of highly suitable agricultural land is 33,7,02.70 hectares (5.26 %), moderately suitable area is 3,60,4,80 hectares (56.26 %), marginally suitable area is 2,24,5,78 hectares (35.05 %), while, 2,24,578 hectares of land (3.44 %) is not suitable for the agricultural activities of the present study area (Table 6, Fig. 12).

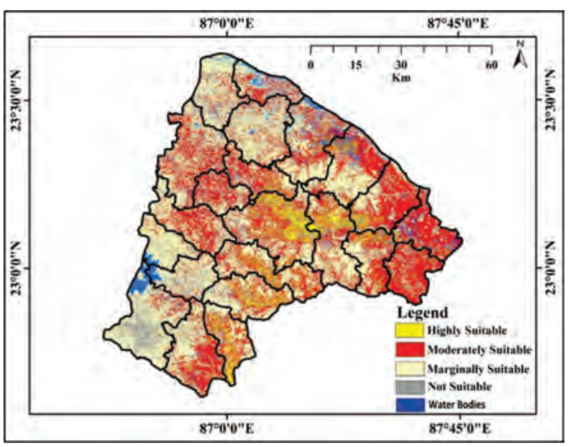

Fig. 12: Land Suitability for Agriculture

Table 6. Land Suitability for Agriculture

LSA classes	Area (h)	Area (%)
Highly suitable	33702.70	5.26
Moderately suitable	360480.00	56.26
Marginally suitable	224578.00	35.05
Not suitable	22029.00	3.44

Highly suitable lands

The highly suitable area is basically composed of low to moderate slope (1°-5°), cultivated land area, and fallow land with a deep alluvium soil and loamy soil with good soil moisture conditions. In the present study, the results showed that about 5.26% of the area is highly suitable for agriculture. In the district, many barriers are like high slope, shallow soil depth, poor soil, dense forest area, and built-up area restrict the area of highly suitable area of the agricultural land. The blocks namely Patrasayer, Sonamukhi, Jaypur, Kotulpur, Taldangra, Simlapal had a maximum area under highly suitable category. These zones do not have many limitations for agricultural practices but maintaining the production rate requires the input of external nutrients.

Moderately suitable lands

The moderately suitable land for agriculture has been estimated at 56.26 % of the land. These lands have 2º to 5º of the slope, sparse forest area, red- yellow soil with a loamy clay texture. Indus, Onda, Chhatna and Jaypur are the blocks where moderately suitable land is maximum. These areas require additional input as an intensive farm management practice for a better improvement of agricultural production.

Marginally suitable lands

About 35.05 % of lands were classified as marginally suitable for agriculture that has low soil depth, less soil moisture, steep slope and, low vegetative area. This type of land is mostly found in the southwestern portion of the district having low potential for agriculture like Khatra, Ranibandh, and Hirbandh blocks. These lands have to be protected from soil erosion, and also need to supply the irrigation water.

Unsuitable lands

The upland area of dissected hills with dense forest is fully restricted for agriculture and therefore this area is accounted as a 'not suitable zone' for agricultural production which is about 3.44 % of the area. Ranibandh block has the maximum area that is unsuitable for agricultural activities due to the high undulating surface or the presence of forest. These regions are restricted from agriculture as the area has been covered by dense forest. Therefore, these regions were reserved for the natural forest.

Validation

For validation of the results, the block wise crop productivity data was collected from the district statistical handbook of the Government of West Bengal (District Statistical Handbook, 2014). The average data was calculated from these data, and Agricultural Efficiency

(AE) was calculated (Bhatia, 1967):

$$AE = \frac{\sum Iij \times Cij}{\sum Cij} \quad (5)$$

$$Iij = \frac{Yij}{Yi} \times 100 \quad (6)$$

Where, Iij = percentage of yield of individual crop, Yij = Yield (Kg/Hectre), Yi = Average Yield of the whole area, Cij= Percentage of area in Individual crop.

To find out the relation between land suitability and the agricultural efficiency, the correlation (r) value is computed. The r = + 0.57 which indicated the positive relation between score of ALSA and AE. It concluded that the level of suitability influenced the productivity of the present study area (Fig. 13).

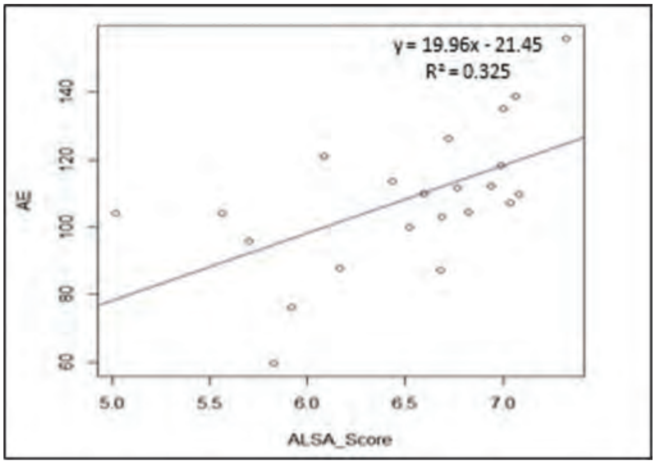

Fig. 13. Correlation between score of ALSA and AE

In several regions, the agricultural land, and also the production has been depleting day by day due to the high demand for food. The analysis of the suitability level of the agricultural lands has been carried out to justify a significant level of agricultural practice. Several studies have been done about the analysis of land suitability for agricultural uses (Kuria *et al.*, 2011, Mesgaran *et al.*, 2017). But our present study has focussed to determine the suitability level of agricultural land. A Similar study based on soil characteristics and the nature of slope has determined the suitability of land that proposed for a plan of sustainable agricultural in their study area (Ennaji *et al.*, 2018). Another study conducted by Kazemi and Akinci (2018) determined the agricultural land suitability and also revealed a compatible site for the rain fed agriculture. In the present study, the area of the high suitable zone is not as small as the results obtained in other studies like a study had been conducted to evaluate the agricultural land suitability on Yusufeli district of Artvin city (Turkey) where only 0.08 % of the land is highly suitable (2013) because this region has a high percentage of the area having a high slope along with the shallow soil depth compared to the present study area. Similarly, a study on Darjeeling district of West Bengal (Pramanik, 2016), and Mula and Pravara basin of Maharashtra (Zolekar and Bhagat, 2015) show 38% areas not suitable for agriculture. In the present study the area of highly suitable land for agriculture has not any barriers or limitations for agriculture but one thing to do is maintaining the nutrients as necessary. The marginally suitable lands require fertilizer to maintain the quality of the soil. These types of land have to be taken up for the terracing practice to reduce runoff and soil erosion. Proper methods have to be used for agriculture otherwise it will decrease the quality of the soil. It is suggested to make social forestry practice to recover the quality of the soil. The lands which are not suitable for agriculture must have more afforestation. These areas should be avoided for the agriculture, and we have to protect natural resources, especially forest.

The demand for agriculture and the agricultural products has been regularly increasing. Therefore, the segregation of agricultural land according to their suitability level will lead to sustainable agriculture practice, and it will help to maintain the demand and supply of the agricultural productions. When the evaluation is not done and no plan is taken for the land, causes the deterioration of the agricultural production rate as well as the environmental problems. Determination of the suitability level of the agricultural land reveals the potentiality uses of land, and also resolves the problem of the lands. The present study will guide the decision maker for further plans from archive data of land suitability for agricultural land. This assessment has played an important role in gathering valuable information about the limitation of land as well as the opportunity of the present area.

Authors' contribution

Conceptualization and designing of the research work (UG, SR); Execution of field/lab experiments and data collection (UG); Analysis of data and interpretation (UG, SR); Preparation of manuscript (UG, SR).

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