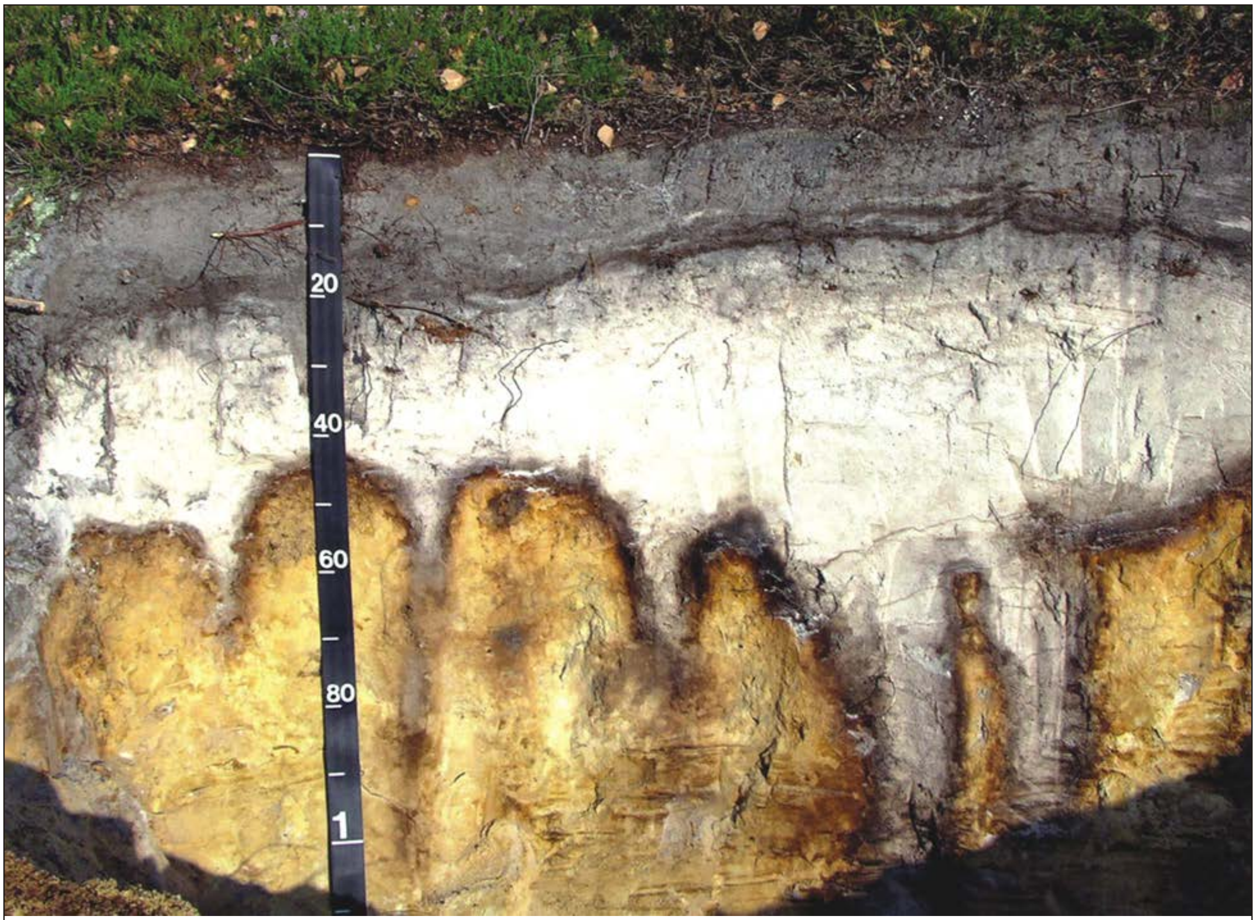

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Conceptualizing and Assessing Sustainability of Contrasting Land Uses in Chitwan, Nepal

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ABSTRACT

A research was conducted in 2011 to assess sustainability of different land uses in Chitwan, Nepal with the integrated use of Geographic Information System (GIS). Six VDCs from Chitwan were randomly selected to represent four types of land uses viz. agriculture, wetland, grazing land and agroforest land. One profile from each land use and two soil samples from each land use were taken from surface soil (0-20 cm soil depth) from each VDC for laboratory analyses. Ten soil parameters were taken to assess the sustainability of different land uses. Half of the agricultural and grazing lands, none of the wetlands and 83.33% of the agro-forest land were sustainable with present land use.

Key words: Geographic information system, soil sustainability, soil fertility, productivity

INTRODUCTION

Sustainability assessment is being increasingly viewed as an important tool to aid in the shift towards sustainability. However, this is a new and evolving concept and there remain very few examples of effective sustainability assessment processes implemented anywhere in the world. Sustainability assessment is often described as a process by which the implications of an initiative on sustainability are evaluated, where the initiative can be a proposed or existing policy, plan, programme, project, piece of legislation or a current practice or activity. However, this generic definition covers a broad range of different processes, many of which have been described in the literature as 'sustainability assessment'. Here we are mainly focusing on sustainability assessment of soils of a particular place of interest.

Sustainable agriculture is one that, over the long term, enhances environmental quality and the resource base on which agriculture depends; provides for basic human food and fibre needs; is economically viable and enhances the quality of life for farmers and society as a whole. Sustainability of soil can be assessed by periodic evaluation of indicators related to soil properties and processes. An appropriate indicator is one which provides a quantitative measure of the magnitude and intensity of environmental stress experienced by plants and animals. These indicators based on properties and processes can be assessed by field and laboratory analyses or predicted by modeling. Resource base indicators deal with broader issue of the overall resource use rather than with inherent properties of soil, water or vegetation components. The resource base is a generic term involving all natural resources i.e., biophysical, socio-cultural and cultural. A system is sustainable only if the land use is compatible with land use capability. An incompatible land use is bound to set-in-motion land degradative processes. Landscape diversity is another useful indicator of sustainability. Diverse landscape is indicative of a sustainable land use. Land forming to remove diverse landscape type may lead to an unstable and an unsustainable landscape. Alternative and diverse land uses, within its land use capability, are also compatible with sustainable land use systems (Shriwastav, 2008).

Sustainability of soil resources can also be assessed from the trends in amount and nature of off-farm inputs required to produce yields equivalent to that obtained before and the degree of managerial skills needed to alleviate soil and crop related constraints to obtain the desired yield level. In general, the more the inputs required producing the same yield, the less sustainable is the system. Need for excessive a managerial input to produce the same yield is indicative of soil degradation. In contrast, science based management in relation to the expected yield is indicative of soil maintenance or enhancement. Timing of farming operations is another useful management indicator. All other factors remaining the same, farm operations done on schedule are indicative of sustainable use of soil resources. Delayed farm operations, due to wet soil or excessive tillage needed to prepare optimum seedbed, are indicative of non-sustainable use of soil resources.

MATERIALS AND METHODS

Study area: The study was carried out in the Western part of the Chitwan district, Nepal. Six VDCs out of eighteen i.e., Mangalpur, Sharadanagar, Shivanagar, Patihani, Phoolbari and Gunjanagar from Western Chitwan were randomly selected to represent four types of land uses viz. agriculture, wetland, grazing land and agroforestry (Fig. 1). One profile from each land use and two soil samples of each land use were taken from 0-20 cm soil depth from each VDC. Altogether there were 122 soil samples for the laboratory analysis. Soil analyses for different properties were carried out by following methods.

The commonly used approach to analyze sustainability of soil resource proposed by Lal (1994) can be adopted. The sustainability analysis is done by taking information about the following parameters: Effective rooting depth, coarse fragments of surface (%), texture, soil structure its morphology, consistency, BD, porosity, AWC, saturated conductivity (Ksat), infiltration rate, pH, CEC organic matter content of soil, plant available N, P, K. Weighing factors for ten relevant indicators are combined into cumulative index (Fig. 2). The relevant indicators may differ among soil types, crops, cropping systems and land uses. The maximum value of the cumulative index based on ten factors is 50.

The research scheme used in present study is shown in Table 1.

Methods of data collection: Sampling locations were selected from cropping system which has more than last twenty years of cropping history and pedon description were carried in mentioned land use system. The collected soil samples were air-dried and sieved through 2 and 0.2 mm sieves. The soil samples were labelled and kept in cool and dry place for physico-chemical analyses (Table 2). The geographic coordinates of the soil profile were recorded on the spot using portable GPS receiver.

All the soil samples were analyzed in the Regional Soil Testing Laboratory, Hetauda, Makawanpur.

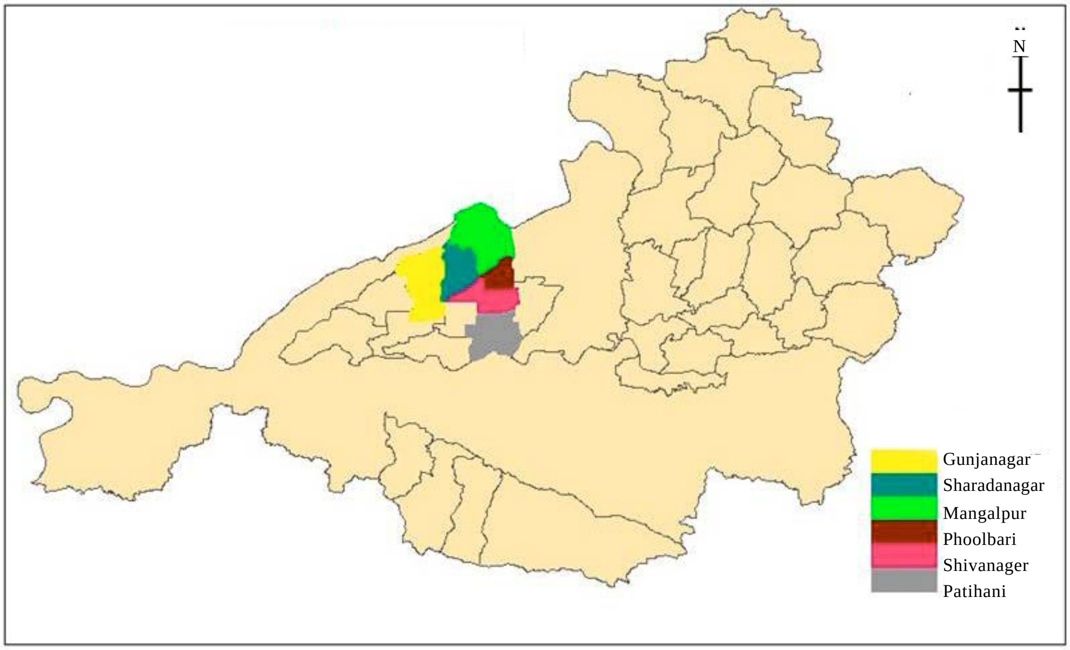

Fig. 1: Chitwan district showing the research sites

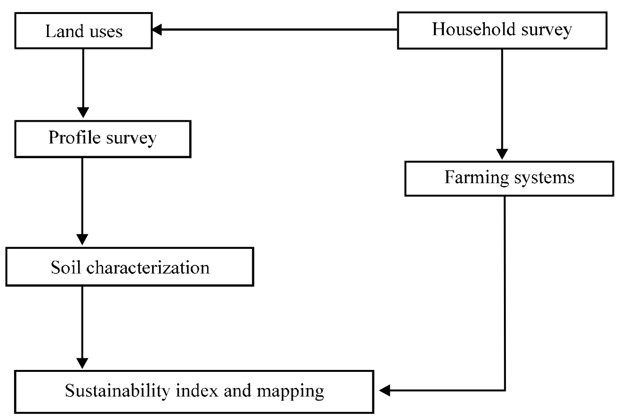

Fig. 2: Flowchart for sustainability of land uses

Table 1: Research scheme for profile study and soil sample collection for laboratory analyses

	Land use/cover	Size	
Village development committees	Profile+soil sample	Profiles	Soil samples
Phoolbari	Agricultural land (1+2)	1*4 = 4	2*4 = 8
	Wetland (1+2)		
	Grazing land (1+2)		
	Agro-forest land (1+2)		
Gunjanagar	Agricultural land (1+2)	1*4 = 4	2*4 = 8

Table 1: Continue

	Land use/cover	Size	
Village development committees	Profile+soil sample	Profiles	Soil samples
	Wetland (1+2)		
	Grazing land (1+2)		
	Agro-forest land (1+2)		
Mangalpur	Agricultural land (1+2)	1*4 = 4	2*4 = 8
	Wetland (1+2)		
	Grazing land (1+2)		
	Agro-forest land (1+2)		
Patihani	Agricultural land (1+2)	1*4 = 4	2*4 = 8
	Wetland (1+2)		
	Grazing land (1+2)		
	Agro-forest land (1+2)		
Sharadanagar	Agricultural land (1+2)	1*4 = 4	2*4 = 8
	Wetland (1+2)		
	Grazing land (1+2)		
	Agro-forest land (1+2)		
Shivanagar	Agricultural land (1+2)	1*4 = 4	2*4 = 8
	Wetland (1+2)		
	Grazing land (1+2)		
	Agro-forest land (1+2)		
Sub total		24	48
Grand total			72

Table 2: Laboratory analysis techniques for different soil physical and chemical properties

Indicators/Attributes	Methods	References
Texture	Mechanical analysis method	USDA (1980)
Soil structure	Field method WSA>1mm	Kemper and Rosenau (1986)
Porosity	Mathematical expression	Brady and Weil (2002)
Coarse fragments in surface (%)	Field method	………………
Consistency (moist)	Field method	………………
pH	pH meter	Mclean (1982)
Soil depth	Field method	………………
Total organic carbon	Titration method	Walkley and Black (1934)
Total nitrogen analysis	Distillation method	Bremner (1965)
Available phosphorus	Olsen method	Watanabe and Olsen (1965)
Available potassium	Ammonium acetate extraction method	Pratt (1965)

Shriwastav (2008)

Statistical analysis and interpretation of results: The data collected through personal interview were coded, tabulated and entered for computer entry. They were analyzed by descriptive as well as inferential statistical tools wherever possible. Soil organic matter, texture, N, , K and pH data obtained from laboratory analyses were rated according to standard rating of Soil Science Division, Khumaltar, Lalitpur (Table 3 and 4) and Khatri-Chhetri (1991) and analyzed using Statistical Packag e for Social Sciences (SPSS 16) and Microsoft Excel 2007.

Table 3: Rating chart for the classification of soil fertility status of soils

Nutrient status	Soil organic matter (%)	Total N (%)	Available P_2O_5 (kg ha^{-1})	Available K_2O (kg ha^{-1})
Very low	<1.0	<0.05	<10	<55
Low	1.0-2.5	0.05-0.1	10-30	55-110
Medium	2.5-5.0	0.1-0.2	30-55	110-280
High	5.0-10.0	0.2-0.4	55-110	280-500
Very high	>10.0	>0.4	>110	>500

Soil Science Division, Khumaltar, Lalitpur, Nepal

Table 4: Rating chart for soil reaction rating of the soils

Soil pH value	Soil reaction rating
<6	Acidic
6.0-7.5	Neutral
>7.5	High

Khatri-Chhetri (1991)

Table 5: Soil texture classification

Soil texture	Soil types
Light	Sands and loamy sands
Medium	Sandy loam, fine sandy loam, very fine sandy loam, loam, silt loam, silt, clay loam, sandy clay loam and silty clay loam
Heavy	Sandy clay, silty clay and clay

Foth (1984)

Broader grouping of textural classes was done as light textured soils (sandy soils), medium textured soils (loamy soils) and heavy textured soils (clayey soils) (Foth, 1984). The classification devised for grouping soils texturally is shown in Table 5.

Assessment of potential and constraints of the resource for different land uses in based on the knowledge of critical level of soil and water indicators. The critical level of an indicator or an attribute is defined as the level beyond (below or above) which crop/animal production declines rapidly. The lower limit of critical level is the one at which degradation rate is high but the trend can be reversed. Upper limit of the critical level refers to the point of no return or irreversible soil degradation. It is extremely important to establish appropriate criteria for establishment of critical levels of soil and water indicators. Sustainable use of soil resources being the principle objective, critical levels should be related to productivity (Table 6). Different critical levels should also assigned rating or weighing factors. Weighing factors, the relative significance of that factor, is based on the productivity loss at that level of soil indicator. To assess the sustainability of different land uses various soil indicators and their critical levels were taken (Fig. 3).

RESULTS AND DISCUSSION

The study revealed only three classes of sustainability index were found in the research area viz. sustainable, sustainable with high input/management and sustainable with another land use. The land uses unsustainable with present land use can be sustained by switching it to another land use in order to improve the soil qualities. Table 7-9 shows that 50% of the agricultural land is sustainable with the present land use, 33.33% is sustainable but only with high input/management and remaining 16.66% is unsustainable with present land use but sustainable with another land

Table 6: Suggested critical levels of soil indicators

Relative weighing	Effective rooting depth (cm)	Texture	pH	SOM (%)	Coarse fragments	Consistency	Nitrogen	Phosphorus	Potassium	Soil structure
1	>150	Loam	6.0-7.0	>10.0	<10	Loose	>0.4	>110	>500	Strong subangular blocky to crumb/granular
2	100-150	Silt loam, silt, silty clay loam	5.8-6.0 and 7.0-7.4	5.0-10.0	10-20	Very friable	0.2-0.4	55-110	280-500	Subangular blocky
3	50-100	Clay loam, sandy loam	5.4-5.8 and 7.4-7.8	2.5-5.0	20-40	Friable	0.1-0.2	30-55	110-280	Moderate subangular blocky
4	25-50	Silty clay, loamy sand	5.0-5.4 and 7.8-8.2	1.0-2.5	40-60	Hard	0.05-0.1	10-30	55-110	Weak subangular blocky
5	<25	Clay, sand	<5.0 and >8.2	<1.0	>60	Extremely hard	<0.05	<10	<55	Massive or single grained

Lal (1994)

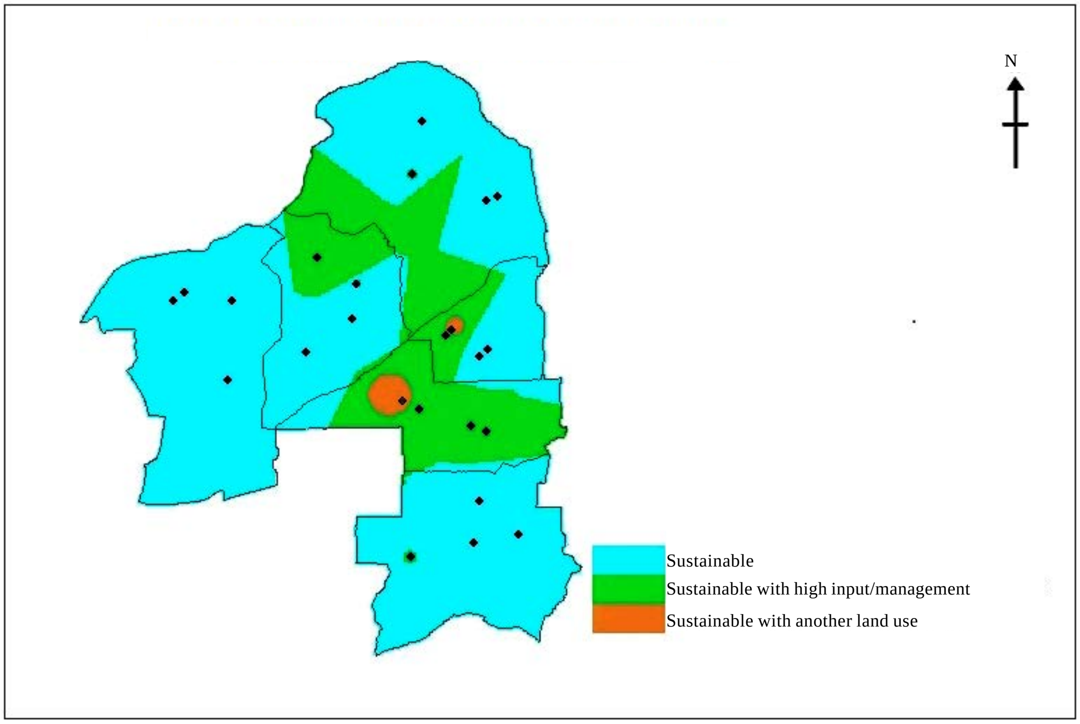

Fig. 3: Research sites showing the different degrees of soil sustainability of the Village Development Committees, Western Chitwan, Nepal, 2011

Table 7: Sustainability of a land use in relation to the cumulative rating index based on 10 soil indicators

Sustainability	Cumulative rating index
Highly sustainable	<20
Sustainable	20-25
Sustainable with high input	25-30
Sustainable with another land use	30-40
Unsustainable	>40

Lal (1994)

use in the study area. The 83.33% of the wetland area is sustainable with high input/management and 16.66% sustainable with another land use. Regarding the grazing lands of the study area, half of the grazing lands were sustainable with present land use and half were sustainable with present land use system but only with high input/management. Greater portion of agro-forests (83.33%) in the study area were sustainable and only 16.66% were sustainable with high input/management.

CONCLUSION

Thus it can be concluded that soil fertility and productivity of the research locale can be improved by better use of agricultural inputs and better management of soil types. Nowadays, there is increasing concerns on sustainability of land uses. Crop diversification and inclusion of tree component along with the leguminous crop species contribute to the sustainability of agro-forest land. Solutions of problems associated with the unsustainability of agriculture, wetland and grazing lands needs to be addressed for further study.

Table 8: Rating of soil qualities for sustainability of land uses of the Village Development Committees, Western Chitwan, Nepal (2011)

VDC	Land use	Effective rooting depth (cm)	Texture	pH	OM (%)	Coarse fragments	Consistency	Nitrogen (%)	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})	Soil structure	Cumulative rating
Phoolbari	Agriculture	4	3	4	3	1	4	3	1	4	1	28
	Wetland	5	3	1	4	1	4	3	2	3	5	31
	Grazing land	5	4	3	3	1	1	3	1	4	2	27
	Agro-forestry	3	3	2	2	1	3	3	2	3	2	24
Gunjanagar	Agriculture	4	3	1	3	1	4	2	2	3	1	24
	Wetland	4	3	1	3	1	3	3	4	4	2	28
	Grazing land	3	4	1	3	1	2	2	3	3	2	24
	Agro-forestry	4	3	3	3	1	2	2	3	3	1	25
Mangalpur	Agriculture	4	3	2	3	1	3	2	1	4	2	25
	Wetland	3	5	1	4	1	2	3	3	5	2	29
	Grazing land	4	1	5	3	1	2	3	3	4	2	28
	Agro-forestry	4	3	3	3	1	2	3	2	3	1	25
Patihani	Agriculture	3	4	1	2	1	4	1	1	3	2	22
	Wetland	3	4	2	3	1	5	3	2	2	1	26
	Grazing land	4	3	2	3	1	4	3	1	3	1	25
	Agro-forestry	4	3	1	3	1	4	3	1	4	1	25
Sharadangar	Agriculture	1	5	3	3	1	1	3	3	4	5	29
	Wetland	5	4	3	3	1	4	2	2	5	1	30
	Grazing land	4	3	2	2	1	1	2	3	5	2	25
	Agro-forestry	3	3	2	2	1	1	2	4	4	2	24
Shivanagar	Agriculture	4	4	1	3	1	4	3	4	5	2	31
	Wetland	5	3	1	3	1	5	3	4	3	1	29
	Grazing land	5	3	1	3	1	1	3	2	3	5	27
	Agro-forestry	4	4	3	3	1	3	3	2	4	2	29

Table 9: Sustainability classification of different land uses of the Village Development Committees, Western Chitwan, Nepal (2011)

	Sustainability classes		
Land uses	Sustainable	Sustainable with high input	Sustainable with another land use
Agricultural land	3 (50)	2 (33.33)	1 (16.66)
Wetland	0	5 (83.33)	1 (16.66)
Grazing land	3 (50)	3 (50)	0
Agro-forest land	5 (83.33)	1 (16.66)	0
Total	12 (50)	10 (41.66)	2 (8.33)

Values in the parentheses indicates percentage

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