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Research Article

USEFULNESS OF GEOSPATIAL TECHNOLOGY TO APPRAISE THE AGRICULTURE POTENTIAL ZONE OF NAWADA DISTRICT, BIHAR (INDIA)

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ABSTRACT
An attempt has been undertaken to investigate the suitable agricultural potential zone using geospatial technology in order to devise land management strategy of Nawada district, Bihar in India. Landsat Thematic Mapper data was used to extract the environmental characteristics, and ASTERGDEM data was used for relief characteristics. Secondary database, like water depth, soil, road and market accessibility were used in this study. Weighted linear combination method was used to evaluate the agricultural suitability index (ASI). The ASI index of the study area is ranged from 14.5 – 45.75 and the statistical accuracy of the model was > 68.30%. The validation of the obtained results shows the simplicity and the potential of this approach for agriculture mapping. However, the information is helpful in identifying the probable agricultural potential areas and will strengthen the agricultural management system.

Key Words: *Geospatial Technology, Weighted Linear Combination, Agricultural Suitability Index, Agricultural Management System*

INTRODUCTION
Worldwide agricultural production encompasses 3500 million ha of pasture and fodder crops and 1559 million ha of cultivated lands, of which 28% is prime land, 52% is good land, and 20% is marginal land (e.g. FAO Statistical Yearbook, 2012). Satellite remote-sensing and close-range-sensing systems offer potentially valuable information for assisting land managers and farmers to monitor land degradation, soil quality, crop yields, and other environmental factors influencing agricultural production. These applications of remote sensing are concerned with sustainable extraction and allocation of natural resources to meet the needs of a growing world population for food, feed, fibre, and fuel. The information gathered must be tailored to allow land managers to take appropriate conservation measures that optimize the use of resources and respond to situations threatening food production at different spatio-temporal scales (Kuenzer and Knauer, 2013). However, remote sensing provides the essential technology and methodology to monitor, map, and observe rice-growing ecosystems over large areas, at repeated time intervals, to interpret rice-growing areas under a variety of aspects. Rice is the staple food for more than half of the world's population, mostly in developing countries in Asia, Africa, and Latin America (Fairhurst and Dobermann, 2002; FAO, 2004c), and is thus of significant importance to food security (FAO 2004b).

India is primarily agricultural based country, with 127 different agro-climatic zones (http://www.imdagrimet.gov.in/node/290). The contact of global climate change is evidential through different seasonal discrepancies such as droughts and floods in various parts of the country, reducing the agricultural production and crop estimation (Nelson *et al.*, 2009; Aydinalp and Cresser, 2008). The scientist of Indian Institute of Tropical Meteorology (IITM) found the temperatures would increase by about 5°C in many parts of India by the end of the century. Rising temperature is affecting reduce of crop yield and create severe water shortages with the entire ecosystems. According to the experts of Indian Agricultural Research Institute (IARI) the yield of some crops could decline significantly as temperature rises, and have devastating effect on crops. Consequently, the unparalleled raise in population of both

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man and animal in the most recent century and emergent industrialization and urbanization in last few decades have burdened the base of natural resource, which are being paid besmirched much quicker than ever before. To attain the essential growth will not be easy as several of the accessible production systems are based on shaky use of the resources.

Agricultural pattern in Bihar is crucially dependent on monsoon. Bihar has been classified in three agro-climatic zones, namely north-west alluvial plane, north-east alluvial plane, and south alluvial plane. The district, Nawada is located in south alluvial plane which receives monsoon showers last of all three zones and also the least amount. As per the report of Central Ground Water Board (CGWB, 2009), barren and uncultivable land constitutes 4.99%, land put to non-agricultural accounts for 8.83% and current fallow land makes up 10.42% of the total geographical area of the districts. Several problems like little scope for moisture storage, high rate of soil erosion, declining groundwater level etc. affect the groundwater level development in the study area. Till date, very little information is available to comprehend the suitable agricultural zone; and to our knowledge, usefulness of the combination of secondary data and remote sensing data to identify the suitable agricultural potential zone is novel.

In this study, an attempt has been made to investigate the suitable agricultural potential zone using remote sensing (RS) and Geographical Information System (GIS) in order to devise land management strategy. It is the utmost importance to the planners and decision makers for formulating the long term plans for water resources development that would improve the resource management situation in the dry and semiarid regions.

Study Area

Nawada district is extending between 24°31’N to 25°08’N latitude and 85°00’E to 86 ° 03’ E longitudes, covering the survey of India (SOI) topographical sheet number of 72H and 72G. The district occupied with an area of 2,492 km^2. The district encompasses of two distinct landscapes i.e., plain land of north and the hilly area of the south.

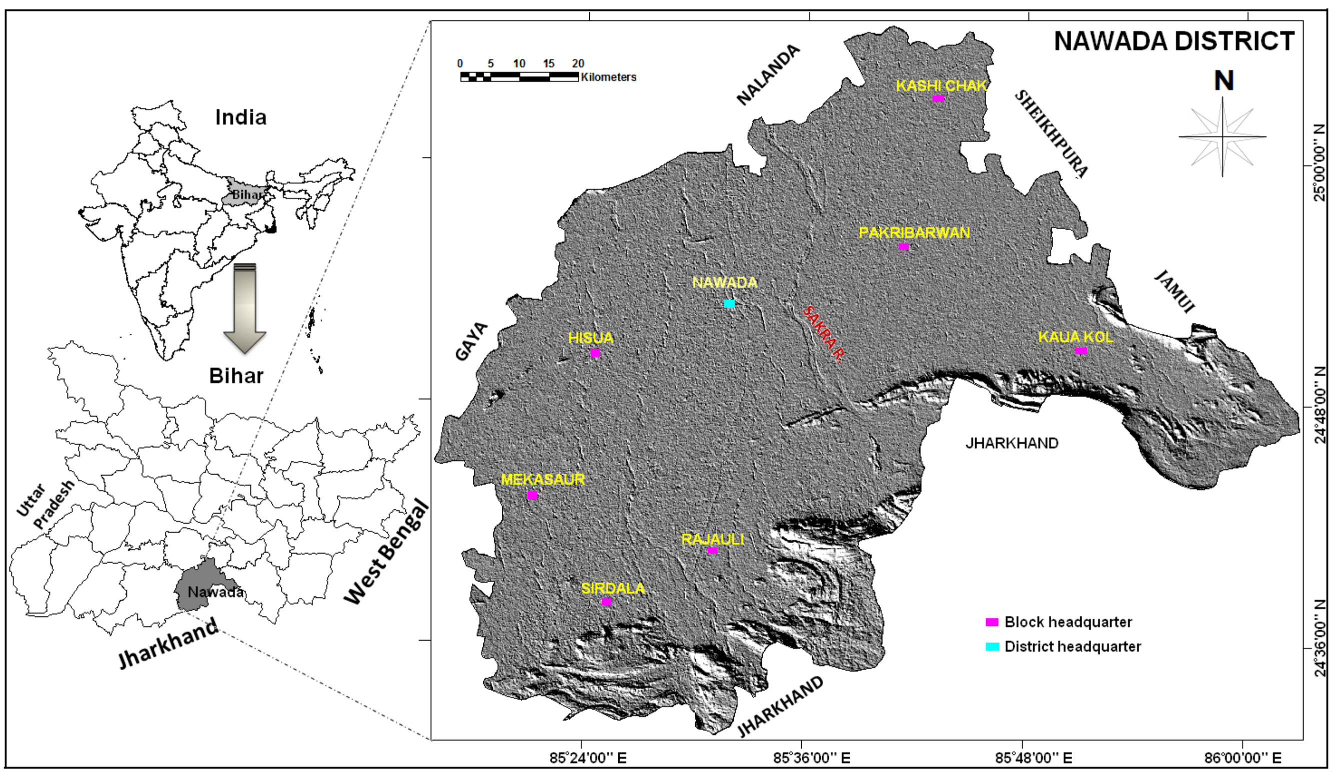

Figure 1: Location map of the study area

The district does not have any perennial river; several seasonal flowing water courses (*i.e.*, Tilaiya, Ghaghra, Khuri and Sakri) were found in the study area. The climate is generally hot and dry with an average annual rainfall of 1037mm, maximum temperature of 46°C in May and minimum temperature of 4°C in the January. 45% comes under the plain land which is used for agricultural purposes. The district has 2, 65, 123 acres net area under irrigation, which constitutes 43.13% of the total geographical area. Out of the total geographical area, barren and uncultivable land makes up 4.99%, 8.83% land put to non-agricultural activity and current fallow land constitutes 10.42%. The climate of the region is sub-tropical to sub-humid in nature, with an average annual rainfall of 1037mm.

MATERIALS AND METHODS

1. Methodology

Data Acquisition and Processing

Landsat Thematic Mapper (TM) satellite data (Path/Row 140/43) was used for the present study which is acquired on 25th April 2010 and obtained from the USGS Earth Explorer Community (http://earthexplorer.usgs.gov/). The image was georeferenced to a map based process using Universal Transverse Mercator (UTM) projection with World Geodetic System 84 (WGS 84) datum, and N45 zone. The study area is extracted based on the administrative boundary layer though clipping/subsetting method in ERDAS Imagine software.

Advanced Space Thermal Emission Radiometer (ASTER) Global Digital Elevation Model (GDEM) satellite data (Scene ID: ASTGTM2-N24E085, ASTGTM2-N24E086 and ASTGTM2-N25E085) is downloaded from the USGS Earth Explorer Community (http://earthexplorer.usgs.gov/), which is in GeoTIFF format with 30 meters ground resolution.

Topographic Analysis

Relief map was generated from the ASTER GDEM data. For each pixel, the change in ground height in the X and Y directions is computed from a 3 x 3 window centered above the pixel. The two values are used to compute a vector which represents a unit normal to the surface at that point. The slope calculates the maximum rate of change between each cell and its neighbors in the ArcGIS software. Every cell in the output raster has a slope value. The lower the slope value represents the flatter the terrain; the higher the slope value, the steeper the terrain. The drainage layer is automatically extracted from the ASTER GDEM using hydrological tools of ArcGIS software (Hosseinzadeh, 2011). The drainage density was calculated based on the spatial analysis tool in ArcGIS software.

Spectral Analysis and Satellite Derived Information Extraction

Surface temperature of the study area is computed based on the model developed by Sorbino *et al.*, (2004) and Artis and Carnahan (1982). The temperature values obtained above are reference to a blackbody. Therefore, correction for spectral emissivity (e) became necessary according to the nature of land cover (Van de Griend and Owe, 1993). The radiometric surface temperature (St) is derived using the formula proposed by Planck's law, including the effects of emissivity (ε) and the atmosphere (Li and Becker, 1993; Goetz *et al.*, 1995).

Wetness index (WI) map was generated based Tassled Cap (Tcap) Transformation technique through the TM image (Qui *et al.*, 1998). The transformation formula for the TM scene is followed in Crist and Cicone (1984) and was employed in the model in model builder of ERDAS Imagine software (version 9.1, Atlanta, Georgia, USA).

Database Creation and Integration with GIS

The water level depth data was obtained from the drilling details of exploratory wells drilled by Central Ground Water Board (CGWB) and the measurement of water levels are taken as point source. A point layer of water level depth (m/bgl) was generated based on the groundwater information booklet provided by the Central Ground Water Board (CGWB), Patna, Bihar (http://cgwb.gov.in/District_Profile-/Bihar/Nawada.pdf). To obtain the information of water level depth, local polynomial interpolation using all points only within the defined neighbourhood were performed based on the weightage value (e.g., recorded from the groundwater information booklet). Interpolated water level depth map was reclassified by into five categories based on geometric intervals (Mitchell, 2005).

Subsequently, a line layer of road systems like, major road, metalled road, minor road, unmetalled road and railway were generated from the Survey of India (SOI) topographical sheet. Location-allocation analysis is performed based on the road networks and Euclidean distance to understand the service area around a location.

A point layer of market location was generated in shapefile (.shp) format in ArcGIS software v9.3 (ESRI, Atlanta, GA, USA). A proximity analysis is performed to understand its accessibility from its neighbouring region. Overlay analysis of each market access zone with village point layer is processed to find out whether the villages are accessible to any kind of market or not. As the distance between the accessibility zone and villages increases, the area is marked out as low suitability and vice-versa.

The soil data has been collected from the District Agricultural Office of Nawada and also available in online database (http://ebookbrowse.com/bi5-nawada-28-08-12-pdf-d401842448). The digital soil database was generated in the ArcGIS environment.

Suitability Rating for Agricultural Potentiality

Agricultural suitability index (ASI) model typically evaluate the agricultural quality by using weighted linear combination method (Saaty, 1980; Malczewski, 2000). In this method, the relative importance of each criterion is evaluated against other criteria through simple weightings/ratings. Using the degree of complimentary environment for agriculture, simple weighting/ratings were applied for all these variables leading to multi-criteria decision support approach (Samanta *et al.*, 2011). We designed rating systems based on values from 1 – 5, where '5' mean very highly suitable, '4' highly suitable, '3' moderately suitable, '2' less suitable, and '1' very less/unsuitable. However, the criterion weights are expressed in percentages, with the total equaling 100 percent. Finally the index value is calculated for each unit area by summing the weighted criterion values and dividing the sum by total of the weights (Equation 1):

$$I = \frac{\sum_{i=1}^{n} w_i x_i}{\sum_{i=1}^{n} w_i} \quad \text{...................................(Equation 1)}$$

where, I is the index value, n is the number of criteria, w_i is the weight of criteria i, and x_i is the standardize value from criterion i.

A true validation of the model, however, can only be made by the thematic map of land use/land cover of Nawada district was extracted from the EO archive data of National Natural Resource Management system, ISRO, 2008 (www.bhuvan.nrsc.gov.in). A total of thirty three sample sites were selected from the thematic map of land use/land cover of Nawada district of land than the sample points were overlaid onto the ASI map to estimate the statistical accuracy.

RESULTS AND DISCUSSION

The highest elevation of Nawada district is 627m recorded in the south-eastern part of the district, while the lowest elevation was 19.00m only (Figure 2A). Based on the agricultural potentiality, the entire district is classified into 5 altitudinal ranges, like (i) less than 50m (very highly suitable for agriculture); (ii) 50.10 – 100.00m (highly suitable for agriculture); (iii) 100.10 – 200.00m (medium suitable for agriculture); (iv) 200.10 – 300.00m (less suitable for agriculture) and (v) more than 300.10m (very less suitable for agriculture).

The slope of the study area varies from 0 – 64.44º (mean±standard deviation 5.43±5.20). The northern and northeastern part of the study area existed with gentle slope (less than 2º) and contributes highly suitable for agricultural potentiality. The maximum slope is found on the southeastern and eastern part of the district (more than 20 º) which is less suitable for agricultural potentiality (Figure 2B).

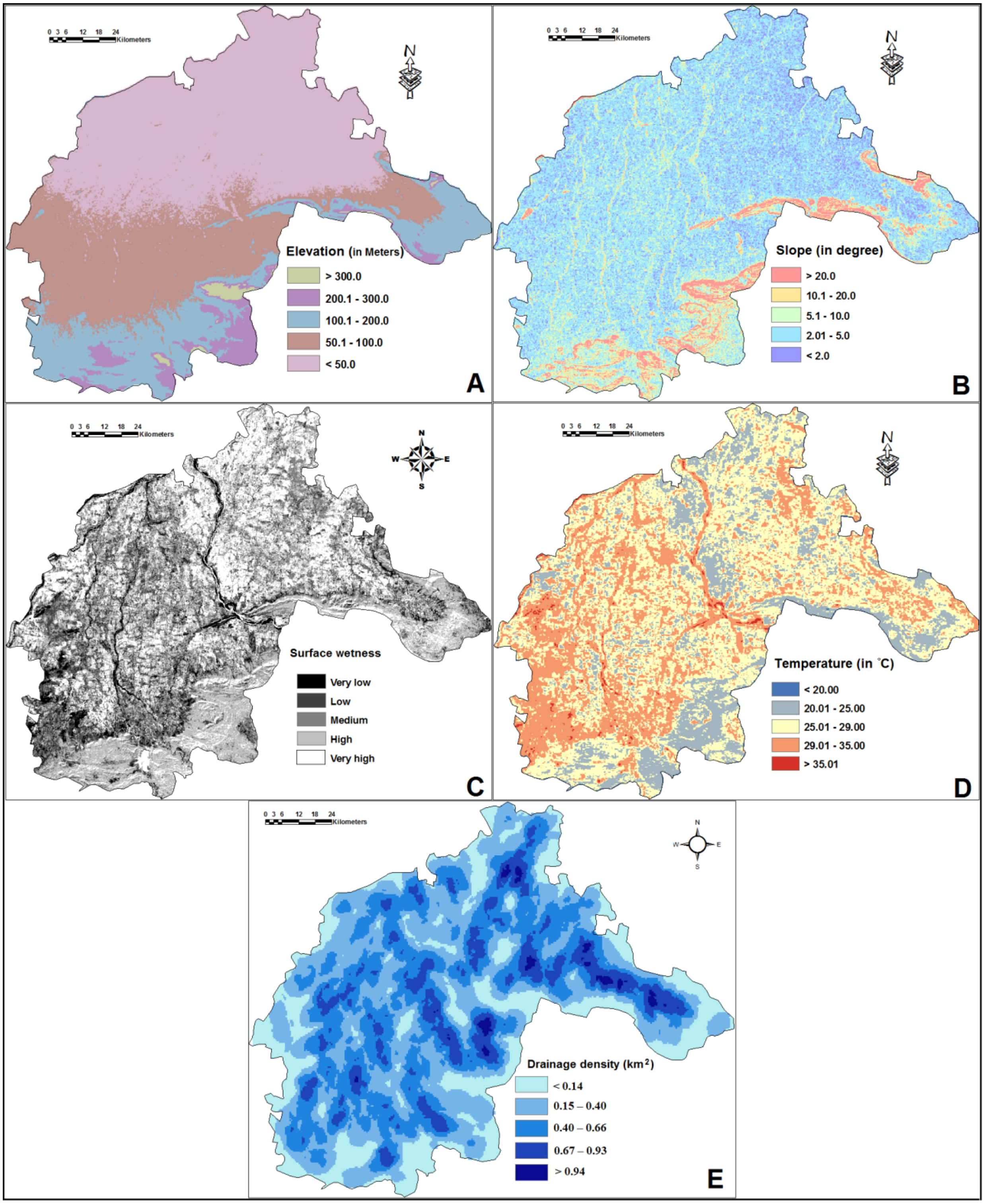

Figure 2: Variables derived through satellite data (Landsat TM) for agricultural potentiality, (A) Elevation characteristics of Nawada district, (B) Slope characteristics of Nawada district, (C) Surface wetness of Nawada district, (D) Land surface temperature characteristics of Nawada district, (E) Drainage density of Nawada district

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The wetness index value of the study area ranges from -91.76 – 45.59 (mean±standard deviation - 23.08±39.91). The maximum wetness value is recorded from the northern part and some small pockets of western parts of the study sites (Figure 2C). Based on the geometric interval the entire district is divided into 5 categories of surface wetness condition, namely (i) very high (ii) high, (iii) medium, (iv) low and (iv) very low. Higher the surface wetness indicated high suitable for agricultural potentiality.

Land surface temperature (LST) is another important component of agricultural productivity. The surface temperature of the study area ranges from 18.25 – 42.14°C (Figure 2D). Based on the geometric interval the entire district is categorized into 5 suitable agricultural zone, like (i) less than 20.00°C (very less suitable for agricultural productivity), (ii) 20.01 – 25.00°C (medium suitable for agricultural productivity), (iii) 25.01 – 29.00°C (high suitable for agricultural productivity), (iv) 29.01 – 35.00°C (very high suitable for agricultural productivity) and (v) more than 35.01°C (less suitable for agricultural productivity).

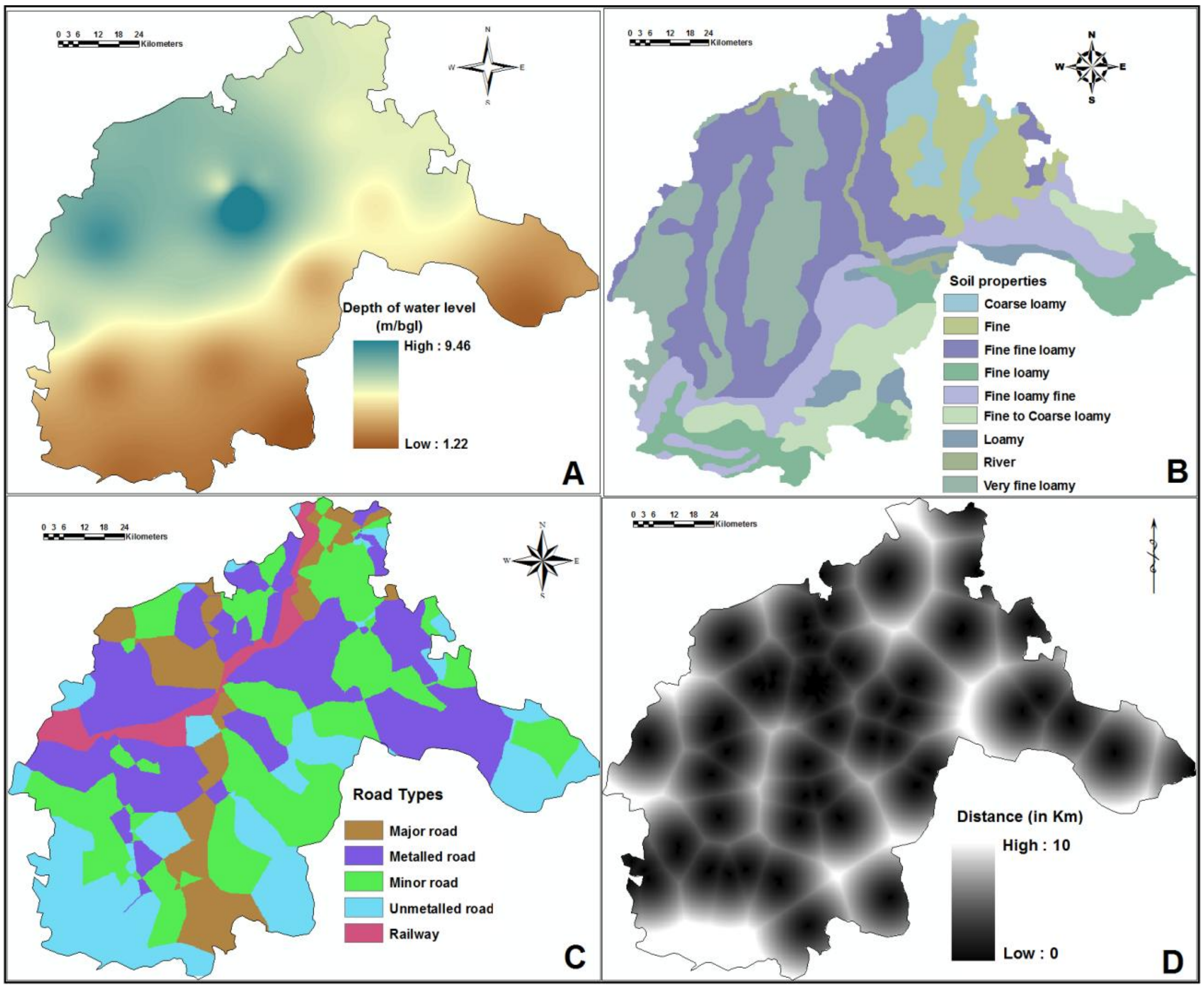

Figure 3: Base layer of environmental variables generated on GIS platform based on secondary data sources and analyses were performed for agricultural potentiality of Nawada district, (B) depth of water level, (B) soil characteristics of Nawada district, (C) road type accessibility map of Nawada district, (D) market accessibility map of Nawada district

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Table 1: Spatial distribution statistics of each suitable rating zone for variables for agricultural potentiality

Variables	Class	Rank	Multiplier (%)
	Less than 50	5	
	50.10 – 100.00	4	
Elevation (m)	100.10 – 200.00	3	10
	200.10 – 300.00	2	
	More than 300.10	1	
	Less than 2.0	5	
	2.1 – 5.0	4	
Slope (°)	5.1 – 10.0	3	7.5
	10.1 – 20.0	2	
	More than 20.1	1	
	Very low (<-37.51)	1	
	Low (-37.52 - -5.37)	2	
Surface wetness	Moderate (-5.38 – 2.18)	3	12.5
	High (2.18 – 8.37)	4	
	Very high (>8.37)	5	
	<20.00	1	
	20.01 – 25.00	2	
Surface temperature (°C)	25.01 – 29.00	4	15.0
	29.00 – 35.00	5	
	>35.01	3	
	less than 0.14/km^2	1	
	0.15 – 0.40/km^2	2	
Drainage density (km^2)	0.40 – 0.66/km^2	3	10.0
	0.67 – 0.93/km^2	4	
	more than 0.94/km^2	5	

Depth of water level (m/bgl)	Less than 2.27	5	15.0
	2.28 – 3.26	4	
	3.27 – 4.60	3	
	4.61 – 5.89	2	
	More than 5.89	1	
Soil texture	Coarse loamy	1	20.0
	Fine	3	
	Fine-fine loamy	5	
	Fine loamy	3	
	Fine loamy fine	4	
	Fine to Coarse loamy	2	
	Loamy	1	
	River	2	
	Very fine loamy	5	
Location-allocation of road (km)	Major road	5	5.0
	Metalled road	4	
	Minor road	3	
	Unmetalled road	1	
	Railway	2	
Market accessibility (km)	Less than 1.60	5	5.0
	1.61 – 3.10	4	
	3.11 – 4.70	3	
	4.71 – 6.50	2	
	More than 6.51	1	

Drainage density of the Nawada district varies from 0.11 – 0.98 per km^2. Based on the drainage density values the district is categorized into 5 sub-division, like (i) less than 0.14/km^2, (ii) 0.15 – 0.40/km^2, (iii) 0.40 – 0.66/km^2, (iv) 0.67 – 0.93/km^2, and (v) more than 0.94/km^2. Higher the drainage density is considered to be high potential for agricultural productivity.

The depth of water level of the study area varies from 1.22 – 9.47 m/bgl (Figure 3A). However, the average depth of water level is recorded as 4.148 m/bgl with a standard deviation of ±2.08. The highest depth of water level is found in the western and central part of the study area. Extreme eastern and southern part of the study site. The highest depth of water level is considered as the suitable for agricultural potentiality.

In the district texturally there are eight types of soils, namely (i) coarse loamy, (ii) fine, (iii) fine-fine loamy, (iv) fine loamy (v) fine loamy fine, (vi) fine to coarse loamy, (vii) loamy and (viii) very fine loamy (Figure 3B). The district is dominated by the coarse very fine and fine loamy soils that manifest in high agricultural potential. Alternatively, coarse loamy and loamy soils provide low potentiality for agriculture development.

Accessibility to road is another important component for determination of suitable for agricultural potentiality. Road accessibility map of Nawada district was generated (Figure 3C). The total length of the major road in this region is 110.02 km, 228.58km. However, the length of metalled road is 283.77km and unmetalled road is 129.19km. There is railway which is about 57.21km in length extended from west to northwest part of the study site. Most of the metalled roads are found in the central and western part of the study area, and also extended to the eastern side. Minor road are extended in the southern and southeast part of the study site. The accessibility between the villages and the market areas through the major and metalled road considered as higher potential for agricultural productivity.

Furthermore, the presence of market and the accessibility to the local regions is another component for agricultural potentiality. Market accessibility map of Nawada district is shown in Figure 3D. A proximity analysis is performed between the nearby villages and the local markets. In this analysis, increasing the distance between the villages and market represents less suitability for agricultural potentiality.

The relative importance of each variables and their categorization is represented in Table 1. In this weighted linear combination model, elevation has a 10% influence, slope at 7.5% influence, drainage 10% influence, soil at 20% influence, depth of water level at 15% influence, surface temperature at 15% influence, surface wetness at 12.5%, location and allocation of road at 5% and market accessibility at 5% influence has been assigned.

Agricultural potential zone of Nawada district is derived based on remotely sensed environmental variables and secondary data represented in Figure 4. The agricultural suitability (ASI) index value of the study area is ranged from 14.5 – 45.75 (mean±standard deviation 33.36±5.10). Based on the geometric interval the agriculture potential index value is categorized into five sub-category, namely (i) very high suitable zone (more than 37.54), (ii) high suitable zone (33.86 – 37.53), (iii) moderate suitable zone (29.82 – 37.52), (iv) less suitable zone (25.28 – 29.82) and (v) very less suitable zone (less than 29.81). The very high suitable agricultural potential zone is shown in 'dark blue' colour in the map, while very less suitable agricultural potential zone is represented in 'red' colour in the map. The result of our analysis also showed that mostly the western part of the study site is very highly suitable for agricultural potentiality in the study site. It may be due to the lower elevation and slope, maximum surface wetness and drainage density, fine loamy soil, and suitable accessibility of road and market. Alternatively, south-eastern and eastern part of the study site is characterized by very less suitable for agricultural potentiality. This may be due to the fact that the higher elevation and slope, lower level of water and low accessibility of road and market etc. that falls under this category. Medium to high agricultural potential zone is found in the northern and central part of the district, and some pockets in the southern corner of the study site. The thematic map of land use/land cover of Nawada district was extracted from the EO archive data of National Natural Resource Management system, ISRO, 2008 (www.bhuvan.nrsc.gov.in) and then verified onto the generated agricultural suitability index map (data not shown). The statistical accuracy of our findings was found to be encouraging that is the correlation value between the sample results and with the agricultural suitability index (ASI) map was more than 68.30%. However, our model does not aim to estimate the agricultural productivity of the study area, but only to identify, the areas suitable for agricultural production. Therefore, our study will greatly helpful in identifying the probable agricultural potential areas and will strengthen the agricultural management system.

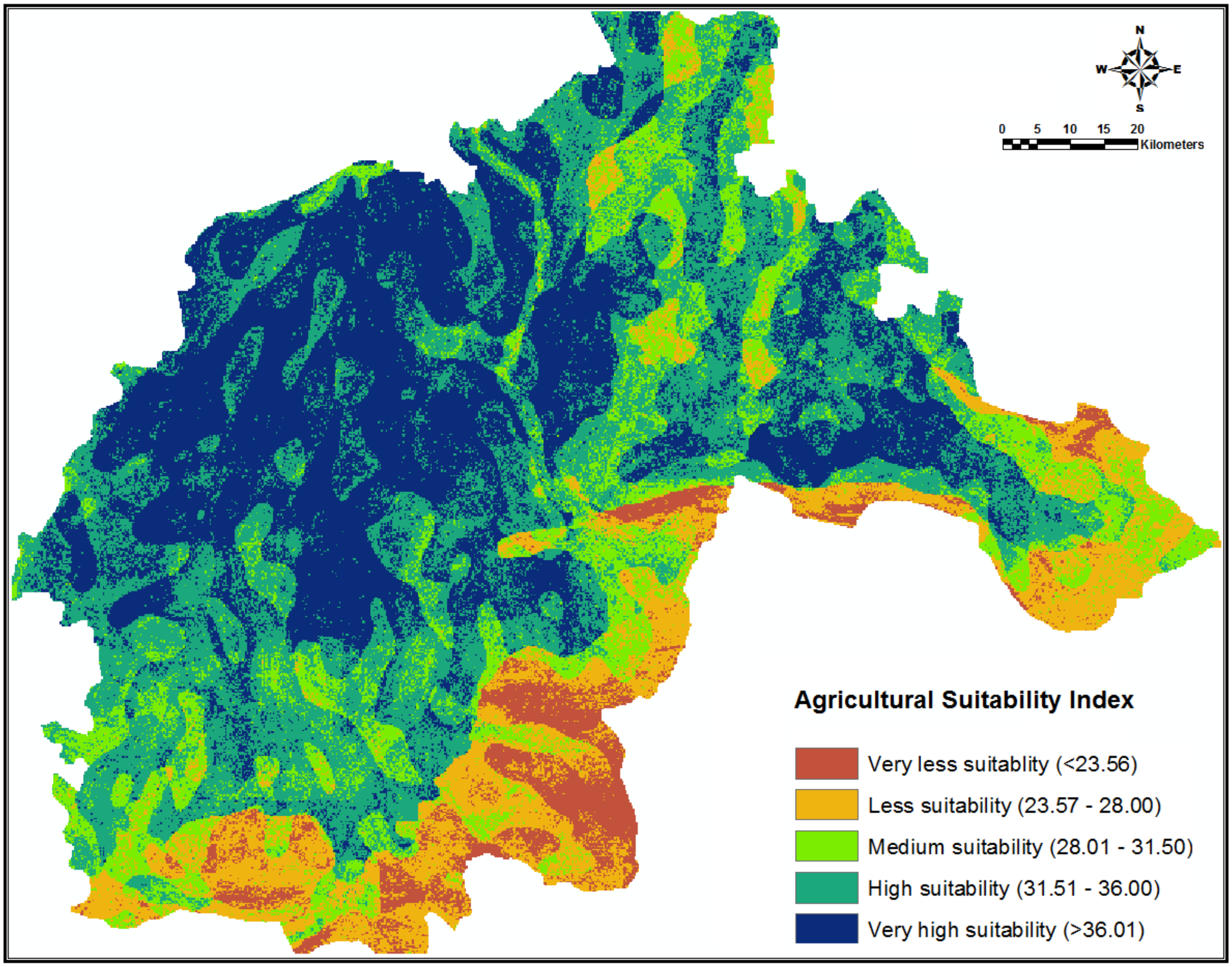

Figure 4: Agriculture potential zone of Nawada dstrict

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