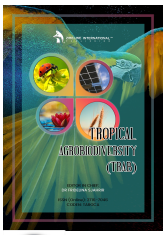
ZIBELINE INTERNATIONAL™ PUBLISHING

ISSN: 2716-7046 (Online)
CODEN: TARGCA

Tropical Agrobiodiversity (TRAB)

DOI: http://doi.org/10.26480/trab.01.2020.42.46



RESEARCH ARTICLE

LAND SUITABILITY EVALUATION USING GIS FOR VEGETABLE CROPS AT SHARADANAGAR, CHITWAN, NEPAL

D. M. Thapa[a*], C.P. Shrivastav[a], S.C. Shah[a], K. Sah[b]

[a] Institute of Agriculture and Animal Science, Rampur, Chitwan Nepal
[b] Soil Science division, Nepal Agriculture Research Council, Khumaltar, Nepal
**Corresponding Author Email: thapadhiren99@gmail.com*

ARTICLE DETAILS

Article History:

Received 16 July 2020
Accepted 18 August 2020
Available online 2 September 2020

ABSTRACT

The present research was conducted at Chitwan district of Sharadanagar to evaluate land suitability integrating with Geographical Information System (GIS) technology-incorporates the multi criteria evaluations (MCE) and analytic hierarchy process (AHP) in 2014. Three major vegetable crops were selected for analysis viz. potato, cauliflower, and radish. Existing geo-data base from National Land Use planning was used and analyzed. The physical suitability was performed by vector-based index modeling in GIS taking soil, land capabilities and land use database into account. The relative importance of each main criterion was determined using AHP procedure. In final model soil, land capability class and land use were given 0.65%, 0.24% and 0.09% weight, respectively having CI of <10%. The study revealed that, potato was highly suitable to the context of 40% of area (582.55 ha), 11.99% (170.72 ha) moderately suitable and 20.35% marginally suitable (298.65 ha) for potato cultivation while only 11.7% (167.6 ha) was highly suitable for radish cultivation. Similarly, 13% of the area (188.9 ha) was highly suitable for cauliflower cultivation. The area not suitable for these vegetable crops should be allocated for another use for optimum utilization of soil resources. This study therefore, revealed that scientific agricultural planning at local level should be based on soil characterization. The soil not suitable for Potato, Radish and Cauliflower should be used for another crop for optimum production.

KEYWORDS

Land resources, Geographical information System (GIS), Multi-criteria evaluation (MEC), Analytical Hierarchy process (AHP)

1. INTRODUCTION

Land suitability evaluation is the prerequisites for sustainable agricultural production and involved in evaluating of the criteria ranging from soil, terrain to socio-economic, market and infrastructure (Prakash, 2003). Land evaluation is a method of estimating the potential for alternative kind of land use. It is also known as Multi Criteria Evaluation that aiming to identify appropriate spatial pattern for future land uses on the basis of specify requirements, preferences or predictors of some activity (Hopkins, 1977; Collins et al., 2001). Suitability categorization can be done with highly suitable (S_1), moderately suitable (S_2), marginally suitable (S_3) and not suitable (N). Land suitability is the assessment or prediction of land quality for a specific use, in terms of its productivity, degradation hazards and management requirements (Austin and Basinski, 1978). Integrating of the GIS and MCE can help land-use planners and implementers to improve decision-making processes (Malczewski, 1999). Using GIS based multi-criteria evaluation approach; Baniya evaluated land suitability for vegetable crops in Nepal (Baniya, 2008). He found that the MCE along with GIS is a useful tool for integration of socio economic and environmental data. This research was carried out at Sharadanagar, Chitwan, Nepal, which evaluates the suitability of vegetable crops production integrating GIS and MCE.

2. MATERIAL AND METHODS

2.1 Research area

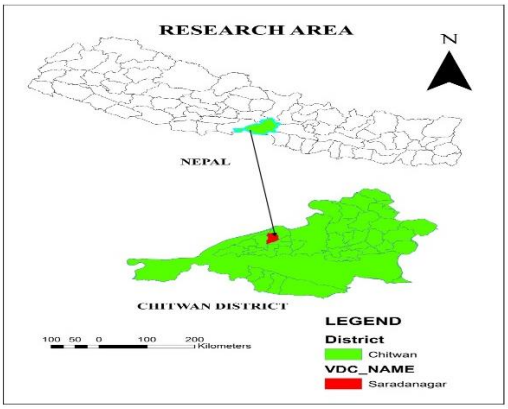


Figure 1: Map of Nepal, Chitwan and Sharadanagar

Quick Response Code	Access this article online	
	Website: www.trab.org.my	**DOI:** 10.26480/trab.01.2020.42.46

The research was carried out at Sharadanagar of western Chitwan (inner terai) district of central development region and lies on the way to Meghauli from Bharatpur, the district head quarter. It shares its border with four VDCs. Mangalpur lies to the north-east, Gunjanagar to the west, Sibanagar to the south-east and Fulbari to the east. The VDC covers an area of 1423 hectares and had a total population of 9,584 (2058 BS).

2.2 Selection of vegetable for suitability study

Three vegetable crops were taken, and they were cauliflower, potato, and radish. The vegetable crops which were considers for research and their classification as given (Table 1).

Table 1: Groups of vegetable to be evaluated for land suitability

Crops Group	Representative species	Nepali name	Family
Cole crops	Cauliflower	Kauli	Brasicaceae
Root and tuber crops	Potato Radish	Aalu Mula	Solanaceae Brassicaceae

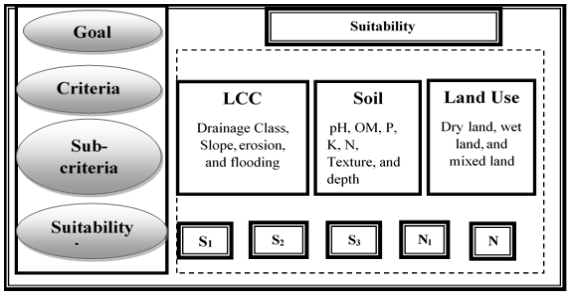
2.3 Creation of thematic maps

Thematic maps were the basis of suitability analysis. Existing geo-database of NLUP such as land capability map, land use map, soil maps were created as thematic maps and analyzed in Geographical Information System (GIS) environment. All needed thematic maps were created and edited, overlaid, and visualized on ArcGIS-10 software of ESRI. Application of GIS for overlaying and intersect of thematic layers to establish new suitability databases with final suitability maps of study area.

2.4 Application of MCE (Multi-Criteria Evaluation) approach using Analytical Hierarchy Procedure (AHP)

Multi criteria evaluation was acquired by applying the various procedure of AHP (Analytical Hierarchy procedure). Analytical Hierarchy Process method used in decision-making was introduced with the assumption that comparison of two elements is derived from their real-time importance (Saaty, 1977).

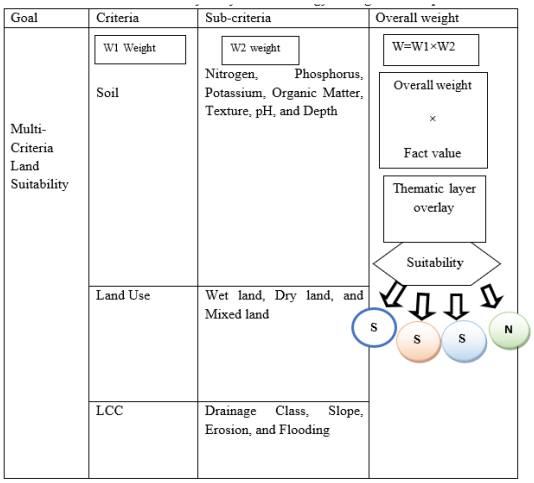
Table 2: Hierarchical organization for the criteria considered in the study area.



2.5 Weightings of criteria and sub-criteria

In the procedure for multi-criteria evaluation using a weighting and comparisons of criteria involved to determine suitability for the stated objective.

Table 3: Flow chart of the suitability analysis methodology for vegetables crops



The main criteria are land capability classification, soil, land use and land capability classification were sub-divide into the sub-criteria at level two. Similarly, criteria soil and land use were divided into sub-criteria at level two.

2.6 Use of pair wise comparison matrix (PWCM) at each level of hierarchy

The pair-wise comparison matrix (PWCM) was carried out for rating and weighting of different sub-criteria and criteria. The fundamental scales given by Satty's for comparing the two criteria or sub criteria were used. The qualitative ratings are provided on a 1-9 points considering the relative importance of two criteria or sub criteria (Satty and Vargas, 2001).

Table 4: Scale of preference between two parameters in AHP

Scale	Degree of preferences	Explanation
1	Equally	Two activities contribute equally to the objective.
3	Moderately	Experience and judgment slightly to moderately favor one activity over another.
5	Strongly	Experience and judgment strongly or essentially favor one activity over another.
7	Very strongly	An activity is strongly favored over another and its dominance is showed in practice.
9	Extremely	The evidence of favoring one activity over another is of the highest degree possible of an affirmation.
2,4,6,8	Intermediate values	Used to represent compromises between the preferences in weights 1, 3, 5, 7 and 9.
Reciprocals	Opposites	Used for inverse comparison.

Table 5: Paired-wise comparison for the six criteria

Goal	M	N	O	P	Q	R	Weights	Rank
M	1	4	2	3	4	6	0.35	1
N	1/4	1	1/2	1/5	2	4	0.09	4
O	1/2	2	1	3	3	4	0.24	2
P	1/3	5	1/3	1	3	4	0.19	3
Q	1/4	1/2	1/3	1/3	1	3	0.07	5
R	1/6	1/4	1/4	1/4	1/4	1	0.03	6
λmax=6.538	CR=8.6%						Σ=1	

Where, CR= Consistency Ratio, λmax= Principle eigen value

This process of comparing the criteria was carried out for six criteria and their sub-criteria to calculate the weightage (normalized priority vector). Further the process of calculation of consistency ratio and principle eigen value was done as below.

2.7 Calculation of consistency ratio

Step 1. Consistency index was calculated,

Consistency index (CI) = (λ max-n)/ (n-1)

Where n = number of criteria

Step 2. Random consistency index (RI) was calculated (Table 6). RI value depends upon the number of criteria or sub-criteria to be taken in the research

Table 6: RI value at different number of criteria

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

Source: (Permadi, 1992)

Step 3: Finally, Consistency ratio (CR) was calculated as below:
CR=CI/RI
Where, RI= Random consistency
CR value ≤ 10% AHP is consistent, then further process was done
CR value > 10% AHP is not consistent, revision of process was done

2.8 Determination of fact value

Fact value for each sub-criterion was classified from the 0-9 scales with suitability order as given below in Table 7.

Table 7: Fact value for criteria/sub-criteria		
Fact value	Suitability order	Classification
9	Highly suitable	S1
7	Moderately Suitable	S2
5	Marginally Suitable	S3
1	Not suitable (Presently)	N1
0	Not suitable (Permanently)	N2

2.9 Calculation of suitability index

After weightings and rating of all criteria over the hierarchy obtained, standardized criteria maps were multiplied (Si = ΣXi x Wi) with those criteria weights at each level of the hierarchy. In land suitability analysis, a map represents each evaluation criterion with alternatives (like S_1, S_2, S_3, and N) indicating the degree of suitability with respect to a criterion.

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

Si = ΣXi x Wi

Where,

Wi is weight of sub criteria i

Xi is 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 suitability index for i criteria.

3. Results and Discussion

3.1 Land suitability evaluation for potato crops

Majority of land from research areas were highly suitable (40.93%) for potato cultivation. Similarly, marginally suitable (20.35%) area was higher than moderately suitable (11.99%) where only 0.31% of areas were not suitable. The study showed that 582.55 ha of land were highly suitable, 170.72 ha and 298.65 ha of land were moderately and marginally suitable, respectively for potato farming. Silty clay soil texture and soil depth were the major limitations of the study areas which can be improved by specific management.

Table 8: Land suitability areas for potato crops under different classes of the Sharadanagar, Chitwan, Nepal, 2014					
Variable	Rating	Suitability order	Percentage (%)	Area (Ha)	Rank
Suitability	Highly Suitable	S_1	40.93	582.558	1
	Moderately Suitable	S_2	11.99	170.727	2
	Marginally suitable	S_3	20.35	298.653	3
	Not Suitable presently	N	0.311	4.45954	4
	Not applicable	-	25.81	367.279	0

The descriptive statistics for the suitability variables over the entire study area are presented at Table 9. The suitability variable count values were 1628 with maximum 10 and minimum 2.32. The value of Sum, Mean, and Median of suitability variable were 13745.59, 8.44 and 10, respectively. Similarly, standard deviation was 2.15; Coefficient of Variance (C.V) was 0.25.

Table 9: Descriptive statistics for suitability index of potato cultivation of the Sharadanagar, Chitwan, Nepal, 2014									
Variable	Count	Minimum	Maximum	Sum	Mean	Median	S.D.	C.V %	Variance
Suitability	1628	2.32	10	13745.59	8.44	10	2.15	0.25	4.30

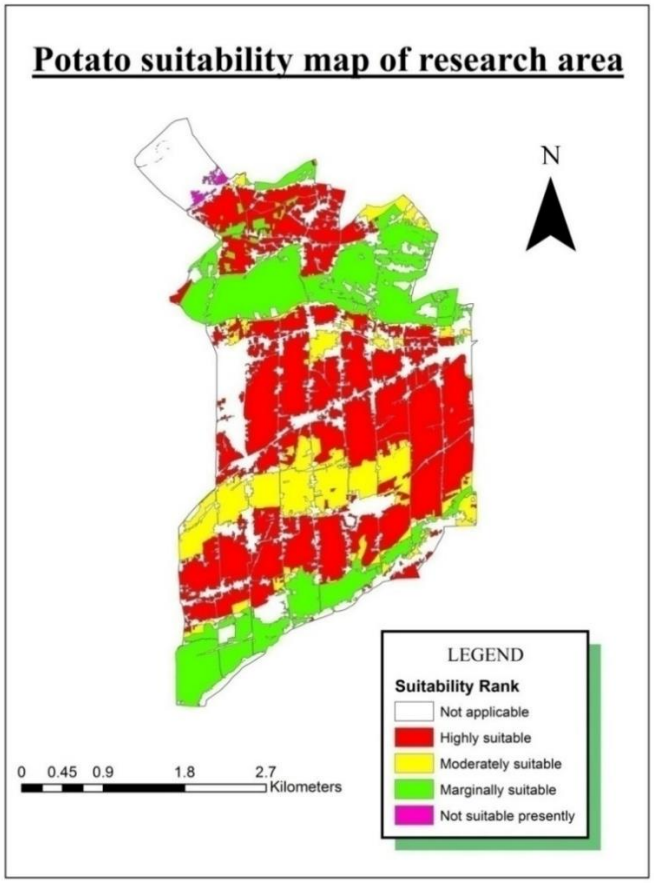


Figure 2: Map of the research sites showing the different degree of potato suitability area of the Sharadanagar, Chitwan, Nepal, 2014

3.2 Land suitability evaluation for radish crops in research area

Table 10 revealed that only 11.78% of the total area was highly suitable for radish cultivation. The study showed that 39.22% of the area was moderately suitable and 22.90 % was marginally suitable. Radish crops were moderately suitable (558.18 ha) of an area and 167.64 ha of land was highly suitable and rest 325.97 ha area was marginally suitable. Low soil depth and moderate fertility status were the limitations of the area which can be improved by specific management.

Table 10: Land suitability evaluation for radish crops of the Sharadanagar, Chitwan, Nepal, 2014

Variable	Rating	Suitability order	Percentage (%)	Area (Ha)	Rank
Suitability	Highly suitable	S_1	11.78	167.64	1
	Moderately suitable	S_2	39.22	558.19	2
	Marginally suitable	S_3	22.90	325.97	3
	Not Suitable presently	N	0.31	4.49	4
	Not applicable	-	25.81	367.28	0

The descriptive statistics for the suitability variables over the entire study area are presented in Table 11. The maximum and minimum suitability values were 10 and 2.41. Similarly, the value of Sum, Mean and Median of suitability variables were 12970.06, 7.96 and 10, respectively with standard deviation 2.77 (Table 11).

Table 11: Descriptive statistics for suitability index of radish crops of the Sharadanagar, Chitwan, Nepal, 2014

Variable	Count	Minimum	Maximum	Sum	Mean	Median	S.D.	C.V %	Variance
Suitability	1628	2.41	10	12970.06	7.96	10	2.77	0.34	7.7

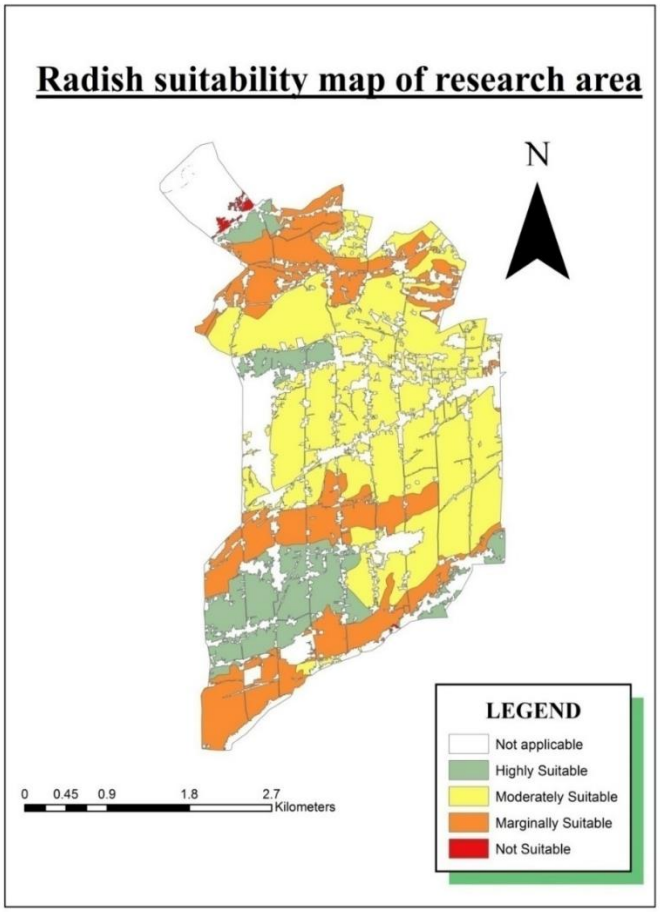


Figure 3: Map of the research sites showing the different degree of radish suitability of the Sharadanagar, Chitwan, Nepal, 2014

3.3 Land suitability evaluation for cauliflower crops in research area

Table 12 revealed that 188.98 ha of the total area (13.28%) was highly suitable for cauliflower cultivation, 452.67 ha was moderately suitable which covered 31.8% of total area. Likewise, 131.05 ha of area (9.20%) was marginally suitable and 283.59ha (19.92%) was not suitable for cauliflower cultivation (Table 12). Highly acidic and poor drainage soil was the limitations of the study area which can be improved by specific management.

Table 12: Land suitability area for cauliflower crops under different classes of the Sharadanagar, Chitwan, Nepal, 2014

Variable	Rating	Suitability order	Percentage (%)	Area (Ha)	Range
Suitability	Highly Suitable	S_1	13.28	188.98	1
	Moderately Suitable	S_2	31.8	452.67	2
	Marginally suitable	S_3	9.20	131.05	3
	Not Suitable presently	N	19.92	283.59	4
	Not applicable	-	25.81	367.37	0

The descriptive statistics for the suitability of cauliflower over the entire study area showed that, minimum index value 3.77 and 10 as maximum index values. Similarly, the value of Sum, Mean and Median of suitability index value were 13997.31, 8.59 and 10, respectively with the standard deviation 1.95 and Coefficient of Variance (C.V) was 0.22 (Table 13).

Table 13: Descriptive statistics for suitability index of cauliflower crops of the Sharadanagar, Chitwan, Nepal, 2014

Variable	Count	Minimum	Maximum	Sum	Mean	Median	S.D.	C.V %	Variance
Suitability	1628	3.77	10	13997.31	8.59	10	1.95	0.22	3.8

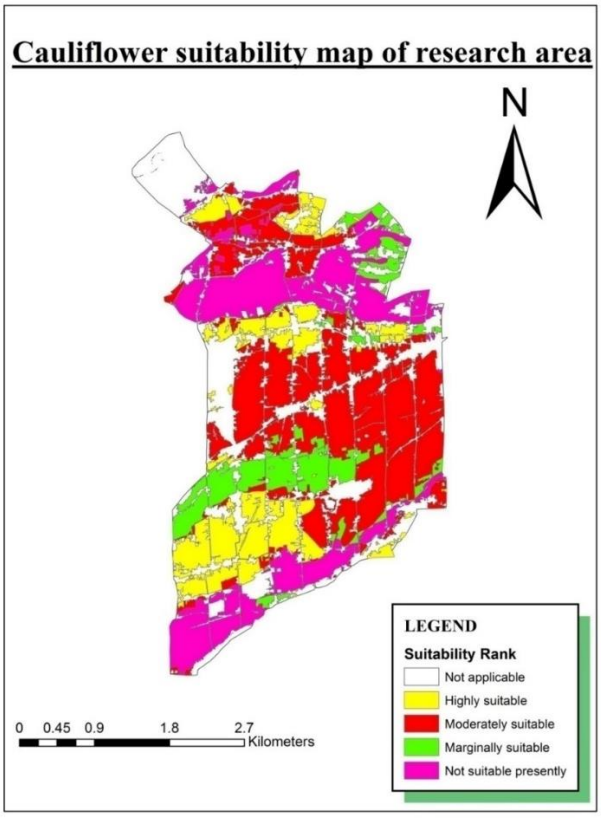


Figure 4: Map of the research sites showing the different degree of cauliflower suitability of the Sharadanagar, Chitwan, Nepal, 2014

4. Conclusion

Current research results that integration of GIS and application of MCE with AHP could provide a superior database and guide map for decision makers, planners and farmers considering crop substitution in order to achieve better agricultural production. However, in Nepal this approach is new in agriculture because it has not been used to identify suitable areas for vegetable crops. Thus, it can be concluded that soil fertility and productivity of the research locate can be improved by better use of agricultural inputs and better management of soils. The area not suitable for these vegetable crops cultivation should be allocated for another use for optimum utilization of soil resources. The soil not suitable for potato, radish and cauliflower should be used for another crop for optimum production.

REFERENCES

Austin, M., Basinski, J., 1978. Bio-physical survey techniques. *In*: Basinski, J. J. (ed.) Land Use on the South Coast of New South Wales. Study in methods of Acquiring and Using Information to Regional Land Use Options. 1. General Report, Melbourne, VIC: CSIRO Australia, 1, Pp. 24-34.

Baniya, N., 2008. Land suitability evaluation using GIS for vegetable crops in Kathmandu valley, Nepal. Ph.D. thesis submitted to Humboldt University of Berlin.

Collins, M.G., Steiner, F.R., Rushman, M.J., 2001. Land use suitability analysis in the United States: historical development and promising technological achievements. Environ. Manage, 28 (5), Pp. 611–621.

Hopkins, L., 1977. Methods for generating land suitability maps: a comparative evaluation. J. Am. Inst. Planning Asso., 34 (1), Pp. 19–29.

Malczewski, J., 1999. GIS and Multi-criteria decision analysis. Wiley & Sons Inc., New York, USA.

Permadi, 1992. Inharited from M. Chuong. 2007. Multi-criteria Land Suitability evaluation for selected fruit crops in Hilly Region of Central Vietnam. PhD dissertation submitted to Humboldt University of Berlin, Germany.

Prakash, T.N., 2003. Land Suitability Analysis for Agricultural Crops: A Fuzzy Multicriteria Decision Making Approach, M.Sc. thesis, ITC, Netherlands. Pp. 6-13.

Saaty, T.L., Vargas, L.G., 2001. Models, methods, concepts & applications of analytical hierarchy process. International Series in Operations Research and Management sciences. Boston/Dodrecht/London, Kluwer Academic Publishers.

Saaty, T.L., 1977. A scaling method for priorities in hierarchical structure. Journal of Mathematical Psychology, 15 (3), Pp. 34-39.