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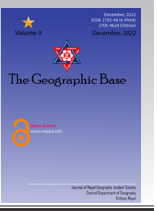

Land suitability Assessment for Cereal Crops in Sainamaina Municipality Nepal

Bishal Gnyawali *, Ishwor Aryal, Umesh Kumar Mandal

Central Department of Geography, Tribhuvan University, Kathmandu 44600, Nepal

* **Corresponding Email:** bishalg853@gmail.com

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Abstract

Land suitability is the fitness of a given type of land for a defined use. The land may be considered in its present condition or after improvements. This paper aims to present the land suitability of the study area for major cereal crops. The present study is conducted in ward no. 5, 6, 7, 8 and 9 of Sainamaina municipality Rupandehi district Nepal. Soil samples were taken from 29 different pits from polygon generated by intersecting land system map and land capability map within agricultural land use map with the help of geographic information system. Collected soil samples were tested in the soil laboratory of central department of geography, Tribhuwan University. Land suitability for major cereal crops paddy, wheat, maize and millet were derived from FAO guideline for land evaluation. As a result, the land of study area is found more suitable for wheat followed by paddy maize and millet.

Introduction

Agriculture is taken as the best occupation followed by trade and job throughout the Vedic age (Gnyawali, 2019). Nepal is known as one of the dominant agricultural countries having various topography and climate. More than 70% of the population's major livelihood source is agriculture (Mandal 2015), but its contribution to the national GDP is gradually decreasing from 40% to 32% (CBS 2011). But due to hill to tarai migration and rapid urbanization agricultural land is decreasing day by day (Gnyawali, Mandal, & Aryal, 2020). Before 1970, Nepal was a food exporter country but nowadays the situation has changed, it is importing a huge amount of agricultural products (MoPE, 2004).

The population of Nepal is increasing day by day and agricultural land is decreasing by the abandonment of agricultural land in the hilly region and the conversion of agricultural land into residential land in tarai region (Paudel, Tamang, & Shreshtha, 2014) . Fulfilling food demand in situations of decreasing agricultural land and growing population, suitability-based agriculture is needed for production of food crops in large amount (Dahal, Ghimire, & Poudel, 2022). Suitability based agriculture is the agricultural activity undertaken based on soil nutrients, climate, physiography and slope of the land (Chalise, Kumar, & Kristiansen, 2019). Land suitability for crops may be increased with the help of modern technology and indigenous knowledge rooted in our society throughout ancient time (Altiari, 2009). Agriculture may have become more profitable, productive and healthy through suitability based-practice. Similarly, the engagement of people in agriculture is also decreasing gradually (Mandal, 2013). So it is important to adopt suitability-based agriculture practices to fulfill food demand, optimum utilization of land and agricultural sustainability (Muhie, 2022).

This paper aims to present the land suitability assessment for major cereal crops for sustainable agriculture of Sainamaina municipality. This study is conducted in Sainamaina municipality. Land suitability assessment involves characterizing soil based on abundant physical chemical and biological properties of soil, climate slopes and drainage as per the requirement of crops. The population of the study area is growing day by day by the hill to Tarai migration and agricultural land is decreasing by changing it into residential land. This study may be helpful for farmers of the study area to choose suitable crops as per the land properties and may be a guideline to solve the problem of food demand in the country.

Methods and Materials

Study area

For this study ward no. 5,6,7,8 and 9 of Sainamaina Municipality, Rupandehi district Lumbini province. is selected. Geographically, it is located between 83°15'44" to83°21'01" E longitude and

27°38'48" to 27°46'05" N latitude. The study area covers a total area of 69.89 km^2. The Elevation of the study area ranges from 95m to 980m from the mean sea level. The extension of the study area is 3.95 km and 12.68 km in east-west and north-south respectively. This area is selected for study because most of the people of this area are engaged in agriculture. The study area lies in the Tarai region where in-migration from the hilly region is rapidly increasing. Due to growing in-migration in the Tarai region, Agricultural land in the Tarai region is decreasing and agricultural land of the hilly region is abandoned day to day. Land suitability assessment is very essential to feed an increasing number of people by producing a large amount of crops according to the suitability of the land.

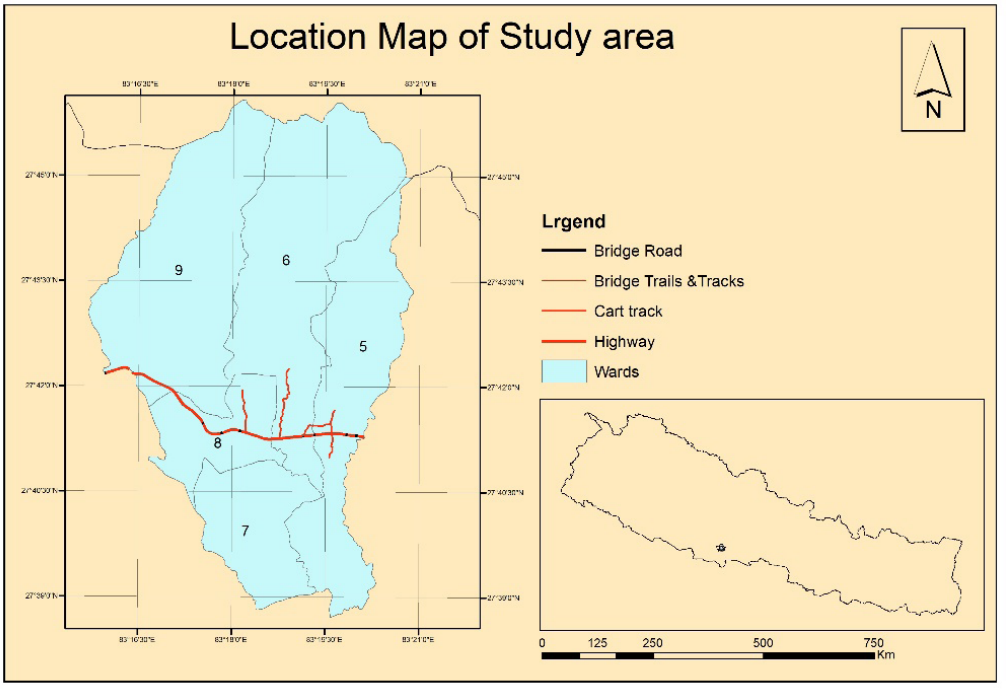

Figure 1. Location map of study area

Data collection

The present study was conducted using both primary and secondary data. Primary data on soil were taken from the field and secondary data were taken from the survey department Government of Nepal and used data from different authentic sources CBS report, VDC profile, and National Land use report.

(a) Primary data collection

Soil sampling

Table 1. Soil sample selection

land use map	Agriculture land								
land system map	Gentle Slopes	Highly Dissected	Intermediate position Level	Lithic Sub Group of 7	Moderate to Steep Slopes	Sand and gravel bar	shallow till or colluvium over bedrock	Undulating	Very Gentle Slopes
land capability map	II	I, II, VI	I, II, IV, VI	II, III, VI, IV	I, II, IV, VI	II, IV, VI	II, VI	I, II, IV, VI	I, II, VI, IV
soil sample	1	3	4	4	4	3	2	4	4
total	29								

For soil samples with the intersection of land system map (LRMP., 1986) and land capability map (LRMP, Land Capability Maps. Land Resource Mapping Poject, 1986) within agricultural land with the help of a geographic information system total of 29 polygons are generated (Table 1). Soil samples were collected from the actual land as demarcated by soil polygon and used soil profile description form prepared by FAO to collect the information of soil from the field. Collected soil samples were tested in the laboratory of central department of geography, Tribhuvan university for Nitrogen (N), Phosphorus (P_2O_5), Potassium (K_2O), Organic matter (OM) and pH content of the soil.

(b) Secondary data collection

In the study area, there are 6 types of land capability class by LRMP. Class I, II, III, IV, VI and VII. All these classes have their own characteristics. Following table shows the characteristics of different land capability classes.

Table 2. land capability class of study area

Land capability class	Characteristics
I	Cultivated <1 degree slope deep soil
II	Cultivated 5 to 30-degree slope50 to 100cm deep soil well drain
III	Cultivated 5 to 30- degree slope 50 to 100cm deep soil well drain
IV	Not cultivated > 30-degree slope more than 20cm deep soil well to imp*
VI	Not cultivated 40 to 50-degree slope <20cm deep soil vegetation
VII	River

(LRMP, Land Capability Report. Land Resource Mapping Project, 1986)

Land use map Prepared by national land use project.

National Land use data of study area taken from survey department Government of Nepal

Topographic map of study area Sheet no. 098-11 and 098-15.

Data analysis

(a) Soil sample analysis process

The soil samples which were collected from the first horizon were air-dried and crushed with the help of Mortar and Pestle. The samples were passed through a 2mm sieve and were kept for soil analysis in the soil laboratory of the Central Department of Geography. The Coarse Fragments >2mm were separated from the soil samples by the sieve method and the remaining soil was used for the soil analysis in the laboratory.

(b) Suitability Analysis Structure by FAO

The structure of soil suitability assessment mentioned in the FAO framework for Land Evaluation (FAO, 1976) includes Order, Classes, Sub-classes, and units as shown in Fig. 3. Orders (S, N) reflect the kind of suitability. Classes (S-1 to 3 under S and N-1 to2 under N) reflect the degrees of suitability within Orders. Land Suitability Subclasses (S2m, S2e, S3me under S and N1m, N1me under N) reflect kinds of limitations, or main kinds of improvement measures required, within Classes. Land Suitability Units (S2e-1, S2e-2) reflect minor differences in required management within Subclasses.

(c) Land suitability subclass

Class S1: Highly suitable land

Land having no significant limitations, or only minor limitations that will not significantly reduce productivity or benefits and will not raise inputs above an acceptable level.

Class S2: Moderately suitable land

The Land has limitations which in aggregate are moderately severe for sustained application of a given use, the limitations will reduce productivity or benefits and increase required inputs to the extent the overall advantage to be gained from the use, although still attractive, will be appreciably inferior to that expected on class S1 land.

Class S3: Marginally suitable land

The land has limitations which in the aggregate are severe for sustained application of a given use and will so reduce productivity or benefits, or increase required inputs, that this expenditure will be only marginally justified.

(d) Not suitable class

Class N1: Currently not suitable land

The land having limitation which may be surmountable in time but which cannot

be corrected with exiting knowledge at a currently acceptable cost; the limitations are so severe as to preclude successful sustained use of the land in the given manner.

Class N2: Permanently not suitable land

The land has limitations that appear as severe as to preclude any possibilities of successful sustained use of land in the given manner.

Results and Discussion

In results and discussions, it deals with land qualities of soil mapping units, criteria/limitation ratings of soil site suitability for selected crops, soil/land unit suitability evaluation for agriculture crops, and comparison between suggested & local farming practices.

Table 3. Suitability criteria for paddy

Land qualities	S1	S2	S3	N
Texture	Clay, clay loam, silt clay loam	Sandy loam, loam, sandy clay loam	Loamy sand, loamy skeletal, clay skeletal, fine sand	Sand fragmental, clay sand
Drainage	Imperfectly to poorly drained	Moderate to well drained	Somewhat excessively drained	excessively drained
Soil Depth	Very deep to deep	Moderately deep	shallow	Vary shallow
Relief	Flat, sub-normal	concave	normal	excessive
Erosion Hazard	none	slight	moderate	Severe
Corse Fragment	none	slight	moderate	severe
Risk of Flooding	None, very low	low	moderate	High
pH	Neutral(6.6-7.3)	Slightly acidic (6.1-6.5) to slight alkaline (7.4-7.8)	Moderate acidic(5.6-6.0) to moderate alkaline(7.9-8.4)	Strong acidic to strong alkaline
Slope	level	Very gently slopping	Gently slopping	Moderate steep to very steep
OM(%)	>2.0	2.0-1.5	1.5-0.8	<0.8
N	H	M	M	L
P_2O_5	H	M	M	L
K_2O	H	M	L	L

Source: (Sehgal, 1996)

Table 4. Suitability criteria for wheat

Land qualities	S1	S2	S3	N
Texture	Silt loam, silt clay loam, sandy clay, sandy clay loam	Clay, silt clay, loamy sand	Loamy sand, fine sand	Fragmental
Drainage	Well drained	Moderate well drained	Imperfectly excessively drained	Very poor to excessively drained
Soil Depth	Deep	Moderate deep	Moderate shallow	Shallow
Relief	Normal flat	Sub-normal	Concave	Excessive
Erosion Hazard	Slight	moderate	severe	severe
Corse Fragment	none	slight	moderate	Severe
Risk of Flooding	None, very low	low	moderate	severe
pH	Neutral to slight acidic	Slight acidic and alkaline	Moderate acidic and alkaline	Strongly acidic and alkaline
Slope	Level to very gently slope	Gently slope to undulating	Moderate steep	Steep to very steep
OM	>1.5	1.5-1.0	1.0-0.5	<0.5
N	H	M	M	L
P	H	M	L	L
k	H	M	L	L

Source: (Sehgal, 1996)

Table 5. Suitability criteria for maize

Land qualities	S1	S2	S3	N
Texture	Sandy clay, loamy sand, fine sand	Loam, silt loam	Clay loam, silt clay loam, clay loamy skeletal, clay skeletal	sand
Drainage	Well drained	Moderate well drained	Imperfectly to somewhat excessively	Poorly drained
Soil Depth	deep	Moderate deep	Moderate shallow	Shallow
Relief	Normal, flat	Sub-normal	concave	Excessive

Erosion Hazard	none	slight	moderate	Severe
Corse Fragment	none	slight	Moderate	Severe
Risk of Flooding	None, very low	low	Moderate	High
PH	Neutral	Slight acidic to alkaline	Moderate acidic to alkaline	Strongly acidic to alkaline
Slope	Level to gently slopping	Undulating sloping	Moderate steep sloping	Steep to very steep slopping
OM	>1.5	1.5-1.0	1.0-0.5	<0.5
N	H	M	M	L
P_2O_5	H	M	L	L
K_2O	H	M	L	L

Source: (Sehgal, 1996)

Table 6. Suitability criteria for millet

Land qualities	S1	S2	S3	N
Texture	Loam, silt loam, sandy clay loam	Clay loam, sandy loam, sandy clay loam, silt clay loam,	Sandy loam, silt clay loam, sandy clay loam	Skeletal, coarse texture, fragmental
Drainage	Moderately well to imperfectly drained	Moderately well to imperfectly drained	Somewhat excessively drained	Poorly drained
Soil Depth	Deep, very deep, moderately deep	shallow	Very shallow	Excessively shallow
Relief	Normal, flat	Sub-normal	concave	Excessive
Erosion Hazard	Debris torrent, river bank cutting	Sheet erosion, moderately rill and gully erosion	Sheet erosion, moderately rill and gully erosion	Sivere gully erosion

Corse Fragment	3-15%	15-35%	35-50%	>50%
Risk of Flooding	None	slight	Water table high, no active flood	Located in river bed
pH	neutral	Slight acidic to alkaline	Moderate acidic to alkaline	Strongly acidic to alkaline
Slope	<1	1-5	5-15	>15
OM	>1.5	1.5-1.0	1.0-0.5	<0.5
N	H	M	M	L
P_2O_5	H	M	L	L
K_2O	H	M	L	L

Source: (Sehgal, 1996)

Soil/land unit suitability evaluation for paddy

Suitability evaluation for paddy in the study area revealed that among 29 land units 23 land units are marginally suitable for paddy production. All 23 land units are suitable for paddy production like land unit 1 is marginally suitable after increasing the quantity of phosphorous. Land unit 1, 5, 6, 7, 8, 9, 11, 12, 13, 15,16, 17, 18, 20, 21 23,24, 25, 26, 27, 28, and 29 are marginally suitable for paddy production. Inland unit 1 phosphorous needs to increase, and in land unit 5 organic matter needs to be increased (Currently LU 5 is not suitable for paddy production but after increasing the quantity of organic matter land may be suitable for paddy production), Land unit 6 lacks the potash and by increasing potash, inland it can be suitable for production, from land unit 7 to land unit 9 it lacks nitrogen, phosphorous and organic matter. Most of the lands are marginally suitable for paddy production in the area.

Soil/land unit suitability evaluation for wheat

Suitability evaluation for wheat in the research area revealed that among 29 land units 14 land units are marginally suitable for wheat production. Some land units are not currently suitable for wheat production but sometimes it may be suitable for the production after increasing the amount of organic matter, phosphorous, drainage, and nitrogen. Land unit 1, 2, 3, 4, 5, 6, 7, 9, 19, 20, 22 and 24, 25, 26 are suitable for wheat production. Land unit 4 lacks the amount

of phosphorous, land unit 5 lacks the organic matter, and land unit 20 to land unit 22 lacks the amount of organic matter, nitrogen, and phosphorous. If organic matter, nitrogen, and phosphorus content is improved currently no suitable land will be suitable for wheat. Thus, it can be suggested that farmers can cultivate wheat in some parts of the land.

Soil/land unit suitability evaluation for maize

Suitability evaluation for maize in the research area revealed that among 29 land units 18 land units are marginally suitable for maize production. All 18 land units are suitable for maize production except some land units are currently unsuitable for maize cultivation. Land units 6, 7, 8, 9, 11, 13, 14, 15, 16, 17, 18, 22, 23, 24 and 26, 27, 28, 29 are suitable for maize cultivation. The result finds these lands are marginally suitable for maize cultivation. None of the lands are highly suitable or moderately suitable. Land units 6, 9, 10, 11, 22, and 26 are currently unsuitable for maize cultivation due to a lack of organic matter, phosphorous, and nitrogen. After increasing the amounts, it may be suitable for maize cultivation.

Soil/land unit suitability evaluation for millet

Some land units are not currently suitable for millet production but sometimes they may be suitable for the production after increasing the amount of organic matter, phosphorous, drainage, and nitrogen. Due to topography, some lands are not suitable for millet cultivation. Land units 1, 6, 9, 10, 11, 22, 25, 26 and 28 are suitable for maize cultivation. The result finds these lands are marginally suitable for maize cultivation. None of the lands are highly suitable or moderately suitable. Land units 6 and 9 are not currently suitable for cultivation and due to topography factors, some land units are also not currently appropriate for millet cultivation (MoPE, 2004)

Suggested crops based on soil suitability analysis for agriculture

The comparison between scientific investigation/ findings and local existing farming practices is essential to understand the knowledge gap between what should be done and what is in practice. We found land units 2, 3,4,19 are suitable for wheat, land units 12, and 21 are suitable for paddy, 14 for maize, and land unit 10 for millet. Even though soil/land mapping units such as 22 are found marginally suitable for paddy and only 9 land units are marginally suitable for millet, 14 land units are marginally suitable for wheat, and same way 18 land units are only marginally suitable for maize, farmers are found growing all food and cash crops such as mustard it is because of subsistence livelihood. Some land units are currently not suitable (sub-class) but if we improve that particular matter then we get that land to unite marginally suitable. E.g, Land unites 2 is currently not suitable for paddy by the lack of pH, but if we improve pH on that land after that it is suitable for

paddy. In the same way land unit 4 is currently not suitable for wheat by the lack of potash, if we improve the potash on that land unit it is surely suitable for wheat production. Some land units are not currently suitable for production but sometimes they may be suitable for the production after increasing the amount of organic matter, phosphorous, drainage nitrogen, and so on. Due to topography, some land is permanently not suitable for millet cultivation. If the land units are not scientifically suitable for particular crop production and still farming such crops, then it increases farming costs and another major thing that must be taken into consideration is that land degradation takes place. The local communities should be aware of the crop suitability assessment through an awareness program to make better and sustainable production with the protection of the environment.

Different soil suitability analysis is done to find out the cultivable land and not cultivable land. As per the result, the study finds different land is cultivable for crops and is suggested to cultivate the crops like paddy, wheat, maize, and millet. Annex 6 represents soil suitability analysis for different crops in different land and also suggests the land lacks crop cultivation.

Table 7. Land suitability status

Land units	Paddy	Wheat	Maize	Millet	Recommendation
1	S3k	S3k	S3t,k	S3k	Paddy, wheat, millet
2	N1pH,	S3n,k	N1pH	N1pH	Wheat
3	S3pH,n,k	S3n,k	S3t,pH,n,k	S3pH,n,k	Wheat
4	N1pH,k	N1k	N1pH,k	N1pH,k	Wheat
5	N1o	N1o	N1pH,o	N1pH,o	Paddy, wheat
6	N1p	N1p	N1p	N1p	Paddy, wheat, Maize, Millet
7	S3n,k,o	S3n,k,o	S3n,k,o	S3t,n,k,o	Paddy, wheat, Maize,
8	S3n,k,o	S3d,n,k,o	S3n,k,o	S3t,n,k,o	Paddy, Maize
9	N1k	N1k	N1k	N1k	Paddy, wheat, Maize, Millet
10	N1o	N1o	N1o	S3o	Millet
11	N1k	N1k,o	N1k	N1k	Paddy, Maize, Millet
12	S3n,k	S3d,n,k	S3t,n,k	S3t,n,k	Paddy

13	S3n,k,o	S3t,d,n,k,o	S3n,k,o	S3t,n,k,o	Paddy, Maize
14	S3n,k,o	S3t,k,o	S3k,o	S3t,k,o	Maize
15	S3k	S3t,k	S3k	S3t,k	Paddy, Maize
16	S3n,k,o	S3t,n,k,o	S3n,k,o	S3t,n,k,o	Paddy, Maize
17	S3n,k,o	S3t,n,k,o	S3n,k,o	S3t,n,k,o	Paddy, Maize
18	S3n,k,o	S3t,n,k,o	S3n,k,o	S3t,n,k,o	Paddy, Maize
19	S3ph,k,o	S3t,k,o	N1pH	N1pH	Wheat
20	N1p,k,o	N1p,k,o	N1pH,p,k,o	N1pH,p,k,o	Paddy, wheat
21	S3k	S3t,k	S3n,p,k	S3t,k	Paddy
22	N1n,k,o	N1p,o	N1p,o	N1p,o	wheat, Maize, Millet
23	S3n,k,o	S3t,n,k,o	S3n,k,o	S3t,n,k,o	Paddy, Maize
24	S3k,o	S3k,o	S3k,o	S3t,k,o	Paddy, wheat, Maize,
25	S3n,k,o	S3n,k,o	S3t,n,k,o	S3n,k,o	Paddy, wheat, millet
26	N1o	N1o	N1o	N1o	Paddy, wheat, Maize, Millet
27	S3n,k,o	S3t,n,k,o	S3n,k,o	S3t,n,k,o	Paddy, Maize
28	S3n,k,o	S3t,n,k,o	S3n,k,o	S3t,n,k,o	Paddy, Maize, Millet
29	S3n,k	S3t,n,k	S3n,k	S3t,n,k	Paddy, Maize

Source: Derived from table 2-6

Conclusion

Soil suitability assessment is one of the basic challenges in front of policymakers and land users. An integrated approach to planning and management of land resources is a key factor in meeting those challenges. Regarding this fact, FAO has developed and successfully applied the framework of land evaluation and supporting software packages to analyze solutions to various problems of land resources for planning and management for sustainable agricultural development.

In the present study, an attempt has been made to demonstrate the integrated use of GIS technology for the soil suitability assessment considering the FAO land evaluation approach and the issues mentioned above for sustainable land use planning and management. Sainamaina municipality of Rupandehi district, ward 5-9 has been taken as a case study for the testing integrated use of GI science in soil suitability assessment.

Based on this soil suitability assessment of the study area, all 29 land units are

suitable for the cultivation of crops but are marginally suitable. From the suitability assessment, it can be concluded that all four crops can be cultivated and some land units are currently unsuitable for cultivation due to a lack of nitrogen, phosphorous and organic matter. Some of the land units are currently unsuitable due to topography reasons 20 land units are not suitable for millet cultivation due to topography. Only 14 land units are marginally suitable for wheat, the same 22 land units are marginally suitable for paddy and 18 land units are marginally suitable for maize.

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