11 Assessing Impact of Climate Variability on Potential Agricultural Land Suitability in Nalanda District, Bihar

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Introduction

Agriculture plays a very prominent role in the Indian economy and contributes up to 18% to GDP that provided up to 50% of their means of livelihood (Madhusudhan, 2015). Agriculture is one among the important sectors of the economy of Bihar state that employs up to 77% of the whole workforce and is accountable for generating 35% of the state's domestic product (Census India, 2011a,b). Out of the entire population, 88% of the state's poor were residing in the rural areas. The Nalanda district is among the prosperous districts of Bihar in agriculture and agricultural products. Here, agriculture is the backbone of their livelihood with many of the population engaged in agricultural practices. The important crops that are accustomed to grow within the district are paddy, pulses, wheat, maize, potato, fruits, and vegetables. A number of problems arose in agricultural practices, and the lack of consolidation ends up in misuse of land and resources (Kumar, 1986). With its predominantly agricultural character, the district is split into the hills in the southern part and lowland in the northern part. The whole district is surrounded by rivers and streams, which contain little or no water during the summer and winter seasons but are filled from bank to bank at the time of heavy rainfall. In the global context, agriculture has been reported to be very prone to agricultural pollution and global climate change. And in due course of time, inadequate human activities, intensive farming, and improper management of the natural resources have highly contributed to land degradation in agricultural areas in many parts of the nation. Management of natural resources is a crucial aspect of agricultural sustainability and ensuring food security within the reporting district. Agricultural land suitability analysis becomes impressive in working out the crop's suitability in a region with exceedingly limited resources (Sarkar et al., 2014; Sajjad & Nasreen, 2016; Singh et al., 2015). This study is an attempt to spot the present land utilization pattern of Nalanda district of Bihar. Agricultural land suitability may refer to "the fitness of a specific land type for specified quite use" (FAO, 1985). In the context of the present scenario, the population of the world is growing dramatically. In this regard, the farmer's communities are fac-

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ing many problems and apparently need to produce more and more crops to satisfy the increasing demand for food and their products. On the wayward, there is an increasing global concern toward environmental aspects, food, and human health on the use of higher amount of chemical fertilizers, pesticides, insecticides, etc. (Feizizadeh & Blaschke, 2013). These effects could unquestionably be liable for the reduction of soil fertility and their ability to nourish crop growth, which consequently could immensely impact agricultural production. One among the intense threats to the agricultural sector is erosion, which is continuously alarming in many parts of our country, and additionally, our study area is affected by such a problem. Hence, priority should be kept on choosing suitable land for growing of crops, and it is our main concern in this research work.

The crops requirements, land characteristics, and soil characteristics are the major determining factors of suitability towards any agricultural-land analysis procedure (Kumar et al., 2018). Agricultural soils are among the predominant factors for the assembly of crops and are also very helpful within the main tenancy of unpolluted air and water, reduction to the emission of greenhouse gases, preserving biodiversity, and ultimately ensuring food security (Mazahreh et al., 2019). Matching such criterion on any farmland will certainly meet the specified goal. Excessive use of chemical fertilizers, immoderate irrigation, and damage to vegetation roots were fairly often and well versed for runoff, waterlogging and salinization of soil, loss of infertility, nutrient deficiency, pollutants discharge, and sedimentation to surface similarly as groundwater bodies, etc. (Ennaji et al., 2018). Aside from the soil and land characteristics, local/global market position, socioeconomic condition, and technological implementation are additionally driving factors that may influence the productivity of crops. Accuracy and reliability of cropland suitability analysis help within the identification of which area is suited to the cultivation or not and also provide information where it has to improve the present paradigm (Jamil et al., 2018). The assembly of quality crops is the key to precise farming practices, which is economically efficient and socially acceptable (Dengiz et al., 2015). In order to properly utilize accessible resources for agricultural practices, there's much-needed evaluation of land resources that helps our food providers comprehend every aspect alongside the policymakers to implement new methods to urge and obviate the present situation (Chandio et al., 2013). The analysis of agricultural land is applied in such the simplest way that it helps farmers, local communities, and anxious officialdom to require authentic decision toward the optimum production to the world.

Land suitability analysis is a multidisciplinary approach that incorporates the impact of the many areas consisting soil science, horticulture, economics, science and technology, management, etc. In the present study, the land suitability analysis, there are basically two approaches: current situation suitability and potential suitability. Current situation suitability evaluates the current conditions with none major improvement within the particular area. This approach evaluates land on a broader scale mainly depending on the farmer's experiences and institutional intuitive prior knowledge. On the opposite hand, potential suitability is predicated on the units of land within the future condition or upcoming data after the desired some improvement paradigm has got to be invoked where necessary (Bozdağ et al., 2016; FAO, 1983; Sys et al., 1993). Based on the characterization of soil, rainfall, slope and elevation, and temperature distribution, the Bihar state is riven into four major agroclimate zones. The Nalanda district falls under the agroclimate zone 3-B (southern-west) in conjunction with the 10 more districts of Bihar state. Distribution of soil resources during this zone except "Tal lands" and "Diara lands" wasn't properly well drained, and soil's texture varies from medium textured to heavy textured alongside soil pH is moderately acidic to slightly alkaline. The soil of the district is moderate to poorer in nutrient values regarding nitrogen and is not properly enriched in phosphorous and potassium contents (Department of

Agriculture, Govt. of Bihar, b). Uninterruptedly inadequate utilization of the agricultural land in the past few decades has encountered much more destruction than the provided resources (FAO, 1976). Agriculture in the entire state is severely affected by the natural calamities, south Bihar districts are struggling with the absolute climatic change in the form of droughts, and north Bihar districts are continuously fighting with the recurrent floods. Hence, the proper evolution of agricultural land use pattern is important to unravel recent or upcoming problems (Bozdağ et al., 2016). The number of literature and research work has been conscientious to the analysis toward the agricultural land using multicriteria decision analysis (MCDA), which is extremely helpful in such context (Elsheikh et al., 2013). Rasheed and Venugopal (2009) used agroecological characteristics for accessing cropland suitability. Bandyopadhyay et al. (2009) uses parameters like soil depth, soil texture, soil properties, organic matter content, erosion, slope, elevation, approximate to road, and land use land cover to investigate the suitability of land for agricultural purposes (Akpoti et al., 2019). Remote sensing and GIS within the context of multicriteria decision-making (MCDA) analysis provide information from different data, which parameters were necessary for identification of appropriate spatial pattern for future land use (Bunruamkaew & Murayama, 2012). For that reason, GIS-based MCDA AHP technique is employed, data from different parameters together with mapping criteria for suitability analysis toward the agricultural land in Nalanda district (Dalavi et al. 2015). Analytical hierarchical process (AHP) is a very common and widespread used method, which is introduced by Thomas L. Saaty (2008). The AHP introduced by Thomas Saaty (1980) has emerged as a preferred decision-making technique for solving multicriterion problems which emphasizes on the additive weightage model (Ayehu et al. 2015; Malczewski, 1999; Feizizadeh et al. 2013; Cinelli et al., 2014). AHP is an effective technique in addressing complex decision-making tool, which involves in identification and weighting criteria selection, analyzing the information and assigning a rank to that, and executing decision-making process in multicriterion decision analysis (Hossain et al., 2007). Additionally, the AHP analysis states the compatibility of the choice maker's evaluations, which help in the reduction of prejudice into the method of decision-making aspects. Multicriteria decision analysis (MCDA) within the context of remote sensing and GIS might be very useful and effective tools in the aspect of agricultural land use planning and management (Bailey et al. 2010; Goswami et al., 2012; Adeniyi, 1993; Malczewski, 2006; Shearer & Xiang, 2009; Jamil et al., 2018; Qiu et al., 2014; Kalogirou, 2002; Saaty, 2004). Within the period of time of technological advancement in GIS, the AHP method was used for agriculture and horticulture (Böhme et al., 2011). It is the very first introduction to a GIS application by Bagchi and Rao (1992). Aside from that, this method was initially developed to outside GIS environment through the number of analytical resources. AHP model is incredibly effective and simple to implement to unravel multicriteria decision problems (Guo & He, 1999). The steps of the AHP criterion are intended by Saaty and further explained by Mau-Crimmins et al. (2005). Improving agricultural performance and related rural nonfarming activity is vital for improving livelihoods, and curbing poverty is one among the aims of this research work. One of the objectives of this work is to investigate problems within the changing climatic patterns to enhance rural livelihood by the implementation of latest technologies and techniques with prime concentration on the combination of farming system in the way to increase income, standards of living, livelihood enhancement, and food security in an optimistic way. Geospatial techniques are very useful tools within the identification of the suitable sites for the agricultural practices based on different criteria like soil characteristics, the topography of the region, geology, drainage density, river basin, and transporting system of any particular area (Duc, 2006; Pramanik, 2016). Crop yield is principally counting on many factors like soil type, its available nutrients status, rainfall, management practices, and other inputs also. Therefore, it's mandated for efficient planning with the use of the latest technology together with the correct understanding of agroclimatic conditions (Bera et al., 2017).

Land suitability analysis involves arriving at important decisions at different levels ranging from the selection of criteria, analysis on major land use type paradigms, an arrangement of the criterion supporting above-said method, and determination of suitability limits for every class of the parameters that are employed in this study area. This study is the step toward understandings to the present problems and provides better suggestions to the agricultural planning authorities, which is the demand of the time. The reliability of accessible information, timely implementation on the extent, and distribution and kind of land use pattern aware decision-makers to require appropriate steps toward sustainable farming. The present literature relies on the land use analysis on the above-said district that was three decades old, so it's much needed to understand the changes occurring within the course due of time with the assistance of newest technologies and supply some mechanism to enhance the farming practices. Multicriteria decision analysis using different parameters such as soil, climate, and other environmental constituents plays a significant role in defining suitable areas for agricultural land evaluation (Baniya, 2008). This study assumed that the technique used is acceptable to integrate soil, climate, and other environmental constituents in the viewpoint of GIS context. Moreover, the weighting factor method produced important information, which will be useful for forthcoming studies on land suitability analysis. Satellite images provide a powerful tool for the identification of crop suitability analysis. Hence, crop suitability/land suitability analysis becomes an indispensable tool for the higher cognitive process that will be beneficial to the farmers. Additionally, it also helps the government in forming new policies to implement new schemes to enhance farmer's productivity and livelihood. This research work is an integration sort of GIS and MCDA to the assessment of land suitability for crops.

Database and Methods

Study Area

Nalanda district is among the 38 districts of Bihar state. Nalanda district can be geographically accessed through 85.4788° E longitude and 25.2622° N latitude. Agriculture is the backbone of this district in which almost 60% of the population engaged in farming practices. The Nalanda district occupies the area of 2324.678 sq. km (898 sq. miles), which is equivalent to Cornwall Island of Canada. Most of the land in this district falls into Indo-Gangetic plain, which is very fertile in nature. In the extreme south end, the *Rajgir* hillsides, and a small hillock in the district headquarter of Bihar Sharif, Nalanda district consists of 20 blocks, and Bihar Sharif is the administrative headquarter. *Phalgu*, *Mohane*, *Jirayan,* and *Kumbhari* are the major rivers of this district. Rice, wheat, maize, potato, and pulse are the main crops of these districts. The net sown area on the Nalanda district is about 119,792 ha, production 381,094 (M. P), and yield 3181 kg/ha (Department of Agriculture, Govt of Bihar, a) (Fig. 11.1).

The latest trend of population growth in Nalanda is 21.18% as per the 2001–2011 census data. According to the 2011 Census of India, the population of the district was 2,872,523 of which 84.09% of the population lives in rural areas and only 15.91% of the remaining population resides in the urban areas (Census-India, 2011a,b). The average annual temperature ranges from 14 °C to 44 °C, whereas the average annual precipitation is about 120 cm (903.5 mm). The typical soil distribution type ranges from sandy to clay loam. The main sources of irrigation in this district are canals, tube well, etc. Development in the agriculture field will not only improve the quality of life of the people residing in rural areas but also helps in promoting their livelihood dependency. However, it will also prevent the local migration of the laborer in search of their jobs in the industrial cities, which is very often in this study area. Apart from that, tourism is also considerable due to UNESCO's declaration as to the Nalanda World Heritage Site for the ruins of ancient Nalanda University, which attracts the tourist all

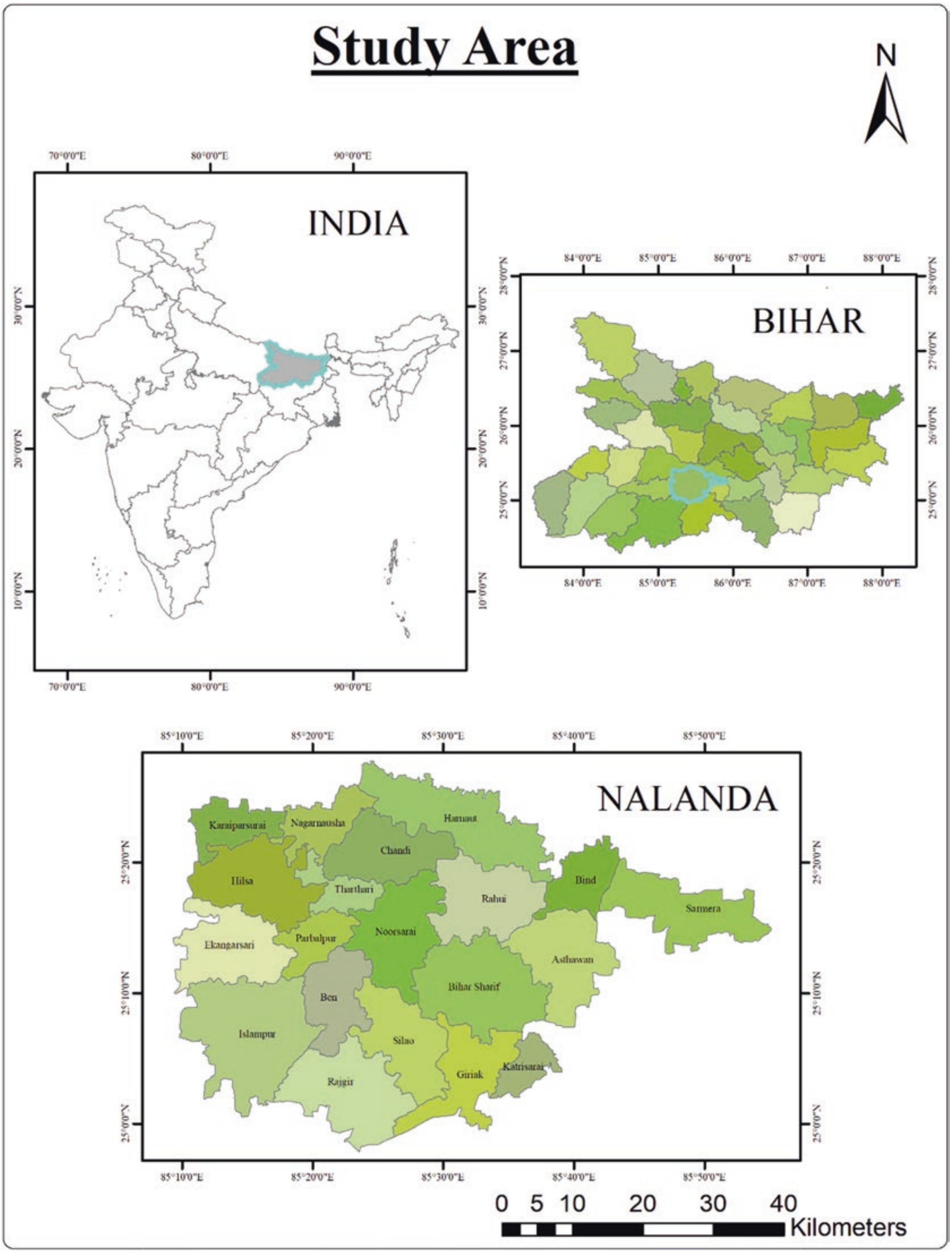

Fig. 11.1 Location of the study area

around the globe (Archaeological Site of Nalanda Mahavihara at Nalanda (a), Archaeological Site of Nalanda Mahavihara at Nalanda (b)). Following the land use pattern of Nalanda district, it is found that 181,130 ha of land belongs to cultivable area, which is 77% to geographical area of the district.

Methodology and Preparation of Input Dataset

After reviewing the various literature and guidelines mentioned for land suitability analysis, this work uses suitability analysis to develop appropriate and potential zonation of agricultural practices based on the set of parameters used. We have taken the parameters like soil texture, drainage pattern, climatic data, and satellite data and then further processed using ArcGIS and ERDAS IMAGINE software for mapping purposes. GIS raster datasets used for each dataset is used from different sources to obtain the land suitability maps for Nalanda district. Based on their importance and significance in this study area, seven different criteria are selected for the accomplishment of the crop suitability analysis (Fig. 11.2, Table 11.1).

Selection and Description of Parameters

Slope and Elevation

Slope is among the basic parameters of topographic elements for agricultural land suitability

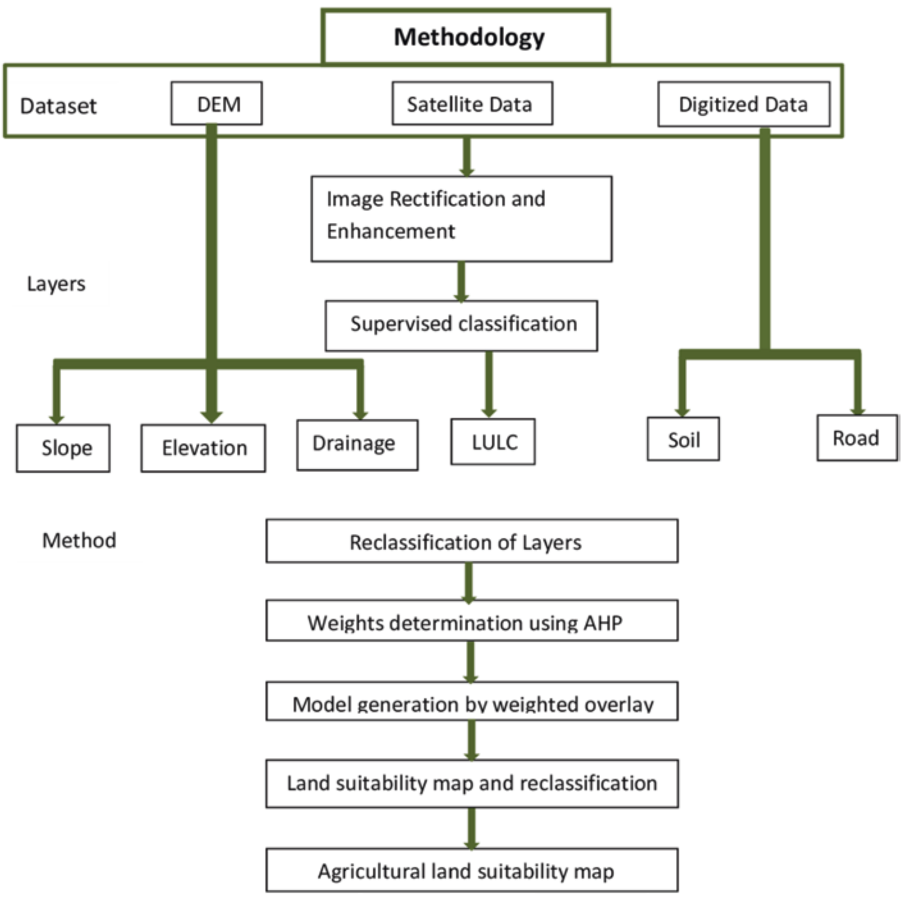

Fig. 11.2 Methodological framework of present study

Table 11.1 Datasets used in the study

Description of the datasets	
Satellite data	*Remarks*
Sentinel	LULC (tiles, T45RUJ, T45RUH, 29/12/2018)
Shuttle radar topography mission (DEM)	Slope degree
	Elevation
	Drainage and river basin
	Drainage density
Website	*Remarks*
USGS Earth Explorer	Satellite data (sentinel)
Indian Meteorological Department	Rainfall map
Central Ground Water Board	Soil type map
DACNET	Soil pH map
DIVA-GIS	Road network map
Census of India	Population dynamics and socioeconomic status of the district
United Nation Food and Agriculture Organization (FAO)	Assess global food security aspects
Department of Agriculture, Govt. of Bihar	Assess district profile and factors
Customized Rainfall Information System (CRIS)	Annual average rainfall

Source: Prepared by the authors

analysis. The shuttle radar topography mission (SRTM) data sources are used globally for DEM data elevation information. The slope map of Nalanda district is obtained with the help of SRTM-DEM (30m) spatial resolution data acquired from USGS Earth Explorer. Further, the slope is a layer obtained from the spatial function of ArcGIS 10.1 software using Spatial Analyst Toolbox. Generally, with the increased amount of slope, the agricultural suitability is reduced gradually as the water-holding capacity is decreased (Figs. 11.3 and 11.4).

Soil Texture

As we all know, the soil is the most dominant and very essential component present on the planet Earth. Soil is considered as a natural body, which developed under the natural forces acting on it and environmental medium too for plant growth. The physical and chemical properties of the soil determine the selection and distribution of the crops over any region. The soil texture map is obtained from the IIRS website for the Nalanda district. The thematic layer for soil texture parameters obtained converts based on their value fields in ArcGIS 10.1 and is further classified into seven classes (Ayehu & Besufekad, 2015). In the spatial context, it is deep or shallow, rich or poor, but everywhere, it consists of organic matters, minerals, air, and water. Therefore, soil texture identification and mitigation are an important aspect of this research (Fig. 11.5).

Soil pH

Soil pH is an appropriate indicator of soil's suitability for plant growth. The soil pH map for Bihar state is extracted from the cereal systems initiatives for south Asia. Geo-referenced shape file creation and geocoding were done for the Nalanda district. Then the obtained map is further classified into eight classes ranging from 6 to 9 (Fig. 11.6).

Rainfall

This district comes under the moderate rainfall zone and major source of irrigation through the canals and streams. The rainfall data of this district is extracted by the IMD station and plotted to the map. The district is divided into five categories ranging from 940 mm to 995 mm for the year 2018. There is a positive established relation between rainfall amount and agricultural production of any region, which is applicable in this study area too (Fig. 11.7, Table 11.2).

Drainage and River Basin

Drainage pattern ensures the appropriate soil aeration and reduces soil nutrient loss because of runoff in the form of erosion. Total area in the context of drainage is best suited for agricultural practices except the hilly region and some plain areas. The three major river basins are Mohane, Jirayan, and Kumbhar. High drainage density ensures optimum supply of water through irrigation practices, which ultimately help the land to become highly suitable for agriculture (Fig. 11.8).

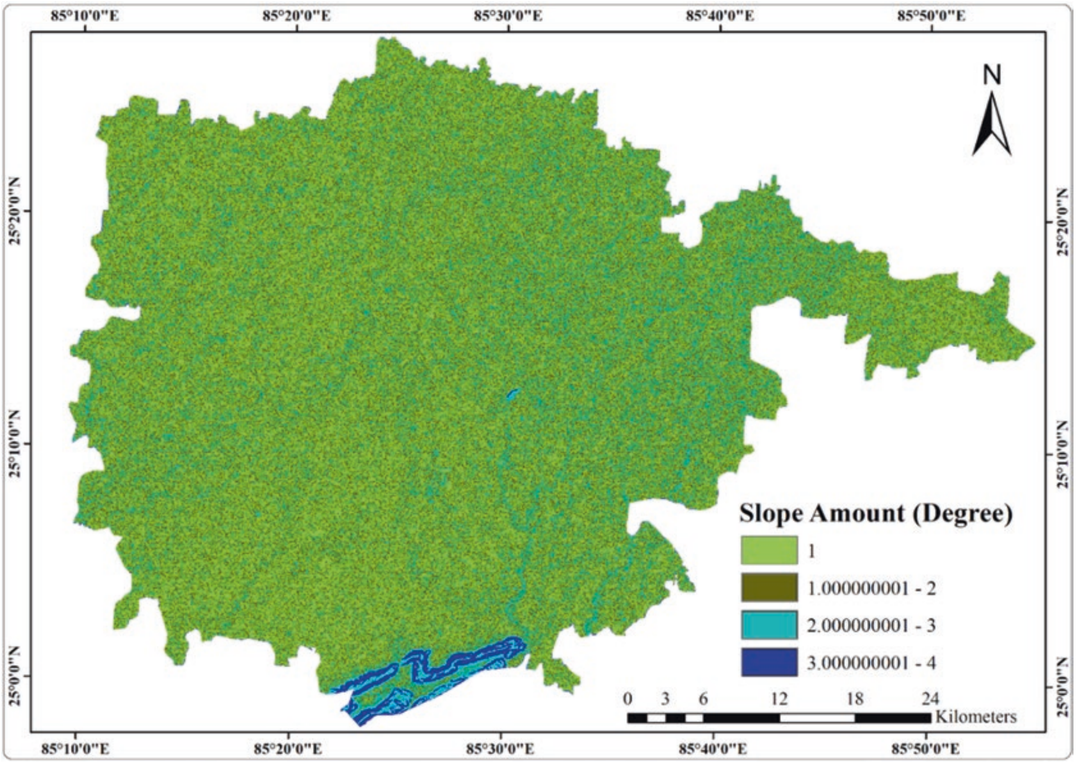

Fig. 11.3 Slope amount (in degree) map of the study area

Drainage Density

It is defined as channel length per unit watershed area in km per sq. km. It can be obtained by the total length of all streams and rivers in a drainage basin divided by the total area of the drainage basin. Drainage density plays an important role in surface runoff processes, concentration, and sedimentation load with respect to water balance in a drainage basin. Basically, the permeability of rocks has greater influence on the presence of drainage density. Clay and shale are the examples of the impermeable rocks, which produce higher surface runoff. In addition to this, humid regions have greater drainage density texture than the semiarid region(Fig. 11.9).

Distance to Major Road

The road network is obtained from the Nalanda district website and further classified into three major categories such as major district road (MDR), national highway (NH), and state highway (SH) (Fig. 11.10).

Road network plays very crucial role in transporting the cultivated crops into the nearest local markets.

Land Use Land Cover

The societal growth is the function of social and economic development by the use of available land resources. The LULC maps play very crucial and significant role in the utilization aspects of resources available in any particular area. In addition, LULC maps were important key elements in management, planning, and monitoring at regional, local, and national levels. This type of paradigm provides brief information in relation to the land utilization patterns, which helps in the formation of policies and development programs. In this study, sentinel satellite image data for the Nalanda district is obtained from USGS Earth Explorer agency. The diverse land use land cover maps were generated using sentinel data using image classification techniques through ERDAS IMAGINE software. Supervised classification

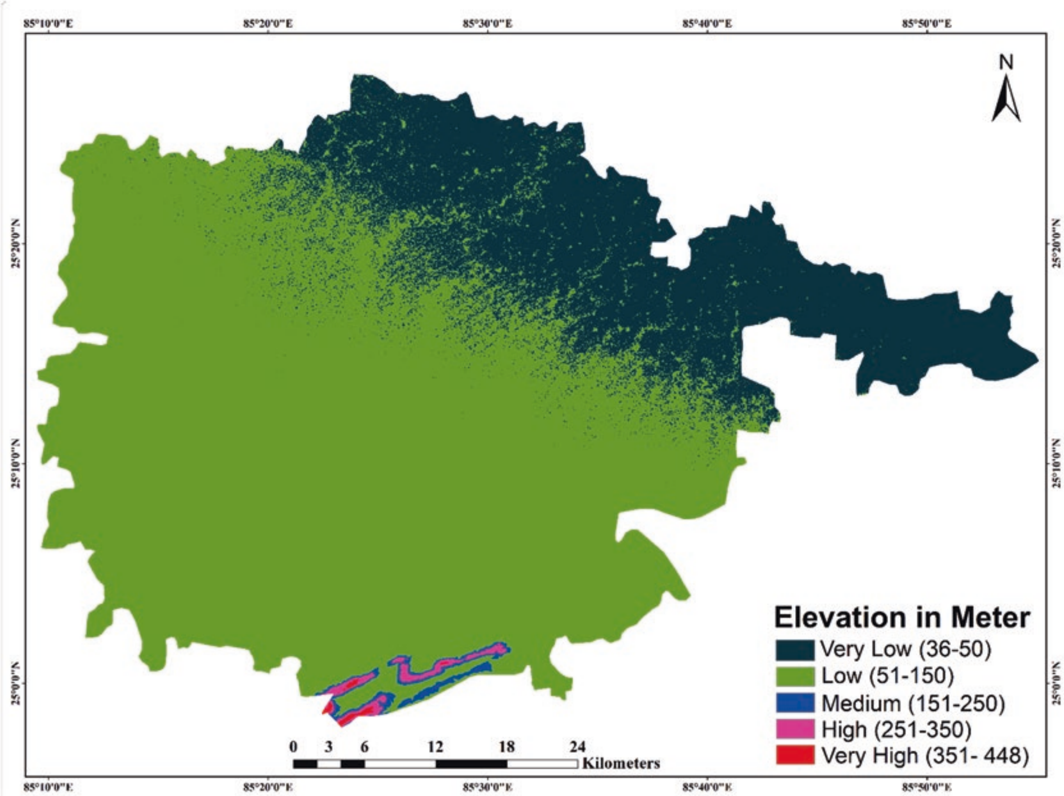

Fig. 11.4 Elevation map of the study area

technique is used in this study to obtain detailed LULC map (Fig. 11.11).

Weightage Estimation Criteria

Thomas L. Saaty (1980) developed the pairwise comparison technique called the AHP model for decision-making, which was based on expert's opinions for assigning the weightage over the various parameters. In the decision-making procedure, each factors/parameters are compared with other factors/parameters with respect to its importance and influence on the basis of Saaty scale, which comprises of rank from 1 to 9 (Yohannes & Soromessa, 2018). Origination of the AHP model starts with the first step to construct the hierarchy of the parameters. In this study area, we have taken seven parameters and grouped them into clusters and further interdependence of parameters for each cluster in design. The importance of each parameter in the form of ranks to each class has been evaluated based on expert opinion acquired from the designed questionnaires (Saaty, 2004) (Balasubramanian, 2017). For an instance, 1 is given for the equally importance and 9 for extremely importance to the parameters. Finally, priority weightage can be calculated using pair-wise comparison matrix and eigenvector values using this formula:

$$\lambda_{\max} = \sum_{j=1}^{n} aij \frac{Wi}{Wj} \tag{11.1}$$

where w_i is the sum of pair-wise comparison, and n is the size of matrix.

The consistency ratio (CR) is computed to check the consistency level of comparison. The sum of weightage criteria should be equal to 1. The CR ratio of 0.1 or less value is being considered as reasonable level of consistency (Saaty, 1980) (Table 11.3).

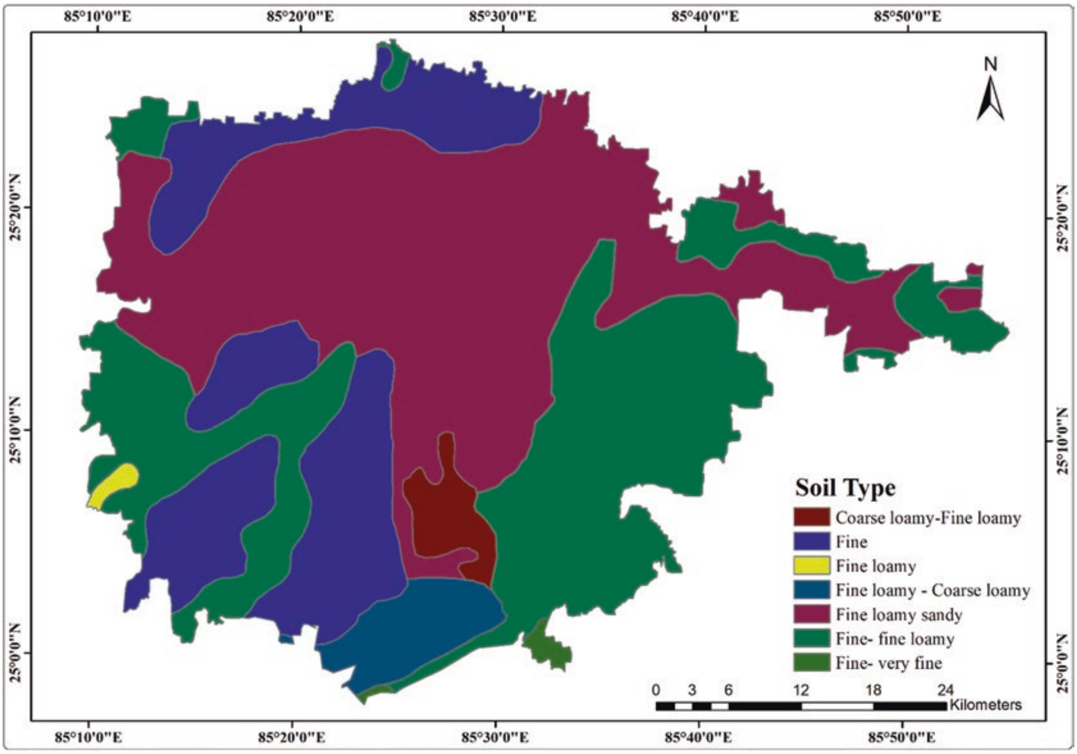

Fig. 11.5 Soil type map of the study area

The consistency index (CI) may be computed through this formula:

$$CI = \frac{\lambda_{\max} - n}{n-1} \quad (11.2)$$

where λ_{max} is the highest eigenvalue of pairwise comparison matrix, and n is the number of classes.

Then consistency ratio is computed as

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}} \quad (11.3)$$

where RI is average value or ratio index of CI for a random value based on Saaty's Table (1980).

Weightage Aggregation

In this study area, weightage overlay analysis method was used to aggregate the criteria and weighted criteria for land suitability analysis. The obtained map is further classified into specified number of criteria, which is our final suitability map for the Nalanda district. The formula is given below (Table 11.4):

$$S = \sum_{i=0}^{n} W \times X \quad (11.4)$$

where S indicates suitability, W indicates weight of factor, and X indicates to rank of factor.

Results and Discussion

Delimitation of fertile areas is a most important process toward the successful operation of the development of a sustainable agriculture. Land suitability analysis was performed by using the AHP method through assigning different weights to all parameters.

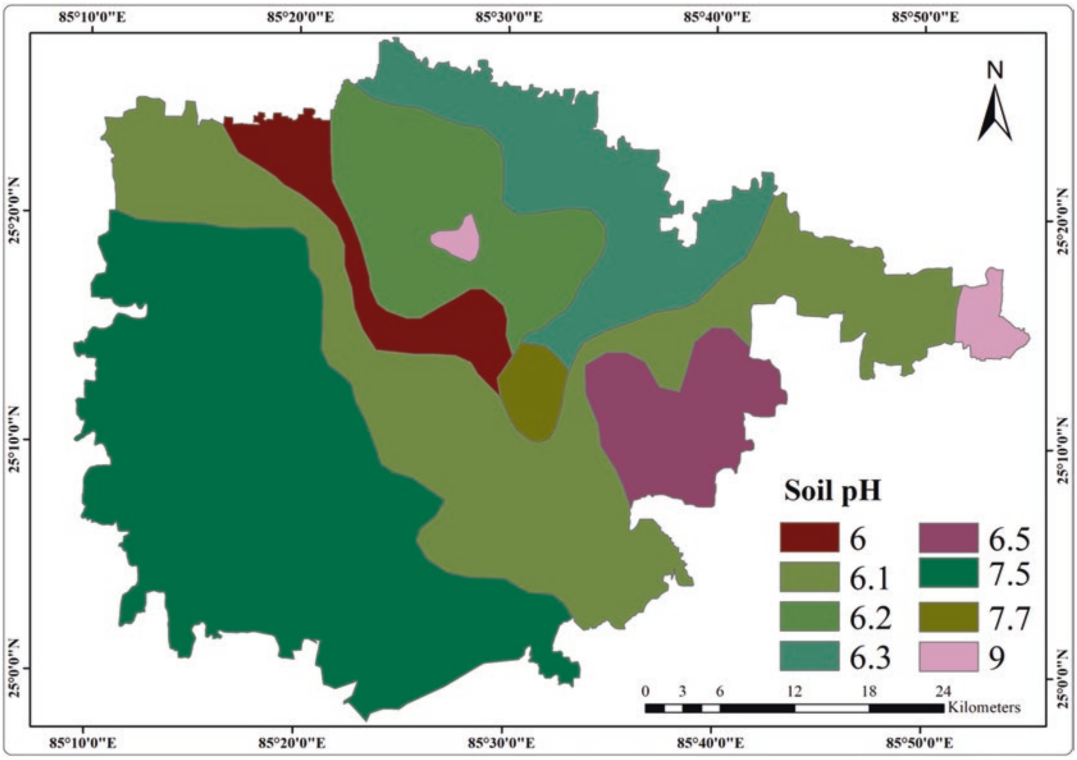

Fig. 11.6 Soil pH map of the study area

Spatial Outlooks of Different Input Parameters

Overall, the topographic elevation is indicated to flat surface, which is reasonably good for developing agricultural practices. Slope is slightly high in the southern part of the study area, which belongs to hilly areas under Rajgir hills. Most areas of the district are flat, which is reasonably well for developing agricultural practices. The highest degree of slope lies in the hilly areas of the Rajgir region named as "Rajgir hill," which is not appropriate for growing crops because of surface runoff of the rainfall water. Following the rainfall pattern, it is clear that there is an increasing trend of rainfall from northwest to southeast direction. Only some parts adjoining to Rajgir hills received annual rainfall above 1000 mm. High drainage density is found in the central part of the study area, which is covered by three major river basins, namely, *Mohane*, *Jirayan,* and *Kumbhar* Rivers. The rest of the region belongs to less drainage density zone in the district. Making assemblage with the slope and topography with rainfall and drainage facility over the study area, there are different soil types in the whole region with varying chemical condition mainly in terms of soil pH. Most of the areas have suitable pH range except some part of Chandi, Bihar Sharif, and Sarmera blocks, which is in extreme red color. The maximum area is covered by fine, loamy, sandy soil, which is surrounded by fine-fine, sandy, and fine soil in Nalanda district. Soil pH is high (7.5 and above) in the western part of the district and in varying condition in some pockets all over the region. From land use perspectives, seven LULC classes are identified in terms of forest, open forest, riverbed, standing crops, built-up, water bodies, and mature crop. Standing crops and matured crop cumulatively cover above 80% of the study area. Almost 10% of the land are used for built-up activities, which are allocated in the central and western part of the study area (Table 11.5).

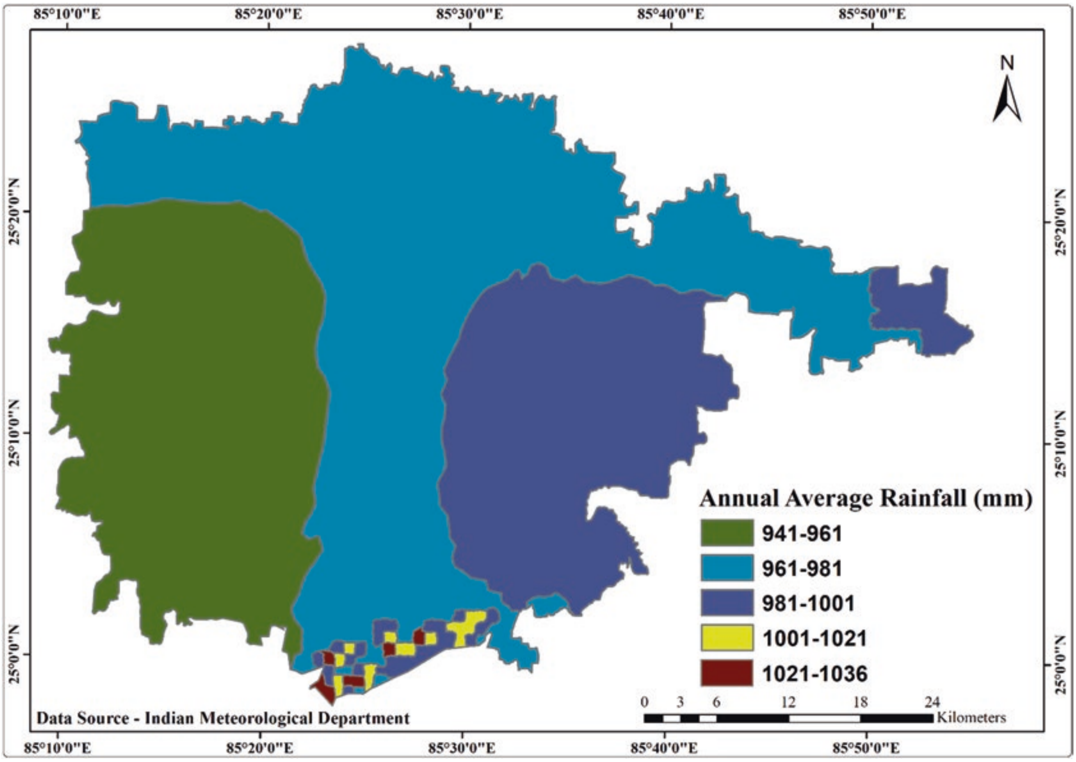

Fig. 11.7 Annual average rainfall map of the study area

Table 11.2 Annual average rainfall in Nalanda district

Year	R/F	%DEP
2014	87.8083	12
2015	55.6583	−26.25
2016	86.675	−26.75
2017	58.3917	−67.75
2018	53.2583	−58.583

Source: Customized Rainfall Information System (CRIS)
Note: (1) The district rainfall in millimeters (R/F) shown below is the arithmetic averages of rainfall of stations under the district
(2) % dep. are the departures of rainfall from the long period averages of rainfall for the district

Agricultural Land Suitability

All the factors found significant in the present study are chalked out from the Spearman rho Rank test (99% significant level). Agricultural suitability of this district has been calculated from slope, rainfall, soil type, drainage density, road density, and LULC. Following the selection of all the six indices, each of them has been categorized based on their respective characteristics, and class weights were assigned (Table 11.4) in a systematic and scientific way that will lead us toward greater accuracy level. Thereafter, AHP has been applied for weight assignment of different themes, and pair-wise comparison matrix has been used for normalizing the weights (Table 11.6) (Saaty 1990). Considering the goodness as a statistical technique for spatially circulated variables, AHP has been used with great precision. Following assignments of weights, six layers containing six different themes have been put into the GIS environment, and weighted sum overlay has been executed to unearth the spatial variation in agricultural suitability. Spatial output in terms of suitability status map exhibits the facts that there was a variation in agricultural suitability, and its coverage was not uniform over the study area. Considering all these parameters with their respective weightages, agricultural land suitability has been evaluated in this district, among which 1144.6 sq. km (49%) and 787.3 sq.

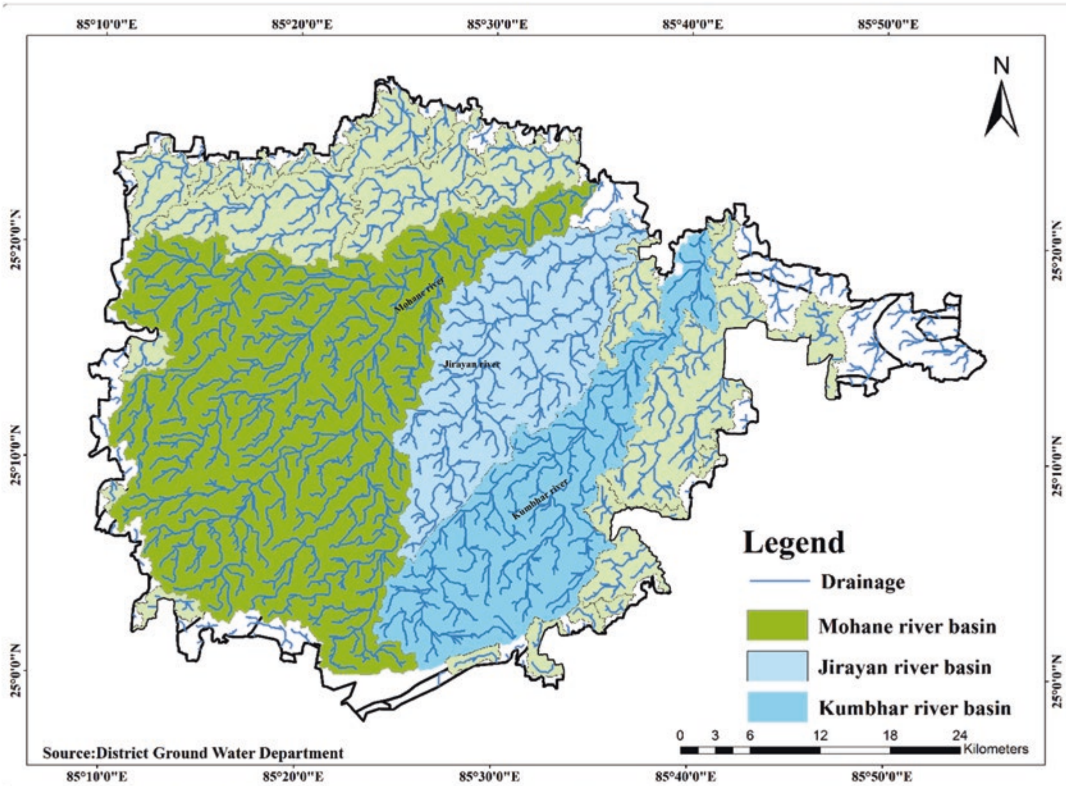

Fig. 11.8 Drainage and river basin map of the study area

km (34%) area mainly in the western and central part of the district covering the location of *Chandi, Tharthari, Parbalpur, Ben, Islampur, and Hilsa* belongs to highly suitable zone and moderately suitable zone, respectively. Marginally suitable zone along with vulnerable zones is found in the eastern part adjoining to *Silao, Bihar Sharif, Bind, Asthawan, and Giriak* locations. This region is mainly covered by sparse vegetation along with built-up land comparison to the rest of the part of the district (Table 11.6).

Any assessment on determination of soil quality comprises a wide-ranging evaluation process in directive to recognize the appropriate agricultural land location. The identified suitable soils must contain the key nutrients for basic plant nutrition in order to reduce organic, mineral, chemical inputs to minimize economic cost and environmental damages. The land in the Nalanda district mainly consists of Kewal kind soil. Kewal soil consists of hard clay and which is very suitable for rice cultivation. This kind of soil has the capacity to retain moisture and is most suitable for rabbi crops. On uplands near the farmstead, "doras" soil is also found that is generally used for growing potatoes and vegetables. The stage of groundwater development of the study area is only 64.9%, which implies that there is a huge scope for further groundwater development. However, the artificial groundwater recharge techniques including rainwater harvesting should be taken to augment the groundwater reserve. Exploitation of groundwater in regions of the study area can be done through both shallow and deep tube wells. Generally, small and marginal farmers frequently use shallow tube wells, and farmers' cooperative can choose for high-discharge deep tube wells. The organic farming techniques were also successfully adopted after being introduced in 2010, and the villages of

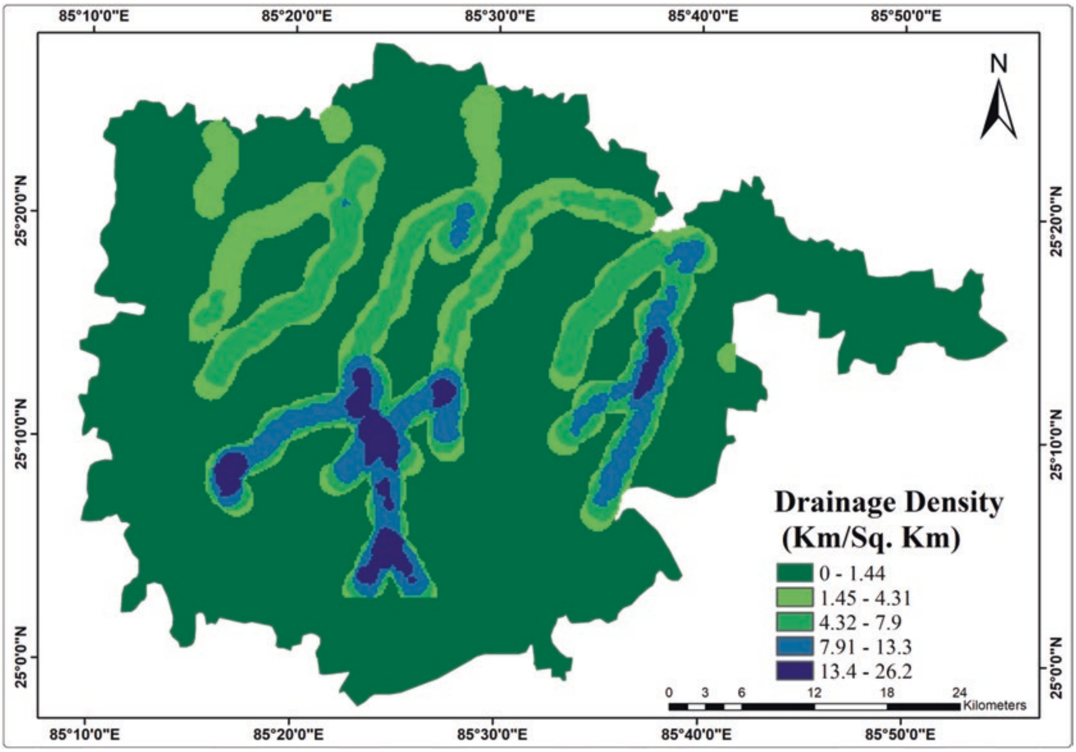

Fig. 11.9 Drainage density map of the study area

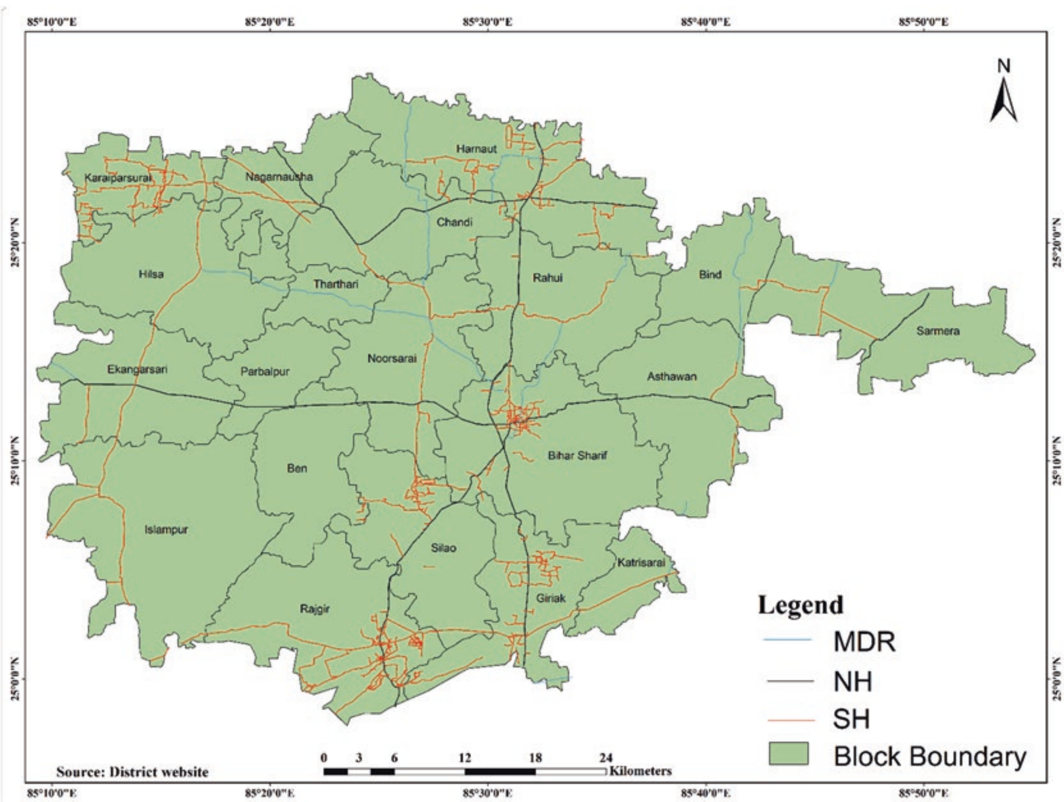

Fig. 11.10 Distance to major road map of the study area

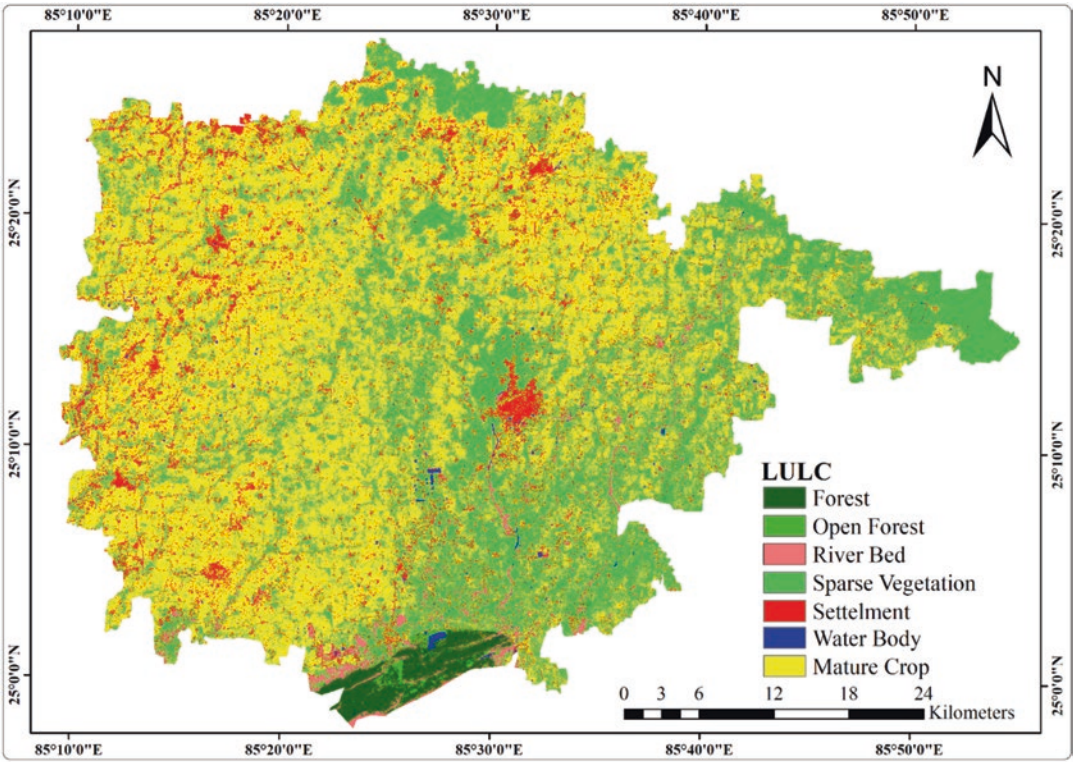

Fig. 11.11 Land use land cover map of the study area

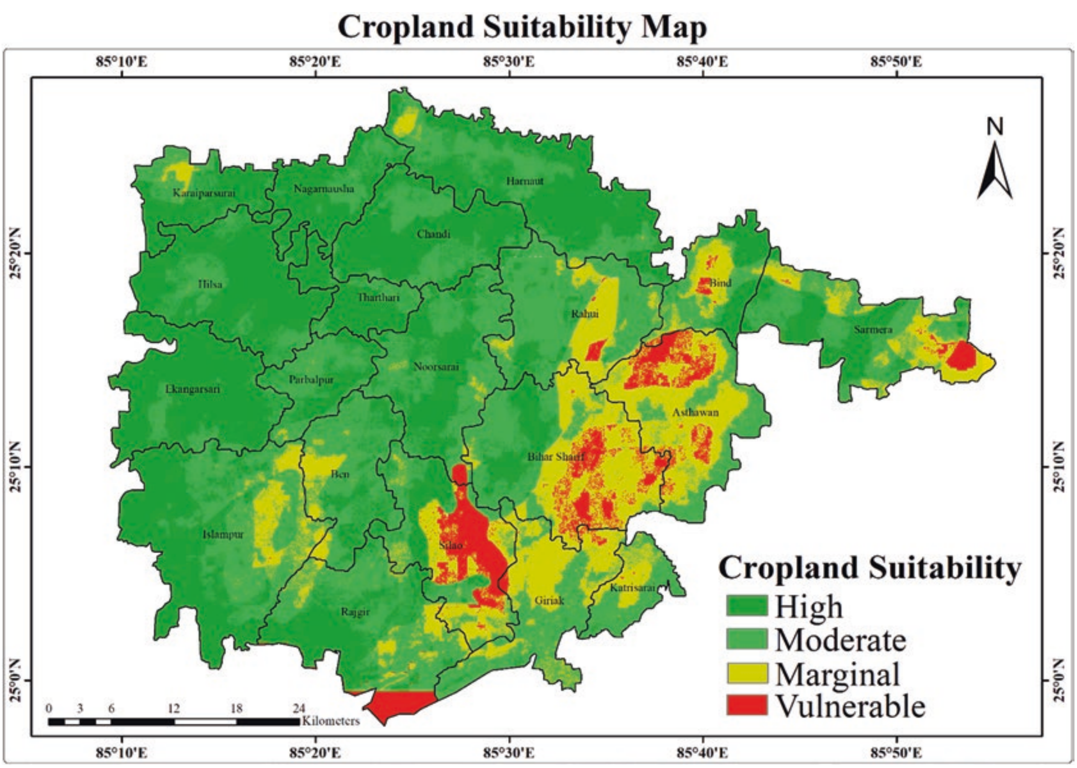

Fig. 11.12 Cropland suitability map of the study area

Table 11.5 Land use land covers distribution in the study area

Classes	Area in hectares	Total % distribution
Forest	3885.86	1.67
Open forest	803.95	0.35
Riverbed	7666.55	3.29
Built-up	21985.80	9.46
Standing crops	68634.80	29.52
Mature crops	128746.00	55.38
Water body	744.81	0.32

Table 11.3 Scale of relative importance (according to Saaty, 1977, 1980)

Definition	Intensity of importance	Reciprocal	Explanation
Equal importance	1	1/1 or 1.00	Two activities contribute equally.
Weak, slight importance	2	1/2 or 0.500	When compromise needed between two
Moderate importance	3	1/3 or 0.333	Experience and judgment moderately favor one element over another.
Moderate plus	4	1/4 or 0.250	When compromise needed between two
Strong importance	5	1/5 or 0.200	Experience and judgment strongly favor one element over another.
Strong plus	6	1/6 or 0.167	When compromise needed between two
Very strong	7	1/7 or 0.143	One element is favored very strongly over another.
Very very strong	8	1/8 or 0.125	When compromise needed between two
Extreme importance	9	1/9 or 0.111	The evidence favoring one element over another is of the highest possible order.

Source: Saaty, 1980

Nalanda and farmers are depending on it and contributing part in the way to sustain soil health, environmental stability, and human health.

Hence, land suitability like AHP techniques were showing good results by using weightage of the indicators and subindicators to estimate their influence in the selective rain-fed agricultural farming areas (Fig. 11.12).

Conclusion

It is estimated that from the overall assessment, 49% of the land area is highly suitable, 34% moderately suitable, 11% marginally suitable, and 6% high risk of degradation of the study area. According to their mutual suitability ratios, i.e., highly, moderately, marginal, and risk or vulnerable suitable areas, it was determined that those areas on high risk of degradation are mainly from two reasons. The first one is improper land use results in land degradation as well as decline in agricultural productivity, and the other is excessive use of chemical fertilizers and changing rainfall pattern are driving factors to land degradation. Changing rainfall pattern is one of the major concerns that affect largely the agricultural practices and agro-based industries. Crop suitability analysis involves major decisions at various levels to build up an efficient crop production system. Additionally, decision-makers have to resolve the land degradation problems by implementing new farming techniques to those affected areas. Adopting organic farming by the few farmers in the district set new records in the potato production. Such type of agricultural adaptation ultimately acts as a path to the small and marginal farmers to beyond the threshold level without affecting the environment.

Recommendation

Research in the future should further examine the suitability analysis by taking more factors that will improve the accuracy of the result, such as-CACO3 content, organic content, socioeconomic condition of the farmers, etc. The extensive study

Table 11.4 AHP matrix table used in the study area

Layers	Soil type	Road	Rainfall	Line density	Slope	LULC
Soil type	1	0.5	1.111	0.5	3.003	2
Road	2	1	0.5	0.5	3.003	2
Rainfall	0.9	2	1	2	2	2
Line density	2	2	0.5	1	3.333	2
Slope	0.333	0.333	0.5	0.3	1	0.5
LULC	0.5	0.5	0.5	0.5	2	1
C.R. = 0.058						

Source: Prepared by the authors

Table 11.6 Area under different land suitability classes

Value	Area (in Km^2)
Highly suitable	1144.699
Moderately suitable	787.3326
Marginally suitable	269.4996
Vulnerable	136.926

Source: Prepared by the authors

should be done in the due course of time using GIS and its proponents because such study has the ability to show greater availability of information from different sources to map land suitability and help in many levels to management authorities. In addition, the work should be on intensifying the analysis to the other part of the Bihar state and examining the impact of climate changes in all conditions in the region on the suitability maps of different parameters, which should be central to a better understanding of the impact on agricultural products and the sustainable use of land resources at the various local and regional levels.

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