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AKADÉMIAI KIADÓ

# Crop-land suitability analysis using geographic information system and remote sensing

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## ORIGINAL RESEARCH PAPER

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### ABSTRACT

Food, water, and energy scarcity threaten India's future, and they must be addressed first. To meet the country's ever-increasing population needs, agricultural productivity must be expanded. For the crop-land suitability, we have studied an area of about 6,539 $km^2$ in Vizianagaram district. The majority of the land is used for paddy agriculture (Kharif). The crop-land suitability has been evaluated based on the different parameters identified in that study area. "Remote sensing (RS)" and "geographic information system (GIS)" were combined for the crop-land suitability using nine parameters. The slope, elevation, rainfall, soil texture, lithology, groundwater, land use–land cover (LULC), TWI, and land surface temperature are the primary criteria used to determine the crop-land suitability in the Vizianagaram district (AP). Thematic maps were created using Landsat 8 images and SRTM DEM images from USGS Earth Explorer. Based on these maps and the influence of these parameters, we may assign weights to the parameters and then rank them, the Analytic Hierarchy Process (AHP) allowing us to identify which area is more suitable for good crop productivity and which is not. In this study, the soils are divided into four categories: low suitability, moderate suitability, high suitability, and extremely high suitability. The suitability index is found to be in the range of 0–55.2%, which indicates the lack of outstanding agricultural lands in the sudy region.

### KEYWORDS

geographical information system, land suitability, remote sensing, thematic map

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## INTRODUCTION

The appropriateness/suitability of land for agriculture is described as the ability of a portion of land for farming maximum yields in a variety of crops (Aguilar-Rivera et al., 2019; Loc et al., 2021). Crop-land has varying quality conditions, which are reflected in its agricultural appropriateness (Aguilar-Rivera et al., 2019; Akıncı et al., 2013; Khan et al., 2022). Crop suitability is the procedure for determining the suitability or ability of a given type of land-based on the growing circumstances of a specific crop (Bozdağ et al., 2016; Everest et al., 2020; Jamil et al., 2018). The land suitability study is a key technique for long-term land usage (Beraet al., 2017; Pramanik, 2016; Taani et al., 2020; Taghizadeh-Mehrjardi et al., 2020; Tashayo et al., 2020). The term "land appropriateness" means the capability of a bit of land to adopt a given usage (Doula et al., 2017; Jamil et al., 2018). The land has been always a basic factor for growing crops (Hossen et al., 2021). In this sense, land suitability categorization refers to the capability of a certain type of land to support a specific use (Taghizadeh-Mehrjardi et al., 2020). The process of identifying the most suited area for a type of use (forest, agricultural, recreation, etc.) based on several degrees is known as the appropriateness of land use analysis (Bera et al., 2017; Everest et al., 2020; Romeijn et al., 2016). A land suitability study assesses the appropriateness of land while also taking environmental and social factors into account (Everest et al., 2020).

Hand-drawn overlay analyses were used to begin crop-land suitability studies in the early twentieth century (Debesa et al., 2020; Everest et al., 2020). Globally, cultivated land is scarce, and most land has been irreversibly damaged, rendering it unfit for agricultural cultivation (Bera et al., 2017; Girmay et al., 2018). So, to improve this, crop-land suitability techniques are very useful for sustainable crop production by using different parameters.

The parameters such as slope, elevation, rainfall, LULC, TWI, soil texture, surface temperature, and lithology are used in the land assessment to determine the suitability for possible land use by land requirement (Hossen et al., 2021; Kumar et al., 2021; Saha et al., 2021; Taghizadeh-Mehrjardi et al., 2020; Yalew et al., 2016). In this land suitability study, the technique employed is a geographical information system, which is highly effective for investigating different geo-spatial data with precision and greater flexibility (Girmay et al., 2018; Hassan et al., 2020; Hossen et al., 2021; Rao et al., 2018; Yalew et al., 2016). For doing the crop-land suitability analysis using geographical information system we employed a method called Analytical Hierarchy Process. One example of a multiple-criteria decision-making (MCDM) procedure is the Analytic Hierarchy Process (AHP) (Penki et al., 2022a, 2022b; Ramu et al., 2020; Ravinder and Ramu, 2020; Saaty, 1990; Saha et al., 2021). Similar other MCDM methods are Electre, Topsis, Promethee, Grey theory. AHP offers many choices based on the relative relevance and weight of the factors inside a hierarchical structure (Penki et al., 2022a; Ramu et al., 2020; Rao et al., 2018; Saaty, 1990). AHP is a system that employs a multi-criteria hierarchical approach (Penki et al., 2022a). To establish the relative relevance of a parameter to other factors on a level, the method uses scoring and a pairwise comparison matrix (Hassan et al., 2020).

In this study, we are defining the land-use efficiency and amount of land suitability for the crops in the Vizianagaram district. In this work, Geographic information systems (GIS) and AHP were used in tandem employed to determine viable agricultural fields suitable for the crops.

In order to increase agricultural productivity and satisfy the rising demand for food, GIS and AHP have been combined. This technique identifies and maps agricultural land suitability areas through crop-land suitability analysis. This can be improved by combining geographical information system, remote sensing and other artificial intelligence tools by using various algorithms to improve the accuracy and save the time as well (Singh, 2019; Talaviya et al., 2020).

## STUDY AREA

The study area was conducted for Vizianagaram district in Andhra Pradesh state located between 18°12′N and 83°24′E coordinates. This district covers a total area of 6,539 $km^2$. It is limited by the state of Orrisa to the north, in the west and south by the district of Visakhapatnam, the district to the east is Srikakulam, and to the south-east by the Bay of Bengal. The district of Vizianagaram is mostly an agricultural district, with 68.4% of workers employed in agriculture and 82 percent of the district's people live in rural areas and rely on agriculture for a living. The district's agriculture is characterized by rainfed farming, with around 60% of its land grown only under rainfed circumstances. Even the rest of the irrigated region is mostly dependent on the amount of rain that falls in the district. Because of the district's unreliable irrigation, the bulk of crops planted are dry crops. Paddy is mostly grown during the Kharif season, with 80 percent of the land under tank irrigation, which is dependent on local rainfall. The principal crops grown in the area include paddy, ragi, bajra, sugarcane, pulses, mesta, cotton, and groundnut (Fig. 1).

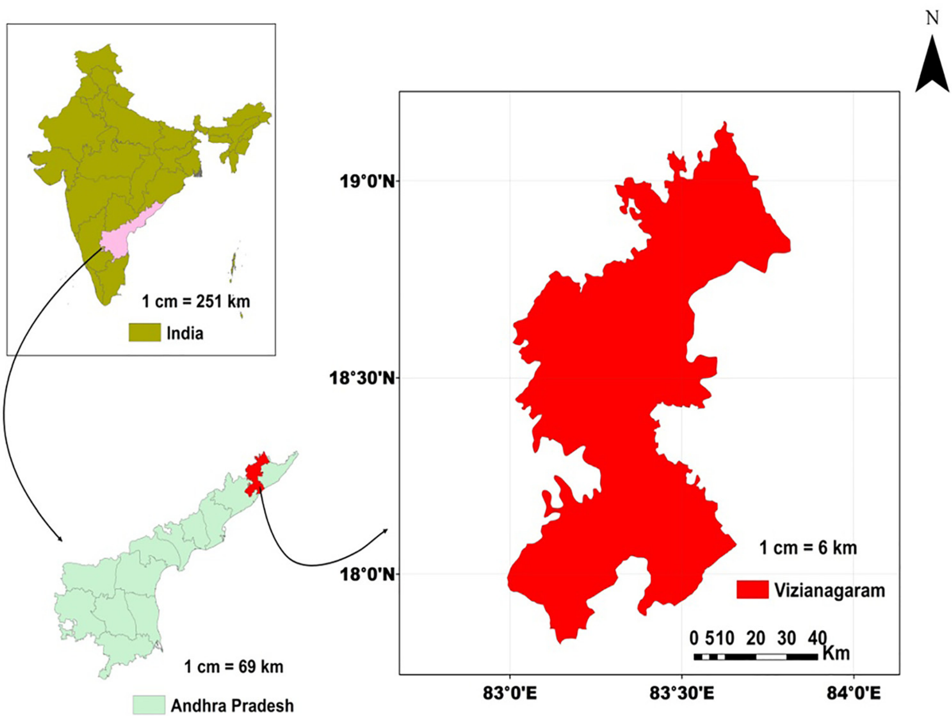


*Fig. 1.* Location map of the study area

## Parameters

***Slope.*** Slope is a crucial aspect of agriculture (Jamil et al., 2018; Singh et al., 2018). The slope has a direct impact on soil depth, erosion, and irrigation, among other things (Everest et al., 2020). The 0°–3° slope has demonstrated a flat zone°, which is for beneficial for agriculture. The 6°–12° slope has some steepness and is suitable for crop production. The higher slopes, such as 12–24 and >24, have various effects on the land, which is not suitable for growing crops due to more surface runoff of rainfall water. The soil layer's thickness reduces as the slope climbs and increases as the slope drops. As the slope angle increases, so does the amount of material carried away by erosion.

***Elevation.*** Elevation is a significant component that influences plant cover variations and causes temperature shifts, especially in highland locations (Saha et al., 2021). Rainfall and soil erosion are more severe in areas with higher topographic elevations (Girmay et al., 2018; Ravinder and Ramu, 2020). Higher elevations result in more soil erosion, which causes landslides and floods (Ramu et al., 2020; Ravinder and Ramu, 2020). In the mountains, for example, every 100 m of elevation gain delays vegetative cycles and plant flowering by 4–6 days. This fact harms the plant varieties that should be chosen for agricultural output. The study area's lowest elevation was discovered to be 0–150 feet, and it has gradually increased, which is higher >450.

***Soil texture.*** The soil texture is important because it determines the soil properties that impact plant development (Hassan et al., 2020; Rao et al., 2018; Ravinder and Ramu, 2020). Three of these attributes are affected by soil texture: water holding capacity, permeability, and soil workability (Everest et al., 2020; Penki et al., 2022a; Romeijn et al., 2016). Water retention capacity refers to a soil's ability to hold water (Ravinder and Ramu, 2020). Loam, clay loam, and clay soils can all be found in this study region.

***Rainfall.*** Rainfall has a substantial influence on the soil (Singh et al., 2018). If the soil is too wet, nutrients may wash off and not reach the plant's roots, as a result, growth and general health suffer (Everest et al., 2020). In addition, too much rain can encourage the growth of bacteria, fungi, and mold in the soil (Penki et al., 2022a). For this study area, we used rainfall data from the APSDPS website (Andhra Pradesh State Development Planning Society) for Vizianagaram district, Mandal level data is taken.

***Groundwater depth.*** In India, groundwater is an important resource for agricultural production, as it is used to irrigate many of the country's primary crops (Debesa et al., 2020). Groundwater reserves are depleting in several parts of the country due to excessive overexploitation (Hossen et al., 2021; Rao et al., 2018; Taani et al., 2020). So, the groundwater level must be at a minimum depth to withdraw the water for irrigation purposes.

***Land use and land cover (LULC).*** The most significant component is LULC, which influences the crop-land suitability of a given location (Aguilar-Rivera et al., 2019; Everest et al., 2020). It is a crucial characteristic that indicates the appropriateness of agricultural output (Loc et al., 2021). Water, trees, flooded vegetation, range land, bare ground, built area, crops, and grass are the eighth class of LULC presence in this study area.

***Land surface temperature (LST).*** The radiative skin temperature of the land as determined by solar radiation is known as land surface temperature (LST) (Debesa et al., 2020; Jamil et al., 2018; Saha et al., 2021). When incoming solar energy interacts with and heats the ground or canopy surface in vegetated regions, LST is measured.

***Topographic wetness index (TWI).*** TWI is also known as the compound wetness index (Ravinder and Ramu, 2020). It is defined as the tendency of water accumulation in the soil (Ramu et al., 2020; Ravinder and Ramu, 2020; Romeijn et al., 2016). The Topographic Wetness Index (TWI) has long been used to explain how topography affects the location and size of saturated source zones for surface runoff to generate (Taani et al., 2020).

# METHODOLOGY

## Data preparation

The approach used in this investigation is shown in Fig. 2. Only a sample of parameters, based on their importance in crop-land suitability was used. Nine thematic maps were used to identify and evaluate the spatial distribution of crop-land suitability including elevation, slope, lithology, land-use/land-cover (LULC), soil texture, topographic wetness index, rainfall, groundwater level, and land surface temperature and they are represented in Figs 3–5. To obtain the final suitability map, these maps were converted to 30m resolution and the Overlay operation was performed in ArcGIS 10.3.

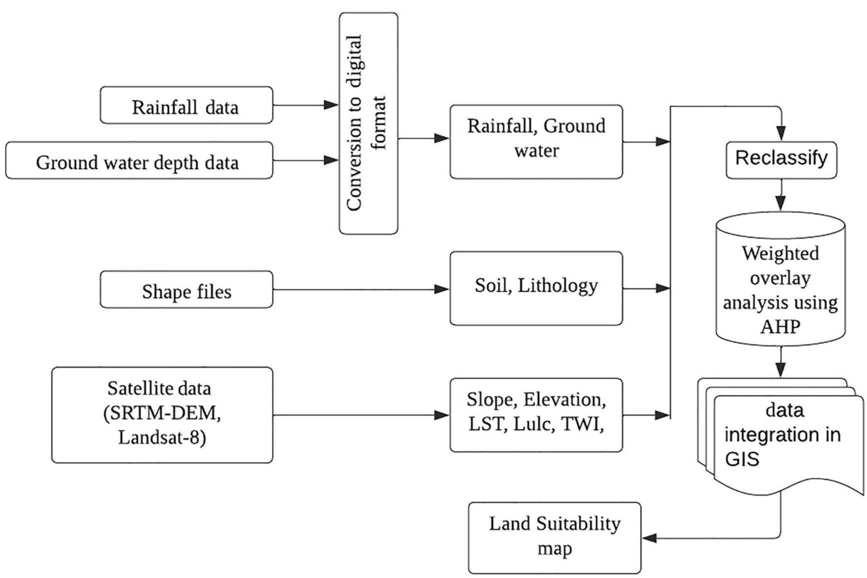


*Fig. 2.* Methodology flow chart

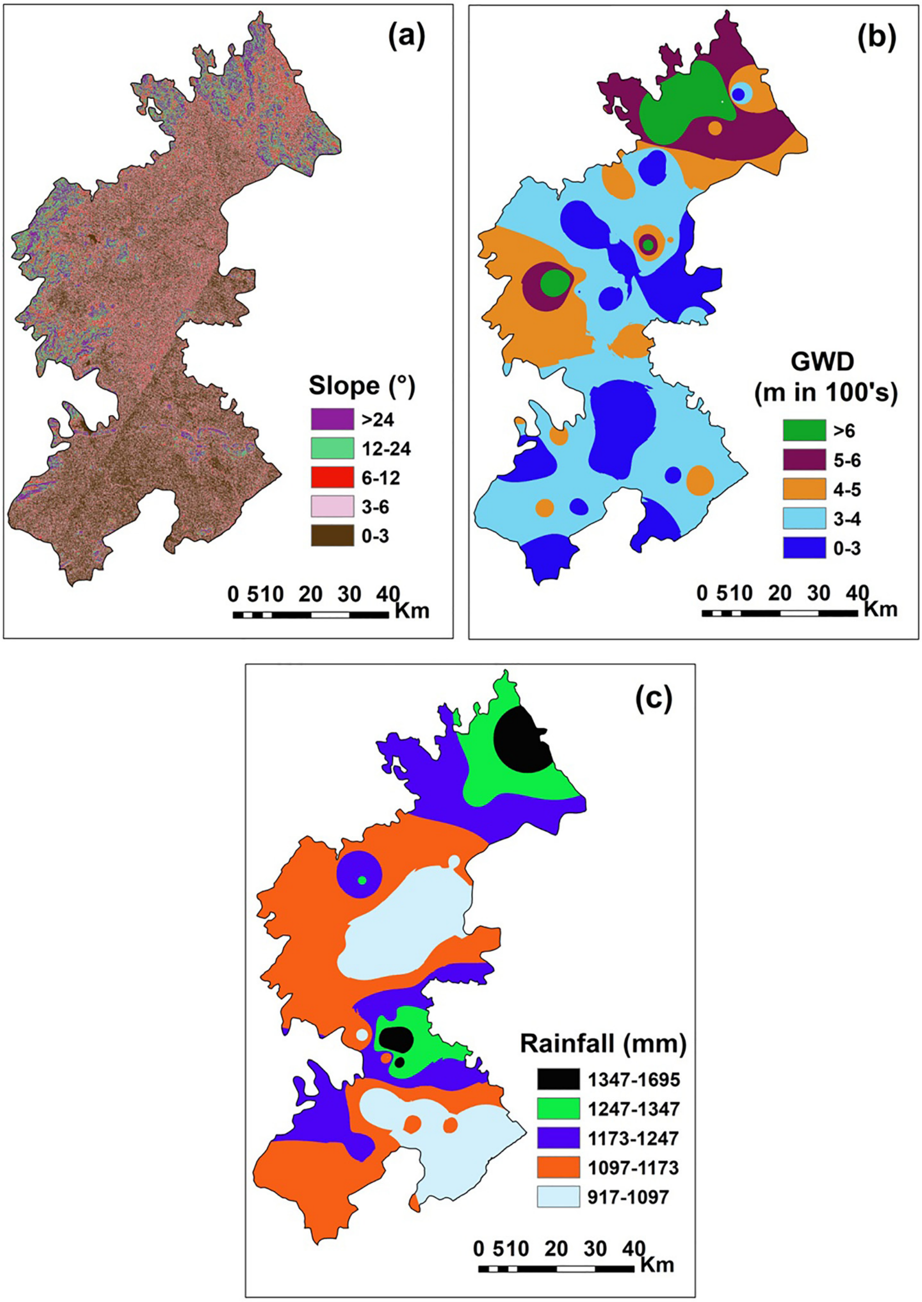


*Fig. 3.* Parameters used for AHP modelling. Slope (a), Ground water depth (b), Rainfall (c)

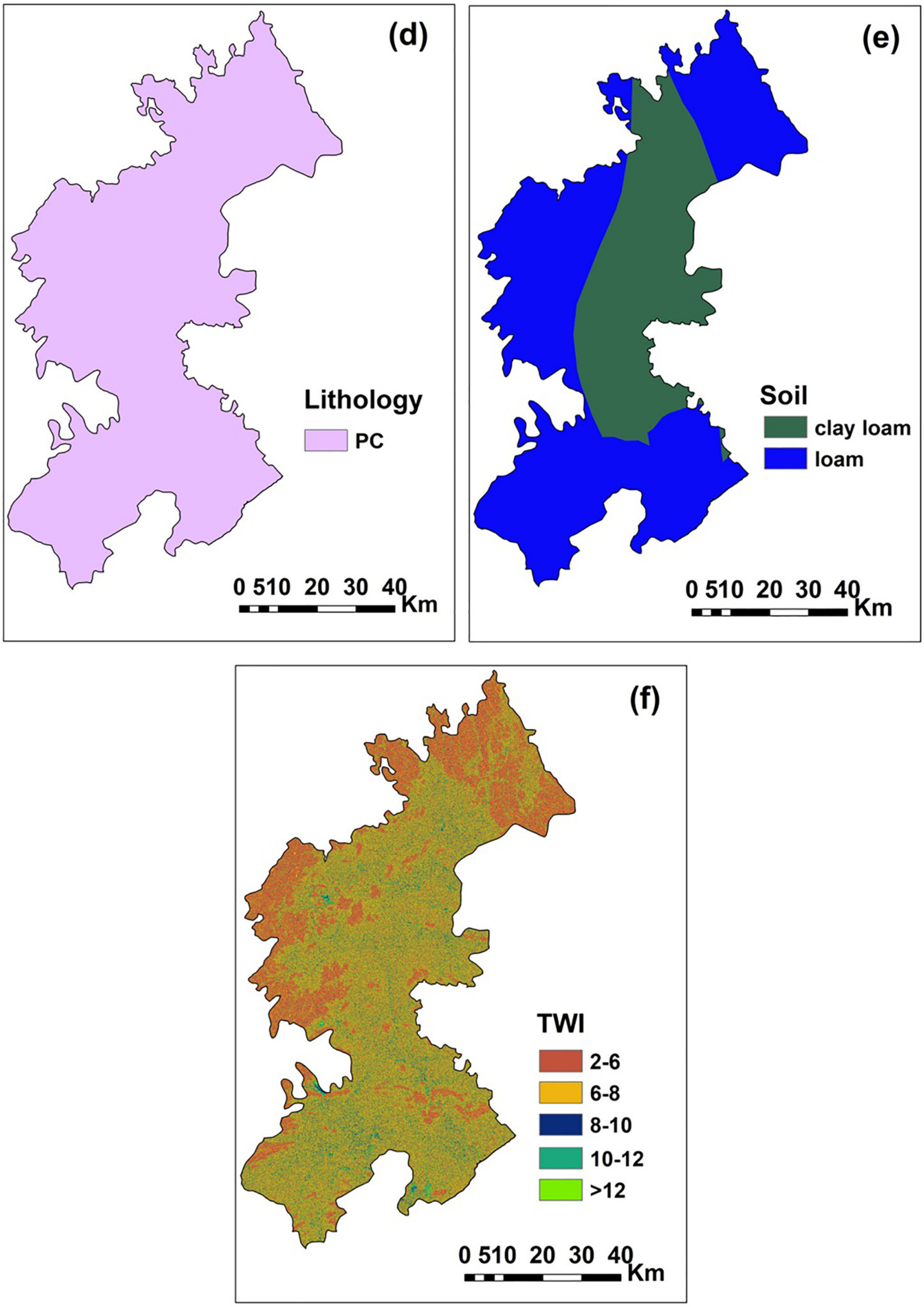


*Fig. 4.* Parameters used for AHP modelling. Lithology (d), Soil (e), TWI (f)

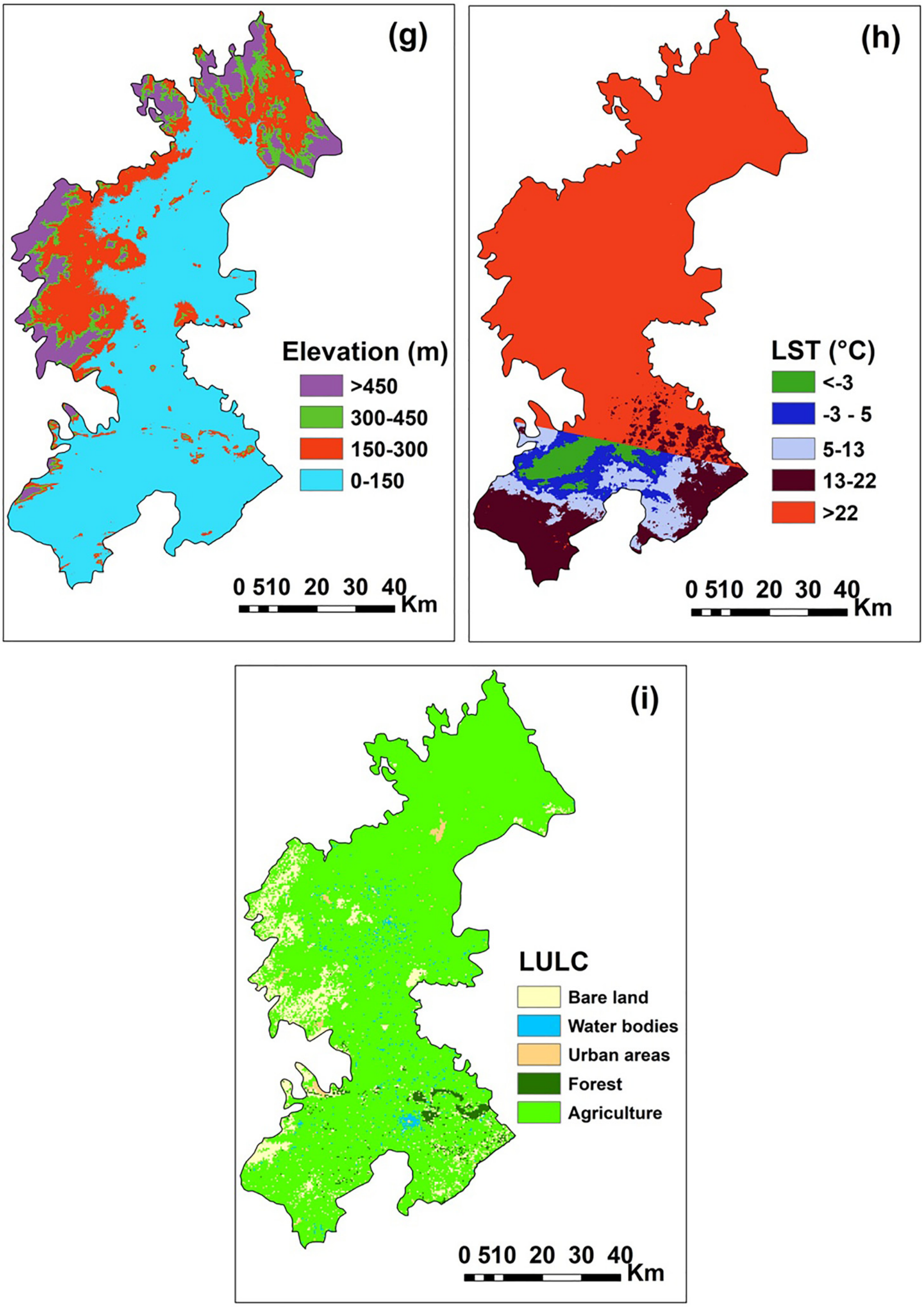


*Fig. 5.* Parameters used for AHP modelling. Elevation (g), LST (h), LULC (i)

The shuttle radar topography mission (SRTM) worldwide 1 arc-second resolution was used in this investigation (30 m) and Landsat 8 (30m) DEM (digital elevation model) data is acquired from USGS earth explorer using Vizianagaram District with a cloud cover of less than 10%, remaining data source is shown in Table 1. The raw DEM data is imported into ArcGIS 10.3 to create an elevation map of the research region. The spatial analysis tool was used to obtain the slope results. The map was built using the landsat8 with a resolution of 30m using supervised classification to obtain land-use/land-cover (LULC). The USGS provides the lithology shape file for South Asia, and the lithology map for the research region is generated using Arc-GIS 10.3's spatial analysis operation. The FAO-UNESCO World Soil Map is used to create the soil map. Groundwater depth is obtained from the Indian Water Resource Information System and interpolated in arc gis using IDW interpolation.

Preparing rainfall maps is critical for determining agricultural suitability regions. However, there are multiple processes involved in this procedure. The information was obtained from the APWRIMS website and then interpolated using IDW.

The Topographic Wetness Index (TWI) is a wetness distribution metric used to govern water flow across land. It is a standard measurement that examines the possibility of water gathering in certain regions. A high index value indicates that there may be a lot of water collected due to the low slope, and vice versa. The TWI of the research region was calculated using the SRTM DEM. Finally, using Eq. (1), the Topographic Wetness Index (TWI) is calculated:

$$\mathrm{TWI} = \mathrm{In}(\alpha/\tan \beta) \tag{1}$$

where α and β are the catchment area and slope.

The Land Surface Temperature (LST) is the temperature of the land surface's radiative skin recorded in the direction of the distant sensor. Temperatures are a combination of plants and bare soil. Because both respond quickly to changes in incoming solar radiation caused by cloud cover and aerosol load alterations, as well as diurnal fluctuation in illumination, the LST also exhibits fast variations. The LST, in turn, regulates the distribution of energy between the ground and plants. The LST for the study region was calculated using Landsat 8. Finally, using Eq. (2), the Land Surface Temperature (LST) is calculated:

$$\mathrm{LST} = \mathrm{BT}/(1 + (\lambda^{*}\mathrm{BT}/\mathrm{c2})^{*}\ln(\mathrm{E})) \tag{2}$$

where c2 = 14,388, Band 10 values are 10.8, BT = Atmosphere Brightness Temperature, and E = Land Surface Emissivity.

*Table 1.* Data source

| S.no | Parameters | Data description | Source | Resolution |
|---|---|---|---|---|
| 1 | LULC, LST | Landsat 8 | USGS Earth Explorer | 30 m |
| 2 | Elevation, Slope, TWI | SRTM DEM | USGS Earth Explorer | 30 m |
| 3 | Rainfall | Annual Rainfall data | APWRIMS | – |
| 4 | Soil Texture | Soil Shapefiles | Food and Agriculture Organization (FAO) | 1:500,000 |
| 5 | Lithology | Lithology | Geological Survey of India (GSI) | 1:500,000 |
| 6 | Groundwater | Groundwater depth | Indian Water Resource information system | – |

## Analytical Hierarchy Process (AHP)

AHP is a method for making multiple-criteria decision-making method for studying the crop-land suitability in the Vizianagaram district (Debesa et al., 2020; Saaty, 1990; Saha et al., 2021). AHP enables a logical and systematic evaluation of group decisions (Akıncı et al., 2013; Penki et al., 2022a). By modeling in a hierarchy, it allows the decision-maker to determine the relationship between criteria and sub-criteria (Penki et al., 2022a; Rao et al., 2018). The weights of the criteria that make up the hierarchy are calculated when the problem is built upon a hierarchical structure (Penki et al., 2022a; Ravinder and Ramu, 2020; Saha et al., 2021). To compare the criteria in one hierarchy level to the criteria in the next hierarchy level, a pairwise comparison matrix is built using the preference scale proposed by Saaty (1990). Hossen et al. (2021), Penki et al. (2022a, 2022b), Ravinder and Ramu (2020), Taghizadeh-Mehrjardi et al. (2020), Tashayo et al. (2020) defined the pairwise comparison matrix as n (n −1)/2 comparisons for n items.

Based on its importance to the other elements, each matrix component was assigned an arithmetic value between 1 and 9 (Penki et al., 2022a, 2022b; Saaty, 1990). The arithmetic value 1 indicates that both components are equally significant, but the arithmetic value 9 indicates that the corresponding column element is especially important, as seen in Table 2 (Bera et al., 2017; Penki et al., 2022a, 2022b; Rao et al., 2018).

A pairwise comparison matrix (Table 3) is built, and the consistency ratio (CR) for the specified parameters indicating crop-land suitability is determined. When the CR exceeds 0.1 (i.e., 10%), the judgments are likely to be too inconsistent. We can proceed with the AHP decision-making method if the consistency ratio (CR) is less than 0.1.

$$CR = CI/RI \tag{3}$$

where, CI is the Consistency index and RI is the Random index.

$$CI = (\lambda_{max} - n)/n - 1 \tag{4}$$

where n is number of factors and $\lambda_{max}$ is average value of the consistency vector.

Following the completion of the pairwise comparison matrix (Table 3), the criteria are normalised to produce the normalised matrix. Normalized values are calculated by dividing each column's value by the sum of the values in each column. Averaging all of the row's components yields later criterion weights. The computed value is then subjected to a consistency check to

*Table 2.* The pairwise comparison matrix's fundamental scale (Saaty, 1990)

| Definition | Intensity of importance |
|---|---|
| Extreme importance | 9 |
| Very strong to extreme importance | 8 |
| Very strong importance | 7 |
| Strong to very strong importance | 6 |
| Strong importance | 5 |
| Moderate to strong importance | 4 |
| Moderate importance | 3 |
| Equal to moderate importance | 2 |
| Equal importance | 1 |

*Table 3.* Pair-wise comparison matrix for crop-land suitability

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 2 | 2 | 5 | 6 | 7 | 4 | 2 | 3 |
| 2 | 0.5 | 1 | 3 | 3 | 4 | 5 | 3 | 3 | 3 |
| 3 | 0.5 | 0.33 | 1 | 5 | 4 | 6 | 3 | 2 | 3 |
| 4 | 0.2 | 0.33 | 0.2 | 1 | 1 | 3 | 1 | 0.25 | 0.33 |
| 5 | 0.17 | 0.25 | 0.25 | 1 | 1 | 3 | 1 | 0.25 | 0.17 |
| 6 | 0.14 | 0.2 | 0.17 | 0.33 | 0.33 | 1 | 0.25 | 0.17 | 0.2 |
| 7 | 0.25 | 0.33 | 0.33 | 1 | 1 | 4 | 1 | 0.33 | 0.2 |
| 8 | 0.5 | 0.33 | 0.5 | 4 | 4 | 6 | 3 | 1 | 2 |
| 9 | 0.33 | 0.33 | 0.33 | 3 | 6 | 5 | 5 | 0.5 | 1 |

*Note*: 1 = Soil, 2 = Slope, 3 = Elevation, 4 = Lithology, 5 = Land surface temperature, 6 = Topographic wetness index, 7 = Ground water depth, 8 = Rainfall, 9 = Land use land cover.

determine its validity. The ratio is calculated by dividing the weighted sum by the criteria weights, and the final crop-land suitability map has a CR of 0.05 (<0.1 valid).

## RESULTS AND DISCUSSION

The Crop-land Suitability in Vizianagaram district was generated utilizing the weight values of selected criteria determined from the Analytic Hierarchy Process and awarded scores of sub-criterion (Table 4). According to the Food and Agricultural Organization (FAO), crop-land suitability is categorized into four levels: 1. Very high suitable agricultural land, 2. High suitable agricultural land, 3. Moderately suitable agricultural land, and 4. Low suitable agricultural land as represented in Table 5. According to Table 4, soil texture is the most important element influencing agricultural land suitability, followed by slope, elevation, and rainfall in the research region.

This study demonstrated the potential for long-term agricultural land use in the study area. According to analysis of current agricultural land use in the Vizianagaram district, land is mostly not being used for what it is best suited for. However, if this trend continues, there will be some challenges in the district's future agricultural land use. As a result, there is a high demand for specific measures to improve soil fertility and protect agricultural lands and they are presented in (Figs 3–5).

### Different crop management techniques

Considering all the climatic factors and parameters we need different management techniques to increase agricultural productivity. In India, mostly the crops are cultivated based on the seasons rather than characteristics and factors. If there is land, it indicates that people are attempting to cultivate it, and some of them are failing due to a lack of management practices and a lack of knowledge on how and what to grow on low-suitable soils. In some crops, such as sunflower or rape, the soil is demolished and a fallow year is required. Plants grow better when they are planted in certain sequences. As an example, cabbage grows faster when legumes

*Table 4.* Crop-land suitability parameters and weighted subclasses of several categories

| Parameters | Sub-class | Rank | Parameter weight | Sub-class weight (%) |
|---|---|---|---|---|
| Slope | 0–3 | 1 | 0.211 | 47 |
| | 3–6 | 2 | | 29 |
| | 6–12 | 3 | | 14 |
| | 12–24 | 4 | | 7 |
| | >24 | 5 | | 3 |
| Elevation | 0–150 | 1 | 0.162 | 51 |
| | 150–300 | 2 | | 30 |
| | 300–450 | 3 | | 15 |
| | >450 | 4 | | 4 |
| TWI | 2–6 | 5 | 0.021 | 5 |
| | 6–8 | 4 | | 7 |
| | 8–10 | 1 | | 56 |
| | 10–12 | 2 | | 24 |
| | >12 | 3 | | 8 |
| LST | <–3 | 5 | 0.039 | 5 |
| | –3–5 | 4 | | 6 |
| | 5–13 | 2 | | 29 |
| | 13–22 | 1 | | 49 |
| | >22 | 3 | | 11 |
| LULC | agriculture | 1 | 0.111 | 57 |
| | bare land | 5 | | 4 |
| | forest | 2 | | 23 |
| | urban areas | 3 | | 10 |
| | water bodies | 4 | | 6 |
| Ground water | 0–3 | 1 | 0.047 | 42 |
| | 3–4 | 2 | | 30 |
| | 4–5 | 3 | | 16 |
| | 5–6 | 4 | | 8 |
| | >6 | 5 | | 4 |
| Lithology | undivided Precambrian rocks (PC) | 2 | 0.042 | 17 |
| | water (H2O) | 1 | | 83 |
| Rainfall | 917–1,097 | 1 | 0.125 | 46 |
| | 1,097–1,173 | 2 | | 24 |
| | 1,173–1,247 | 3 | | 17 |
| | 1,247–1,347 | 4 | | 8 |
| | 1,347–1,695 | 5 | | 5 |
| Soil texture | loam | 1 | 0.242 | 79 |
| | clay loam | 2 | | 13 |
| | clay | 3 | | 8 |

follow it. As it turned out, legumes release ammonium nitrogen into the soil by converting atmospheric nitrogen into ammonium nitrogen. In response to these observations, crop rotation or monocropping were considered as alternative types of cropping systems. Accordingly, the same species or different species are grown every year. In addition, intercropping, which

*Table 5.* Spatial distribution of crop-land suitability classes

| S No. | Crop-land suitability class | Range (%) | Area in hectare |
|---|---|---|---|
| 1 | Low suitability | 10.3–28.3 | 74,142.94 |
| 2 | Medium suitability | 28.3–35.6 | 197,824.75 |
| 3 | High suitability | 35.6–44.1 | 110,440.73 |
| 4 | Very high suitability | 44.1–55.2 | 181,973.25 |

involves sowing several mutually beneficial and 'friendly' crops at the same time on the same field, for instance, wheat, corn, and soybeans in six rows each is one option.

***Interplanting.*** It is a method of farming many crops at the same time. It is the most effective method for increasing the productivity of a growing area. Some crops complement one another well, whereas others not. This approach is not affected by the seasons.

***Plant more densely.*** The most basic method for increasing farm productivity is to plant crops close together. Planting density affects crop yield by regulating the integrated use of key input resources (such as radiation, water, and nutrients).

***Restoration of abandoned lands.*** The abandonment of agricultural lands is one of the most serious challenges confronting the agricultural and rural sectors. These changes in recent decades have had a variety of social, economic, and environmental consequences, and managing them has always been one of the most difficult challenges that policymakers and decision-makers have faced. A farmer in Banka District, Bihar, took the initiative to convert unsuitable cultivated land into cultivated land by constructing drip irrigation and rainfall collection structures, as well as pond, digging, and check dam construction. They grew mangos, lemon grass, and other plants on mostly red laterite soil, adding manure to the soil to encourage the growth of beneficial microbes, insects, and worms. Their consistent movement will loosen the soil particles, allowing it to become more fertile.

## Various wasteland reclamation practices

***Leaching and land development.*** To reclaim the salt-affected soil, the salts must be removed from the root-zone, which is usually accomplished by leaching, or applying an excessive amount of water to push the salts down. Land levelling is done after a survey of the extent of the salinity problem, soil texture, depth of impermeable layer, and water table to facilitate efficient and uniform water application. After levelling and ploughing, the field is divided into small plots and leached. Continuous leaching requires 0.5–1.0 cm of water to remove 90% of soluble salts from each cm of soil, depending on texture. Intermittent sprinkling with 25 cm water reduces salinity in the upper 60 cm layer by about 90%.

***Irrigation practices.*** Surface irrigation, along with precise land levelling, smoothening, and efficient hydraulic design, aids in the reduction of water logging and salinity. Water availability in the upper root zone can be improved by frequent irrigation with a controlled amount of water. When the irrigation water is saline, thin and frequent irrigations have been found to be more beneficial for crop yield than heavy irrigation.

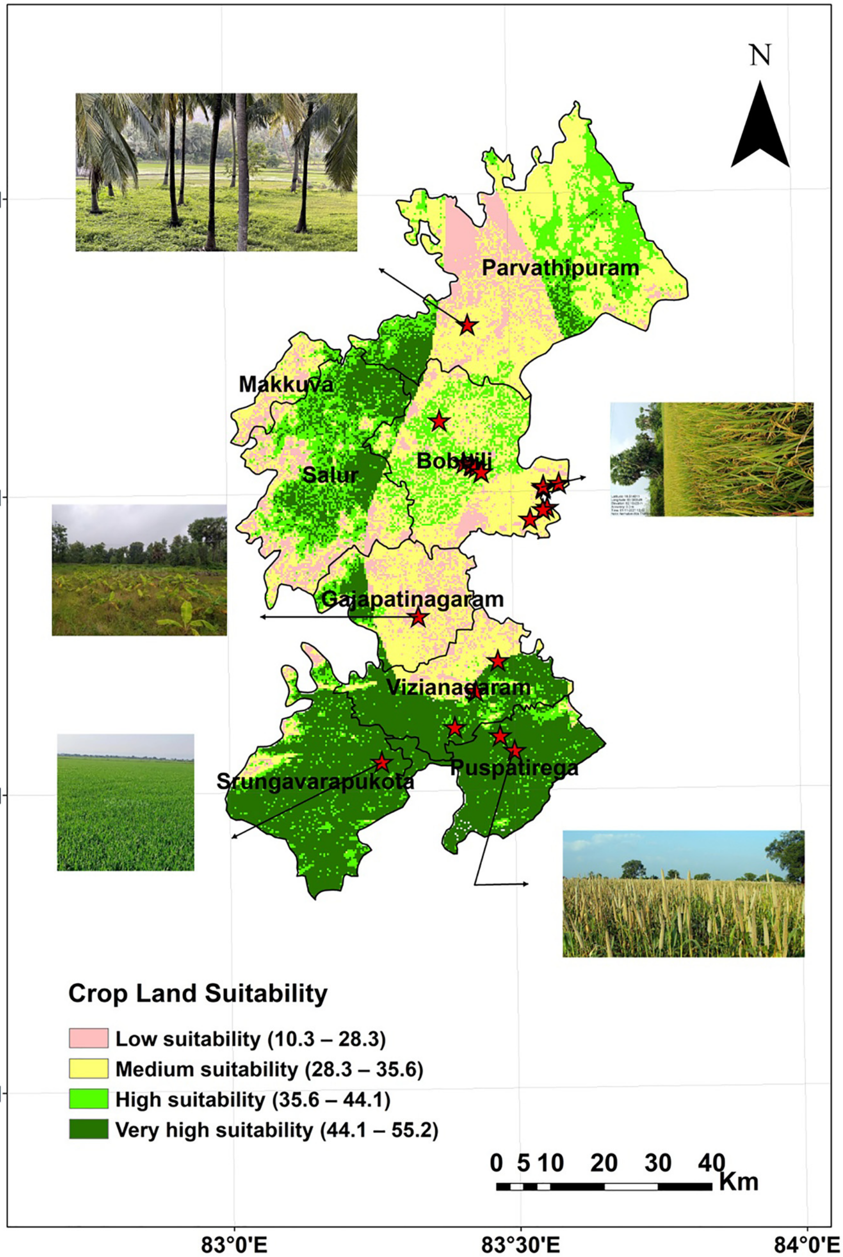


*Fig. 6.* Crop Land Suitability mapping of the study area

***Social forestry schemes.*** These initiatives primarily involve strip plantation along roads, rail lines, and canals, rehabilitation of degraded forest lands, farm-forestry, and waste-land forest development, among other things.

***Gypsum amendment.*** Sodic soils should be amended with gypsum to reduce sodicity because calcium in gypsum replaces sodium at exchangeable sites.

***Crop rotation and selection of tolerant crops.*** There are different levels of salt tolerance among crops, ranging from highly tolerant to sensitive. Even at high salinity with an electrical conductivity level of 10 dS $m^{-1}$, barley, sugar beet, and date palm have no yield loss. In addition to wheat, sorghum, pearl millet, soyabean, mustard, and coconut, there are several crops that are salt-tolerant. Many plants such as rice, millets, maize, pulses, sunflower, sugarcane, and bottle gourd, as well as vegetables like brinjal and bottle gourd, are semi-tolerant. There are a variety of combinations of crops that are suitable for saline soils.

## VALIDATION DISCUSSION

The validation is done by identifying the various crops, as seen in Fig. 6. Using GPS and other tools, a total of 34 crop samples were collected from various locations. The validation shows that the crops and mapped zones have a good correlation. The Crop Land Suitability Map, however, showed that areas like Srungavarapu Kota, Pusapatirega, and the southernmost part of Vizanagaram are very highly suitable. Rice, groundnuts, mesta, sugarcane, cotton, maize, ragi, bajra, and pulses are the main crops grown in the district during the Rabi season as agriculture is a significant economic activity (Akıncı et al., 2013). Due to erratic rainfall, the district's average yield is low. As 68.4% of the labour force in this district works in agriculture, it is primarily an agricultural district. One of the main focuses of the district's overall development is horticulture, and post-harvest management is encouraged in sustainable horticulture development in order to increase area and productivity. Growing mangoes, cashews, oil palms, and vegetables are all viable options. At specific locations in the district, the promotion of the necessary arrangements for safe production (polyhouses/shade nets) under safe cultivation is also ongoing.

## CONCLUSIONS

This work intends to provide a basic framework for identifying suitable lands for sustainable farming techniques. In this context, a GIS and AHP-based Land Suitability Analysis methodology were used to determine Vizianagaram's suitability for agricultural production. In the study, the crop land suitability index is 55.2%, with 86.86% of lands deemed suitable for agricultural use to varying degrees. But only 32.24% of the study area was covered by highly suitable lands. These lands should only be used for agriculture, but urbanization is the most pressing issue in these areas. Farmers and other stakeholders should pay closer attention to these lands. Erosion in these areas will be exacerbated by improper land use. With GIS and AHP combined, decision-makers could develop a high-quality database and guide map for evaluating cropland substitution in order to achieve adequate agricultural production. With this information, future crop planning and decision making for agricultural production can be based on soil and climatic conditions similar to these. While various land appraisal methodologies consider all factors to be equal, AHP assigns varying weight values. During the weighing process, expert opinions and recommendations are crucial. In addition to helping decision-makers develop plans and regulations for production, the results of the study will also help product support and marketing initiatives.

A significant agricultural potential exists in the target zone, based on the analysis presented. In order to increase food production, highly and moderately suitable regions can be cultivated, and marginally and unsuitable regions can be replaced with crops that are more suitable to them. It is expected that agriculturalists will be able to use the maps to make better decisions about cropping patterns based on high, moderate, low, and unsuitable regions.

## FUTURE SCOPE

The inclusion of socio-economic factor, resiliency index, public opinions into the frame work can result in more robust crop land suitability map for operational purpose.

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