Spatial and Temporal Dynamics of Flora in Forest, Grassland and Common Land Ecosystems of Western Chitwan, Nepal

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Abstract

This paper describes changes of species composition and population of flora in space and time in western Chitwan, Nepal. This paper also discusses on the changes in flora due to flood and human activities. To illustrate these changes, we used survey data collected from January to April of 1996, 2000, and 2007 from the Barandabhar forest, National Park forest and the forests along the Narayani River banks, grasslands of National Park and common lands of western Chitwan as a part of longitudinal study on "reciprocal relation of population and the environment". From these data, density values were calculated to analyze spatial and temporal changes in flora species composition and population. We also noted the changes of top species in time and space in due course of time. If the species and its rank not changed, their densities (population) values of flora species changed. We found that changes in species composition, population, appearance or disappearance of flora from a particular space (research plot) were noted as a result of natural forces or human activities.

Key words: Flora change, forest vegetation, Barandabhar forest, Chitwan National Park, grasslands, common lands

1. Introduction

Ecosystems provide chiefly provisioning, regulating, supporting and cultural services. These services are outcomes of abiotic, biotic and microbial interaction. Among the biotic components of ecosystem, Plants are considered as one of important biotic components as they provide food, fodder, fiber, fuelwood, fodder, medicine, timber (Matthews et al., 2000; Dangol, 2008) and are also getting other environmental services. The species composition and structure of plants vary from one ecosystem to another. In order to understand status of plants and their linkage with people, many researchers have reported their studies from different countries including Nepal. In Nepal, Chitwan district is one of the districts which has received a number of floristic studies and flora have been reported from agricultural fields (Gupta et al., 1977; Dangol and Gurung, 1988), forests (Dangol et al., 1995; Dangol and Shivakoti, 2001; Shrestha et al., 2006), grasslands (Lehmkuhl, 1994; Joshi and Jha, 1995; Shrestha and Dangol, 2006), common lands (Dangol and Shivakoti, 2001) and wetlands (Dangol 2000-2001; Jha, 2007). Some studies highlighted about the plant communities/vegetation (Dangol et al., 1995; Dangol and Shivakoti, 2001) and disclosed the interrelation between population and the environment (Axinn and Shivakoti, 1997; Richter and Chhetri, 1997; Shivakoti et al., 1998, 1999; Barber et al., 2003;

Ghimire and Mohai, 2005).

Flora is always in dynamic state and changes with the change of time and space. These changes may be due to a number of human activities or natural forces or by both. Such changes in flora again affect on human activities such as food habits, habitat preferences, even child bearing decision of spouse selection (Barber et al., 2003) or natural/environmental processes. Although there are many studies in abroad (see Freckleton and Watkinson, 2002; Karahalil et al., 2009), research works are lacking or very few to answer the questions of causes and consequences of flora changes in species level occurred in forest, grassland and common lands in due course of time series or changes due to natural or anthropogenic activities. This paper attempts to illustrate spatial and temporal dynamism in flora of western Chitwan, Nepal and also examines the dynamism in flora due to natural and anthropogenic forces. This paper also highlights about some invasive alien species and possible impacts of flora change in people, wildlife and livestock.

2. Study area

The portion of the Chitwan district under study lies in the southernmost part of the Narayani zone in Central Nepal. It extends between 83°55'- 85°37' E longitude and 27°21'-27°46' N latitude covering an area of about 2510 km^2 that is nearly 30% of the Narayani zone. Makawanpur district in the east, Nawalparasi and Tanahun districts in the west, Gorkha district in the north and the Someshwor range (Churia hill) in the south surround this district. The Mahabharat range and the Churia hills surround the entire land of this district, which is called Bhitri Madhesh (Dun Valley or Inner Terai). This district enjoys a subtropical climate with fertile soils suitable for growing a variety of plants including crops. Chitwan district, once known as the Death Valley due to infection of malaria, is now experiencing a lot of change in demography, biodiversity and the environment. Some studies reveal that the migrated people in Chitwan were mostly come from Lamjung (8%), Gorkha (6%), Kaski and Tanahun (4.5% each) and Baglung (5%), who were born in other districts (PERL, 2055).

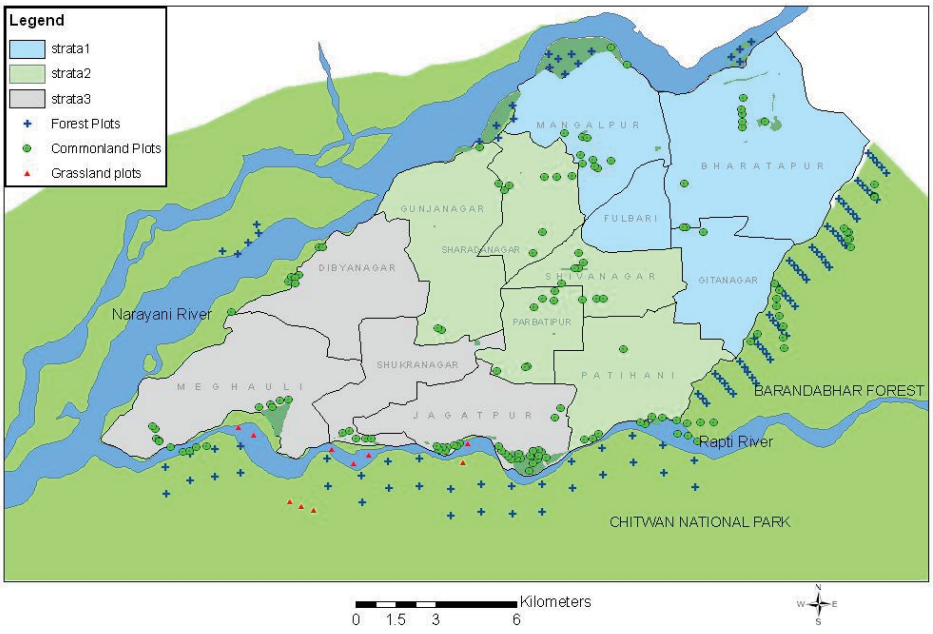


Figure 1. Map of Western Chitwan, Nepal

3. Methods

We used survey data collected from January to April of 1996, 2000, and 2007 from the Barandabhar forest, National Park forest and the forests along the Narayani River banks, grasslands of National Park and common lands of western Chitwan as a part of longitudinal study on "reciprocal relation of population and the environment".

3.1 Location of research sites and plots

For this study, a research plot was defined as a 10 x 10 m^2 stratified fashion in the forests, grasslands, and common lands decided on the basis of 1992 aerial map. Our research plots are confined in the different sites (Blocks) in the Western Chitwan of

lowland Nepal (Figure 1).

Forest Block A: Forest Block A was represented by the Barandabhar (also called Tikauli) forest which was extended about 13 km, south of the East-West Highway. The entire research plots of this Block A in the Tikauli Jungle were located within this strip of forest. Each set of plots was approximately 1,250 m (4,100 ft) wide, running inward from the edge of the forest to the center. The area within which the 62 plots were located is the Sampling Frame of Forest Block A. The research plots are based on Plot Sampling Method.

The Sampling Frame of Forest Block A consisted of twelve rows, the first 11 rows with 5 research plots in each row and 12th one with only 3 research plots. The remaining four plots (A0P08, A0P88 A0P09 A0P99) were selected, 2 from left side and 2 from right side of the Khageri Irrigation Canal in the forest. In each row the research plots were spaced at an interval of 250 m (820 ft). This was a standard design. The bearing between every two research plots was set at 140 degrees (note that this bearing is calculated using the East-West Highway as reference point). The distance between each row of plots was 1 km. The 12 rows of plots began 250 m due south from the East-West Highway crossing of the Narayani Irrigation Canal which runs along the edge of the forest.

Forest Block B: To the south of the Study Site located the Chitwan National Park (south of the Rapti river). This block consisted of altogether 44 research plots: 34 in forests and 10 in grasslands of Chitwan National Park. The Sampling Frame of the Forest Block B in the National Park started from the Jarneli Post in the east and went up to the confluence of the Reu Khola (stream) and Rapti river to the west. The sampling frame of Forest Block B had seventeen rows with two research plots in each row in each row. Within each row the first research plot was located 250 m inwards and due south from the forest edge along the Rapti River. The second research plot was located 1 km due south from the first research plot.

Forest Block C: The forest Block C included the forests that expand along the south edge of the Narayani River, from the East-West Highway to the confluence of the Narayani and Rapti Rivers was the northwest boundary of the study area. This block included Nagarban (4 plots); Jhanjhaneban (7 plots); Gobreniban (also called Majhuwaban) (5 plots); and Kalaban (5 plots).

National Park grasslands: A total of 10 research plots were identified in the grassland located between the Dhruba post and Sukhibar post of the Chitwan National Park.

Common lands: A total of 138 research plots were selected purposively in the common lands (for common purposes of the residents) located in 48 Neighborhoods of the POPENV (Population and Environment) study. These plots represented different habitats used for different purposes: such as plantation areas, flood affected area, common grazing lands, Barandabhar grazing and grass cutting area, school ground and airport area, wetlands (ponds and marshy areas), roadways and canal ways.

3.2 Design of the research plots

For all research sites (except canal ways and roadways), three types of sampling units (quadrats) were used: (a): 10x10 m^2, (b) 3x3 m^2, and (c) 1x1 m^2. One quadrat of 3x3 m^2 size was laid down at the centre of big quadrat in three forests (Block A, B, and C). Five 1 m^2 quadrats were positioned in each of the largest quadrat (10x10 m^2) in forests and grasslands where as three quadrats of 1 m^2 size were put diagonally in each 10 x 10 m^2 (Figure 2d) or 1 x 25 m^2 sampling plot (Figure 2c) in the common lands. The sampling plot of 1 x 25 m^2 size was determined for the canal ways and roadways as there was no space for laying down 10 x 10 m^2 plot. Table 1 shows the number of quadrats of different sizes employed for the present study. Frequencies of sampling quadrats in the particular study areas are given below (Table 1). Detail procedure for making sampling plots can be found in Dangol (2009) and Richter and Chhetri (1997).

Table 1. Size and number of quadrats studied in different research sites in west Chitwan, Nepal.

Research sites	Quadrat sizes			Remarks [Number of 1x1 m^2 quadrat in each 10x10 m^2]
	10x10 m^2	3x3 m^2	1x1 m^2	
Barandabhar forest	62	62	310	FIVE 1x1 m^2
National Park forest	34	34	170	FIVE 1x1 m^2
National Park grassland	10	-	50	FIVE 1x1 m^2
Forests along Narayani river	21	21	105	FIVE 1x1 m^2
Common lands	138	-	414	THREE 1x1 m^2
Total	265	117	1049	

3.3 Data Set

Environmental data: Information on plot type, plot direction, soil color and texture, condition of plot, soil erosion, crown cover, animal damage, insect damage, fire damage, storm damage, flooding, tree falls, dead trees, were recorded.

Flora count data: Once the sample units were marked and clearly plotted, plant species were counted: (a) trees and woody

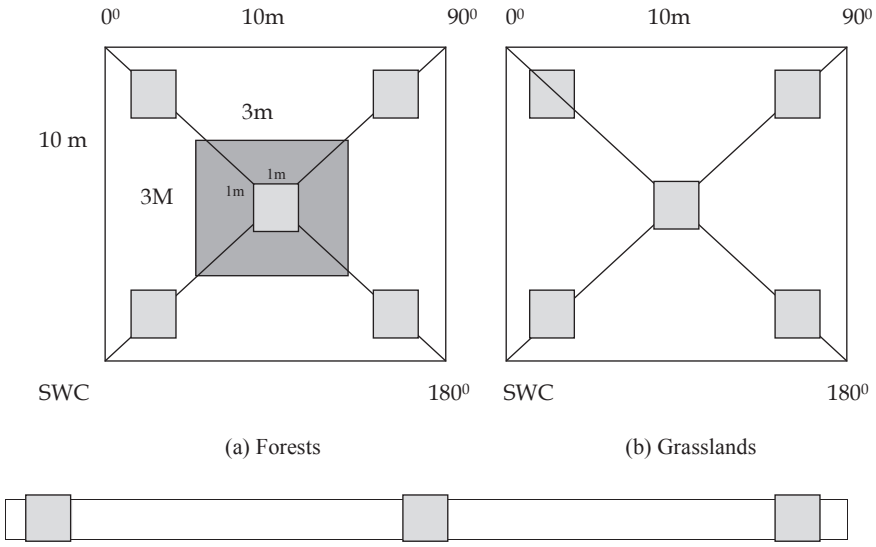
climbers from 117 quadrats of 10 x 10 sq meter plots located in forests; (b) shrub, sapling (of woody plants), and herbaceous climbers from 117 quadrats of 3 x 3 sq. meter plots, (c) herbs and tree seedlings from 1049 (635 quadrats in forests and grasslands and 414 quadrats in common lands).

Plant identification: The plant specimens were identified with the help illustrated manuals and Flora books such as Aquatic and Wetland Plants of India (Cook, 1996), Flora of Bhagalpur: Dicotyledons (Varma, 1981) and The Flora of Tripura State (Deb, 1983). The identification was further conformed matching with the herbarium specimens in National Herbarium and Plant Laboratories of the Department of Plant Resources, Godawari. Some specimens are identified by local names only.

All the voucher specimens collected during the present study are housed in the Herbarium of the Department of Environmental Science, Institute of Agriculture and Animal Science, Rampur, Chitwan, Nepal.

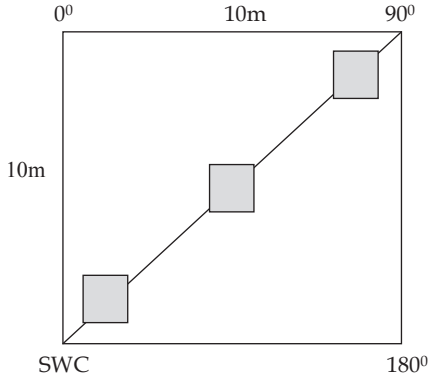
3.4 Data analysis

The flora count data were converted into density (population of plants per square meter) of plants (trees, shrubs and herbs) for each research plot using Microsoft Excel program. The density of plants was used to analyze the changes in Time 1, Time 2 and Time 3 with respects to research plots.



(a) Forests (b) Grasslands

(c) Research plot in the common lands (eg. Canalways, roadways)



(d) Research plot in the common lands (eg. School ground)

Figure 2. Outlines of research plots in forests (a), grasslands (b) and common lands (c and d)

4. Results and discussion

4.1 Trees in forest plots

Barandabhar forest: The five top tree species included *Shorea robusta, Terminalia alata, Cleistocalyx operculatus,*

Semecarpus anacardium and Pipal (Table 2). The population of top three species (*Shorea, Terminalia* and *Cleistocalyx*) was increasing in order in Time 2 compared to Time 1 (Table 2). This increase may be due to protection of forest by barbed wire, recruiting forest guards, and formulation of rules and regulations of forest utilizations implemented by the forest user groups. All the tree species, except *Shorea robusta*, were found decreased in Time 3 compared to Time 2 and remained same (*S. anacardium* and *F. religiosa*) or increased in Time 3 compared to Time 1. The reason may be illegal cutting of the trees except *S. robusta*. This may be issues to be studied.

Chitwan National Park forest: Ten species were among 5 top species of trees Time 1, Time 2, and Time 3 (Table 2). Except *Dillenia pentaphylla*, *Shorea robusta*, *Trewia nudiflora*, *Cleistocalyx operculatus*, and *Bombax ceiba* were the species that occurred in three Time periods with almost same or slightly decreased population. *Mallotus philippensis* and *Syzygium cumini* in Time 2 and *Aegle marmelos*, *Butea monosperma*, and *Gmelia arborea* in Time 3 occurred among top 5 species (Table 2).

Narayani River forests: *Alsonia scholaris*, *Bauhinia malabarica*, *Bombax ceiba*, *Dalbergia sissoo*, *Erhetia laevis*, *Holarrhina pubescens* and *Trewia nudiflora* were the tree species found among the top 5 species in the forests (Table 2). Except Kalaban, the forests were replanted with *Dalbergia sissoo*. The population of *Trewia nudiflora* was found in increasing order where as the population of *B. ceiba*, *T. nudiflora* and *E. laevis* was found increased in Time 2 compared to Time 1 and decreased or remain same in Time 3 in compared to Time 2.

S. robusta and *Cliestocalyx operculata* shared as the common top species by Barandabhar forest and Chitwan National Park forest and *Trewia nudiflora* and *Bomax ceiba* by Chitwan National Park forest and Narayani river forests. We did not find common top species between Barandabhar (sal) forest and Narayani River (riverine) forest. This may be due to difference in ecosystems. However, the sharing of tree species of Chitwan National Park forest by Bharandabhar forest and by Narayani forest may due to occurrence of two types of forests (riverine and sal forest) in Chitwan National Park.

Some species showed uniqueness in distribution, occurring only in one forest as among the dominant species. We found three species (*Terminalia alata*, *Semicarpus anacardium* and *Ficus religiosa*) in Barandabhar forests; six species (*Dillenia pentagyna*, *Mallotus phillipensis*, *Sygygium cumini*, *Aegle marmelos*, *Butea monosperma*, and *Gmelina arborea*) in the Chitwan National Park Forest, and five species (*Dalbergia sissoo*, *Erhetia laevis*, *Alstonia scholaris*, *Bauhia malabaricum* and *Holarrhina pubescens*) in Narayani river forests as the unique species among the top 5 species. The uniqueness of distribution of these species may be due to their preference of suitable habitat.

4.2 Shrubs in forests

Barandabhar forest: There were altogether 11 species of shrubs which occupied as the five top species in three time periods (Table 3). Only two species (*Clerodendrum viscosum* and *Flemingia strobilifera*) were the species that occurred in Time 1, Time 2 and Time 3 among the top 5 species; two species (*Swida oblonga* and *Xeromphis spinosa*) were the species that occupied top positions in Time 1 and Time 2. The rest species were found among the top species either in Time 1 or Time 2 or Time 3. *Chromalaena odorata*, an invasive plant, was recorded as third position in Time 3.

Chitwan National Park forest: *Callicarpa macrophylla*, *Chromalaena odorata*, *Clerodendrum viscosum*, *Colebrookea oppositifolia*, *Helicteres isora*, *Murraya koenigii* and *Pogostemon benghalensis* were the species that occurred as top 5 species in Time 1 or Time 2 or Time 3 (Table 3). Among them, *Clerodendrum viscosum*, *Colebrookia oppositifolia* and *Helicteres isora* occurred in all study periods. *Callicarpa macrophylla* occurred in Time 1 and Time 2 as the top 5 species. Compared to Time 1, *Callicarpa macrophylla* decreased in Time 2, *Cleredendrum viscosum* increased in Time 2 and Time 3, *Colebrookia oppositifolia* increased in Time 3, and *Helicteres isora* decreased in Time 2 and Time 3. As in Barandabhar forest, *Chromalaena odorata* occurred as the fifth important species in Time 3 indicating the growth of invasive plant.

Narayani River forests: *Callicarpa macrophylla*, *Cleredendrum viscosum*, *Coffea benghalenis*, *Colebrookea oppositifolia*, *Lantana camara*, *Murraya koenigii*, *Osbeckia stellata*, and *Pogostemon benghalensis* were the species that occupied top 5 positions in different time periods (Time 3). Among them, *C. viscosum*, *C. oppositiifolia* and *P. benghalensis* were the three species which 5 species in Time 1, Time 2 and Time 3. The population of *C. viscosum*, *C. oppositiifolia*, *P. benghalensis* and *Coffea benghalensis* were found decreased in both Time 2 and Time 3 periods or in Time 3. *Lantana camara* appeared as the fifth important species indicating the spread of this invasive alien species in the forests along the Narayani river.

C. viscosum and *Murraya koenigii* were found among the top 5 species in the forest of Barandhabhar, Chitwan National Park and Narayani River area (Table 3). *H. isora* and *C. odorata* were the two common species to Barandabhar forest and Narayani river forests whereas *C. macrophylla*, *C. oppositiifolia* and *P. benghalensis* were common to Chitwan National Park forest and Narayani River Forests. Five species occurred as unique to Barandabhar forest, one to Chitwan National Park forest and three to the Narayani river bank forests (Table 3).

Table 2. Spatial and temporal dynamism in top tree species (number/m^2) of Barandabhar forest, Chitwan National Park Forest and Forests along the Narayani River (hereafter Narayani river forests)

Scientific names [English name] "Nepali name"	Barandabhar forest			Chitwan National Park forest			Narayani River forests		
	1996	2000	2007	1996	2000	2007	1996	2000	2007
Shorea robusta Gaertn. [Sal tree]	0.92	1.50	2.09	1.38	1.26	1.21			
Terminalia alata Heyne [Indian laurel]	0.13	0.97	0.16						
Cleistocalyx operculatus (Roxb.) Merr. & Perry [Water rose apple]	0.06	0.15	0.11	0.47	0.29	0.29			
Semecarpus anacardium L. f. [Oriental cashew]	0.02	0.03	0.02						
Ficus religiosa L. [Sacred tree]	0.02	0.03	0.02						
Trewia nudiflora L. [Rhino apple]				0.62	0.56	0.56	0.14	0.19	0.29
Bombax ceiba L. [Silk cotton tree]				0.44	0.38	0.38	0.33	0.38	0.19
Dillenia pentagyna Roxb.				0.24	0.29	0.38			
Mallotus philippensis (Lamk.) Muell.-Arg. [Kamala tree]					0.35				
Syzygium cumini (L.) Skeels [Java plum]					0.29				
Aegle marmelos (L.) Corr. [Stone apple]						0.29			
Butea monosperma (Lam.) Kuntz [Flame of the forest]						0.29			
Gmelina arborea Roxb. [Beechwood]						0.29			
Dalbergia sissoo Roxb. ex DC. [Indian rosewood]							4.33	4.09	4.43
Erhetia laevis Roxb. [Chamror]							0.05	0.09	0.09
Alstonia scholaris (L.) R. Br. [Indian devil tree]									0.09
Bauhinia malabarica Roxb. [Butterfly Leaved tree]									0.05
Holarrhina pubescens (Buch.-Ham.) Wall. ex G. Don [Tree jasmine]									0.05

Table 3. Spatial and temporal dynamism in top 5 shrub species (number/m^2) of forests of Barandabhar forest, Chitwan National Park Forest and the Narayani River Forests

Scientific names [English name] "Nepali name"	Barandabhar forest			Chitwan National Park forest			Narayani River forests		
	1996	2000	2007	1996	2000	2007	1996	2000	2007
Clerodendrum viscosum Vent. [Hill glory bower]	2.69	5.02	3.66	4.62	7.71	6.29	5.95	4.76	1.38
Swida oblonga (Wall.) Sojak	0.81	0.81							
Flemingia strobilifera (L.) Ait. [Wildhops flemingia]	0.56	3.09	4.41						
Xeromphis spinosa (Thunb.) Spreng. [Emetic nut]	0.77	0.97							
Murraya koenigii (L.) Spreng. [Curryleaf plant]	0.77				0.63			0.57	
"Chepte kuro"	0.59								
Tadahagi triquetrum (L.) Ohasi [Triquetrous tadehagi]			1.48						
Uraria lagopoides (L.) Desv. [Hansia dafer]			1.35						
Helicteres isora L. [Indian squirrel]		0.74		4.68	1.85	3.23			
Callicarpa macrophylla Vahl [beauty berry]				4.47	1.50			2.52	
[§]*Chromalaena odorata* (L.) King & H. E. Robins [Jack in the bush]			1.82			1.53			
Colebrookia oppositifolia Sm. [Indian squirrel tail]				1.74	0.94	2.18	15.25	3.09	2.00
Pogostemon benghalensis (Burm.f.) Hassk. [Bengal pogostemon]						1.74	9.33	2.66	0.95
Grewia sapida Roxb. [Cross berry]				1.59					
Osbeckia stellata Buch.-Ham. ex D. Don [Starry osbekia]							17.24		
Coffea benghalensis Heyne ex Schult. [Bengal coffee]							16.33		0.81
[§]*Lantana camara* L. [Lantana, Yellow sage]									0.57

[§] Invasive Alien Plants

Table 4. Spatial and temporal dynamism in the top 5 herbaceous plant species (number/m^2) of Barandabhar forest, Chitwan National Park forest, and Narayani River forests

Scientific names [English name] "Nepali name"	Barandabhar forest			Chitwan National fark Forest			Narayani River forests		
	1996	2000	2007	1996	2000	2007	1996	2000	2007
Imperata cylindrica (L.) P. Beauv. [Cogon grass]	39.08	38.37	31.92	79.56	33.26	2.93	20.91	17.26	7.22
Rungia parviflora (Retz.) Nees [Small flowered rungia]	13.49		6.17		1.94		22.08	8.26	
Oxalis corniculata L. [Yellow woodsorrel]	22.19						20.39	6.22	
Chrysopogon aciculatus (Retz.) Trin. [Golden false beardgrass]	15.63	11.98							
Brachiaria spp. "Likhe banso"	8.56								
Desmodium triflorum (L.) DC. [Three flowered ticktrefoil]		19.46	4.97	2.58					
"Khar" [Thatch grass]		11.17		5.87		5.83			
Paspalum scrobiculatum "Mane banso"		12.07							
Sporobolus diander (Retz.) P. Beauv. [Indian dropseed]			3.97						
Echinochloa colona (L.) Link [Barnyard grass]			2.96						
Desmostachya bipinnata (L.) Stapf. [Kush grass]				3.11		1.07			
Hemarthria compressa (L. F.) R. Br. [Whip grass]				2.43					
Themeda arundinacea (Roxb.) Ridley [Khadai grass]					2.35	1.51			
Saccharum benghalense Retz. [Baruwa grass]					4.79				
Saccharum spontaneum (Retz.) P. Beauv. [Wild sugarcane]					2.31				
Oplismenus compositus (L.) P. Beauv. [Running mountain grass]						1.58			7.37
Ageratum spp. ([§]*A. houstonianum* Mill. [Garden ageratum] and *A. conyzoides* L. [Goatweed])							22.90	21.31	7.22
Commelina spp. "Kane jhar"							9.55		
Panicum sp.								9.39	
Cynodon dactylon (L.) Pers. [Bermuda grass]									2.61
Lepidagathis incurva Buch.-Ham. ex Don [Curved lepidagathis]									5.13

[§] Invasive Alien Plant

4.3 Herbaceous plants in forests

Barandabhar forest: There were 10 species that occurred as top 5 positions in Time 1, Time 2 and Time 3. Among them, *Imperata cylindrica* was the species found in all the time periods studied where as *Rungia parviflora*, *Chrysopogon aciculatus* and Khar (Thatch grass) occurred in two time periods as top 5 species, but their population was found decreased compared to previous one (Table 4). Five species occurred among the top 5 species in one Time period. Except *Rungia parviflora* and *Oxalis corniculata*, the rest represented grasses.

Chitwan National Park forest: *Imperata cylindrica* was recorded as one of the important species in three time periods. *Themeda arundinacea*, *Desmostachya bipinnata* and Khar (thatch grass) were the species which occurred among top five species in two time periods. The rest species were found among the five top species in only one study time (Table 4). Compared to Time 1 or Time 2, the population of the species was reduced very much. This may be due to increase in the number of shrubs, sampling and saplings in the research plots.

Narayani River forests: Eight species comprised of the top positions in the forests of Narayani river. Among them, only two (*Imperata cylindrica* and *Ageratum houstonianum*) was recorded among the top species in three time periods. *Rungia parviflora* and *Oxalis corniculata* were the two species recorded in Time 1 and Time 2 as the common top species. The rest 5 species occurred among top species in only one time period. All the species which were recorded two or time time periods were found in decreasing order.

4.4 Grasses of Chitwan National Park grasslands

Table 5 shows the top five grass species of grassland of Chitwan National Park in three study periods. *Imperata cylindrica* and *Saccharum spontaneum* remained top two species in 1996, 2000 and 2007. However, the density values were reduced in Time 3 up to six times of *I. cylindrica* (148.76 per sq m) l and up to double of *Saccharum spontaneum* (44.47). The tall grasses (*Phragmites karka*, *Saccharum spontaneum*, *Saccharum benghalensis*, and *Themeda arundinacea*) were recorded among III- V positions in the plant species rankings. The tall grasses were also reported as diet of elephant, rhino and gaur (Chetri, 2006; Steinheim et al., 2005) and construction materials for indigenous people (Dangol, 2009).

Table 5. Temporal dynamism in top 5 grass species (number/m^2) in the grassland of Chitwan National Park

Scientific names [English name] "Nepali name"	**1996** (Time 1)	**2000** (Time 2)	**2007** (Time 3)
Imperata cylindrica (L.) P. Beauv. [Cogon grass] "Siru"	712.70	717.16	148.76
Saccharum spontaneum L. [Wild sugarcane] "Kans"	78.08	73.62	44.47
Saccharum benghalensis Retz. [Baruwa grass] "Baruwa"		6.62	8.16
"Khar"	18.80		
Themeda arundinacea (Roxb.) Ridley [Khadai grass] "Khadai"	11.18		
Phagmites karka (Retz.) Trin. [Reed Chamorro] "Narkat"	5.08		
Cynodon dactylon (L.) Pers. [Bermuda grass] "Dubo"		19.94	
Pogonatherum crinatum (Thunb.) Kunth [Baby panda bamboo]		3.80	
Cymbopogon sp.		3.88	
Desmostachys bipinnata (L.) Stapf [Kush grass, Big cordgrass] "Kush"			6.80
Paspalum scrobiculatum L. [Kodo millet] "Mane banso"			1.20

4.5 Grass species in common lands

Among the grasses, six species (*Imperata cylindrica*, *Cynodon dactylon*, *Saccharum spontaneum*, *Chrysopogon aciculatus*, *Hemarthria compressa*, *Paspalum scrobiculatum* and *Axonopus compressus*) have higher density (Table 6). *Imperata cylindrica* and *Cynodon dactylon* ranked the first and the second positions in the common lands, respectively, in all Time 1-3. However, third position was shared by *Saccharum spontaneum* (in Time 1) and by *Axonopus compressus* (in Time 2 and Time 3). The grasses of common lands were also reported as important diet of domestic animals (Dangol, 2008).

Table 6. Temporal dynamism in the top 5 grass species (number/m^2) in common lands of western Chitwan, Nepal.

Scientific names [English name] "Nepali name"	**1996** (Time 1)	**2000** (Time 2)	**2007** (Time 3)
Imperata cylindrica (L.) P. Beauv. [Cogon grass] "Siru"	129.55	126.95	137.94
Cynodon dactylon (L.) Pers. [Bermuda grass] "Dubo"	83.34	68.43	58.45
Saccharum spontaneum L. [Wild sugarcane] "Kans"	43.72	29.86	29.36
Hemarthria compressa (L.f.) R. Br. [Whip grass] "Ghode dubo"	40.55		16.59
Axonopus compressus (Swartz) P. Beauv. [Tropical carpet grass] "Makaipate banso"		57.57	30.65
Chrysopogon aciculatus (Retz.) Trin. [Golden false beardgrass]	42.18		
Paspalum scrobiculatum L. [Kodo millet] "Mane banso"		35.35	

4.6 Flora change due to natural disaster (flood)

Out of 138 research plots in common land, 10 were swept away due to flood. To illustrate the flora change due to flood (natural disaster), we took here the research plot (CL 26) of common land of Laukhuri area of western Chitwan. Table 7 indicates that there were 9 herbaceous species with 379.66 populations per quadrat in Time 1. Just one year before Time 2 data collection, there was heavy flood in 1999 during rainy season and only two species (*Cynodon dactylon* and *Saccharum spontaneum*) were recorded in Time 2. It is clear from this data that perennial plant species like *S. spontaneum* and *C. dactylon* colonize the flood affected areas first and make their vegetation (Table 7). *Brachiaria* sp. and *Imperata cylindrica* were observed in Time 1 and Time 3. *S. spontaneum* was found almost four times more in Time 3 compared to Time 2. Six species were unique to Time 1 where as nine species were unique to Time 3 (Table 7).

Table 7. Temporal dynamism of plant species (number/m^2) due to flood in Laukhuri, western Chitwan (Density values of the average of 3 quadrats). **CL 26**

Scientific names [English name] "Nepali name"	**1996** (Time 1)	**2000** (Time 2)	**2007** (Time 3)
Cynodon dactylon (L.) Pers. [Bermuda grass]	32.66	0.66	
Brachiaria sp.	4.66		2.66
Imperata cylindrica (L.) P. Beauv. [Cogon grass]	2.66		360.33
Saccharum spontaneum L. [Wild sugarcane]		5.00	19.00
Oxalis corniculata L. [Yellow woodsorrel]	148.00		
Rungia parviflora (Retz.) Nees [Small-flowered rungia]	86.00		
Chrysopogon aciculatus (Retz.) Trin. [Golden false beardgrass]	54.00		
Launaea aspleniifolia (Willd.) Hook. f. "Dudhe jhar"	35.66		
Eragrostis tenella (L.) P. Beauv. [Japanese lovegrass]	26.00		
Cassia occidentalis L. [African coffee]	4.66		
"Neuro"			5.00
Hemarthria compressa (L.f.) R. Br. [Whip grass]			4.33
"Gurmi"			2.00
Emilia sonchifolia (L.) DC. ex Wight [Cupid's shaving brush]			1.66
Desmodium sp. "Bhatmase jhar"			1.66
Blumea lacera (Burm. f.) DC. [Malay blumea]			1.33
Pouzolzia zeylanica (L.) Benn. [Graceful pouzolzsbush]			1.00
"Bankareli"			0.66
Solanum aculeatissimum Jacq. [Indian nightshade] "Kantakari"			0.33
Total population	394.30	5.66	399.96

4.7 Flora change due to human activities

Flora change due to project activity

To understand change in flora due to project activity, we took the data recorded in 100 square meter quadrat in flood-affected plantation area of the Rapti River where the Timber Corporation of Nepal planted Sissoo trees (*Dalbergia sissoo*). In Time 1, the ground area of Sissoo plantation was almost open with *Oxalis corniculata*, *Rungia parviflora*, sedges and others. The area was used as grazing land or picnic spot. To reduce the dependency of the people on national park, the People and Park project fenced the area with barbed wire and managed guards to look after the area and formed the community forest users group. Table 8 compares the flora change in a common land plot (CL 08) due to implementation of management policy of a project in the area. The table reveals that the species richness in Time 2 (after protection of the area) became double than that of open nature of research plot in Time 1. But the population of species was found decreased after the protection of area. Some shade loving shrubs (*Callicarpa macrophylla*, *Pogostemon benghalensis*, and *Murraya koenigii*) and herbaceous climbers (*Mucuna pruriens* and *Piper longum*) replaced or reduced the population of Time 1. We recorded 3 m tall *Urtica dioica* in the area, which was not recorded in Time 1. The populations of *P. longum* and *P. benghalensis* were found increased in Time 3 compared to Time 1 and Time 2, respectively. New species (*Cirsium arvense*, *Solanum aculeatissimum* and *Trewia nudiflora*) were observed in Time 3 which may be due to dispersal due to rhinos. One invasive species, *Mikania micrantha* was observed in Time 3.

Table 8. Temporal dynamism of plants (number/m^2) in ground flora due to management in Ghailaghari, Jagatpur

Scientific names [English name] "Nepali name"	**1996** (Time 1)	**2000** (Time 2)	**2007** (Time 3)
Piper longum L. [Long pepper]	6.00	1.33	29.33
Oxalis corniculata L. [Yellow Woodsorrel]	174.33	29.00	
Rungia parviflora (Retz.) Nees [Small flowered rungia]	51.66	0.33	
Urtica dioica L. [Stinging nettle]		6.66	1.66
Pogostemon benghalensis (Burm.f.) Hassk. [Wild sage]		0.66	2.00
Sedge (*Cyperus rotundus* L. [Yellow nutsedge], *Kyllinga brevifolia* Rottb. [Green kyllinga])	5.66		
Unidentified 1	1.00		
Unidentified 2	0.33		
Desmodium triflorum (L.) DC. [Three flowered ticktrefoil]		10.66	
"Fusre unyue"		8.00	
Mucuna pruriens (L.) DC. [Velvet bean]		2.33	
Blumeopsis flava (DC.) Gagnep. 'Torigande"		0.33	
Callicarpa macrophylla Vahl [Beauty berry]		0.33	
Murraya koenigii (L.) Spreng. [Curry leaf plant]		0.33	
Mikania micrantha Kunth [Mile-a-minute] [§]			4.33
Circium arvense (L.) Scop. [Canada thistle]			3.33
Colebrookia oppositifolia Sm. [Indian squirrel tail]			3.00
Unknown climber			1.66
Solanum aculeatissimum Jacq. [Indian nightshade]			1.33
Trewia nudiflora L. [Rhino apple]			0.33
Total population	**238.98**	**59.96**	**46.97**

[§] Invasive Alien Plant

Flora change due to ecosystem conversion

Among the many factors, environmental factors and human forces cause change in plant composition and abundance or disappearance of a species or invasion by a species. To understand change in flora composition and abundance, here the data of Time 1 and Time 2 of a common land research plot (CL 105) was taken. In Time 1, the common land plot was the school ground, which was changed into lentil field in Time 2. It is also clear that how flora is changed with the conversion of one type of

ecosystem to another type (Table 9).

Table 9 shows that species diversity was more in *Lens esculentus* (lentil) field with 15 weed species than that of school ground (10 species). However, the population of plants was higher in school ground (1078.96 plants/sq m) than that of lentil field (388.94 plants/sq m). Three species (*Cynodon dactylon, Desmodium triflorum* and *Hemarthria compressa*) were common to Time 1, Time 2 and Time 3; one species (Hydrocotyle sibthorpioides) common to Time 1 and Time 2; two species (*Kyllinga brevifolia* and *Vicia tetraperma*) common to Time 1 and Time 3; four species (*Gnapalium purpureum*, *Polygonum plebeium*, *Alternanthera sessilis* and *Ageratum houstonianum*) to Time 2 and Time 3. Five, nine and 11 species were unique to Time 1, Time 2 and Time 3, respectively (Table 9). This table also indicates that the conversion of one type of ecosystem to another brings changes in species diversity, species density (population) and cause disappearance or appearance of some species (Table 9). The plants recorded from the Time 2 were also reported as weeds of lentil at IAAS, Rampur, Chitwan (Dangol, 1990; Dangol and Gurung, 1988).

Table 9. Temporal dynamism in herbaceous flora (number/m^2) in Hanuman Nagar of western Chitwan due to conversion of school ground (Time 1) to lentil field (Time 2)

Scientific names [English name] "Nepali name"	**1996** (Time 1) (School ground)	**2000** (Time 2) (Lentil field)	**2007** (Time 3)
Cynodon dactylon (L.) Pers. [Bermuda grass]	264.66	42.66	70.66
Desmodium triflorum (L.) DC. [Three leaved ticktrefoil]	57.66	36.66	2.00
Hemarthria compressa (L. f.) R. Br. [Whip grass]	56.66	4.00	33.33
Hydrocotyle sibthorpioides Lam. [Lawn marshy pennywort]	98.00	60.00	
Kyllinga brevifolia Rottb. [Green kyllinga]	225.00		3.33
Vicia tetrasperma (L.) Moench [Four-seeded vetch]	0.33		0.33
Gnaphalium purpureum L. [Purple cudweed]		11.66	4.33
Polygonum plebeium R. Br. [Small knotweed]		8.66	44.00
Alternanthera sessilis (L.) DC. [Sessile joyweed]		4.00	9.33
Ageratum houstonianum Mill. [Garden ageratum]		1.33	1.66
Axonopus compressus (Swartz) P. Beauv. [Tropical carpet grass]	160.00		
Paspalum scrobiculatum L. [Kodo millet]	120.33		
Androsace umbellata (Lour.) Merr.	50.66		
Eragrostris unioloides (Retz.) Nees ex Steud. [Chinese lovegrass]	34.33		
Chrysopogon aciculatus (Retz.) Trin. [Golden false beardyard]	11.33		
Wahlenbergia marginata (Thunb.) A. DC. [Southern rockbell]		76.00	
Lens esculentus Moench. [Lentil] (planted crop)		71.66	
Digitaria ciliaris (Retz.) Koeler [Crab grass]		33.00	
Mazus pumulus (Burm.f.) van Steens		16.66	
Vicia angusitifolia L. [Blackpod vetch]		8.66	
Vicia hirsuta (L.) S. F. Gray [Hairy vetch]		6.00	
Ixeris polycephala Cass. ex DC. "Dudhe jhar"		3.33	
Euphorbia hirta L. [Asthma weeds]		3.00	
Grangea maderaspatana (L.) Poir. [Madras carpet]		1.66	
Hydrocotyle seibthorpioides Lam. [Lawn march pennywort]			39.33
Brachiaria distachya (L.) Stapf [Armgrass millet]			36.66
Medicago lupulina L. [Black medic]			34.33
Mecardonia procumbens (Mill.) Small [Baby jump-up]			27.66
Oxalis corniculata L. [Yellow woodsorrel]			27.33
Lindernia sp.			18.33
Rotala indica (Willd.) Koehne [Indian toothcup]			9.00
Centella asiatica (L.) Urb. [Asian pennywort]			5.00
Schoenoplectus juncoides (Roxb.) Palla [Hard-stemmed bulrush]			2.33
Hedyotis diffusa Willd. [White flower snake-tongue grass]			1.66
Lippia nodiflora (L.) Greene [Turkey tangle fogfruit]			1.33
Total population	**1078.96**	**388.94**	**371.93**

5. Invasive Alien Species (IAS)

Chromalaena odorata, *Lantana camara*, and *Ageratum houstonianum* are the invasive alien species reported among top 5 species in the study areas. *C. odorata* occupied the third position (with 1.82 density value) in Bharandabhar forest in 2007 and the fifth position (with 1.53 density value) in Chitwan National Park forest in 2007. Similarly, *L. camara* occupied the fifth position (0.57 density) in the forest along the Narayani river. This species was also reported as a problematic weed in the grasslands of Chitwan National Park of western Chitwan (Dangol, 2007). These species were also mentioned as the invasive alien species in Nepal (Poudel et al., 2005; Tiwari et al., 2005). In addition, *Mikania micrantha* was recorded in sissoo plantation area of Ghailaghari, Jagatpur in 2007 (Table 8). The occurrence of *Mikania micrantha*, also popularly known as mile-a-minute in English, was reported in the research plots of western Chitwan (Shrestha et al., 2008). This Mikania was also reported as serious alien species from Chitwan National Park grasslands (Sapkota, 2006, 2007; Dangol, 2007) and Koshi Tappu wildlife reserve (Shivakoti, 2007).

Chromalaena odorata

Lantana camara

Ageratum houstonianum

Figure 3. Three invasive alien plants of the study areas in western Chitwan, Nepal

6. Potential impact of flora change

Figure 4 illustrates some potential impacts on human beings or wildlife or domestic animals of the study areas. The flora change may result into the increase the number of invasive species (*Chromalaena odorata*, *Lanata camara*, *Ageratum houstonianum*) that may cause negative effects on environmental quality loss and scarcity of native food plants for the wild herbivores in the forests, ultimately cause movement of wildlife from that habitat. If the flora change results in the increase of useful plants such as stinging nettle, there may be possibility of initiating plant-based small enterprises. Flora change may be experienced with the decrease in the number of useful plants such as NTFPs, it will have effect on livestock or human beings. To understand detail relationship, further research is needed to discourse the effect of flora change on wildlife, human livelihoods, tourism and ecosystems.

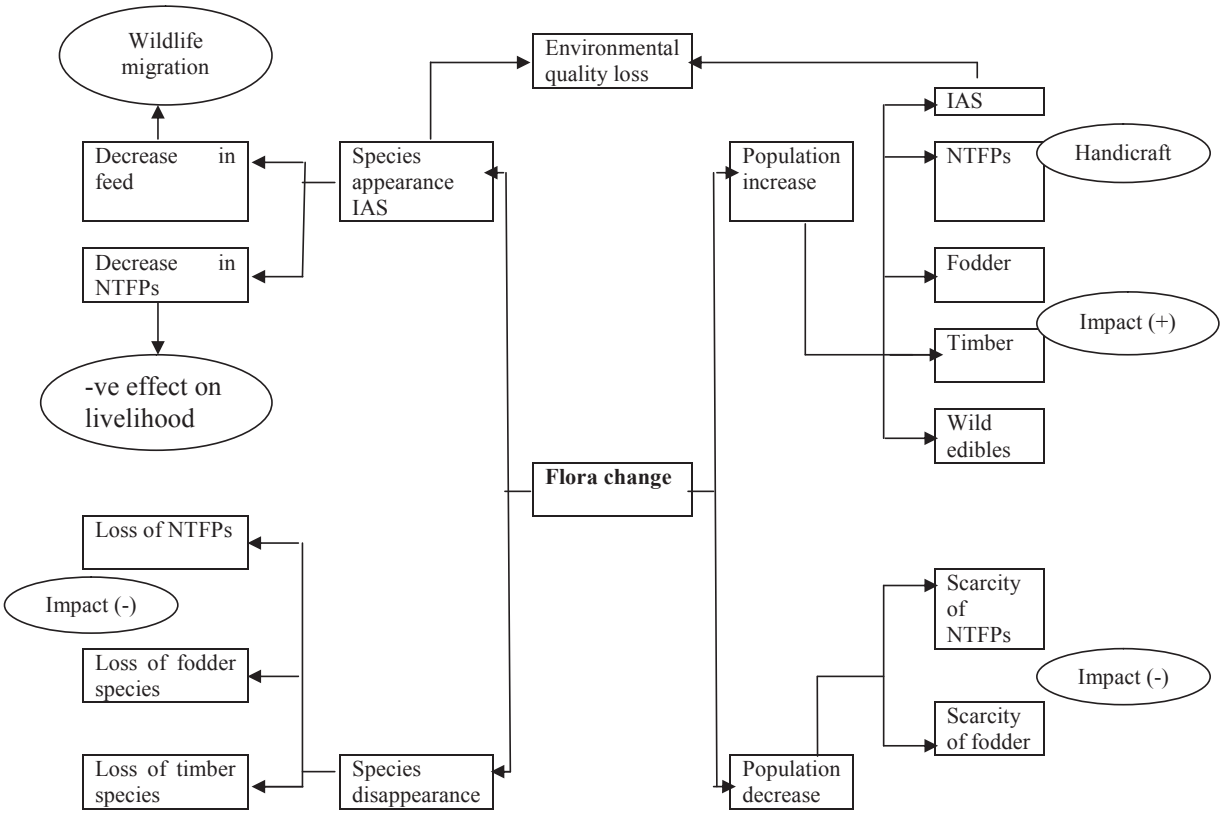


Figure 4. Schematic representation of flora change in different sectors
(IAS: Invasive alien species; NTFPs: Non-timber forest products)

7. Conclusion

From this paper, we found that flora and its population is in dynamic state and observed changes in plant population of dominant species in forest, grassland and commonland ecosystems of western Chitwan, Nepal over short time period. This change was pronounced and seen clearly when anthropogenic activities and natural forces disturbed the ecosystems. It was noticed that, in our research sites, some species were disappeared and some new species were appeared in the studied plots due to such forces. The disappearance of useful plants (NTFPs) or introduction of invasive plants (*Chromalaena ordorata*, *Lantana camara* and *Ageratum houstonianum*) cause direct or indirect effect on human beings, livestock and wildlife. As the present paper is based on the data collected from January to April of 1996, 2000 and 2007, it is recommended to conduct collaborative research to collect data in summer and fall seasons as well to understand the trend of flora change with causes and consequences.

Acknowledgement

This research was supported by a grant from the National Institute of Child Health and Human Development (Grant # ROl-HD 33551), USA. We extend our sincere thanks to Dr. William G. Axinn (Principal Investigator), Jennifer Barber, Kerry Richter, Dirgha Ghimire, and Prem Bhandari for advice during the sample design stages, with special thanks to Netra Chhetri, Sujan Shrestha, Harimaya Poudel, Rajendra Darai, Janaki Rimal, Binoj Shrestha, and Shree Bhakta Dhungana for supervising the collection of flora data from the research sites.

References

Axinn, W. G. and Shivakoti, G. P. (1997), Demographic issues and use of natural resources. Pp. 83-85, In: Shivakoti et al. (eds.), *People, Participation, and Sustainable Development: Understanding the Dynamics of Natural Resource Systems*, (Proceedings of an International Conference held at the Institute of Agriculture and Animal Science, Rampur, Chitwan, Nepal, 17-21 March, 1996), Bloomington, Indiana and Rampur, Chitwan.

Barber, J. S., Biddlecome, A. E. and Axinn, W. G. (2003), Neighborhood social change and perception of environmental degradation, *Population and Environment*, 25(2), 77-108.

Chetri, M. (2006), Diet analysis of gaur, *Bos gaurus gaurus* (Smith, 1827) by micro-histological analysis of fecal samples in Parsa wildlife reserve, Nepal, *Our Nature*, 4, 20-28.

Cook, C. D. K. (1996), *Aquatic and Wetland Plants of India*, New York: Oxford University Press.

Dangol, A. (2007), Study of grassland community and monitoring of vegetation succession in Old Padampur site of Chitwan National Park- A tool for management prescription, B. Sc. Thesis, Department of Environmental Science and Engineering, School of Science, Kathmandu University, Dhulikhel.

Dangol, D. R. (1990), Lentil weeds in Rampur, Chitwan Valley, Nepal, *Lens Newsletter*, 17(1), 11-13.

Dangol, D. R. (2000-2001), Aquatic plant resources and their uses: Observation from Beesh Hazar Lake, Chitwan, *Journal of Institute of Agriculture and Animal Science*, 21-22 (2001), 119-133.

Dangol, D. R. (2008), Traditional uses of plants of commonland habitats in Western Chitwan, Nepal, *Journal of Institute of Agriculture and Animal Science*, 29, 71-78.

Dangol, D. R. (2009), Reciprocal relation between population and the environment: Innovations on flora data collection, *Journal of Institute of Agriculture and Animal Science*, 30, 143-149.

Dangol, D. R. and Gurung, S. B. (1988), Preliminary survey of major field crops weeds and farmers' weed management practices in Chitwan, Nepal, A report submitted to Royal Nepal Academy of Science and Technology (RONAST), Kathmandu, Nepal.

Dangol, D. R. and Shivakoti, G. P. (2001a), Plant diversity of western Chitwan: floristic approach, *Journal of Natural History Museum*, 20,129-148.

Dangol, D. R. and Shivakoti, G. P. (2001b), Species composition and dominance of plant communities in western Chitwan, Nepal, *Nepal Journal of Science and Technology*, 3, 69-78.

Dangol, D. R., Gurung, S. B. and Bhandary, A. (1995), Studies on plant communities of natural and man-engineered ecosystems in Chitwan valley, *Research Report*, pp. 116-162. NEMP/IUCN and NAHSON Chitwan Unit, Nepal.

Deb, D. B. (1983), *The Flora of Tripura State*, New Delhi: Today and Tomorrow's Printers and Publishers.

Freckleton, R. P. and Watkinson, A. R. (2002). Large-scale spatial dynamics of plants: metamopopulations, reginonal ensembles and patchy populations, *Journal of Ecology*, 90, 419-434.

Ghimire, D. J. and Mohai, P. (2005), Environmentalism and contraceptive use: How people in less developed settings approach environmental issues, *Population and Environment*, 27(1), 29-61.

Gupta, O. P., Bajracharya, S. B. and Shivakoti, G. P. (1977), A study of weed problems at Rampur, Chitwan, Nepal, *Journal of Institute of Agriculture and Animal Science*, 1, 1-86.

Jha, S. (2007), Phytodiversity in Beeshazar lake and surrounding landscape system, *Our Nature*, 5, 41-51.

Joshi, S. R. and Jha, P. K. (1995), Biomass production in grasslands of the Royal Chitwan National Park, Nepal, *Ecoprint*, 2(1), 40-45.

Karahalil, U., Alihsan K. U., Emin Z. B. K. and Selahattin, K. (2009), The spatiotemporal forest cover changes in Köprülü Canyon National Park (1965 - 2008) in Turkey, *African Journal of Biotechnology*, 8 (18): 4495-4507.

Lehmkuhl, J. F. (1994), A classification of subtropical riverine grassland and forest in Chitwan National Park, Nepal, *Vegetatio*, 111, 29-43.

Matthews, S. A., Shivakoti, G. P. and Chhetri, N. (2000), Population forces and environmental changes: Observations from western Chitwan, Nepal, *Society and Natural Resources*, 13, 763-775.

PERL (2055), Respondents' report, Rampur, Chitwan, Nepal: Population and Ecology Research Laboratory, Institute of Agriculture and Animal Science.

Poudel, A., Baral, H. S., Ellison, C., Subedi, K., Thomas, S. and Murphy, S. (2005), *Mikania micrantha* weed invasion in Nepal. A summary report of the First National Workshop for Stakeholders held on 25 November 2004 in Kathmandu, Nepal, Himalayan Nature, IUCN Nepal, and CAB, UK.

Richter, K. and Chhetri, N. (1997), Issues and strategies for understanding population and ecology interlinkages in western Chitwan, pp. 114-125, In: Shivakoti et al. (eds.), *People, Participation, and Sustainable Development: Understanding the Dynamics of Natural Resource Systems*, (Proceedings of an International Conference held at the Institute of Agriculture and Animal Science, Rampur, Chitwan, Nepal, 17-21 March, 1996), Bloomington, Indiana and Rampur, Chitwan.

Sapkota, L. (2007), Ecology and management issues of *Mikania micrantha* in Chitwan National Park, Nepal, *Banko Janakari*, 17(2), 27-39.

Sapkota, L. N. (2006). Invasive alien species in Chitwan National Park, Nepal, A Special Study Report for the Partial Fulfillment of M. Sc. Forestry, Submitted to Institute of Forestry, Tribhuvan University, Pokhara, Nepal.

Shivakoti, G. P., Axinn, W. G., Bhandari, P. and Chhetri, N. B. (1999), The impact of community context on land use in an agricultural society, *Population and Environment*, 20, 191-213.

Shivakoti, G. P., Matthews, S. A. and Chhetri, N. B. (1998), Anthropogenic impacts on flora biodiversity in the forests and common land of Nepal, Paper presented at the 1998 Annual Meetings of the Population Association of America, Chicago, II, April 1-4.

Shrestha, B. K. and Dangol, D. R. (2006), Change in grassland vegetation in the northern part of Royal Chitwan National Park, *Scientific World*, 4(4), 78-83.

Shrestha, B. K., Dangol, D. R. and Ghimire, K. (2006), Heterogeneity in plant population and species diversity in Barandabhar Corridor Forest, Chitwan, *Banko Janakari*, 16(2), 58-63.

Shrestha, B. K., Ghimire, D. J. and Dangol, D. R. (2008), Lahare banmara atikraman badhdo chunauti (Increasing threat of invasive *Mikania micrantha*), *Paryabaran*, 89, 16(4): 26-30.

Siwakoti, M. (2007), Mikania weed: A challenge for conservationists, *Our Nature*, 5, 70-74.

Steinheim, G., Wegge, P., Ejellstad, J. I., Jnawali, S. R. and Weladji, R. B. (2005), Dry season diets and habitat use of sympatric Asian elephants (*Elephas maximus*) and greater one-horned rhinoceros (*Rhinocerus unicornis*) in Nepal, *J. Zool. Lond*., 265, 377-385.

Tiwari, S., Adhikari, B., Siwakoti, M. and Subedi, K. (2005), *An Inventory and Assessment of Invasive Alien Plant Species of Nepal*, Kathmandu: IUCN Nepal.

Varma, S. K. (1981), *Flora of Bhagalpur: Dicotyledons*, New Delhi: Today and Tomorrow's Printers and Publishers.