LAND SUITABILITY FOR ORGANIC AGRICULTURE ANALYSIS USING GIS AND REMOTE SENSING IN MANDYA TALUK OF MANDYA DISTRICT, KARNATAKA

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ABSTRACT

This research assesses land suitable for organic farming in Mandya Taluk through a combined method involving Geographic Information System (GIS), Remote Sensing (RS), and Multi-Criteria Decision Analysis (MCDA). Essential soil, climatic, and topographic factors such as soil moisture, organic carbon content, texture, actual evapotranspiration, rainfall variability, temperature, drought intensity, and terrain roughness were examined and prioritized through the Analytic Hierarchy Process (AHP). The standardized thematic layers were integrated using Weighted Overlay Analysis to create a map for organic farming suitability. The findings categorized the study region into three suitability zones: highly suitable (13.28%), moderately suitable (15.62%), and low suitable (71.10%). Particularly suitable areas are primarily found in the southern sections of Mandya Taluk, marked by beneficial soil qualities, sufficient moisture levels, gentle landscapes, and appropriate climate conditions. The research shows that GIS-based MCDA is an effective decision support tool for pinpointing potential zones for sustainable organic farming and offers useful information for planners and policymakers to encourage environmentally responsible landuse approaches.

Keywords: Organic farming, GIS, AHP, Multi-criteria decision analysis, Mandya.

INTRODUCTION

A significant challenge for ecological intensification in agroecosystems is generating greater quantities of food and feed while minimizing greenhouse gas (GHG) emissions, soil erosion, biodiversity decline, and leaching. The negative ecological impacts of traditional agroecosystems have heightened the need for more sustainable production methods. Organic farming is recognized as a potential approach to enhance sustainability in these systems. Organic farming is a production method that avoids agrochemicals, such as insecticides or pesticides, and employs plants that are not genetically altered. it indicate that organic farming can enhance ecological mechanisms that promote plant nourishment while preserving soil and water resources.

As stated by the International Federation of Organic Agriculture Movements (IFOAM International Federation of Organic Agriculture Movements, Citation2004), organic agriculture represents a farming system that encourages environmentally friendly, socially responsible, and economically viable food and fiber production, while prohibiting the application of synthetic fertilizers, pesticides, growth enhancers, animal feed additives, and genetically engineered organisms. IFOAM outlines the four principles of organic farming as ecology, health, fairness, and care

The aims, regulations, and guidelines of organic farming are explicitly outlined by the European Commission. According to the European Commission, there are three regulations:

(1) banning synthetic fertilisers, synthetic herbicides and pesticides, (2) mandating the use of only organically produced seeding and propagating materials, and (3) necessitating the implementation of diverse crop rotations.

Organic farming began as a reaction to an increasing recognition that the well-being of the soil is tied to the well-being and future of humanity. This system is currently implemented in nearly every nation globally, and the area of certified organic land is also increasing. Organic farming systems demonstrated reduced surface runoff and increased water infiltration capacity compared to conventional agriculture systems. Consequently, the shift from traditional to organic agriculture led to increased infiltration and decreased surface runoff, which is an advantage of sustainable organic farming practices to mitigate flood and erosion risks. This indicated that profitability, economic and financial factors, environmental and health safety issues, alongside ideological and philosophical reasons, were significant in transitioning from conventional to organic systems. Numerous research works have explored the potential of organic agriculture to improve biodiversity on farmland, with findings differing primarily due to the influence of the landscape.

Determining appropriate locations for organic agriculture necessitates evaluating various factors, including climatic conditions, soil properties, socio-economic aspects, water availability, topography, and topological and geophysical elements. Multi-Criteria Decision Analysis (MCDA) utilizing Geographic Information System (GIS) and Remote Sensing (RS) methods is employed as a decision-making mechanism to identify optimal locations for organic farming. The analytic hierarchy process (AHP), utilized as an MCDA method, has been implemented to address various issues that entail intricate criteria at different levels, where interaction among criteria is frequently observed. GIS-based MCDA is commonly applied in analyses of land suitability. For instance, determined that remote sensing and GIS can significantly aid in pinpointing appropriate areas for the advancement of organic farming in the Uttarakhand region, India. In separate research, a land assessment model for rainfed agriculture employing GIS and MCDA in Golestan Province, Iran. In related studies conducted in China, a thorough assessment of tobacco cultivation suitability was performed using fuzzy and hierarchical analysis methodologies, along with GIS techniques in the Henan area. A web-based framework was created by integrating various data from multiple sources for a multi-criteria agricultural land suitability assessment using the Google Earth Engine platform. In Iran, a land suitability model for faba bean cultivation through spatial multi-criteria analysis

examined soil fertility for Tulaipanji rice farming in Kaliyaganj, India, employing AHP and machine learning techniques. Findings indicated that 18.01% of the land was in optimal health to facilitate Tulaipanji cultivation. In a different study, a GIS-based AHP model was used to determine appropriate locations for agricultural activities in the Anabranching area of the Sooin River, India. In 2017, organic farming systems encompassed 50.9 million hectares globally, accounting for approximately 1.1% of total agricultural land across 179 nations. The organic farming system has not significantly developed in Iran. As per the FAO statistical report, organic farming in Iran spanned 18,000 hectares in 2016. This paper presents a model designed to pinpoint appropriate areas in Mandya taluk of Mandya district for organic agriculture development. A key region for agricultural production in Mandya taluk is the Cauvery River.

Study area

The Mandya Taluk is located between North latitudes 12o 44' 42.6" to 12o 25' 50.7" and East longitudes 76o 42' 05.6" to 77o 0' 22.9,". The Taluk has a total land area of 705 km². The taluk is made up of 175 villages spread within the Mandya metropolis and one town. Mandya taluk has thin, gravelly soils with a marram zone, a layer of weathered rock beneath them. The soils lack bases and are heavily leached. With temperatures between 160 and 350 degrees Celsius, the taluk has a subtropical climate. The hottest month is April, and the temperature significantly decreases in June when the southwest monsoon arrives. The coldest month is December. Except for the western sector, where it is somewhat greater, the district's rainfall is consistent.

Methodology:

The methodology uses a GIS-based multi-criteria approach to evaluate land suitability by integrating soil, topographic, and climatic statistics. Soil grid databases were used to determine soil parameters such as clay content, sand, soil moisture, soil organic carbon, and coarse fragments. The Topographic Ruggedness Index (TRI), which was taken from SRTM-DEM data, was used to depict the topographic effect. The Terra Climate database was used to gather climate data, including mean annual temperature, real evapotranspiration, post-monsoon conditions, summer and winter rainfall, and drought severity.

The Analytic Hierarchy Process (AHP) was used to standardize and weight each thematic layer in order to measure its relative significance. The final land suitability map was created by integrating the weighted layers using GIS overlay analysis, making it possible to identify the region's best suited for the Organic agriculture in Mandya taluk.

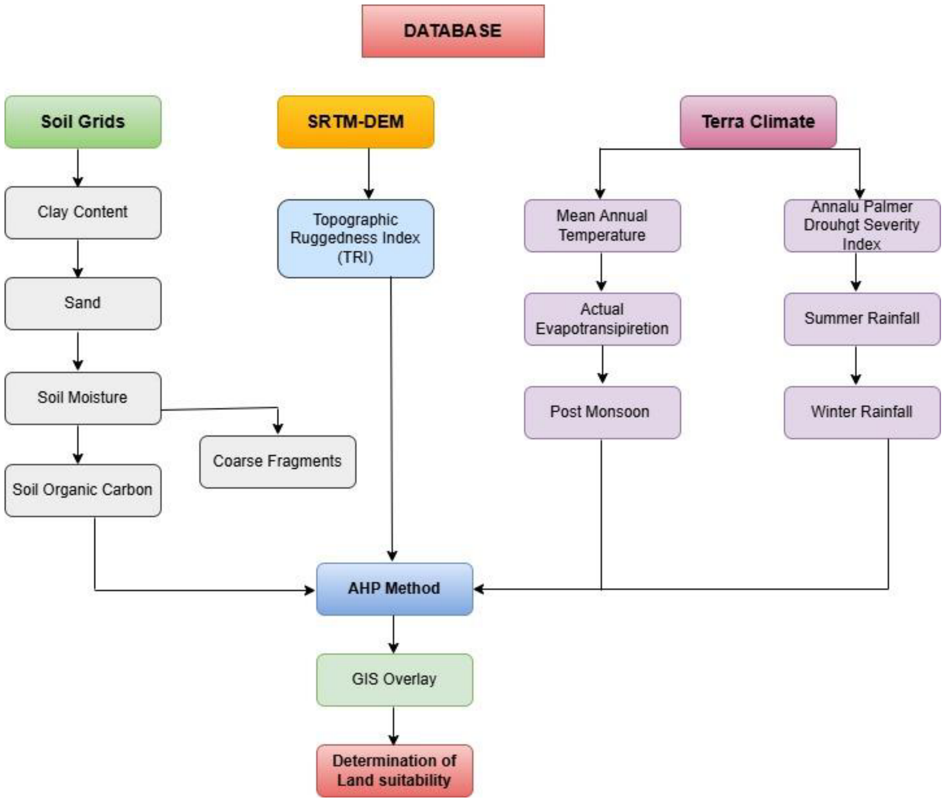


Figure 1: flow chart developed for organic agriculture suitability

Spatial indicators and data used

1. Actual Evapotranspiration (AET)

The AET map illustrates the geographic differences in water loss due to evaporation and plant transpiration. Regions with elevated AET values suggest improved soil moisture availability, enhanced vegetation cover, and greater irrigation effects, while areas with reduced AET signify arid conditions, moisture deficits, and limited vegetation. This pattern emphasizes the reliance of evapotranspiration on rainfall patterns, soil characteristics, and land management, establishing AET as an important measure of agricultural water needs and drought susceptibility.

2. Clay Content

The map of clay content shows how fine soil particles are spread throughout the area. Regions with high clay levels show better water retention but can experience drainage issues, whereas areas with low clay are linked to sandy or loamy soils offering improved drainage but less moisture retention. This geographical variation greatly affects crop adaptability, irrigation effectiveness, and soil fertility strategies.

3. Coarse Fragments

The coarse fragments map shows the percentage of gravel, stones, and rock pieces within the soil. Areas with significant coarse fragment content typically exhibit shallow effective soil depth and diminished water retention, rendering them less ideal for intensive farming. In contrast, regions with minimal coarse fragments enhance root penetration and moisture availability, promoting crop growth. This map is essential for grasping soil constraints and land potential.

4. Palmer Drought Severity Index (PDSI)

The PDSI map shows the intensity and geographical reach of drought situations. Negative values signify moderate to severe drought, whereas positive values represent wet conditions. The map distinctly marks areas susceptible to drought, typically aligning with low precipitation, elevated evapotranspiration, and inadequate soil moisture levels. This index is extremely valuable for assessing climate impact, monitoring drought conditions, and planning for agriculture.

5. Post-Monsoon Rainfall

The map of post-monsoon rainfall shows the spread of rainfall collected following the southwest monsoon period. Regions experiencing increased post-monsoon rainfall enjoy prolonged soil moisture, aiding in rabi crop growth and groundwater replenishment. Areas experiencing low rainfall after the monsoon face moisture stress, leading to a greater reliance on irrigation. This geographic variability is crucial for making cropping choices and developing climate resilience approaches.

6. Sand Content

The sand content map illustrates the geographical spread of coarse soil particles throughout the study region. Areas with elevated sand composition demonstrate significant permeability and quick drainage, leading to reduced water retention and increased moisture stress, particularly in arid times. Regions with low sand concentration typically possess finer-textured soils that hold moisture for extended periods, rendering them more suitable for continuous agricultural practices.

7. Soil Organic Carbon (SOC)

The SOC map illustrates the spatial differences in organic matter levels in soils, serving as an essential measure of soil fertility and health. Regions with elevated SOC levels signify greater nutrient accessibility, better soil structure, and increased moisture retention, fostering enhanced crop yield. Conversely, areas with low SOC indicate degraded soils, frequently associated with intensive farming, erosion, or minimal biomass input, underscoring the importance of soil conservation and organic matter management.

8. Soil Moisture

The soil moisture map depicts the presence of water in the soil layers at a specific moment. Areas with elevated soil moisture typically correlate with increased precipitation, beneficial soil texture, and irrigation effects, which promote crop development and lessen drought impact. Regions with low soil moisture signify water shortage and susceptibility to drought, especially impacting rainfed farming. This map is essential for comprehending crop stress situations and planning irrigation.

9. Terrain Ruggedness Index

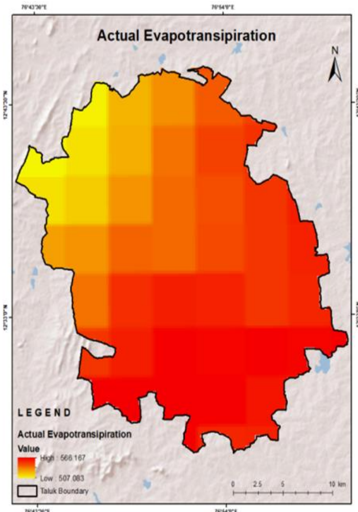
The Terrain Ruggedness Index (TRI) map shows distinct variations in topographic complexity and surface roughness. The steep, undulating, and structurally complicated terrain seen in areas with high TRI values may limit agricultural growth but promote biodiversity and forest cover. Low TRI zones, on the other hand, are plains and gently sloping regions that are better suited for infrastructure development, agriculture, and settlement. Variations in soil depth, erosion susceptibility, and accessibility throughout the area are explained by the TRI pattern.

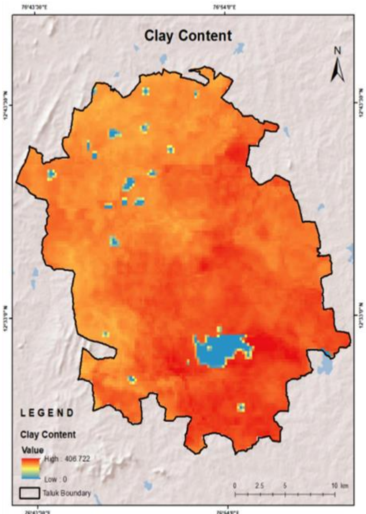
10. Winter season

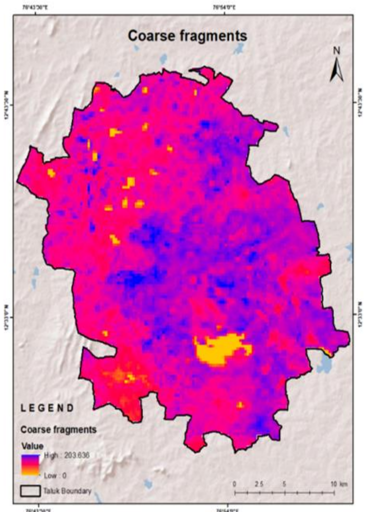
The map of the winter season shows how the weather is distributed geographically during this time. Elevated and hilly areas tend to have colder winters, whilst plains experience comparatively warmer winters. Cropping schedules, crop stress levels, and irrigation needs are all impacted by these seasonal changes, especially for rabi crops. The winter pattern also reflects the combined effects of altitude, terrain, and regional climatic controls.

11. Temperature

The region's temperature chart exhibits discernible geographic fluctuation. Higher temperature zones are largely concentrated in the relatively low-lying and plain areas, indicating greater heat accumulation due to lower elevation and reduced vegetation cover. On the other hand, higher or forested areas exhibit moderate to lower temperatures, indicating the role of altitude, topography, and land cover in controlling surface temperature. This variation has direct implications for crop suitability, evapotranspiration, and water demand.







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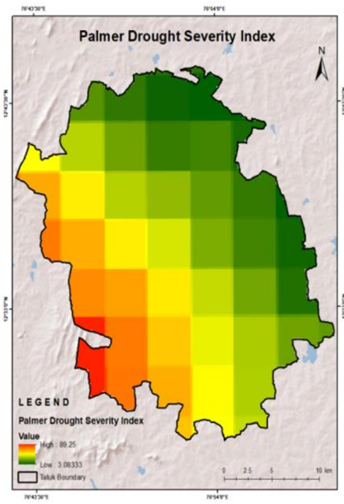

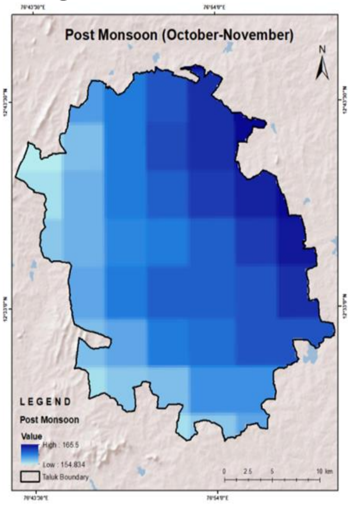

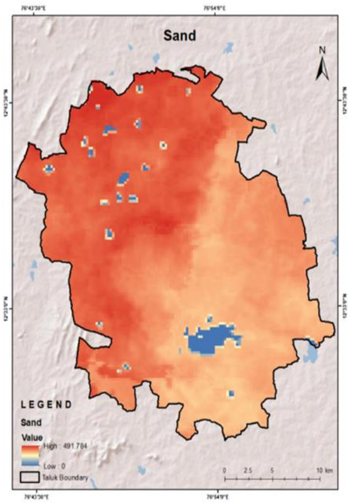

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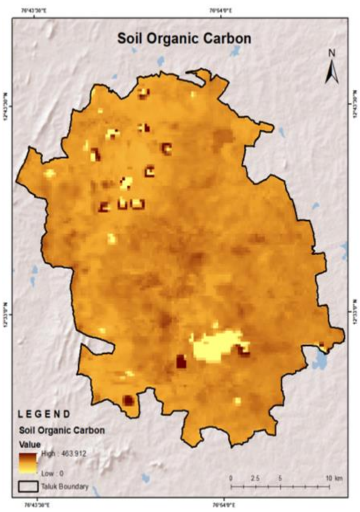

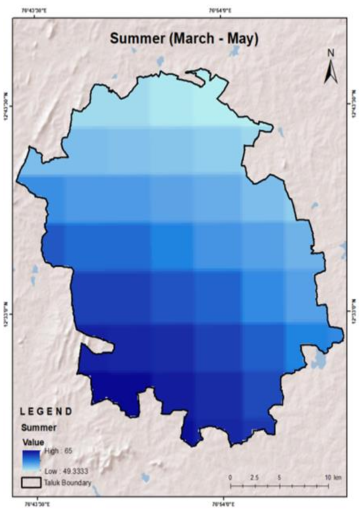

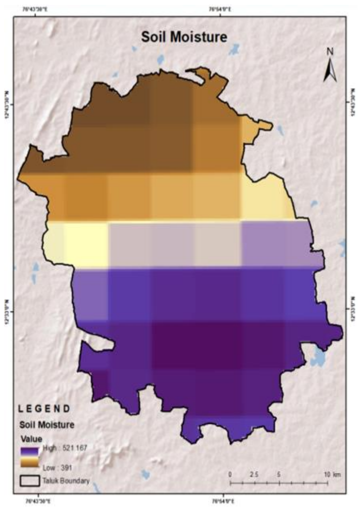

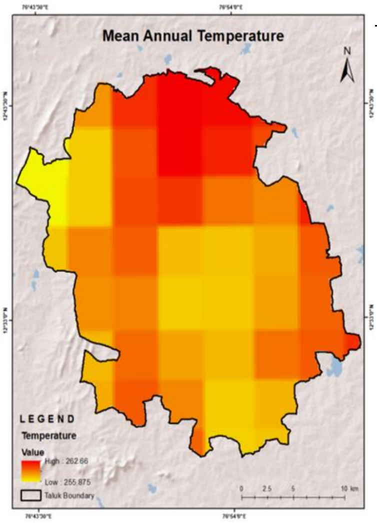

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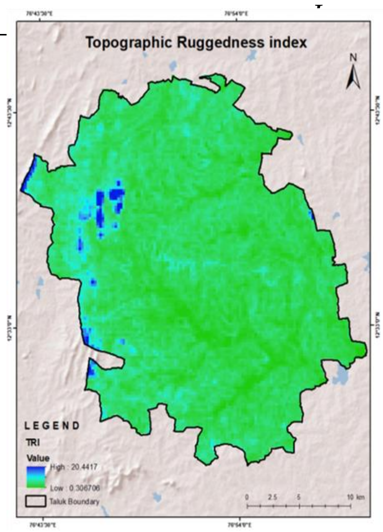

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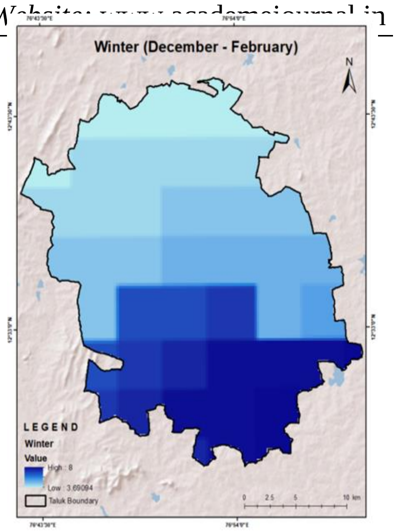

Figure.13

Standardization of layers

After data collection and preparation of thematic layers, all spatial indicators were converted into raster format with a spatial resolution of 30 m using the ArcGIS 7.1.1 platform. The land use/land cover map of Mandya taluk was utilized to delineate and exclude non-planting areas from the analysis. Subsequently, raster layers representing soil moisture, summer, winter, and monsoon rainfall, soil organic carbon, soil pH, actual evapotranspiration (AET), sand, clay, silt, and the Topographic Ruggedness Index (TRI) were standardized. These layers were then classified into three suitability categories: highly suitable, moderately suitable, and low suitable based on the land suitability requirements of an organic farming system in Mandya Taluk.

Model description

A spatial model based on GIS was created to address the requirements of the organic farming system in Mandya taluk to evaluate the suitability of land for organic agriculture. The illustration shows a schematic representation of the model's performance mechanisms. After mapping the essential layers, an extensive literature review was conducted to identify the agricultural standards for an organic farming system.

In the subsequent phase, the weights obtained from AHP were assigned to the criteria. Essentially, AHP serves as a significant and universal approach within MCDA. Saaty developed a hierarchical model to address complex problems based on criteria and alternatives, as noted by Roig-Tierno et al. In the AHP model, the goal was to analyze land use suitability for organic farming in Mandya taluk, considering criteria such as soil moisture, seasonal rainfall (summer, winter, monsoon), soil organic carbon, soil pH, actual evapotranspiration (AET), sand, clay, silt, and the Topographic Ruggedness Index (TRI). A nine-point scale derived from the Saaty method is utilized to determine the relative significance of criteria. The weights for land suitability factors were derived from local experts using a pairwise comparison statistical analysis in Expert Choice software. Weights fall between 0 and 1, and their total is 1. For assessing the reliability of pairwise comparison evaluations, the Inconsistency Ratios (IR) introduced by Saaty were utilized. The Inconsistency Ratios (IR) for this comparative matrix were 0.1. This indicates that the comparisons of land features were entirely consistent, and the relative weights were suitable for use in land suitability analysis using AHP.

Sub-parameter scores and parameter weights were assigned to the corresponding layers, and thematic maps of 12 factors were overlaid using Weighted Overlay Analysis (WOA) in

ArcGIS with raster calculator tools. Ultimately, the organic farming suitability maps were created and categorized into three classes with equal ranges: highly suitable, moderately suitable, and not suitable areas.

Results and Discussion

Results of AHP analysis

The results indicated that the most important criteria were Actual Evapotranspiration, clay content, coarse fragment, PDSI, post monsoon, sand, Soil organic carbon, soil moisture, temperature, and topographic ruggedness index according to their specific weighting. Also, among the climate criteria, annual rainfall and maximum temperature had the highest and lowest weights, respectively. It should be noted that, among the soil criteria, organic matter played a major role in the delineation of suitable areas for organic farming. Lai et al. applied AHP in group decision making, which has proved to be more beneficial than conventional techniques such as the AHP techniques. In general, combining the potential of spatial analysis with AHP analysis enables researchers to understand the potential value of organic crop production in this region. Mishra et al. reported that the AHP technique can help to identify and prioritise the potential sites for organic farming in Mandya taluk. Based on their results, the weighted overlay method, along with the AHP, had very favourable results for the site suitability analysis of organic farming in this region. The results of Sajadian et al. showed that management of pest and disease, yield, soil nutrient management, water consumption rate, chemical fertiliser consumption rate, and the use of transgenic materials had the highest weights for development and assessment of organic farming in Iran, respectively.

Table 1: Comparison matrix and relative score of each parameter

Parameters	**AET**	**CC**	**CF**	**PDSI**	**PMR**	**SC**	**SOC**	**SM**	**TRI**	**summer**	**winter**	**temperature**
AET	1	3	1	2	3	1	3	1	3	5	1	3
CC	0.33	1	1	2	1	1	3	1	5	1	2	3
CF	1	1	1	3	2	3	6	1	3	5	1	3
PDSI	0.5	0.5	0.33	1	2	1	3	1	3	1	2	3
PMR	0.33	1	0.5	0.5	1	1	3	1	5	4	3	5
SC	1	1	0.33	1	1	1	1	1	5	2	1	1
SOC	0.33	0.33	0.17	0.33	0.33	1	1	1	1	1	1	2
SM	1	1	1	1	1	1	1	1	3	4	1	4
TRI	0.33	0.2	0.33	0.33	0.2	0.2	1	0.3	1	1	1	3
summer	0.2	1	0.2	1	0.25	0.5	1	0.3	1	1	1	1
winter	1	0.5	1	0.5	0.33	1	1	1	1	1	1	6
temperature	0.33	0.33	0.33	0.33	0.2	1	0.5	0.3	0.33	1	0.17	1

Note:AET, Actual Evapotranspiration, CC: clay content, CF: coarse fragment, PDSI, post monsoon, sand, Soil organic carbon, soil moisture, temperature, and topographic ruggedness index.

Table.2 Normalized weight values in the standardized pair-wise comparison matrix.

Parameters	AET	CC	CF	PDSI	PMR	SC	SOC	SM	TRI	summer	winter	temperature	total weight	nor weight
AET	0.14245	0.2762431	0.1390821	0.154	0.2437	0.0787402	0.122	0.1	0.1	0.1852	0.066	0.08527	1.6909	0.1409
CC	0.04701	0.092081	0.1390821	0.154	0.0812	0.0787402	0.122	0.1	0.16	0.037	0.132	0.0857143	1.2304	0.1025
CF	0.14245	0.092081	0.1390821	0.2309	0.1625	0.2362205	0.245	0.1	0.1	0.1852	0.066	0.0857143	1.7824	0.1485
PDSI	0.07123	0.0460405	0.0458971	0.077	0.1625	0.0787402	0.122	0.1	0.1	0.037	0.132	0.0857143	1.0558	0.0879
PMR	0.0449	0.092081	0.069541	0.0385	0.0812	0.0787402	0.122	0.1	0.16	0.1481	0.198	0.1428571	1.2326	0.1027
SC	0.14245	0.092081	0.0458971	0.077	0.0812	0.0787402	0.041	0.1	0.16	0.0741	0.066	0.0285714	0.988	0.0823
SOC	0.04701	0.0303867	0.023644	0.0254	0.0268	0.0787402	0.041	0.1	0.03	0.037	0.066	0.0571429	0.5665	0.0472
SM	0.14245	0.092081	0.1390821	0.077	0.0812	0.0787402	0.041	0.1	0.1	0.1481	0.066	0.1142857	1.1772	0.0981
TRI	0.04701	0.0184162	0.0458971	0.0254	0.0162	0.015748	0.041	0.03	0.03	0.037	0.066	0.0857143	0.4636	0.0386
summer	0.02849	0.092081	0.0278164	0.077	0.0203	0.0393701	0.041	0.03	0.03	0.037	0.066	0.0285714	0.5147	0.0428
winter	0.14245	0.0460405	0.1390821	0.0385	0.0268	0.0787402	0.041	0.1	0.03	0.037	0.066	0.1714286	0.9204	0.0767
temperature	0.04701	0.0303867	0.0458971	0.0254	0.0162	0.0787402	0.02	0.03	0.01	0.037	0.011	0.0285714	0.3768	0.0314

Table.3: distribution of organic agriculture

Classes	**area**	**Percentage**
Highly Suitable	94.61028	13.28
Moderate Suitable	111.2339	15.62
Low suitable	506.494	71.10
Total	**712.3382**	**100**

ISSN: 2249-040X
Peer Reviewed & Refereed Journal (IF: 6.25)
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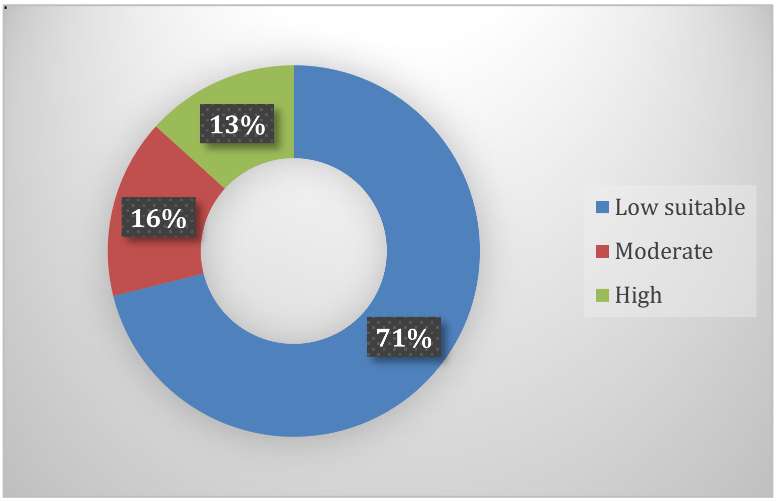

Figure.14: distribution of organic agriculture land in Mandya taluk

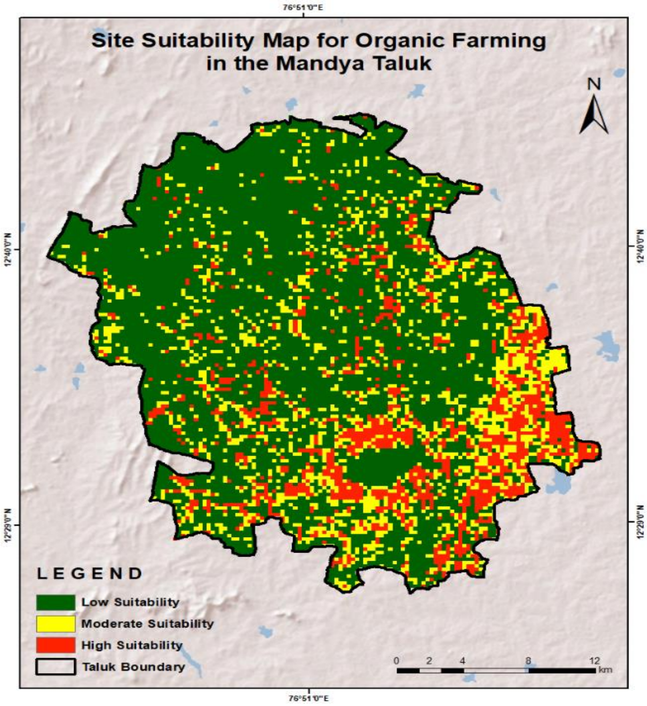

Figure.15: Land suitability map for organic agriculture

Highly suitable zone

The highly suitable area for organic farming included all the southern regions of Mandya taluk (Figure 15). This region possesses great potential for organic production and is well-suited for crop cultivation. The performance of the organic farming suitability model showed that 13.28% of the assessed region fell within the highly suitable category (94.61028 sq.km). These regions possessed the appropriate characteristics, including low altitude, adequate annual rainfall, ideal temperatures, rich soil organic matter, robust agrobiodiversity, favorable pH levels, minimal pesticide usage, proximity to local markets, roads, and natural ecosystems.

MODERATELY SUITABLE

Moderately suitable regions were recognized as locations that are somewhat beneficial for conducting organic agriculture. These regions encompassed 111.2339 sq.km, accounting for 15.62% of the entire surveyed region. The moderately suitable class was identified in the south-east and south-west regions of Mandya taluk.

LOW SUITABLE

This class encompassed an area of 506.494 ha, which represented approximately 71.10% of the examined region. These areas were defined by sloping terrain, limited annual precipitation, soil pH, clay composition, temperature variations, greater distance to nearby markets and natural ecosystems, low agricultural biodiversity, increased use of chemical pesticides and fertilizers, and elevated relative humidity in northern regions. In this region, crop production will encounter significant challenges from drought and salinity in the north and northeast. From a climatic perspective, precipitation and temperature are two key elements that affect crop productivity in arid and semi-arid areas, and these two factors are the primary weather variables that dictate the fluctuations in crop yield.

CONCLUSION

The current research effectively illustrates the success of combining GIS, Remote Sensing, and Multi-Criteria Decision Analysis (AHP–WOA) to evaluate land suitability for organic farming in Mandya Taluk. Through a thorough assessment of essential soil, climate, and topography factors, the research identified regions as highly suitable, moderately suitable, and less suitable for organic farming. The findings indicate that merely 13.28% of the region is classified as highly suitable and 15.62% as moderately suitable, while a significant share (71.10%) encounters limitations caused by unfavorable terrain, soil characteristics, and climatic challenges, especially drought and temperature fluctuations.

The generated suitability map acts as a helpful decision-support resource for farmers, policymakers, and planners by pinpointing key areas for advancing organic agriculture. The research emphasizes the essential importance of soil organic carbon, moisture accessibility, evapotranspiration, and climatic elements in assessing the potential for organic agriculture. The selected methodology is strong and adaptable, and it can be efficiently utilized in other areas with comparable agro-ecological characteristics to enhance sustainable agricultural strategies and environmentally responsible land-use practices.

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