Research Article

GIS BASED APPROACH IN LAND SUITABILITY ANALYSIS OF LOKTA (*Daphne bholua*)

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ABSTRACT

Land suitability analysis is a pre-requisite in achieving optimum utilization of the available land resources. The main objective of this study was to develop a suitability map for *lokta* based on topographic, soil, land-use, land cover, and climatic factors of production using a Multi-Criteria Evaluation (MCE) & GIS approach. The study was carried out in Suspa Community Forest of Dolakha district. Biophysical variables of soil, climate, topography, and land use land cover (LULC) and water availability were considered as variable influencing for the study suitability classes. For MCE, Pairwise Comparison Matrix was applied and the suitable areas for *lokta* crop were generated and graduated. Finally, the land cover map was overlaid with the suitability map to identify variances between the present land cover. The crop-land evaluation results of this study showed that out of total 625 hectare area, 9% was under highly suitable, 22% were moderately suitable, 36% of the land was marginally suitable, and 33% were currently and permanently also not suitable. Also the suitable classes were overlaid over present land use and land class. It was found that 100% of the highly suitable land was under forest land of land use and hardwood of land cover. Thus findings of this research provided information at local level that could be useful in determining suitability status of desired species.

Key words: Land resource, optimum utilization, MCA and AHP

INTRODUCTION

Nepal is a biologically rich country with tremendous potential of high value Non Timber Forest Products (NTFPs) in the hills and mountains. NTFPs refer to all biological resources other than timber that may be extracted from natural ecosystems and managed plantations and are utilized within the household or marketed at domestic, national and international markets (Wickens, 1991). Many NTFPs in the country are also associated with their social, cultural or religious significances in different regions. (Joshi & Shrestha, 2010).

The significance of NTFPs in rural livelihood improvement and for subsistence has been established by a number of studies at the national level in Nepal (Gauli & Hauser, 2009), but little is known about their natural areas of production, sustainable collection and marketing dynamics (Bista & Edward, 2006). Tracing the history of NTFPs exploitation reveals an over-harvesting of medicinal plants; management and conservation aspects are largely being ignored. The documentation of other uses of NTFPs is essential in the sense that it will provide choices and help the communities to improve their economic conditions by exploring more market values and potentialities. (Gauli & Hauser, 2009; Uprety et al., 2010)

Among the different NTFPs found in the middle hills and high mountains of Nepal, *Lokta* (*Daphne bholua*) is used to produce handmade paper commonly known as '*local paper*' or '*Nepali paper*' or '*Nepali kagat*'. This plant grows gregariously at an elevation of 1,600 m. to 4,000 m. to the south slopes of Nepal's Himalayan forests (Biggs & Messerchmidt, 2005).

Lokta or hand-made paper is made up from fiber of native plant. It is renowned for its rough but attractive texture, durability, strength, and resistance. *Lokta* receives its name from one of the local plant species (*Daphne bholua* and *D. papyracea*) from which it is made. These plants are also known as Baruwa or KaagtePaat. They are generally small and woody and grow as shrubs reaching maximum height of 7 feet (Poudyal & Thapa, 2004).

The significance of *lokta* in rural livelihood improvement and for subsistence has been established by a number of studies at the national level in Nepal (Gauli & Hauser, 2009) but little is known about their natural areas of production, sustainable collection and marketing dynamics (Bista & Edward, 2006). In the last few couple of years, evolution of the usage of traditional *lokta* paper has been incredible. It contributes approximately 2 % to Nepal total export and market of it has been growing on 7-8 % on average every year (Dhakal, 2010).

Dolakha is one of the potential district for NTFP production. The main NTFPs traded from the regions are Chiraito (*Swertia chirayita*), Majhito (*Rubia manjith*), Allo (*Girardinia diversifolia*), *Lokta* (*Daphne bholua*), Argeli (*Edgeworthia gardneri*), Jatamansi (*Nardostachys jatamansi*), Panchaunle (*Dactylorhiza hatagirea*), Sunpati

(*Rhododendron anthopogon*), Dhupi (*Juniperus species*), Bhir mauri *(Apis laboriosa)* and several others (Subedi et al., 2010). The forest type's ranges from *Schima-Castanopsis* though the majority is formed by Rhododendron forests, extending high up to Quercus forest, representing the dominant higher altitudinal coverage by the landscape to lower temperate (Quercus) forests.

Dolakha district has enormous potentials for production of *lokta*. Dolakha is practicing community forestry program since its emergence from early 1980s and have shown significant success on resource and institutional development. Since that time forest user groups are formed that have been managing community forests. They are in the process of building alliances in managing and utilizing *lokta* particularly the process of harvesting, transportation and papermaking. (Poudyal & Thapa, 2004).

GIS is a computer based information system that has a capability of handling all kinds of spatially referenced land related data at all mapping scales in support of decision making. It enables the contribution, management, operation, analysis, modeling, amount produced, and dissemination of spatially referenced land-related data. It is the fundamental science geographic concepts and many applications in various fields. Land suitability classification is the appraisal and grouping of specific areas of land in terms of their suitability for defined uses (Chen & Khan, 2010). The Food and Agricultural Organization recommended an approach for land suitability evaluation for crops in terms of suitability ratings ranging from highly suitable to not suitable based on climatic and terrain data and soil properties. Cropland suitability analysis is a prerequisite to achieve optimum utilization of the available land resources for sustainable agricultural production. Land evaluation and crop suitability analysis using GIS and remote sensing would resolve these issues while providing better land use options to the farmers. Productivity of land can be determined by environmental components such as climate, local topography (roughness, steepness, and exposure), soil type and existing vegetation. Improper land use results in land degradation and decline in agricultural productivity (Chen & Khan, 2010).

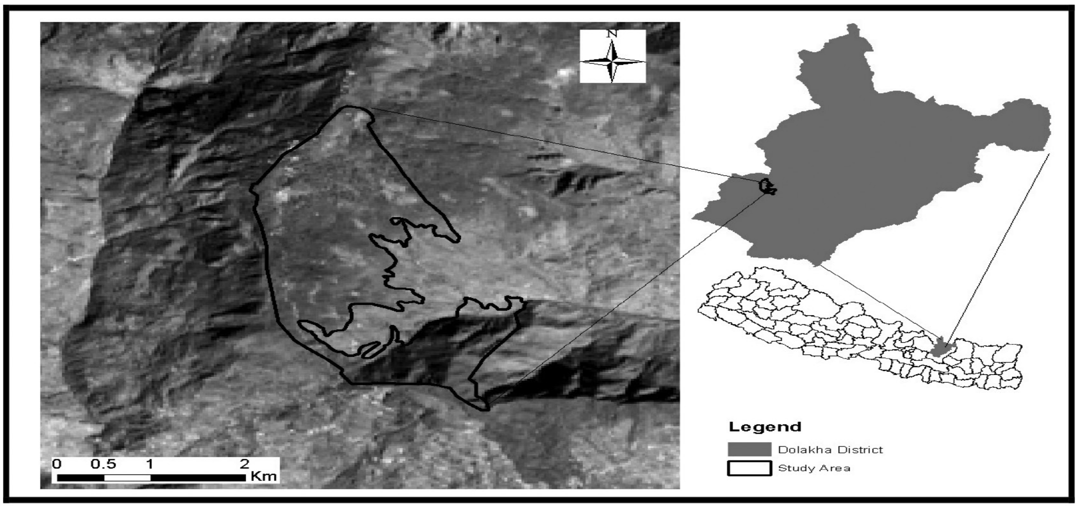
Spatial Multi Criteria Decision Making (SMCDM) adds the spatial component to the decision making process so that the entire process requires: The GIS component (e.g.: data acquisition, storage, retrieval, manipulation, and analysis capability), and the MCDM analysis component (e.g.: aggregation of spatial data and decision maker's preferences into discrete decision alternatives) (Jankowski, 1995)

Land evaluation and crop suitability analysis using GIS and remote sensing would resolve the issues for providing better land-use options to the people depending on land and natural resources. Productivity of land can be determined by environmental components such as climate, local topography (roughness, steepness, and exposure), soil type and existing vegetation. Improper land use results in land degradation and decline in agricultural productivity (Chen & Khan, 2010). Under this context, this study was done with the main objective to integrate the application of the GIS for land suitability evaluation of the *lokta* in the community managed forest of Charnawati landscapes of Dolakha District of Nepal.

MARERIAL AND METHODS

Study area

Suspa Community forest (CF) is located on the south-west part of Dolakha district. Federation of Community Forestry Users (FECOFUN) and Asia Network for Sustainable Agriculture and Bio-resources has collaborated and able to certified 11 community forest of Dolakha under Forest Stewardship Certification (FSC) Scheme. Suspa CF is one of FSC certified forest. The study area is located in Charnawati landscape having 625 hector areas with elevation range of 1660m to 3120m. The forest has slope range from 0 to 63 degree with soil three different soil orders i.e. Humic Cambisol, Chromic Cambisol and Eutic Cambisol.



Location Map of the study Area

Materials and software

Different data sources and software were used during the research (Table 1).

Table 1. Materials and software used in the study

Materials and software	Source	Purpose
GPS Point	Field	Field verification
Land use and Land cover Map	ANSAB	Suitability Analysis
Soil Data	Soil and terrain database (SOTER)	Soil Suitability Analysis
Temperature and Precipitation	Worldclim	Suitability Analysis
ARC MAP 10.1	ESRI	Suitability Analysis
MS excel 2013	Microsoft Cooperation	AHP and MCD Analysis
Google Earth Pro		Digitization and verification

Methods

Variable identification

Possible variables that affect the suitability of *lokta* were found out through the help consultation with expert, local informant and field verification. List of variable which influence the growth of *lokta* is prepared and participatory resource mapping was done to identify tentative distribution zone of *lokta*. Detail information of *lokta* and its distribution on study area were collected from field and cross verification was done with the information collected from local informant and expert. Elevation, Aspect, Slope, Soil Classification, Land use, Land cover, Precipitation, Temperature, and Stream distance are found most influencing factor.

Variable influence assessment

Influence of variable on the growth and availability of *lokta* was identified through the AHP and Multi criteria assessment. For the listed variable, pair wise comparison matrix was prepared on 9 by 9 matrix (Saaty, 1990). Each factor is paired with another factor and a comparison is made on a scale of 1 to 9 by using 1,3,5,7 and 9 for equal influence, slightly strong influence, strong influence, very strong influence and extreme importance. Intermediate value (2, 4, 6 and 8) for the comparison between main values.The comparison were made by the group of expert of four member from different field i.e. GIS expert, NTFP researcher, *Lokta* researcher and forest and climate change expert. After that, Normalized matrix was used to find out the influence weight. The values in the pairwise comparison matrix were normalized by using the relation.

Normalized value = Rating value of the cell /sum of the column containing the cell

This relation helped to obtain pairwise normalized comparison matrix. From the normalized matrix, weight of each criteria were assigned by taking the average of the rows.

Weight = Average value of the row of each variable

Weight in % = Weight * 100 %

After finding the weightage of the variable, it is necessary to calculate the consistency of the pairwise comparison matrix. To find out the consistence, the value of relative consistency Index (RCI) is obtained from the standard table. Maximum Eigen vector is calculated to find out maximum Eigen number. Consistency index and consistency ratio is calculated by using following relation.

Eigen number = Row average of Eigen vector / column sum of original matrix.

Consistency Index (CI) = (λ – n) / (n -1)

Consistency Ratio = CI/RCI

Suitability class of each variable

Suitability class S1 to S5 (Table 2) were used in ranking suitability where suitability classes were highly suitable, moderately suitable, marginally suitable, currently not suitable, and permanently not suitable (FAO, 1976). Slope, aspect and elevation suitability classes were produced by using Digital Elevation Model. For the land use and land cover suitability classes classification map prepared by ANSAB was used. Temperature and precipitation suitability classes were produced by reclassification of bioclimatic variable from Global Climate Data. Proximity to stream was prepared by digitizing stream from google earth pro and buffer analysis of that digitized streams.

Table 2. Variable and Suitability classes

VARIABLES	S1	S2	S3	S4	S5
	1	**2**	**3**	**4**	**5**
Slope (degree)	25.46-38.20	38.20-50.93	12.73-25.46	50.93-63.66	0-12.73
Aspect (degree)	South(45-135)	West(225-315)	East(45-135)	North(315-45)	Flat(0)
Elevation (m)	2828-3120	2536-2828	2244-2536	1952-2244	1660-1952
Soil Order	Humic Cambisol	Chromic Cambisol	Eutic Cambisol	-	-
Land use	Hardwood	Conifer	Shrub land	Grazing land	Level terrace
Precipitation (mm)	220.6-255.50	255.50-288.48	288.48-318.29	318.29-345.57	345.57-382.35
Proximity to Stream (m)	50-100	Up to 50	100-150	150-200	200 above
Temperature (° C)	13.51-15.94	15.94-17.24	17.24-20.6	-	-

Suitability analysis

After preparing the suitability classes for each variable, weightage overlay analysis function were ran where weight were used from the result of AHP and MCD Analysis. Total areas on each suitability class were obtained accordingly (Figure 1).

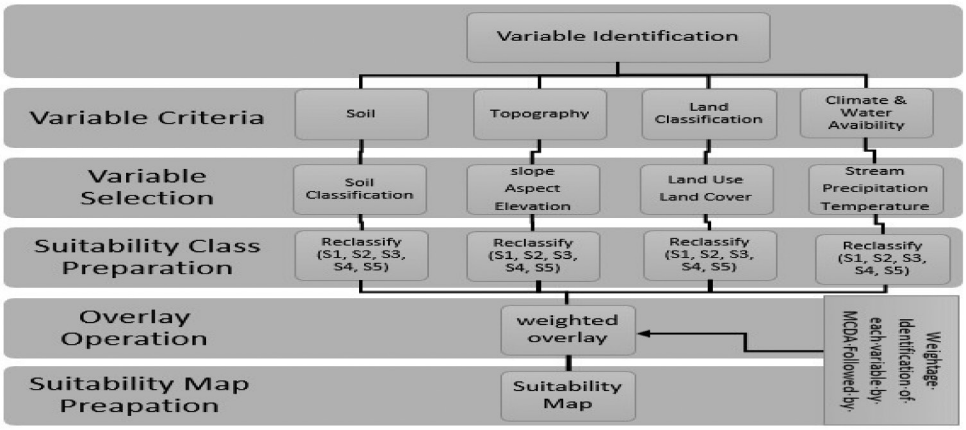


Figure 1. Methodological framework

RESULTS AND DISCUSSION

Variable and their influence on growth and availability on *lokta*

Major nine variable which have key role on availability of *lokta* were identified and each variable is paired with another variable and a comparison is made on the basis of their importance for the availability of *lokta* and mention on the scale of 1 to 9 where 1 is least important and 9 is extremely important than paired variable and the result area as follow on Table 3. For eg. Elevation is more important than precipitation as value is 5 (Row 2, Column 8). So precipitation and elevation pair has 0.14 value i.e 1/7 (Row 8, Column 2)

Table 3. Pairwise comparison matrix

Variables	Elevation	Aspect	Slope	Soil	Land cover	Land use	Precipitation	Stream	Temp.
Elevation	1	5	3	3	5	7	5	9	9
Aspect	0.2	1	5	5	3	5	7	7	9
Slope	0.33	0.2	1	0.33	5	3	3	5	7
Soil	0.33	0.2	3	1	5	5	3	5	5
Land cover	0.2	0.33	0.2	0.2	1	3	3	5	5
Land use	0.14	0.2	0.33	0.2	0.33	1	3	3	5
Precipitation	0.2	0.14	0.33	0.33	0.33	0.33	1	2	3
Stream	0.11	0.14	0.2	0.2	0.2	0.33	0.5	1	2
Temperature	0.11	0.11	0.14	0.2	0.2	0.2	0.33	0.5	1
Sum	2.62	7.32	13.2	10.46	20.06	24.86	25.83	37.5	46

Out of major nine influencing variable, five variable i.e. elevation, aspect, soil, slope and land use have more influence with weight 27%, 22%, 14%, 11% and 10% whereas land cover, precipitation, temperature and stream proximity has low influence with weight 8%, 4%,2% and 2% (Table 4).

Table 4. Normalized Matrix for Weightage Calculation

Variables	Dem	Aspect	Slope	Soil	Land cover	Land use	Precipitation	Stream	Temp.	Weight	Weight %
Dem	0.35	0.41	0.23	0.29	0.25	0.28	0.19	0.24	0.2	**0.27**	**27**
Aspect	0.07	0.08	0.38	0.48	0.15	0.2	0.27	0.19	0.2	**0.22**	**22**
Slope	0.12	0.02	0.08	0.03	0.25	0.12	0.12	0.13	0.15	**0.11**	**11**
Soil	0.07	0.02	0.23	0.1	0.25	0.2	0.12	0.13	0.11	**0.14**	**14**
Land cover	0.12	0.03	0.02	0.02	0.05	0.12	0.12	0.13	0.11	**0.08**	**8**
Land use	0.12	0.41	0.03	0.02	0.02	0.04	0.12	0.08	0.11	**0.1**	**10**
Precipitation	0.07	0.01	0.03	0.03	0.02	0.01	0.04	0.05	0.07	**0.04**	**4**
Stream	0.05	0.01	0.02	0.02	0.01	0.01	0.02	0.03	0.04	**0.02**	**2**
Temperature	0.04	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.02	**0.02**	**2**
Sum	1	1	1	1	1	1	1	1	1	**1**	**100**
Maximum Eigen Value(□)				**9.06**							

Consistency index (CI) of 0.008 was found through the consistency test with maximum Eigen value 9.06 (table 4) for the nine variable. From the ratio of consistency index and relative consistency index, consistency ratio was calculated and found 0.05 which is less than 0.1, and then the matrix is consistence enough.

Suitability class (S1 to S5) for each variable

Based on the nature of data and availability of *lokta* on the study area, each variable were classified on five suitable classes except temperature and soil. Out of five suitable classes, study area is found highly suitable as per the land cover (84%) and Soil (78%), whereas maximumarea is foundmoderately suitable on the basis of slope (48%), Land use (45%) Temperature (44%), and Proximity to stream (26%). Maximum land on the basis of aspect (43%) and elevation (38%) variable foundmarginally suitable. For the precipitation variable the maximum land (41%) found permanently not suitable (Table 5).

Table 5. Suitability Criteria of *Lokta* availability

	Variables								
	Aspect	**Elevation**	**Stream**	**Precipitation**	**Temperature**	**Land Use**	**Slope**	**Soil**	**Land Cover**
S1	130 (21%)	87 (14%)	145 (23%)	66 (10%)	243 (39%)	251 (40%)	204 (33%)	482 (78%)	524 (84%)
S2	116 (19%)	165 (27%)	160 (26%)	75 (12%)	274 (44%)	279 (45%)	303 (48%)	110 (17%)	65 (10%)
S3	271 (43%)	239 (38%)	121 (19%)	118 (19%)	108 (17%)	28 (4%)	56 (9%)	33 (5%)	10 (2%)
S4	98 (15%)	100 (16%)	85 (14%)	111 (18%)		23 (4%)	53 (8%)		26 (4%)
S5	10 (2%)	33 (5%)	113 (18%)	225 (41%)		45 (7%)	10 (2%)		1 (0%)

The figure was generated showing different spatial context of suitability on each variable. The dark green color in the map is highly suitable area where as yellow region is marginally suitable and red area is currently to permanently unsuitable region for the each variable (Figure 2).

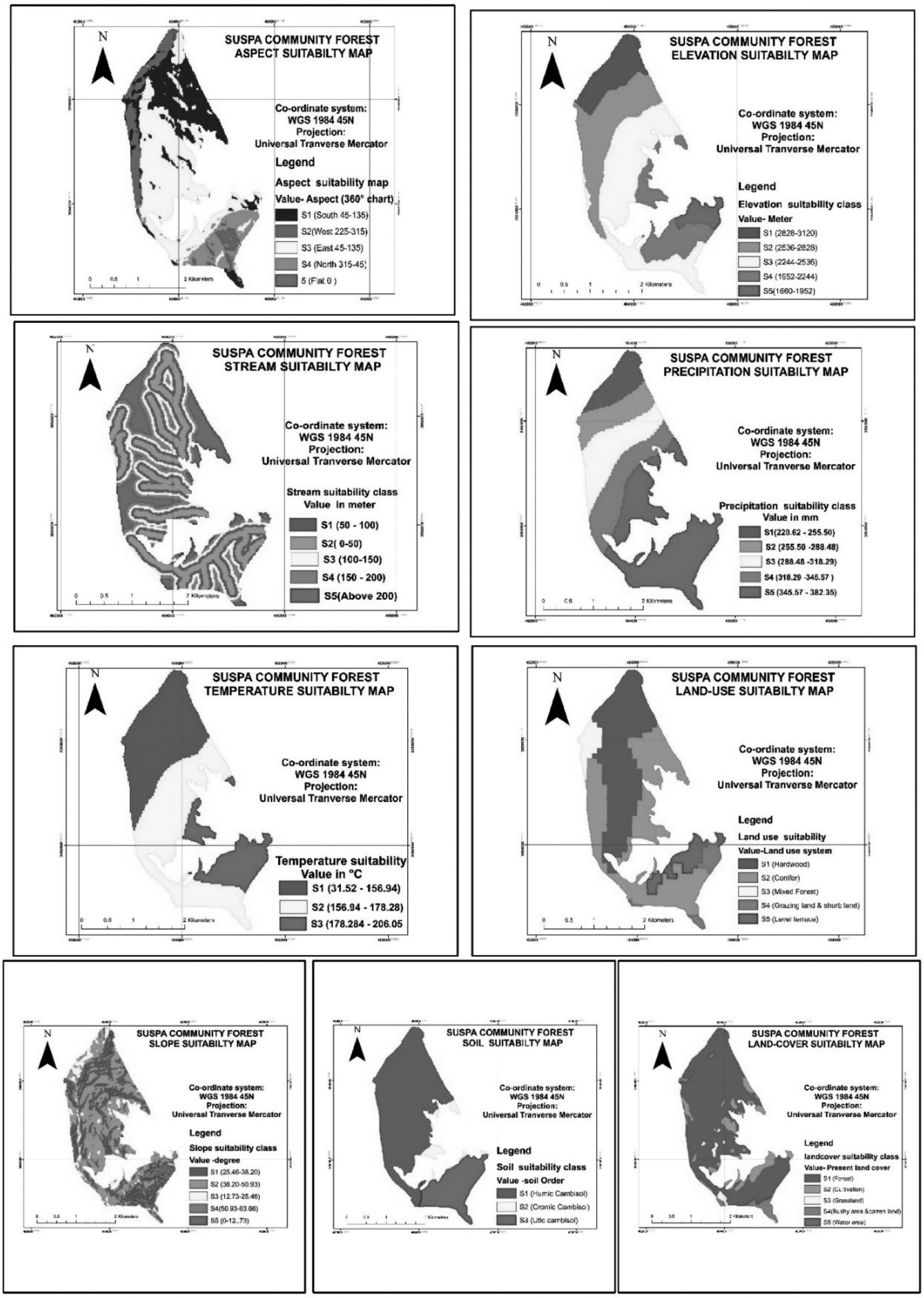


Figure 2. Map showing suitable region according to each variable for *lokta* availability

Overall Suitability of Land for *Lokta*

After all those variables with the suitability of sub variable were overlaid on the basis of the influence of the variable, suitable map containing suitable classes was obtained (Figure 3). The suitable classes were ranged from highly suitable to permanently not suitable land. Maximum area 225 ha (36%) is found marginally suitable (S3) followed by moderately suitable (135 ha), currently not suitable (135ha) whereas 75 ha land is permanently not suitable and 55 ha is highly suitable.

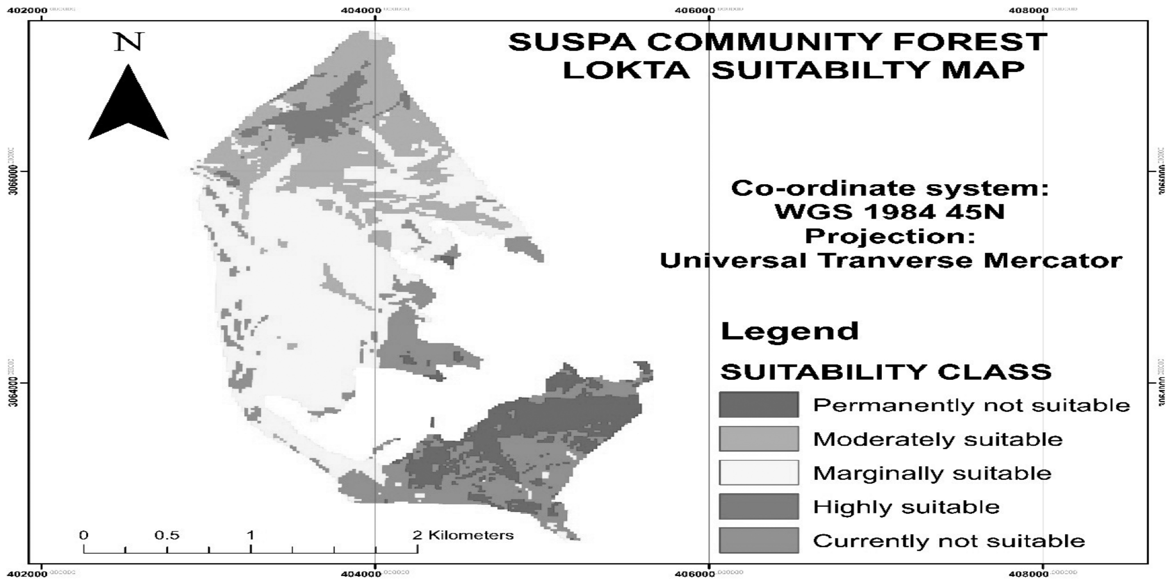


Figure 3. Overall Suitability map for *Lokta*

On the different land use system, highly suitable (55 hectare) is found under forest which is hardwood forest. The results shows that hardwood forest area the most productive area for the *lokta*.

Table 6. Area under each suitability class

Suitability class	Area (m2)	Area (Hectare)	Covered area in %
Highly suitable (S1)	550000	55	9%
Moderately suitable (S2)	1350000	135	22%
Marginally suitable (S3)	2250000	235	36%
Currently not suitable (S4)	1350000	135	22%
Permanently not suitable S5)	750000	75	12%
SUM		625	100%

Khadgi et al. (2013) has discussed about habitat analysis of *Lokta* in Aannapurna Conservation Area on which studies all the scenarios of the habitat is presented statistically which information is crucial for the conservation and management of *Lokta* but cannot get spatial knowledge. The study using same methodology has found most of the land of Kathmandu valley has good potential for the cereal crop production and need to this communicate to make the full use of land potential (Baniya, 2008). This method of land suitability assessment has previously used especially for the agricultural crops (Neupane et al., 2014) and wildlife habitat management (Kafley et al, 2009; Thapa, 2014) but it also has very potential for the NTFP management. This study mainly focused and provide the spatial information, so particularly the result from this research is equally important for the policymakers, researchers as well as farmers.

CONCLUSION

More than two third areas were potential for cultivation of *lokta*. The approximately one third land of community forest was highly and moderately suitable land whereas another one third land was under marginally suitable condition, but remaining one third land was under currently as well as permanently not suitable condition. It was also found that 100 % (55 hectare) land of highly suitable class lies in forest area of land use and hardwood forest of land cover. Also the overlay analysis of suitable map for the validation of the map with respect to the present distribution of *lokta* showed that 90 % of the land of highly suitable area is within the distribution zone. Likewise 60 % of the land of moderately suitable land were under distribution zone. This validation shows that the suitable maps are of great accuracy and the result can be used for the planning of *lokta* and its production within the region. The results obtained from this study indicate that the use of GIS and application of Multi-Criteria Evaluation using AHP could provide a superior database and guide map for decision makers considering crop substitution in order to achieve better production.

This kind of research and study helps to create a sustainable use of the resources. As *lokta* production can be effectively done in highly and moderately suitable land, CFUGs are recommended to carry out planation and production of *lokta* on those areas. The land lying on the marginal suitability and other suitability classes are recommended to be diversified for other plant production rather than *lokta*. The management of the forest activates can be based on the suitable areas. Local people, stakeholders, natural planners, enterprise developers and marking agencies are recommended to integrate this result to plan several other activities related to the *lokta*. The variables chosen for the study were limited and which can limits its application. For further study, it is important to consider several other factors such as soil properties, irrigation facilities and socio-economic which are also quite related to the sustainable use of the land.

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