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GIS-based land suitability evaluation for pigeonpea cultivation in Ganjam district, Odisha

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Abstract

Pigeonpea (*Cajanus cajan*) plays a pivotal role in nutritional security and sustainable agricultural systems in Odisha. The present study assesses the land suitability for pigeonpea cultivation in the Ganjam district of Odisha. In this study GIS based multi-criteria evaluation approach ^[1, 2] was adopted integrating the spatial data as per the guidelines of the National Bureau of Soil Survey and Land Use Planning. The process involved matching of specific land quality parameters viz. soil texture, pH, and drainage along with the bio-physical requirements of the pigeonpea crop. From the analysis, it was revealed that highly suitable (S1) areas are primarily concentrated in talukas of Aska, Chikiti, Digapahandi, Ganjam, Hinjicut, Kukudakhandi, and Sorada. These regions have ideal environmental conditions required to obtain maximum yield and to support the physiological requirements of pigeonpea crop. This study helps in providing a scientific roadmap for local farmers and policymakers to optimize land-use efficiency by the identification of these favorable landscapes. These findings have a data driven strategy for enhancing the pulse productivity and improving the livelihoods status of the farming community ensuring long-term ecological health of the Ganjam district.

Keywords: Land suitability, GIS, pigeonpea, Ganjam district, multi-criteria evaluation, NBSS and LUP

Introduction

Land suitability evaluation is an important step in sustainable land use planning. It helps in identifying the environmental limitations of a particular area. The process mainly assesses the suitability of land for crop production. Land evaluation is considered as an important resource assessment tool. It helps in understanding the capability of land for different agricultural uses. The evaluation includes collection and analysis of information related to soil, climate, topography, and other land characteristics. This information is used to identify and compare suitable land use options. Based on the suitability of different land units, appropriate cropping patterns can be recommended. Existing cropping systems and the socio-economic conditions of farmers are also considered during this process ^[3]. Therefore, land evaluation plays a key role in the efficient and sustainable use of agricultural land. Therefore, soil surveys and land evaluations facilitate improved land use planning and management by recognizing the inherent potentials and limitations of biophysical factors in the region ^[4]. Consequently, the inventory of land resources necessary for farm-level planning is one that examines all the parameters critical to productivity, such as soils, site characteristics including slope, erosion, gravel content, and stoniness, as well as climate, water availability, topography, geology, hydrology, vegetation, crops, land use patterns, animal populations, socio-economic conditions, infrastructure, marketing facilities, and various government schemes and developmental projects. This inventory can be utilized for land use planning and development ^[5]. In the current century, to guide agricultural advancements towards the goal of an 'evergreen revolution,' it is essential to integrate standard information with cutting-edge technologies. Information and communication technology, remote sensing technology, and geographical information systems (GIS) are the tools of these advanced technologies that will aid in creating agricultural management systems, designing sustainable agriculture, and transforming new areas (through the development of wastelands) into productive agricultural land.

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The functions of remote sensing and GIS in agricultural applications can be broadly divided into two categories: inventorying/mapping and management. Sustainable agricultural land use can be achieved through the integration of remote sensing and GIS data, which supports the assessment of land capability, land productivity, soil suitability, terrain characteristics, and socio-economic factors, among others [6]. The programs for this area focus on developing effective soil and water conservation strategies, enhancing the productivity of current crops, diversifying crops with horticultural varieties, rehabilitating wastelands through the introduction of multi-purpose forestry species, and improving livelihood prospects for landless individuals. In this study, a land suitability assessment within this area has been conducted through a detailed analysis of land suitability indicators. An integrated land suitability potential (LSP) index was calculated by considering the contributions of various land suitability parameters. The area was classified into categories of highly suitable, moderately suitable, marginally suitable and not suitable based on logical criteria. These classifications were developed by integrating multiple layers with corresponding weights within a geographical information system (GIS). For this study, the land use suitability classification was executed by merging actual soil-land data with land evaluation for crop planning at the landscape level within the area. The objectives of the present study are: (i) to characterize and classify soils, followed by mapping for land evaluation, and (ii) to integrate soil-land information within a GIS environment to assess their suitability for locally adopted crops aimed at crop development. The research highlighted that, taking into account the soil

properties and terrain characteristics while analyzing the current land use, the spatially distributed agricultural potential zones can be classified within the area.

Objective

The goals of the current research are: (i) to identify and categorize soils, subsequently creating maps for land assessment, and (ii) to incorporate soil-land data within a GIS framework to evaluate their appropriateness for regionally selected crops intended for agricultural advancement.

Methodology

The Food and Agriculture Organization (FAO) has developed a classification system for land suitability, and the guidelines established by NBSS & LUP (1990) [7] have been designed for the land suitability model. This study utilizes the guidelines from both entities. The land suitability model highlights various factors, including climatic conditions, the physical and chemical characteristics of the soil, soil drainage, soil depth, soil texture, and slope. The Ganjam district is categorized into three land suitability classes [8] based on rainfall, temperature, and elevation. Ratings S1 (highly suitable), S2 (moderately suitable), and S3 (marginally suitable) are assigned based on the evaluation of each parameter. Field survey and laboratory analysis had also been done.

Study Area

The Ganjam district is situated between 84.7° E and 85.12° E longitude, as well as between 19.4° N and 20.17° N latitude (Fig.1).



(Source: GIS Division Bhubaneswar)

Fig 1: Location map of Ganjam district

Land Suitability Analysis

Table 1: Type of land suitability in Ganjam district for pigeonpea crop in 2025

Order	Area in ha (% total gradient amplitude)
S1 (Highly Suitable)	212338 (52.3%)
S2 (Moderately Suitable)	151032 (37.2%)
S3 (Marginally Suitable)	42630 (10.5%)

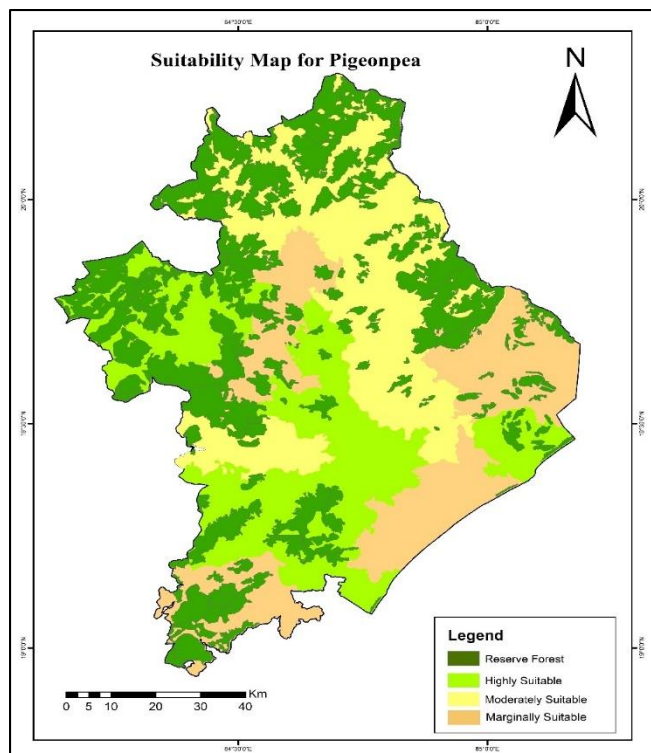


Fig 2: Land suitability for pigeonpea crop in Ganjam district

Highly Suitable (S1)

Pigeonpea can be cultivated year-round as it thrives in warm climates. The optimal temperature range for its growth is between 25 °C and 34 °C, with the most ideal conditions occurring between 31 °C and 34 °C. The distribution of rainfall during the growing season is more critical than the total precipitation amount, with an annual rainfall of 850 mm to 1250 mm being most advantageous for its growth. Pigeonpea prefers well-drained soils, as it cannot tolerate waterlogged conditions. Soils with textures such as loamy, silt loam, clay, silt clay, and sandy clay are particularly suitable, with a pH range of 6.0 to 7.8 and an electrical conductivity of less than 0-3 dS/m. Additionally, a soil depth exceeding 125 cm and a slope ranging from 0 to 3 percent are optimal for pigeonpea cultivation. According to Table 1, 52.3% of the study area, which is equivalent to 212338 hectares, is classified as highly suitable for pigeonpea cultivation (Fig. 2).

Moderately suitable (S2)

The characteristics of land that is moderately suitable for pigeonpea cultivation include a mean temperature range of 35 °C to 37 °C and 21 °C to 24 °C, as well as annual rainfall that varies from 650 to 850 mm and from 1250 mm to 1500 mm. The soil drainage is classified as moderately well-

drained or imperfectly drained, which is considered moderately suitable. Additionally, the soil pH ranges from 5.5 to 5.9 and from 7.9 to 8.4, while the electrical conductivity (EC) of the soil falls between 3.0 and 5.0, indicating moderate suitability. A soil depth of 75 cm to 100 cm and a slope of 3 to 5 percent are regarded as moderately suitable for pigeonpea cultivation. These observations have been recorded in specific regions. Table 1 presents the area identified as moderately suitable for pigeonpea cultivation in the study area, covering 1,51,032 ha and representing 37.2% of the total geographical area (Fig. 2).

Marginally Suitable (S3)

Land characteristics classified as marginally suitable for pigeonpea cultivation showed certain limitations in climate and soil conditions. Mean temperature in these areas ranged from 38-40 °C and 18-20 °C. Annual rainfall varied from 550-650 mm, while in some locations it exceeded 1500mm. Poorly drained and somewhat poorly drained soils were also grouped under the marginal suitability class. Soil pH ranging from 5.0-5.4 and 8.5-8.9 indicated less favourable conditions for pigeonpea cultivation. Similarly, soil electrical conductivity (EC) between 5.0 and 8.0 dS m⁻¹ was considered marginally suitable. Soil depth of 50-75 cm and slope between 5-10% also imposed certain constraints on crop performance. These conditions were observed in specific pockets of the study area. Table 1 shows that the marginally suitable area for pigeonpea cultivation covered 42,630 ha, accounting for 10.5% of the total study area (Fig. 2).

Conclusion

Geographic Information Systems (GIS) provide accuracy in land use planning. They also offer flexibility in land resource analysis. Therefore, many researchers [9-14] have highlighted the importance of GIS in land suitability studies. In the present study, highly suitable (S1) areas for pigeonpea cultivation were identified in several taluks of Ganjam district. These included Aska, Chikiti, Digapahandi, Ganjam, Hinjlicut, Kukudakhandi, and Sorada. These taluks provided favourable conditions for pigeonpea cultivation. The S1 suitability class covered 52.3% of the study area [15].

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Appendix No 1: Soil-Site suitability criteria (crop requirements) for Pigeonpea

Soil-Site Characteristics	Unit	Highly Suitable S1	Moderately Suitable S2	Marginally Suitable S3	Not Suitable N
Mean temperature in growing season	°C	25-28 31-34	35-37 21-24	38-40 18-20	>40
Total rainfall	mm	850-1000 1000-1250	650-850 1250-1500	550-650 >1500	<450
Soil drainage	Class	Well/SW Excessive	Mod. Well Imperfect	SW Poor/Poor	Not drainable
Texture	Class	l, sil, cl, silcl, scl	sic, sl, sc	Ls, vfs, c (<60%v)	Cs, skeletal
pH	1:2.5	6.0-6.5 6.6-7.8	5.5-5.9 7.9-8.4	5.0-5.4 8.5-8.9	<4.5 >9.5
Effective soil depth	cm	100-125 >125	75-100	50-75	<25
Salinity (EC saturation extract)	ds/m	0-3	3-5	5-8	>10
Slope	%	0-3	3-5	5-10	>15

Source: NBSS & LUP