



## REVIEW ARTICLE

# LAND SUITABILITY EVALUATION OF WHEAT AND MAIZE CROPS USING GIS AND REMOTE SENSING TECHNOLOGIES AT RATNANAGAR MUNICIPALITY, CHITWAN

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## ARTICLE DETAILS

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## ABSTRACT

The research was conducted at Ratnanagar municipality of Chitwan districts to evaluate the land suitability by integrating the Geographical Information System (GIS) that incorporates the multi-criteria evaluations (MCE) and analytical hierarchical process (AHP). Two crops wheat and maize were selected for analysis. Ten parameters taken for study are nitrogen, phosphorus, potassium, organic matter, soil PH, precipitation, temperature, slope, aspect, and elevation. A pair-based comparison was done for all the parameters and they were reclassified as per their weights. Weighted overlay analysis was done in ArcGIS 10.2 software. Elevation, slope, aspect, and organic matter were identified as the most influencing factors for both crops. The study revealed that 1456.01ha (21.70%) was moderately suitable (S2), 5106.92 ha (76.14%) was marginally suitable (S3), 143.25 ha (2.13%) was not suitable (N) and 0.53 ha (0.0079%) was not applicable for wheat crop production. Similarly, 22.184 ha (0.33%) was highly suitable (S1), 2631.60 ha (39.23%) was moderately suitable (S2), 3854.62 ha (57.46%) was marginally suitable (S3) and 199.18 ha (2.96%) was not suitable (N) for maize crop production. The area that is not suitable for wheat and maize cultivation should be allocated for other crop cultivation for optimum use of available soil resources. The findings of the study, reveal that the area of the study site is marginally suitable and crops can be grown with major limitations for sustained productivity.

## KEYWORDS

Analytical Hierarchy Process (AHP), Multicriteria evaluation, Geographic Information System (GIS), Pair-wise comparison, Remote sensing

## 1. INTRODUCTION

Land suitability is a technique for evaluating land that gauges how suitable a piece of land is for growing particular crops by meeting the needs of the crops and the soil (FAO, 1976). Variations in the distribution of land elements determine its suitability for agriculture, plantation, recreation, settlement, industry, watershed management, etc. However, land elements are used haphazardly to fulfill the growing demands of the population all over the world. Land suitability analysis is an effective method to achieve optimum utilization of the available land resources for sustainable agricultural production. It is a function of different parameters such as climate, soil, topography, land use, infrastructure, water availability, socio-economic and environmental factors, etc. The relative importance of these parameters can be evaluated to determine the suitability by different statistical techniques such as MCE (multicriteria evaluations) integrated with geospatial techniques such as RS (Remote sensing) and GIS (Geographic Information System) (Trigoso et al., 2020; Perveen et al., 2007). The geographic information system (GIS) technique is a potent instrument for determining whether a piece of land is suitable for agricultural land use planning. It can integrate various geographic technologies, including remote sensing and the global positioning system (GPS), and it supports the process of making spatial decisions (Foote, K.E.; and Lynch, 2018). A popular method for LSA is multi-criteria assessment (MCE), which incorporates socio-eco-cultural factors and bio-physical factors like slope, relief, drainage, soil characteristics, vegetation, climate, etc. into the decision-making process. (Akinci et al., 2013). The Analytical Hierarchy Process (AHP) is a popular method for MCDM of land suitability that uses pairwise comparisons of characteristics based on relative relevance to estimate the weight of impact on a particular land use (Saaty, 1980). In this study, GIS integrated with MCE and AHP was applied to evaluate the suitability of the study area for wheat and maize crop production using the relative importance of soil chemical properties, and meteorological and topographical parameters throughout the MCE

technique with the objectives of performing crop suitability evaluation for wheat and maize crops in Ratnanagar municipality, Chitwan.

## 2. MATERIALS AND METHODS

## 2.1 Study Area

The study was conducted in Ratnanagar municipality of Chitwan district, Bagmati province of Nepal, located at 27° 37' 2.40"N latitude and 84° 30' 42.23"E longitude. The municipality is present in the inner terai zone with an elevation range from 170 meters above sea level (masl) to 293 masl has a total of 16 wards, which are scattered across 686 square kilometers of geographic area. The slope of municipality ranges from gentle (0°) to steep slope (19°).

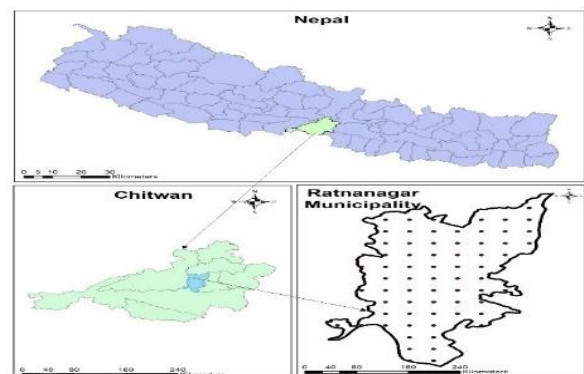


Figure 1: Map of the study area showing soil sampling points

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2.2 Data Collection and Sources

The study's primary data came from a field survey conducted with Google Earth Pro whereas to determine topographic conditions, secondary data

with a resolution of 1 arc second was gathered from the USGS Shuttle Radar Topography Mission (SRTM). The meteorological data such as temperature and rainfall were obtained from the Climatic Research Unit (CRU) with a resolution of 0.5\*0.625 degrees.

Table 1: Primary and Secondary Data Sources		
Data Type	Data Source	Remarks
Elevation, Slope, Aspect	Shuttle Radar Topography Mission (SRTM) USGS 1 arc second resolution ( <a href="https://earthexplorer.usgs.gov/">https://earthexplorer.usgs.gov/</a> )	Determine the study area's aspect and slope.
Rainfall and Temperature	Climatic Research Unit (CRU) with a resolution of 0.5*0.625 degrees.	Average monthly and annual temperature and precipitation statistics.
Soil Properties	Digital soil map of National Soil Science Research Center (NSSRC)	PH, N, P, K, OM
Soil Types	Land resource mapping project (LRMP) of Nepal.	Land Unit

2.3 Soil Sample Collection

For calculating the soil data, random sampling points were generated by using the arc toolbox called Fishnet in the software called Arc Map 10.2 software. Then those generated points were presented in the software Google Earth Pro to generate the coordinates of the points. The coordinates were then used to draw the soil data from the Digital Soil Map (web-based application) of the National Agriculture Research Council (NARC)'s National Soil Science Research Center (NSSRC). For the development of the Digital Soil Map, the soil profile data were collected by NSSRC from various government projects including the National Land Use Project, Irrigation and Water Resources Management Project, Central Agriculture Laboratory (previously Soil Management Directorate), and Nepal Agricultural Research Council (NARC).

2.4 Ordinary kriging interpolation

An estimated surface is produced from a dispersed collection of points with z-values using the sophisticated geostatistical technique known as "kriging." Using the Kriging tool effectively entails an interactive examination of the spatial behavior of the phenomena represented by the z-values before choosing the best estimating approach for creating the output surface, in contrast to other interpolation techniques in the Interpolation toolset. Soil chemical properties, annual rainfall, and temperature were interpolated using the ordinary kriging method in Arc map 10.2 software shown in Figure 2 and Figure 3. The spatial surface tool was used to interpolate the topographic factors as shown in Figure 4.

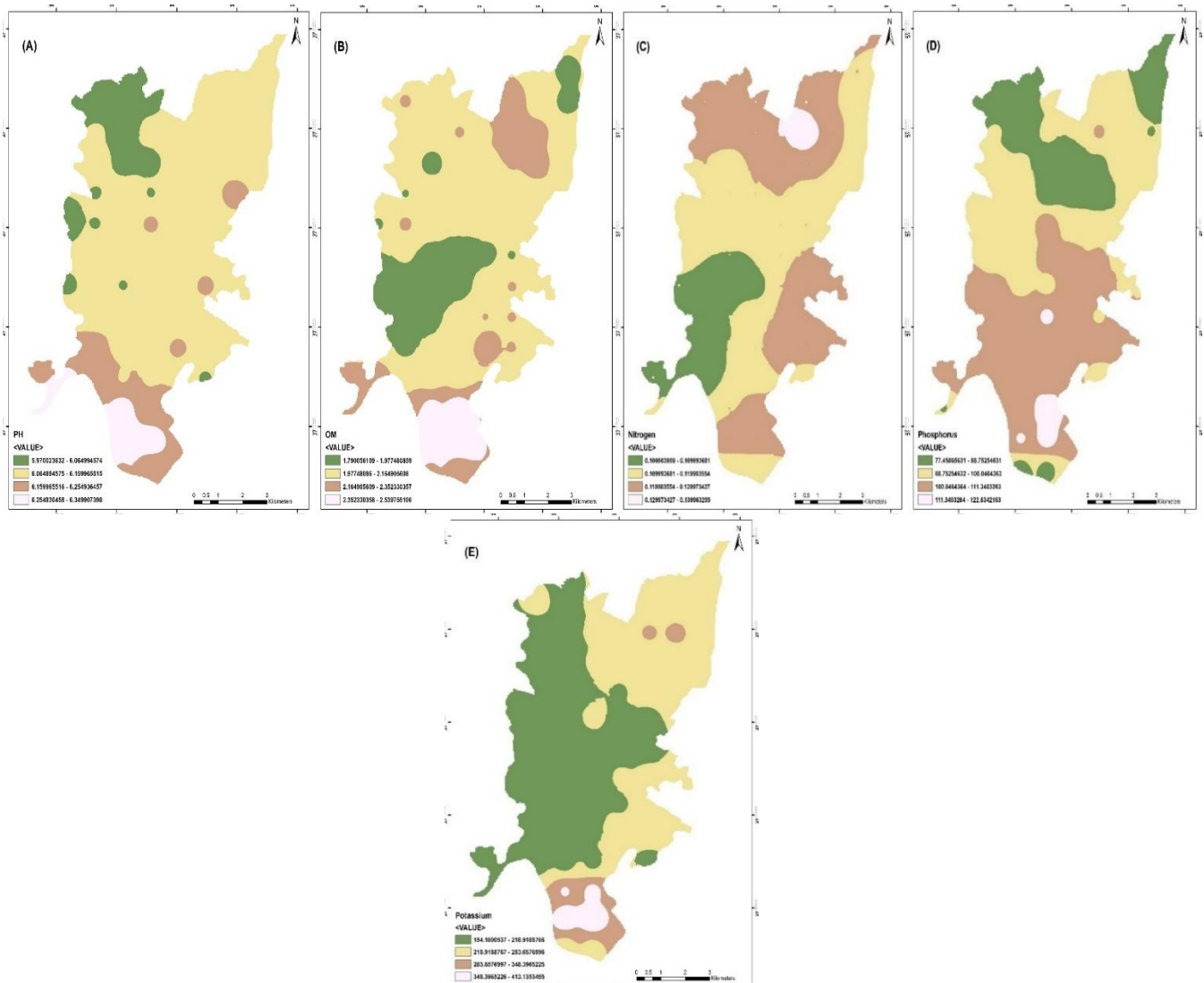


Figure 2: Spatial map of (A) Soil PH, (B) Organic matter (C) Total Nitrogen (D) Phosphorus (E) Potassium

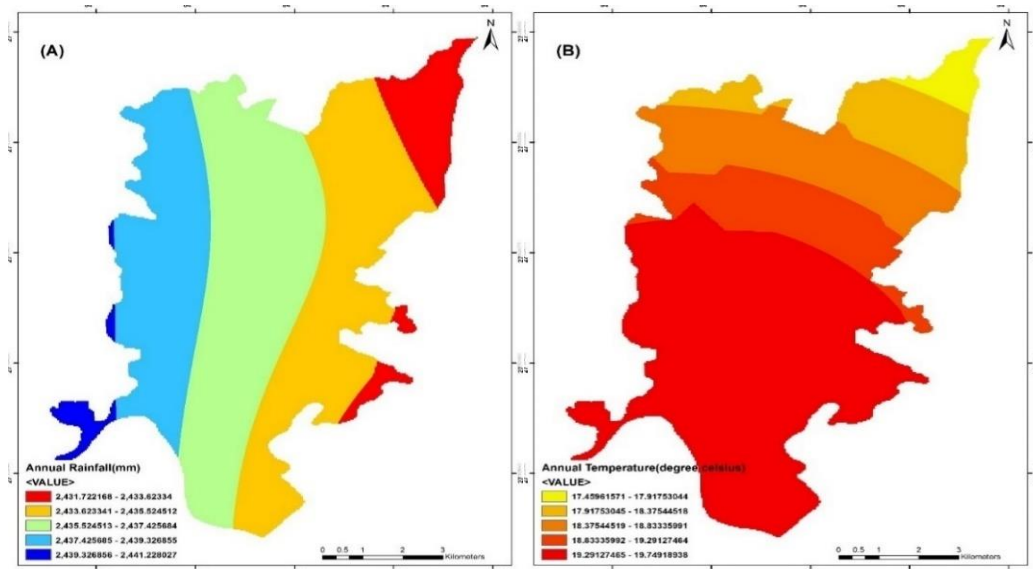


Figure 3: Spatial map of (A) Annual Rainfall (mm) and (B) Annual Temperature (degree celsius)

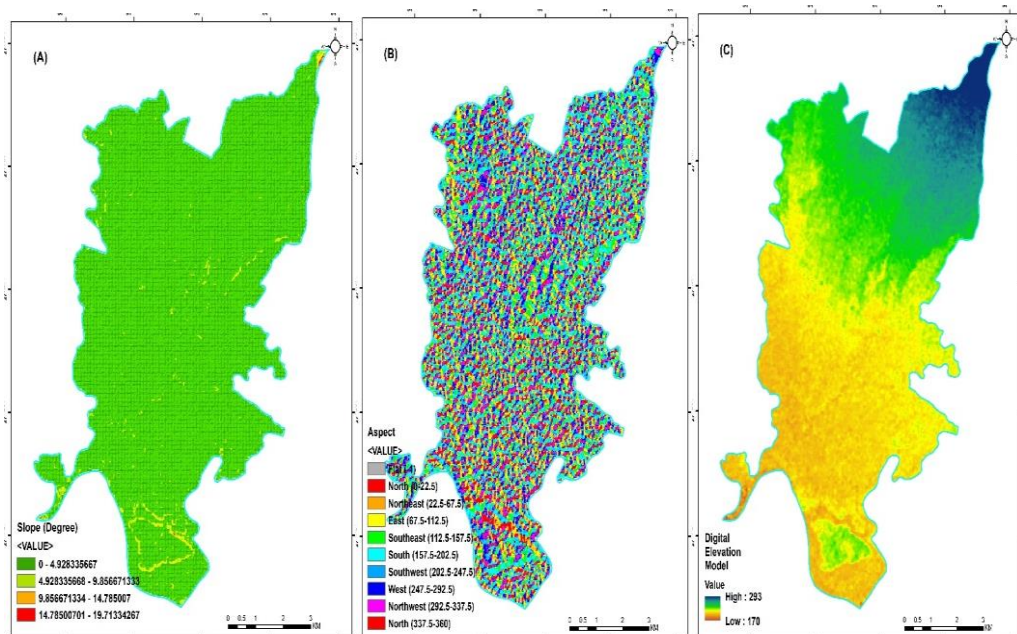


Figure 4: Spatial map of (A) Slope (degree), (B) Aspect and (C) DEM

### 2.5 Analytical Hierarchical Process (AHP)

A researcher proposed that Analytical hierarchical process is widely used MCDM techniques (Saaty, 1980). AHP is a methodical approach to structuring and resolving intricate mathematical and psychological decision-making issues. AHP offers a thorough and rational framework for measuring every structural decision-making component in a hierarchical structure. The decision criteria are chosen first in the AHP, and the alternatives are then assessed in light of the criteria that have been chosen. AHP prioritizes each criterion using pairwise comparisons between them

and the concepts of reciprocal condition, homogeneity, reliance, and expectancies. The significance and preference of pairwise comparisons are assessed using a 9-point rating system. At this step, preferences need to meet the requirements for reciprocity and homogeneity (Tavana et al., 2023). The FAO general framework for evaluating land suitability places lands into several orders, denoted by symbols: (S1) highly suitable with no limitations on crop cultivation, (S2) moderately suitable with certain limitations on sustained productivity, (S3) with significant limitations on sustained productivity, and (N1) and (N2) with current and permanent suitable with severe limitations on land properties (FAO, 1976).

Table 2: shows the intensity of the factor's importance based on the literature review, analytical study, and expert opinion.

Qualitative definition	Explanation	Intensity of Importance
Equal significance	The two factors contribute equally to the outcome.	1
Moderate significance	Experience and opinions tend to favor one factor over another	3
Strong significance	Experience and judgment greatly favor one factor over another.	5
Very strong significance	A strong preference for one factor over another results in dominance in day to day interactions.	7

Table 2 (cont): shows the intensity of the factor's importance based on the literature review, analytical study, and expert opinion.		
Extreme significance	When behavior is supported over another by evidence, this is the strongest conceivable order of affirmation.	9
Intermediate	When a comparison is needed between two qualitative definitions	2, 4, 6, 8
Reciprocals	Less importance	1/9, 1/7, 1/5, 1/3

2.6 Pairwise comparison matrix

Table 3: Pairwise comparison of wheat crop									
Elevation	PH	Aspect	Slope	OM	N	P	K	Rainfall	Temperature.
1	3	2	1	4	5	6	5	4	3
0.33	1	0.5	0.33	0.5	3	3	4	0.33	0.33
0.5	2	1	2	3	6	5	6	4	3
1	3	0.5	1	1	3	4	3	2	1
0.25	2	0.33	1	1	2	3	4	0.33	0.5
0.2	0.33	0.166667	0.33	0.5	1	2	2	0.33	0.33
0.166667	0.33	0.2	0.25	0.33	0.5	1	2	0.5	0.5
0.2	0.25	0.166667	0.33	0.25	0.5	0.5	1	0.25	0.3
0.25	3	0.25	0.5	3	3	2	4	1	0.5
0.333333	3	0.333333	1	2	3	2	3	2	1

Normalized pairwise comparison

Factors	Elevation	PH	Aspect	Slope	OM	N	P	K	Rainfall	Temp.
Elevation	0.236407	0.167504	0.367197	0.129199	0.256739	0.185185185	0.210526	0.147059	0.27137	0.286807
PH	0.078014	0.055835	0.091799	0.042636	0.032092	0.111111111	0.105263	0.117647	0.022388	0.031549
Aspect	0.118203	0.111669	0.183599	0.258398	0.192555	0.222222222	0.175439	0.176471	0.27137	0.286807
Slope	0.236407	0.167504	0.091799	0.129199	0.064185	0.111111111	0.140351	0.088235	0.135685	0.095602
OM	0.059102	0.111669	0.060588	0.129199	0.064185	0.074074074	0.105263	0.117647	0.022388	0.047801
N	0.047281	0.018425	0.0306	0.042636	0.032092	0.037037037	0.070175	0.058824	0.022388	0.031549
P	0.039401	0.018425	0.03672	0.0323	0.021181	0.018518519	0.035088	0.058824	0.033921	0.047801
K	0.047281	0.013959	0.0306	0.042636	0.016046	0.018518519	0.017544	0.029412	0.016961	0.028681
Rainfall	0.059102	0.167504	0.0459	0.064599	0.192555	0.111111111	0.070175	0.117647	0.067843	0.047801
Temp.	0.078802	0.167504	0.0612	0.129199	0.12837	0.111111111	0.070175	0.088235	0.135685	0.095602

Table 4: Pairwise comparison of maize crop									
Elevation	PH	Aspect	Slope	OM	N	P	K	Rainfall	Temp.
1	3	2	1	4	5	6	5	4	3
0.33	1	0.5	0.33	0.5	3	3	4	0.33	0.33
0.5	2	1	2	3	6	5	6	4	3
1	3	0.5	1	1	3	4	3	2	1
0.25	2	0.33	1	1	2	3	4	0.33	0.5
0.2	0.33	0.166667	0.33	0.5	1	2	2	0.33	0.33
0.166667	0.33	0.2	0.25	0.33	0.5	1	2	0.5	0.5
0.2	0.25	0.166667	0.33	0.25	0.5	0.5	1	0.25	0.3
0.25	3	0.25	0.5	3	3	2	4	1	0.5
0.333333	3	0.333333	1	2	3	2	3	2	1

Normalized pairwise comparison

Factors	Elevation	PH	Aspect	Slope	OM	N	P	K	Rainfall	Temp.
Elevation	0.236407	0.167504	0.367197	0.129199	0.256739	0.185185185	0.210526	0.147059	0.27137	0.286807
PH	0.078014	0.055835	0.091799	0.042636	0.032092	0.111111111	0.105263	0.117647	0.022388	0.031549
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Factors	Elevation	PH	Aspect	Slope	OM	N	P	K	Rainfall	Temp.
K	0.047281	0.013959	0.0306	0.042636	0.016046	0.018518519	0.017544	0.029412	0.016961	0.028681
Rainfall	0.059102	0.167504	0.0459	0.064599	0.192555	0.111111111	0.070175	0.117647	0.067843	0.047801
Temp.	0.078802	0.167504	0.0612	0.129199	0.12837	0.111111111	0.070175	0.088235	0.135685	0.095602

**2.7 Calculation of consistency ratio**

They defined the consistency ratio criterion as a maximum for every matrix and the hierarchical analytical process to verify accuracy (Saaty, 1980). The pairwise comparison results are deemed acceptable with

inconsistency ratio 0.1 or below it whereas they are returned to the expert or experts for inspection and reexamination with the inconsistency ratio above 0.1. Participants may become less motivated as a result of the subsequent evaluation process's complexity, which could also lower the accuracy of the results.

**Table 5: Random index value for 1 to 10 parameters (Saaty, 2008)**

N	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

If CR ≤ 10%, means the matrix is consistent and the weighted overlay can be continued.

If CR > 10%, the assessment requires revision because the matrix is not consistent.

**Table 6: Consistency index, Random index and consistency ratio for wheat and maize crops**

Crops	Maximum eigenvalue (Lmax)	Total Criteria (n)	Lmax-n	Consistency Index (CI)	Random Index (RI)	consistency Ratio (CR)
Wheat	11.33902	10	1.339023	0.14878	1.49	0.099853
Maize	11.18678	10	1.186777	0.131864	1.49	0.088499

**2.8 Weighted overly analysis**

The weighted overlay is one method of modeling suitability. In this method, a numerical weighting factor was obtained from AHP and for every thematic layer, an AHP was allocated based on how significant it is in relation to every other layer.

The formula for calculating the suitability index for each vegetable crop's layer was

$$Si = \sum Xi \times Wi$$

Where,

Wi is the weight of sub-criteria i

Xi is the fact value of criteria or sub-criteria the fact-value was calculated for

each criterion, and sub-criteria based on expert opinion, local farmers experience and literature review.

Si is the suitability index for the i criteria.

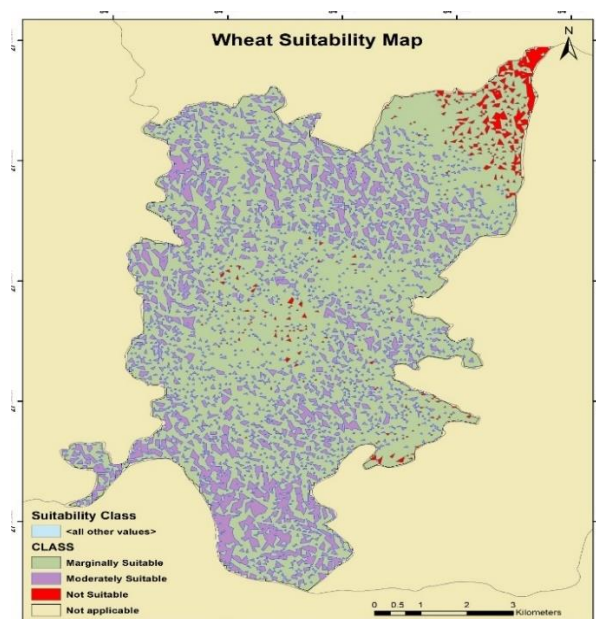
**3. RESULTS AND DISCUSSION**

**3.1 Effects of parameters on wheat and maize suitability**

The pairwise comparison matrix between three major criteria (Soil chemical properties, meteorological and topographic factor) of ten sub-criteria for wheat suitability results that the total nitrogen (N), phosphorus (p), potassium (K), organic matter (OM), and soil pH influences the 5%, 4%, 3%, 8%, and 7% of weight respectively. Likewise, temperature, rainfall, elevation, slope, and aspect influence 10%, 9%, 23%, 12%, and 19% of weight respectively. Similarly, for the maize suitability N, P, K, OM, soil pH influences the 4%, 4%, 3%, 8%, and 7% of weight respectively. Sub-criteria under meteorological and topographic factors such as temperature, rainfall, elevation, slope, and aspect influence 10%, 9%, 22%, 13%, and 20% of weight respectively.

**3.2 Land suitability for wheat**

The study revealed that out of the total agricultural area, 1456.01 ha (21.70%) was moderately suitable (S2), 5106.92 ha (76.14%) was marginally suitable (S3), 143.25 ha (2.13%) was not suitable (N) and 0.53 ha (0.0079%) was not applicable for wheat crop production. Similar research on wheat and maize crops land suitability in Naraharinath rural municipality, kalikot shows that 12.73%, 29.39%, 44.16%, and 13.71% of the area were highly suitable, moderately suitable, marginally suitable, and not suitable for wheat crop production respectively (Dhakal, 2025).



**Figure 5: Wheat suitability map of Ratnanagar municipality, Chitwan**

### 3.3 Land suitability for maize

The study revealed that out of the total agricultural area, 22.184 ha (0.33%) was highly suitable (S1), 2631.60 ha (39.23%) was moderately suitable (S2), 3854.62 ha (57.46) was marginally suitable (S3) and 199.18 ha (2.96%) was not suitable (N) for maize crop production. Suitability evaluation for maize crops in Naraharinath rural municipality, kalikot shows that 32.27%, 60.14%, and 7.59% were highly, moderately, and marginally suitable respectively (Dhakal, 2025).

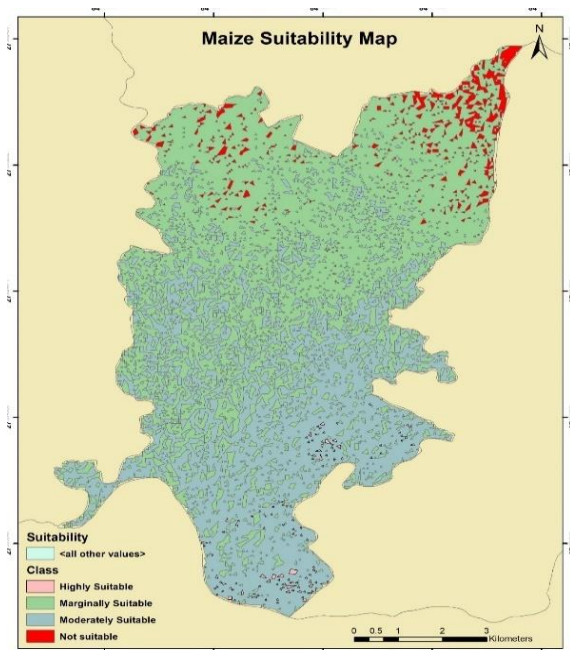


Figure 6: Maize Suitability map of Ratnanagar municipality, Chitwan

### 4. CONCLUSION

The research was conducted by integrating the multi-criteria assessment (MCE) and Geographic information system (GIS) techniques to forecast the regions that are ideal for growing wheat and maize crop cultivation at Ratnanagar, municipality, Chitwan. The outcome derived from this research indicates that the integration of GIS and MCE could provide a good database and information for planners considering crop substitution to get better agricultural production. A pairwise comparison was done which shows that out of the ten parameters, the most important parameters were elevation, aspect, slope, and organic matters for both crops. The analysis in the study revealed that the majority of the study area was marginally suitable for wheat crops and a highly suitable area was not identified currently. Similarly, the majority of the study area was marginally suitable and only 0.33% of the study area was highly suitable for maize production. Due to some limitations, 2.96% was not suitable for maize production. The area that is not suitable for maize and wheat crop cultivation should be used for other crop cultivation to exploit the available soil resources. Except for inappropriate places, the majority of

the municipality is relatively favorable for wheat and maize crop production, while a small percentage is extremely and not suitable. Furthermore, this model can be used to smoothen the decision-making process for management, planning, and recommendations to researchers, farmers, decision-makers, and policymakers to solve complex problems related to crop production in the agriculture sector.

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