Journal of Environment Sciences

(JoEnvSc)

Year 1 | 2015 A.D. | Volume 1

Published by:

Government of Nepal
Ministry of Science, Technology & Environment
Department of Environment
Tel: +977-1-5551161, 5551167
Fax: +977-1-5551149
E-mail: info@doenv.gov.np
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Publisher :

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URL: http://doenv.gov.np

Design & Layout : **Bhojendra Basnet**
basnet.bhojendra@gmail.com
+977-9851180936

Printing : **Prasanna Printers**
Gothatar-8, Kathmandu
Mob.: +977- 9851091100
Email: prasanna.printers731@gmail.com

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About the Journal of Environment Sciences (JoEnvSc)

In Nepal Department of Environment (DoEnv) is in very early stage of evolution with the mandate of planning, implementing, monitoring and enforcement of environmental activities within the framework of Environmental Protection Act-1996, Environmental Protection Regulation-1997, standards, guidelines and Nepal government's laws and rules. As we all know environment does not have any political or physical boundaries we need the knowledge about the natural science (environmental science, environmental management, environmental engineering, etc.) to fulfill the mandate given to DoEnv. To pile of scattered knowledge, information, technique, technologies that have been generated in different paradigms of environment, DoEnv has brought/published a peer reviewed journal "Journal of Environment Sciences (JoEnvSc)". The journal aims to share environmental information and also establishes relationship among professionals, researchers, academicians and policy makers in broad arena. It is the first volume of journal that has got immense effort from environmental academicians, specialist and professionals.

The support that we have obtained from the professionals, experts, and academicians we are full with hope and confident to publish succeeding volumes of JoEnvSc in coming years. And also hope for the spontaneous support from you all.

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Comb Building Behavior of Wild Honeybee, *Apis dorsata* Fab. in Chitwan, Nepal

Suroj Pokhrel, Ph.D.[1]

Abstract

A field survey was undertaken to investigate the comb building behavior influenced by colony sizes, seasons and sites of Apis dorsata Fab. colonies at Sukranagar, Mangalpur, Narayanghat, Yagapuri, Aaptari and Bharatpur of Chitwan valley in 2004. The primary immigration of A. dorsata small colonies occurred during November (591.8 cm^2)-December (549.8 cm^2) and secondary type mainly from site shifting of the large colonies towards north in January (2302.8 cm^2)-February (1188.6 cm^2) and smaller colonies through swarming in March (713.0 cm^2)-April (225.0 cm^2), respectively. They preferred non-disturbed previous nesting sites on tall water towers, Bombax trees and residential buildings. They built new comb with slightly changed alignment. All the colonies performed rapid comb building during November-December and March-April and by the larger immigrants even during January-February. It was completely stopped in May-June. The maximum comb size was up to 7200 cm^2 (60 x 120cm). Nesting period ranged from a week to eight months. The comb building slowed, foraging and brood rearing stopped at the absconding period in May-June.

Keywords: *absconding, comb building, immigration, nesting*

Introduction

Honeybee diversity in Hindu Kush Himalayan (HKH) region consists of *Apis cerana* F., *A. dorsata* F., *A. florea* F. and *A. laboriosa* Smith and exotic *A. mellifera* L. Among these honeybees *A. dorsata* is a wild, open nesting and single comb building honeybee and is a natural pollinator of several cultivated and wild plants in Asia (Atwal, 1970; Maun and Gurdip, 1983; Singh, 2000). They are distributed throughout the foothills, Terai and inner Terai of Nepal. Their nesting sites are tall trees, buildings, and water towers with available food resources (Hadorn, 1984; Lindauer, 1956: Morse and Benton, 1967; Reddy, 1980, Pokhrel, 2005). However, the biology, aggregation, migration and immigration of this species are poorly understood (Sihag, 1998; Roepke, 1930; Hadorn, 1984; Lindauer, 1956; Morse and Benton, 1967; Koeniger and Koeniger, 1980; Seeley *et al*,. 1982). The members of this species are furious and attack in mass for defense (Maschwitz, 1963; Frish, 1967; Morse *et. al.*, 1967; Koeniger *et. al.*, 1979). They are good honey collectors (Thakar and Tonapi, 1961; Singh, 1980), and therefore, important source of honey in Nepal (Shrestha, 2001). The role of these bees as crop pollinators to augment national income through increased bio-diversity and crop production has been forgotten. In addition, honey hunting, destruction of the nesting

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sites and the natural pasture (forest), increasing trend of pesticide use for crop protection, reduction of cultivated bee flora and the rapid multiplication of *A. mellifera* colonies in its natural habitat in Chitwan valley Nepal, in nineties, pushed this species on the verge of extinction (Pokhrel, 2005; Pokhrel, 2006; Pokhrel, 2008; Pokhrel, 2009; Pokhrel, 2010; Shrestha, 2001). Thus, study on the natural biology and cause of decline of *A. dorsata* population in its natural habitat in Chitwan valley was necessary. The objective of the study was to investigate the phenomena of seasonal immigration, aggregation and staying of *A. dorsata* colonies in Chitwan valley, Nepal.

Materials and method

Research site

The research was conducted in Chitwan district (inner Terai) at central Nepal. Sites selected for the study were the man-made structures and *Bombax* trees, which had the previous history of having this bee colonies nesting onto them in aggregate of 3-30 colonies on a single structure/tree at Sukranagar, Mangalpur, Yagapuri, Narayanghat, Aaptari and Bharatpur. All the sites were at 350 m.asl.

Research time and duration

Study was carried throughout the year, starting from May 2003 to July 2004.

Observation

Survey of the nesting sites was carried out at monthly interval to find out the seasonal migration of *A. dorsata* colonies in Chitwan. Observations were recorded every month on the dates of immigration, rate of comb development (size) and number of colonies nesting at particular sites (Sukranagar, Mangalpur, Yagapuri, Narayanghat, Aaptari and Bharatpur). Weather data (temperature, humidity and rainfall) were collected from National Maize Research Program, Rampur.

Data processing

Collected data were tabulated using EXCEL software and necessary tables, graphs and figures were prepared. Means, variance and standard errors were calculated.

Result

Immigration season

November was the beginning month of immigration of *A. dorsata* colonies in Chitwan. The first immigration site noticed was Sukranagar (near by Chitwan National Park) followed by Yagyapuri (Horticulture Farm). Out of five sites observed in Chitwan, the immigration was continued during winter, spring and ended by early summer. In November, there were all together 12 colonies, 9 in Sukranagar and 3 in Yagyapuri. The number increased by 66.7% in December, which decreased in the winter by 60.0% and

increased again in spring by 225.0%. Of the total colonies immigrated in Sukranagar, 92.8% occurred in November–December (N=26) and the rest in March-April (N=2). Yangapuri was only a site of continuously immigrating colonies for five months from November to March. Immigration of the colonies in Mangalpur occurred only in January and in Bharatpur (Narayani Safari & Hotel Island) in February-March (Fig. 1).

The immigration was mainly of two types: primary and secondary immigration.

Primary immigration

The colonies from a long distance flight arrived to the southern area of the Chitwan, near the Chitwan National Park where the early mustard, *Brassica* spp. and buckwheat, *Fagopyrum esculentum* Moench bloomed earlier in November-December. Of the total colonies (N=83), 38.6% (N=32) were the primary immigrant colonies. Over 80.0% of the primary observed immigrant (early in-coming) colonies from long distance nested at a private building at Bishalchock, Sukranagar and the rest nested on the water tower, Yagyapuri (Fig.1).

Secondary immigration

Secondary immigration was of two types: site shifting and swarming**.**

Secondary immigration through site shifting

Out of the total colonies (N=32) immigrated during November-December in Chitwan, 52.0% (N=17) shifted their nesting sites in January-February. In a total of five locations, incoming colonies (N=83), the secondary immigrants through temporary site shifting were 44.6% (N=37).

Secondary immigration through swarming

Secondly, about one-forth of the colonies immigrated in November-December produced 4-7 queen cells per colony and swarmed in late February. Nearly 17% (N=14) colonies immigrated from swarming in February-March (Fig.1).

Both the secondary type of immigrants spread to water tower at Yagyapuri, *Bombax* tree at Hotel Narayani Safari and Hotel Island at Bharatpur, and private building at Mangalpur.

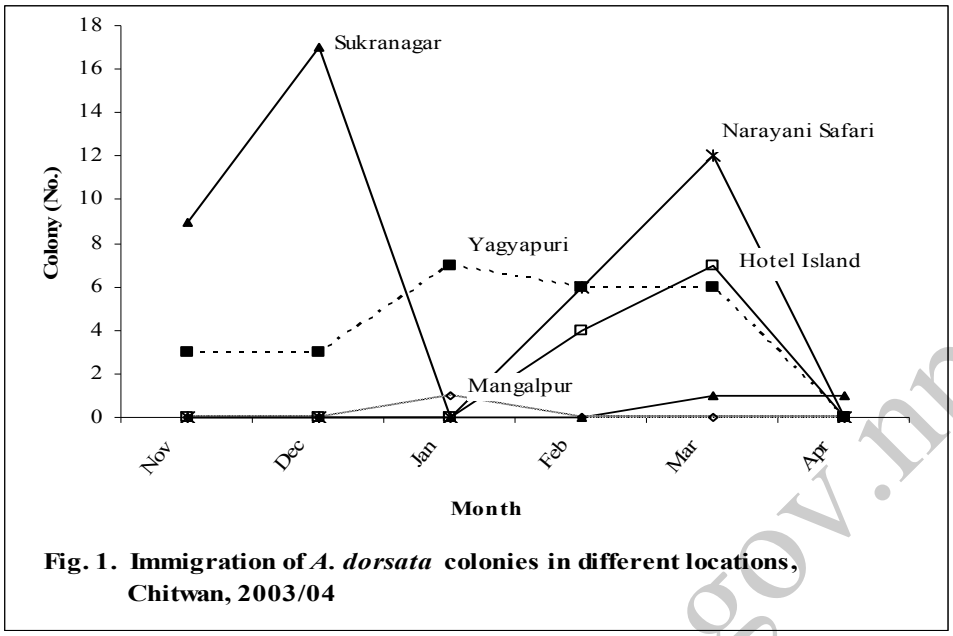

Fig. 1. Immigration of *A. dorsata* colonies in different locations, Chitwan, 2003/04

Colonies of *A. dorsata* preferred non-disturbed previous nesting sites. They denied using white washed building at Narayanghat and the standing dead *Bombax* tree at Aaptari. The private building at Bishalchok, Sukranagar was most preferred due to the least disturbance and being near by the Chitwan National Park where mustard, *Brassica* spp. and buckwheat, *F. esculentum* bloomed earlier in November. They nested on tall water towers (Fig. 2 and 3), *Bombax* trees and taller buildings at different locations. The private building at Bishalchok, Sukranagar was most preferred due to the least disturbance and being near by the Chitwan National Park where mustard, *Brassica* spp. and buckwheat, *F. esculentum* bloomed earlier in November. They nested on water towers, *Bombax* trees and taller buildings at different locations.

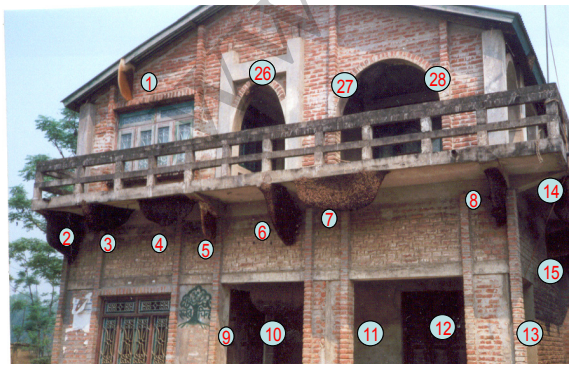

Fig-2: Colonies nesting on a non-disturbed building at Sukranagar, Chitwan, 2003/04

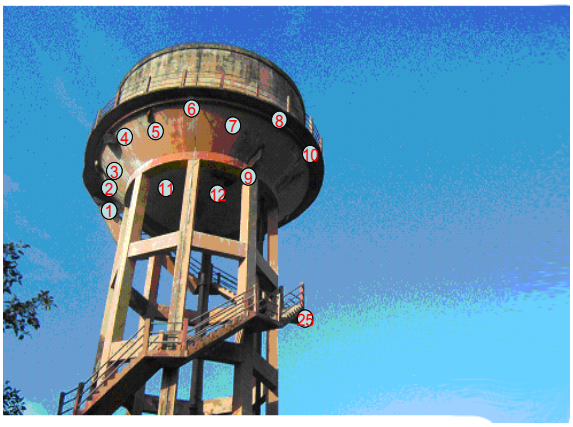

Fig 3: Colonies nesting on a non-disturbed water tower at Yagyapuri, Chitwan, 2003/04

3.3 Nest alignment

The colonies occupied the old nesting site, but they did not reuse the old nests; they changed the comb alignment (Fig.4), which could be due to weak, infested old foundations/combs.

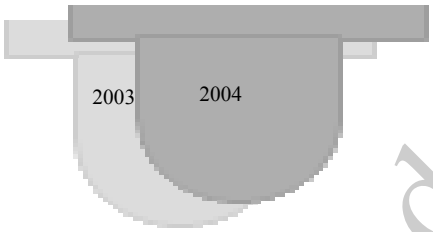

Fig. 4: Change on comb alignment by *A. dorsata* colonies on the old nesting site, Chitwan, 2003/04

Arrival time and colony size

The mean colony size of *A. dorsata* differed with its arrival time from location to location. The early immigrant colonies in November (591.8 cm^2, N=12) and December (549.8 cm^2, N=20) were of smaller size, which increased to maximum mean size in January (2302.8 cm^2, N=8), then after the colony size decreased gradually every succeeding month with the smallest mean size in April (225 cm^2, N=1). Similarly, the primary immigrants in Novemver-December were smaller, secondary immigrants from site shifting in January-February were larger and secondary immigrants from swarming in March–April were smaller in size (Table 2, Fig. 5).

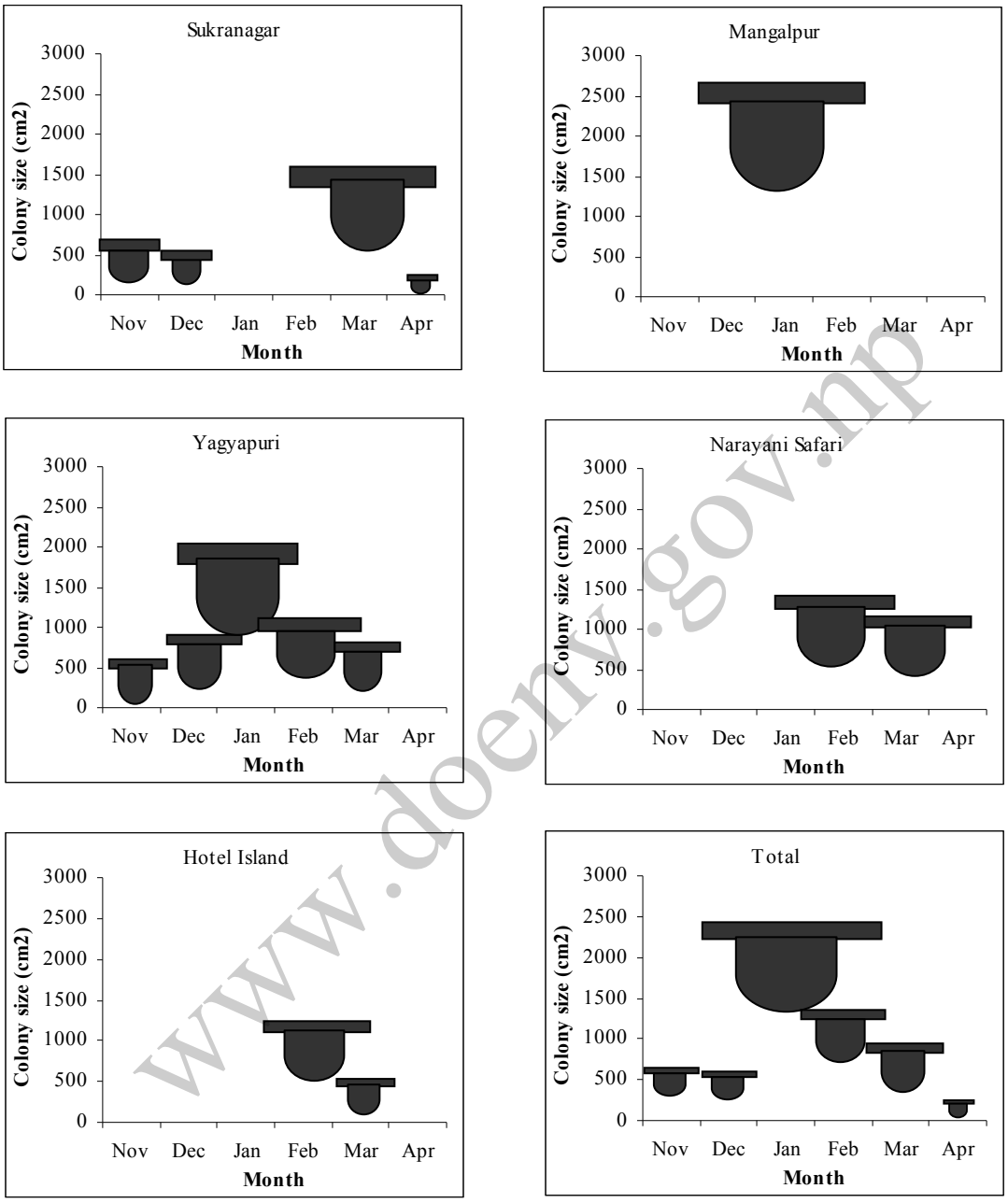

Fig.5. Colony size of *A. dorsata* by its arrival time at different locations, Chitwan, 2003/04

Table 1. Variation in *A. dorsata* comb size (cm^2) by its arrival time, Chitwan, 2003/04

Location	2003		2004				Total
	Nov	Dec	Jan	Feb	Mar	Apr	
Sukranagar	578(9)	488(17)	0	0	2025(1)	225(1)	562.4(28)
Yagapuri	633(3)	900(3)	2246(7)	1037(6)	713(6)	0	1232.8(25)
N. Safari	0	0	0	1304(6)	1117(12)	0	1179.3(18)
Mangalpur	0	0	2700(1)	0	0	0	2700(1)
H. Island	0	0	0	1243(4)	471(7)	0	751.7(11)
Average	591.8(12)	549.8(20)	2302.8(8)	1188.6(16)	884.8(26)	225(1)	949.0(83)

Figures in parentheses are the colony number.

Comb building rate

Comb building by *A. dorsata* colonies also differed from location to location, season to season and colonies to colonies (Table 3). The smaller colonies had only of 25 cm^2 and the lager had 7200 cm^2 (60 x 120cm) during the peak growth period. Initially, the nest was nearly roundest, which flattened and widened later during the growth period. The rate of comb building was faster at Sukranagar in November-December, slower in January- February, fastened again in March-April and almost ceased in May-June (Fig. 6). The same was true in Yagyapuri site, i.e. faster comb buiding in November-December and slower in January-February (Fig. 7). However, bigger colonies just after arriving at Bharatpur (Narayani Safari and Hotel Island) and Mangalpur had faster growth rate during January-February (Fig. 8, Fig. 9, Fig. 10). The comb building coincided with heavy flow season having optimum temperature (max. 29.0^0 and min. 15.1^0 C) in November and slowed as the temperature

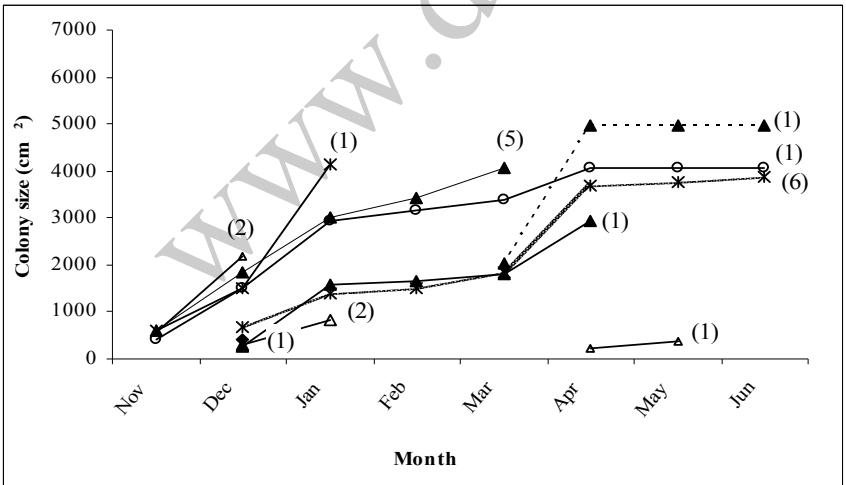

Fig. 6. Growth rate of *A. dorsata* colonies in Sukranagar, Chitwan, 2003/04

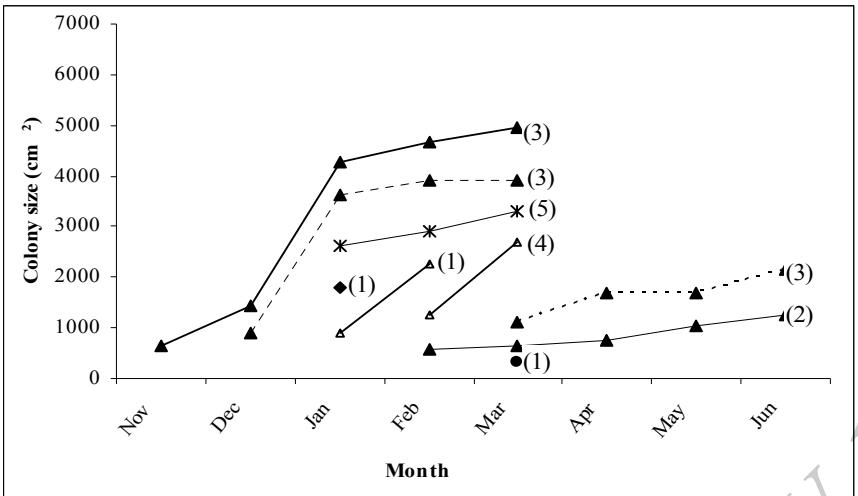

Fig. 7. Growth rate of *A. dorsata* colonies in Yagyapuri, Chitwan, 2003 /04

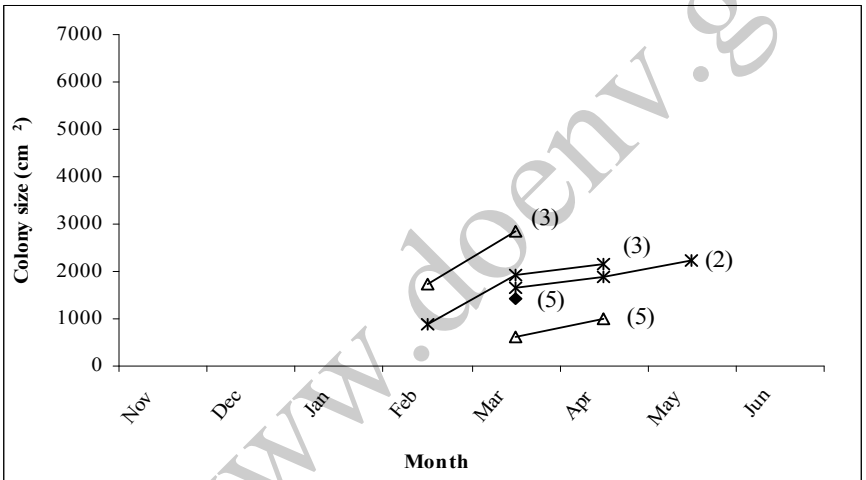

Fig. 8. Growth rate of *A. dorsata* colonies in Hotel Narayani Safari, Chitwan, 2003/04

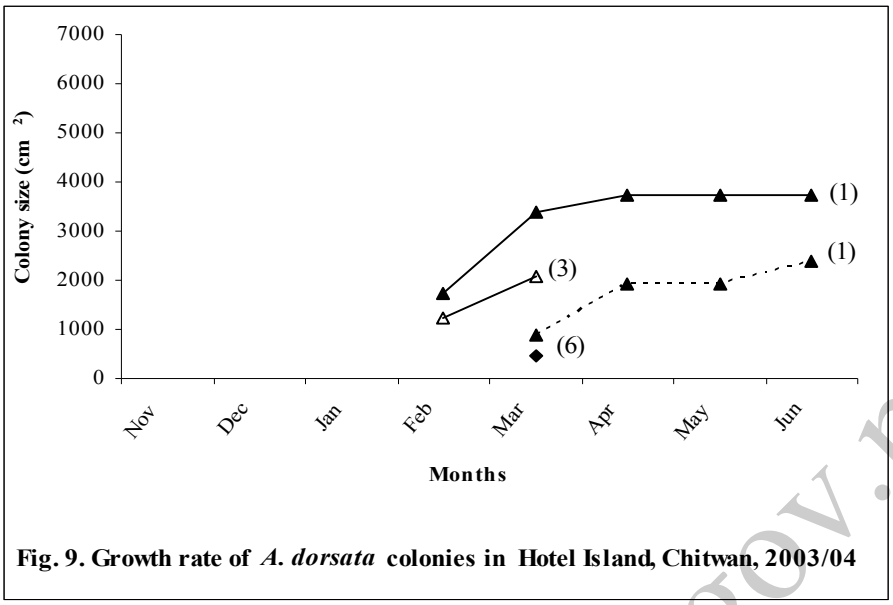

Fig. 9. Growth rate of *A. dorsata* colonies in Hotel Island, Chitwan, 2003/04

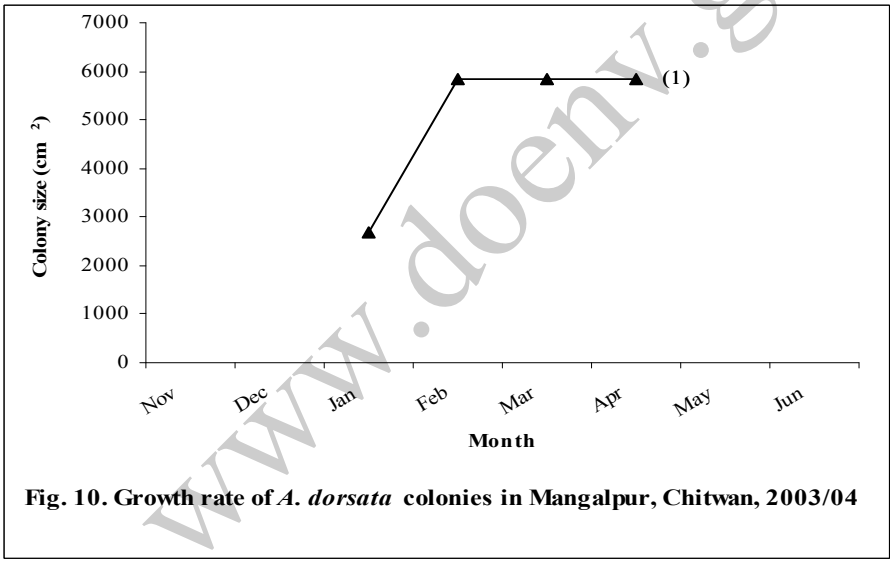

Fig. 10. Growth rate of *A. dorsata* colonies in Mangalpur, Chitwan, 2003/04

and slowed as the temperature decreased (max. 21.30 and min. 9.30C) in January, finally completely ceased at high temperature (max. 33.4.00 and min. 20.2 0C) in April (Table 3).

Usually, the larger colonies had faster comb building capacity even if the temperature was lower than required. Sukranagar site showed unique increasing trend of *A. dorsata*: first in autumn just after arrival and next in spring during March-April (Table 3). Rest of the sites had single peak growth during autumn for primary immigrant colonies and in

winter for the site shifted secondary immigrant colonies. In general, the rapid growth rate of the comb (colony size) building was in November-December or in March-April, when the air temperature was favorable. Their growth rate reduced in January-February due to the low temperature. After March the colony strength remained constant due to high temperature and decreasing bee pasture (Table 10).

Table 3. Mean comb growth rate (cm^2) of *A. dorsata* colonies in Chitwan, 2003/04

Month of arrival and location	Staying (month)	Colony (No)	2003		2004						
			Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
Sukranagar Nov, 2003	8	1	400	1500	2925	3150	3375	4050	4050	4050	Left
	5	5	615	1845	3020	3415	4050	Left			
	3	1	600	1500	4125	Left					
	2	2	563	2175	Left						
Dec, 2003	7	6		675	1396	1496	1846	3700	3775	3871	Left
	5	1		270	1575	1650	1800	2925	Left		
	2	2		300	813	Left					
	1	8		422	Left						
Mar, 2004	4	1					2025	4950	4950	4950	Left
Apr, 2004	2	1						225	375	Left	
Yagyapuri Nov, 2003	5	3	633	1442	4260	4650	4950	Left			
Dec, 2004	4	3		900	3625	3925	3925	Left			
Jan, 2004	3	5			2604	2925	3285	Left			
	2	1			900	2250	Left				
	1	1			1800	Left					
Feb, 2004	5	2				575	638	750	1050	1263	Left
	2	4				1269	2706	Left			
Mar, 2004	4	3					1117	1682	1682	2158	Left
	1	3					308	Left			
Narayani Safari Feb, 2004	3	3				875	1923	2158	Left		
	2	3				1733	2850	Left			
Mar, 2004	3	2					1650	1875	2250	Left	
	2	5					615	1015	Left		
	1	5					1405	Left			
Mangalpur Jan, 2004	4	1			2700	5850	5850	5850	Left		
Hotel Island Feb, 2004	5	1				1750	3375	3750	3750	3750	Left
	2	3				1244	2094	Left			
Mar, 2004	4	1					875	1925	1925	2400	Left
	1	6					471	Left			

Comb size

Among the total colonies, 37% (N=31) were very small (<1000 cm^2) and absconded within 1-2 months of primary immigration or as new swarms in March-April. However, 19% (N=16) colonies were small (1000-2500 cm^2) and 31% (N=26) were medium (2500-4500 cm^2) followed by 10% (N=8) large (4501-6000 cm^2) and 2% (N=2) very

large (6001-7500 cm^2), respectively (Table 3, Fig. 11). Among the colonies nesting in Sukranagar, more than one-third (35.7%, N=10) were of medium (2501-4500 cm^2), followed by 32.1% very small (<1000 cm^2) and 17.9% small (1000-2500 cm^2), 7.1% larger (4501-6000 cm^2) and 7.1% very large (6001-7500 cm^2) size. At Yagyapuri, 40.0% colonies were of medium, 24.0% very small, 20.0% small and 16.0% large. Moreover, the highest proportions of nesting colonies at Bharatpur (Narayani Safari 50.0% and Hotel Island 63.6%) were very small fallowed by small size (22.2% and 18.2%) and medium (22.2% and 18.2%). The proportion of large colonies was very low (5.6% in Hotel Narayani Safari) at absconding time in April-May.

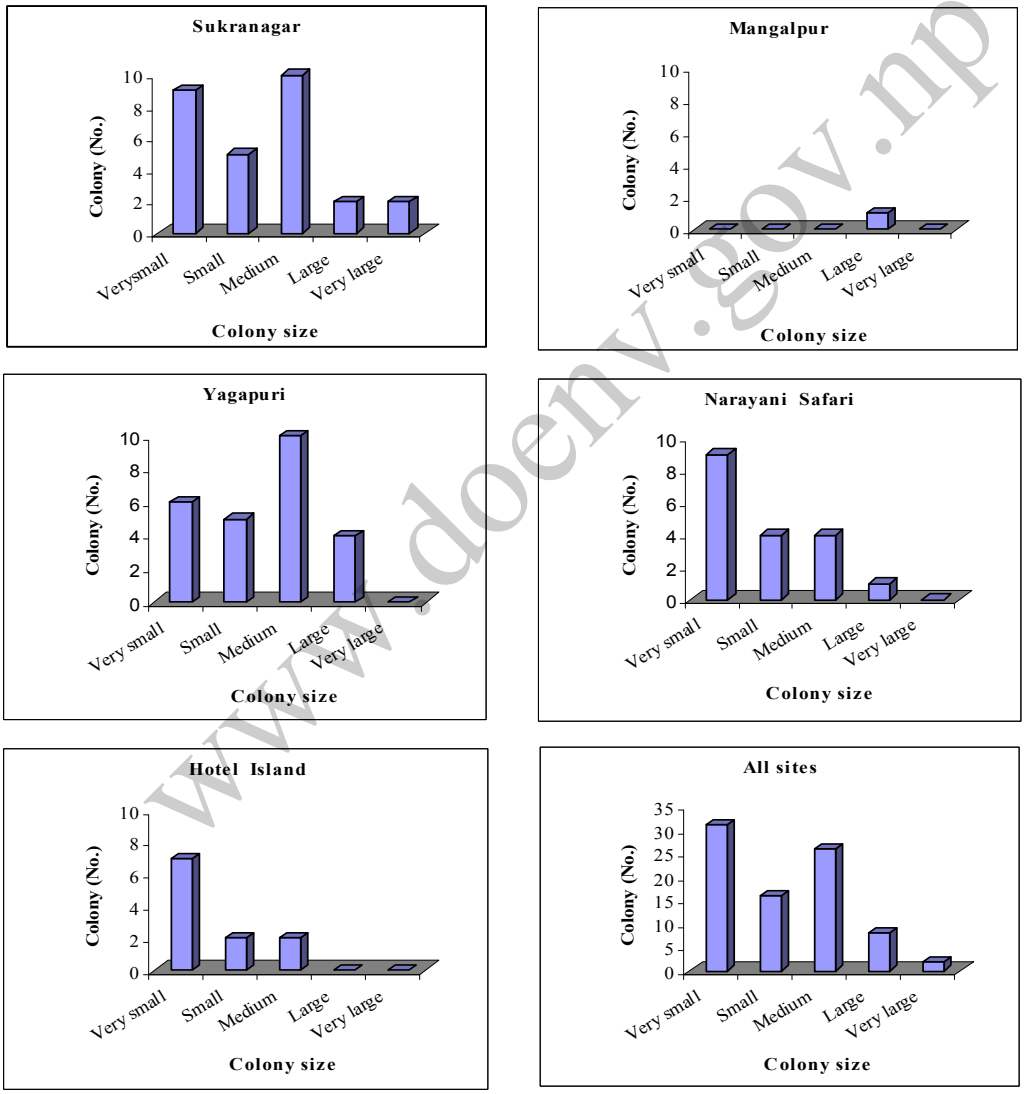

Fig. 11. Size of *A. dorsata* combs at different sites, Chitwan, 2003/04

Table 4. Growth of *A. dorsata* combs at different nesting sites, Chitwan, 2003/04

Location	Colonies under different category (%)					Range (cm^2)
	Very small (<1000 cm^2)	Small (1000-2500 cm^2)	Medium (2501-4500 cm^2)	Large (4501-6000 cm^2)	Very large (6001-7500 cm^2)	
Sukranagar	32.1(9)	17.9(5)	35.7(10)	7.1(2)	7.1(2)	25-7200
Yagyapuri	24.0(6)	20.0(5)	40.0(10)	16.0(4)	(0)	100-5400
Hotel Safari	50.0(9)	22.2(4)	22.2(4)	5.6(1)	(0)	150-4950
Mangalpur	(0)	(0)	(0)	100.0(1)	(0)	5850
Hotel Island	63.6(7)	18.2(2)	18.2(2)	(0)	(0)	100-3750
Total	37.3(31)	19.3(16)	31.3(26)	9.6(8)	2.4(2)	25-7200

Figure in parentheses are the actual colony number

Flora availability and comb building

All the colonies performed rapid comb building during November-December when the bee flora mustard, *Brassica* spp. and buckwheat, *F. esculentum* were bloomed in wider coverage. It was reaccelerated in March-April when a large number of bee flora bloomed with favorable temperature regime for the bees (Table 5).

Table 5. Number of bee flora available in Chitwan, 2004

Location	Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sukranagar	Total	22	33	51	49	54	51	41	36	29	26	17	12
	Pollen	20	29	42	45	52	49	39	34	27	21	12	10
	Nectar	16	24	39	38	38	36	27	23	16	17	13	9
Bharatpur	Total	19	30	51	52	53	57	47	42	34	27	17	13
	Pollen	17	26	43	46	51	53	42	37	32	23	13	11
	Nectar	13	23	40	39	37	39	33	29	21	20	13	10

Correlation between the parameters

All parameters except colony growth rate (r=-0.011) and initial colony size (r=-0.211) with colony immigration were positively correlated with each other (Table 6). Aggregation of *A. dorsata* colonies positively correlated with immigration (r=0.473), colony growth rate (r=0.213), initial colony size (r=0.307), and colony migration (r=0.263). Similarly, colony migration was positively correlated with colony immigration (r=0.258), colony aggregation (r=0.263), colony growth rate (r=0.070), and initial colony size (r=0.141).

Table 6. Correlation between the parameters of *A.dorsata* colony migration in Chitwan, 2005.

Parameter	Colony immigration (No.)	Colony aggregation (No.)	Colony Growth rate (cm^2)	Initial colony size (cm^2)	Migration (No.)
Colony immigration	1.000	0.473	-0.011	-0.211	0.258
Colony aggregation	0.473	1.000	0.213	0.307	0.263
Colony growth rate	-0.011	0.213	1.000	0.145	0.070
Initial colony size	-0.211	0.307	0.145	1.000	0.141
Migration	0.258	0.412	0.070	0.141	1.000

Discussion

Three cyclic immigrations of the *A. dorsata* colonies occurred in November-December, January-February, and February-March in Chitwan, Nepal. The primary immigration of 38.6% very small colonies (591.8 cm^2 and 549.8 cm^2) occurred in November-December from the long distance flight. In January-February, the secondary immigration (44.6%, N=37) of the larger colonies (2302.8 cm^2 and 1188.6 cm^2) was through temporary site shifting and nearly 17.0% (N=14) much smaller (225-713 cm^2) colonies spread from swarming in March-April. Shrestha (2001) reported that most of them immigrated in Chitwan in November. The returning time of this bee in the upland of Srilanka and in Banglore, India was little earlier i.e. at the starting of dry period (October-December) (Koeniger and Koeniger, 1980) but it was late at the end of February in Mae Tung Ting and Mae Hong Son, Thailand. Hadorn (1984) observed only two cyclic immigrations of 2-3 months in Sumatra and Thapa (1998) observed two peaks of reoccupation and abandonment of nest sites in Chiang Mai, Thailand, first in November and second in January-February. The first two immigrations were similar with as explained by Thapa (1998), Shrestha (2001) and Pokhrel (20100. In Chitwan, additional third immigration was observed in March-April, which was from queen rearing during favorable season in February and swarming during March-April, when maximum number of bee flora were available (N=96). The honeybee colonies nested on tall water towers, *Bombax* trees, and taller buildings at different locations in Chitwan. The first site of immigration was in south, near Chitwan National Park and around a horticulture farm in South-west of Chitwan. They preferred non-disturbed previous nesting sites near fields having early crop of mustard, *Brassica* spp. and buckwheat, *F. esculentum* blooming in November-December. They denied nesting on white washed buildings and standing dead *Bombax* trees. Lindauer (1956), Morse and Benton (1967), Reddy (1980) and Seeley *et. al.* (1982) also found the similar, non disturbed nesting sites of *A. dorsata* throughout South and South-east Asia. Deodikar *et.al.* (1977), Mardan (1989) and Crane (1990) explained the nest site chosen by *A. dorsata* swarms for nesting was usually not directly exposed to wind currents and partially sheltered. Swarms closer to the old nest sites got first opportunity to occupy the protective nest sites and also exploited natural and

cultivated flora for their survival, growth and development. The colonies occupied the old nesting sites in Chitwan, but did not use the old nests. They changed the comb alignments. Non-preference of the old nests may be due to their weakness and also for escaping from their natural enemies. Husain (1938), Pandey (1974), Ahmad (1989), Thapa (1998) and Shrestha (2001) also reported the old nest sites occupied by *A. dorsata* colonies in the consecutive years. The result agreed with Hadorn (1984) that *A. dorsata* never accepted the deserted comb while immigration to the original nesting sites, which might be a special ecological adaptation practice against their natural enemies. The deserted empty combs and the wax bulbs were source of recognition of the old nest sites (Lindauer, 1956; Mahindra *et. al.*, I977; Reddy, 1980; Thapa, 1998, Pokhrel, 2010). Comb building correlated with initial colony size, pasture availability and air temperature, which differed from colony to colony, location to location, and season to season. Comb size at the end of the season measured up to 7200 cm^2 (0.6 m x 1.2 m), while the smallest comb was 25 cm^2. Thapa (1998) reported higher comb building rate in Thailand during honey flow season. Comb growth was facilitated by regular availability of bee forage i.e. ornamental plants, eucalyptus, alfalfa, barseem and sunflower at Hissar (India), where new colonies established in October-November developed comb size of 1.0-1.5 m in length and 0.5 m in height (Sihag, 1998).

Nesting period of *A. dorsata* colonies was up to eight months, beginning from November and ending in June, which varied from locations to locations. Majority (53.0%, N=44) of the colonies absconded within 1-2 months, which was mainly from disturbed sites and in search of natural food. The period was longer, i.e. eight months near Chitwan National Park and five months at horticulture farm, because of the least disturbance and availability of bee flora for longer period (November-May). Sihag (1982) reported the average staying period of established *A. dorsata* colonies at a site to be for eight months and for a new swarm to be for 2.5 months in India. Thapa *et. al.* (1998) reported *A. dorsata* colonies staying up to 14 months in Mae Tung Ting and Mae Hong Son, non-disturbed sites in Thailand. Shrestha (2001) found the longest staying (9 months) of the colonies near Chitwan National Park in Chitwan. The trend of *A. dorsata* colony immigrating in Chitwan was declined by 54%, 50% and 100% in May, June, and July 2004 respectively compared to 2003. Shrestha (2001) recommended conservation and protection from factors or activities bringing about their devastation or pushing them towards the course of extinction from their habitat. The reason might be environmental, agricultural and the biological. Rapid multiplication of exotic honeybee, *A. mellifera* L. reduction on the area of bee crops, i.e. mustard, deforestation, pesticide poisoning and predation of the colonies might be the causes. Hadorn (1984) and Schmidt *et. al.* (1985) also explained extensive predation of *A. dorsata*, however, the impact on the species was smaller than the destruction of the primary forests with its tall trees in its habitat. The comb building of *A. dorsata* slowed and foraging and brood rearing stopped at the time of absconding. The absconded combs contained no honey,

brood and pollen. Koeniger and Koeniger (1980), Mahendra *et. al.* (1977) and Reddy (1980) also found similar results in Srilanka and India.

Conclusion and recommendation

Comb building by *A. dorsata* colonies differed from location to location, season to season and colony to colony. It was correlated with initial colony sizes, pastures availability and air temperature. Aggregation of the colonies, staying period and the size of the comb of this bee is decreasing year after year. Conservation of *A. dorsata* in its traditional habitat for the maintenance of biodiversity and raising the crop productivity is needed. For which promotion of bee pasture both in forest and agro ecosystem, prevention of pesticide poisoning, reduction of house bee colonies and prevention of honey hunting is necessary.

References

Ahmad, R. 1989. A note on the migration of Apis dorsata in the Andanman and Nicobar Islands. Bee World 70 (2): 62-65.

Atwal, A.S. 1970. Insect pollinators of crops. Punjab Agric. Univ. Press, Ludhiana, India.

Crane, E. 1990. Bees and beekeeping: Sciences, practice and world resources. Heinemenn Newnes, Oxford, UK. 274 pp.

Deodikar, G.B., A. L. Ghatge, R. P. Phadka, D. B. Mahindra, K. K. Kshirsagar, S. Muvel and C. V. Thaker. 1977. Nesting behavior of Indian honeybee III. Nesting behavior of Apis dorsata Fab. Indian Bee J. 30: 1-12.

Frisch, K.V. 1967. The dance language and orientation of bees. In: Morse R.A. and F.M. Laigo (eds.). 1969. Apis dorsata in the Philippines. The Beknap Press, Harvard Univversity,. Cambridge, USA 93 pp.

Hadorn, H. 1984. Betrachtungen liber wilde Bienen in Sumatra. Schweiz Bienenztg. 1984:309-314. Apis Arten mellifera, cerana, florea and dorsata. Proc. Intl. IUSSI Congr. 7:151-153.

Husain S.W. 1938. How honey is extracted from the combs of giant bee of India. Bee World. 19: 139-140.

Koeniger, N. and G. Koeniger. 1980. Observations and experiments on migration and dance communication of Apis dorasata in Sirlanka. J. Apic. Res. 19:21-34.

Koeniger, N., J. Weiss and U. Maschwitz. 1979. Alarm pheromones of the sting in the genus Apis. J. Insect. Physiol. 25: 467-476.

Lindauer, M. 1956. Uber die Verstandigung bei indischen Bienen. Z. Vgl. Physiol. 38:521-557.

Mahindra, D.B., K.S. Muvel, K.K. Kshirsagar, C.V. Thakar, R.P. Phadke and G.B. Deodikar. 1977. Nesting behavior of Apis dorsata. Proc. Int. Beekeep. Conger. 26: 299-300.

Maschwitz, U. W. 1963. Gefahrenlarmstoffe und Gefahrenalarmierung bei soizialen Hymenoptera. Z. Vgl. Physiol. 47: 596-695.

Maun, G.S. and S. Gurdip. 1983. Activity and abundance of pollinators of plums at Ludhiana (Punjab). American Bee J. 123: 595.

Morse, R.A. and A.W. Benton. 1967. Venom collection from species of honeybees in South-East Asia. Bee World. 48: 19-29.

Morse, R.A., D.A. Shearer, R. Boch and A.W. Benton. 1967. Observations on alarm substances in the genus Apis. J. Apic. Res. 6: 113-118.

Pandey, R.S. 1974. Honey collection in relation to migration schedule of wild honeybees in Utter Pradesh, India. Am. Bee. J. 114: 379-379.

Pokhrel, S. 2005. Behavior and Management of Domesticated and Wild honeybees (Apis spp.) in Chitwan, Nepal. Ph.D. dissertation. Tribhuvan University. 240 p.

Pokhrel, S. 2006. Present status of bee keeping in Chitwan, challenges and opportunity. Smarika, Chitwan Mahotsab 2063, Chamber of Commerce and Industry Narayanghat, Chitwan, Nepal (in Nepali).

Pokhrel, S. 2008. The ecological problems and possible solutions of beekeeping in hills and terai of Chitwan, Nepal. The Journal of Agriculture and Environment.9: 23-33.

Pokhrel, S. 2009. Climate Change, Inter Species Competition of Honeybees and possible effects on bio-diversity (in Nepali). Hamro Sampada. 9(1):29-32.

Pokhrel, S. 2010. Climeto-cylic immigrations with declining population of wild honeybee, Apis dorsata F. in Chitwan valley, Nepal. The Journal of Agriculture and Environment.11: 51-58.

Reddy, C.C. 1980. Studies on the nesting behavior of Apis dorsata F. Intl. Conf. Apic. Trop. Climate. 2: 391-397.

Roepke, W. 1930. Beobachtungen an indishen Honigbienen insbesondere on Apis dorsata Meded Landbounwhooge-School Wageninger. 34:1-28.

Schmidt, J.O., P.I. Schmidt and C. K. Starr. 1985. Investigating the giant honeybee, Apis dorsata, in Sabah. Am. Bee J. 125: 749-751.

Seeley, T.D., R.H. Seeley and P. Akratanakul. 1982. Colony defense strategies of the honeybee in Thailand. Ecol. Monogr. 52: 43-63.

Shrestha, J.B. 2001. Investigation of the parasitic mite, Tropilaelaps clareae Delfinado and Baker, and its host, Apis dorsata Fab., in Chitawan Nepal. Master's Thesis. Tribhuvan University, Institute of Agriculture and Animal Science. Rampur, Chitwan. 79 pp.

Sihag, R.C. 1982. Problems of wax-moth (Galleria mellonella L.) infestation on giant honeybee (Apis dorsata Fab.) colonies in Haryana. Indian Bee J. 44(4): 107-109.

Sihag, R.C. 1998. Eco-biology of the giant honeybee (Apis dorsata) in semi-arid sub-tropical climates of India. In: M. Mastsuma, L.R. Verma, S. Wongsiri, K.K Shrestha (eds.), Asian bee keeping: Progress of research and development. Oxford and IBH publishing Co. Pvt. Ltd. pp. 50-52.

Singh, A.K. 2000. Species of honeybees and their importance. In: R. Singh, P. Kumari and H. Chand (eds.), Manual on honeybee management. Apiary Unit, Rajendra Agricultural University, Bihar, Pusa. pp 20-21.

Singh, Y. 1980. Beekeeping in Uttar Pradesh-A review. In: Proc. Intl. Conf. Apic. Trop. Climmate. 2:211-226.

Thakar, C.V. and K. V. Tonapi. 1961. Nesting behavior of Indian honeybees: Differentiation of worker, queen and drone cells of the combs of Apis dorsata Fab. Bee World. 42: 61-62, 71.

Thapa, R. 1998. Colony migration of the giant honeybee Apis dorsata Fab. Ph.D Dissertation. Chulalongkorn University, Thailand. 102 pp.

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Impact of Forest Cutting and Pruning Activities on Tree Species Diversity, Regeneration and Forest Structural Complexity

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Abstract

The impacts of forest cutting, pruning and cleaning on the diversity and regeneration of tree species and forest structural complexity were analyzed in 2014. The study was carried out in Padali Community Forest, Lalitpur. Vegetation characteristics and forest structural features were studied in two strata of the forest: the cleaned stratum and the non-clean stratum. Stratified random sampling technique was used for vegetation sampling. The analysis showed that the diversity, richness and regeneration status of tree species in non-cleaned stratum was better than the cleaned one. Although, it was satisfactory in both the stratum. The approach of structural diversity index revealed notable differences in forest structural features in two strata. In the cleaned stratum, 65.7% of the forest area was under low structural diversity class while only 0.2% of the area was under high structural diversity class. But in the stratum which was not cleaned, only 17.2% of the area was covered by low structural diversity class and 47.1% of the area was covered by high structural diversity class.

Keywords: *Forest structural diversity, GIS, regeneration, species diversity*

Introduction

Forest Act 1993 defines community forest as the national forests handed over to a user group for development, conservation and utilisation for the collective benefit of the community (GoN, 1993). Master Plan for Forestry Sector (MPFS) (1988) of Nepal recognizes community forestry as one of its six priority sector programmes (Singh and Smith, 2009). Community forestry in Nepal has evolved through policy restructuring and the strengthening of rules and regulations on local control over forest resources (MoFSC/GoN, 2002). It has been described as the most successful primary forestry programme in Nepal especially in mid-hills (Singh and Smith, 2009; Winrock International/Nepal, 2002). The major management objectives of community forest are production and sustainable utilization of forest products and conservation of forest biodiversity (MoFSC/GoN, 2002).

There is increasing concern of accompanying biodiversity conservation issues with forestry practices (McCleary and Mowat, 2002; Torras and Saura, 2008). Maintenance, conservation and appropriate enhancement of biological diversity in forest ecosystems

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are important criteria for sustainable forest management (Freer-Smith and Carnus, 2008). Active intentional management addressing multiple objectives of conservation, production, utilization and recreation has been emphasized in forestry (Carey, 2006).

Cutting, pruning and cleaning activities are practiced annually in community forests of Nepal as a part of forest management practices (Prajapati, 2009). These activities annually generate large amount of biomass which has been used to produce charcoal and bio-briquette by many community forest user groups (CFUG) (Prajapati, 2009). Sustainable production of charcoal might help address the poverty issues of rural households (MoFSC/GoN, 2009). But in the absence of proper monitoring, the practices of charcoal and bio-briquette production may lead to the deforestation as there is always the risk of woody biomass being used for charcoal production. Many CFUGs have included phrases such as "removal of unwanted species" in their forest operational plans, yet these species may be ecologically important and biodiversity may suffer as a result of their removal (Acharya, 2004; MoFSC/GoN, 2002). Moreover, removal of dead wood, leaf litter and non-woody biomass from the forest for charcoal production may lead to reduced biodiversity (MoFSC/GoN, 2002).

In this context, this study analyzed tree species diversity and regeneration, and forest structural complexity in the managed and unmanaged blocks of community forest in which charcoal and bio-briquette production has been practiced for several years.

Material and method

Study area

This study was carried out in Padali Community Forest (PCF) which is located at Lamatar VDC-7, Lalitpur. The study area is bounded by 27°37.26'N to 27°37.80'N latitude and 85°22.86'E to 85°23.22'E longitude covering an area of 37 ha (Fig. 1). PCF was first handed over to the community in 1995 (PCFUG, 2008). Current operational plan of the community forest is the third amendment which has been adopted since 2008 (PCFUG, 2008). According to the operational plan, major long term objectives are to provide forest products to the users by sustainable forest management, to control soil erosion, to maintain environmental balance, to conserve wildlife and biodiversity, to conserve and utilize non timber forest product, do develop ecotourism, to conserve natural resources and to upgrade socioeconomic status of forest user group. Short term objectives are to upgrade the forest health, to ensure easy access to forest products for daily use, to increase peoples participation, to enhance technical skills, to upgrade economic status of poor and women and to provide employment opportunities (PCFUG, 2008). Annual forest cleaning, cutting, pruning and singling activities were found to be practiced from October to March in each year. Charcoal and bio-briquette production from forest biomass was found to be practiced actively by the user group.

Sampling

Random sampling design was adopted for vegetation study. GPS was used to make the boundary map of forest area. Hawth's tool was used in ArcMap 9.3 (ESRI, 1999) to generate 50 random sampling points. A minimum distance of 75 m was maintained between any two sampling points. The sampling points were taken as the centre of quadrats. Due to accessibility problems, only 36 out of 50 quadrats were studied under two strata (Fig. 1). Quantitative parameters characterizing the vegetation and forest structural features were calculated and monitored for the forest area where cleaning has been done within last three years and where intentional cleaning has not been done.

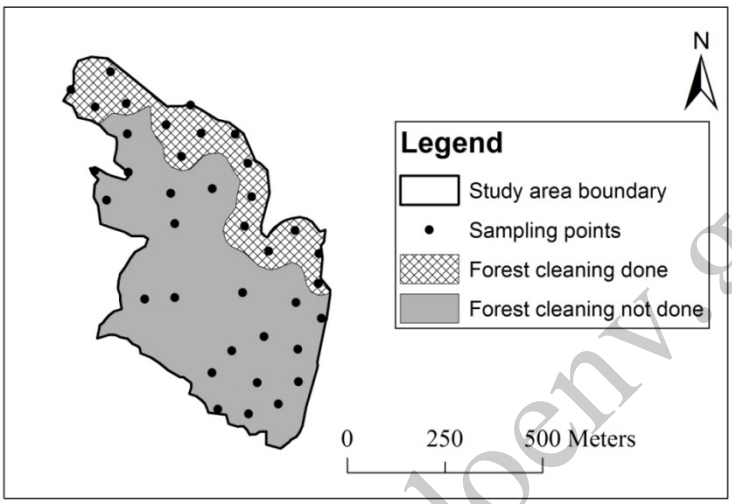

Fig 1. Study area showing vegetation sampling points

The revised community forest inventory guideline 2004 suggests minimum sampling intensity of 0.1 to 0.5% for forest inventory (MoFSC/GoN, 2004). Sampling intensity for current study was maintained at about 4%. Square quadrats were used for sampling units as given in table 1.

Table 1. Size of quadrats for trees, poles and regenerations (MoFSC/GoN, 2004)

Plant category	Criteria	Quadrat size
Tree	dbh (≥30cm)	20m×20m
Pole	dbh (10 to 29.9cm)	10m×10m
Regeneration (sapling)	Height (>1m), dbh(<10cm)	5m×5m
Regeneration (seedling)	Height (30 to 100cm)	2m×5m

At each quadrat, the number and dbh of trees, poles and saplings and number of seedlings were recorded by using dbh tape (KINGLON DIAMETER TAPE No. DP5). Only the tree species were considered in present study. Plant species were identified in the field and the help of local people was also taken for species identification. Herbarium was prepared for unidentified species and experts of related field were

consulted for identification. Spherical densiometer (Model A, FOREST DENSIOMETERS) was used for estimating the total canopy openness. Foliage covers at A, B_1 and B_2 (A-layer included mature trees >10 m in height; B_1 layer included regenerating trees, mature deciduous trees, tall shrubs, or woody plants 2–10 m in height; B_2 layer included shrubs or regenerating trees <2 m in height) layers were estimated visually (McCleary and Mowat, 2002). Canopy density at A, B_1 and B_2 layers were used to calculate foliage height density (FHD) as per equation-1 (Mccleary and Mowat, 2002).

$$Foliage\ Height\ Diversity\ (FHD) = -\sum p_i log_e p_i \quad Equation - 1$$

Litter layer depth was measured at 5 places within a quadrat and was averaged. Slopes were measured by using clinometers (SUUNTO TANDEM 0422122). Information regarding forest cleaning activity was also recorded at each plot which was later used to form the strata of forest where cleaning has been done and where cleaning has not been done yet. Every analysis related to vegetation was carried out separately in these two strata and the comparisons were made between them.

General characteristics of forest

Quantitative parameters like density, relative density, frequency, relative frequency, basal area, relative basal area and importance value index (IVI) were calculated as per the standard formula (Krebs, 1994; Odum, 1996). Shannon-Wiener function was used to assess the species diversity (Krebs, 1994). These parameters were calculated for 4 categories of plants i.e. trees, poles, saplings and seedlings as per the definition adopted by community forest inventory guideline (MoFSC/GoN, 2004).

Regeneration status

Regeneration status was assessed through the number of sapling and seedling per hectare of the forest. The analysis was done for each quadrat as well as for stratum of forest where cleaning has been done and the stratum of the forest where cleaning has not been done.

Inverse distance weighted (IDW) spatial interpolation technique was applied for preparing regeneration density map of the forest. For preparing both of the sapling and seedling density map, IDW with optimum power in terms of root mean square error (RMS) was used for interpolation. Geostatistical wizard of ArcMap (ESRI, 1999) was used for optimization. The interpolated maps were reclassified into poor, medium and good category and the area of each category under two strata of the forest studied was calculated. The poor, medium and good regeneration categories were based on the criteria as shown in table 2.

Table 2. Regeneration categories of the forest based on sapling and seedling density (MoFSC/GoN, 2004)

Parameters	Good	Medium	Poor
Seedling no./ha	>5000	2000-5000	<2000
Sapling no./ha	>2000	800-2000	<800

Forest structural diversity

Different forest structural features have been used to develop structural diversity indices (McCleary and Mowat, 2002) out of which only 3 relevant features were used with logical modifications in the present study. Standard methods given in relevant scientific works were used to calculate an additive index representing forest structural diversity (McCleary and Mowat, 2002). Foliage height diversity, depth of litter and duff layer and the density of trees (dbh≥30cm) were the parameters used in current study. These 3 parameters were calculated for each of the study quadrats and a single average was calculated for the whole study area. Then an additive index was calculated for each quadrat that reflects the overall structural diversity. A quadrat having the value of particular parameter above the average was given a score of 1, otherwise the score given was 0. Scores for each of 3 parameters were then summed up to form a single index of structural diversity.

Spatial analyst tools and IDW with the power optimized for minimum RMS error were used for preparing structural diversity map in ArcMap 9.3. The map was classified under low, medium and high structural diversity with the respective values of structural diversity index of <1, 1 to 2 and ≥2. The proportions of areas of forest strata under these three categories of structural diversity were calculated. The majority of analysis was focused on tree species while the analysis of structural diversity of forest considered other components too.

Result

Quantitative characteristics of the forest

A total of 17 species were recorded from the area of forest where cleaning has been done, 25 species were recorded from the area where cleaning has not been done recently and 26 species were recorded over the whole area of forest. The species recorded were *Alnus nepalensis, Castanopsis indica, Castanopsis tribuloides, Choerospondias axillaris, Eurya acuminate, Fraxinus floribunda, Gravellis robusta, Lyonia ovalifolia, Madhuka indica, Maesa chisia, Myrica sp., Myrsine capitellata, Myrsine semiserrata, Osyris wightiana, Persea sp., Pinus roxburghii, Pinus wallichiana, Prunus cerasoides, Pyrus pashia, Quercus glauca, Rhododendron sp., Rhus javanica, Saurauria nepaulensis, Schima wallichii, Syzygium cumini, Zizyphus recurva.* Plant species richness under various categories in two strata is presented in figure 2. The species richness was more in area of forest where cleaning has not been done than in cleaned

area for sapling and seedling while it was more in cleaned area for poles. Species richness was equal for trees.

The maximum similarity in species composition between two strata was found for poles with 44% common species between the two while most dissimilarity was found for trees with large diameters. The result of similarity analysis is depicted by figure 3.

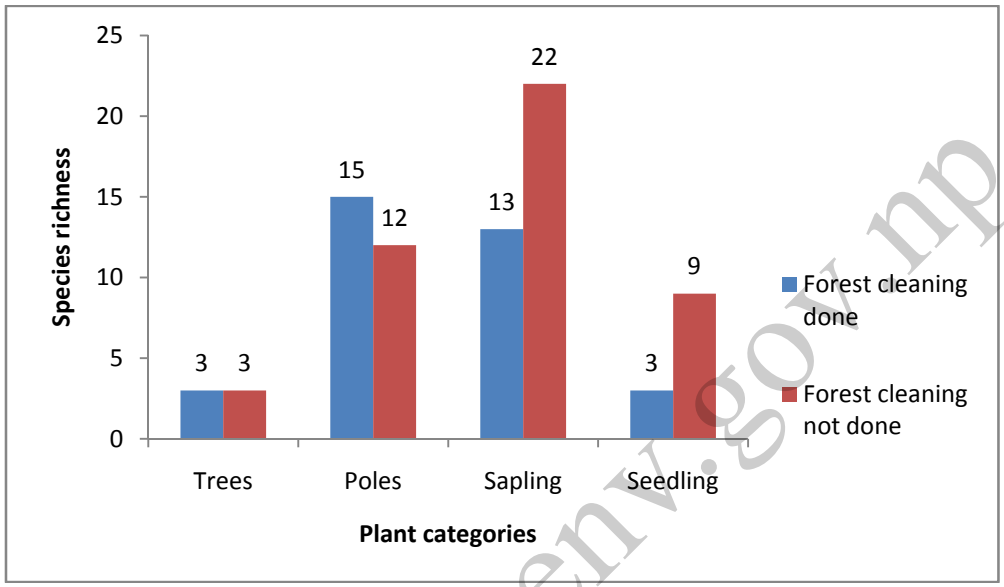

Fig 2. Number of plant species in two strata of forest

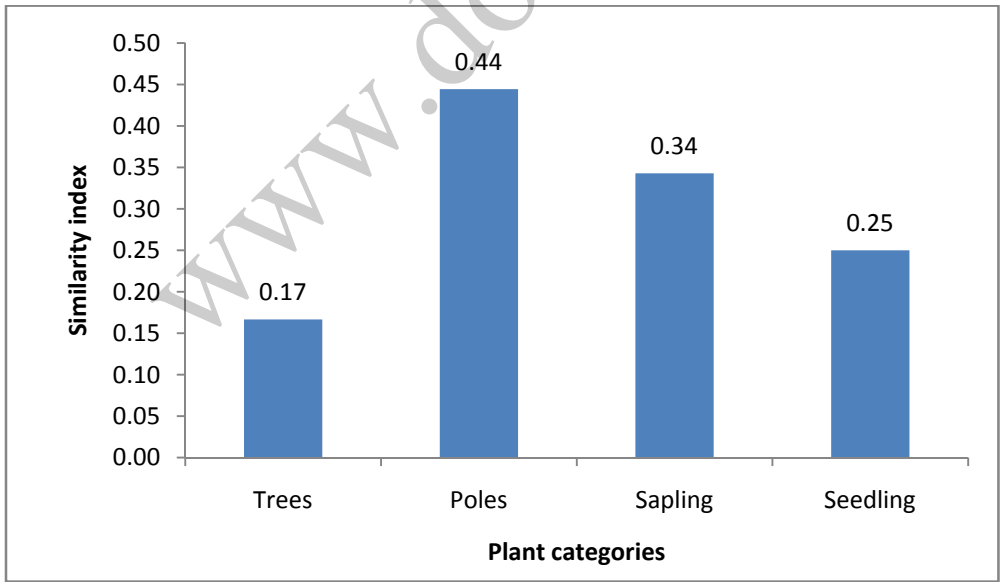

Fig. 3. Species similarity between the forest strata where cleaning has been done and where cleaning has not been done

The important species in terms of density in two strata of forest were found to be *Pinus roxburghii, Schima wallichii, Castanospsis tribuloides, Lyonia ovalifolia, Myrsine capitellata* under tree, pole, sapling and seedling categories. The maximum densities of tree and pole for these species were higher in the area where cleaning has not been done than that in the cleaned area while opposite was the case for sapling and seedling categories. These were the most frequent species too. The detail calculation for all species under tree, pole and sapling categories in two strata have been put in annex IV.

The importance value indices (IVI) of the species recorded under tree category in two strata of the forest are presented in the figure 4. *Schima wallichii* and *Pinus roxburghii* were most important species under pole category in terms of IVI in cleaned stratum of the forest while *Pinus roxburghii* and *Castanopsis tribuloides* were found to be the species under pole category with highest IVI in the forest area where cleaning has not been done. The IVIs of all species under pole category in two strata of forest are shown in figure 5.

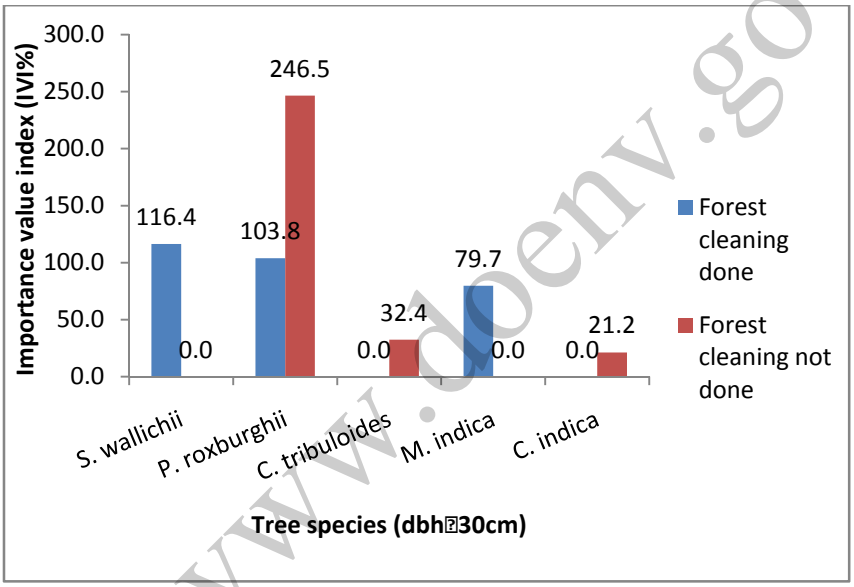

Fig. 4. Importance value indices (IVI) of various species under tree category in two forest strata

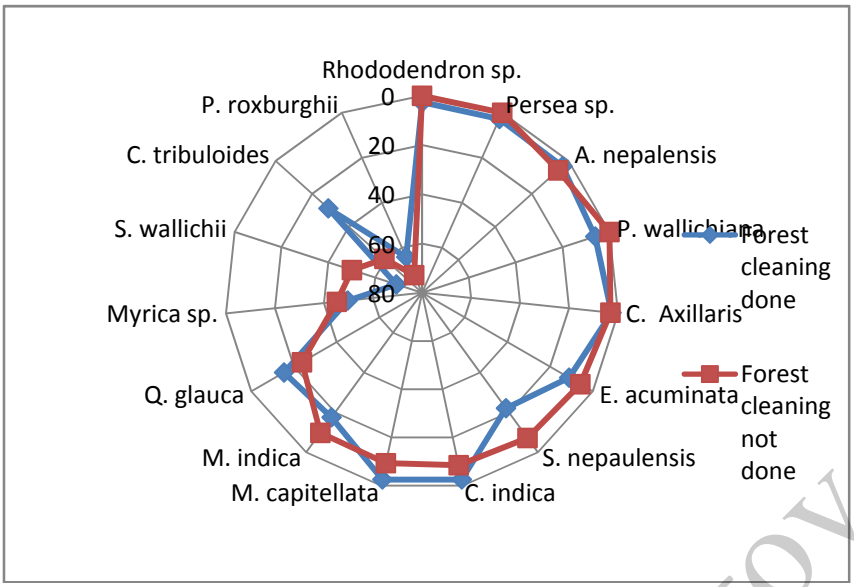

Fig. 5. Importance value indices (IVIs) of plant species under pole category in two forest strata

Schima wallichii was found to be most important species under sapling category in terms of IVI in cleaned stratum of forest. *Myrsine capitellata* was the species under sapling category with maximum IVI in the forest stratum where cleaning has not been done. The IVIs of all species have been put in annex IV.

The degree of species dominance under tree, pole, sapling and seedling categories was assessed through index of dominance. Dominance under tree category was higher in cleaned area than in area where cleaning has not been done while it was higher in later than in former strata for regenerations (sapling and seedling). Same degree of dominance was observed under pole category in both strata. The dominance indices are presented in figure 6.

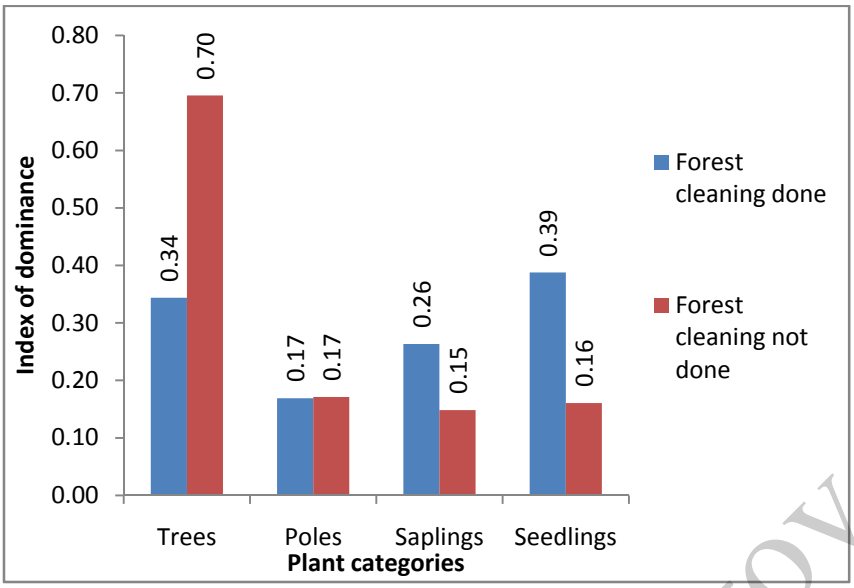

Fig. 6. Index of dominance under tree, pole and regeneration categories in two strata of forest

Shannon-Wiener index of diversity was found maximum under sapling category in the area of forest where cleaning has not been done. Diversity was higher in this stratum of forest under seedling category too. Higher species diversity in cleaned stratum of the forest was observed for trees and poles. The diversity indices are shown in figure 7.

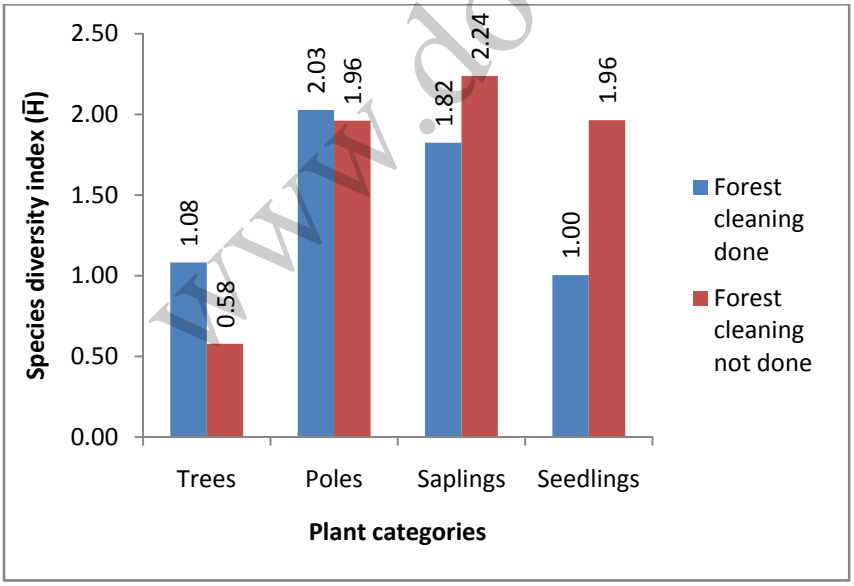

Fig. 7. Shannon-Wiener index of diversity under tree, pole and regeneration categories in two strata of forest

Regeneration status

Regeneration status was analyzed through the density of saplings and seedlings. Sapling and seedling densities in two strata of the forest are shown in figure 8. Both strata were found to have medium regeneration status based on sapling and good regeneration status based on seedling density.

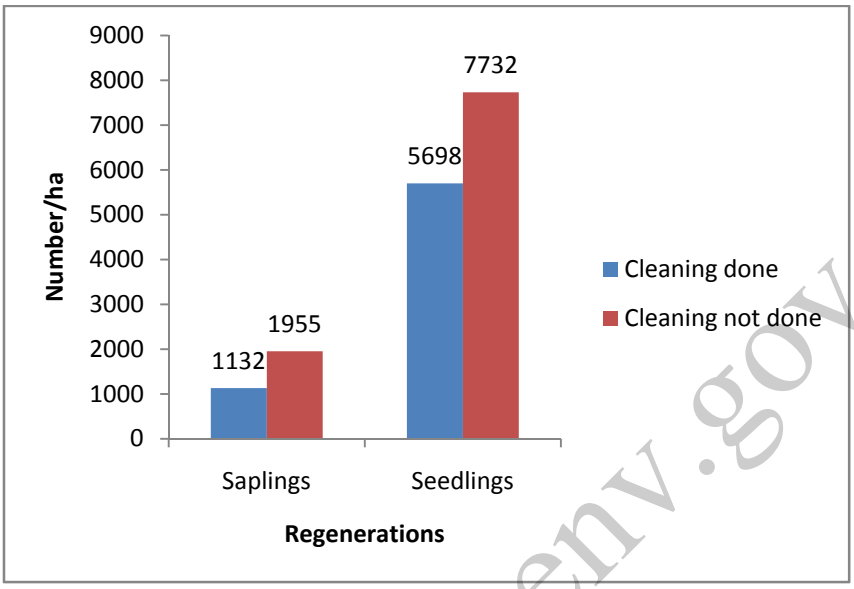

Fig. 8. Number of regenerations per hectare of forest in two strata

The regeneration density maps obtained through IDW interpolation was analyzed for proportion of forest area under good, medium and poor regeneration condition and the results obtained are shown in table 2. Proportion of area under poor regeneration condition was higher in cleaned strata of the forest.

Table 2. Percentage of areas of forest stratum under poor, medium and good regeneration categories

Regeneration status	Sapling		Seedling	
	Cleaning done	Cleaning not done	Cleaning done	Cleaning not done
Poor	2.15	0.03	2.85	0.21
Medium	97.29	52.19	49.55	15.57
Good	0.56	47.78	47.59	84.22

Diameter class distribution

The dbh class distribution of plants under the category other than seedling in two strata of the forest is shown by figure 9. It shows highest density of plants in 5 to 10 cm dbh class while density of this category is higher for the stratum where cleaning has not been done than in cleaned stratum. Tree and pole category had the densities of 16/ha

and 1555/ha respectively in cleaned strata of the forest while 24/ha and 1397/ha respectively in the forest stratum where cleaning has not been carried out.

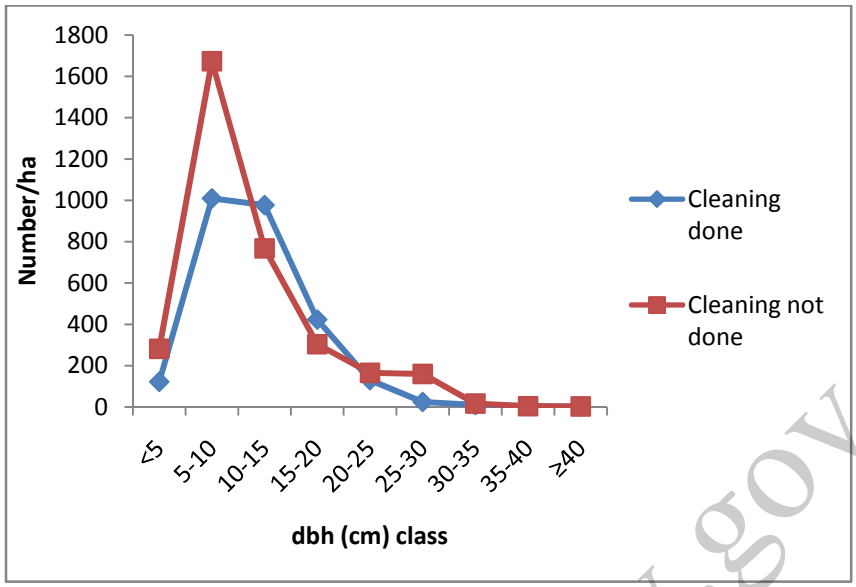

Fig. 9. Number of plants per hectare of forest under different dbh classes in two strata

Density of poles was found to be higher in cleaned stratum of the forest while rest of the components had higher density in the stratum of the forest where cleaning has not been done. But the statistical tests did not reveal any significant difference in the densities among two strata at 0.05 level. Since the variables analyzed did not meet the normality requirement as revealed by Spiro-Wilk test for normality, Mann-Whitney test which is non-parametric test suitable for small samples was used. The results of Mann-Whitney test for differences in densities of trees, poles, sapling and seedling are shown in table 3.

Table 3. Mann-Whitney test for differences in densities of trees, poles, sapling and seedling in cleaned stratum of forest and the stratum of the forest where cleaning has not been done

Variables	Exact significance (2-tailed)	Interpretation
Tree density	0.097	No significant difference
Pole density	0.580	No significant difference
Sapling density	0.128	No significant difference
Seedling density	0.105	No significant difference

Forest structural features

The canopy density of the forest ranged from 70 to 96%. The difference in canopy density was not significant in cleaned stratum and the stratum of forest where cleaning has not been done as revealed by Mann-Whitney test (exact significance P=0.069).

Foliage height diversity (FHD) of the whole forest ranged from 0.13 to 1.07. The 95% confidence interval of mean FHD was found to be 0.46 to 0.76 for cleaned strata for the forest while it was 0.65 to 0.83 for the stratum of the forest where cleaning has not been carried out. The mean FHD in two strata are presented in the figure 10. Independent sample t-test showed that the difference in FHD between cleaned stratum of the forest and the stratum of the forest where cleaning has not been done is not statistically significant at 0.05 level.

Leaf litter and duff layer depth of the whole forest ranged from 0.8 to 10.2 cm. The 95% confidence interval of mean litter depth was found to be 2.5 to 4.0 cm for cleaned stratum of the forest while it was 5.3 to 7.6 cm for the stratum of the forest where cleaning has not been carried out. Independent sample t-test showed statistically significant difference in litter layer depth between cleaned stratum of the forest and the stratum of the forest where cleaning has not been done (P<0.01).

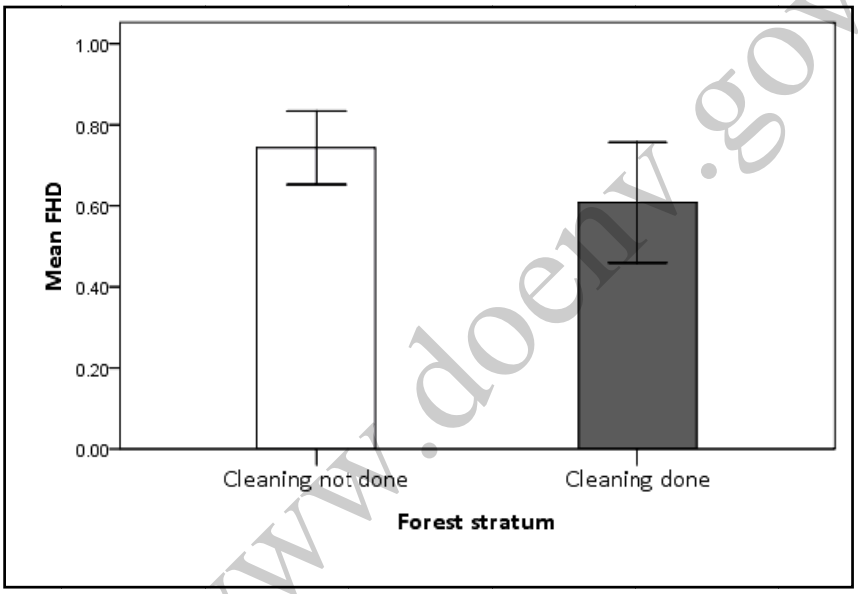

Fig. 10. Mean foliage height diversity in two strata of the forest; error bars represent 95% confidence intervals of mean

A composite additive index of forest structural diversity was calculated based on the density of large trees (dbh≥30 cm), foliage height diversity and the depth of litter and duff layer for each quadrat studied. Mann-Whitney test revealed significant difference in the forest structural diversity in the forest strata where cleaning has been done and where cleaning has not been done (P<0.01).

The of forest structural diversity map prepared by using IDW spatial interpolation is shown in figure 11. The map showing low, medium and high structural diversity is as shown in figure 12 while the proportion of area of forest strata under these categories is

summarized in table 4. Large proportion of the cleaned stratum of the forest was found under low structural diversity class while a negligible fraction was found under high structural diversity class. But the least fraction of stratum of forest where cleaning has not been done was under low structural diversity class while maximum fraction was under high structural diversity class.

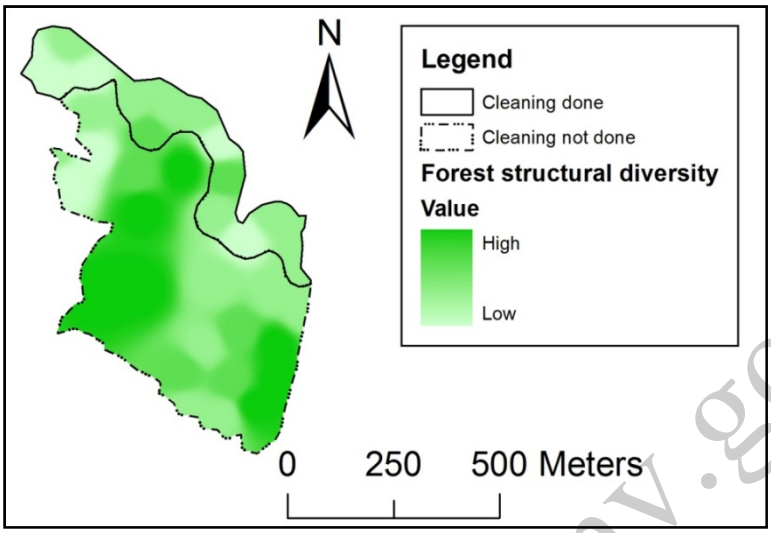

Fig. 11. Forest structural diversity map

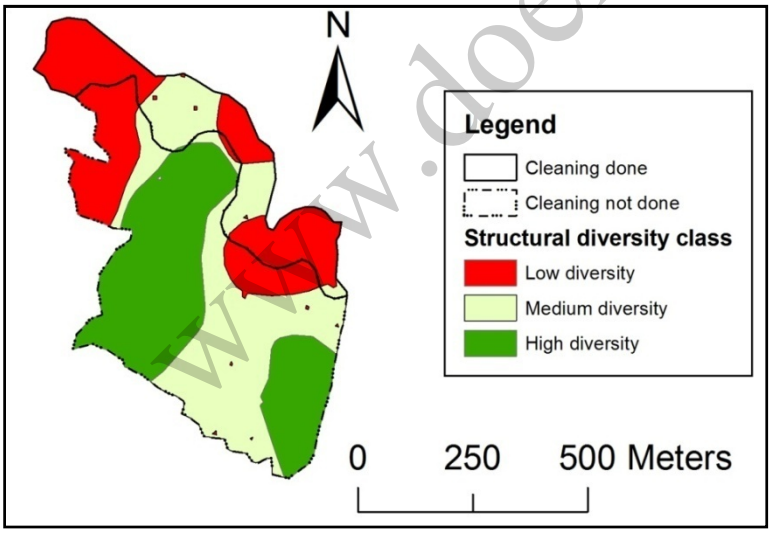

Fig. 12. Structural diversity classes in the forest

Table 4. Percentage of forest strata under low, medium and high structural diversity classes

Structural diversity class	Forest strata	
	Cleaning done	Cleaning not done
Low (SDI<1)	65.68	17.22
Medium (1≤SDI<2)	34.14	35.71
High (SDI≥2)	0.19	47.07

Discussion

Forest status and biodiversity

Species richness was found higher in the forest stratum where cleaning activities have not been carried out than in cleaned stratum of the forest. Species richness under sapling category was found particularly higher in this stratum; it might be the result of the removal of most of the ground vegetation and bushes during cleaning activities.

Myrsine capitellata, Schima wallichii, Pinus roxburghii and *Castanopsis tribuloides* were important species in terms of density. The densities of these species were higher in the forest stratum where cleaning has not been done.

The species dominance was higher in the stratum which has not been cleaned than in cleaned stratum for trees and poles category. Excessively dense individuals are removed during forest cleaning activity which might be the reason behind lesser degree of dominance in cleaned strata of forest. Thus forest cleaning and thinning activities can be expected to increase the diversity of large size trees. But however dominance was more for sapling and seedling category in the cleaned stratum of the forest and this might be the result of selective removal of sapling and seedling of so called "unwanted species". Removal of such "unwanted species" has been found guided by even the forest operational plans (MoFSC/GoN, 2002; PCFOP, 2008). Species preference by CFUG members have also been reported (Acharya, 2004). Another reason behind this could be the excessive disturbance posed upon ground vegetation and seedlings during forest cleaning activity. The results of dominance analysis of present study have been supported by diversity analysis too.

Shannon-Wiener index of diversity was higher in cleaned stratum of forest under tree and pole categories while it was higher in the stratum which has not been cleaned for sapling and seedling categories. Thus better diversity under regeneration category can be expected to contribute to higher overall diversity with the course of time in the forest stratum which has not been cleaned while the regeneration status may degrade in the cleaned stratum. But a long term study might be needed to draw concrete conclusions regarding the impacts of forest cleaning. High diversity and low degree of dominance in the forest have been reported from the forest where selection cutting is practiced (Acharya, 2004; Torras and Saura, 2008) and this was consistent with the result of

present study for trees and poles. Forest cleaning activity with preference of the plants of socio-economic values and ignorance of ecological factors has also been reported in community forests of Nepal (Acharya, 2004).

Number of regenerations (sapling and seedling) per hectare was found to be higher in stratum where cleaning has not been done than in cleaned stratum. Community Forestry Operational Plan, Third Amendment, of Padali Community Forest has mentioned the seedling and sapling number up to >5000/ha and more than >1400/ha respectively (PCFOP, 2008). The results of present study showed a bit higher density of regenerations than that mentioned in operational plan and the improvement in forest regeneration condition might be the cause. But the results are not directly comparable as the operational plan was prepared on the basis of block number while this study has calculated the densities on the strata that are different from existing block numbers. Both strata studied in current study were under medium regeneration category based on sapling density while these were under good category based on seedling density as per the community forestry inventory guideline of Nepal (MoFSC/GoN, 2004). Classification of the forest area under poor, medium and good regeneration category by spatial interpolation of the quadrat data showed that 0.56% of the total area of cleaned stratum was under good category for sapling while 47.78% of the stratum which has not been cleaned was under good category for sapling. Similarly for seedling, 47.595 of the cleaned area was under good category while 84.22% of the stratum which has not been cleaned was under good category. This analysis showed negative impact of cleaning activity on regeneration status but the impact is not of high degree as the proportion of the area under poor category was less than 3% even in cleaned strata of the forest.

Forest structure and structural diversity

Distribution of plant number under different dbh classes in two strata of the forest was comparable with the peak at dbh class of 5 to 10 cm and successively decreasing the number in higher dbh classes. This pattern reveals that the forest is dominated by small diameter plants and the forest is still in developing phase.

Statistical tests did not showed significant differences in tree, pole, sapling and seedling densities in cleaned strata of the forest and the forest strata where cleaning has not been done. Thus forest cleaning activity was not found to be affecting significantly the plant number distribution in different dbh classes.

Forest canopy density was also not significantly different in cleaned stratum of the forest and the stratum where cleaning has not been done. Vertical structure of the forest was analyzed through foliage height diversity (FHD). The FHD in two strata of the forest studied was significantly different. This shows that forest cleaning activity destroys the natural vertical structure of the forest. Since ground bushes and short trees

are usually removed during cleaning activity, it greatly removes the covers at B_2 layer. This might be the reason behind difference in FHD among two strata.

Litter and duff layer depth differed significantly in two strata of the forest. Removal of biomass during forest cleaning activity reduces the biomass accumulation on the forest floor. This might be the reason behind difference in litter and duff layer depth.

Forest structural diversity index was calculated based on number of large trees, forest litter and vertical stratification. These features have been considered important while assessing forest structure (Franklin *et. al.*, 1981; McCleary and Mowat, 2002; Torras and Saura, 2008). The forest structural diversity map prepared by spatial interpolation revealed impacts of forest cleaning activity on forest structure. The forest area was classified in to low, medium and high diversity categories based on this diversity map. The analysis showed that 65.68% of the cleaned stratum of the forest was under low structural diversity class while only 0.19% of the area was under high structural diversity class. 17.22% of the area was covered by low structural diversity class and 47.07% of the area was covered by high structural diversity class in the stratum where cleaning has not been done yet. Thus the approach of composite additive index of forest structural diversity was found to be capable to reflect the impacts of forest cleaning activity on forest structure.

Biodiversity maintenance has become a key management objective and a requisite for sustainable forestry (McCleary and Mowat, 2002; Torras and Saura, 2008). Forest and wildlife conservation is one of the long term objectives of Padali Community Forest too (PCFUG, 2008). Since, forest structural diversity has been considered important for faunal diversity (Hansen *et. al.*, 1995; McCleary and Mowat, 2002), maintenance of structural diversity is vital to achieve the objectives of community forestry.

Conclusion

The study revealed higher tree species richness and regeneration density in the forest stratum which has not been cleaned yet for charcoal production. However both strata were under good and medium regeneration status based upon seedling and sapling density respectively. Conventional measures of forest status like species diversity and species richness did not reveal significant differences in two strata of the forest studied. Analysis of structural diversity showed that 65.7% of the cleaned stratum of the forest was under low structural diversity class while only 0.2% of the area was under high structural diversity class. But only 17.2% of the area was covered by low structural diversity class and 47.1% of the area was covered by high structural diversity class in the stratum where cleaning has not been done yet. Thus the approach of structural diversity showed notable impacts of forest cleaning activity associated with charcoal production on forest structure.

Acknowledgements

The authors gratefully acknowledge RenewableNepal Program, KU for funding this study. Authors are thankful to Padali Community Forest User Group, Lalitpur for their active support during fieldwork.

References

Acharya, K.P. 2004. Does community forest management supports biodiversity conservation? Evidences from two community forests from the Mid Hills of Nepal. Journal of Forest and Livelihood, 4:44-54.

Carey, A.B. 2006. Active and passive forest management for multiple values. Northwesternn Naturalist, 87:18-30.

ESRI, 1999. ArcGIS Desktop 9.3. Environmental Systems Research Institute, Redlands, California, USA.

Franklin, J.F., K. Cromack, J.W. Denison, A. McKee, C. Maser, J. Sedell, F, Swanson and G. Juday 1981. Ecological characteristics of old-growth Douglas-Fir forests. United States Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experimental Station. General Technical Report PNW-118.

Freer-Smith, P. and J.M. Carnus. 2008. The sustainable management and protection of forests: analysis of the current position globally. Ambio, 37:254-262.

GoN, 1993. Forest Act, 2049. Government of Nepal.

Hansen, A.J., W.C. McComb, R. Vega, M.G. Raphael and M. Hunter 1995. Bird habitat relationships in natural and managed forests in the west cascades of Oregon. Ecological Applications, 5:555-569.

Krebs, C.J. 1994. Community organization I: biodiversity. In Ecology: the experimental analysis of distribution and abundance. Addison-Wesley Education Publishers, Inc.

McCleary, K. and G. Mowat. 2002. Using forest structural diversity to inventory habitat diversity of forest-dwelling wildlife in the West Kootenay region of British Columbia. B.C. Journal of Ecosystems and Management, 2:1-13.

MoFSC/GoN. 2002. Nepal biodiversity strategy. Ministry of Forests and Soil Conservation, Government of Nepal.

MoFSC/GoN. 2004. Community forest inventory guidelines 2061 (Revised). Ministry of Forest and Soil Conservation, Department of Forest, Community Forest Division, Babarmahal, Kathmandu.

MoFSC/GoN. 2009. Nepal fourth national report to the Convention on Biological Diversity. Ministry of Forests and Soil Conservation, Government of Nepal.

Odum, E.P. 1996. Principles and concepts pertaining to organization at the population level. In Fundamentals of ecology. Natraj Publishers, Dehradun, India.

PCFUG, 2008. Community forestry operational plan-third amendment. Shree Padali Community Forest User Group, Lamatar, Lalitpur.

Prajapati, S. 2009. Studies on the application of renewable solid fuel alternative to the imported coal fuel in vertical shaft brick kiln, M.E. Thesis. Institute of Engineering, Pulchowk Campus, Tribhuvan University, Nepal.

Singh, B.K. and P. Smith, 2009. An assessment of climate change, forests, and biodiversity in Nepal. USAID/Nepal.

Torras, O. and S. Saura. 2008. Effects of silvicultural treatments on forest biodiversity indicators in the Mediterranean. Forest Ecology and Management, 255:3322-3330.

Winrock International. 2002. Emerging issues in community forestry in Nepal. Winrock International/Nepal, Mahadevsthan, Kathmandu.

Evaluation of Energy Content of Municipal Solid Waste: A Case Study from Kathmandu Metropolitan City

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Abstract

A study was conducted to investigate the calorific value of solid waste of Kathmandu Metropolitan city in 2012. Fresh waste samples were collected from both households and commercial buildings then first sundried and segregated. Organic material was oven dried to constant weight. Energy content of each segregated portion of waste was measured separately. The energy content of this sample was measured by following IP-12 standard method, using bomb calorimeter. The gross total energy content per kg dry weight of house hold waste and commercial waste was found 17.82 MJ and 17.77 MJ respectively while the gross total energy content per kg wet weight was found 8.76 MJ and 11.52 MJ respectively. Similarly Net energy of household waste and commercial waste was found 7.33 MJ/kg and 10.54 MJ/kg respectively. Municipal solid waste has low calorific value as compared to other commercial fuels. However it can be used as alternative energy source. The choice of the methods for harnessing energy from waste will depend upon various social, economical and environmental factors.

Key words: *alternative energy, bomb calorimeter, calorific value. municipal solid waste*

Introduction

Solid waste management is one of the major environmental problems faced by the municipalities of Nepal. Generally greater the economic prosperity and higher the percentage of urban population, the greater the amount of solid waste produced (World Bank, 1999). The rapid population growth and urbanization in Kathmandu metropolitan city has resulted increased solid waste generation. Changing consumption pattern has contributed to the increased generation rates. Use of packaged food items, electronic products, plastics and other modern household appliances are some of the examples indicating the changing consumption pattern (SWMRMC, 2008). The improper disposal of municipal solid waste has serious impact on a wide range of areas. Waste is disposed in land fill in Kathmandu metropolitan city. Although land filling method has compatibility to control the wastes, there are several disadvantages such as hazardous gas emission and leachate production arises from land filling waste (Dong *et. al.* 2003; Shu *et al*. 2006). Hence there is urgent need of better waste management practice. In this study the potential of urban refuse in Kathmandu metropolitan city for energy production and as a means of minimizing environmental Pollution is explored. MSW collected continuously from cities has recently thought as one of the important renewable energy resources. Recovering energy from MSW is feasible by means of

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number of processes such as combustion, pyrolysis and gasification (Dong *et. al.* 2003). Design and operation of the mentioned operation system based on MSW are highly related to heating value of the used municipal solid waste materials. Thus determining heating value of MSW is a key work to perform the efficient design and operation of the waste to energy conversion technologies (Akkaya and Demir, 2009).

The lower heating value of municipal waste is the most relevant parameter that can be used to assess the energy content of waste as a fuel because it represents the energy actually available to be converted into heat and/or electricity (Maginho and Semiao, 2008).

The LHV is the energy content released from the combustion of the organic content of MSW in incinerator and can be used to represent the energy content of MSW (Ogwueleka and Ogwueleka, 2010).

Because some materials have higher heat content than others, the amount of energy that can be provided by combusting MSW is function of the composition of the waste stream.LHV has a strong relationship with plastic, paper, glass, textile and food (Ogwueleka and Ogwueleka, 2010).

Methodology

Study area and households selected

This study was conducted in Kathmandu metropolitan city, which is the capital Of Nepal. It is the largest among Nepal's leading urban centers, with population of 671846 in 2001(CBS, 2001) with annual growth rate of 4.6% in 2001 the total no. of household residing in KMC was 1852155 (total no of residential building was 66236).

Ten residential houses and five commercial buildings were selected. For the selection of residential houses 10 wards were selected randomly and one house from each ward was selected. Similarly five wards of core city were randomly selected and one commercial building from each ward was selected. Refuse of the ten residential houses of five days was pooled together from each residential house similarly refuse of five days from each commercial building was pooled. The weight of the each fresh sample was taken immediately. Each sample was dried in sun for two days. After two days all the waste except organic waste was again sun dried until it become completely dry. Then each component of waste was weighed. A small sample of organic waste of known weight from each master samples was oven heated at 85°C to a constant weight. Then the weight of dry organic waste was again taken. Hence the moisture content of the waste was calculated by subtracting the dry weight of waste from fresh weight. The type of materials present in the waste stream and the amounts and proportions of waste on dry basis was determined. The component materials in the waste stream were classified as: Food and organic waste, Paper and cardboard, Plastics and rubber, Glass, Metals and cans, Textile, Wood and Miscellaneous or other waste.

Determination of gross total energy content of waste

The calorific value of combustible portion of solid waste was determined. Combustible materials included the organic, plastic, paper, textile and wood in small amount. Two subsamples each of organic, paper, plastic and textiles were chosen. The different components were separately milled and small pallets were made. The calorific value was determined by following IP-12 standard method, using calibrated bomb calorimeter. The calorific value of unit weigh dry refuse was calculated from the calorific value of each component of waste and their relative proportion in the waste stream. Then the net energy or high heating value of the refuse was calculated by considering the moisture content of the waste.

Calculating net energy of waste

For calculating the net energy content of waste the following equation is adapted from Fobil *et al* 2002:

Net energy (*N*e) = gross total energy (*G*te) – energy required in drying the waste (*E*d).

$Ne = Gte - Ed$ (1)

But the energy required for drying MSW to a constant weight (*E*d) is given by the sum of the energy required to raise the temperature of the water in waste from its initial temperature to a vaporization temperature of 100°C (*H*I) and the energy required to completely vaporize the water in the waste at 100°C or heat of vaporization (Hv).

This means that $Ed = HI + HV$

$Ne = Gte - (H1 + HV)$ (2)

Again, $HI = m \times c \times \theta$

And where, m= mass of moisture in MSW

C= specific heat capacity of water and

Θ=100°C – initial temperature of water in MSW assumed to be the average annual temperature in Kathmandu

And $HV = m \times cv$.

Where , cv=× latent heat of vaporization of water

Therefore, equation (2) becomes $Ne = Gte - (m \times c \times \theta + m \bullet cv)$.

Result and discussion

Physical composition of waste

Physical analysis of waste samplings collected from different representative households during the survey was carried out. The waste material was classified in to Organic (food waste plus other organic material), Plastic and rubber, Paper, Textile, Metal, Glass and other. The dry weight composition of the waste is presented in the figure 1 and 2.

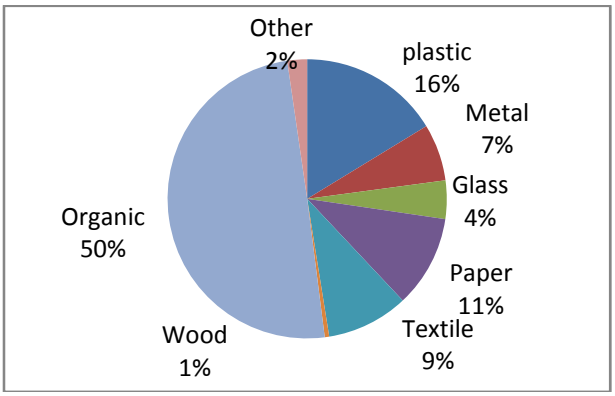

Figure 1: Physical composition of household waste (percentage dry weight)

The organic waste constitutes the highest proportion in the composition followed by plastic and paper in both household and commercial waste. The organic waste mainly contains the food waste. Only very small fraction constitutes other type of organic waste. Textile also shares the significant share in the composition which is followed by metals and glass. The biodegradable waste constitutes about 70% by dry weight in household waste. The proportion of organic waste is lower in commercial waste than in household waste while the proportion of plastic and paper is higher in commercial waste.

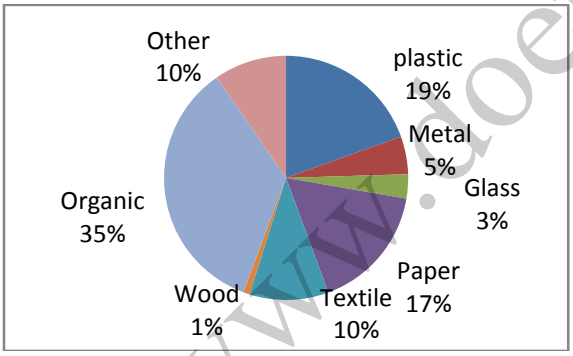

Figure 2: Physical composition of commercial waste (Percentage dry weight)

Moisture content

Moisture content of the waste is very important for evaluating the energy content of the waste. The higher amount of the moisture degrades the energy quality of the waste. The average value of the moisture content of the household waste is 50.91% while that of commercial waste is 35.15%. There is strong correlation between moisture content and percentage of the organic waste (dry weight basis). The Karl Pearson's coefficient of correlation was found 0.83. Hence the higher moisture content of the household waste is due to higher amount of organic waste. The waste having higher proportion of organic waste also has higher moisture content.

Energy content of different component materials in the waste stream

Mainly four types of combustible components of the waste stream were identified (organic waste, paper, textiles and plastic and rubber) and there calorific value was determined. The average energy content of these different waste streams is presented in the figure 3. Among the four components plastic has the highest energy. It has 40.61MJ energy per kg dry weight. Rests of three are much closer in energy content. Textiles has 17.5461MJ, Organic waste has 15.68 MJ and paper has 15.64 MJ energy per kg dry weight

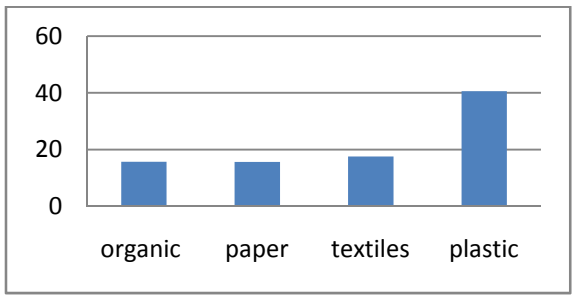

Figure 3: Energy content of different component of waste in Mega Joule (MJ) per Kg dry weight

Gross total and net energy of municipal waste of Kathmandu Metropolitan city

The gross total energy was calculated from the energy content of different component of waste and the composition of waste. The gross total energy content per kg dry weight of house hold waste and commercial waste was 17.82 MJ and 17.77 MJ respectively while the gross total energy content per kg wet weight was 8.76 MJ and 11.52 MJ respectively. The gross total energy content per kg dry waste of household waste and commercial waste is very much similar but the gross total energy content per kg dry weight varies with significant amount. The lower gross total energy per kg wet waste in household waste is due to higher amount of moisture content in the waste. This gross total energy content is also known as the higher heat value (HHV), or gross heat value. Included in the HHV is energy contained in the vaporized water that is produced during combustion of waste. This energy contained in the vaporized water cannot be usually recovered. More realistic estimate of the energy that can be recovered is obtained by subtracting the energy contained in the vaporized water. This is known as net energy or lower heat value.

Table 1. Gross total and net energy of municipal waste of Kathmandu Metropolitan city

S.N	Average Gross total energy (MJ per kg wet waste)	Average Net energy (MJper kg wet waste)
House hold waste	8.76	7.33
Commercial waste	11.52	10.54

The average temperature of Kathmandu metropolitan city is taken 15^{o}c for the calculation of net energy. The net energy of household waste is calculated to be 7.33 MJ/kg. Here the net energy of waste is 84% of the gross total energy. It is because 16% of gross total energy is not available due to moisture content. Net energy of commercial waste is calculated to be 10.54 MJ/kg. This is 91% of the gross total energy.

In figure 4 net Energy content in Y axis is plotted against the moisture content on X axis. The R^2 value is 0.610. This value though indicates that this relation is not very strong. It is clear that moisture content has strong influence in the net energy.

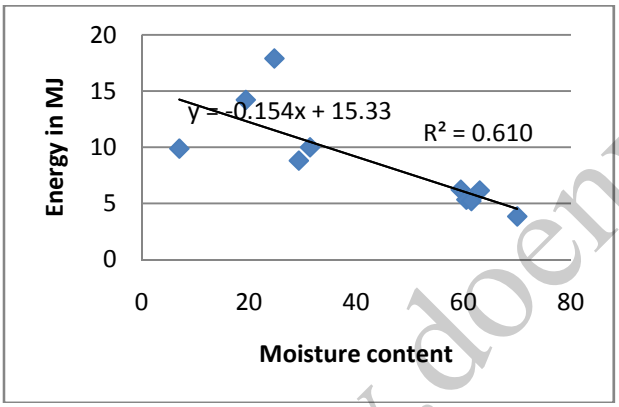

Figure 4: Relation of net energy content and moisture content of household waste.

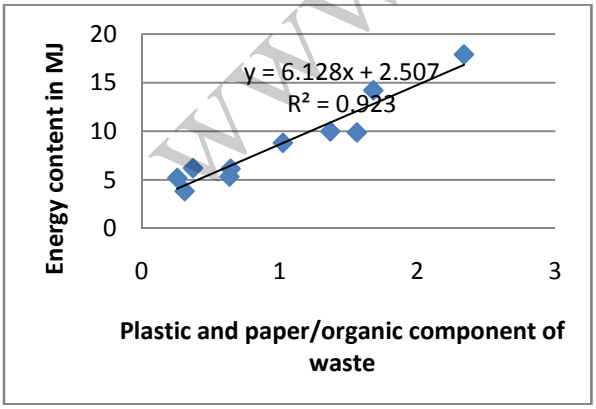

Figure 5: Relation of net energy content and Pl+P/O.

In figure 5 net energy content is plotted in Y axis againast a cofficient obtained by dividing the percentage of plastic and paper by percentage of organic component of the waste in dry weight basis. The R^2 value of 0.923 indicates very strong relationship between these two values. Hence the cofficient obtined by dividing percentage of plastic and paper by organic component of the waste can be a good indicator of net energy contnet of the waste in KMC. The effect of paper and plastic in net energy content is not only due to their energy content but also due to their effect on moisture content.

Total net energy of municipal waste of Kathmandu Metropolitan city

For the calculation of total energy the finding of the SWMRMC, 2008 is adopted (SWMRMC, 2008). This study shows that 337 ton of waste is generated per day with the generation rate of 0.4 kg/person/day. To avoid the overestimation of the energy the lower value of net energy i.e. energy of household waste is used to calculate the total energy of MSW and also with the assumption that much of the waste comes from household. The total net energy of 337 ton of waste with energy of 7.33 MJ/kg becomes 2470210 MJ. That means daily waste containing 2470210 MJ of energy is produced. This is equivalent to 28.59 MW of energy. This value is total energy and although all the waste is used to produce energy all this energy cannot be recovered since there is energy loss during the energy conversion process.

Conclusion and recommendation

The MSW of Kathmandu has low calorific value that is about 26% to 37% that of bituminous coal. Another aspect of municipal waste as fuel is that the net energy of the waste depends much upon the moisture content. In terms of net energy and energy quality it is less preferred than other commercial fuel like coal, oil, natural gas etc. Since solid waste management is becoming troublesome use of solid waste as energy source can serve two purposes while providing the useful energy it can also help in the management of the solid waste. It is amply clear that use of solid waste as energy source, like any other energy source, has its merits and demerits .On the other hand various methods and techniques can be used for harnessing the energy of the waste. And each of them has their own merits and demerits. The choice of the method and technology depend on a number of factors such as economic, social and environmental benefits that would be achieved in the implementation of such a scheme. This will also include the evaluation of alternative energy sources and social as well as political acceptability of such a scheme in the region. For the proper management of the MSW only one or two management option cannot provide solution. Many management options should be integrated. Of course first priority should be given to recycling, reusing. Recovery of energy from solid waste can be a valuable tool in solid waste management.

Acknowledgement

We want to acknowledge Central Department of Environment Science, TU for providing research opportunity and Center for Environment, Energy and Water for providing fund for this research.

References

Akkaya, E. and A. Demir, 2009. Energy content estimation of municipal solid waste by multiple regression analysis, 5th International Advanced Technologies Symposium (IATS'09), May 13-15, 2009, Karabuk, Turkey.

CBS, 2001. Population of Nepal (central development region, Kathmandu,), Central Bureau of statistics, Kathmandu.

Dong C., B. Jin and D. Li, 2003. Predicting the heating value of MSW with a feed forward neural network. Waste Management 23: 103–106.

Fobil J.N., D. Carboo and C. Clement, 2002. Defining options for integrated management of municipal solid waste in large cities of low-income economies: the case of the Accrametropolis in Ghana', The Journal of Solid Waste Technology and Management 12:106–117.

Maginho A. and V. Semiao, 2008. Estimation of residential MSW heating value as a function of waste component recycling. Waste Management 28: 2675-2683.

Ogwueleka T.C. and F.N. Ogwueleka, 2010. Modelling energy content of municipal solid waste using artificial neural network, Iran. Journal of Environ. Health. Sci. Eng 7: 259-266.

Shu HY, C. Lu, H.J. Fan, M.C. Chang and J.C. Chen, 2006. Prediction for energy content of Taiwan municipal solid waste using multilayer perceptron neural networks. Journal of Air and Waste Management Associatee. 56: 852-858.

SWMRMC 2008. Baseline study on solid waste management in municipalities of Nepal. Solid waste Management and Resource mobilization center (SWM&RMC), Ministry of local Development.

World Bank 1999. World development report: Development and Environment. Oxford University Press, New Delhi, India.

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Assessment of Cleaner Production Opportunities in Nepal Dairy Industry

Anish Shrestha[1] and Bhai R. Manandhar[2]

Abstract

Adopting Cleaner Production (CP) practice helps in preventing inefficient use of resources and avoiding unnecessary generation of waste. Companies that consider environment into the design stage of a product will bewell placed to benefit from the marketing advantages. This research presents CP opportunities in Nepal Dairy Pvt. Ltd., with a focus on the packing process and Cleaning in Place (CIP) system. Its purpose is to introduce CP assessment methodology and promote resource saving opportunities which can minimize the adverse environmental impacts. In this study, the CP assessment methodology developed by UNEP and UNIDO was applied. The key environmental issues associated with dairy processing are the consumption of water, energy, fuel and generation of effluent streams and solid waste. In the focused area of packing process and CIP system the CP options generated are within the area of chemical, milk, water, energy (electricity and liquid fuels) saving and solid waste and wastewater reduction. Among the generated CP options, no cost-low cost options have been recommended for immediate implementation whereas for cost incurring option, it is recommended to conduct further financial, technical and environmental feasibility. This study hypothesis was to test the possibility of significant resource saving by the application of generated CP options in the area of packing and CIP process. In case of Nepal Dairy 10% to 40% of resource saving was feasible. The recommended CP options will help Nepal Dairy in enhancing profitability and creating the right enabling environment to facilitate the switch to cleaner and more efficient production.

Key words: *Cleaner Production, Clean in Place, Solid waste, Waste water*

Introduction

This research is a study for the application of Cleaner Production (CP) in the Nepal Dairy (ND) industry. ND is a medium scale industry located at Dhapakhel, Lalitpur established in 1980 by a group of entrepreneurs. In country like Nepal, where industries are exposed to frequent load shedding and shortage of resources there is a sever need of switching the industries to CP for making them sustainable and profitable.

CP is defined as the continuous application of an integrated preventive environmental strategy applied to processes, products and services to increase overall efficiency and reduce risks to humans and the environment (UNEP, 1999). As mention that CP is an approach to environmental management that aims to improve the environmental performance of products, processes and services by focusing on the causes of

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environmental problems rather than the symptoms. In this way, it is different from the traditional 'pollution control' approach to environmental management. Where pollution control is an after-the-event, 'react and treat' approach, CP reflects a proactive, 'anticipate and prevent' philosophy.

Another important feature of CP is that by preventing inefficient use of resources and avoiding unnecessary generation of waste, an organization can benefit from reduced operating costs, reduced waste treatment and disposal costs and reduced liability.

The processing of milk to produce dairy products is a significant contributor to the overall environmental load produced over the life cycle of milk production and consumption. Therefore the application of CP in this phase of the life cycle is important. As in many food processing industries, the key environmental issues associated with dairy processing are high consumption of water, generation of effluent streams and consumption of energy and fuel. For some sites, noise and odor may also be of concern. In this study, the upstream process of fresh milk production, distribution process and post-consumer packaging management are not covered.

Considering CP while processing a product can help in preventing inefficient use of resources and avoiding unnecessary generation of waste, an organization can benefit from reduced operating, waste treatment and final disposal costs. This study has recommended feasible CP options in packing process and CIP system through assessment at ND.

Methodology

Industrial visit to Dairy Development Corporation (DDC), ND and Bhaktapur Dairy (BD) was arranged that are located within Kathmandu Valley and are of different production scale from large to small respectively. Propose of visit to three different industries of different scale was to understand dairy processing and technology used in these industries. After having proper concept about dairy industries, ND was finally selected to study further for the assessment of CP opportunities, since they were more interested in CP concept and was committed in contributing time. The CP opportunities that exist in ND were systematically identified, developed and evaluated using UNEP/UNIDO CP assessment methodology. The methodology used in this research involved five phases as given below:

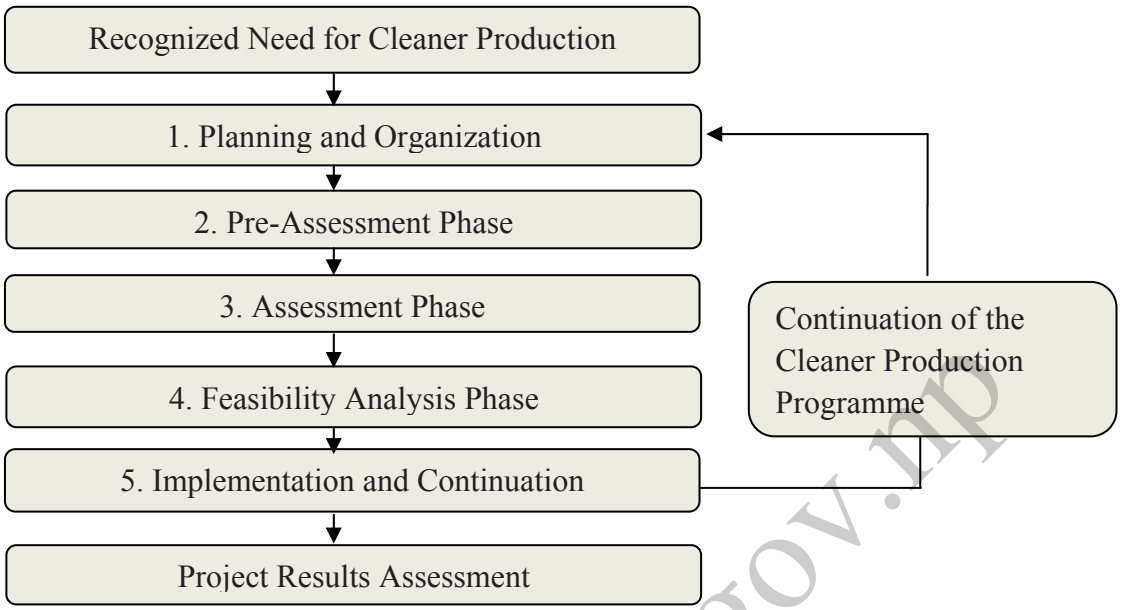

Figure 1: Overview of the cleaner production assessment methodology (UNEP and UNIDO 1996)

During the study, first visit was made to BD, a small scale industry situated at Bhaktapur Industrial District. The second industry visited was ND, a medium scale industry operating at Dhapakhel, Lalitpur District. Then after DDC was visited, a large scale public sector dairy operating inside the Balaju Industrial District, Kathmandu District. These visits helped the researcher to gain clear concept on dairy sector before conducting CP assessment. The UNEP/UNIDO methodology which consists of five phase and 20 steps were all applied during CP assessment at ND in rapid manner. For the collection of data and information, an assessment questionnaire was developed which consisted of both qualitative and quantitative data. The questionnaires were mainly about quantification of the volume and composition of the various resource intensive sections and detailed understanding of the uses of these resources was acquired. Due to limitation of time and information this study was limited to CP option generation of packing process and CIP system of ND industry. This lead to the development of a comprehensive set of alternate CP options.

Result and discussion

Planning and organizing

The concept of CP was proposed to Mr. Arniko Rajbhandari, Director of Production at ND. Since, CP has both environmental and financial benefits Mr. Rajbhandari was interested in this concept. After briefing the research objectives to the top level management, Mr. Rajbhandari appointed individuals to collect information that was

needed for this research during CP assessment. In the course of Planning & Organization phase, Mr. Rajbhandari became the promoters of the necessity to adopt CP. This facilitated the execution of the CP assessment for the research.

At the time of walk-through inspection in ND, the milk production process followed; milk reception; raw milk holding and cooling; pasteurization, cream separation, cooling and storing; packing; and cold storage. In this process it was observed that packing and CIP process were generating more waste.

Pre-Assessment phase

In ND, it was found that their annual production of different dairy products is from 5,792,000 L of milk and the industry is running at its full capacity. The variation in production is during change in seasonal demand. During the festival time, the demand for milk products exceeds its capacity. At present in total 110 persons (60 male and 50 female) are employed in this industry. ND is operating in single shift from 9am to 5pm, but during high demand season (April to October) it operates in two shifts, from 7am to 2pm and 2pm to 7pm. The distribution of dairy products as per the input milk quantity in ND is presented below:

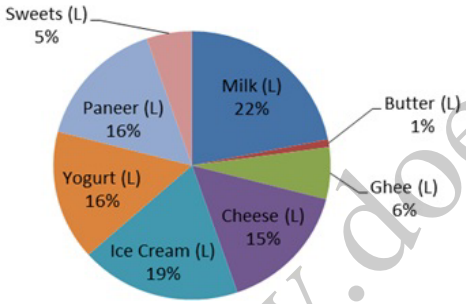

Figure 2: Distribution of Dairy Products (%)

ND has conducted Initial Environmental Examination (IEE) but does not have wastewater treatment plant yet. According to Government of Nepal, industries are allowed to operate in Kathmandu Valley only after conducting EIA/IEE study and implementing mitigation measures as stated in the approved EIA/IEE report. However, ND has allocated land for constructing wastewater treatment plant and has a plan to construct it in near future. The table given below is a snapshot of general practices inside ND.

Table 1: General Practice of Industries

Industry	IEE	Wastewater Treatment Plant	QMS	EMS	Environmental Policy	Occupational Health and Safety Policy
ND	√	×	×	×	×	×

Due to factors such as deteriorating market situation, unstable political situation in the country, out-migration of labor force and irregular power supply, ND was not motivated to invest in new technology and new products.

A walk-through inspection of the factory production process was done in order to do a preliminary identification and evaluation of the CP potential that exists. This provided the research with a first inventory of the obvious options as well as a preliminary estimate of problems that needs to be addressed. The process flow chart of ND's production of pasteurized milk is given below:

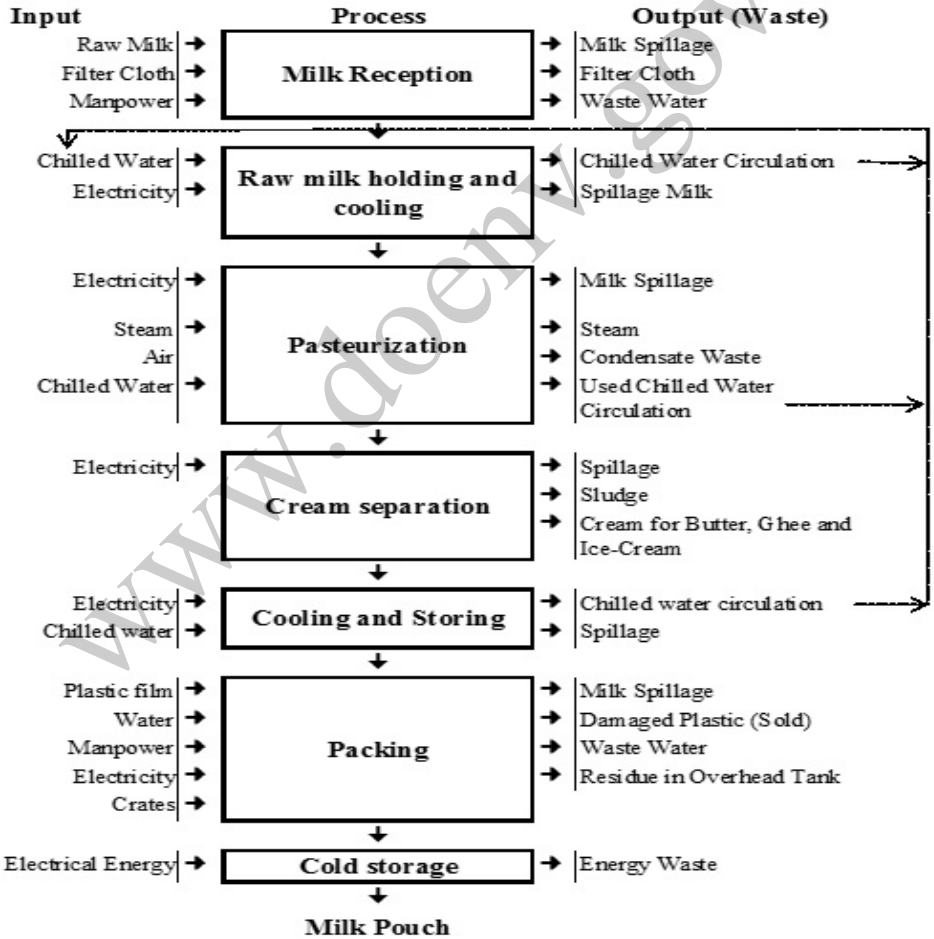

Figure 3: Flow chart for milk production process in ND

This research pre-assessment focus was on packing and CIP process. During the walk-through inspection it was observed that packing process is generating more quantity of waste and there can be significant improvement in CIP system by shifting from batch process of operation to continuous process. These two systems were studied in detail during assessment phase through material balance, cause analysis and developing feasible CP options.

Assessment phase

During the assessment phase collection of data and information as per the questionnaires was completed with the help of concerned in-charge at ND. The quantification of the volume and composition of various resource intensive sections and detailed understanding of the use of these resources was acquired. The assessment questionnaire conducted study in case of chemical, water, milk and energy consumption and solid waste and was water generation activities identified in dairy processing but more detail in case of packing process and CIP system at ND. Material balance of packing process and CIP system was important to identify and quantify input and output during the process. This was developed from the study of one complete batch of milk processing. The detail material balance of packing process is presented below:

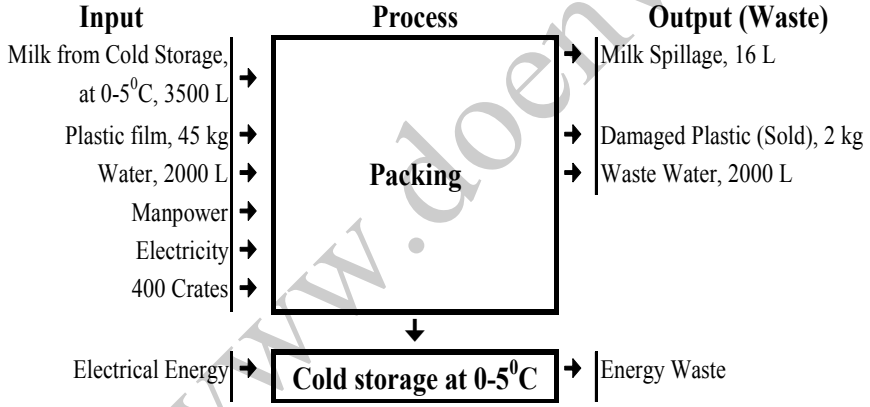

Figure 4: Schematic description of material balance (milk packing)

The material balance is based on the measurements in the packing process during the single batch operation of milk processing of 3500L of pasteurized milk from cooling and storing tank on that day. For carrying out the material balance, tentative quantity of plastic film, water, crates, milk spillage and damaged plastic was measured. While the total water used in this process is assumed to be discharged as waste water.

As seen from the material balance of packing process, approximately 0.4 % of milk is spilled during packing and about 4.4 % of milk packing plastic is generated as plastic waste.

The annual cost of waste in packing process was derived by multiplication of quantity of loss with frequency of loss in a year with purchasing price of the same resource for the industry. The information related to milk, plastic and water were provided by the finance and production staff.

Table 2: Annual Cost of Waste in Packing Process

SN	Particulars	Loss in test batch	Annual generation	Annual loss	Unit cost (NRs)	Annual cost of waste (NRs)
1.	Milk spillage in packing process	16 L/3,500 L Milk	1,267,000 L Milk	1,664 L Milk	43/L	71,552
2.	Damaged milk packing plastic in packing process	2 Kg/45 Kg Plastic	16,290 Kg of Plastic	724 Kg of Plastic	290/Kg	209,960
3.	Waste water generated	2,000 L/2,000 L Water	724,000 L of Water	724,000 L of Water	0.21/L	154,936
Total						**596,576**

The detailed material balance of CIP process is presented below:

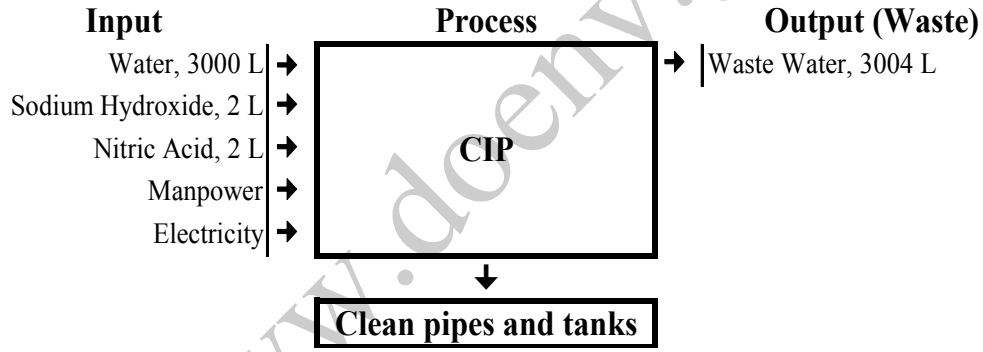

Figure 5: Schematic description of material balance (CIP process)

The material balance is based on the measurement of CIP process operated during the starting of first batch operation of that day. While running CIP the entire pipe lines and tanks are washed by pumping about 3,000 L of water, 2 L of sodium hydroxide and 2 L of nitric acid for one time. It is assumed that 3,004 L of waste water is generated in this process. This CIP process is carried out 4 to 6 times depending upon the number of batch process carried out on a day.

The annual cost of waste in packing process was derived by multiplication of quantity of loss with frequency of loss in a year with purchasing price of the same resource for the industry. The information related to milk, plastic and water were provided by the finance and production staff.

The information provided in the above table reflects the cost of running CIP system for 362 days a year with one time operation every day. This CIP process is carried out 4 to 6 times depending upon the number of batch process carried out on a day. The annual cost of waste in CIP system was derived by multiplication of quantity of water, sodium hydroxide and nitric acid used in 362 days operating once in every day with purchasing price of the same resource for the industry. The information related to water, sodium hydroxide and nitric acid were provided by the finance and production staff.

Table 3: Annual cost of waste in CIP process

SN	Particulars	Loss in test batch	Annual generation	Annual loss	Unit cost (NRs)	Annual cost of waste (NRs)
1	Waste water generated	3,000 L/3,000 L Water	1,086,000 L of Water	1,086,000 L of Water	0.21/L	232,404
2	Sodium Hydroxide in waste water	2 L/2 L	724 L of Sodium Hydroxide	724 L of Sodium Hydroxide	610/L	441,640
3	Nitric Acid in waste water	2 L/2 L	724 L of Nitric Acid	724 L of Nitric Acid	660/L	477,840
Total						**1,151,884**

As a result of material balance and cause analysis comprehensive set of alternative CP options was developed. The generated CP options were screened and only those which are environmentally and financially feasible were recommended. After the material balance in the focus areas, it was also discussed with the relevant personnel of ND to find out the causes of the waste streams and to generate options for preventing or minimizing the causes of wastes. The analysis of the causes of waste generation is presented in Table 4 below:

Table 4: Cause analysis of waste generation

Source	Waste Stream	Cause of Waste	Options	CP Technique	Directly Implementa-ble	Needs Further Study	Rejected	Remarks
Milk packing process	Cleaning of floor and crates using water	1. Excessive amount of water is used for floor and crates washing as pipe end is without self closing nozzles	1. Procure two set of water gun which discharge water with high pressure and low volume	EM&TC	□			
		2. Water loss for few minutes from open end pipe before and after cleaning						
		3. Limitation of the operator during packing	2. Train the operator on attitude change for reducing waste	GH&BPC		□		
		4. There is no alternative of water that can be used for cleaning	3. Use compressed air instead of water where appropriate	EM&TC		□		
	Milk spillage from packing process	5. Start packing before the metal gets properly heated	4. Let the metal get properly heated for 10 minutes and only start packing milk	GH&BPC	□			
		6. Limitation of the operator during packing	5. Train the operator on attitude change for reducing waste	GH&BPC		□		
		7. Breaking of packing process for 2 to 3 time	6. Conduct continue packing of milk with	GH&BPC	□			

Source	Waste Stream	Cause of Waste	Options	CP Technique	Directly Implementa-ble	Needs Further Study	Rejected	Remarks
			shifting of operators					
		8. Absence of pans or trays to collect drips and spills of milk during packing	7. Install drip pans or trays to collect drips and spills below the packing machine	OR&R	□			
		9. Sometimes over filling of milk collection tank where milk gets collected before packing	8. Use level controls and automatic shut-off systems to avoid spills	EM&TC	□			
	Damaged milk (pouch) plastic waste	10. Lack of timely maintenances of packing machine	9. Timely servicing of packing machine	GH&BPC		□		
		11. Untrained operator handling packing machine	10. Train the operator in handling packing machine	GH&BPC		□		
Obvious area for Improvement								
CIP	Sodium Hydroxide Nitric Acid Water	12. Repeated cleaning of pipes and tanks to eliminate microbial decomposition	11. Shifting from batch process to continuous process will reduce cleaning from 5 times a day to 3 times a day	EM&TC		□		

Feasibility analysis phase

The proper implementation of identified CP options can reduce wastewater generation and energy, fuel, water, milk and chemical loss to significant amount, resulting in

environmental and financial benefits. CP options 3, 7 and 11 listed in table 5 require significant investment and retrofitting; thus, a much more in-depth study is needed in order to determine the feasibility of those CP options. These opportunities will significantly minimize the amount of energy, fuel, chemical and water used in the production process and the wastewater that requires treatment. At present ND doesn't have wastewater treatment plant and the effluent is directly discharged to the municipal drainage system. In order to reduce the cost of waste in packing process following options have been recommended.

Table 5: Recommendation for packing process

SN	Options	Saving/year		Investment (NPR)	Pay back (year)
		Resource	Amount (NPR)		
1.	Procure two set of water gun which discharge water with high pressure and low volume	Water = 362,000 L	77,468	3,000	0
2.	Use compressed air instead of water where appropriate	Water = 181,000 L	38,734	70,000	1.8
3.	Install drip pans or trays to collect drips and spills	Milk = 312 L	12,480	24,000	1.9
4.	Use level controls and automatic shut-off systems to avoid spills	Milk = 520 L	20,800	4,000	0.2
	Total		**149,482**	**117,000**	

In the above table, amount of resource saving was generated from the approximate saving that can be gained from the installation of generated CP options and the amount of saving was generated from the cost of resources for the industry that can be saved from getting loss. For the information on investment cost, equipment supplies were contacted but detail quotation was not called. In case of options related to training of operator (option 2, 5 and 10), it need further study to identify the probable service provider. The options such as 4, 6 and 9 are the ones which can be managed by the industry itself with improvements in good housekeeping practices. At present ND is operating in batch process, if this system is upgraded to continuous process then the use of CIP is limited to 2 to 3 times a day from 4 to 6 times a day. In this way approximately 2 times the use of CIP is reduces every day by installation of this option. Then onwards this will save 6,000 L of water, 4 L of Sodium Hydroxide, 4 L of Nitric Acid and electricity cost for pumping water. From the material balance of CIP process it is clear that by upgrading to continuous process, it will save approximately 40% of water, 40% of Sodium Hydroxide and 40% of Nitric Acid. In case of CIP process detail recommendation about total investment could not be derived due to lack of information and technical expertise. This option was explored in DDC which is operating in continue process and are using CIP system 2 to 3 times a day as per need.

In this research a general feasibility study was conducted on the CP opportunities identified. Considering general environmental benefits, testing if its implementation is financially feasible for the industry was derived by the consultation of the key relevant staff from ND.

Environmental benefits

Implementation of identified CP options will reduce the loss of resources which will enhance the profitability of the industry and at the same time it will benefit the environment by releasing less chemical, wastewater and solid waste. The following figure display the benefits that can be added to the environment through implementation of the generated CP options in terms of reduced resource consumption and waste generation.

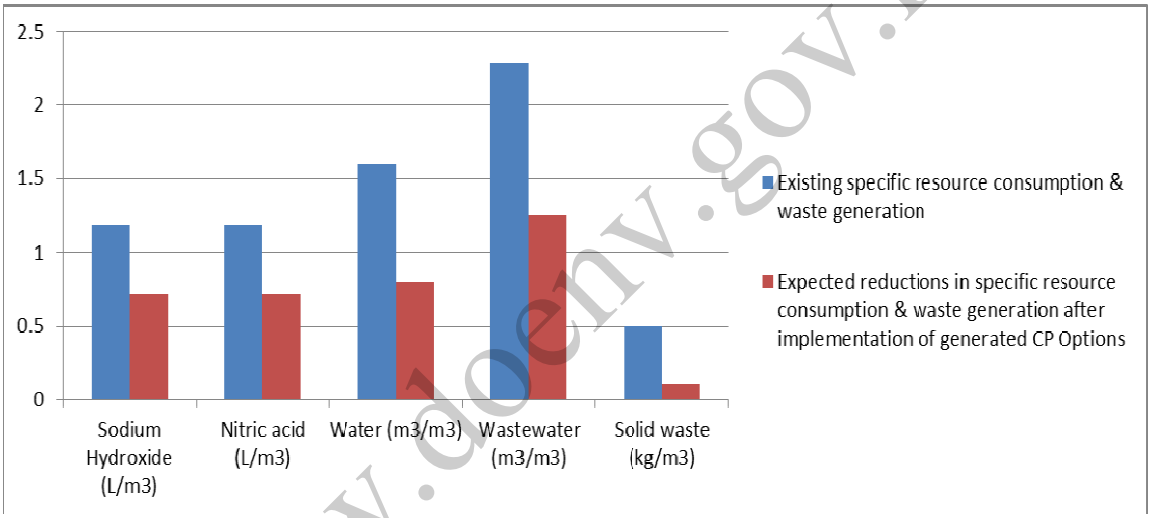

Figure 1: Specific resource consumption & specific waste generation and expected reductions therein

Implementation and continuation

The CP options identified by this research were proposed to the director of ND. It was recommended that no cost low cost CP options to be implemented first. In case of this study, "no cost low cost" options are those which have payback period less than or equal to 6 months, those CP options are option 1, 2, 4, 5, 6, 8, 9 and 10. For the successful implementation of the CP options, a monitoring and evaluation system will be required, to measure the results achieved by the implementation of this feasible options. This responsibility was handed over to the maintenance in-charge. The successful application of the CP options in ND is expected to initiate and sustain a continuous process of CP application.

Conclusion and recommendations

From the CP assessment in ND, altogether 11 CP options were generated. In packing process, excessive use of water and unexpected milk spillage was observed. By the use of level controller in milk collection tanks and drip pans in 2 milk packing machine, spillage of milk can be reduced to zero. These options seem to be directly implementable since the benefit is obvious and investment is low. Similarly use of water gun for washing floors and crates will reduce about 30% of water used in cleaning process. Additional use of compressed air as an alternative for water can reduce further about 25% of water uses. For Option 6 continue packing of milk without break in between by shifting of operators can reduce the volume of solid waste by significant amount. Option 2, 4, 5, 9, 10 will collectively support in reducing the milk spillage and generation of plastic waste. In case of training, there is a need of further study on identification of probable service provider.

ND shifting its production from batch process to continuous process is one of the important CP option that can reduce use of sodium hydroxide, nitric acid and water by 40% that is used in CIP process. At present ND use CIP 4 to 6 times a day but switching to continuous process it can be limited to 2 to 3 times a day. Detail feasibility study for this option could not be conducted due to lack of information and expertise in dairy sector. This option was explored in DDC which is operating in continue process.

The overall conclusion of this study is that research hypothesis defining significant resource saving from the generated CP options in the packing and CIP process is true and possible. In case of ND, resource saving from 10% to 40% is possible through implementation of generated CP options. Similarly, approximate reductions of 70% in wastewater generation and 80% in solid waste generation are expected as environmental benefits.

On the basis of the CP assessment conducted, 11 CP options have been generated for the saving of resources and reduction of waste in ND. For enhancing efficiency and to increase profitability in ND following recommendations have been made:

1. Implement no cost low cost CP options (with payback period less than equal to 6 months) immediately as identified by the research. Those CP options are option 1, 2, 4, 5, 6, 8, 9 and 10.
2. In case of cost incurring CP options such as option 3, 7 and 11 there is need of more financial and technical feasibility analysis.
3. Energy audits must be carried out periodically so that opportunities in the area of electricity and fuel are known and understood.
4. Awareness for the low level staff as well as section chief is necessary. Awareness level in the industry on resource saving is still low.

5. It is important to send staff of different department for training, to gain knowledge on new technologies, certifications and best practices. Trained staff will be an asset to an industry.

Acknowledgement

I would like to specially thank Mr. Arniko Rajbhandari, Mr. Sanjev Vele, Mr. Prachanda Shrestha, Ms. Punye Shakya and Mr. Uddab Adhikari from Nepal Dairy who helped me in conducting Cleaner Production Assessment. I would like to equally thank Dairy Development Corporation and Bhaktapur Dairy who provided me with opportunity to visit their industry, understand dairy processing and also provided relevant information and data needed for this research.

References

U. N. (UNEP). 1999. Cleaner Production Working Group for the Food Industry.

COWI Consulting Engineers and Planners AS, D. (n.d.) 2014. Cleaner Production Assessment in Dairy Processing. Denmark: United Nations Environment Programme and Danish Environmental Protection Agency.

UNEP and UNIDO. 1996. Cleaner Production Assessment Methodologies. UNEP and UNIDO.

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Climate Change Impact on Rice Production: A Case of Chitwan, Nepal

Resham B. Thapa[1] and Tittha R. Panthi[2]

Abstract

A survey was conducted to assess impact of climate change on rice production and find alternatives for sustainability of rice production under diverse climatic situations in Chitwan, Nepal. In this study, 90 households, 30 each from western, middle, and eastern parts of Chitwan were randomly selected and face-to-face interview conducted to gather necessary information in semi-structured questionnaire. Secondary information from other sources were collected and analyzed using excel and SPSS 16.0 software for windows to assess the vulnerability of main season rice production in Chitwan. Findings showed that rice was the most important crop contributing 40.68% shares of all agricultural components. The annual increment of temperature was slightly on rise, while the rainfall was erratic though there was no decline in total rainfall, which influenced rice production in Chitwan. Farmers practiced some adoptive measures to mitigate influence of fluctuating weather effects in order to reduce natural calamities due to erratic weather pattern to sustain rice production and productivity, which included changing cropping time, cultivation of drought tolerant and short duration varieties. There is need to build farmer's capacity, conduct research, and promote alternatives options to cope climate vulnerability and sustain rice production and productivity in Chitwan.

Key words: *adaptation, Climate, humidity, rainfall, temperature.*

Introduction

Agriculture provides the primary source of livelihoods for over one-third of the world's workforce and rice (*Oryza sativa* L.) is the staple food of more than half of the world's population (FAOSTAT, 2012). About 91% of rice grown in the world is produced and consumed in the Asian region, where more than half the world's people and about two-thirds of the world's poor live (Basnet, 2008). Rice stands in the first position in terms of area and production with an average productivity of 3.39 mt/ha in Nepal. In fact, it contributes more than 50% of the caloric intake of Nepalese peoples and plays a significant role in the national economy contributing over 20% to the Agricultural Gross Domestic Product (AGDP). Terai region (tropical area) is the pocket area for rice production, which contributes about 50% in total cereal production in terms of monitory value, and covers about 70% of the total rice growing areas of Nepal (MoAD, 2013).

Agriculture is always vulnerable to unfavorable weather events and climate conditions. The impacts of climate change on agriculture and food production are global concerns and it is crucial in Nepal, where lives and livelihoods depend mainly on agriculture; they are exposed to a great danger, as the country is one of the most vulnerable

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countries due to climate change. Temperature rise influences rice & wheat yields in Terai & tropical parts, where these crops are already being grown close to their temperature tolerance threshold (Panthi, 2012). Indirect impact of rise in temperature is in water availability, change in soil moisture & the incidence of pest & disease outbreak. Therefore, Nepal's struggle for food security would further be intensified with climate change, unless alternative measures are taken to adapt changing climate in order to sustain production & productivity of crops particularly rice in Terai & Inner belts.

Materials and method

Site selection and sampling

Sample household survey and face to face interview schedule was administered for primary data collection. For this, three rice growing pockets - Gunjanagar and Patihani VDCs from western, Gitanagar VDC and Ratnanagar Municipality from middle, and Bhandara and Piple VDCs from eastern Chitwan were selected to gather information of rice growers. Then, 90 farmers (i.e. 30 from eastern, 30 from middle and 30 from western Chitwan) were randomly selected and interviewed. All the ninety respondents were inquired on cultivated area of rice (ha), production (qt), productivity (qt/ha), price (NRs/ha), total value (NRs) and home consumption (qt) in the current year and before 10 years. For the analysis of data, the productivity and price was fixed after the average calculation of all the 90 respondents.

Secondary data (year wise production records of rice and monthly rainfall and maximum as well as minimum temperature) were gathered through various sources, i.e. various journals, websites, published reports and theses including Government Offices (DHM, DADO- Chitwan, NARC, MoAD), NGO's and institutions working in the field of climate change and their publications etc.

Statistical analysis

The survey data and weather-especially temperature and rainfall were entered in computer and statistical analysis performed for developing appropriate tables, figures and graphs to present findings. Farmer's responses and mean of 25 years temperature as well as rainfall of Chitwan from Meteorological Station, Rampur and rice production records of 12 years, i.e. 1997 to 2008 was calculated and presented in results.

Result and discussion

Rice cultivation

After the discussion with respondent farmers in Chitwan, the most common and important twelve agricultural components were identified and categorized on the basis of their component wise contribution on agricultural production (Table 1). Rice cultivation had the highest production value and share of 40.68% followed by maize 20.86%, poultry 9.70%, buffalo 8.95%, wheat 8.28% and cattle 5.69%, remaining other commodities contributing in small proportion, respectively.

Table 1. Contribution of agricultural commodity in Chitwan (n=90)

SN	Commodity	Value (NPR)	Share (%)
1	Rice	2350951	40.68
2	Wheat	362700	6.28
3	Maize	1205250	20.86
4	Mustard	76600	1.33
5	Legumes	48800	0.84
6	Fruits	90000	1.56
7	Goats	83100	1.44
8	Cattle	328500	5.69
9	Buffalo	517000	8.95
10	Poultry	560300	9.7
11	Fish	89120	1.54
12	Bee keeping	66500	1.15

Source: Field Survey, 2010

Rainfall pattern

The rainfall in Chitwan varied from June to October (monsoon) as seen from the rainfall data analysis provided by DHM. The monthly average rainfall from 1996 to 2009 increased by 76.83 mm as compared to during the period 1983 to 1995. The range of monthly monsoon from June to October increased to 885.9 mm from 450.5 mm (Table 2). It indicates that though the total monsoon from the month of June to October was increased in late years; the range of rainfall was also increased with year wise variation thereby causing the unpredictable rainfall during main season rice growing in Chitwan.

Table 2. Rainfall variations during main rice growing season in Chitwan (1983-2008)

Rainfall from June to October (mm)	1983 to 1995	1996 to 2008
Total rainfall	1592.62	1835.58
Ave. monthly rainfall	318.52	395.36
Change in rainfall	450.5	885.9

Source: DHM, 2010

The variation of average rainfall from 1983 to 2008 is presented in Figure 1. There was no uniformity in the annual monsoon (June to October). Some years rainfall was more

intense as compared to normal rainfall pattern in other years; 2298.6 mm was the maximum rainfall recorded in 1998 and 2378 mm was the another high rainfall recorded in 2007 in Chitwan (Rampur station) where as 1387 mm, 1480.9 mm, 1492 mm of rainfall was recorded in 1988, 1992 and 2005, respectively. Such variation influences rice cultivation and also causes havoc, like soil erosion, water logging, and flooding in Chitwan, which is harmful to all living beings.

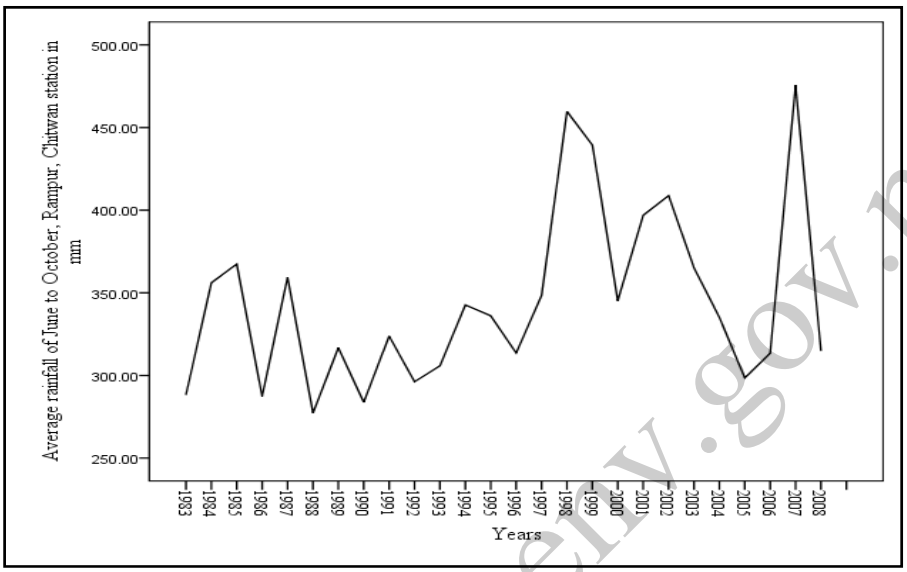

Figure 1. Annual rainfall pattern in Chitwan (Source: DHM, 2010)

Temperature variation

Temperature variation was clearly seen in Chitwan from the analysis of the temperature data provided by DHM (Table 3). The overall annual temperature increased by 0.24^0C in past 13 years, i.e. annual increment of temperature from June to October in Chitwan was 0.02^0C, while from November to May it was 0.03^0C.

Table 3. Temperature variations during rice growing seasons in Chitwan (1983-2008)

Yearly avg temp (^{0}C)			Avg temp from June to Oct (^{0}C)			Avg temp from Nov to May (^{0}C)		
1983 to 1995	1996 to 2008	Diff.	1983 to 1995	1996 to 2008	Diff.	1983 to 1995	1996 to 2008	Diff.
22.87	23.11	0.24	28.54	28.74	0.20	21.20	21.54	0.33

Source: DHM, 2010

The variation of average temperature from June to October from 1983 to 2008 is presented in Figure 2. The lowest average temperature was 27.9^0C from June to October in 1986. The hottest months recorded 31.1^0C in June 1983, 30.3^0C in August 1984,

30.45^{0}C in June 1986, 30.4^{0}C in June 1990, 30.65^{0}C in June 1992, 30^{0}C in July 1993, 30.1^{0}C in August 1994, 30.2^{0}C in July 1994, 30.6^{0}C in June 1994, 30.3^{0}C in June 1997, 30.5^{0}C in June 1998, 30.2^{0}C in August 2004, 30.75^{0}C in June 2005, 30.1^{0}C in August 2006, and 30.1^{0}C in July 2006, respectively. The highest average temperature recorded were 29.24^{0}C, 29.02^{0}C, 29.08^{0}C and 28.96^{0}C from June to October in 1983, 1994, 2005 and 2006, respectively, which influence rice production and other living beings.

Figure 2. Annual temperature variations from June to October in Chitwan (Source: DHM, 2010)

Rice production trend

Survey findings showed that the productivity of rice decreased by 1.43%, cultivated area decreased by 5.33% and production decreased by 6.55% as compared to 10 years before (Table 4). While, in per unit price, the total monitory value and home consumption of rice was increased by 90.41%, 77.94% and 6.47%, respectively, from last 10 years to current years.

Table 4. Differences on rice pruduction in ten years, Chitwan (n=90)

Rice	Before 10 years (A)	At present (B)	Change A to B (%)
Area (ha)	45.18	42.77	-5.33
Production (qtl)	1480.8	1383.82	-6.55
Productivity (qtl/ha)	32.78	32.31	-1.43
Price (NRs/qtl)	892.22	1698.89	90.41
Vaue (NRs) ('000')	1321.2	2350.95	77.94
Home cunsumption (qtl)	1201.3	1279	6.47

Source: Field Survey, 2010

Farmer's cropping calendar

All the 90 respondents replied that in recent years, nursery preparation time was delayed one week because of lack of timely rainfall, seedling transplanting time extended 3 weeks in adoption of cropping, and harvesting time started prior to 2 weeks and terminated prior to 3 weeks with cultivation of short duration variety of rice as compared to 10 years before (Table 5).

Table 5. Differences on farmers' rice cultivation calendar in ten years, in Chitwan (n=90)

Cultivation practice	Before 10 years	At present	Remarks
Nursery preparation	May 3rd-June 3rd week	May 4th-June 4th week	Based on rainfall
Transplanting	June 3rd- July 3rd week	June 3rd-Aug 2nd week	At present, cropping intensity is increased so transplanting date is delayed in some extent
Harvesting	Nov 2nd–Dec 2nd week	Oct 4th - Nov 3rd week	At past times local varieties of rice were cultivated, so the harvesting time was delayed at that time

Source: Field survey, 2010

Irrigation source and rice cultivars

In past, cannel irrigation was used or rice cultivation was based on monsoon rainfall and with commonly grown local cultivars of rice. Now, boring as the source of irrigation are practiced by farmers with improved rice varieties under cultivation instead of local cultivars because of their high productivity, in which, *Sabitri* is the most commonly cultivated by farmers in Chitwan (Table 6).

Table 6. Differences on rice cultivars grown by the farmers in ten years, Chitwan (n=90)

	Before 10 years	At present	Remarks
Source of irrigation	Cannel irrigation or monsoon rain	Cannel and boring or monsoon rain	Change in irrigation and erratic rainfall pattern
Rice varieties	Masuli, Achhami masino, Aanpjhutte, Sattari, Anadi, Dudhraj, Battisara, Gola, Bhatti, Budharaj, Gauria	Radha-4, Hardinath-1, Sabitri, Makawanpur-1, Loktantra, Himali, War, Katari and 1442	*Sabitri* is dominant at present time

Source: Field survey, 2010

Effect of rainfall on rice cultivation

Farmer's opinion on the effect of rainfall during different growth stages of rice is shown in Table 7. Rainfall was the most important and critical factor in the seedling transplanting stage and another critical stage of rice was flowering and fruiting requiring irrigation, while delayed rainfall during last week of September to October caused problem in rice harvesting.

Table 7. Different growth stages of rice and critical stages requiring irrigation in Chitwan (n=90)

SN	Rice growth stage	Rainfall	Remarks
1	Nursery establishment	0.58	
2	Seedlings transplanting	0.76	Rainfall is important factor
3	Growth and tillering of rice	0.61	
4	Flowering and fruiting of rice	0.72	Irrigation is important factor
5	Rice harvesting	1.51	

Source: Field survey, 2010

Rice pests' problems

Responses were collected from farmers on common diseases, insect pests and weeds in the rice field of Chitwan district. Blast disease was more severe in recent years as compared to 10 years ago. In the past, farmers were not fully aware and familiar about all diseases as in the recent years. Same types of insect pests were found at past years as present years; however their severity was more intense in recent years as compared to 10 years ago. Rice crop was severely damaged by green leaf hoppers in 2045 BS in Gitanagar VDC. Jwone (*Juncus wallichianus* (Laharpe), Gholsag (*Symplocos* sp.) Jalkumbhi (*Eichhomia crassipes* (Mar.) and Nilogandhe (*Ageratum houstonianum* Mill.) were new weeds in rice fields in recent years, while Mothe (*Cyperus rotundus* L.), Suire (*Schonenoplectus juncoides* (Roxb.), Jwone (*Juncus wallichianus* Laharpe) and Chariamilo (*Oxalis* sp.) were prevalent before 10 years. Banso was found to be very common in the past and at present as well (Table 8). *Cyperus* was diminished and some new weeds like *Ageratum, Eichhomia* and *Symplocos* were seen causing serious effects in recent years.

Table 8. Rice pest problems experiences by the farmers before ten years and at present in Chitwan (n=90)

Pests	Before 10 years	At present
Diseases	*Sete*, *Khaira*, Black smut, Unknown	Blast, Black smut, *Sete* and *Khaira*
Insects/ pests	Rice ear-head bug (*Leptocorisa oratorius* (Fab.), Yellow rice borer (*Scirpophaga incertulas* Walk.), Green rice leafhopper (*Nephotettix nigropictus* (Stal.)	Yellow stem borer (*Scirpophaga incertulas* Walk.), Rice ear-head bug (*Leptocorisa oratorios* (Fab.), Green rice leafhopper (*Nephotettix nigropictus* (Stal.), leaf roller (*Cnaphalocrosis medinalis* Guen.)
Weeds	Banso, Mothe (*Cyperus rotundus* L.), & Suire (*Schonenoplectus juncoides* (Roxb.), Jwone (*Juncus wallichianus* Laharpe) and Chariamilo (*Oxalis* sp.) were prevalent	*Banso*, *Jwone* (*Juncus wallichianus* (Laharpe), *Gholsag* (*Symplocos* sp.) Jalkumbhi (*Eichhomia crassipes* (Mar.)) and Nilogandhe (*Ageratum houstonianum* Mill.) is new in this area

Source: Field survey, 2010

Sustainable rice production strategy

One group discussions was also organized at each site (using rank value from 0 to 40 on the interval of 5) by pair ranking method. Changing cropping times based on rainfall, irrigation management, introduction of improved varieties, alternative plant protection measures, farmers' empowerment, technical inputs, financial support (loan), and crop insurance were valued as 160, 80, 120, 95, 110, 75, 60 and 65, respectively. Similarly, for responsible persons or organizations, individual farmer, government, I/NGOs, IAAS, banks, agro-vets, farmers groups and NARC were valued 295, 210, 60, 25, 40, 50, 60 and 25, respectively (Table 9).

Table 9. Farmers perception matrix for sustainable rice production in Chitwan

SN	Sustainability factor	Individual farmer	Gov	I/NGO	IAAS	Bank	Agro-vets	Farmer groups	NARC	Total
1	Change cropping time according as rainfall	110	15	10	10	0	0	15	0	160
2	Irrigation mgmt	5	45	20	0	0	0	10	0	80
3	Improved varieties	25	20	10	10	0	40	5	10	120
4	Plant protection	70	5	0	5	0	10	0	5	95
5	Famers empowerment	55	35	10	0	0	0	0	10	110
6	Technical inputs	30	35	10	0	0	0	0	0	75
7	Financial support	0	20	0	0	40	0	0	0	60
8	Crop insurance	0	35	0	0	0	0	30	0	65
	Total	295	210	60	25	40	50	60	25	

Source: Field survey, 2010.

Changing the cropping time according to the rainfall (monsoon) was the most important factor and introduction of suitable varieties was another important factor to increase the rice production in Chitwan. Similarly, farmers empowerment, plant protection measures, irrigation management, technical inputs, crop insurance and financial support to the farmers were other valuable factors for the sustainable rice production in Chitwan (Figure 3).

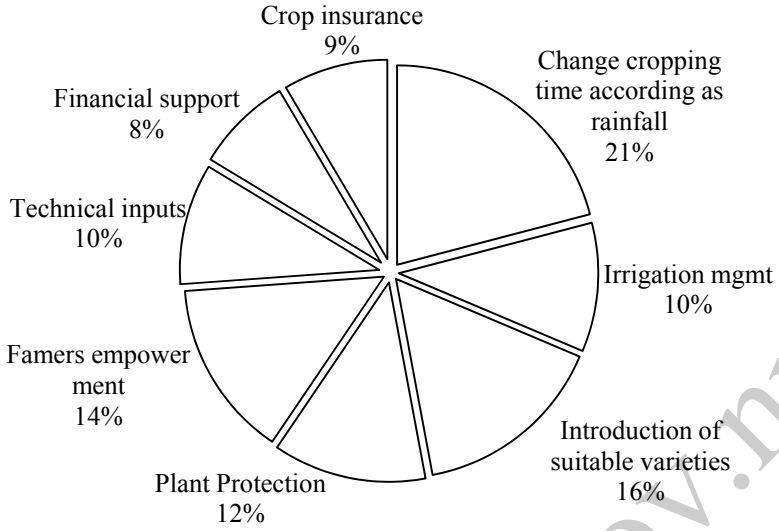

Figure 3. Different factors associated with sustainable rice production in Chitwan (Source: Field survey, 2010)

All 90 respondents emphasized managing of cropping time and using drought tolerant varieties at present and even in the future strategy. As given in the Table 10, use of chemical fertilizers was more important in recent years as compared to ten years ago, when they applied organic fertilizers. Use of short duration variety, hybrids/ improved crop varieties and appropriate plant protection measures were more realized at present than in the past and thus could be in line for future strategies as well.

Table 10. Farmers strategic priority for sustainable rice production in Chitwan

SN	Strategic issues	Before ten years	At present	Remark
1	Manage cropping time to match monsoon pattern	1.21	1.07	These
2	Use drought tolerant rice varieties	0.78	0.8	issues
3	Apply more organic fertilizers	0.83	1.59	are
4	Apply more chemical fertilizers/ pesticides	1.52	0.79	in line
5	Use short duration & hybrids/improved varieties	0.71	0.81	to future
6	Practice appropriate plant protection measures	0.77	0.86	thinking

Value: 2 = less, 1= high & 0= medium important (Source: Field survey, 2010)

Discussion

"Decision Support System for Agro-technology Transfer" (DSSAT) was used with CO_2, temperature and rain as climatic parameters to study impact of climate change in rice, wheat and maize in NARC, which showed that the rice yield increased under elevated CO_2 in the terai, hills and mountains initially, but it dropped to 3.4 % in the terai, and continued to increase by 17.9% in the hills and by 36.1% in the mountains, when the temperature was increased by 4^oC. Climate change effect on rice production in

Bangladesh shows that yields depend on actual patterns of climatic in rice growing regions. Both higher maximum and minimum temperature decrease rice yields due to spikelet sterility and higher respiration losses (Basak, 2009). Research conducted with increased CO_2 and temperature in NARC, Khumaltar shows the increase of rice yield by 17.07 and 26.58% even at the increase in temperature in chamber by 6.2^{o}C and 7.36^{o}C (Malla, 2008). Nitrogen content of the rice was increased by16.3% due to rise in temperature, but decreased by 9.8% due to doubling of CO_2. Panicle initiation, flowering, heading, milking stage and crop maturity period was decreased by 7, 4, 4, 4, and 6 days, respectively due to the increase in temperature.

According to FAO (2008), there is a temperature increment of 0.04^{0}C in terai of Nepal, more in winter. So, there is a need of a research on location/district specific temperature variation. This study finds out the temperature increment of 0.02^{0}C per annum in Chitwan. According to a study at the International Rice Research Institute (IRRI), the yield of rice was observed to decrease by 10% for every 1^{0}C increase in growing season (IPCC, 2008). If 1^{0}C temperature is increased to June to August, then adaptation measures to be followed for the sustainable crop production included: i) use more heat/ drought, disease, pest and salt tolerant crop varieties, ii) altered application of fertilizers, iii) altered application of insecticides/ pesticides, and iv) change in planting date to effective use of the prolonged growing season and irrigation (IPCC, 2008).

In Chitwan, most of the respondents confidently expressed their views to dig 40 to 50 feet to reach ground water for tube-well establishment in recent years, while it was sufficient to dig only 20-22 feet in 25-30 years ago. Now in rice fields, new weeds, like Banso, Jwone (*Juncus wallichianus* (Laharpe), Gholsag (*Symplocos* sp.) Jalkumbhi (*Eichhomia crassipes* (Mar.)) and Nilogandhe (*Ageratum houstonianum* Mill.) are dominant weeds in recent years, while in past years Banso, Mothe (*Cyperus rotundus* L.), Suire (*Schonenoplectus juncoides* (Roxb.), Jwone (*Juncus wallichianus* Laharpe), and Chariamilo (*Oxalis* sp.) were prevalent. Farmers land was left barren because of lack of rainfall in recent years (2008, 2009 and 2010) in Chitwan. Transplanting date of rice was extended up to three weeks as compared to past years because of uncertainty of rainfall. Blast disease and infestation of insects are severe in recent years. In fact, Chitwan is different in terms of temperature, solar radiation and carbon/ nitrogen ratio, soil fertility and other aspects. Therefore, variation of result is seen from location to locations, which further requires scientific studies.

Conclusion

The rainfall pattern was erratic and temperature increment per year was 0.018^{0}C in Chitwan, which is particularly useful for rice farmers in Chitwan However, rice production could be severely influenced/ threatened in other vulnerable areas due to change in carbon and nitrogen ratio, relative humidity and other many anthropogenic interventions, which needs to be considered in the future study. Furthermore,

development of cultivars that would be able to withstand higher temperature and more water stress condition having grater photosynthesis efficiency is really line of work to mitigate the production problems in the coming years. Finally, efficient monitoring and evaluation and information exchange system, mitigating measures including public awareness of the impact of climate change in agriculture should be strategic issues to be addressed for sustainable rice production.

References

Adger, W.N., S. Adhikary, M. Ando, Y. Anokhin, R.V. Cruz, M. Ilyas, Z. Kopalaini, F. Lancigan, L. Kongxian, A. Patwardhan, U. Safrial, H. Suharyono and X. Zhang (eds.). 2001. IPCC third assessment report. Climate change 2001: Working group II: Impacts, adaptation and vulnerability. Available at: http://www.grida.no/climate/ ipcctar/wg2/ 415.htm (retrieved on March 7, 2012).

Agarwal, P.K. 2003. Impact of climate change on Indian agriculture. Journal of Plant Biology 30: 189-198.

Agriculture Dairy. 2011. Agriculture Information and Communication Centre. Ministry of Agriculture and Cooperatives, Harihar Bhawan, Lalitpur, Nepal.

Basak, J.K. 2009. Climate change impact on rice production in Bangladesh: Results from a model: Available at: www.unnayan.org (retrieved date: Feb 11, 2011).

Basnet, B.M.S. 2008. Environment friendly technologies of increasing rice productivity. Journal of Agriculture and Environment 9: 34 – 40.

Bockmuhl, K. 2008. Comparing species-temperature relationships of Arctic-alpine plants among three altitudinal transects in Svalbard. M. Sc. Thesis, Bergen University, Norway.

Cheema, S. S., B. K. Dhaliwal and T. S. Sahota. 1991. Agronomy theory and digest. Kalyani Publishers, New Delhi, India.

DADO. 2010. Chitwan Annual Bulletin 2008/2009. Bhatpur, Chitwan, Nepal.

Dahal, H. and D.R. Khanal. 2010. Food security and climate change adaptation frame work: Issues and challenges, MoAC/NG. Available at: www.moac.org.gov.np (retrieved on May 29, 2011).

DHM. 2010. Climatic records of Rampur, Chitwan station (temperature, rainfall and relative humidity) of the years 1984-2008. Department of Hydrology and Metereology, Kathmandu, Nepal.

FAO. 2008. Organic agriculture and climate change. Available at: http://www.fao.org/ DOCREP/005/Y4137E/y4137e02b.htm#89 (retrieved on February 10, 2010).

FAOSTAT. 2012. Statistics information. Food and Agriculture Organization of the United Nations, FAO, Rome.

Fari, Z. 2009. The greenhouse effect. Available at: http:/ /www. en. wikipedia. org/ wiki/ Greenhouse _gas (retrieved on May 29, 2011).

Haq, M., M.A. Taher Mia, F.M. Rabbi and M. A. Ali. 2008. Incidence and severity of rice diseases and insect pests in relation to climate change. International Symposium on Climate Change and Food Security in South Asia, 25-30 August, 2008. Dhaka, Bangladesh. pp. 1 – 37.

ICIMOD. 2007. Global climate change and retreat of Himalayan glaciers in China, India, Bhutan and Nepal. ICIMOD, Lalitpur, Nepal. pp. 7-19.

IPCC. 2001 Climate change 2001: Impacts, adaptation and vulnerability. Contribution of working group II to the third assessment report of the Intergovernmental Panel on Climate Change (IPCC), J.J.

McCarthy, O.F. Canziani, N.A. Leary, D.J. Dokken and K.S. White (eds.). Cambridge University Press, Cambridge.

Joshi, J. 2011. Managing environment and cities for sustainable development. MS Offest Press, Kathmandu, Nepal.

Malla, G. 2008. Climate change and its impact on Nepalese agriculture. Journal of Agriculture and Environment 9: 62– 71.

Michael, A.M. 2001. Irrigation theory and practice. Vikas Publishing House Pvt. Ltd., New Delhi, India.

MoAC. 2008. Collection of agriculture related policies, acts, regulations and orders (Nepali). Ministry of Agriculture and Cooperatives, Kathmandu, Nepal.

MoAC. 2009. Annual reports of organizations associated with Agriculture and Cooperative Ministry (F.Y. 2064/065) (Nepali). Monitoring and Evaluation Division, Singh durbar, Nepal. Pusplanjali Chhapakhana, Anamnagar, Kathmandu, Nepal.

MoAD. 2013. Selected indicators of Nepalese agriculture and population. GoN/MoA, Ag-Business Promotion and Statistics Division, Singh Durbar, Kathmandu, Nepal.

MoE. 2010. National adaptation program of action (NAPA) to climate change (report). Ministry of Environment, Kathmandu, Nepal. Available at:www. napanepal. gov.np/ pdf reports/NAPA_Report.pdf (retrieved on March 1, 2012).

Panta, K.P. 2011. Economics of climate change for smallholder farmers in Nepal: A review. Journal of Agriculture and Environment 12: 104- 112.

Panthi, T.R. 2012. Impact of climate change on rice production in Chitwan, Nepal. M. Sc. Thesis., Pokhara University, Nepal.

Parry, M.L. 2007. Technical summary. Climate change 2007: Impacts, adaptation and vulnerability. Contribution of working group II to the fourth. M. L. Parry, O.F. Canziani, J.P. Palutikof and Co-authors (eds) Assessment Report of the Intergovernmental Panel on Climate Change.

Pokharel, D. M. and B. Pandey. 2011. Climate change adaptation: Strategic vision in agriculture. The Journal of Agriculture and Environment 12: 104-112.

Rohde, A.R. 2010. Global sources of greenhouse gases (for eight different sectors for the year 2000). Available at: http://www.solarnavigator.net/greenhouse_gases.htm (retrieved on May 29, 2011).

Rosenzweig, C. and D. Hillel. 1995. Potential impacts of climate change on food supply and consequences V-1,#2, summer. Available at: http://www.cgrio.org/ Consequences/ summer95/agriculture.html (retrieved on February 3, 2011).

Seppala, R., A. Buck and P. Katila. 2009. Adaptation of forests and people to climate change. A global assessment report. World Series 22, IUFRO.

Shrestha, H.B. 2007. Business statistics and data management. Ekta Books Distributors Pvt. Ltd., Kathmandu, Nepal.

Singh, C. 1996. Modern techniques of raising field crops. Oxford & IBH Publishing Co. Pvt. Ltd., Calcutta, India.

Winrock. 2007. Identifying priorities and opportunities, for actions on climate change adaptation in Nepal, Kathmandu, Nepal: Background. Workshop Proceeding: Organized by Ministry of Environment Sciences and Technology, World Bank, Department of Hydrology and Meteorology, and Winrock International Nepal on January 17, 2007, Kathmandu, Nepal. pp.1-38.

Ziska, L.H. 2010. Climate change impact on weeds. Climate change and agriculture: Promoting practical and profitable responses. USDA-ARS. Crop Systems and Global Change Laboratory III 2: 1-4.

Climate Change Vulnerability Mapping of Kathmandu Valley Using Multi-Criteria Decision Analysis

[1]Arun Rai and Ajay B. Mathema[2]

Abstract

In recent times climate change has accelerated due to human activities. Effect of climate change increases the vulnerability of community, at the same time, increases exposure and risk of people residing in that particular community. Thus in order to address the vulnerability of Kathmandu valley(Kathmandu, Lalitpur & Bhaktapur) to climate change impacts, the climate change vulnerability was assessed through Multi-Criteria Decision Analysis (MCDA) tools in this study and mapped with the use of GIS. Indicators for vulnerability, exposure, sensitivity and adaptive capacity were selected through Mean Rating with 5 Likert's scale. In addition, weighing for these indicators was done by pair-wise comparison. MCDA value for sensitivity for Kathmandu, Lalitpur and Bhaktapur were 0.62 (very low), 0.63 (very low) and 0.26 (Moderate) respectively. Similarly, MCDA value for exposure/risk for Kathmandu, Lalitpur and Bhaktapur were 0.26 (High), 0.73 (very low) and 0.55 (low) respectively. Moreover, MCDA value for adaptive capacity for Kathmandu, Lalitpur and Bhaktapur were 0.84 (very high), 0.44 (high) and 0.33 (moderate) respectively. Lastly, MCDA value for overall vulnerability for Kathmandu, Lalitpur and Bhaktapur were 0.56 (moderate), 0.58 (moderate) and 0.46 (moderate) respectively.

Keywords: *adaptive, climate change, MCDA, sensitivity, vulnerability*

Introduction

The phenomenon of Climate Change is a long term significant change in the average weather patterns of the region or the earth as a whole. It mainly involves changes in the variability or average state of the temperature, precipitation and wind patterns over durations ranging from decades to millions of years (Joshi, 2009). According to Intergovernmental Panel on Climate Change (IPCC), Climate Change refers to any change in climate over time, whether due to natural variability or as a result of human activity.

This study was carried out to prioritize the climate change vulnerability of three districts of Kathmandu valley, namely, Kathmandu, Lalitpur and Bhaktapur using Multi-Criteria Decision Analysis (MCDA). Moreover, MCDA values of study districts were mapped using GIS application. Major objective of this study was to prioritize the study districts based upon climate change vulnerability using MCDA tools. The specific objective of this study includes prioritizing and mapping the study districts based upon their exposure, sensitivity and adaptive capacity with MCDA and GIS respectively.

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Methodology

Selection of indicators

Indicators were selected from the report "Climate Change Vulnerability Mapping for Nepal" (2010). They were picked from Mean Rating with 5 Likert's Scale with 10 experts working in environmental field.

To identify the vulnerable study district, this research had adopted the concept contained in the Third Assessment Report (TAR) of the IPCC, where **vulnerability** was defined as the function of exposure, sensitivity and adaptive capacity.

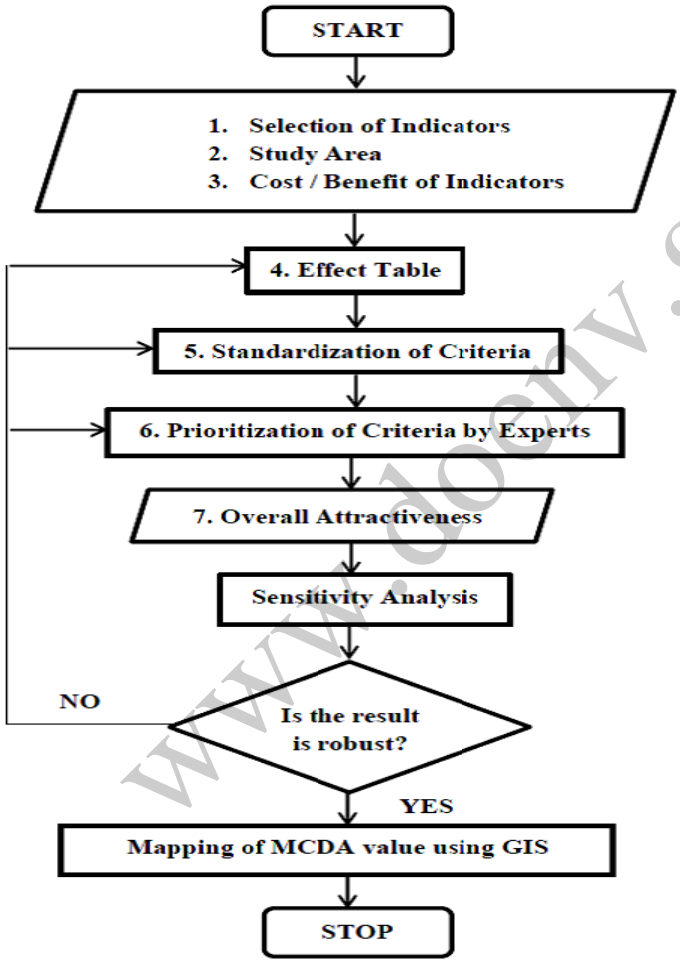


Figure 1: Methodology of the study

Mathematically, Vulnerability = f (exposure, sensitivity, adaptive capacity)

Exposure was defined as the nature and degree to which a system is exposed to significant climatic variations (IPCC, 2001). In this study, exposure/risk was represented as the function of temperature & rainfall, landslide & flood, drought and ecology.

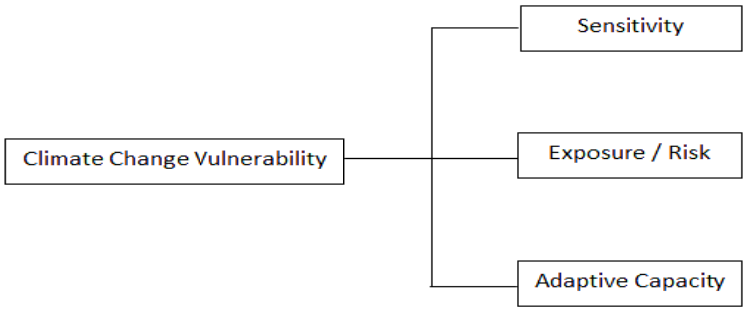


Figure 2: Structure tree of climate change vulnerability

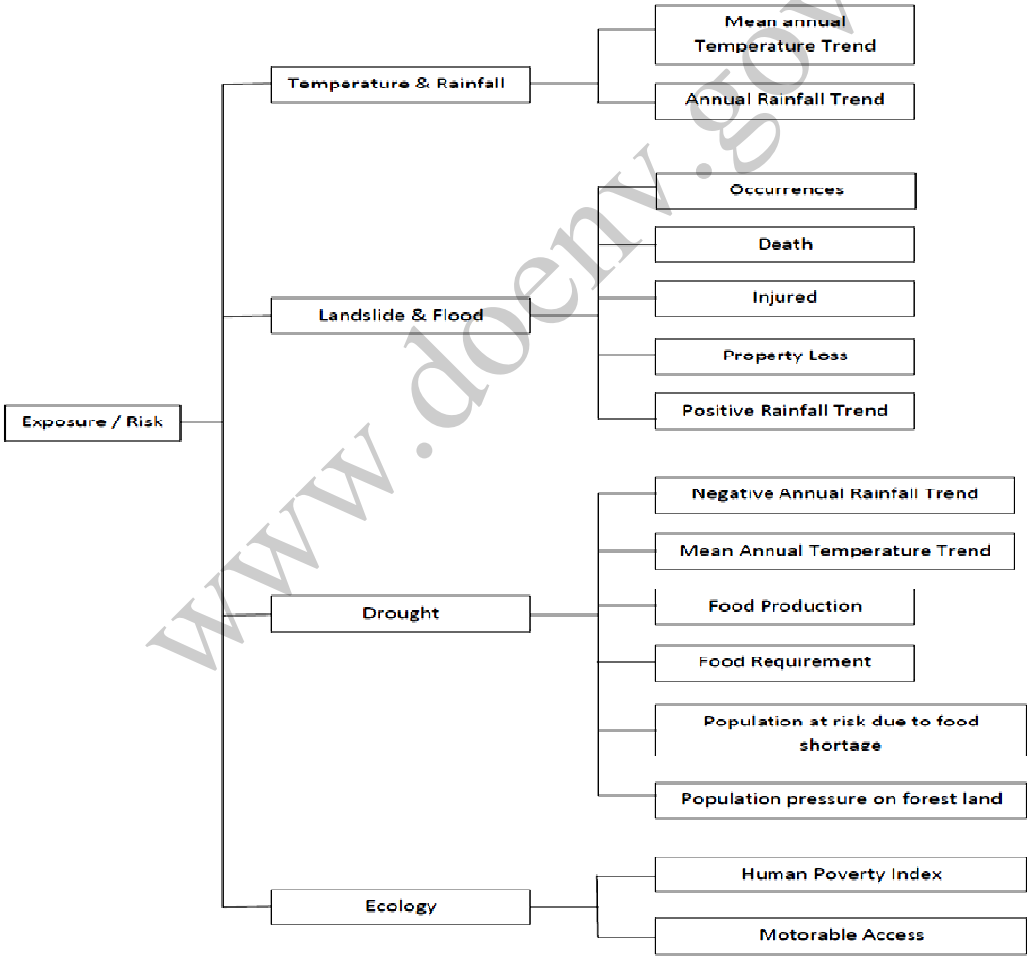


Figure 3: Structure tree of exposure / risk

Mathematically,
Exposure / Risk = f (temperature & rainfall, landslide & flood, drought, ecology)
Where,
Temp. & Rainfall = f (mean annual temp. trend, annual rainfall trend)
Landslide & flood = f (occurrences, death, injured, property loss, positive rainfall trend)
Drought = f (-ve annual rainfall trend, mean annual temp. trend, food production, food requirement, population at risk due to food shortage, population pressure on forest land)
Ecology = f (human poverty index, motorable access)
Sensitivity was defined as "the degree to which a system is affected either adversely or beneficially, by climate-related stimuli" (IPCC, 2011). In this study, sensitivity was represented as the function of human sensitivity and ecology sensitivity.

Mathematically,
Sensitivity = f (human sensitivity, ecological sensitivity)
Where,
Human sensitivity = f (Population, district area)
Ecological Sensitivity = f (Protected area coverage, forest area coverage, district area)

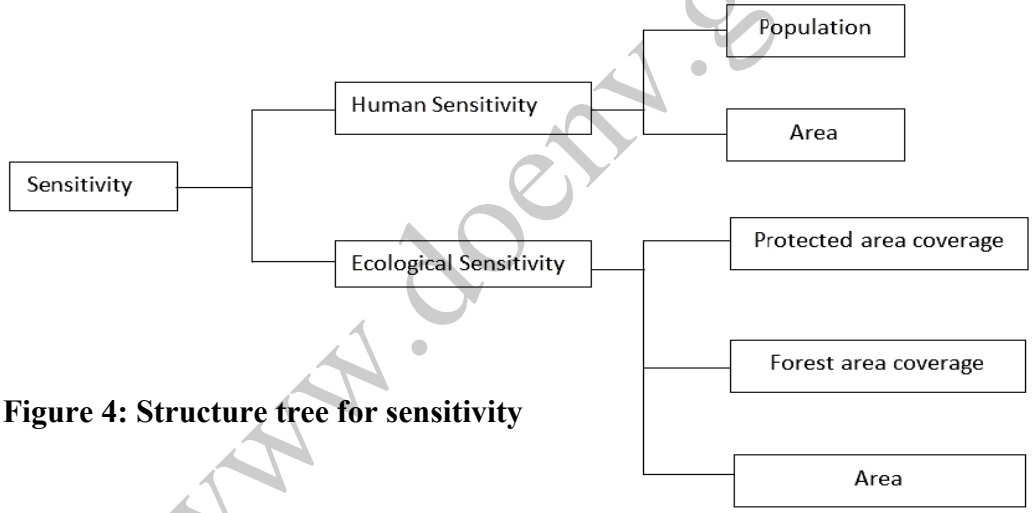


Figure 4: Structure tree for sensitivity

Adaptive capacity was defined as "the ability of a system to adjust to climate change (including climate variability and extremes), to moderate the potential damage from it, to take advantage of its opportunities, or to cope with its consequences" (IPCC, 2001). This research had used adaptive capacity as the function of socio-economics, infrastructures and technological adaptation.

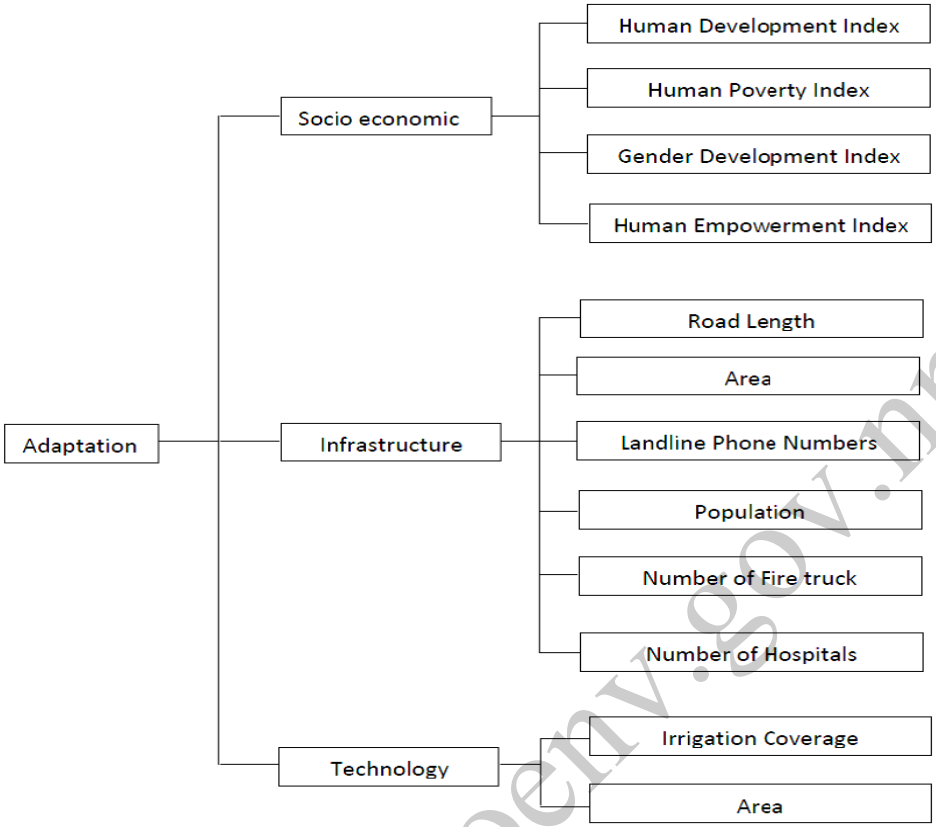


Figure 5: Structure tree for adaptive capacity

Mathematically,

Adaptive capacity = f (socio-economic, infrastructure, technology)
Where, *Socio-economic* = f (human development index, human poverty index, gender development index, human empowerment index)
Infrastructure = f (road length, district area, landline phone numbers, population of district, number of fire-truck in district, number of hospitals)
Technology = f (irrigation coverage, district area)

Study area

Three districts of Kathmandu valley were selected for analysis namely, Kathmandu, Lalitpur and Bhaktapur. Kathmandu, Bhaktapur and Lalitpur districts rank very high to high in the risk specific and combined vulnerability maps (NAPA, 2010). These districts located within the Kathmandu valley, the capital of Nepal, have been enjoying the larger share of national development budgets and very likely will continue to enjoy the same status in future. The major characteristics of Kathmandu valley is that it has high adaptive capacity at the same time high risk, making it unique.

Cost / Benefit of indicators

Indicator that has benefit attributes are term as Benefit (higher the better). For example protected area coverage, it means that higher the protected area better will for environment as well as for mankind.Indicator that has cost attributes is generally term as Cost (lower the better). For example lower the death from natural disaster better will be for nation.

Effect table

Effect table specifies the indicators by which we can evaluate and place them in hierarchy. In simple term, it is structuring of the problem. It includes matrix having indicators in row and study area in column. Effect table for exposure / risk, sensitivity, adaptive capacity and overall vulnerability are given in Table 1, Table 2, Table 3 and Table 4 respectively.

Table 1: Effect table for exposure / risk

Indicator	Sub-Indicator	C/B	Unit	Kathmandu	Lalitpur	Bhaktapur
Temperature	Mean annual temperature trend	C	^{o}C	0.05	0.05	0.05
	Annual rainfall trend	C	mm	4.71	1.09	5.93
Landslide and Flood	Occurrences	C	No.	5	3	6
	Death	C	No.	5	0	0
	Injured	C	No.	1	0	0
	Property losses	C	NRs.	3128700	979488	575000
	Positive rainfall trend	C	mm	4.71	1.09	5.93
Drought	Negative rainfall trend	C	mm	0	0	0
	Food production	B	Ton	48924	35716.5	28408.5
	Food requirement	C	Ton	290058	80031	53355.75
	Population at risk due to food shortage	C	No.	0	0	0
Ecology	Population pressure on forest land	C	No.	174424	468132	304651
	Human poverty index	C	No.	22.5	19.2	19.4
	Motorable access	C	No.	3.24	1.20	0.44

Table 2: Effect table for sensitivity

Indicator	Sub-indicator	C/B	Unit	Kathmandu	Lalitpur	Bhaktapur
Human sensitivity	Population density	C	Population/sq. area	4415.79	1215.92	2560
Ecological sensitivity	Protected area coverage	B	Ha	9659	0	0
	Forest area coverage	B	Ha	14118	15253	2120
	District area	C	Square Km	395	385	119

Table 3: Effect table for adaptive capacity

Indicators	Sub-indicator	C/B	Unit	Kathmandu	Lalitpur	Bhaktapur
Socio-economic	HDI	B	No.	0.632	0.601	0.573
	HPI	C	No.	22.5	19.2	19.4
	GDI	B	No.	0.635	.569	0.578
	HEI	B	No.	0.66	0.657	0.645
Infrastructure	Road length	B	Km	1279	464	53
	District area	C	Square Km	395	385	119
	Landline phone number	B	No.	220275	53435	20097
	Number of fire truck	B	No.	3	1	3
	Number of hospital	B	No.	85	48	55
Technology	Irrigation coverage density	B	Irrigation coverage/area	0.392	0.175	0.3

Table 4: Effect table for overall vulnerability

	Indicator	Sub-Indicator	C/B	Unit	Kathmandu	Lalitpur	Bhaktapur
Sensitivity	Human Sensitivity	Population	C	No.	1744240	468132	304651
		District area	C	Sq. Km	395	385	119
	Ecological Sensitivity	Protected area coverage	B	Ha	9659	0	0
		Forest area coverage	B	Ha	14118	15253	2120
Exposure/ Risk	Temperature and rainfall	Mean annual temperature trend	C	^{o}C	0.05	0.05	0.05
		Annual rainfall trend	C	^{o}C	4.71	1.09	5.93
	Landslide and Flood	Occurrences	C	No.	5	3	6
		Death	C	No.	5	0	0
		Injured	C	No.	1	0	0
		Property losses	C	NRs	3128700	979488	575000
	Drought	Negative annual rainfall trend	C	^{o}C	0	0	0
		Food production	B	ton	48924	35716	28408.5
		Food requirement	C	ton	290058	80031	53355.75
		Population at risk due to food shortage	C	No.	0	0	0
	Ecology	Population pressure on forest land	C	No.	1744240	468132	304651

	Indicator	Sub-Indicator	C/B	Unit	Kathmandu	Lalitpur	Bhaktapur
		Motorable access	C	Per Km	3.24	1.20	0.44
Adaptive capacity	Socio-economic	HDI	B	No.	0.632	0.601	0.573
		HPI	C	No.	22.5	19.2	19.4
		GDI	B	No.	0.635	0.569	0.578
		HEI	B	No.	0.66	0.659	0.645
	Infrastructure	Road length	B	Km	1279.09	464	53
		Landline phone numbers	B	No.	220275	53435	20097
		Number of fire trucks	B	No.	3	1	3
		Number of hospital	B	No.	85	48	55
	Technology	Irrigation coverage density	B	Km^2/Km^2	0.392	0.175	0.3

Standardization of criteria

The conversion of raw data to dimensionless unit is called standardization. Through standardization procedure the measurement units are made uniform and the scores lose their dimension along with their measurement unit. Maximum standardization method and interval standardization method were used for analysis.

Prioritization of indicators

Criteria were prioritized through pair-wise comparison method. Altogether 10 experts were used in this process.

Prioritization of Indicators for exposure / risk, sensitivity, adaptive capacity and overall vulnerability were given in Figure 6, 7, 8 and 9 respectively.

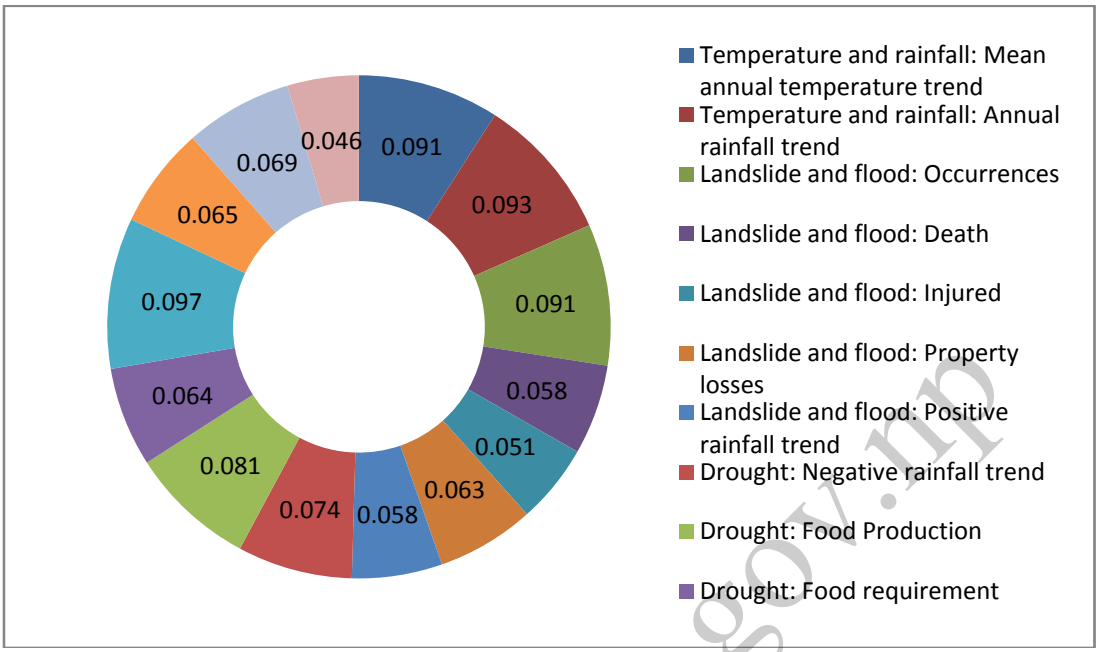


Figure 6: Prioritization of exposure/risk

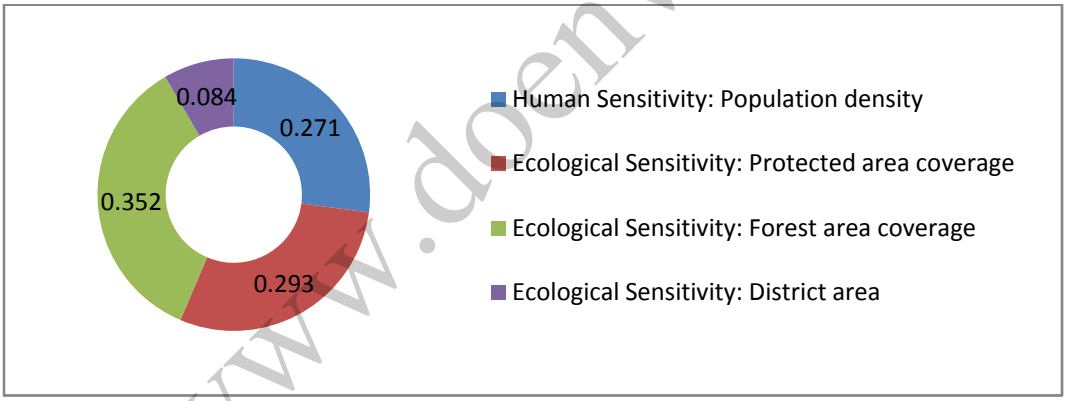


Figure 7: Prioritization of sensitivity

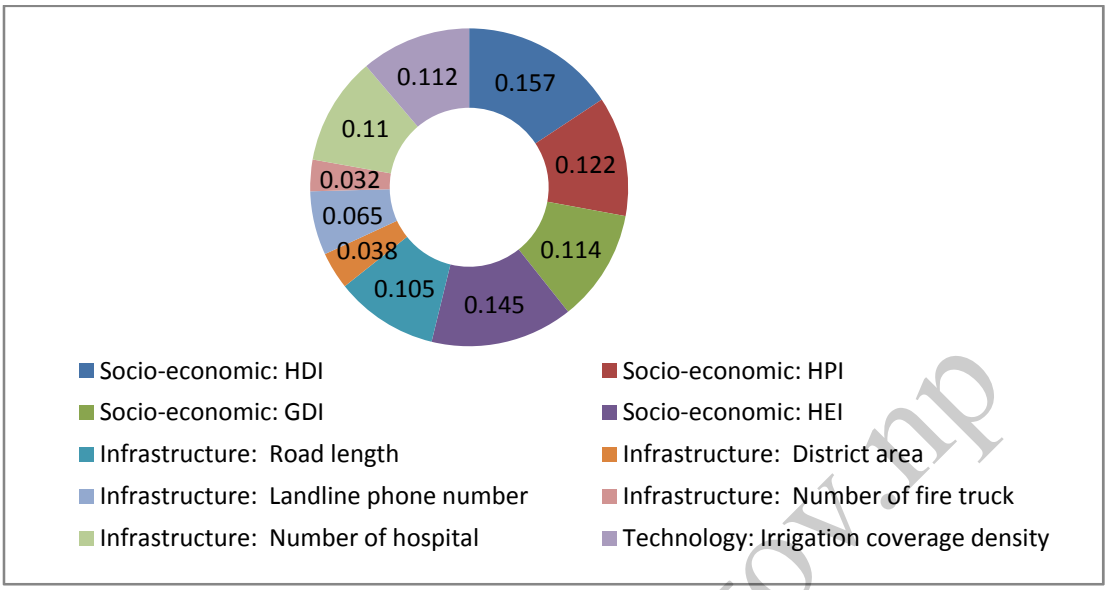


Figure 8: Prioritization of adaptive capacity

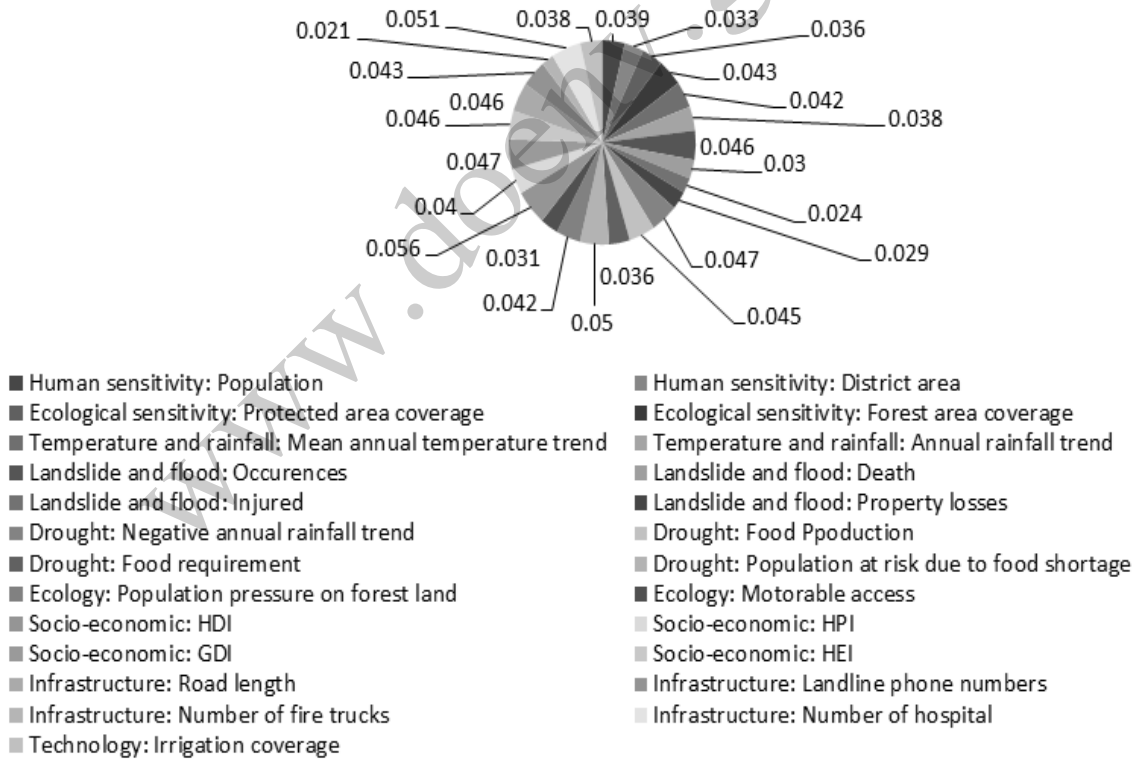


Figure 9: Prioritization of overall vulnerability

Result and discussion

Overall attractiveness

Overall attractiveness is the result of the analysis. It is resulted from multiplying standardized indicators with weights of each indicator and lastly summing each study districts (Fig. 10, 11, 12, 13 and 14).

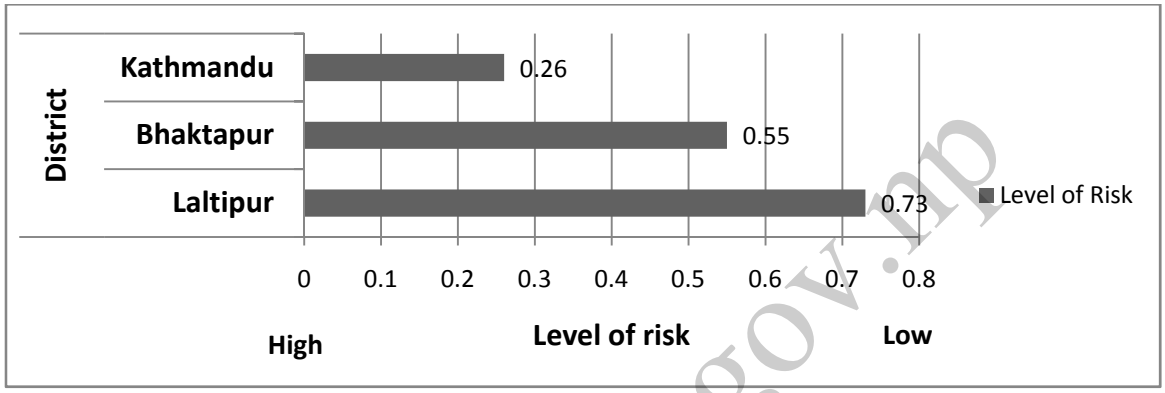


Figure10: Result of exposure / risk

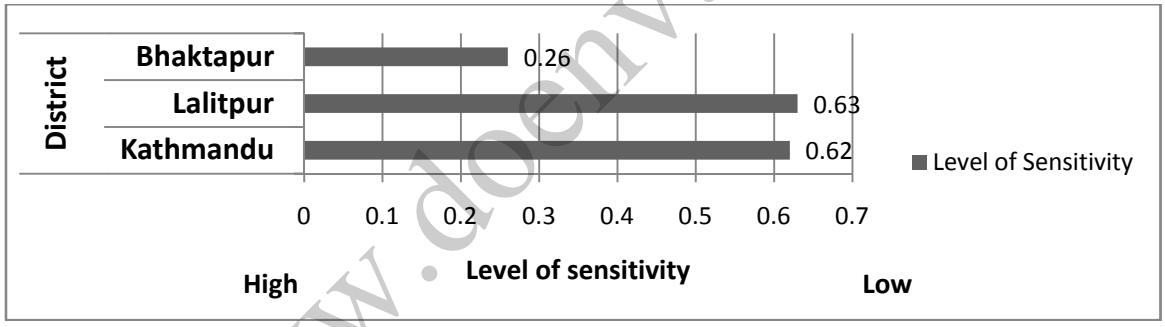


Figure11: Result of sensitivity

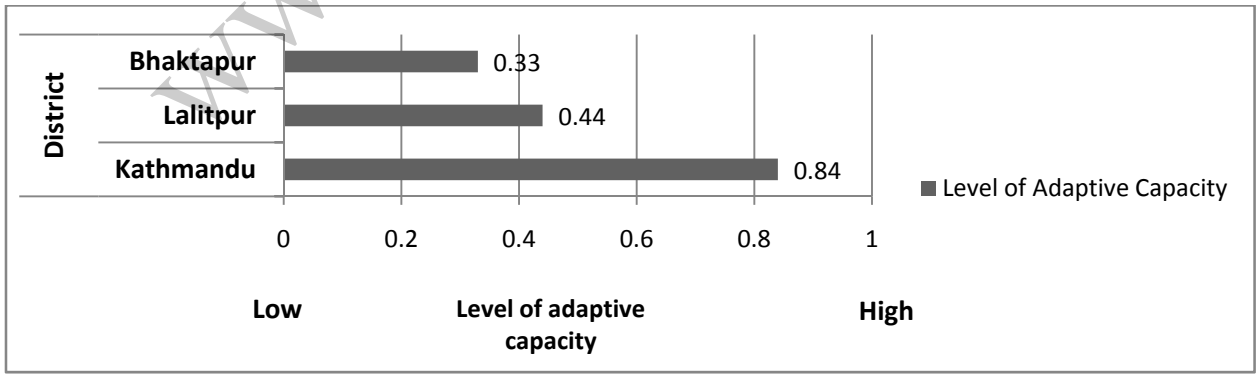


Figure12: Result of adaptive capacity

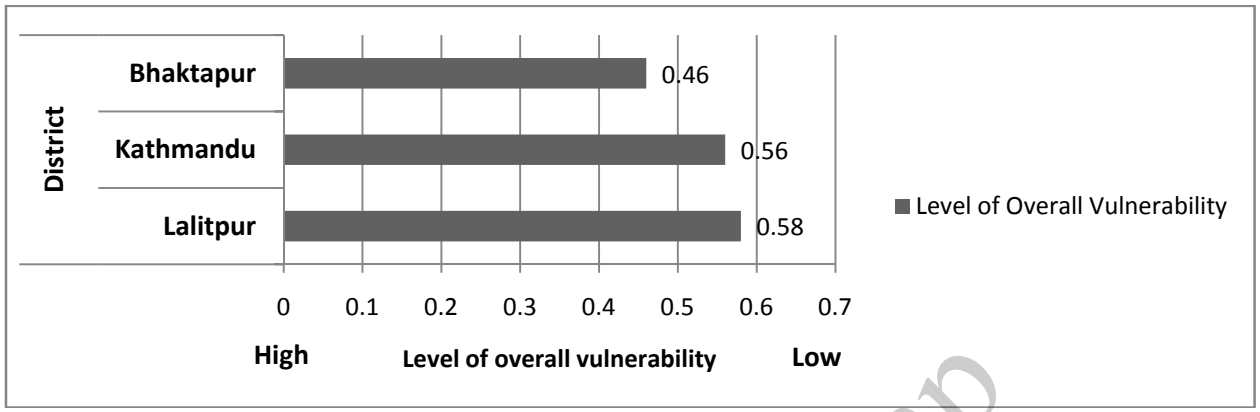
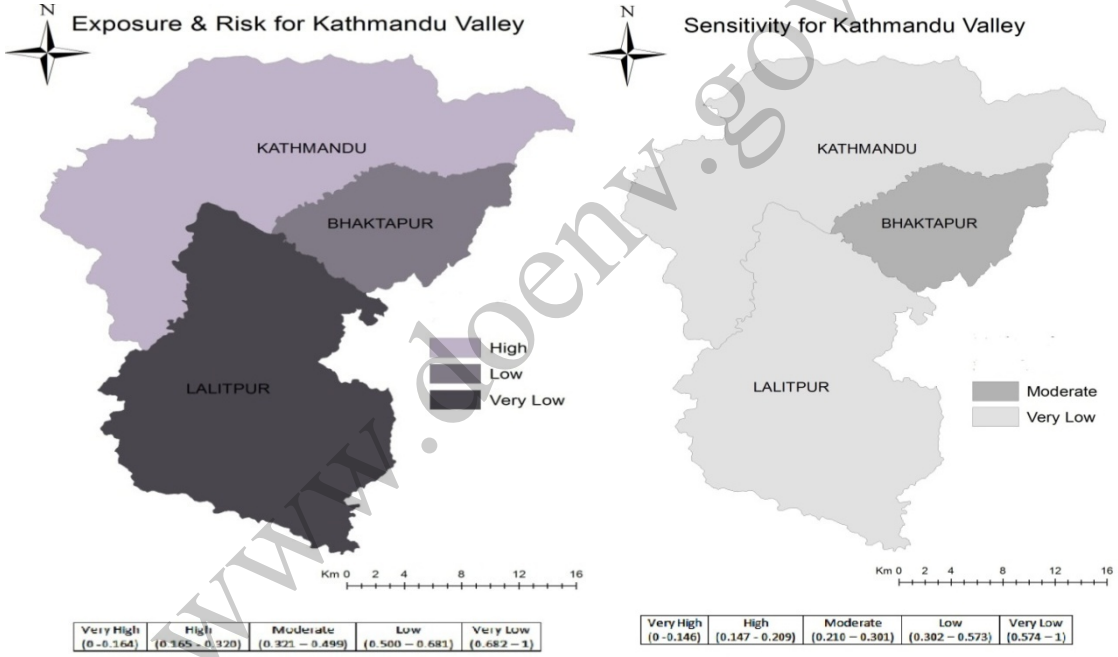


Figure13: Result of overall vulnerability

Mapping of climate change vulnerability



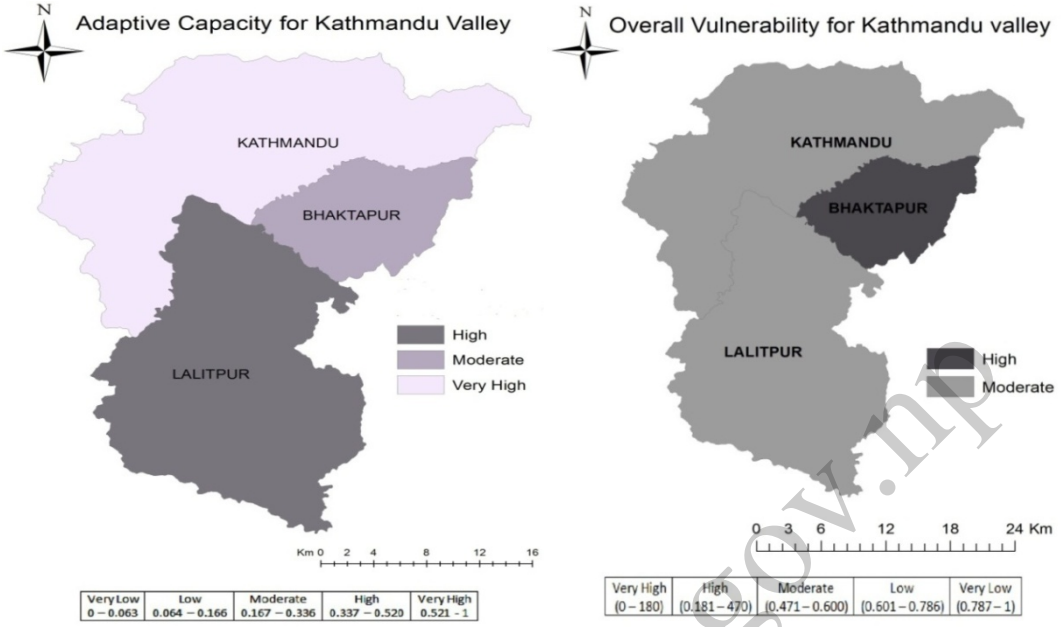


Figure 14: Overall risk sensitivity, adoptive capacity and vulnerability of Kathmandu valley.

Conclusion and recommendation

	Very High	High	Moderate	Low	Very Low
Exposure and risk		*Kathmandu*		*Bhaktapur*	*Lalitpur*
Adaptive capacity	*Kathmandu*	*Lalitpur*	*Bhaktapur*		
Sensitivity			*Bhaktapur*		*Kathmandu Lalitpur*
Overall Vulnerability		*Bhaktapur*	*Kathmandu Lalitpur*		

Safe		Moderate		Danger

Reference

GoN. 2010. Climate change vulnerability mapping for Nepal. Kathmandu, Nepal: Ministry of Environment.

IPCC. 2001. Climate change 2001: Impacts, adaptation, and vulnerability. Cambridge: Cambridge University Press.

IPCC. 2001. Climate change 2001: Impacts, ddaptation, and vulnerability. Cambridge: Cambridge Unversity Press.

IPCC. 2007. Climate Change 2007: Adaptation and Vulnerability. Summary for policy makers. Geneva, Switzerland: Intergovernmental Panel for Climate Change.

Joshi, N. 2009. Local people's perception on the impact of climate change. A comparative study of two VDC's of Langtang area. Syabrubesi & Dhunche. Thesis submitted to Kathmandu University.

UNFCC. 2007. Climate Change: Impacts, vulnerabilities and adaptation in developing countries. United Nations Framework Convention on Climate Change.

Community Adaptation to Climate Change: A Case Study of Chepang Indigenous Group

Reshu Bashyal[1] Dinesh R. Bhuju[2] and Kumar Paudel[3]

Abstract

Climate change undoubtedly is a global issue, but its anomalies are observed at local level. Even at the local level, the most marginalized section of the community must be the focus as they are the ones who are the most vulnerable. In this direction, this study is focused on the Chepang community, one of the highly marginalized indigenous nationalities in the rural mid-hills of Nepal, which constitutes 0.23% of the total population. Based upon the preliminary field visit, consultation with key informants, viz. VDC Secretary, local leaders, semi structured questionnaire survey and literature reviews, their understanding towards Climate change was known. Climate change and its impact on their livelihood were not new to them. Agriculture was mostly affected with pest outbreak, decrease in productivity and cropping cycles as major anomalies. Precipitation, water resources, temperature too were affected however; forest was good thanks to community forestry. Owing to these impacts, the Chepang people with the support of I/NGO's and VDC, constructed small scale water collection tanks, micro irrigation schemes, home gardening, cash crops and District climate change coordination committee were formed for adaptation. Despite of such huge inputs yet Chepang people were in misery, so, any development programmes should prioritize adaptation as improperly planned programmes amplify the impacts.

Key words: *adaptation,chepang, climate change, impacts, marginalized*

Introduction

There is now a strong consensus that global climate change is occurring at an unprecedented rate and scale, in large part because of anthropogenic or human activities (Adger *et. al.*, 2003; IPCC, 2007). Climate change is undoubtedly a global issue but its anomalies are observed at local level. Despite of its minimal contribution to the global GHG emission, Nepal is quite vulnerable to the impacts. For instance, Climate Change Risk Atlas 2010 ranks Nepal as the 4th most vulnerable country worldwide, indicating the extreme vulnerability that the country faces (NDRRC, 2013). Similarly, vulnerability projection under A2 emission scenario in 2050 places Nepal under significant vulnerability (Gurung & Bhandari, 2009). The groups who are already discriminated and marginalised are experiencing the worst increase in vulnerability (MoE 2010). The marginalized group of people, the Chepangs who solely depend upon the forest and forest products are mostly vulnerable to climate change impacts.

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Chepangs are one of the indigenous nationalities having population of 52,237 constituting 0.23% of the total population of Nepal (Piya et. al., 2012). More than 95% of Chepangs live in hilly villages of Chitwan, Makwanpur, Dhaging and Gorkha districts (CBS 2011). Nepal Federation of Indigenous Nationalities (NEFIN) has categorized Chepangs as highly marginalized indigenous nationality from the hills. According to Brian Hodgson, 1874, Chepangs were described as a nomadic group living entirely upon wild fruit and the produce of the chase (Hodgson, 1874).

The general objective of the study was to assess the climate change impacts on the livelihood of Chepang communities living in the area of Jugedi, Chitwan of central Nepal Mountain. The Specific objectives were:

1. To know the understanding of Chepang community on climate change impacts.
2. To determine the impacts of climate change in agriculture and food security of the Chepangs of Jugedi.
3. To determine the adaptation practices of Chepang community to cope with the climate change impacts.

Methodology

Study Area

Kabilash VDC lies in Chitwan district, Central Nepal. Kabilsh is situated at 27.79^{0}N 84.48^{0}E at an altitude of 141-1945masl and has population of 5,815 (CBS 2011). It has sub-tropical climate. Out of total 9 wards, ward no. 1 and 9 representing Bharlang and Beldada were selected for the study. (Fig.1)

The households in the two villages of Bharlang and Beldanda are located with almost equal geographical features. They are exposed to the same climate changes and natural hazards, they have been involved under the same project interventions and they live under the same governance structure. Beside the apparent difference in the current living conditions, the households are exposed differently to the impacts from flooding, landslides and erosions depending on their location, which made them differently vulnerable to these hazards (VDC, 2012; DDC, 2012). The major source of income is agriculture, while they solely depend upon the forest products for their livelihood. Bharlang

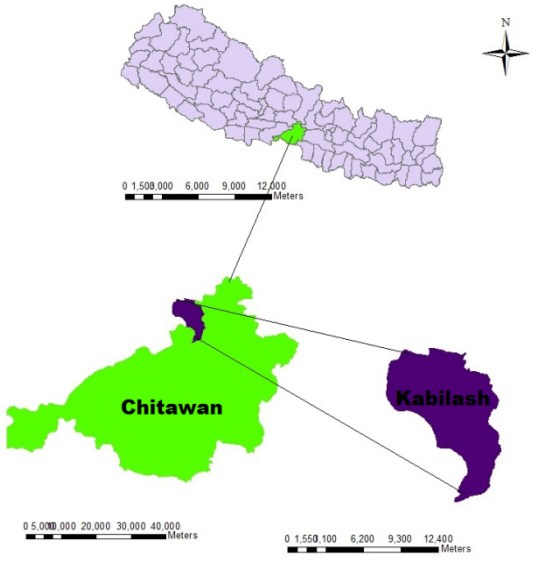

Figure 1: Map of the Study Area

has mixed community of Newar, Gurungs, Brahmin and some Chepangs and Beldada is totally inhabited by Chepangs (VDC 2011/12).

Data collection

Both primary as well as secondary data were considered for information collection. Table 1 indicates the detail of number and types of interviews for data collection.

a) Primary data collection:
   - Focus group discussion (FGD) was done to identify areas of focus for climate change adaptations. Data was collected from the semi structured questionnaire survey.
   - KII (Key Informants Interview): DDC and VDC representatives; Local I/NGOs representatives.
   - Expert advice

b) Secondary information collection:
   - From VDC, topographical and socio economic information of the study area were generated.
   - Some literatures were consulted to know the status of temperature and precipitation tends and other climatic hazards.
   - Other relevant journals, websites, articles and information regarding past important events and other adaptation measures were considered.

Table 1: Number and types of interviews for data collection

Type of respondents	No.	Interview techniques	Gained knowledge about
Residents of Bharlang and Beldada (representing a local HH)	27	Semi-structured Questionnaire	Study area, resource basis, adaptive capacity and adaptation actions
Experts	3	Open explorative	Strategic CC adaptation and development
DDC and VDC authorities, (KII)	2	Semi-structured	Study area and their plans
NGO representatives (KII)	3	Semi-structured	Study area, activities, experiences
Local focal person	1	Semi-structured	Study area, NGO activities

Result

Understanding of Chepang community on climate change impacts

The understanding of chepangs based on literacy, age and gender was known considering different parameters affected by the impacts of climate change.

Agriculture and precipitation sector was much affected by climate change followed by water resources, temperature and forest resources (Table 2).

Table 2: Understanding of Chepang community on climate change impacts

SN	Parameters affected	%
1	Water Resources	20.77
2	Agriculture	23.38
3	Precipitation	23.38
4	Forest resources	14.29
5	Temperature	18.18

Similarly, the understanding of people was assessed based on literacy. People had different perception on the parameters affected (Table 3).

Table 3: Understanding based on literacy

SN	Parameters affected	Education	
		Educated	Uneducated
1	Water resources	43.75	56.25
2	Agriculture	27.78	72.2
3	Precipitation	38.89	61.11
4	Forest resources	36.36	63.64
5	Temperature	50	50

Similarly, based on age too they had different understanding. As elder citizen (more than 41 years old) had experienced more their surroundings, they were comparatively more aware of changes they are facing (Table 4).

Table 4: Understanding based on age groups

SN	Parameters affected	Age (years old)		
		<20	21-40	>41
1	Water resources	6.25	43.75	50
2	Agriculture	6	44	50
3	Precipitation	11.11	33.33	55.55
4	Forest resources	9.09	27.27	63.66
5	Temperature	15.38	30.77	53.85

Moreover, regarding the understanding based on gender, male were comparatively more aware of the changes (Table 5).

Table 5: Understanding based on gender

SN	Parameters affected	Gender	
		Male	Female
1	Water resources	50	50
2	Agriculture	50	50
3	Precipitation	55.56	44.44
4	Forest resources	54.55	45.45
5	Temperature	57.14	35.71

The impacts of climate change in agriculture and food security

All the people agreed that climate change had negative impacts. Change in crop cycle, crop yield, productivity, outburst of pests and diseases and loss of native species were the major impacts of climate change observed in agriculture sector. However, there were various responses (Fig. 2).

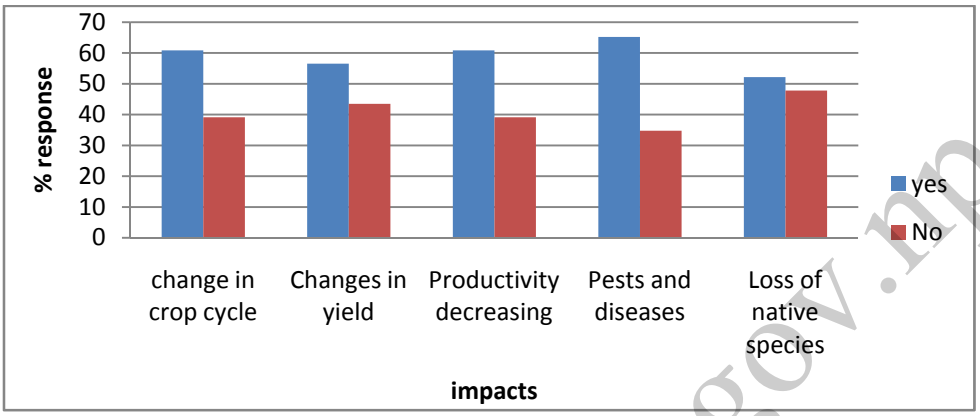

Figure 2: Impacts of CC on agriculture and food security

The varying response was found based on gender as well as literacy rates (Table 6).

Table 6: Responses on each impact

SN	Impacts	Gender (%)		Education (%)	
		Male	Female	Literate	Illiterate
1	Changes in crop cycle	73.33	26.67	55.55	44.44
2	Changes in yield	64.29	35.71	66.67	33.33
3	Productivity decreasing	64.29	35.71	66.67	33.33
4	Pests and Diseases	76.92	23.08	66.67	33.33
5	Loss of native species	66.67	33.33	44.44	55.55

Similarly, for further information, key informants and focal persons were consulted and some of the information's from them are:

- Kabilash VDC had to face flooding as well as landslides on 2060's and 2063's. 18 people died, 59 houses collapsed, a large agricultural land wasted, infrastructure of development were collapsed due to the flooding of 2060's.
- Few years ago Barlang too had the similar problem but after the irrigation project, there's huge positive change. However, Chepang community of Beldada, is one which totally depends upon forest and forests resources.
- Because of limited farming land, population is dependent on livestock, forest, and seasonal wage labour. Chepang has been practicing the shifting cultivation (*Khoria Phadani*) for their livelihoods. These two study areas are repository of non-timber

forest products, critical biodiversity and ecosystem services over which local livelihoods depend.

- Though there have been many organizations, but Chepangs don't show interest to get involved in their schemes and usually spend most of their times in selling firewoods and buying alcohol from the income.

From the secondary data, the climatic variables like precipitation patterns and trends (Drought, untimely and erratic rains) and temperatures (pest and diseases) experienced major changes. In last 42 years, the former had increased by 8.04mm and latter by 0.056-0.098^{o}C. The drought, untimely and erratic rains were major instances to show precipitation changes while pest and disease outbreak were major evident for temperature changes (Maskey 2013).

Adaptation practices of Chepang community

People had practiced different adaptation strategies to cope with the impacts of climate change. They had adapted different new practices in water resources, food security and forest resources either on their own or via the support of I/NGOs (Table 7).

Table 7: Adaptation practices of Chepang community

SN	Sectors	New practices	Remarks
1.	Water Resources	Construction of small scale plastic or cement water collection tanks; micro irrigation schemes; Pipelines and other irrigation canals	Forward Nepal, DADO, Red Cross, PAN, VDC
2.	Food Security	home gardening, seed production programs, agro-forestry integrating legumes crops; Collecting wild edibles, Wage labouring, Nonfarm jobs, Varietal selection, Adjusting sowing times (winter farming tomatoes, maize, potatoes), Cash crops, vegetables, liquor selling and animal husbandry	FORWARD Nepal, Neighbours, VDC's awareness programmes, RRN, SHRAM Nepal Goat sharing schemes, loans as Ghumti kosh
3.	Forest	Collection of NTFP's from nearby forest and Community forestry	VDC's support
4.	Livelihood	• District CC coordination committee is doing awareness raising program -a radio program, Training in VDC level about LAPA , plantation programs in the villages • Establishment of district Risk Reduction committee • Integrated Planning Commission with 22 members includes chepangs • Budget comes to mitigate CC impacts under Climate Change and mitigation Committee	

Discussion

Most of the people were aware about the changes occurring in their environment in last three decades. 23.38% reported changes in precipitation patterns over 20-30 years, most significant changes being unusual and untimely rainfall. Whereas, 18.18% of the respondents experienced changes in temperature. This result is supported by secondary data too. Similarly, on the age basis too, the people with ages more than 41 years were more aware about these changes followed by 21-40 years. There's a different understanding of elder citizens in such parameters. May be because of that though they were not educated, they were quite aware about the changes in these parameters are worried. As the research was, focus on documenting the experiences of climatic variability and its consequences over past 20-30 years or more, the elder local people were the target group for the survey and were considered as the key informant of the research.

In study done by Dhakal (2013) the people of Jugedi had observed the increasing temperature, this result coincided with the study done by Practical Action (2009). Similar study had been carried out Maskey in Kabilash VDC where most of the respondents experienced the change in precipitation patterns in the summer and winter, and highlighted irregular precipitation and absence of rainfall in important farming periods as characteristics for the change (Maskey, 2013) which is comparable with finding of this study. Study carried out by Paudel *et. al.* in Chitwan district also revealed experience of changes in the local climate by farming community (Paudel *et. al.*, 2014) and the finding can be validated by this study where 67% of household reported increased summer temperature and the trend of summer temperature also exhibits the increasing trend.

The agricultural sector is highly dependent on the rainfall and temperature. Climate changes, especially in temperature, humidity and radiation, have great effects on the incidence of insects, pests, diseases and microorganisms. A change of $1^{o}C$ changes the virulence of some races of rust infecting wheat. The major impacts were changes in crop cycle from two to three cycles per year, changes in yield, decrease in productivity, pest and disease outbreak and loss of native species with invasion of old ones. Decreasing the productivity is the serious problem in the agriculture, which may be due to climate-induced hazards in the study area. Lack of rainfall at proper period caused decrease in the production of all crops even on use of new fertilizers. Agricultural production was decrease drastically in this area, which has threatened the food security.

The response was considered on the basis on gender as well as literacy. As expected, in this regard, literate and male were more aware regarding the impacts of climate change in agriculture and food security. It was found Most of the people in this area are depended on the rainwater to plant their crops with little being irrigation friendly. Many of the productive lands were left without any crops due to lack of rainfall in the proper

time. During the field survey time, the lands especially in Beldada were found barren due to lack of irrigation. Other problems were the unwanted weeds occupying the farmland, intervening the agriculture. The most noticed weed was Gandhe Jhār (*Ageratum conizoides*) and Banmara (*Mikania micrantha)*.

Communities are trying to adapt the climate-induced impacts and have developed some range of strategies to cope with climatic risks. However, measures taken were not found sufficient for the study area. So losses from climatic variations and extremes are substantial and in some sectors increasing. These losses indicate that adaptation measures have not been sufficient or not success to cope with such risks.

As the area was totally destroyed by huge floods and is inhabited by indigenous Chepangs, different organizations like PAN, FORWARD Nepal, RRN, SHRAM Nepal, Red Cross, DADO including VDC were actively involved in dealing with the problems.

Different tanks, micro irrigation schemes were made to cope with water problems (Table 7). In the sector of food, different ways of producing food, cash crops, etc were promoted. To cope with the impacts from the drought, they promoted the crops, which need less amount of water. They started planting new varieties of rice that takes short period to harvest and the species that need less amount of water. Also, winter maize was grown including involvement in goat sharing and other animal husbandry schemes.

Different attempts were made from VDC and other organizations to cope with the people; despite all these attempts, the Chepangs in Beldada were totally backwards.

Conclusion

From the observation we can conclude that Chepangs communities are highly vulnerable to climate change amid their lack of knowledge on climate change, high dependency on natural resources directly and low adaptive capacity. To reduce the effects, adaptation practices are being carried out in the sector of agriculture, water, forests and livelihood; which are more traditional in approach and based on local level knowledge. However, community-based adaptation strategies must give a higher priority to breaking down these barriers in order to support the processes which make the most vulnerable groups capable of utilizing tangible and intangible resources to adapt to climate change.

References

Adger, W.N., K. Brown, D.R. Nelson, F. Berkes, H. Eakin, C. Folke, E.L. Tompkins 2003. Resilience implications of policy responses to climate change. John Wiley & Sons, Ltd., 2:757-766.

CBS 2011. Statistical Year Book Nepal. Central Bureau of Statistics, National Planning Commission, Kathmandu, Nepal.

DDC 2002. District Profile of Chitwan. p15.

DFO 2010. Information of the Community Forests.p19-25.

IPCC 2007a. Adaptation and Vulnerability, Summary for Policymakers. Geneva, Switzerland, Intergovernmental Panel on Climate Change.

Maharjan, K., N. Joshi, et. al. 2012. Vulnerability of Rural Households to Climate Change and Extremes: Analysis of Chepang Households in the Mid-Hills of Nepal. A journal on Regional Environmental Change. ***13****: 438-447.*

NDRRC 2013. A guidebook on Nepal Disaster Risk Reduction Consortium on Flagship Programmes. National Level Workshop on Flagship Programmes. Kathmandu, Nepal, Nepal Disaster Risk Reduction Consortium.

Shambhu, C. 2010. Exploring Existing Local Adaptation Practices and Potential Strategic Options to Address Climate Change Impact on Biodiversity and its Dependents of Nepal. Kathmandu, Nepal, National Adaptation Programme of Action/ Ministry of Environment/ Government of Nepal.

V.D.C. 2011/12. VDC Profile of Kabilash: 2011/12. Kabilash, Chitwan, Kabilash VDC Center.

*Gurung, G. B., & D. Bhandari 2009. Integrated Approach to Climate Change Adaptation. A journal of Forest and Livelihood***,** *8: 1-5.*

MoE 2010. Climate Change Vulnerability Mapping for Nepal. Kathmandu, Nepal, Ministry of Environment.

CBS. 2013. Statistical Year Book Nepal. Central Bureau of Statistics, National Planning Commission, Kathmandu, Nepal.

Piya, L., K.L. Maharjan, and N.P. Joshi 2012: Perceptions and Realities of Climate Change among the Chepang Communities in Rural Mid-Hills of Nepal. Journal of Contemporary India Studies Space and Society. Hiroshima University. Vol. 2: 35-50, 2012.

Hodgson, B.H. (1874): On the Chepand and Kusunda tribes of Nepal. In Essays on the languages, literature and religion of Nepal and Tibet. Manjushri Publishing House, New Delhi, India, 45-54.

Dhakal, I. 2014. Impact Assessment of Climate Change on Water Resources of Jugedi Watershed, Chitwan. A master dissertation of Central Department of Environmental Science, Tribhuvan University, Kritipur, Kathmandu.

Maskey, G. 2013. Local Peoples' Perception and Adaptation to Climate Change Impacts: A Study in Kabilash and Shaktikhor VDCs of Chitwan district. A master dissertation of Khwopa Collage, Tribhuvan University, Bhaktapur, Nepal.

Practical Action 2009. Promoting Adaptation to Climate Change in Nepal. Kathmandu, Nepal.

Paudel, B., B.S. Acharya, R. Ghimire, K.R. Dahal, & P. Bista 2014. Adapting Agriculture to Climate Change and Variability in Chitwan: Long-Term Trends and Farmers' Perceptions. Agric Res. 32: 165-174. doi: 10.1007/s 40003-014-0103-0

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Robustness-Vulnerability Characteristics of Irrigation Systems in Nepal

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Abstract

Small scale irrigation systems in Nepal have been facing diverse sets of disturbances in the recent periods. This paper is based on case studies of 30 irrigation systems from different physiographic regions of Nepal: covering 17% from Mid-mountains; 43% from Mid-hills/valleys and 40% from the Siwalik/Terai. The command area size varied across the regions, small-medium in Mid-mountains and Mid-hills/valleys to medium-large systems in Siwalik/Terai. Using the Anderies et al (2004) robustness framework. We analyze the five entities of the irrigation systems and interaction between them. Natural disturbances, such as impacts of climate change and disasters affecting temporary-nature irrigation infrastructure, have significantly affected the water availability especially in winter and summer seasons. The increasing share of market-oriented agricultural activities clearly shows the continued importance of irrigation systems, which is further justified with the need to meet the deficit in food sufficiency. But, the increased level of seasonal outmigration of labor force has negatively affected the operation and maintenance of those systems, through the declining level of labor availability. The increasing levels of vulnerability to the external disturbances have caused negative consequences to the performance of the systems ultimately affecting the robustness in the long-term. However, appropriate governance structure, with increased participation of users in management and role in formation of necessary rules, could be helpful in maintaining those systems. It helps the users adopt coping strategies in short-term and plan for the long-term adaptation.

Keywords: *external disturbances, governance structure, market-oriented agriculture, operation and maintenance*

Introduction

Irrigation systems operate under the environment of pressure from several external and contextual factors. As a social-ecological system (SES), an irrigation system faces ever-increasing scale of influence of human activity. Specially, the indigenous irrigation systems are facing new threats because of openness to the new world, commercial interests of farmers, rise in cost of maintenance, increased competition of water and weakened social cohesion due to reasons including state interventions (Barker and

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Molle, 2005; Lam, 2001; Shivakoti et al 2005). At the same time the climatic variations also pose threats to the small-scale irrigation systems.

It has been observed that irrigation systems are directly affected by a variety of disturbances like policy changes, market pressures and the changes in the biophysical context where it operates (Bastakoti et. al., 2010).The social-ecological system, irrigation systems in our case, is a complex collection of human, physical and institutional entities that respond to internal and external disturbances through a diverse array of rules in different conditions (Shivakoti and Bastakoti, 2006; Bastakoti and Shivakoti, 2012). The nature of resource (mobile or stationary) responds differently to predictable and unpredictable disturbances (Janssen et al, 2003). The CPR theorists consider lack of storage and non-stationary character of a resource, spate irrigation in our case, as major obstacle for collective action (Ostrom et al, 1994). The strong connections of SES with large-scale phenomenon pose challenges and opportunities for the stakeholders. Literature based on past performance of resource systems shows that many long endured SES have successfully adapted their institutions to these disturbance regimes (Ostrom, 1990; Agrawal, 1999; Shivakoti and Bastakoti, 2006), while others collapsed (Baker, 2005).

This paper focuses on irrigation systems from different physiographic regions of Nepal. The cases covered in this study have also endured to known shocks of regular climate variability such as droughts and floods with varying degree of success in different management regimes and resource uncertainty, and are now exposed to climate related shocks and disturbances at an increased pace. We assess how the external disturbances make the irrigation systems vulnerable and how they adapt to such external disturbances develop long-term robustness of the system. We focused our analysis on major external disturbances and possible panaceas considering the across four first level core components of an SES *viz* resource system; governance system; resource units; resource users individually and the interaction that affect effect each other and related ecosystems (Anderies*et al*, 2004; Ostrom, 2009).

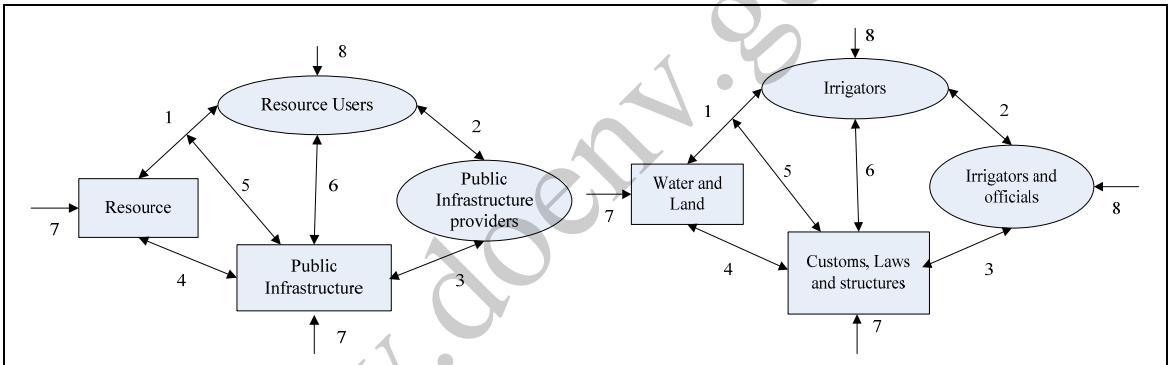
Analytical framework

In our analysis we adopted the framework proposed by Anderies *et. al.* (2004) that provides guideline to analyze core entities of the SES and understand interactions between them. The framework focuses on four entities that are mostly involved in CPRs harvested by people (Figure 1a). The two entities in the framework namely, ‘resource users’ and ‘public infrastructure providers’ involve humans. Other two entities namely ‘resource’ and ‘public infrastructure’ involve physical and institutional aspects. The public infrastructure consists human-made physical and institutional capital (Ostrom and Ahn, 2003). The ‘resource’ entity represents biophysical system used by ‘resource users’ through joint provision effort of the two human based entities in framework that is ‘public infrastructure’ and ‘public infrastructure providers’. The internal fluctuations

can result from changes in relationships between resource users and infrastructure providers and can affect various components and linkages in the framework. The arrows 7 and 8 represent the external disturbances to the ecological and social components of the SES. Other numbered arrows show the linkages and interaction between different components.

In FMIS, the resource users and public infrastructure providers are the same (Fig 1b), and the factors that affect one entity also in turn affect the other (if provision of public infrastructure is affected by some factor, the users are also affected by it). While in case of AMIS/JMIS in our study, the human entities of the framework involve different actors, that is, the public infrastructure providers are mainly the state departments and officials thus affecting the infrastructure. The local communities have limited influence compared to the community-managed systems (Fig 1b).

In this paper we focus on how internal and external disturbances differently impact the core entities of the framework and their interactions in irrigation systems under different management regimes, and variation in resource uncertainty.



Part (a) framework of Anderies *et. al*. 2004 | **Part (b) framework adapted for the irrigation systems**

Fig. 1. (a) A simple framework that highlights the main components of SES and their linkages (Anderies et al 2004), (b) Modified framework for the irrigation systems

Method

This paper is primarily based on information collected at the irrigation system level supported by necessary secondary information from various sources such as policy documents, official reports and published literature.

Sampled irrigation systems

For the field survey sample irrigation systems were selected from 8 districts in different physiographic regions of Nepal (Figure 2). The primary information was collected from the sampled irrigation systems.

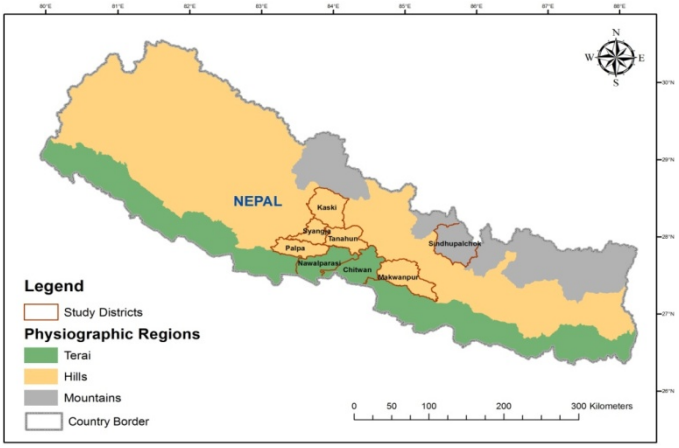


Fig. 2. Study districts in different physiographic regions of Nepal

Irrigation systems were selected based on– ecological region, economic characteristics, and management structure. A sample of 30 irrigation systems was selected covering different physiographic regions of the country (Table 1). Out of the 30 sampled irrigation systems, 40% were from Siwalik/Terai, 43% from Mid-hills/valleys and 17% from Mid-mountains (Figure 3).

Table 1. Distribution of sampled irrigation systems in different agro-ecological regions of Nepal

Physiographic region	District	Number of sampled Irrigation Systems
Siwalik/Terai	Nawalparasi	4
	Chitwan	5
	Makwanpur	3
Hills/Valleys	Kaski	4
	Tanahu	3
	Syangja	3
	Palpa	3
Mid-Mountain	Sindhupalchok	5
Total		**30**

Likewise, out of 30 systems, currently, 29 irrigation systems are farmer-managed irrigation systems (FMIS) and one is under joint management (JMIS). Among the FMIS, 24 were initiated and managed by farmers themselves, whereas, other 5 were initiated by government agency (Department of Irrigation) and later the management responsibility was transferred to the users (management transferred systems – MTIS). (Figure 3)

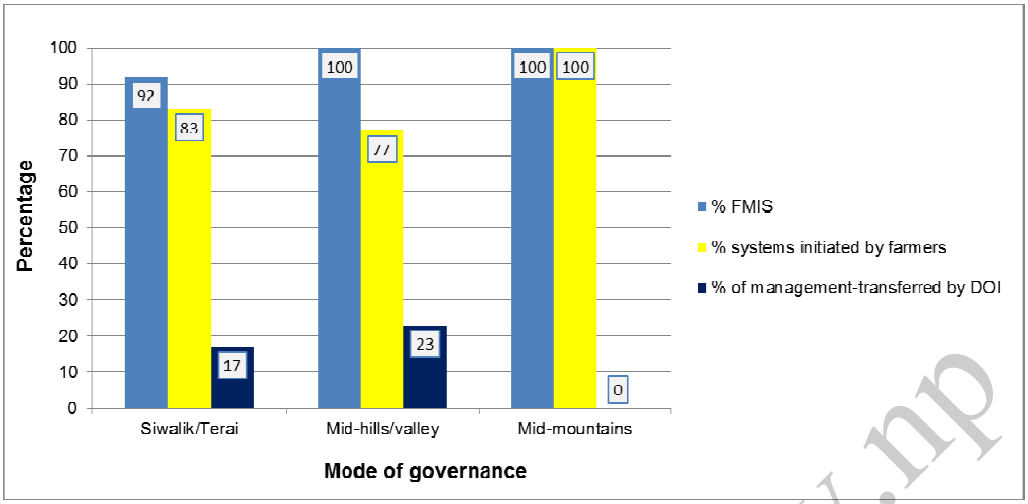


Fig. 3. Governance structure of the sampled irrigation systems

Collection techniques and variables

The system level information was collected by conducting interviews with the officials of water user associations (WUA) in the selected irrigation systems. In each interview, 2-5 persons provided the response about their irrigation system and management aspects in detail. We used structured checklist for the interview. The checklist included the variables covering physical attributes of the system, social context of the users, local institutional arrangement, and existing rules besides others. After the interview with the officials from WUAs information was also cross-checked against official records of WUA wherever possible, for example the date of initiation, command area, number of user households and so on.

Result

Biophysical context of irrigation infrastructure

Traditional farmer-managed irrigation systems are predominant mostly in the hills/siwalik areas of the country. These systems feature infrastructure made-up of with the use of local construction materials. Such infrastructure often needed annual repair and maintenance. However, with changes in government policies, those traditional irrigation systems have also received support to improve their infrastructure.

A look on size distribution across physiographic regions showed existence of large number of medium-large irrigation system in Siwalik/Terai. But, both Mid-hills/valley and Mid-mountains showed dominance of small-medium traditional irrigation system (Figure 4). All the studied irrigation systems were of run-off-the-river type. In Nepal, due to the existence of large number of local streams and topographic suitability, systems operated through gravity flow are common. These are also cost effective as

well. However, due to flood in monsoon and low water level during dry season, this kind of system has low reliability compared to storage type. In the context of growing competition for water, storage and pumping systems provide opportunity to control water supply depending on the need.

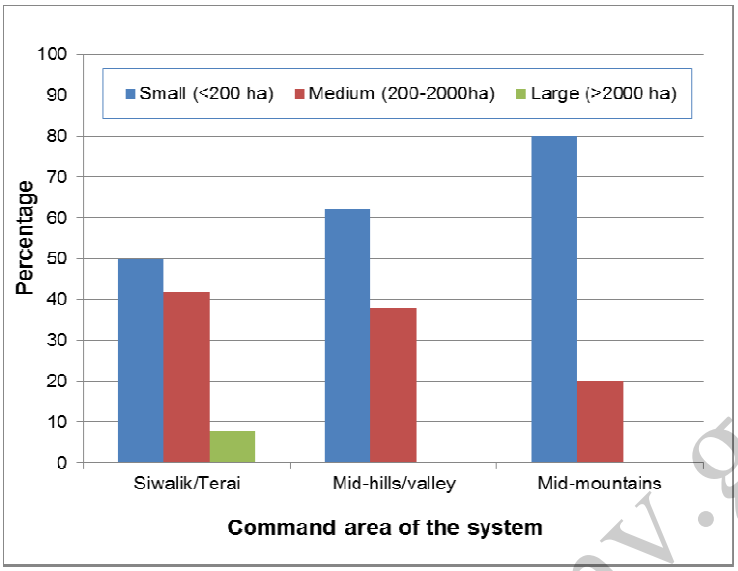


Fig. 4 Distribution of samples irrigation systems based on the size of command area

Many sampled irrigation systems still have temporary headwork. Especially in hilly areas, headwork is made from wood, stones and other local materials. The temporary headwork reduces reliability of the irrigation system. The irrigation systems in Mid-hills/valleys were older than irrigation systems in Siwalik/Terai and Mid-mountains (Figure 5).

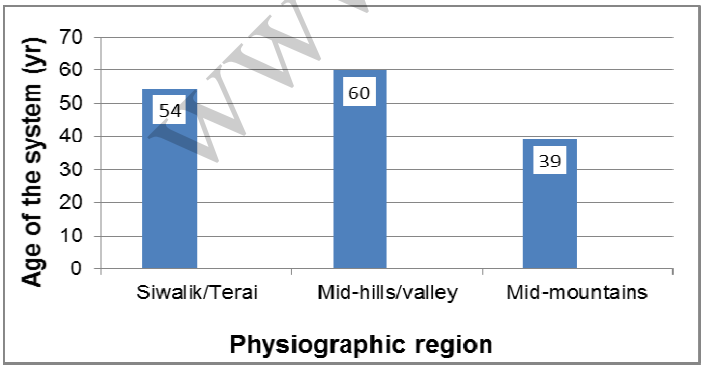


Fig. 5. Distribution of the sampled irrigation systems based on the age of the system

External disturbances to the irrigation systems and increasing vulnerability

Natural events as external disturbances

Irrigation systems are adversely affected by climatic variability such as the erratic rainfall pattern causing recurring occurrence of droughts and floods. About half of the irrigation systems reported major losses from such natural events (Figure 6). Droughts, floods, landslides and resulting damage to infrastructure made irrigation systems vulnerable.

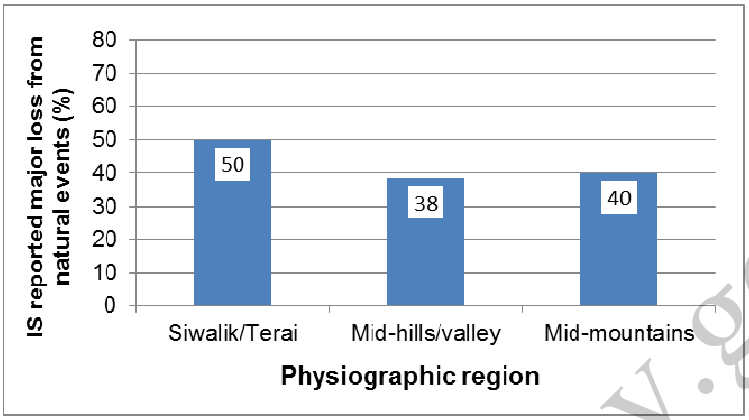


Fig.6. Percentage of irrigation systems reporting major loss from natural events

In the recent decades the delayed onset of monsoon has become common that affects the capacity of irrigation system to supply the water when there is need. The changing rainfall patterns due to the climate change significantly affect the irrigation systems dependent on non-perennial sources. The main effect was seen in varying water availability in different seasons (Figure 7).

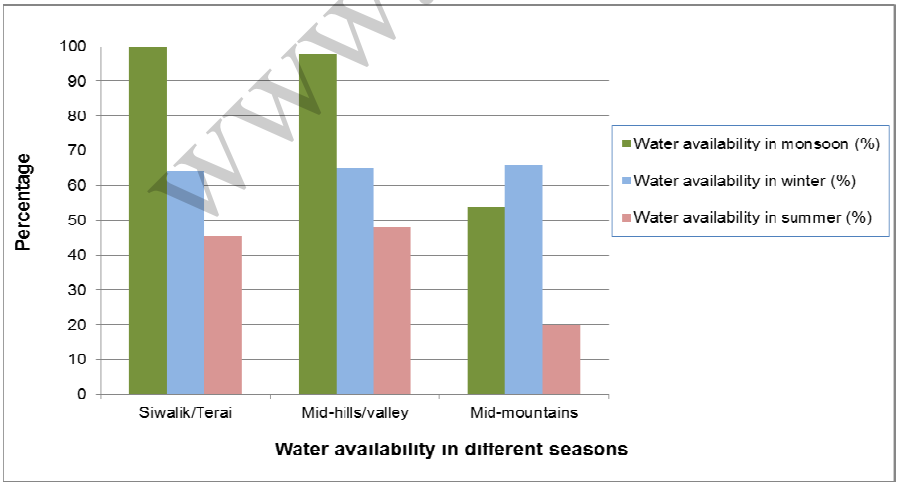


Fig. 7. Variations in water availability in different seasons

The commonly observed situation is such that farmers cannot get sufficient water in their irrigation canals at the time when they need to start the cultivation practices for the priority crop. The climate change and the variability have adversely affected the capacity of the irrigation systems to maintain the steady supply of irrigation water. Such external disturbances have increased the vulnerability of the irrigation systems. Irrigation systems are sensitive to the changes in the infrastructure and the degree of sensitiveness significantly affects their capacity to maintain robustness.

Policy changes

Another major external disturbances that the irrigation systems face is the changes in related policies at different level. Such changes affect the entities of the SES in different ways especially on the public infrastructure and public infrastructure providers. The policy changes may result in the area expansion, system rehabilitation, management change and others.

Nepal focused on expanding irrigation areas after the initiation of planned development efforts during 1950s (Shah and Singh 2000). During 1970-1985 the focus shifted from the infrastructure development to production enhancement activities. It included completion of water distribution structures of already constructed irrigation systems, rehabilitation support to FMIS and other activities related to improved agricultural technology.

Major policy shift was observed after the formulation of new irrigation policy 1992, giving the main emphasis on users' participation. The government adopted the participatory irrigation management policy with two action plans: turn-over, or more commonly known as Irrigation Management Transfer [IMT], of AMIS to the user groups, and joint management of large irrigation systems where users and government agencies share the responsibilities.

The changes in government policies have, over the period, affected the various entities. The major effect was on the irrigation infrastructure, the public infrastructure, mostly the increase in overall capacity to supply the irrigation water. Similarly, the policy changes have affected the composition of public infrastructure providers and thereby the service delivery mechanism (water allocation). Many agency-initiated systems, where the irrigation officials used to play the role of public infrastructure providers, are now handed over to the user groups. In the changed situation the resource users and the public infrastructure providers have become more or less the same. The new policy has improved the water delivery, the resources condition, and resulted into better outcome, the increase in agricultural production. The adoption of IMT resulted into strengthened the capacity of the Water Users' Association (WUA), the public infrastructure providers. The empowered WUAs became more capable in dealing with the external or internal disturbances to their system.

Overall, the policy changes seemed to have positive effects on the various entities of irrigation system and interactions among them. But in some cases it also resulted into conflict and lack of coordination between public infrastructure providers, the WUA and irrigation agencies. Similarly, the changes in policy meant that the resources users needed to cover the direct costs related to operation and management of their irrigation systems.

Market pressure

Changes in agricultural technology and markets have driven changes in water use in Nepal. Adapting to these influences is a significant challenge to individual irrigation systems. Market diversification and integration affect irrigation water management (FAO 2007). Various aspects such as, commercialization of the farming activities, seasonal migration, changing pattern of water use, contract farming, have direct effect to the water use dynamics and the characteristics of the water users.

Crop intensification, multiple cropping and increased vegetable cultivation was noted in case of many sampled irrigation systems in Nepal. A large portion of command area has been allocated for market-oriented commercial production even though meeting the subsistence need is main objective of irrigation in majority areas. Especially the vegetable cultivation requires more water in dry season when there is water shortage in general. High comparative advantage, better market and price, however, has tempted farmers to grow the commercial crops but the water shortage means possible conflict among the users. The interdependencies between market trends, demand and price, and the farming decision also play important role in water use and thereby robustness of the irrigation system.

In the recent decades, the seasonal migration of the economically active population to the regional urban centers or the capital is on rise. The result showed higher level of outmigration from Mid-hills/valley followed by from Mid-mountains and Siwalik/Terai (Figure 8). This demographic transition in the farming areas has created labor shortage. Many irrigation systems we studied reported this situation. It has two implications. First it directly affects the labor availability of the household farming activities thereby forcing people to bring the hired labor. Second, farmers cannot allocate necessary time to contribute in repair and maintenance of the irrigation system. Such changes in the characteristics of the resource users due to the market associated factors ultimately result into less collective action to manage the resource and the public infrastructure. Many others have also reported the effect in resource management due to increasing market integration (Agrawal and Yadama 1997) that often results in decreasing collective action (Araral 2009).

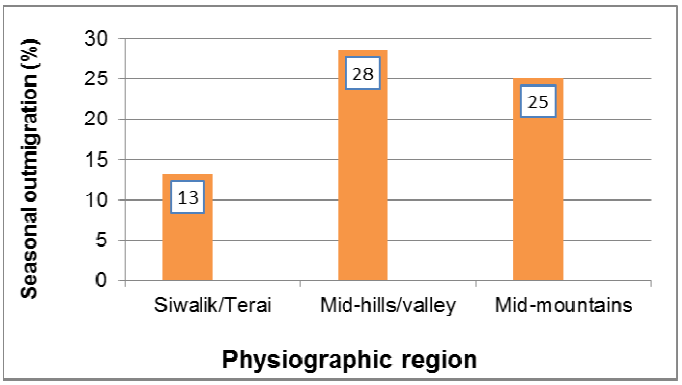


Fig. 8. Seasonal outmigration of the people from different regions

Overall, the expanding markets and trade have influenced the land-use decisions of farmers in Nepal. In many cases it has resulted in intensification of farming and introduction of new commercial crops thereby increasing per-unit return from the farmland. But at the same time the increasing demand in agriculture and other sectors has created competition for water, especially during dry season. The increased competition and shift in irrigation practices have resulted in reduced collective action for irrigation management. This ultimately has made irrigation systems more vulnerable.

Internal disturbances to the irrigation systems

Internal disturbances refer to rapid reorganization of the ecological or social system induced by the subsystems of the ecological or social system (Marty et al, 2005). We discuss here commonly observed disturbances in the irrigation systems included in this study: change in internal management, and change in users' characteristics.

Internal management change on the entities

Infrastructure providers and resource users make up human part of the framework (Figure 1). The resource users and the service providers can be same (in FMIS case study systems) or separate entities (AMIS in our analysis). The effects of management change depend on the underlying change process. The FMIS, with long history of democratic decision-making and close ties, have lesser chances to go into elite capture. Whereas the AMIS, with more involvement of outsiders, is more exposed to threat of bureaucratic trap and elites capture. However, even in case of FMIS sometimes the internal dynamics may influence the resource use pattern.

In Nepal, the leadership of Water Users' Association [the Executive Committee] is normally changed at the interval of 2 years. In the past, farmers used to select the committee mostly on the basis of consensus, in case of FMIS, often bringing more experienced and committed people in the leadership. Slowly, they have adopted voting

system for selection of leadership, mostly after political change of 1990. In general, voting system is the better system. But due to the vested interests of local politicians or local elites in some cases it has resulted into selection of not-so-competent leadership. In such cases due to the lack of proper experiences or interest to contribute such leadership are not able to bind-together the resource users and manage the operation and maintenance of the irrigation infrastructure.

Change in users' characteristics

The other humanly devised component of the analytical framework is resource users. The users are affected by and influence other three entities in the framework (Figure 1). The users have multiple roles as service providers or responsible for their selection (in FMIS) and directly affected by the decisions. On the other hand users face challenge to make decisions from available choices. With declining relative value of farming compared with other non-farm jobs and decreased per capita land availability, the users face choice of whether to remain in farming or quit it. At the same time seasonal outmigration has affected demographic composition in rural areas. It also put pressure on the time availability to contribute on collective activities. Ultimate it may affect the proper maintenance of the irrigation infrastructure.

Responses to the disturbances

It is important to understand how irrigation systems [and farmers in particular] deal with disturbances to their system; and cope with scarcity, competition and conflict situations as a result of such disturbances. The role of governance structures and institutions in mediating such disturbances and maintain the robustness of the irrigation system is the major concern. Thus in this section we discuss how irrigation systems respond to the particular disturbances.

Institutional responses

In this sub-section we assess 'How the autonomy of SES affect on robustness; are the highly autonomous systems able to respond firmly to the shocks and disturbances; if so why?' In previous sections we noted that majority of the sampled irrigation systems in Nepal were managed by farmers. And Water users' associations (WUAs) are community organizations responsible for the management of irrigation systems. The FMIS were initiated and are being managed by farmers themselves for long periods through WUAs. WUAs in FMIS have high degree of autonomy than the AMIS/JMIS. Autonomy means the freedom of water users to design rules for water allocation and to design collective choice making mechanisms. Higher the degree of autonomy of the irrigation systems, the more will be the recognition of the users' rights to organize without external interference. The result showed that highly autonomous WUAs in FMIS also satisfy the conditions as mentioned in the design principles (Ostrom 1990) that characterize robust self-governing CPR institutions. Thus the highly autonomous

FMIS those satisfy the conditions as discussed in the design principles are more robust compared to AMIS. Here, the robustness was defined on the basis of satisfying the institutional conditions and the autonomy of the WUAs. The robustness is reflected in their capacity to respond firmly to the disturbances. For example, in case of many FMIS they are capable of generating quick response from the users to fix the infrastructure in case of damage due to flash floods. It was mostly due to well-defined rules, roles and responsibilities, and most importantly well enforced monitoring mechanisms.

In many cases social capital and networks play important part. The role of local leadership is crucial in dealing with external shocks. In most of the FMIS of Nepal, the head of WUA is generally the experienced farmers, who based on his/her experience in farming and water management play important role in dealing with the problems at system level. Moreover, the WUAs of FMIS are federated at different level in Nepal. It provides them the opportunity for mutual learning and, thus, to deal with uncertainties.

Rules and allocation practices

The focus of this subsection is on to discuss 'What sorts of rules and allocation practices are in place to deal with the complexity created by the nature of public infrastructure?' In this sub-section we discuss about various kinds of rules and the enforcement mechanisms.

Operational level rules establish the operational level action and specify rights and responsibilities to the users. The operational level actions, in turn, interact with the physical attributes of the resource to produce outcomes array from sustainable use of the resource to its complete destruction. Operational rules to manage the common pool resources are grouped into seven categories (Ostrom, 2005): position, boundary, choice, aggregation, information, payoff and scope rules. We also followed the same categories for analysis. The comparison shows that the rules evolve in different ways in resources of different nature and with variation in management. If certain type of rule is present in our case study systems we denote bye 'Y' (Yes), and if absence we denote by 'N' (No) for comparison (Table 2). The list of the rules presented in the table is not the exhaustive list of all operational rules. We present only the most commonly used and known rules to the farmers.

Table 2. Comparison of operational rules across management regimes

Rules type and rules	Management regimes	
	FMIS	AMIS/JMIS/MTIS
Position Rules		
Does position of water Monitor exist?	N	Y
Boundary Rules		
Is it possible to get irrigation rights from outside community authorities?	N	-
Are water rights fixed with land and transfer together in land documents?	Y	Y

Rules type and rules	Management regimes	
	FMIS	AMIS/JMIS/MTIS
Choice (Allocation) Rules		
Is the allocation procedure fixed (fixed time slots etc)?	Y	Y
Is the sequence of irrigation fixed?	Y	Y
Aggregation Rules		
Is monitoring community's own responsibility?	Y	N
Monitors selected solely by community	Y	N
Users strictly follow mutually agreed and understood rules	Y	N
Information Rules		
Community elected members inform about input contribution	Y	N
Is record maintained for labor contribution?	Y	N
Pay off Rules		
Does the punishment always start with monetary penalties?	N	N
Are the decisions for infraction and conflicts decided outside community?	N	Y
Is the proposed punishment implemented by outside community agencies?	N	Y
Scope rules		
Are the crops cultivated as mentioned in irrigation rights documents?	Y	N

Results showed that in most of the studied systems in all physiographic regions, the operational rules are formed by the community (Figure 9). In Nepal, the WUAs in FMIS have greater autonomy to make and enforce the rules. In FMIS users can devise rules based on their interest and necessity, and manage rules themselves. The experienced committee members in FMIS formulate rules based on interest and necessity of the users. But in AMIS/JMIS agency involvement in drafting rules is high.

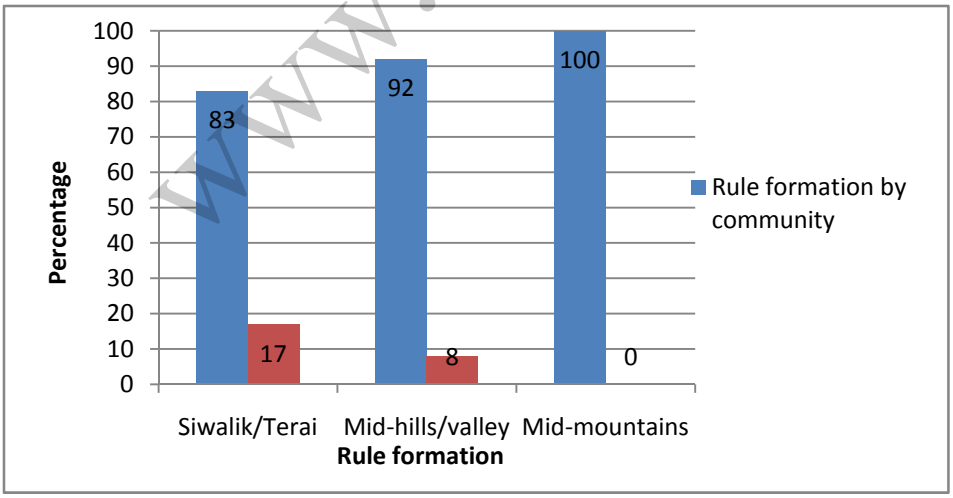


Fig.9. Involvement of community and external agencies in rule formation

Regarding monitoring and sanctioning arrangement, majority of the systems in all physiographic region reported the chance of detection of rule breaking and then imposing the penalty in such cases (Figure 10). The FMIS are far better than AMIS/JMIS in monitoring and sanctioning arrangements as well. The rule enforcement mechanisms are well institutionalized in case of FMIS. In addition, in FMIS a majority of the users follow the rules whereas in AMIS/JMIS substantial levels of violations were found in more than half of the irrigation systems. The higher the proportion of rule violators and higher level of violations, the greater is the chance of less collective action. Ultimately it affects the smooth operation and management of irrigation systems and their capacity to deal with disturbances.

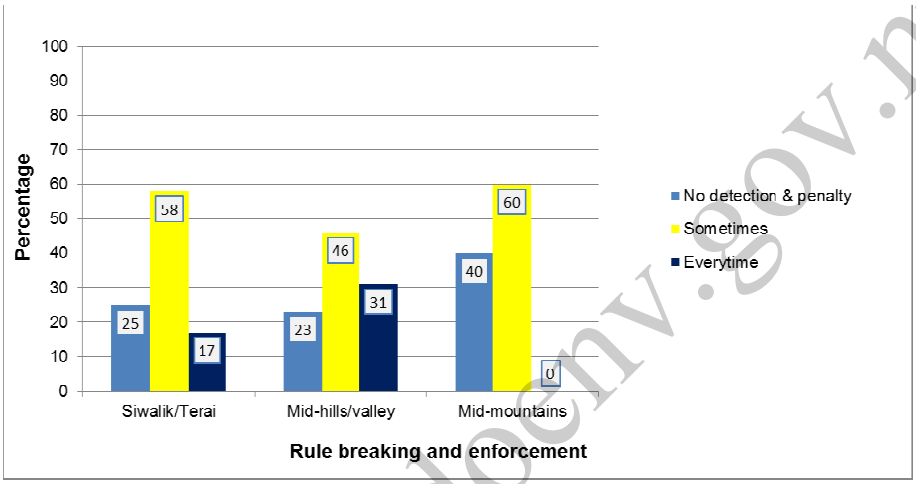


Fig. 10. Rule breaking and enforcement situation in sampled irrigation systems across different physiographic regions

Discussion

The analysis of external and internal disturbances, and the responses in the changes circumstances provided the interesting facts on changes in the characteristics of resource and public structure, changes in different aspects of resource users and the role of public infrastructure providers. In this section we analyze the linkages and interactions among various entities of the irrigation system, as a social ecological system. The changed role of resource users and public infrastructure providers (human components of the Anderies et al, 2004 framework) resulted in the form of variation in operational-level rules and variation in interventions in the form of structural improvements of systems. The interactions among the entities of the core subsystems of SES (Table 3) provides the hints on difference in robustness due to variation in capacity to cope challenges associated with these systems. The inherent uncertainty in these systems has been a major threat and will be further aggravated due to climate change

and preparedness of systems under two different management regimes with variation in resource uncertainty.

Table 3.Entities of irrigated social ecological system and linkages among entities

Entities/linkages	Major threats to irrigation systems	Issues related to:	
		AMIS/JMIS/MTIS	FMIS
Resource	Rainfall patterns; floods intensity and frequency	Low reliability and uncertainty in availability of the water	Less reliable water availability in some situation but flexible rules to allocate
Resource users	Outside interference in rules	Users have limited role in rule formation	High autonomy in forming rule based on the need
Public Infrastructure	Insufficient infrastructure to distribute water	Infrastructure do not match with traditional systems that were prevalent in the area; costly to replace when damage	Simple and flexible structure using locally available materials, easy to re-build in case of damage
Public Infrastructure Providers	Insufficient capacity to operate the infrastructure in change situation	Agency officials lack clear understanding of local situation and local need	Same people as resource users and so have better knowledge to operate the canal infrastructure
Between resource and resource users	Changing rainfall patterns, variation in available water and changing use pattern	Not enough attention and capacity to deal with the shocks and changing demand	Fast and collective response capacity, alternate to deal with demand
Between resource users and public infrastructure providers	Declining deliberation process and weak monitoring	Low resource contribution for O&M, poor condition, free-riding, poor monitoring	Competition due to market pressure, reduced collective action
Between public infrastructure providers and public infrastructure	Fixation of rules, social capital and new infrastructural challenges	Infrastructure and allocation mechanism decided on top-down approach	Change in management, and transfer the responsibility of O&M of the systems
Between public infrastructure and resource	High failure rates of structures and unpredictable resource availability	Infrastructure not fit to biophysical context, Ineffective due to lack of maintenance	Labor shortages for contributing in O&M
Between public infrastructure and resource dynamics	Ground water pumping, head-tail end issues	Use of groundwater and in some cases overexploitation	Sometimes tension between head-end tail-end users, but does not become severe
Between resource users and public	Conflicts, free riding issues	No-incentive to maintain the infrastructure, free-	Good conflict resolution arena, local institutions

Entities/linkages	Major threats to irrigation systems	Issues related to:	
		AMIS/JMIS/MTIS	FMIS
infrastructure		riding	manage the conflict, if any
External forces on resource and infrastructure	Flash floods, delayed monsoon	Increasing frequency of floods with uncertain strength damage infrastructure	Flash floods, but the users provide quick response to fix it
External forces on resource users	Preference for non-farm jobs due to economic integration.	Outmigration, labor scarcity	Trend of seasonal outmigration, but still maintaining systems mainly for subsistence oriented farming

External disturbances most often affected the public infrastructure and resource characteristics directly affecting the water availability. At the same time the interventions by public infrastructure providers' in the form of changed rules at constitutional choice level have impacted operational level rules through changed role of actors at collective choice arenas mostly in AMIS. In such situation resource users in case of AMIS/JMIS, were not willing to contribute in maintaining the resource systems mainly due to the inflexible rules. The lack of maintenance further aggravated the capacity of infrastructure to cope the damage by floods. The FMIS, on the other hand, also faced the external disturbances but the flexible rules and better monitoring mechanism help keep the functioning intact by providing fast collective response.

Similarly, as a result of market forces there was competing resource use and increased demand for the water resulting into conflict in many cases. It resulted into reduced collective action in case of FMIS also. But the FMIS has shown the robustness to adjust with the effects of external factors. The flexible rules, autonomous WUAs and local institutions provided the capacity to self-govern and maintain the robustness of their irrigation systems.

The repeated experience of the irrigation systems to deal with particular disturbances enhances their adaptive capacity in the long-run. The adaptive learning could ultimately help develop long-term robustness of the system.

Conclusion

Natural events as a result of climatic variability and change, policy changes and market pressure are the major external disturbances affecting core entities of the framework at varying degree. Among these disturbances, the natural events seem to have universally negative affects due to its uncertain nature. The vulnerability of the irrigation systems to those disturbances also depends on the sensitiveness to small changes in infrastructure and biophysical context.

The policy changes, on the other hand, have both positive and negative effects. The policy change brought realizing the experiences at community level and devised considering customary rights and local institutions have positive outcomes in the form of strengthened public infrastructure and the providers. The negative affects of policy changes are felt from rules violation, worsening resource condition including inefficient use and conflicts among users.

The market pressure have multidimensional effects in the form of tendency to use more water by some at the cost of others and also in the inter-sectoral competition causing shift in manpower from agriculture to other employment and investment opportunities. The internal disturbances in the form of management changes of WUAs affected the irrigation systems in different ways. External interference was always dominant in AMIS and thereby affecting the public infrastructure providers. In some cases FMIS also fell into the trap of local selfish politicians and local elites who often wanted to use the CPR in their personal or group benefits. Seasonal outmigration of the people also affected the collective action.

Irrigation systems dealt with external disturbances in various ways. Governance structure and local institutions were found crucial in deal with the disturbances. Mostly, highly autonomous FMIS were able to adjust with the changing situation. High autonomy provided them the opportunity to adjust their institutional conditions according as the changed context. It in turn enhanced their adaptive capacity making them capable of generating rapid response to the external shocks and maintain the robustness of their system. Existence of various forms of rule and better compliance by the users was another important aspect in FMIS. But in AMIS rule formation was mainly done by the agencies being it ineffective in implementation. But in many FMIS the centuries old local rules prevailed and new rules were also formed based on the community needs. The irrigation systems showed their robustness in the form of diversity of rules to different situations, stronger institution of local leaders, and adoption of coping strategies to match with uncertainty in irrigation.

Acknowledgement

We acknowledge the financial assistance by the NSF grant provided to IWMI-Nepal through CSID-ASU.

References

Agrawal, A. and N.Y. Gautam.1997. How do local institutions Mediate Market and Population Pressures on Resources? Forest Panchayats in Kumaon, India. Development and Change, 28 (3), 435-465.

Anderies, J.M., M.A. Janssen, and E.Ostrom. 2004. A framework to analyze the robustness of social-ecological systems from an institutional perspective. Ecology and Society, 9(1): online: http://www.ecologyandsociety.org/vol9/iss1/

Araral, E. 2009. What explains collective action in the commons? Theory and evidence from the Phillippines. World Development 37:687-697.

Barker, R.and F.Molle. 2005. Perspectives on Asian Irrigation. In G.P. Shivakoti, D. Vermillion, W.F. Lam, E. Ostrom, U. Pradhan, and R. Yoder, eds. Asian Irrigation in Transition: responding to the Challenges. New Delhi: Sage Publications. pp 45-78

Bastakoti R.C., G.P Shivakoti & L. Lebel. 2010 Local irrigation management institutions mediate changes driven by external policy and market pressures in Nepal and Thailand. Environmental Management, 46:411–423.

Bastakoti, R.C. and G.P. Shivakoti. 2012. Rules and collective actions: An institutional analysis of irrigation systems in Nepal. Journal of Institutional Economics, 8 (2): 225-246.

Lam, W.F. 1998. Governing Irrigation Systems in Nepal: Institutions, Infrastructures, and Collective Action, Oakland, CA: ICS Press.

Lam, W.F. 2001. Coping with change: A study of local irrigation institutions in Taiwan. World Development, 29(9):1569 – 1592.

Ostrom, E. 2009. A general framework for analyzing sustainability of social-ecological systems.Science.Vol. 325.

Ostrom, E. and T.K. Ahn. 2003.Foundations of Social Capital.Cheltenham. U.K.

Ostrom, E., R. Gardner and J. Walker. 1994. Rules, Games, and Common Pool- Resources.The University of Michigun Press.

Ostrom, E. 1990. Governing the Commons: The Evolution of Institutions for Collective Action: Cambridge University Press.

Scheffer, M., S. Carpenter, J.A. Foley, C. Folke and B. Walker. 2001. Catastrophic shifts in ecosystems. Nature, 413:591–596, 2001.

Shivakoti, G.P. and R.C. Bastakoti. 2006. The robustness of Montane irrigation systems of Thailand in a dynamic human-water resources interface. Journal of Institutional Economics, 2: 227-247

Shivakoti, G.P., D. Vermillion, W. F. Lam, E. Ostrom, U. Pradhan and R. Yoder, eds. Asian Irrigation in Transition: responding to the Challenges. New Delhi: Sage Publications. pp 45-78.

❑

Effect of Insect Pollination on Buckwheat Production in Chitwan, Nepal

Suroj Pokhrel[1] and Resham B. Thapa[2]

Abstract

A study was made to access the present status of research and development on buckwheat pollination in Nepal in 2012. The result finding showed that the impact of natural pollination and hand pollination on grain yield, seed number and the seed viability of buckwheat were significantly higher over the control in Chitwan Nepal. The mean seed formation/inflorescence were highest (7.44) in natural pollination followed by hand pollination (6.10) and the control (2.78). Several dozens of insect pollinators from different texon has been reported. However, declining their population is an alarming threat for pollination services. Developing pollination management policy, plan, program, conducting basic and participatory research on pollination deficits/needs buckwheat, promotion of pollination friendly practices and conservation of the natural pollinators is urgent for promoting an essential ecosystem services for buckwheat pollination in Nepal.

Keywords: *buckwheat, ecosystem, pollination, pollinators*

Introduction

Pollination is the transfer of pollen from the male parts of the flower (the anther) to the female part (stigma) of the same or a different flower of the same plant or the different plants (Pokhrel, 2009). Not all flowering plants have the same pollination requirements. Cross-pollination is the transfer of pollen from flowers of one plant to the flowers of a different plant or different variety. Many crops require or benefit from cross-pollination. Self-fertile plants can develop seeds and fruit when pollen is transferred from anthers of a flower to the stigma of the same flower or different flower on the same plant. However, such plants are not necessarily self-pollinating. Insects still may be necessary or helpful in moving pollen to the stigmas. Inter planting of varieties is not necessary but may be helpful; for example, many self-fertile crops respond well to cross-pollination. Self-sterile plants require pollen from a different plant or even a different variety. If the plant requires different varieties, the grower must interplant pollenizer varieties with the main variety. *Cross-compatible* varieties are receptive to each other's pollen, whereas *cross- incompatible* varieties are not. Sometimes, a flower has only male or female parts. An example of this is most squashes and melons. Monoecious plants have both male and female flowers on the same plant. Dioecious plants have only one sex of flower on the same plant (Pokhrel, 2009 and Thapa *et.al*, 2008). Having separate male and female flowers makes cross-pollination obligatory. There are several

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means of pollination eg insects, birds, animals, wind, water and gravity. Insect especially the honeybees and solitary bees are the most efficient and dominating natural pollinators of the mountain crops providing the pollination services. Honeybees have the special appendages eg worker bees help to carry and transfer the pollen from flower to flower (Pokhrel, 2005).

They have special proboscis and crop to suck and store the nectar, strong mandible to scrap the anther, pollen collecting brush and pollen press hold on inner surface of basitursus in hind legs, pollen basket (corbicula) hold on the outer surface of hind tibia, antennae cleaner hold with 1st pair, pollen rake hold at the end of hind tibia, body hairs presence all over the body for pollen collection. They can easily identify the time of pollen dehiscence and nectar production. Solitary bees are also important pollinators of buckwheat. They are well adopted their life cycle with buckwheat flowering. Adult bees die and young one goes in to diapauses' until next flowering. Some of the crop plants need specific insect pollinators in a particular time like hawk moth on papaya, snout beetle on palm tree, blow fly on mango and solitary bee on buckwheat, etc (Pokhrel, 2009 and Thapa *et.al*, 2008). However, degradation of environment is curving the pollinator's population, declining the pollination services in agro ecosystem in Nepal due to manmade causes. Agro-ecosystem is rapidly threatening the pollination ecology due to destruction of pollinator's habitat both in farm and forest areas. Several pollinators species are pushed in the verge of extinction due to miss management, honey hunting, increasing slash-burn agro-system, conversion of forests and natural vegetation to human use, grazing, grass-cutting, over exploitation of resource, deforestation, fire, soil erosion and nutrient loss, exploitation of natural resources due to poverty and food insecurity, use of agro-chemicals, declining agro biodiversity, climate change effects are the alarming threats on pollination services (Pokhrel, 2009 and Thapa *et.al*, 2008). Farmers are almost ignoring pollination management of their crops because of which, the diversity and population of crop pollinators is decreasing resulting failure in pollination, low production and productivity. Insect pollinators are decreasing and hand pollination is costlier. There is absence of National policy on Conservation and Management of Pollinators for Sustainable Agriculture, in Nepal. However, there are several policies declared they support it through an Ecosystem Approach.

Pollinators provide an essential ecosystem service for production of seeds or fruit and diversity maintenance. There is an unequal pollination need of different crop plants eg cross-pollinating plants, self-fertile plants, self-sterile plants, cross-compatible varieties, monoecious, dioecious etc. Properly pollinated seeds hold larger seed vigor, longer viability, pose higher germination capacity, seedling vigor, pest resistance, and yielding capacity. Devkota (2000) concluded that pollination could significantly improve in both yield and the quality of seed in cross pollinating crops under Chitwan condition.

Sihag, 2000 reported a unique method of accessing the pollinators population required per unit area is given below:

Nos. pollinators required (N)=d/PE X Y/T x a

Example-1: Honeybee colonies needed for buckwheat pollination

$$N = \frac{\text{Floral longevity /receptivity}}{\text{Pollinating efficiency}} \times \frac{\text{Average floral density}}{\text{Avg. foraging duration}} \times \text{Cropped area}$$

$$= \frac{28\text{days}}{12\text{ flowers/min}} \times \frac{40000\text{ flowers/m}^2}{6\text{ hours/day}} \times 1\text{ ha} = \frac{1120000}{72} = 14755\text{ foragers/ha}$$

ie. each strong honeybee colony consists around 20000 workers with 25% foragers ie 5000 /colony.

So, $N = \frac{14755}{5000} = 2.9$ colonies (2-3 colonies recommended/ha)

The number can be reduced from calculating the intra species and inter species competition.

Methodology

Intensive review of the publications, journals, thesis, books and web materials was carried on pollination research and development in Nepal in 2012. The research findings relevant to Nepalese context in Nepal and across the world were collected from different secondary sources. Tables, figures, findings were systematically reorganize to prepare the paper.

Result and discussion

Present status problems and challenges of pollinators

Farmers are almost ignoring pollination management of their crops. Diversity and population of crop pollinators is decreasing resulting failure in pollination, low production and productivity. Destroying the habitat (bund & ridge destruction, firing, destruction of natural and semi natural vegetation, deforestation, etc.) and shortage of food because of decline in crop diversity (crop and variety-monoculture) with synchronize planting resulted lower pollinators population. Hand pollination is costlier, tedious and not effective as insect pollinators. Use of chemical fertilizers and pesticides is hampering on natural pollinators. Climate change effects (low temperature, rainfall, hailstorm, frost during the flowering time hampers pollination). Bee poisonings occur when bees visit flowers treated with insecticides. This exposure is much more hazardous than pesticide spray that lands on a bee hive or nest. It is a concern because of high mortality of foraging pollinators, more severe sub-lethal effects with impacts on homing behavior. Pesticides can repel pollinators from crops. Some time these pollinators may have exposure to nonagricultural pesticides too (Pokhrel, 2009).

Field experimentation on pollination need on buckwheat

Buckwheat (*Fagopyrum esculentum* Moench) is a well known important food crop of the high mountain. It is also widely cultivated on marginal farmlands even down in the low hill agro-ecozone. This crop prefers a moist climate, blossoms during August-September (Pratap, 1997) in mountain and December-February in Terai. The productivity of buckwheat crop is 600 to 800 kg/ha and is in decline trend in Nepal (Rajbhandari and Hatley, 1991/92). Different research activities were performed in intensive (Sukranagar, Mangalpur) and semi-intensive (Meghauli) VDCs Chitwan to access the pollination need of buckwheat in 2007.

Thapa *et.al*, 2008 found higher plant population of buckwheat in intensively cultivated areas (98.5 vs 92.0 plants/m^2). Lower the plant population higher was the number of branches/plant, number of inflorescence/branch and flower numbers/plant. The inflorescence/plant was found 9.19% higher in semi-intensive areas than in intensive areas. The average flower number was found higher in semi-intensive areas (39700 vs 35043.5 flowers/plant) than in intensive areas. Higher number of flowers/plant was also found in the areas proximity to natural vegetation in Parsadhap of semi-intensive sites (40050 vs. 393350 flowers/plant) than in Shajapur. It was higher in Mangalpur of intensive sites (36780 vs 33307 flowers/plant) than in Sukranagar. The experiment showed that the mean plant population of buckwheat in Chitwan was 95.25 plants/m^2, the mean inflorescence was 14.86 /plant and the floral number was 37371.75/m2.

The mean seed weight per plant per ten flowers was 200% higher in open pollination and 150% higher in hand pollination than the control. Where, the number was higher by 167.6% and 119.4% in open and hand pollinated plants (Pokhrel, 2009 and Thapa *et.al*, 2008) (Table 1, Fig. 1).

Table 1: Effect of different pollination practices on Buckwheat yield, Chitwan, 2007

Sites	Closed pollinated		Hand pollinated		Open pollinated	
	Seeds/ Inflorescence (Nos)	Seed weight (gms)	Seeds/ Inflorescence (Nos)	Seed weight (gms)	Seeds/ Inflorescence (Nos)	Seed weight (gms)
Semi intensive						
Parsadhap	2.44	0.038	6.20	0.103	9.00	0.149
Sajhapur	2.84	0.048	6.68	0.113	6.88	0.110
Mean	**2.64**	**0.04**	**6.44**	**0.10**	**7.94**	**0.12**
Intensive						
Mangalpur	3.72	0.056	6.48	0.103	8.2	0.134
Sukranagar	2.12	0.031	5.04	0.079	5.68	0.103
Mean	**2.92**	**0.04**	**5.76**	**0.09**	**6.94**	**0.11**
Grand Mean	**2.78**	**0.04**	**6.10**	**0.10**	**7.44**	**0.12**

The difference on buckwheat yield from each ten flower per plant in semi intensive and intensive areas of Chitwan was found non-significant. However, the seed number and seed weight both were found highest in case of open pollinated plants by 200.75% and 200.00% respectively and was higher by 158.33% and 150.00% in case of hand pollinated plants than the control (Table 1, Fig. 2).

Among two different semi-intensive locations the yield was found higher (by 30.00% seed number and 35.45% seed weight) in Parsadhap than in Sajhapur. Where, the yield difference between the locations in both hand pollinated and control was found non-significant. Similar to the semi-intensive areas the yield from each inflorescence in the intensive areas of Chitwan was found highest (by 137.7% seed number and 175.00% seed weight) in case of open pollinated flowers followed by hand pollinated (by 97.30% seed number and 125.00% seed weight) than the control. Among two different locations in the intensive buckwheat areas the yield was significantly higher in Mangalpur than in Sukranagar. The yield from the open pollinated flowers was higher by 44.40% seed number and 30.10% seed weight in Mangalpur.

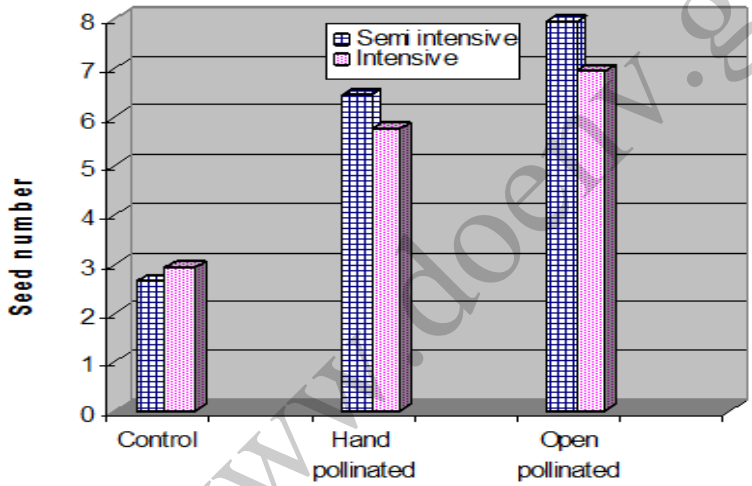

Fig. 1: Effect of pollination on buckwheat seed formation, Chitwan

Among the locations of the experiments in both the semi-intensive and intensive side the yield differences was found non-significant in case of control and hand pollinated flowers where it was significantly higher in Mangalpur than Sukranagar in intensive areas and higher in Parsadhap than in Sajhapur in the semi-intensive areas in case of open pollinated flowers. The reasons behind was because of the proximity of the natural vegetation (Forest), thereafter facilitating the natural pollination through the insect pollinators.

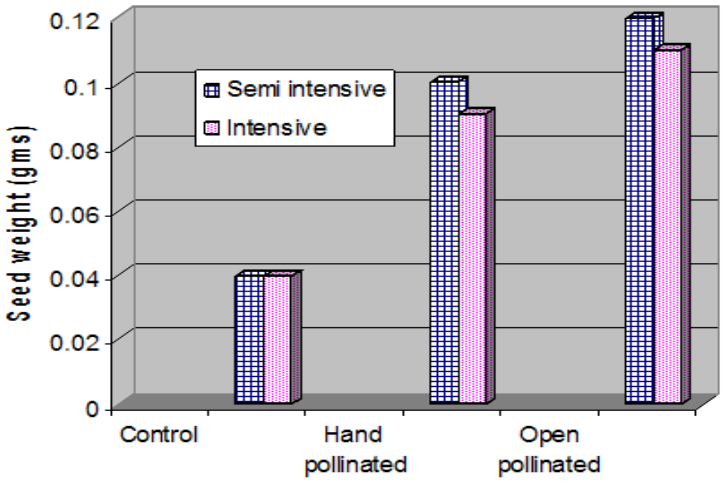

Fig. 2: Effect of pollination on buckwheat seed weight, Chitwan

The most frequently visiting pollinators in both the semi-intensive and intensive areas of buckwheat cultivation were the honeybees. Among the honeybees, *Apis dorsata* Fab. (10.18 bees per minute) was the most efficient pollinators followed by *A. mellifera* Lin. (9.90 per minute). There mobility was higher in semi-intensive areas than in intensive areas. It showed that the numbers of pollinators are in deficit in the intensive areas because of larger cultivated areas with low number of honeybees' colonies. Bee's mobility started from early in the morning and reached 10.52 bees per minute per square meter in between 7.0 to 8.0 AM. It was reached in climax in between 8.0 to 11.0 AM (11.26 bees/ minute) and declined at the noon (7.86 bees/ minute). It was completely ceased by 4.0 PM.

Apis dorsata, the wild honeybee was the most dominating insect pollinators; most frequently visiting buckwheat flowers in both locations of semi-intensive sites in Chitwan followed by *A. mellifera* the domestic imported honeybees. The mean number of bees (*A. dorsata* and *A. mellifera*) visiting buckwheat flower per minute was 12.5 vs. 12.15 in Parsadhap followed by 79.6 vs 74.6 in Sajhapur. Hence, higher the numbers of honeybees' visitors higher was the production of seed number and seed weight. Parsadhap is nearer to natural forest providing better nesting sites for *A. dorsata* in the winter. Moreover, the land in the Sajhapur areas is comparatively lowland having continuous cropping of rice and buckwheat, resulting low productivity than in Parsadhap (Fig. 3).

Similar to the semi-intensive areas, the most efficient insect pollinators found in the intensive areas of buckwheat was *A. dorsata* followed by *A. mellifera*. The mean number of these bees visiting buckwheat flowers/minute in two different locations was found higher in Mangalpur than in Sukranagar (105 vs. 75.2 *A. dorsata* and 103 vs 73.4 *A. melliera*). Hence, higher the number of insect pollinators visiting Buckwheat flowers

higher was the buckwheat yield (both number of seeds and seeds weight). It was also due to the proximity of natural vegetations, supporting for the nesting site for *A. dorsata* and higher number of. *A. mellifera* colonies migrated on the vicinity.

The foraging duration of *A. dorsata* was found longer than *A. mellifera*. Hence, more than nine *A. dorsata* bees per minute were found foraging even after 4.00 PM in different intensive and semi-intensive areas. Where, the number of *A. mellifera* at the same time period was found less than eight bees per minute. The total bees visited in semi-intensive areas at different hours of a day was found higher (20.9 bees/minute) than in intensive areas (19.81 bees/ minute) providing higher buckwheat yield in semi intensive areas in terms of seed number and weight than in intensive areas.

The difference on the mean number of flowers visited by *A. mellifera* and *A. dorsata* was non-significant. However, the numbers of flowers visited were higher at the morning and decreasing from noon onwards and ceased at the evening. The number of flowers visited by honeybees was found higher in the semi-intensive than in intensive areas (*A. dorsata* 10.73 vs. 10.2 and *A. mellifera* 10.2.1 vs. 11.26 flowers/bee/min). The number of pollen deposited on the stigma of buckwheat flowers by *A. dorsata* was higher in semi-intensive areas (31.00 vs 28.10/stigma) by *A. mellifera* in intensive areas (36.7 vs. 28.00/stigma).

The rate of pollen deposition per stigma by *A.dorsata* was found higher in semi-intensive areas compared to intensive areas. The rate was higher in Parsadhap than in Sajhapur (31.0 vs 28.4 pollen/stigma). The reason behind might be better nesting sites for *A. dorsata* in the vicinity of Parsadhap than in Sajhapur because However, the pollen deposited by *A. mellifera* was found higher in Sajhapur than in Parsadhap. Sajhapur is major pocket for in migration of *A. mellifera* colonies on buckwheat pasture during late winter for the east and west Chitwan beekeepers. Hence, the mean pollen deposited by both the honeybees' species was higher in Parsadhap than in Sajhapur. The plant vigor, number of branches per plant, number of inflorescence per branch and the flower number per inflorescence were found higher in Parsadhap than in Sajhapur. It was because of continued buckwheat cultivation in the low land of Sajhapur for more than ten years resulting low productivity and production (Fig. 4 & 5).

The mean pollen depositions by the insect pollinators in the intensive areas were comparatively lower than in semi-intensive areas (302.97 vs. 296.28). It might be due to need of higher number of insect pollinators for the large pockets of insect pollination demanded crops. The rate of pollen deposition by *A. mellifera* honeybees was higher than that of *A. dorsata* (304.95 vs. 284.27). The mean pollen deposited by these pollinators was higher in Mangalpur than in Sukranagar (358.9 vs. 213.65). Sukranagar is growing as a commercial pocket for vegetables with higher rate of pesticide use. In the other hand, Sukranagar is a major pasture site for honeybees on a wild flora Gumpate, *Leucas lanata* Benth attracting honeybees for its sweet nectar. The rate of

pollen deposition by *A. mellifera* was higher in both the locations compared to *A. dorsata*. The number of *A. mellifera* colonies is dramatically increasing in both the areas with increasing trend of colonies' migration (Fig. 4 & 5).

The pollen deposited per stigma was highest in case of hand pollinated flowers (58.25 vs. 29.55 *A. dorsata* and 32.35 *A. mellifera*) than that of insect pollinated. However, the yield was found highest in case of insect pollinated plants. The reason could be because of physical injury of pollen grains, appropriate time of pollen reception, pollen maturity and unhealthy pollens etc. Negligible pollen grains were counted from the stigma of pollination blocked flowers, which could be due to difficulty in complete removal of anthers, wind blowing during the trial set up and other errors in the open field condition. However, the numbers of pollen deposited on the stigma from the insect pollinators were higher in Parsadhap than in Sajhapur. Higher the number of pollen deposited by insect pollinators higher was the grain yield (number and weight). The mean number of pollen deposited by insect pollinators by *A. dorsata* was found higher in both Parsadhap and Sajhapur than *A. mellifera*. It was because of the proximity of natural vegetation, and tall trees in the nesting sites of *A. dorsata*. However, several *A. mellifera* are seasonally migrated from east chitwan Bharatpur and other district in Meghauli too (Fig. 4 & 5).

The number of pollen deposited on stigma in the intensive areas of buckwheat cultivation in Chitwan was found higher in Mangalpur (*A. dorsata* 28.1 vs 26.3 and *A. mellifera* 36.7 vs. 32.6/stigma) than in Sukranagar. Efficiency of pollen deposition by *A. mellifera* was higer in both the locations than that of *A. dorsata*. It is because of the on field sitting of the *A. mellifera* colonies and distance foraging of *A. dorsata* from distance nesting sites.

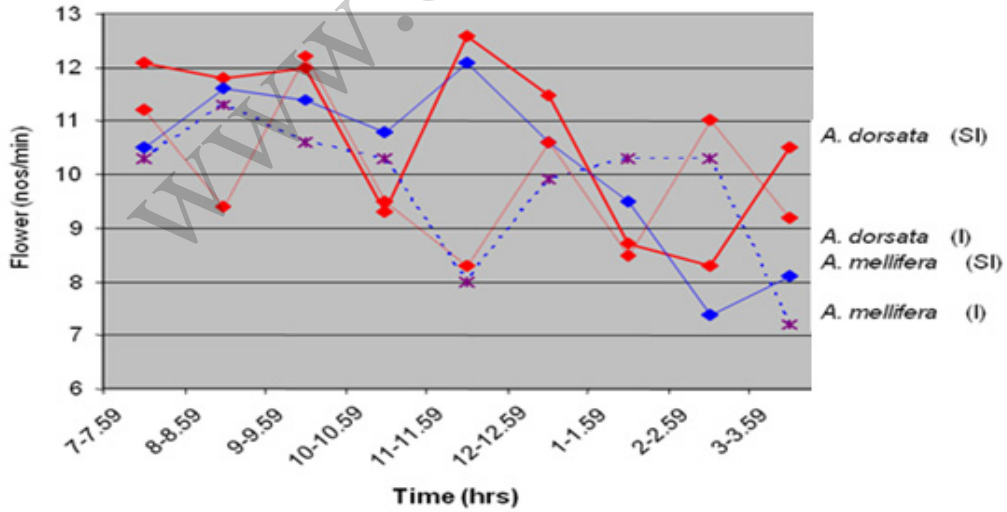

Fig. 3: Buckwheat flowers visited by the insect pollinators

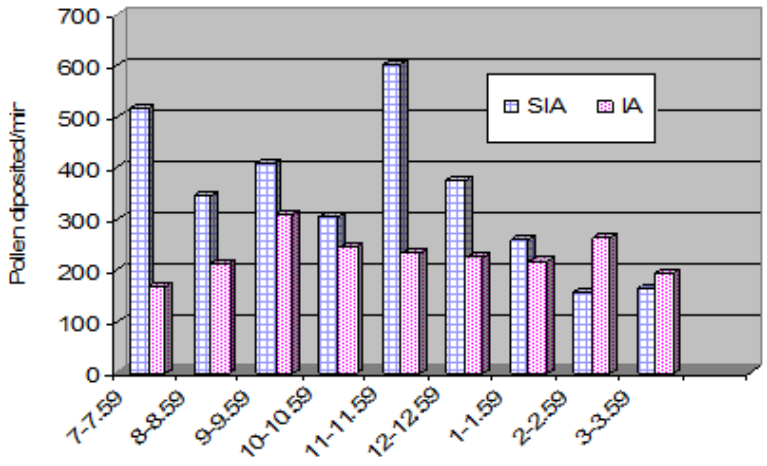

Fig. 4: Buckwheat pollen (Nos) deposited by *A. dorsata*,Chitwan, 2007

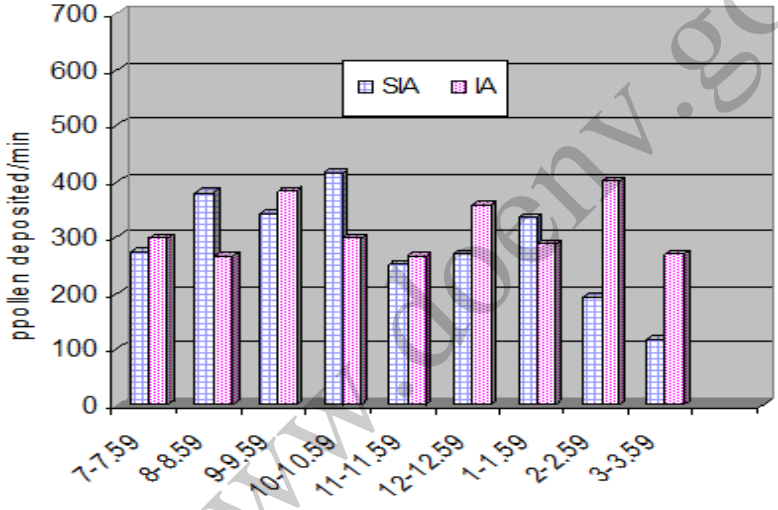

Fig. 5: Buckwheat pollen (Nos) deposited by *A. mellifera*,Chitwan, 2007

There were several other insect pollinators found in the intensive and semi-intensive areas. Thus the actual requirement may be greatly reduced; however the availability of the insect pollinators is far behind than floral requirements (Table 2 &3, Fig. 6).

Table 2: Insect visitors on buckwheat flowers, Chitwan, 2006/2007

S.N.	Common name	Scientific name	Family	Order
1	European honeybee	*Apis mellifera* Lin.	Apindae	Hymenoptera
2	Asiatic honeybee	*Apis cerana* Fab.	Apidae	Hymenoptera
3	Rock bee	*Apis dorsata* Fab.	Apidae	Hymenoptera

S.N.	Common name	Scientific name	Family	Order
4	Little bee	*Apis florea* Fab.	Apidae	Hymenoptera
5	Syrphid fly	*Syrphus* sp.	Syrphidae	Diptera
6	Tabanid fly	*Tabanus* spp.	Tabanidae	Diptera
7	Marsh fly	*Bibilio* sp.	Babilionidae	Diptera
8	Rice skipper	*Pelopidas mathias* (F.)	Hesperidae	Lepidoptera
9	Lady beetle	*Coccinella* spp.	Coccinellidae	Coleoptera
10	Carpenter bee	*Xylocopa* sp.		Hymenoptera
11	Legume pod bug	*Riptorus lineralis* Fab.		Hemiptera
12	Mud wasp	Synoeca spp.	Sphecidae	Hymenoptera
13	Cabbage butterfly	*Pieris brassicae* Lin.,	Pieridae	Lepidoptera
14	Cabbage butterfly	*P. canidia Lin.*	Pieridae	Lepidoptera
15	Legume pod borer	*Lampides boeticus* Lin.	Lychinidae	Lepidoptera
16	Castor butterfly	*Ergolis merione* Cram.	Nymphalidae	Lepidoptera
17	Housefly	*Musca sp.*	Muscidae	Diptera
18	Oriental wasp	*Vespa orientalis* (Lin.)	Vespidae	Hymenoptera
19	Yellow banded wasp	Campeomeri spp.	Campeomeridae	Hymenoptera
20	Ichneumonid wasp	*Ichneumonus* sp.	Ichneumonidae	Hymenoptera
21	Green bug	*Nezara viridula* Lin.	Pentatomidae	Hemiptera
22	Yellow butterfly	*Therias* sp.	Pieridae	Lepidoptera

Table 3: Family wise list of insect visitors on Buckwheat flowers

S.N.	Family	Nos	S.N.	Family	Nos
1	Apinae	3	9	Lychinidae	1
2	Pieridae	3	10	Muscidae	1
3	Un identified	2	11	Nymphalidae	1
4	Babilionidae	1	12	Pentatomidae	1
5	Campeomeridae	1	13	Sphecidae	1
6	Coccinellidae	1	14	Syrphidae	1
7	Hesperidae	1	15	Tabanidae	1
8	Ichneumonidae	1	16	Vespidae	1
				Total	24

The most efficient insect pollinator was *A. dorsata* followed by *A. mellifera* in all sites and locations. However, Dragon fly, Syrphid fly, March fly, Lady bird beetle, Wasps and Butterflies were other visitors frequently visiting the buckwheat flowers in both intensive and semi intensive areas.

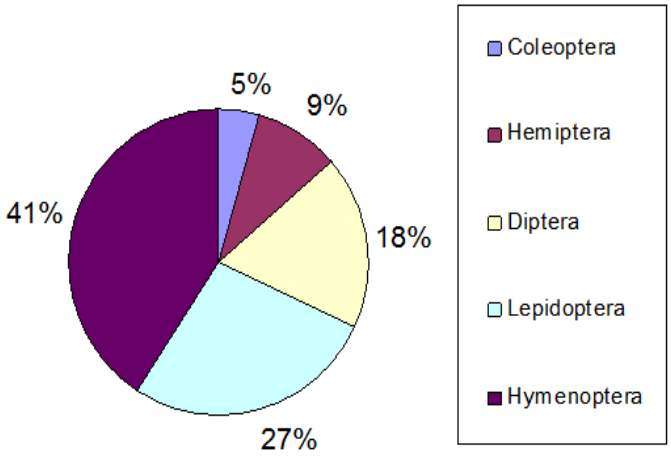

Fig. 6: The order of insect pollinators on buckwheat, Chitwan, 2007

The number of insect visitors was higher in semi-intensive areas in different time of a day than in intensive one. The number of total visitors in different day time was higher in Parsadhap than in Sajhapur (166 vs 160/10 min). However, it was opposite in case of 2nd and 3rd visitors (63 vs 64 2nd and 52 vs 56 3rd visitors).

The first visiting pollinator in Mangalpur was higher (115 vs 113 1st) than in Sukranagar. However, it was opposite in case of 2nd visitor (43 vs 56 visits). However the 3rd visitors in Mangalpur were negligible (Pokhrel, 2009 and Thapa *et.al*, 2008).

Conclusion and recommendation

It is suggested to conduct basic and participatory research on pollination deficits/needs of crop plants and socio-economic value of pollination. Developing standard methodologies and tools for pollinator sampling/monitoring and identification, developing conservation packages of good pollination management practices, establishing the Pollination Interaction Database for developing decision-support system, carry out agro-ecosystem based pollination management surveys and develop GIS maps / site and target land area are also equally important. Promotion of beekeeping, prevent honey hunting, promote beekeeping primarily for crop pollination and production of hive products, adopt migratory beekeeping, initiate hiring *Apis* colonies for crop pollination can increase the pollination services. Beekeeping policy for the conservation of wild honeybees, promotion of Asian hive bees and selection, propagation and commercialization of supersedure *A. mellifera* is suggested. Packaging and promotion of pollinator-friendly best management practices, suitable crop/variety selection and better crop management for best attraction of the pollinators eg soil nutrients and water management, judicious use of agro-chemicals, i.e. fertilizer,

pesticide, and management of industrial and agriculture wastes, adoption of the pollination friendly crop protection method eg IPM/ IDM, organic farming, floral calendar preparation and planting the crop/s to have bloom round the year or the artificial feeding, adopt mix/relay/sequential/multiple/stripe cropping etc., avoiding mono/ synchronize planting, hedge row maintenance and better land scaping can help for the conservation of natural pollinators. Natural pollinators habitat conservation with optimizing the natural resource management and reducing over-grazing, honey hunting, slash-burning, deforestation, firing, soil erosion, etc with protection of the nesting site eg the ridges, bunds, natural and semi natural vegetation and the nests of the natural pollinators are recommended. Promote community forestry; establish protected area, and biodiversity garden etc are also helpful. Education included course curricula on crop pollination services in colleges and universities, year round farmers training on Farmers Field School mode and developing web-site with database of pollinators are equally important. For this, development and declare the National Pollinator's Conservation and Management policy focus on research, development and extension, with effective management plan, programs with ample supporting budget in a participatory mode is suggested.

References

CDD (Crop Development Directorate). 2068/069. Annual Report. 147pp.

Devkota, F.P. 2000. Comparative pollination behavior of Apis cerana F. and A. mellifera L. on brocauli and their impact on seed production. Master Thesis Tribhuvan University. Institute of Agriculture and Animal Science, Rampur, Chitwan, Nepal. 78 pp.

Pokhrel, S. 2005. Behavior and Management of Domesticated and Wild Honey bees (Apis spp) in Chitwan, Nepal. PhD dissertation, IAAS/TU. 240p.

Pokhrel, S. 2009. Publication and collections of Suroj Pokhrel, 2009. C9,1-59p.

Pratap, U. 1997. Bee-Flora of the Hindu Kush Himalayan – Inventory and Management. ICIMOD, Kathmandu, Nepal. 293p.

Sihag, R.C. 2000. Diversity, visitation frequency, foraging behaviour and pollinating efficiency of different insect pollinators visiting fennel. en.wikipedia.org/wiki/ User:Sihagrc

Thapa, R.B.; S. Pokhrel; S. Tiwari; S.C. Dhakal and H. Barbara. 2008. Proceedings of the workshop on conservation and management of pollinators for sustainable agriculture through an ecosystem approach, Global pollination project activities. 75P.

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Rooftop Rainwater Harvesting Potential of Apartment System: A Case Study of Kathmandu Residency, Nakhu Kathmandu

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Abstract

Water scarcity is being characteristics of Kathmandu valley nowadays. The continuous population pressure as well as the financial, administrative and technical deficiencies of the supply system has lead to the deterioration of the water service in the city. In the meantime, the water demand has considerably increased due to the improvement of living standards. This has resulted in an increasing pressure onunderground water resource, which in turn, has contributed to an alarming depletion of aquifers. From this overall situation arises the need of the use of complementary alternative sources of water in Kathmandu valley. With the objectives to estimate the water demand and supply, to estimate potentiality of rooftop rainwater harvesting and to study the cost-benefit relation of water use, the study was conducted in Kathmandu Residency in Lalitpur; the first apartment system in Nepal. Meteorological data were acquired from Department of Hydrology & Meteorology/Government of Nepal and analysis for the estimation of water harvesting potential, measurement of rooftop area for the computation of cost benefits. Key Informant Interview and Shared Learning Dialogue to assess the perception of locals were the methods used for this research. The average annual rainfall in the study area was calculated as 1,620.21 mm with highest depth of rainfall in the month of July and smallest depth in December. If this rainwater was to be harvested in all 36 blocks of the study area, with the average rooftop area of 37.1612 m^2, then approximately 1,950,707 liters/year could be harvested for the average family of 3 members. The total demand of water per year of the study area was found to be 15,337,665 liters/year which they have been fulfilling from private suppliers. If the rainwater is harvested, then there will be annual saving of Rs. 292,606 from the colony.

Keywords: *apartment, rainwater harvest, water demand*

Introduction

Water is most important natural resources and is vital for all life on earth. Only about 0.014% of earth's total volume of water is easily available to us as soil moisture, ground water and water bodies (Miller, 2005). Even this is unevenly distributed, both in space and time (Reddy, 2004). Lack of enough freshwater is becoming one of the world's most serious environmental problems and it highlights the urgent need for all nations to develop and implement policies for using water resources more sustainably (Barlow, 2001).

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Kathmandu Valley has been suffering from a shortage of drinking water since the 1980s, and the situation is getting worse (Shrestha, 2009). The valley's current water demand is about 350 million liters per day (MLD), but the Kathmandu Valley Water Utility (KUKL) can only supply about 67 MLD during the dry season and 115 MLD during the wet season (KUKL, 2013). The increasing demand for water is not fulfilled by existing resources especially in urban areas. At present, only about 72% of country's population has access to basic water supply. Moreover, most of the urban water supply systems are not delivering an efficient and effective service (WECS, 2011). This gap in demand and supply has led to heavy extraction of ground water and reliance on tanker water supply which consumes high amount of fuel. The historic cities in Kathmandu valley established over 2000 years ago supplied and managed water in urban areas by collection of rainwater in large rain fed ponds and supplied through stone spouts, canals small ponds etc. However, this system was neglected after the introduction of piped water system nearly a century ago (Shrestha, 2009).

The term 'rainwater harvesting' is usually taken to mean the immediate collection of rain water running off surfaces upon which it has fallen directly to cause rainfall to percolate the ground rather than run off its surface, to forms of flood control. The collected water is stored either in tanks or jars for immediate or future use. It can also be recharged into underground sources like wells. Thus, rooftop rainwater harvesting is a subset of rainwater harvesting, albeit an important one (Thomas & Martinson, 2007).

Sophisticated RWH systems have been developed, especially in industrialized countries, in order to reduce water bills or to meet the needs of remote communities in arid regions. Traditionally, in Uganda and Sri Lanka, rainwater is collected from trees, using banana leaves or stems as temporary gutters (Warwick, 2015).

The broad objective of this research is to assess the quantity of the rooftop rainwater harvest of study area. The research owes specific objectives to estimate the water demand and supply, to estimate potentiality of rooftop rainwater harvesting and to study the cost-benefit relation of water use. Consideration of large rooftop as catchment and exclusion of water purifiers cost used by few households have been considered as limitations of the study.

Materials and method

Study area

The study area lies within Lalitpur district near the Ring road. It is located in the co-ordinates N27^{o} 40'8.85" and E85^{o}18'16.64" at an elevation of 1310.94m. Kathmandu Residency is the first apartment system in Nepal which was established in 2058 B.S. by Ansal Chaudhary developer's private limited. There are total 36 blocks each containing 4 apartments. One block is nearly 400 square feet. The average family size is 3 members per family in total of 161 families. They do not have groundwater supply from

well or any kind of deep boring plants. So they mainly depend on water supply by tanker for their daily needs. Approximately, 3 and a half tanker (each contains 12,000 liter) is required daily for all households. Some families use it for drinking purpose by using purifiers while others depend on jar water for drinking.

Primary data collection

Measurement of rooftop area

The rooftop of one block was measured using measuring tape. The area was calculated. Since all the blocks were of same area, it was multiplied with number of blocks for total rooftop area.

Key informant's interview (KII

The key informant for the research work was Mrs.Sanju Ghimire (administration staff). She was made clear about the objective of the study prior to the data collection.

Shared learning dialogue (SLD)

This method was used to collect the residents view and need. The views of the residents were known by talking to them. They were also made clear about the objective of the study prior to data collection.

Secondary data collection

The secondary data was collected from DHM. The mean monthly rainfall of six surrounding stations of last ten years was taken. Also, average monthly temperature of nearby four stations of last ten years was taken. This data was analyzed as per the need of our research.

Estimation of water demand

Water is required by the public for various uses such as domestic use, industrial and commercial use, public use etc. Domestic water demand includes the water required for drinking, cooking, bathing, washing of utensils, clothes and houses, flushing of latrines, gardening etc.

Computation of water demand of study area

First, the average water demand of an individual per day was estimated by the questionnaire survey. Then,

The water demand per day of study area = water demand of an individual HH per day (y) * n liters

Water demand per month of study area = (y x n x 30) liters/month

Water demand per year of the study area = (y x n x 365) liters/year

Where,

y = Water demand of an individual HH per day
n = total no. of HH in the study area

Estimation of cost for water

Cost for KUKL supply (per month) = x
Per day cost for tanker: no. of tankers * cost for each tanker = y
Per day cost for jar water: total no. of jar used each day= z
Total cost

Estimation of rainwater harvesting potential

The potential rainwater harvesting volume was estimated using the total roof area, the average annual rainfall and the runoff coefficient.

Runoff coefficient is the factor which accounts for the fact that all the rainfall falling on catchments cannot be collected. Some rainfall will be lost from the catchments by evaporation, and retention on the surface itself. Runoff coefficients of 0.8 indicate a loss of 20% of the rainwater to roof cleaning and evaporation.

Table 1: Runoff coefficient for various surfaces

SN	Type of catchment	Runoff coefficient
1	RCC/Tin	0.90-0.95
2	Pitch road/ paved stone pitch	0.85-0.90
3	Gravel road	0.70-0.85
4	Brick pavement	0.50-0.70
5	Green land area	0.50-0.60
6	Slope land area	0.20-0.50

Source: Guidebook and Guidelines on Rainwater Harvesting, 2066

Thus, the total volume of rainwater that could be harvested in the study area was determined by using equation: V = R x A x C

Where,
V = Annual volume of rainwater that could be harvested in the study area in liters (l)
R = Average annual rainfall of the study area (mm)
A = Total roof area of the study area (m^2)
C = Runoff coefficient

Data interpretation and analysis

The collected data was interpreted and analyzed in MS-Excel 2010.

Results

Availability of rainfall depth

The average annual rainfall from 2002 to 2011 A.D. in the studied area estimated by the average annual rainfall of six surrounded different rain gauge stations was found to be 1620.21mm. This data shows that rainwater is available in adequate quantity in the study area, which is located within the Kathmandu valley.

Table 2: Average monthly rainfall (mm) and annual rainfall (mm) for the studied area, 2002 - 2011

Stations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total (mm)
Chapagaun	15.8	31.0	20.2	56.5	105.5	178.3	335.2	324.5	179.4	42.4	1.9	4.4	1839.8
Godavari	18.8	30.1	26.7	65.3	156.1	250.2	448.4	413.0	223.1	54.8	2.2	6.0	1694.9
Ktm Airport	14.8	26.7	44.5	70.7	118.9	214.5	378.8	322.3	225.7	46.1	8.1	3.8	1475.3
Nagarkot	19.0	30.0	33.3	75.5	148.9	256.3	469.8	452.5	306.3	55.7	5.1	2.9	1855.5
Panipokhari	8.0	25.0	32.8	67.7	123.8	211.8	405.1	368.5	253.7	45.3	12.4	5.8	1560.4
Sankhu	12.9	30.7	35.3	51.7	203.1	221.0	476.1	480.5	260.6	61.0	2.8	4.1	1839.8
Monthly average (mm)	**14.9**	**28.9**	**32.1**	**64.6**	**142.7**	**222.0**	**418.9**	**393.6**	**241.5**	**50.9**	**5.4**	**4.5**	**1620.2**

Rainwater harvesting potential study

From the field survey and the rainfall data analysis,
Average rooftop area, A= 37.16m^2, runoff coefficient, C= 0.9, annual rainfall, R= 1,620.21mm
The volume of water collected from annual rainfall in single house of study area is calculated as:
V = R x A x C
V = 1,620.21 x 37.16 x 0.9 mm. m^2
Therefore, V = 54,186.303 liters/year.
For the entire study area, V = 54,186.303 * 36
= 19, 50,706.908 liters/year.
= approx. 1,950,707 liters/year.

Computation of water demand of study area

Water demand of individual HH per day= 260.86 i.e. approx. 261 liters
Total no. of HH in study area= 161
The water demand per day of study area = water demand of an individual HH per day (y) * n liters
= 261 * 161

= 42,021 liters
Water demand per month of study area = (261 x 161 x 30) liters/month
= 1,260,630 liters/month
Water demand per year of the study area = (261 x 161 x 365) liters/year
= 15,337,665 liters/year (Adopted from Rai, 2010)

Calculation for cost of water of study area

Cost for KUKL supply (per month) = Rs. 13,000
Per day cost for tanker: no. of tankers * cost for each tanker
= 3.5 * Rs. 1800 = Rs. 6300
Per day cost for jar water: total no. of jar used each day * Cost of each jar
= 43 * Rs. 58.3 = Rs. 2506.9
i.e. approx. Rs. 2,507
Total cost per year for jar water = 2507 * 365 = Rs. 915,055
Therefore, Cost for water per day (excluding KUKL) = Rs. 6300 + Rs. 2,507
= Rs. 8,807
Total cost for water per month = (Rs. 8,807 * 30) + Rs. 13,000
= Rs. 277,210
Total cost for water per year = Rs. 277,210 * 12
= Rs. 3,326,520

Cost-benefits of study area

The harvested rain water will not be used for drinking purpose. Hence, for the cost-benefit, the cost for jar water is to be deducted.

Total cost for water per year – Total cost for jar water per year
Rs. (3,326,520 – 915,055) = Rs. 2,411,465.
Therefore, cost of water for household purpose is Rs. 2,411,465.
The potential of water collection from entire area was found to be 1,950,707 liters/year. If RWH is done, they can save the amount equivalent to the harvested rainwater.
Cost of 1 liter water is Rs. 0.15
Cost of 1,950,707 liters of water is 0.15 * 1,950,707 = 292,606.05 i.e. approx. Rs. 292,606
Therefore yearly save in water is Rs. 292,606.

Discussion and conclusion

This case study was conducted to assess the potential of rooftop RWH and analyze the cost benefit from it. The average annual rainfall in the study area was calculated as 1,620.21mm with highest depth of rainfall in the month of July and smallest depth in December. If this rainwater isto be harvested in all 36 blocks of the study area, with the

average rooftop area of 37.1612m^2, then approximately 1,950,707liters/year could be harvested.

The total demand of water per year of the study area was found to be 15,337,665 liters/year which they have been fulfilling from private suppliers. If the rainwater is harvested, yearly Rs. 292,606 can be saved from the colony.

When the water demand was compared with Thapa (2013) in which monthly water demand of Fakhel VDC, Makwanpur was found to be 1,367,400 liters/month with total population of 2279. The monthly water demand of Kathmandu Residency is not very significantly less than that of Fakhel VDC, Makwanpur although the population is very much high in her study area. This might be because of the economic status of people. According to her, the respondents were usually of lower caste and their water consumption for hygienic purpose was very low. But the present study shows higher water demand and the people were of upper middle class family and well educated. This shows that the economic status of people also plays vital role in water consumption pattern.

It was found that nearly 10% of the families used purification system like *Euroguard, Kent, PureIt* etc for drinking water to filter the tanker water. However maximum families relied on jar water for drinking purpose and tanker water for other household purposes. Nevertheless, amount of Rs. 13,000 is paid to KUKL every month which is the minimum charge. Since it is Nepal's first apartment system built in 2058 B.S, they don't have ground water supply.

Thus, RWH can be a sustainable approach for water resource consumption for the people. The equivalent amount of water provided by RWH can be a good substitute to KUKL which can be supplied to other needy areas. Since, it is predicted that the future demand of water is likely to increase; sustainability of urban water supply requires a change from coping with water supply without controlling demand, to coping with supply by controlling demand. The introduction of demand side management encourages all citizens to adopt a water conservation approaches, including the use of freely available, locally supplied rainwater.

Recommendation

1. For the rooftop RWH, roof must be kept clean. Frequent cleaning of roof is necessary in order to harvest clean water.
2. The quality of the harvested rain water should be should be checked if it is to be used for consumption. Proper purification techniques must be used.
3. Automatic first flush system should be designed which will help to minimize the difficulty of people for being there to do it.

4. Construction of underground storage tank would be very costly in the study area as it is already paved. Instead small tanks for each block or two can be made for storing the harvested water.
5. The harvested rain water is recommended for the technical uses of the colony.

References

Acharya, D. 2011. Assessment of Roof Rainwater Harvesting of Imadol VDC ward no. 4 of Lalitpur District.M.Sc. Case Study. Submitted to Central Department of Environmental Science, Tribhuwan University, Kirtipur, Nepal.

Barlow, M. 2001. Blue Gold: The Global Water Crisis and the Commoditization of the World's Water Supply.IFG Committee on Globalization of Water.

Dahal, B. and M. Shrestha. 2010. Rainwater Harvesting in Nepal, A Case Study on social acceptability and performance evaluation of RWH schemes implemented in Syangja and Tanahun districts.B.Sc Civil Engineering. Submitted to Institute of Engineering, Western Regional Campus, Pokhara, Nepal.

Eruola, A.O. 2010.Qualitative and Quantitative Assessment of Rainwater Harvesting from Rooftop Catchments: Case Study of Oke-Lantoro Community in Abeokuta, Southwest Nigeria. E.W. Publications, European Water, 32: 47-56, 2010.

Miller, G.T. 2005. Living in the Environment. Thomson Asia Pvt. Ltd, Singapore, 13th Edition.

MoPP, 2066. Guidebook and Guideline on Rainwater Harvesting.Ministry of Physical Planning, Department of Urban Development, Babarmahal, Kathmandu.

KUKL, 2013. Kathmandu UpatyakaKhanepani Limited.Fifth Annual Report. Tripureshwor, Kathmandu, Nepal.

Rai, S. 2010. Rooftop Rainwater Harvesting Potential: A Case Study in Ward no. 35 of Kathmandu Municipality City. M.Sc. Dissertation, Submitted to Central Department of Environmental Sciences, Tribhuwan University, Kirtipur, Nepal.

Reddy, J.R. 2004. A Text Book of Hydrology. Laxmi Publications Private Limited, New Delhi, India

Shrestha, R.R. 2009. Rainwater Harvesting and Ground Water Recharge for Water Storage in the Kathmandu Valley. Water for Asian Cities Programme, UN-HABITAT, Nepal.

Thapa, G. 2013.Qualitative, Quantitative and Economic Evaluation of Domestic Rainwater Harvesting System of Fakhel, Makwanpur District, Nepal. M.Sc. Dissertation, Submitted to Central Department of Environmental Sciences, Tribhuwan University, Kirtipur, Nepal.

WECS, 2011.Water Resources of Nepal in the Context of Climate Change.Water and Energy Commission Secretariat, Government of Nepal, Singhadurbar, Kathmandu, Nepal.

Thomas, K. and K. Martinson. 2007. Roof water Harvesting: A Handbook for Practitioners. Delft, The Netherlands, IRC International Water and Sanitation Centre. (49). 160 p.

Warwick, 2015. Rainwater Harvesting: Introduction to Roofwater Harvesting.Assessed in April, 2015, inhttp://www2.warwick.ac.uk/fac/sci/eng/research/civil/dtu/rwh/.

❑

Effect of Pollination on Cucumber (*Cucumis sativa* L.) Production in Chitwan, Nepal

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Abstract

An experiment was conducted to evaluate the effect of pollination oncucumber production in Chitwan, Nepal. The experiment was carried out in randomized complete block design from March to June, 2013 and the treatments were: i) Apis cerana F. pollination, ii) A. mellifera L. pollination, iii) hand pollination, iv) open pollination, and v) control replicated four times. The findings showed positive influence on yield and yield components of cucumber pollination by different honeybee species. Plant growth and number of branches were significantly the highest in control. Fruit length, diameter and weight were better in honeybee pollination, with the best pollination by A. cerana. Number of fruits and yield was higher in A. cerana pollinated plots, while fruit deformity was 100% in control. The seed number per fruit was significantly higher on A. cerana pollination. Therefore, A. cerana pollination on cucumber is imperative to exploit the yield potential of cucumber in Chitwan Nepal.

Key words: *A. cerana, Cucumber, Pollination*

Introduction

Cucumber (*Cucumis sativa* L.) is a widely cultivated summer vegetable crop under family Cucurbitaceae. It is a monocious annual climber that has been cultivated for more 3,000 years and is still widely cultivated today (Adetula and Denton, 2003).

Flowering phenology of cucumber ensures better cross pollination, as it produces male and female flowers separately on the same plant at different internodes. The ratio of male to female flower is 15:1. The pistillate and staminate flowers arise singly from different internodes and open on the same day but, the male flowers are borne first, a fortnight earlier than the female flowers. The female flower borne on ovary, *i.e.* inferior ovary, and the stigma is receptive throughout the day, while the size of pollen is large and they are sticky (Lauria and Fred, 1995). Therefore, in male flowers, anther dehisces when the corolla expands but the pollens remains on the anther as a sticky mass. The maximum pollination occurs in the forenoon. As the female flower closes in the afternoon and never reopens whether or not pollination has taken place; furthermore, the

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highest percent of fruit set results from deposition of pollen on the stigma between 09:00 AM to 12:00 noon (Bailey, 1949). Cervancia and Bergonia (1990) reported that 75 and 58 percent fruit set was obtained in cucumber in bee and open pollinated plants, respectively, and these were significantly higher than the non-pollinated plant which was only 33 percent. Bee pollination and open pollination produced heavier and uniform fruits. One honeybee colony per acre increased yield by 39 percent as compared to fields without bees (Steinhauer, 1971). Hence, the impact of cross pollination on cucumber productivity definitely depends upon on the extent to which the crop can be pollinated. If crop pollination is managed, a new dimension will be added to increase yield and improve quality, and the area under these crops could be expanded substantially.

Materials and Method

The experiment was conducted in RCBD with 5 treatments and 4 replications in Gitanagar VDC of Chitwan, Nepal from March to June 2013. The treatments were: i) *Apis cerana* pollination, ii) *A. mellifera* pollination, iii) hand pollination, iv) open pollination, and v) control (covered with mosquito net). The plot size was 4m x 2.7m. The variety Bimal was seeded @ 2kg/ha (2 seeds/pit), for which pit size of 20cm x 30cm was dug out spacing at 1m x 0.9m fortnight before cucumber planting. Compost was used @30 mt/ha, i.e. 2 kg/pit and NPK @ 140: 40: 100 kg/ha. The DAP and MOP was applied as basal application and urea in split dose, which was top dressed 25 days after sowing. Bamboo and jute string were used for staking. Neemix 2ml/liter was applied at seedling stage to control red pumpkin beetle. Irrigation was applied as per requirement. Fruits were harvested at weekly interval. Two fruits per plot were left up to maturity.

All the plots were caged by using mosquito net of size 5 x 3 x 7 m^3 except a plot in each block which was left for open pollination. Each plant of the treatment with hand pollination was caged with mosquito net. Colonies of honeybee having 3 frames bees, i.e. one *A. mellifera* hive/replication and one *A. cerana* hive/replication were placed separately inside the cage when cucumber plant started flowering. Honeybee was fed with sugar syrup (1:1) and artificial pollen. Caging was done at 5-10% flowering to 90% of flowering. Data were collected from 3 plants per plot and analyzed using statistical tools.

Result

The caged plots without pollinator had maximum branches (14.5 branches/plant), which was statistically significant from the rest of the treatments (Table 1). The plant height was the shortest on *A. cerana* pollinated plots (306.8 cm). Caged plants without pollinators were significantly taller (443.6 cm), which was followed by hand pollinated

plants (386.7 cm). Open pollinated plants and *A. mellifera* pollinated plants were statistically similar (Table1).

Table 1. Effect of pollination on number of branch/plant and plant height of cucumber at Gitanagar, Chitwan Nepal, 2013

Treatment	Branch/plant*	Plant height (cm)*
A. cerana pollination	10.25^{b}	306.8^{c}
A. mellifera pollination	11.00^{b}	343.9^{bc}
Hand pollination	11.75^{b}	386.7^{ab}
Open pollination	12.00^{b}	345.7^{bc}
No pollination (caged)	14.50^{a}	443.6^{a}
CV %	13.09	12.06
LSD	2.399	67.88
SE	0.7786	22.03

* Means followed by the same letters in a column are not significantly different by DMRT at ≤0.05 level

A. cerana pollinated fruits were superior to other treatments and *A. mellifera* pollinated fruits (5.525 cm) was at par with open (5.008 cm) and *A. cerana* (5.930 cm) and hand pollinated fruits (5.008), i.e. open pollinated fruit diameter was followed by hand pollinated fruits (4.247 cm). The lowest diameter was measured in caged plants without insect pollinators (2.825 cm) (Table 2).

Fruit length was superior in both *A. cerana* (22.05cm) and *A. mellifera* (21.27 cm) pollinated plants as compared to other treatments. This was flowed by open pollinated fruits (18.48 cm) and then by hand pollinated fruits (15.48 cm). Control plots resulted in the inferior fruits with the lowest length which is presented in Table 2.

Fruit weight was significantly the highest on the *A. cerana* pollinated plants (568 gm), followed by *A. mellifera* pollinated plants (515.3 gm). Hand pollinated fruits had significantly lower weight (246.5 gm) than open pollinated fruits (365.4 gm). The most inferior fruit was non-pollinated one with only 81 gm weight (Table 2).

Table 2. Effect of pollination on fruit diameter, length and weight of cucumber at Gitanagar, Chitwan Nepal, 2013

Treatments	Diameter of fruit (cm)*	Length of fruit (cm)*	Weight per fruit (gm)*
A. cerana pollination	5.930^{a}	22.05^{a}	568^{a}
A. mellifera pollination	5.525^{ab}	21.27^{a}	515.3^{b}
Hand pollination	4.247^{c}	15.48^{c}	246.5^{d}
Open pollination	5.008^{b}	18.48^{b}	365.4^{c}
No pollination (caged)	2.825^{d}	11.15^{c}	81^{e}
CV	8.82	8.08	9.35
LSD	0.6390	2.202	51.18
SE	0.2074	0.7145	16.61

* Means followed by the same letters in a column are not significantly different by DMRT at ≤0.05 level

The maximum number of fruit was harvested from the *A. cerana* pollinated plants (6.355/plant) followed by *A. mellifera* pollinated plants (5.977/plant) and open pollinated plants (4.020/plant).

Yield per ha was significantly the highest in *A. cerana* pollinated plants, which was more than 40 mt/ha. This was followed by *A. mellifera* pollinated plants, i.e. 34.32 mt/ha. Open pollinated plot yielded about 16.5 mt/ha and hand pollinated has less than 6 mt/ha. Caged plants without pollinators produced yield only about1/4th mt/ha (Table 3).

Table 3. Effect of pollination on fruit number and yield of cucumber at Gitanagar, Chitwan, Nepal, 2013

Treatments	Number of fruits/plant*	Yield/ha (mt)*
A. cerana pollination	6.355^{a}	40.13^{a}
A. mellifera pollination	5.977^{a}	34.32^{b}
Hand pollination	2.142^{c}	5.861^{d}
Open pollination	4.020^{b}	16.12^{c}
No pollination (caged)	0.1225^{d}	0.2560^{e}
CV%	11.19	13.36
LSD	0.6427	3.980
SE	0.2086	1.292

* Means followed by the same letters in a column are not significantly different by DMRT at ≤0.05 level

A. cerana and *A. mellifera* pollinated plants had 440.3 and 428.8 seeds per fruit, respectively. Open pollinated cucumber consisted of 388.8 and hand pollinated plants had 309.5 seeds per matured fruits (Table 4).

In case of caged plants without pollinators, all fruits harvested were deformed. This was followed by hand pollinated plants (about 60% deformed). Open pollinated plants had more than 27% of deformed fruits (Table 4). The minimum deformed fruits were observed in *A. cerana* pollinated plants.

Table 4. Effect of pollination on seeds and deformed fruits at Gitanagar, Chitwan, Nepal, 2013

Treatments	Seed number /fruit*	Deformed fruit (%)*
A. cerana pollination	440.3^{a}	6.122^{d}
A. mellifera pollination	428.8^{a}	11.05^{d}
Hand pollination	309.5^{c}	60.55^{b}
Open pollination	388.8^{b}	27.53^{c}
No pollination (caged)	0.000^{d}	100^{a}
CV %	5.56	9.32
LSD	26.87	5.893
SE	8.721	1.912

* Means followed by the same letters in a column are not significantly different by DMRT at ≤0.05 level

Discussion

Branch number per plant and plant height indicated that vegetative growth was higher in the plants which were not pollinated. They had less number of fruits and smaller sized fruits. The fruit size and number is typically correlated negatively with the amount of vegetative growth (Proebisting, 1958).

Fruit diameter was 5.93 cm 5.525 cm in *A. cerana* and *A. mellifera* pollinated plants, which are in accordance with the findings of Gingras *et. al.* (1999), who reported that circumference of cucumbers fruit was correlated positively with pollination of honeybees (*A. mellifera*) . Kauffeld and Nilson (1982) obtained the longer size cucumber from the plots pollinated by *A. mellifera* as reported by Gingras *et. al.* (1999). *A. cerana* was superior to *A. mellifera*, which might be due to the well adopted native bees with longer foraging hours. Chauta-Mellizo *et. al.* (2012) observed increased fruit mass, size and diameter in *Physalis peruviana* compared to manual and self-pollination.

Flowers that produced fruits were associated with higher number of visits by honeybees. The results of the present investigations further revealed that flowers in caged without bees that received zero visits did produced negligible weight of cucumber. This might be due to auto pollination as reported by Jenkins (1942) who stated that very less percentage of auto pollination could occur in the absence of insects in cucumber.

A. cerana and *A. mellifera* pollinated plants produced more number of fruits. Noguera and Calmona (1993) also reported that honeybee (*A. mellifera*) constituted 82.6% of visitors to cucumbers flower and showed that plots netted with bees yielded more fruits/m^2 with heavier and higher quality than other plots (open and covered without bees).

Matured fruit from the *A. cerana* pollinated and *A. mellifera* pollinated contained the highest number of seeds per fruit. This might be the result of bee pollination. Honeybee pollination favors the competition and selection of higher quality pollen grains (Winsor *et. al.,* 2000), and hence increase seed set (Cowan *et. al.,* 2000; Winsor *et. al.,* 2000; Al-Ghzawi *et. al.,* 2009). Chauta-Mellizo *et. al.* (2012) reported that amount of or manner in which pollen deposited on stigmas by bees increased the number of successfully fertilized ovules which led to higher seed set.

Fruit deformity was found 100% in control plots. The fruits were misshapen unless the adequate number of pollinator visited the flowers. Beste *et. al.* (1999) reported that fruit enlargement is promoted by growth stimulating hormones and they are produced by developing seeds. They noted that the hormones are provided from the pollen placed to the stigmas in seedless varieties of watermelon.

Conclusion

This study was designed to investigate the best pollinator for achieving higher yield with quality fruits of cucumber. Major findings showed that the vegetative growth increases in cucumber which doesn't receive pollination services from the selective pollinators . Fruit yield, seed number and uniform fruits were the best from *A. cerana* followed by *A. mellifera* pollination. Thus, *A. cerana* found most efficient pollinator in field condition and therefore, its management during cucumber growing is imperative for higher and healthy cucumber production.

References

Adetula, O. and L. Denton. 2003. Performance of vegetative and yield accessions of cucumber (Cucumis sativa L.). Proceedings of 21st Annual Conference, Horticultural Society of Nigeria (HORTSON). pp. 10-13.

Al-Ghzawi, A. A-M., S. Zaitoun, N. Freihat and A. Alqudah. 2009. Effect of pollination on seed set of Origanum syriacum under semiarid Mediterranean conditions. Acta Agriculturae Scandinavica Section B: Plant Soil Science 59: 273–278.

Bailey, L. H. 1949. Manual of cultivated plants. Revised edition. The MacMillen Company, New York, USA. 956 p.

Beste, E., D. Caron, G. Dively, K. Everts, E. Kee, S. D. Walker, J. Whalen, J. Windsor and T. Wootten. 1999. Watermelon production guide for Delaware and Maryland. University of Maryland/University of Delaware, Cooperative Extension Publication, USA. 52p.

Cervancia, C.R. and E.A. Bergonia. 1990. Insect pollinators of cucumber (Cucumis sativus L.) in the Philippines. In: The Sixth International Symposium on Pollination, Tilburg, Netherlands, pp. 27-31.

Chautá-Mellizo, A., S. A. Campbell, M.A. Bonilla, J.S. Thaler and K. Poveda. 2012. Effects of natural and artificial pollination on fruit and offspring quality. Basic and Applied Ecology 13: 524–532.

Cowan, A.A., A.H. Marshall and T.P.T. Michaelson-Yeates. 2000. Effect of pollen competition and stigmatic receptivity on seed set in white clover (Trifolium repens L.). Sexual Plant Reproduction 13: 37–42.

Gingras. D., J. Gingras and D. de-Oliveria, 1999. Visits of honeybees (Hymenoptera: Apidae) and their effects on cucumber yields in the field. Journal of Economic Entomology 92 (2): 435-438.

Jenkins, J.M. 1942. Natural self-pollination in cucumbers. Proceeding of American Society of Horticultural Science 40: 411-412.

Kauffeld, N.M. and J. Nelson. 1982. Production of fruit from Gynocious pickling cucumbers with the three honeybee (A. mellifera L.). Journal of Georgia Entomological Society 17: 471-477.

Lauria, H. and B. Fred. 1995. Bee-pollination of cucurbit crops. Available at: www.pubs .unl.edu (Retrieved on 16th October 2013).

Nogueira, C.R.H. and R.C. Calmona, 1993. Insect pollination of cucumber (Cucumis sativus L.). Naturalia Sao Paulo 18: 77-82.

Steinhauer, A.L. 1971. The pollination of cucumbers in Maryland. American Bee Journal 111: 224-225.

Winsor, J.A., S. Peretz, and A.G. Stephenson. 2000. Pollen competition in a natural population of Cucurbita foetidissima (Cucurbitaceae). American Journal of Botany 87: 527–532.

Effect of Biochar and Ash Amendment on Soil Quality and Crop Productivity

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Abstract

A pot trial was carried out to investigate the effect of soil treatment with biochar and ash on crop yield (Brassica juncea) and the soil quality of acidic sandy loam soil from Dadhikot-9, Bhaktapur, Nepal in 2014. Biochar was prepared from maize residue. Ash prepared from agricultural residue was obtained from a local farm. The experimental design was a factorial randomized design with three replications of each treatment. The treatments comprised of control, biochar (4t/ha) and ash (4t/ha). Biochar production result revealed that nutrient rich and alkaline biochar might be produced from maize residue. Significant increase (P=0.05) was observed in soil quality such as pH and cation exchange capacity of both biochar and ash treated soil as compared to the control soil. Significant increase in organic matter percentage, total nitrogen, available phosphorus and available potassium was observed with only biochar treated soil. Numerically higher but insignificant crop yield was observed with biochar treatment followed by ash treatment and the control. Further investigation with either higher application rates of biochar or longer duration trials is required to confirm the long term effects of soil amendment with biochar.

Keywords: *Biochar, crop yield, maize residue, pot trial, pyrolysis*

Introduction

Biochars refer to the high carbon materials produced from the slow pyrolysis (heating in the absence of oxygen) of biomass (Chan *et. al.* 2008a). Biochar is essentially charcoal, the high carbon product of heating biomass in a closed chamber with limited air supply. However, the term 'biochar' has been established for use when charred organic matter is applied to the soil in a deliberate manner, with the intent to improve soil properties (Lehmann and Joseph 2009).

Biochar is produced from a variety of biomass residues (feedstock) and under different pyrolytic conditions, and thus has varying nutrient contents. For example, the total nitrogen and phosphorus contents are typically higher in biochars produced from feed stocks of animal origin than those of plant origin (Chan and Xu 2009). Biochar can be produced from virtually any organic material including plant wastes like peanut hulls (Kammann *et. al.* 2011), coffee husks (Dias *et. al.* 2010), animal wastes (Chan *et. al.*

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2008b; Uzoma *et. al.* 2011), industrial wastes (Van *et. al.* 2010) and woody materials (Laird *et. al.* 2010b).

Soil amendment with biochar has been proved to bring alterations in soil physical, chemical, and biological properties such as reduced acidity (Topoliantz and Ponge 2005), increased cation exchange capacity (Cheng *et. al.* 2008; Liang *et. al.* 2006), enhanced nitrogen retention (Lehmann *et. al.* 2003), increased microbiological activity (Steiner *et. al.* 2008), and increased mycorrhizal associations (Warnock *et. al.* 2007). Pyrolysis of crop residues with carbon returned to the soil in the form of biochar may help maintain or increase stable soil organic carbon pools and cycle nutrients back into agricultural fields (Gaskin *et. al.* 2008).

Soil fertility is one of the key factors in determining agricultural output. Depletion in soil fertility is seen as the most important process in the land degradation and a primary constraint to improve food security in developing countries (Drechsel *et. al.* 2004). The threats of nutrient depleted soils associated with food insecurity, global warming and the urgent demand for renewable energy alternatives are a growing global concern. Although several options have been proposed for contending with these issues, no single solution has been found. However, biochar technology has been proposed to offer an integrated approach to contribute to the solution of these challenges (Lehmann and Joseph 2009).

Agricultural wastes are important in soil agro-ecosystems as they are able to provide plant nutrients such as C, N, K, P, Ca, and Mg if they are returned to the soil. Above all, when these wastes are used to produce charcoal, they bring about an opportunity to prevent increased fertilizer-use (Laird 2008), and avoid the further reduction of soil organic carbon (Gaskin *et. al.* 2008).

Widespread degradation of soils under existing agricultural practices also draws an attention to move towards such a technology which is relatively low cost and sustainable. Soil amendment with biochar might be one of such technologies. Biochar can be produced by using the existing local agricultural and forest residues as feedstock.

The objectives of this study were to prepare biochar from maize residue, to measure the changes in soil properties after treatment with biochar and ash; and to measure crop productivity after soil treatment.

Materials and method

Soil was collected from the experimental plot of Dadhikot, Bhaktapur ($27^0$40'03.11" N, $85^0$23'03.77" E, 1312 masl). A composite sample was collected from the 0-20 cm layer, brought back to laboratory of Central Department of Environmental Science, Tribhuvan Universtiy, Kathmandu. The soil was kept indoors to let it air dry until it could be crumbled to pass through a 2 mm sieve for the pot trial. Maize residue (Stem and leaf)

was used as the feedstock for biochar production. Biochar was produced at three different pyrolysis temperatures using a Top-lit Updraft stove. The biochar thus produced was grounded to small granules and passed through 2 mm sieve in order to have the same particle size as that of the soil used for pot trial. Ash was obtained from a local farm of Dadhikot. Test crop used for the study was *Brassica juncea (rayo marfa chaudapaat)*. The seed of the test crop was obtained from a local agro shop, Khumaltar, Lalitpur.

Pot trial was carried out from 17th August to 11th October, 2014. Plastic pots measuring 58 cm circumference at the top and 15.8 cm height were filled with 2 kg of 2 mm sieved dry soil. The application rate for amendments was calculated on weight basis. The experimental design used was factorial randomized design with three replications of each treatment. The treatments comprised of control (no treatment application), biochar and ash. The equivalent of 4t/ha (3.57 gm) of both biochar and ash was applied per 2 kg of soil. One seedling of two weeks was transplanted to each pot after two weeks of treatment application. Water was applied as per requirement based on visual observation and dipping finger inside the soil.

The air dried soil samples were passed through a 0.25 mm-sieve for analysis. Soils from experimental plot and pot trial were analyzed for selected parameters such as soil pH, cation exchange capacity, soil organic matter, total nitrogen, available phosphorus and available potassium as per the standard methods of soil analysis (Pradhan 1996). Similarly, biochar and ash were analyzed.

Soil from pot trial was analyzed in two batches. First batch analysis was done before plantation (following the second week of treatment application) and second batch analysis was done after harvesting of the plants (after six weeks of plantation).

The height of all leaves of each plant was measured weekly from the day of transplantation to the day of harvest. The plant height was measured from the bottom to the top using a simple ruler. For fresh weight determination, the whole plant was collected from each pot and washed off any loose soil. The plant was blotted gently with soft paper to remove any free surface moisture such that there would not be breakage of any part of the plants. The fresh weight of complete plant body (shoot and root) was measured immediately by using an electronic balance that can measure up to 3 digits because plants have a high composition of water so waiting to weigh them may lead to some drying and therefore produce inaccurate data. For dry matter content determination, the plants were wrapped by using a soft paper and tagged clearly. The plants with wrapping paper were dried at a temperature of 70^{0}C in a hot-air oven overnight. The plants were let to cool in a dry environment and the dry weight was measured on a digital weighing machine.

The difference between treatments means were compared by using analysis of variance (ANOVA) in SPSS 16. Unless otherwise stated, differences were significant at P= 0.05.

Results

Biochar production

The highest amount of biochar, in terms of percentage of initial feedstock mass, was produced in the first batch. The pyrolysis temperature ranged from 350^0C to 430^0C for biochar production. The conversion ratio (mass of biochar/ mass of feedstock) was noted to follow a decreasing order with the increase in pyrolysis temperature (Table 1).

Table 2: Effect of pyrolysis temperature on biochar yield

S.N.	Batch	Feedstock (gm) (a)	Duration of firing (min.)	Pyrolysis temperature (^{0}C)	Amount of biochar (gm) (b)	Conversion ratio (b/a)
1	I	1160	110	350-353	324.95	0.28
2	II	1050	120	385-390	273.00	0.26
3	III	1000	135	425-430	210.48	0.21

Analysis of biochar revealed an increase in pH, CEC, organic carbon with increase in pyrolysis temperature but total nitrogen decreased as temperature increased. The biochar produced was found to be alkaline and nutrient rich (Table 2).

Table 3: Physico-chemical parameters of biochar produced at different temperatures

S.N	Batch	pH	CEC (me/100 gm)	C (%)	N (%)	P (ppm)	K (ppm)
1	I	9.22	69.40	11.19	0.82	1.33	103.00
2	II	9.92	70.00	11.97	0.60	1.01	101.50
3	III	10.30	85.20	14.30	0.42	1.39	96.80

Analysis of experimental soil and soil amendments

The experimental soil was found to be moderately productive. Both biochar and ash used for soil amendment were alkaline and nutrient rich than the experimental soil (Table 3).

Table 4: Characteristics of experimental soil and selected soil amendments

Soil/ soil amendments	pH	CEC (me/100 gm)	SOM (%)	Carbon (%)	N (%)	P	K
Experimental soil	5.7	7.40	2.14	1.24	0.32	289.49 kg/ha	158.59 kg/ha
Biochar I*	9.22	69.40	19.30	11.19	0.82	1.33 ppm	103 ppm
Ash	8.54	23.80	14.2	8.24	0.24	0.64 ppm	37.1 ppm

* Biochar produced in batch I was used as soil amendment

Soil quality changes

Both biochar treated and ash treated soils revealed significant increase in soil pH and cation exchange capacity as compared to the control soil. Organic matter percentage, total nitrogen, available phosphorus and available potassium were increased significantly by biochar treatment only (Table 4).

Table 5: Changes in soil properties as a result of different treatment application

Parameters	Control		Biochar		Ash	
	I	II	I	II	I	II
pH	6.26a	6.33a	6.48b	6.80b	6.44c	6.42c
CEC (me/100 gm)	6.67a	10.27a	12.53b	21.20b	16.07c	14.60c
SOM (%)	1.52a	3.57a	2.50b	5.18b	2.14a	2.41a
N (%)	0.15a	0.22a	0.32b	0.35b	0.25a	0.23a
P (kg/ha)	309.06a	427.45a	477.27b	573.80b	323.47a	517.71a
K (kg/ha)	159.49a	218.63a	227.58b	255.36b	210.56a	260.74a

I = before plantation II = after harvest

Within rows, means followed by the same letter are not significantly different ($P > 0.05$)

Crop productivity

Crop productivity based on height measures the mean percentage increase in plant height of each treatment at harvest as compared to the mean height at plantation (cm). Percentage increase in plant height was found more in biochar treatment (223.60%) which was followed by ash treatment (164.43%) (Figure 1). However, the treatment wise difference in percentage increase in mean height was not statistically significant as compared to the control.

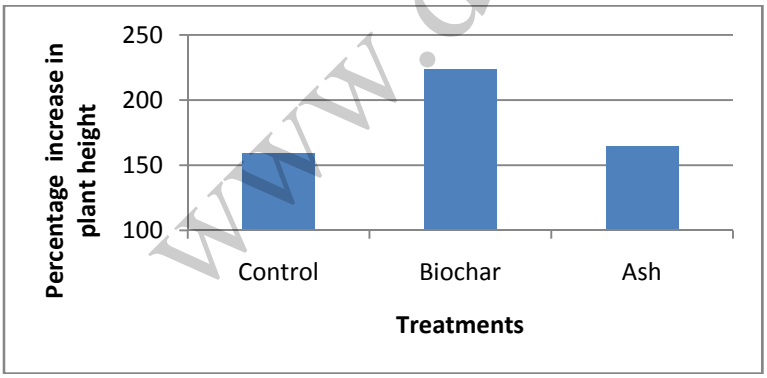

Figure 1: Percentage increase of mean initial plant height at harvest

The maximum dry weight (gm) was observed with biochar (1.724) treatment followed by ash (1.240) treatment (Figure 2). However, no significant difference was observed between the mean dry weights of different treatments as compared to the control.

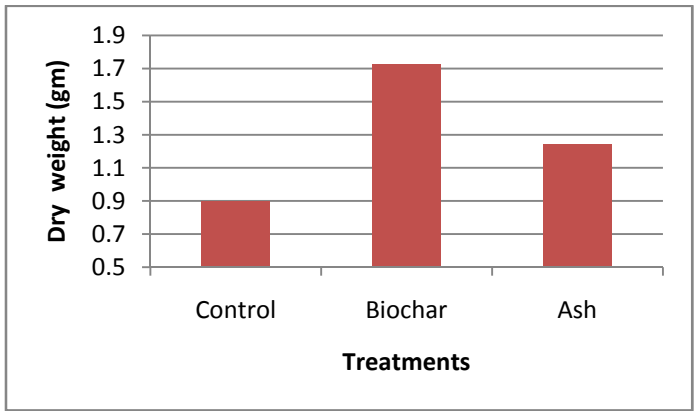

Figure 2: Mean dry weight of plant by treatment type

Discussion

Biochar production

Maize is the second leading food crop in Nepal (AICC 2014). After harvest, maize residue can be easily available in adequate quantity as agricultural residue. In the study area, most common practice of treating the residue is either burning or left for decaying to be used as compost. Therefore, maize residue was used to produce biochar. The biochar stove was used because of its characteristics like portability, easy to operate and suitable for low scale production.

The conversion ratio was found in decreasing order along with increasing temperature resulting biochar with higher pH values and carbon (Table 1). Similar results have been reported by previous researchers (Collins *et. al.* 2009; Novak *et. al.* 2009a). The more biochar yields at lower pyrolysis temperatures may be due to minimal condensation of aliphatic compounds, and lower losses of CH_4, H_2 and CO (Antal and Grønli 2003). The decrease in yield, at higher temperatures, may be due to dehydration of hydroxyl groups and thermal degradation of ligno-cellulose structures of the feedstock (Amonette and Joseph 2009; Antal and Gronli 2003).

During pyrolysis, part of the feedstock biomass rearranges into gases and volatile compounds resulting mass loss in biochar usually around 50% or more, meaning that biochar yield will be half or less by weight than the amount of feedstock pyrolyzed (Major 2011). At least 50% yield recovery was obtained below 350ºC. The yield declined to about 30% as the pyrolysis temperature was increased up to 500 or 700ºC (Amonette and Joseph 2009; Antal and Grønli 2003). A conversion ratio of 33.2% was reported by Alvum *et. al.* (2011) while producing biochar from three different plant materials. The maximum yield obtained in the present study was 28% which might be due to the variability of feedstock composition and the biochar production technology. It is not clear whether the ratio and burning time are related in the same way as ratio and

temperature, or only a result of the material composition regarding the increased biochar yield with decreased temperature (Gaskin *et. al.* 2008; Yip *et. al.* 2010).

The biochar produced from the maize residue was alkaline (Table 2). The pH of 8 was reported with the biochar produced from maize and wood residues by Cornelissen *et. al.* (2013). There was substantial increase in pH at the higher temperatures (Table 2) which might be due to concentration of non pyrolyzed inorganic elements in feedstock; and higher carbon content (Table 2) might be due to removal of volatile compounds at the higher pyrolysis temperatures (Novak *et. al.* 2009a).

The CEC of biochar was found to be increased with the increase in temperature. There was decrease in nitrogen content which might be due to volatile nature of nitrogen along with increase in temperature (Gaskin *et. al.* 2008).

Soil quality changes

The maximum pH was found to be 6.8 with biochar treatment after plant harvest which is very slightly acidic (6.5-7) and hence might be expected to support for optimal plant growth. Remaining all pH values indicated the soil to be slightly acidic (6.0-6.5) (Table 4) (Khadka, 2013).

Cation exchange capacity (CEC) of ash treated soil was found higher than that of biochar treated soil before plantation but opposite result was obtained after harvest (Table 4). The CEC of biochar treated soil was substantially and significantly higher than ash treated soil after harvest. These results suggest that biochar treatment increases CEC of the soil better than ash with the passage of time which might be expected to support optimal plant growth.

Significant increase in soil pH and CEC by the application of amendments, especially biochar during the growth trial had been observed in other studies (Chan *et. al.* 2008b; Topoliantz *et. al.* 2002; Tryon 1948).

Biochar retains nutrients in soil directly through the negative charge that develops on its surfaces, and this negative charge can buffer acidity in the soil, as does organic matter in general (Lehmann and Joseph 2009). The results from this experiment match up appropriately with the underlying theory of organic matter's negative charge buffering soil acidity.

Biochar has relatively higher CEC and with its high recalcitrance (Glaser *et. al.* 2002), it is reasonable that soil amended with biochar had the highest CEC.

Increase in CEC as a result of biochar addition to the soil indicates that soil amendments are likely to have an effect on the nutrient availability in soil. The negative surface charge of biochar also attracts cations to its surface, allowing for better nutrient retention in the soil (Lehmann and Joseph 2009). Increases in cation exchange capacity imply that the amount of readily available nutrients in the soil has increased, which

provides a healthier soil and a better environment for plant health (Lehmann *et. al.* 2006).

The organic matter percentage was found significantly higher in biochar treated than ash treated soil (Table 4). There was a jump in organic matter percentage of biochar treated soil from medium level (2.5-5%) before plantation to high level (5-10%) after harvest which might be supposed to enhance plant growth. However, in case of ash treated soil, there was very slight increase from 2.14% to 2.41%, both values being in low range (1.0-2.5%) (Khadka 2013). These results suggest that biochar treatment works better than ash in increasing soil organic matter.

The positive effect of biochar on soil organic matter was expected due to its high carbon content (11.19%) than the ash (8.24%). Similar result was reported by Prabha *et. al.* (2013) in a pot trial with wood derived biochar. The higher percentage of soil organic matter might be due to the potential of biochar to increase the recalcitrant pool of soil carbon and will persist in the soil environment much longer than carbon added in the form of compost (Novak *et. al.* 2009b).

The increase in total nitogen with biochar teatment was found to be significant as compared to the control (Table 4). The nitrogen content of both biochar and ash treated soils were high (0.2-0.4%) before plantation as well as after harvest. However, total nitrogen was decreased in ash treated soil after harvest than before plantation whereas the case was opposite in biochar treated soil.

Increased nitrogen in biochar treated soil might be due to the biochar itself being rich in nitrogen (Table 2). There might have been used up of nitrogen to some extent by growing plants till the time of harvesting. However, it is noticeable that in spite of possible consumption of nitrogen by growing plants, the nitrogen content of biochar treated soil was still high (0.35%) after harvesting of plants. This observation, to some extent, could be caused by a lower of possible nitrogen leaching due to increasing of soil cation exchange capacity (Liang *et. al.*, 2006; Masulili *et. al.*, 2010). This in turn would decrease plant nutrient lost (especially $N\text{-}NH_4^+$ and K^+). The increase in soil nitrogen content in the biochar treated soil could be originated from retardation of $N\text{-}NH_4^+$ to $N\text{-}NO_3^-$ transformation (Widowati *et. al.*, 2011) which will further lowered nitrogen leaching. Increased retention of nitrogen with biochar addition has been observed by several researchers (Ding *et. al.*, 2010; Lehmann, 2003; Laird *et. al.*, 2010a; Major *et. al.*, 2010a).

Significant increase in phosphorus concentration of biochar treatment was found as compared to both ash treated and the control soil (Table 4) which might suggest that biochar is better than ash in improving soil phosphorus. Increased phosphorus availability due to biochar addition has been also reported by Petter *et. al.* (2012).

Biochar treatment showed significantly higher potassium as compared to the control but there was no significant difference in available potassium between biochar treated and ash treated soil. This might be due to both amendments being rich in potassium concentration as compared to the control (Table 3).

Crop productivity

The crop yield was found highest in biochar treated soil which was followed by ash treated soil and the control soil. However, these results were not statistically significant.

The primary nutrients for plant growth are nitrogen, phosphorus and potassium (known collectively as NPK). When they are insufficient, they will be responsible for limiting crop growth (Gruhn *et. al.* 2000). In the present study, very high phosphorus concentration was observed with all treatments including the control. Potassium concentration was medium with all treatments. The total nitrogen was found ranging medium to high with different treatment applications. On the basis of these observations, it might be concluded that the total nitrogen and potassium concentration might had limited the crop yield in this study.

It is common knowledge that supply of N limits crop growth and productivity more often than the supply of any other nutrient element (Aslam *et. al.* 1994). The N availability is the main factor determining crop production. The increase in lettuce yield with biochar treatment might be due to increased nitrogen utilization in the soil treated with nitrogen rich biochar.

Significant increase in radish yield was not obtained even at the highest rate of 100 t/ha green waste biochar application in absence of nitrogen fertilizer in a pot trial of six weeks. However, significant biochar+nitrogen fertilizer interaction was observed, in that higher yield increases were observed with increasing rates of biochar application in the presence of nitrogen fertilizer, highlighting the role of biochar in improving N fertilizer use efficiency of the plant (Chan *et. al.* 2008a). These results may support why there might not have been significant lettuce yield in the present study. However, there was numerically higher yield in biochar treatment which was followed by ash treatment. On the basis of these observations, it can be said that significant yield might be observed even in short term pot trial if biochar is applied at higher concentrations along with nitrogen fertilizer. In this case, further research with different concentrations of biochar with and without nitrogen fertilizer will help to better understand the effect of biochar on crop yield.

Cornelissen *et. al.* (2013) reported significant maize yield from more acidic and sandy soil in a field trial with the application rate of 4 ton/ha of maize cob biochar. In contrast, significant yield was not obtained with the same rate of maize residue biochar application to acidic and sandy loam soils in the present study. One of the reasons might be due to the different nutrient requirements of the different plants (maize and lettuce)

used in the two studies. This might be also due to the different soil environment of the field trial as compared to the pot trial.

Even with higher rate of biochar application (10 t/ha) with and without compost to an already productive loamy sand soil in a field trial of three months, beet yield was not observed to be significantly higher (Dennis and Kou 2013). Hence, there might be insignificant yield in present study due to either the low treatment application rate or the non-amended soil being moderately productive in terms of soil organic matter (low), total nitrogen (high), available phosphorus (very high) and potassium (medium).

For the significant crop yield, long term soil amendment with biochar might be required as reported by researchers such as Islami *et. al.* (2011a), Sukartono *et. al.* (2011) and Yamato *et. al.* (2006) for maize, Tagoe *et. al.* (2008) for soybean and Islami *et. al.* (2011b) for cassava.

Potential benefits of biochar may, in some cases, be expected immediately after soil amendment but often it takes a number of years for the biochar to integrate with the soil matrix (physically, chemically and biologically) in order to express its full impacts (Collins *et. al.* 2009). Biochars undergo a range of complex reactions in soil that vary depending on the particular properties of the biochars and soils involved. Factors such as nutrient composition and availability, organic matter content, soil mineralogy and texture, pH, presence of toxins, soil biota, the type of plants grown, the proximity of the biochars to the rhizosphere and the temporal variation in soil moisture can all impact the nature of biochar reaction (Joseph *et. al.* 2010). It is possible that two months was not a significant amount of time for biochar to have had an impact on overall soil properties and processes.

There might be many other aspects by which biochar ameliorate the overall soil health leading to higher plant yield. Other key variables that might be affected by biochar and ash amendment were not measured namely soil water retention and soil microbial dynamics without which the full effect of soil amendment on the agro ecosystem may not be assessed (Dennis and Kou 2013). There might be many other factors that contribute to plant growth, and only a few of those factors were measured. Micronutrients and microorganism within the soil also might have a strong effect on plant growth (Lodhi *et. al.* 2009) but the scope of this experiment did not allow for these to be measured.

Conclusion and recommendation

Maize residue might be an appropriate feedstock for producing biochar because of its easy availability in adequate quantity. Nutrient rich alkaline biochar might be produced from maize residue. Relatively higher yields of biochar could be obtained with lower pyrolysis temperatures. Maize residue biochar can work as better soil amendment than ash in improving soil organic matter, total nitrogen, phosphorus and potassium of acidic

sandy loam soil. Based on crop productivity analysis, relatively higher but insignificant yield was achieved with biochar treatment followed by ash treated and control soil in a short duration such as of six weeks. Longer duration pot trial with higher biochar application rates might be required to confirm these results.

Acknowledgement

We are thankful Dr. Dinesh Raj Bhuju for his inspirational guidance and valuable suggestions to make this study a success. We are grateful to Central Department of Environment Science Faculty Research Grant Section for financial support. We would also like to thank District Forest Office, Machhapuchre Development Organization and Panchase Protected Forest Program Office, Kaski for necessary arrangements for the field visit. Finally, I offer my thanks to my friends and family.

References

AICC (Agriculture Information and Communication Center, Lalitpur, GoN). 2014. Krishi Diary.

Alvum-Toll, K. T. Karlsson and H. Ström. 2011. Biochar as soil amendment– a comparison between plant materials for biochar production from three regions in Kenya (Degree project in Biology): Swedish University of Agricultural Sciences

Amonette, J.E., and S. Joseph (2009). Characteristics of biochar: Microchemical properties. Biochar for environmental management: Science and technology. Earthscan, London, 33-52.

Antal, M.J., and M. Grønli (2003). The art, science, and technology of charcoal production. Industrial and Engineering Chemistry Research, 42(8), 1619-1640.

Aslam, M., M. Ali, S. Parveen, and S. Nawaz (1994). Nitrogen management in dense saline sodic soil. Pak. J. Soil Sci, 9, 96-99.

Brady, N.C., and R.R. Weil (1996). The nature and properties of soils: Prentice-Hall of India (P) Ltd. New Delhi India.

Chan, K., L.V. Zwieten, , I. Meszaros, A. Downie, and S, Joseph (2008a). Agronomic values of greenwaste biochar as a soil amendment. Soil Research, 45(8), 629-634.

Chan, K., L.V. Zwieten, I. Meszaros, A. Downie, and S. Joseph (2008b). Using poultry litter biochars as soil amendments. Soil Research, 46(5), 437-444.

Chan, K.Y., and Z. Xu (2009). Biochar: nutrient properties and their enhancement. Biochar for environmental management: science and technology, 67-84.

Cheng, C.H., J. Lehmann, and M.H. Engelhard (2008). Natural oxidation of black carbon in soils: changes in molecular form and surface charge along a climosequence. Geochimica et Cosmochimica Acta, 72(6), 1598-1610.

Collins, H., R. Cochran, J. Smith, M. Garcia-Perez, C. Kruger, and D, Granatstein (2009). Use of Biochar from the Pyrolysis of Waste Organic Material as a Soil Amendment. Wenatchee: Centre for sustaining agriculture and natural resources.

Cornelissen, G., V. Martinsen, V. Shitumbanuma, V. Alling, G.D. Breedveld, D.W. Rutherford, et. al. (2013). Biochar effect on maize yield and soil characteristics in five conservation farming sites in Zambia. Agronomy, 3(2), 256-274.

Dennis, J., and K.C.S. Kou (2013). Evaluating the agronomic benefits of biochar amended soils in an organic system. Vancouver University of British Columbia.

Dias, B.O., C.A. Silva, F.S. Higashikawa, A. Roig, and M.A. Sánchez-Monedero (2010). Use of biochar as bulking agent for the composting of poultry manure: Effect on organic matter degradation and humification. Bioresource technology, 101(4), 1239-1246.

Ding, Y., Y.X. Liu, W.X. Wu, D.Z. Shi, M. Yang, and Z.K. Zhong (2010). Evaluation of biochar effects on nitrogen retention and leaching in multi-layered soil columns. Water, Air, and Soil Pollution, 213(1-4), 47-55.

Drechsel, P., M. Giordano, and L. Gyiele (2004). Valuing nutrients in soil and water: concepts and techniques with examples from IWMI studies in the developing world (Vol. 82): Iwmi.

Gaskin, J., C. Steiner, K. Harris, K. Das, and B. Bibens (2008). Effect of low-temperature pyrolysis conditions on biochar for agricultural use. Trans. Asabe, 51(6), 2061-2069.

Glaser, B., J. Lehmann, and W. Zech (2002). Ameliorating physical & chemical properties of highly weathered soils in the tropics with charcoal–a review. Biology & fertility of soils,35(4), 219-230.

Gruhn, P., F. Goletti, and M. Yudelman (2000). Integrated nutrient management, soil fertility, and sustainable agriculture: current issues and future challenges: Intl Food Policy Res Inst.

Islami, T., B. Guritno, N. Basuki, and A. Suryanto (2011). Biochar for sustaining productivity of cassava based cropping systems in the degraded lands of East Java, Indonesia. Journal of Tropical Agriculture, 49(1-2), 40-46.

Islami, T., B. Guritno, N. Basuki, and A. Suryanto (2011b). Maize yield and associated soil quality changes in cassava+ maize intercropping system after 3 years of biochar application. Journal of Agriculture and Food Technology, 1, 112-115.

Joseph, S., M. Camps-Arbestain, Y. Lin, P. Munroe, C. Chia, J. Hook, et. al. (2010). An investigation into the reactions of biochar in soil. Soil Research, 48(7), 501-515.

Kammann, C.I., S. Linsel, J.W. Gößling, and H.W. Koyro (2011). Influence of biochar on drought tolerance of Chenopodium quinoa Willd and on soil–plant relations. Plant and Soil, 345(1-2), 195-210.

Khadka, Y.G. (2013). Purpose of soil sampling and methods of sampling for soil analysis. Khumaltar, Lalitpur: Nepal Agricultural Research Council.

Laird, D., P. Fleming, B. Wang, R. Horton, and D. Karlen (2010a). Biochar impact on nutrient leaching from a Midwestern agricultural soil. Geoderma, 158(3), 436-442.

Laird, D.A. (2008). The charcoal vision: a win–win–win scenario for simultaneously producing bioenergy, permanently sequestering carbon, while improving soil and water quality. Agronomy Journal, 100(1), 178-181.

Laird, D.A., P. Fleming, D.D. Davis, R. Horton, B. Wang, and D.L. Karlen (2010b). Impact of biochar amendments on the quality of a typical Midwestern agricultural soil. Geoderma, 158(3), 443-449.

Lehmann, J., J.P. da Silva Jr, C. Steiner, T. Nehls, W. Zech, and B. Glaser (2003). Nutrient availability and leaching in an archaeological Anthrosol and a Ferralsol of the Central Amazon basin: fertilizer, manure and charcoal amendments. Plant and Soil, 249(2), 343-357.

Lehmann, J., J. Gaunt, and M. Rondon (2006). Bio-char sequestration in terrestrial ecosystems–a review. Mitigation and adaptation strategies for global change, 11(2), 395-419.

Lehmann, J., and S. Joseph (2009). Biochar for environmental management: science and technology. London: Earthscan.

Liang, B., J. Lehmann, D. Solomon, J. Kinyangi, J. Grossman, B. O'neill, et. al. (2006). Black carbon increases cation exchange capacity in soils. Soil Science Society of America Journal, 70(5), 1719-1730.

Lodhi, A., M. Arshad, F. Azam, M. Sajjad, and M. Ashraf (2009). Changes in mineral and mineralizable N of soil incubated at varying salinity, moisture and temperature regimes. Pak. J. Bot, 41(2), 967-980.

Major, J. (2011). Biochar: a new soil management tool for farmers and gardeners (Report): Appalachian Sustainable Development.

Major, J., J. Lehmann, M. Rondon, and C. Goodale (2010). Fate of soil applied black carbon: downward migration, leaching and soil respiration. Global Change Biology, 16(4), 1366-1379.

Masulili, A., W.H Utomo, and M. Syechfani (2010). Rice husk biochar for rice based cropping system in acid soil 1. The characteristics of rice husk biochar and its influence on the properties of acid sulfate soils and rice growth in West Kalimantan, Indonesia. Journal of Agricultural Science, 2(1), P39.

Novak, J.M., W.J. Busscher, D.L. Laird, M. Ahmedna, D.W. Watts, and M.A. Niandou (2009b). Impact of biochar amendment on fertility of a southeastern coastal plain soil. Soil Science, 174(2), 105-112.

Novak, J.M., I. Lima, B. Xing, J.W. Gaskin, C. Steiner, K. Das, et. al. (2009a). Characterization of designer biochar produced at different temperatures and their effects on a loamy sand. Annals of Environmental Science, 3(1), 2.

Steiner, C., K.C. Das, M. Garcia, B. Förster, and W. Zech (2008). Charcoal and smoke extract stimulate the soil microbial community in a highly weathered xanthic Ferralsol. Pedobiologia, 51(5), 359-366.

Sukartono, W.H.U., Z. Kusuma, and W.H. Nugroho (2011). Soil fertility status, nutrient uptake, and maize (Zea mays L.) yield following biochar and cattle manure application on sandy soils of Lombok, Indonesia. Journal of Tropical Agriculture, 49(1-2), 47-52.

Tagoe, S.O., T. Horiuchi, and T. Matsui (2008). Effects of carbonized and dried chicken manures on the growth, yield, and N content of soybean. Plant and Soil, 306(1-2), 211-220.

Topoliantz, S., and J.F. Ponge (2005). Charcoal consumption and casting activity by Pontoscolex corethrurus (Glossoscolecidae). Applied Soil Ecology, 28(3), 217-224.

Topoliantz, S., J.F. Ponge, D. Arrouays, S. Ballof, and P. Lavelle (2002). Effect of organic manure and the endogeic earthworm Pontoscolex corethrurus (Oligochaeta: Glossoscolecidae) on soil fertility and bean production. Biology and fertility of soils, 36(4), 313-319.

Tryon, E.H. (1948). Effect of charcoal on certain physical, chemical, and biological properties of forest soils. Ecological Monographs, 81-115.

Uzoma, K., M. Inoue, H. Andry, H. Fujimaki, A. Zahoor, and E. Nishihara (2011). Effect of cow manure biochar on maize productivity under sandy soil condition. Soil Use and Management, 27(2), 205-212.

Van, Z. L, S. Kimber, S. Morris, K. Chan, A. Downie, J. Rust, et. al. (2010). Effects of biochar from slow pyrolysis of papermill waste on agronomic performance and soil fertility. Plant and Soil, 327(1-2), 235-246.

Warnock, D.D., J. Lehmann, T.W. Kuyper, and M.C. Rillig (2007). Mycorrhizal responses to biochar in soil–concepts and mechanisms. Plant and Soil, 300(1-2), 9-20.

Widowati, U.W., L. Soehono, D. Shi, and B. Guritno (2011). Effect of biochar on the release and loss of nitrogen from urea fertilization. Journal of Agricultural Food Technology, 1, 127-132.

Yamato, M., Y. Okimori, I.F. Wibowo, S. Anshori, and M. Ogawa (2006). Effects of the application of charred bark of Acacia mangium on the yield of maize, cowpea and peanut, and soil chemical properties in South Sumatra, Indonesia. Soil Science and Plant Nutrition, 52(4), 489-495.

Yip, K., M. Xu, C.Z. Li, S.P. Jiang, and H. Wu (2010). Biochar as a fuel: 3. Mechanistic understanding on biochar thermal annealing at mild temperatures and its effect on biochar reactivity. Energy and Fuels, 25(1), 406-414.

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Pollinators Foraging Activities on Cucumber (*Cucumis sativa* L.) in Chitwan, Nepal

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Abstract

A study was conducted to identify the pollinators and study their foraging activities on cucumber in Chitwan district, Nepal in March to June, 2013. Insect pollinators were collected by sweeping net and pan trap method, while foraging activities were observed in 4 open blocks of cucumber field 6 times a day from 8:00 AM to 6:00 PM in 2 hours interval. Similarly, outgoing and incoming number of Apis cerana F. and A. mellifera L. from the hive were observed in the study area. A.Hymenopteran were most abundant pollinator speciesdominated by A. florea F. followed by A. ccerana. A. dorsata. A. Activities of A. florea were found maximum at 12 noon whereas A. mellifera and A. cerana were more active during 10:00 AM. Both species A. cerana and A. mellifera outgoing number from hive was in peak at 10 AM while incoming toward hive was highest at 12 noon which is appropriate time for cucumber pollination. Thus the honeybee species are the most efficient pollinators of cucumber in Chitwan, Nepal.

Keywords: *apis species., cucumber, foraging, pollination*

Introduction

Mutual relationship has been existed between flowering plants and pollinators throughout evolutionary development by which both are benefited. While pollinators foraging the flowers, energy spent in nectar production by the plants is actually for the pollen transport and out crossing of them by pollinators (Price, 1975). Among the total pollination activities, over 80% is performed by insects and of which bees contribute nearly 80% of the total insect pollination, and therefore, they are considered the best pollinators (Robinson and Morse, 1989). The foraging time of the pollinators also varied with the environmental temperature, flowering period and the nectar content of the flower species.

Cucumber is cross pollinated crops which required ample foraging activities by the pollinators. Flowering phenology, its structures, different blooming time of male and female flower and their emergence in different nodes ensure bee pollination. Ovary and stigma remains receptive throughout the day but anther dehisces when the corolla expands but the pollens remains on the anther as a sticky mass. The maximum pollination occurs in the afternoon therefore the pollinators must forage at the mean

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time. For the maximum production of cucumber it is most important to identify the most efficient pollinator species. In this experiment, number of pollinators and their peak foraging time has been studied.

Materials and method

To find the pollinator fauna of cucumber, sweeping was conducted in field at three stage of crop at 10% blooming, at peak blooming stage and at 10% remaining of blooming. Similarly, pan traps were put in the 1 m distance with alternating yellow, blue, green and white traps in the experimental field. The 2/3rd of the colored pans were filled with water mixed with pril They were replicated thrice in the three blooming stages. All the insect species collected from both methods were identified with the help of faculties and available reference in Institute of Agriculture and Animal Science, Rampur, Chitawan. Then the number of pollinators was converted into relative percentage.

Foraging behavior was studied in open pollinated plots from four replicating blocks which were marked as 5 small plots with area 1 m^2 with the help of string. The numbers of the flower visitors were counted from 8:00 AM to 6:00 PM in 2 hour interval, 6 times a day.

Observations on foraging behavior of honeybees as well as other insect species were recorded in the plots for five weeks after 10% flowering of cucumber. They were counted in each week from 8:00 AM to 6:00 PM in every 2 hours interval per square meter for 5 minutes in each replication. The observation regarding time setting was made with the help of stop watch.

In case of honeybee hives placed in the research area the commencement, cessation, outgoing, incoming and time spent by honeybees/flower were recorded.

Result

Insect pollinators

Seventeen species of the pollinators were found foraging on cucumber flowers. Among them, 10 species belonged to order Hymenoptera, 3 species to Coleoptera, 2 species Diptera and 2 species of Lepidoptera, respectively. Major natural pollinator species of cucumber was Hymenopterans dominated by *A. florea* The flower visitors found in the experimental area are listed in Table 1.

Table 1. Relative abundance of pollinators of cucumber at Gitanagar, Chitwan, Nepal, 2013

S.N.	Pollinator	Systematic position		Relative abundance (%)
		Order	Family	
1	*Apis dorsata*	Hymenoptera	Apidae	12
2	*Apis florea*	Hymenoptera	Apidae	27
3	*Apis cerana*	Hymenoptera	Apidae	24
4	*Apis mellifera*	Hymenoptera	Apidae	6
5	*Nomia* spp.	Hymenoptera	Halictidae	2
6	*Helictus* spp.	Hymenoptera	Halictidae	1
7	*Trigona irridepennis*	Hymenoptera	Miliponidae	1
8	*Megachile conata*	Hymenoptera	Megachilidae	1
9	*Coelioxys* spp.	Hymenoptera	Megachilidae	10
10	*Xylocopidae* spp.	Hymenoptera	Xylocopidae	1
11	*Eristalinus arvorum* (F)	Diptera	Syrphidae	1
12	*Bombilidae* spp.	Diptera	Bombilidae	2
13	*Ixias marianne* (Cramer)	Lepidoptera	Pieridae	1
14	*Chilopoda acuta*	Coleoptera	Scarabaeidae	1
15	*Aulacophora foveicollis*	Coleoptera	Chrysomelidae	4
16	*Coccinella* spp.	Coleoptera	Coccinellidae	5
17	*Pelopodas mathias* ()	Lepidoptera	Hesperidae	1

Foraging behaviors of pollinators

The activity of *A. dorsata* commenced with 1.575 bees/ m^2/5 min on an average at 8:00 AM, which were the lowest and 6.773 bees/ m^2/5 min at 12 noon which was the highest number of bees. The activity declined to 2.055 bees at 6:00 PM.

The average activity of *A. cerana* of all the weeks was the highest at 10:00 AM and it was followed by 12:00 noon, 4:00 PM and 8:00 am of the day. The minimum activity occurred at 2:00 PM and 6:00 PM, which were statistically similar to each other.

Similarly, average of foraging activity of *A. florea* in the five weeks after 10 % flowering, was found highest at 12:00 noon (16.070 bees/m^2/5 min) followed at 10:00 AM (12.23 bees/m^2/5 min), while the lowest activity was observed at 6:00 (2.105 bees/m^2/5 min).

While average activity of *A. mellifera* was found 1.245 bees/m^2/5 min at 8:00 AM. Maximum activity occurred at 10:00 AM, i.e. 4 bees/m^2/5min, followed by 2.815 bees/m^2/5 min) at 12:00 noon. It decreased to 1.045 bees/m^2/5min at 2:00 PM and then increased to 1.995 bees/m^2/5min at 4:00 PM and declined to the lowest level at 6:00 PM (0.810 bees/m^2/5min).

The average number of other pollinators after five weeks of 10% of flowering, 4.493 pollinators/m^2/5 min were observed at 8:00 AM and their peak activity at 10:00 am with

6.080 pollinators/m²/5 min. The activity gradually decreased from 10:00 am to 4:00 PM. The detail of the foraging activity is given in Table 2.

Table 2. Foraging activity of cucumber pollinators at Gitanagar, Chitwan, Nepal, 2013

Average number of pollinators/m^2/5 minute at flowering periods of cucumber					
Time	***A. dorsata***	***A. cerana***	***A. florea***	***A. mellifera***	**Other pollinators**
8:00 AM	1.575^{f}	4.910^{d}	3.680^{e}	1.245^{d}	4.493^{c}
10:00AM	4.670^{b}	11.26^{a}	12.23^{b}	4.000^{a}	6.080^{a}
12:00noon	6.773^{a}	7.950^{b}	16.00^{a}	2.815^{b}	5.605^{b}
2:00 PM	3.178^{c}	2.780^{e}	6.070^{d}	1.045^{e}	4.280^{c}
4:00 PM	2.463^{d}	5.980^{c}	8.445^{c}	1.955^{c}	3.280^{d}
6:00 PM	2.055^{e}	2.750^{e}	2.105^{f}	0.810^{f}	3.390^{d}
CV(%)	3.48	3.89	2.44	4.81	4.73
LSD	0.1783	0.3740	0.2976	0.1430	0.3233
SE	0.05916	0.1151	0.09874	0.04743	0.1072

Number of outgoing and incoming honeybees

The number of the bees for foraging increased up to 10:00 AM in both *A. cerana* and *A. mellifera* with 45.33 and 58.67 bees/5 min. respectively. The lowest number of bees foraged at 6:00 PM with 7 bees per 5 min in *A. cerana* and only 2 bees /5 min in *A. mellifera* The number of incoming bees was the highest at 12:00 noon for *A. cerana* (37.67 bees/5min) and in *A. mellifera* (67/5min). Their number gradually declined and was minimum at 6:00 PM. The detail is presented in Table 3.

Table 3. Outgoing and incoming behavior of *A. cerana* and *A. mellifera* at Gitanagar, Chitwan, Nepal, 2013

Number of outgoing bees from hive/5min.			Number of incoming bees to hive/5min.	
Time	***A. cerana***	***A. mellifera***	***A. cerana***	***A. mellifera***
8:00AM	30.33±1.53	27.0±2.0	10.00±2.00	17.0±3.0
10:00AM	45.33±4.51	58.67±4.51	26.67±3.51	56.33±2.52
12:00noon	35.0±3.61	37.0±2.65	37.67±4.51	67.0±4.58
2:00PM	21.0±6.0	30.0±2.65	22.67±1.53	58.66±4.16
4:00PM	27.67±7.51	18.67±1.53	21.33±3.51	25.0±4.0
6:00PM	7.00±2.65	2.00±1.00	16.00±2.00	10.00±1.00

Discussion

In the experiment, more than fifteen species of insect pollinators were recorded. Hymenoptera found to be the most abundant in the area. Among the five groups of the pollinators *A. florea* was predominant species. Prakash (2002) also reported that the cucumber crop is visited by 27 species of which 16 belonged to Hymenoptera and four each to Diptera, Lepidoptera and Coleoptera. *A. dorsata* , *A. cerana* , *A. florea* and *T. iridipennis* share was more than 82 percent of the pollinators. Thapa (2006) also

reported that along with honeybee species *Aulacophora foveicolis* Lucas, *Chiloloba acuta* were the pollinators of cucumber in Nepa Kapil and Chaudhary (1974) also reported that *A. florea* comprised 33.1% of bee population as cucumber pollinators and the findings are in line with this experiment.

Foraging behavior of *A. dorsata* was found throughout the day. These honeybee colonies were prevalent in Chitwan district. They built hive in large cliff, water tank and underside of the roof of tall buildings (Pokhrel, 2010). Since the honeybee is wild and can tolerate high temperature it was observed in cucumber all day long after 10 percent of flowering of the cucumber. The maximum activity was found during 12:00 noon and it was followed by 10:00 AM and then by 2:00 PM. Dinesh (2003) who reported similar result with present findings on foraging activity of *A. dorsata* on cucumber.

A. cerana foraged throughout the day and maximum activity did occur during 10:00 am. The findings are in close collaboration with Mohan Rao and Suryanarayana (1988) who reported that the peak activity of *A. cerana* occurred at 9:00 am in watermelon. Kulkarni and Dhanorkar (1998) confirmed that *A. cerana* foraged for nectar from 7:00 AM to 3:30 PM and for pollen from 7:00 AM to 3:00 PM in niger, while Panda *et a* (1995) reported that the peak activity of the honeybees occurred from 11:00 AM to 12:00 noon.

The peak activity of *A. florea* was at 12:00 noon which was followed by 10:00 AM and then by 4:00 PM. The honey bees comprised the largest population among all the honeybees in the experimental site. There must be colony near by the experimental site because it was near to the natural habitat of the pollinator. These findings are in line with the Panchbhavi and Rao (1978), Mohan Rao and Suryanarayana (1990) on watermelon. Similar report was found by Mane (2003) on coriander.

A. mellifera activity was peak at 10:00 AM in the morning. There were fewer visits of the species than other honeybee species. The reason might be that European honeybees were kept less by the farmers in that area.

Other pollinators' foraging activity continued throughout the day after flowering. It was observed highest during fourth week of 10 percent flowering. On an average the maximum activity was found at 10:00 AM followed by 12:00 noon and then by 8:00 AM. The findings are in line with Nidagundi (2004) in bitter gourd.

Number of outgoing bees from a hive was the highest at 10:00 AM in both *A. cerana* and *A. mellifera* Number of incoming bees were found maximum at 12:00 noon in *A. cerana* and *A. mellifera* These findings are similar to Dhakal (2003) who observed that number of outgoing bees maximum before noon and it reduced later in both species *A. cerana* and *A. mellifera* He reported that the number of incoming bees were highest at 12:00 noon in both species.

Conclusion

The study was conducted to identify the pollinator species and foraging behavior of pollinators. The most predominant species of insect pollinators of the crop in Chitwan condition is *A. florea* followed by *A. cerana* Peak foraging occurred at 10 AM in case of domesticated honeybee species while that of wild honey bees it was 12 at noon. These honey bee species are the best pollinators for the cucumber production in Nepal.

Reference

Dhakal, G.C. 2003. A comparative study of A. cerana and A. mellifera on pollination of Brassica campestris var. toria and Fagopyrum esculentum Moench. at Rampur, Chitwan. M. Sc. Agriculture Thesis, Institute of Agriculture and Animal Science, Tribhuvan University, Nepa

Dinesh, B.K. 2003. Resource partitioning by honey bees in different crops with special reference to cucumber (Cucumis sativus) and impact of bee pollination on cucumber yield. M.Sc. (Agri.) Thesis, University of Agricultural Sciences, Dharwad.

Kapil, R P. and J.P. Chaudhary. 1974. Biology and utilization of insect pollinators of crop production (A7-Ent-118). First Annual Report (1973-74), Haryana Agricultural University, Hissar, India, p.30.

Kulkarni, S.N. and B.K. Dhanorkar. 1998. Effect of A. cerana indica on niger seed production in Marathawada region. Paper presented at FAO workshop on Sustainable Bee Keeping Development. Dharwad, p.35.

Mane, P. 2003. Pollination potentiality of honey bees in coriander seed production. M.Sc. (Agri.) Thesis, University of Agricultural Sciences, Dharwad, India.

*Mohan Rao, G. and M.C. Suryanarayana 1990, Studies on the foraging behavior of honeybees and its effect on the seed yield of Niger. Indian Bee Journal, **52**: 31- 33.*

Mohan Rao, G. and M. C. Suryanarayana. 1988. Studies on pollination of watermelon (Citrulus lanatus (Thumb.) Mans). Indian Bee Journal 50: 5-8.

Nidagundi, B.R. 2004. Pollination potentiality of honeybees on yield of bitter gourd (Momordica charantia). M.Sc.(Agri.) Thesis, University of Agricultural Sciences, Dharwad, India.

Panchavi, K.S. and J. Rao. 1978. Note on the effect of mixed cropping of niger on the activities of insect pollinators and seed filling of sunflower in Karnataka. Indian Journal of Agricultural Sciences 48: 254-255.

*Panda, P., K. Rath, J. Padhi and P. Manigrahil 1995. Relative abundance and foraging behaviour of common bee species on niger in Parbhani district, Orissa, India. Indian Bee Journal, **57**: 10-14.*

Pokhrel, S. 2010. Climeto-cyclic immigrations with declining population of wild honeybee, A. dorsata in Chitwan Valley, Nepa Journal of Agriculture and Environment 11: 51-58.

Prakash, K.B. 2002. Pollination potentiality of Indian honey bee viz., A. cerana on the production of cucumber (Cucumis sativus (Linn.) S.W.: Cucurbitaceae). M.Sc. (Agri.) Thesis, University of Agricultural Sciences, Bangalore, India.

Price, P.W. 1975. Insect Ecology. John Wiley and Sons, New York. USA.

Robinson, W.E. and R.A. Morse. 1989. The value of honeybees as pollinators of US crops. America Bee Journal 129 (1): 477-487.

Thapa, R.B. 2006. Honeybees and other insect pollinators of cultivated plants: A review. Journal of Institute of Agriculture and Animal Science 21-22: 179-186.

❑

Effect of Chemical Pesticide on Insect Pests and Beneficial Organisms in Nepal

SundarTiwari [1] and Sheela Sharma[2]

Abstract

Various insecticides were tested to find out the mortality percentage for insect pest and beneficial organisms in Chitwan Nepal in 2014. The mortality rate was measured from lowest 60% to 100%. The effects of chemical pesticides were observed very quickly for beneficial organisms like lady bird beetle and honeybees than insect pests. Alphamethrin 10% EC has found more toxic and Imidachlorpid effect has been found low effect for insects. Similarly, the effect of Deltamethrin was found more toxic (mortality 83.33%) followed by Imidachloropid (76.66%) in laboratory condition. However, all pesticides have the toxic affect on all the insects and are comparatively more toxic to natural enemies and pollinators than insect pests.

Keywords: *chemical pesticide, insect pest, NEs, pollinators*

Introduction

Pesticides vary in their activity, which not only impact how they kill arthropod pests but also how they may indirectly influence natural enemy populations. Pesticides may be classified as contact, stomach poison, systemic, and/or translaminar (Ware and Whitecre, 2005, Cloyd, 2011). Broad-spectrum, nerve toxin pesticides such as most of the older pesticides in the chemical classes, organophosphate (acephate and chlorpyrifos), carbamate (carbaryl and methiocarb), and pyrethroid (bifenthrin and cyfluthrin) may be both directly and indirectly more harmful to natural enemies than non-nerve toxin type pesticides ncluding insect growth regulators (kinoprene and pyriproxyfen), insecticidal soaps (potassium salts of fatty acids), horticultural oils (petroleum or neem-based), selective feeding blockers (flonicamid and pymetrozine), and microbials (entomopathogenic fungi and bacteria, and other micro-organisms) (Cloyd, 2006). The non-nerve toxin pesticides are generally more specific or selective in regards to arthropod pest activity with broader modes of action than nerve toxin pesticides (Croft, 1990). From the above evidence it is proved that chemical pesticide has also effect on natural enemies and pollinators in addition to the target pest. Hence, the small study was conducted to know the mortality effect of chemical insecticide for the pest and in natural enemies in laboratory conditions.

Materials and method

The commonly used pesticides were collected from the pesticide dealer of Chitwan and tested in the Rampur Entomology Laboratory in 2014. There were altogether seven treatments and three replications. The experiment was laid out in CRD design.

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The chemical pesticides available in market were collected and tested on different beneficial and harmful organisms. The tested pesticides were:

T1: Doom (Dichlorovus) @ 1ml/lit

T2: Pataka (Profenofos 40EC + Cypermethrin 4 EC) @ 1ml/lit

T3: Cypermethrin 10% EC @1.5 ml/lit

T4: Tridelta (Deltamethrin) @ 1.5 ml/lit

T5: Imidachloropid (17.4% SL) @ 0.5ml/lit

T6: Thril (Alfamethrin 10% EC) @ 1ml/lit

T7: Control

Those chemical pesticides were tested on red pumpkin beetle (RPB), flea beetle lady bird beetle and honey bees. For this, 10 number of each insect were put in to the petri plate and which was replicated thrice for each treatment. The pesticide were sprayed in different concentrations as mentioned in the above treatments details. The mortality percentages of insect and natural enemies were observed at different time intervals. Data were analyzed with MSTAT-C packages and DMRT were done to differentiate the treatment differences at 99% level of significance.

Result and discussion

Effect of chemicals for insect pest, NEs and Pollinators in lab condition

Maximum mortality were recorded by Alfamethrin (80.00%) followed by Cypermethrin (73.33%) whereas least mortality was observed in Control followed by Imidachloropid (Table 1). That might be due to Alphamethrin has contact nature and Imidachlropid has systemic nature.

Table 1. Effect of chemical pesticide on mortality of RPB in lab

Treatments	Insect No.	Mortality %	Live %
Doom (Dichlorovus) @ 1ml/lit	10 ±0.00	66.66ab ±15.28	33.33ab ±15.28
Pataka (Profenofos 40EC + Cypermethrin 4 EC) @ 1ml/lit	10 ±0.00	70.00ab ± 10.00	30.00ab ± 10.00
Cypermethrin 10% EC @1.5 ml/lit	10 ±0.00	73.33ab ± 11.55	26.66ab ± 11.55
Tridelta (Deltamethrin) @ 1.5 ml/lit	10 ±0.00	70.00ab ± 20.00	30.00ab ± 20.00
Imidachloropid (17.4% SL) @ 0.5ml/lit	10 ±0.00	60.00ab ± 20.00	40.00ab ± 20.00
Thril (Alfamethrin 10% EC) @ 1ml/lit	10 ±0.00	80.00a ± 26.46	20.00b ± 26.46
Control	10 ±0.00	0.00b ± 0.00	100.00a ± 0.00
CV %	0.00	27.94	8.08
LSD Value	0.0126	70.56	70.56
P Value	0.01	0.01	0.01
SEM	0.00	9.68	9.68
Significance	NS	NS	NS

90% mortality was due to Alfamethrin because Flea beetle has been affected by contact nature of pesticide. The control treatment was significantly different with other treatments, in which 100% live was recorded (Table 2).

Table 2: Effect of chemical pesticide on the mortality of flea beetle in lab condition

Treatments	Total Larva	Mortality %	Live %
Doom (Dichlorovus) @ 1ml/lit	10 ±0.00	76.66a ±5.77	23.33b ±5.77
Pataka (Profenofos 40EC + Cypermethrin 4 EC) @ 1ml/lit	10 ±0.00	90.00a ± 0.00	10.00b ± 0.00
Cypermethrin 10% EC @1.5 ml/lit	10 ±0.00	83.33a ± 5.77	16.66b ± 5.77
Tridelta (Deltamethrin) @ 1.5 ml/lit	10 ±0.00	83.33a ± 5.77	16.66b ± 5.77
Imidachloropid (17.4% SL) @ 0.5ml/lit	10 ±0.00	76.66a ± 5.77	23.33b ± 5.77
Thril (Alfamethrin 10% EC) @ 1ml/lit	10 ±0.00	90.00a ± 10.00	10.00b ± 10.00
Control	10 ±0.00	0.00b ± 0.00	100.00a ± 0.00
CV %	0.00	8.08	20.21
LSD Value	0.0126	24.32	24.32
P Value	0.01	0.01	0.01
SEM	0.00	3.33	3.33
Significance	NS	S	S

Effect of chemical pesticide for predators and pollinators

The lady bird beetle is sap sucker and more affected by systemic pesticide. Hence, the table 3 showed that Imidachloropid has maximum mortality than other pesticide. The mortality of all other chemical pesticide has been recorded more than 50% but control has not any kind of effect on lady bird beetle.

Table 3: Effect of chemical pesticide on the mortality of lady bird beetle in lab condition

Treatments	Total Larva	Mortality %	Live %
Doom (Dichlorovus) @ 1ml/lit	10 ±0.00	73.33a ±11.55	26.66b ±11.55
Pataka (Profenofos 40EC + Cypermethrin 4 EC) @ 1ml/lit	10 ±0.00	83.33a ± 5.77	16.66b ± 5.77
Cypermethrin 10% EC @1.5 ml/lit	10 ±0.00	86.66a ± 5.77	13.33b ± 5.77
Tridelta (Deltamethrin) @ 1.5 ml/lit	10 ±0.00	90.00a ± 10.00	10.00b ± 10.00
Imidachloropid (17.4% SL) @ 0.5ml/lit	10 ±0.00	93.33a ± 11.55	6.66b ± 11.55
Thril (Alfamethrin 10% EC) @ 1ml/lit	10 ±0.00	83.33a ± 5.77	16.66b ± 5.77
Control	10 ±0.00	0.00b ± 0.00	100.00a ± 0.00
Treatments	**Total Larva**	**Mortality %**	**Live %**
CV %	0.00	8.08	30.08
LSD Value	0.0126	34.37	34.37
P Value	0.01	0.01	0.01
SEM	0.00	4.71	4.71
Significance	NS	S	S

Similarly, the effect of chemical pesticide has always been found more than 50% mortality. Maximum mortality was caused by Profenofos and Cypermethrin mixing pesticide followed by Deltamethrin. The least effect was observed by Imidachlorpid followed by Dichlorovus (Table 4).

Table 4. Effect of chemical pesticide on the mortality of Bees in lab condition

Treatments	Total Larva	Mortality %	Live %
Doom (Dichlorovus) @ 1ml/lit	10 ±0.00	73.33a ±11.55	26.66b ±11.55
Pataka (Profenofos 40EC + Cypermethrin 4 EC) @ 1ml/lit	10 ±0.00	83.33a ± 11.55	16.66b ± 11.55
Cypermethrin 10% EC @1.5 ml/lit	10 ±0.00	80.00a ± 10.00	20.00b ± 10.00
Tridelta (Deltamethrin) @ 1.5 ml/lit	10 ±0.00	83.33a ± 5.77	16.66b ± 5.77
Imidachloropid (17.4% SL) @ 0.5ml/lit	10 ±0.00	76.66a ± 5.77	23.33b ± 5.77
Thril (Alfamethrin 10% EC) @ 1ml/lit	10 ±0.00	80.00a ± 10.00	20.00b ± 10.00
Control	10 ±0.00	0.00b ± 0.00	100.00a ± 0.00
CV %	0.00	12.82	27.36
LSD Value	0.0126	36.75	36.75
P Value	0.01	0.01	0.01
SEM	0.00	5.04	5.04
Significance	NS	S	S

The mortality of tested chemicals for all tested insect has been found more than 60% but the mortality effect by the same pesticide for beneficial insects has been found more than agricultural insect pest. The maximum mortality effect for Red Pumpkin Beetle (*Aulacophora foveicollis*) has been found maximum by Alfamethrin (10% EC) and least damage was recorded by Imidachloroid (17.9% SL). Simialry, more or less same range of mortaliy was also observed for flea beetle (*Monolepta signeta*). Regarding, beneficial insect, effect of Deltamethrin was found highest mortality for lady bird beetle and pollinators and Imidachloropid and Dichlorovus mortality has been found less for lady bird beetle and for pollinators. The effects of pesticides on natural enemies are typically associated with determining direct effects such as mortality or survival over a given time period (24 to 96 hours). While evaluations associated with the direct effects of pesticides on natural enemies are important, what are actually more relevant are the indirect or delayed effects of pesticides because this provides information on the long-term stability and overall success of a biological control program when attempting to integrate the use of pesticides with natural enemies (Jacobs et. al., 1984, Desneux *et. al.*, 2007). Systemic insecticides, when applied to the soil or growing medium, may have minimal direct effects on aboveground natural enemies (both parasitoids and predators); however, they may indirectly influence natural enemies if mortality of prey populations is high (>90%). This results in a reduction or potential elimination of available prey that serve as a food source for natural enemies (Radcliffe, 1972, Bjorksten and Robinson, 2005), making it difficult for natural enemies to locate any remaining individuals

Summary and conclusion

There are direct negative effects of chemical pesticide for human health and environment. The pesticide kills the insect pest, and all other natural beneficial organisms. Farmers have been applying the chemical pesticide for targeting the insect pest but haven't considered that it also kills the beneficial organisms. To give information about the killing effect of pesticide for beneficial organisms and pollinators, the study was done. The tested chemicals have lethal effect for all organisms like insect pest, lady bird beetle and bees. The mortality effect of chemical pesticide has been found more for beneficial organisms than insect pest. Hence, pesticide has more non-target effect than the target effect. The study also helps to search other indirect effects, which are sometimes referred to as sub-lethal, latent, or cumulative adverse effects which may be associated with interfering with the physiology and behavior of natural enemies by inhibiting longevity, fecundity, reproduction, development time, mobility, searching (foraging) and feeding behavior, predation and/or parasitism, prey consumption, emergence rates, and/or sex ratio etc. Finally, it can be concluded that pesticide not only kills the insect but also kills the beneficial organisms and the lethal effect for beneficial organisms has been found more than pest.

References

Bjorksten, T.A. and M. Robinson. 2005. Juvenile and sub-lethal effects of selected pesticides on the leafminer parasitodis from Australia. Journal of Economic entomology. Vol. 156: 122-125.

Cloyd, R.A. 2006. Compatibility of insecticides with natural enemies to control pest of greenhouses and conservatores. Journal of Entomological Sciens. 89

Cloyd, R.A. 2011. Managing insect and mite pest. In: Nau J. (ed). Ball.145 p

Croft, B.A 1990. Arthropod biological control agents and pestiicdes. John Wiley and Sons, New Your. 156

Desneus, N,A. Decourtye and J. Delpuech. 2007. The sub-lethal effects of pesticides on beneficial arthropods. Annual review of entomology. Endosulphan, Environmental entomology. 126

Radcliffe, E.B. 1972. Population responses of green peach apid on potatoes treated with various insecticides. In: proceedings of the North Central branch of the ESA. Red book 2nd Edition. Ball publishing West Chicago. 167-178.

Stapel, J.L. A.M. Corteser and W.J. Lewis. 2000. Disruptive sub-lethal effect of insecticides on biological control: Altered foraging ability and life span of a parasitoid after feeding on the extra floral nectar of cotton treated with systemic insecticides. Biological control, 128

Ware, G.W. and D.M. Whitacre. 2005. The pesticide book. Meister Pro-Informatin Resources Willoguhby, OH.

❑

Environmental Assessment (EA) of Devastating 2015 Gorkha Earthquake: Issues for Assessment

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Abstract

Environmental resources including forest, biodiversity and ecosystem services provides material things essential for our life and they also play an important role in regulating environment. Natural disaster like earthquake has great potential for negative impact on environmental resources, livelihoods and economy. In the context of recent April 2015 Gorkha earthquake in Nepal, this article tries to develop a framework of issues for consideration while undertaking environmental assessment of the earthquake. Similarly, the paper also analyzes what impacts have been created by earthquakes in other parts of the world and status of knowledge on this particular discipline. It is aimed that this paper will provide a general guideline for policy makers and researcher for undertaking study related to environmental impact of the earthquake and may help to develop appropriate policy, strategy and action plans to deal with recovery and reconstruction of in the post-disaster scenario.

Keywords: *biodiversity, EA, earthquake, ecosystem, environment*

Introduction

Environment is the foundation and basis of life and livelihoods for the people living on planet earth. Environmental resources and ecosystem services directly and indirectly strengthen economic growth, improves socio-economic condition, supply materials for development infrastructure and improve quality of life of people(Hamdani and Shah, 2005; Wang and Manga, 2010). Environmental management concerns for environmental protection and improvement of the health of the environment, and advocates the preservation, restoration and/or improvement of the natural environment.

It is evident that ecosystems provides *provisioning services* such as food, water, timber, and fiber; *regulating services* such as such as the control of climate, floods, wastes, disease and water quality; *cultural services* that provide recreational, aesthetic, and spiritual benefits; and *supporting services* such as soil formation, photosynthesis, and nutrient cycling(Millennium Ecosystem Assessment, 2005). An assessment conducted by the Millennium Ecosystem Assessment (MEA) to examine the linkages between ecosystems and human well-being, in particular, on "ecosystem services and the consequences of ecosystem change for human well-being, suggests that people are integral parts of ecosystems, and changes in biodiversity, ecosystems and environmental condition changes in human well-being. It is argued that the harmful effects of the degradation of ecosystem services have adverse impact to vulnerable people that are

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highly dependent on environmental resources (Díaz and others, 2006; Millennium Ecosystem Assessment, 2005).

It is argued that natural disasters create environmental degradation, however, there is little study and attention paid to their interaction. Moreover, disasters damage natural resources and reduce environmental quality, indirectly contributing to increasing poverty which in turn, adds to the vulnerability of both natural and human systems, so further increasing disaster losses(Tran and Shaw, 2007).

Earthquakes are among the most destructive natural events that involve the creation of sesmic waves throughout the Earth's crust. Earthquake has effects on the natural environment either directly linked to the earthquake source or provoked by the ground shaking. Earthquake has impacts such as surface deformation, faulting and geological affects like landslides, soil liquefaction, tree falls, fires, tsunamis, floods and damage to built environment. Moreover, underwater fault ruptures and seismically-triggered landslides can generate destructive tsunami waves in the coastal areas as well as glacier lakes outburst floods (GLOFs) in the downstream of the glacier lakes.

Context

Entire Himalayan belt lies in the seismically active zone posing high risk of earthquake, which has potential for huge loss of life and property and heavy cost to the natural environment as of recent *Gorkha* earthquake. Geoscientists believed that the Main Himalayan Thrust, a plate boundary fault in between the Indian and Eurasian plates, as a major seismogenic fault in the Himalaya to generate most of the earthquakes in the region. Previous records shows that Nepal can expect two earthquakes of magnitude 7.5-8 on the Richter scale every forty years and one earthquake of magnitude of 8+ in Richter scale every eighty years(Chamlagain, 2009). Chronicles suggest that Himalayan region experiences great earthquakes throughout past centuries.

There was great earthquake on 7 June 1255 causing widespread damage in Kathmandu and King Abhaya Malla was killed by the earthquake. Historical account shows that great Himalayan earthquake hit this region in 1803, 1833, 1842 1897, 1905, 1934, and 1950 and at other times that must have been of considerable size(Bilham and others, 1995). In 26 August 1833 earthquake, thousands of buildings were destroyed in Kathmandu and its vicinity and the damage was extensive in the east and less in the west. The 1934 Bihar-Nepal destructive earthquake had devastating impact on environment too beside physical destruction(Pandey and Molnar, 1988). In a book "*Nepalko Mahabhukampa*" General Brahma Sumsher J. B. Rana clearly mentioned that beside ground shaking there was also slumping, landslide and rockslides having extensive destruction(Pandey and Molnar, 1988). Moreover, Bramha Shamsher Rana's, 1935 account of the 1934 great Bihar- Nepal earthquake by Pandey and Molnar (1988)

indicates that it killed more than 8519 people, 80,893 houses destroyed and an additional 120,000 damaged.

In a series of earthquake a devastating earthquake measuring Mw7.8 magnitude hit Nepal on 25April 2015 at 11:56 NST with an epicenter at Barpak of Gorkha district, 77 km (48 miles) northwest of Kathmandu, and at a focal depth of approximately 10-15 km. with a heavy loss of life and properties(Aydan and Ulusay, 2015; MoHA, 2015b). Subsequent aftershock of 7.3 magnitude struck on May 12, causing further loss of life and damage to many already weakened structures(Pathak, 2015; WFP, 2015), which may also have had severe consequences to the environment and natural resources, that needs a systematic examination. The degradation of environmental and ecosystem services from the impact of earthquakes that may have altered the flow of benefits which ultimately worse off significantly livelihoods of people dependent on these resources and to the socio-economic development and human well-being.

Map 1: Map of Nepal showing earthquake epicenter Source: IAEG, 2015

The epicenter of the second largest quake was approximately 80km from the Kathmandu, near the Everest base camp in Namche Bazaar, Dolakha district. According to Ministry of Home Affairs there are 49 quake-hit districts and among them, 14 districts including Sindhupalchowk, Kathmandu, Nuwakot, Dolakha and Dhading have been the hardest hit. The massive quakes and aftershocks have severely injured and killed thousands of people, flattened homes, downed power and destroyed infrastructure, including roads to access affected populations. Official record as of 14 June 2015shows that until now 8,786 people were died; more than 22,303 injured. Among the infrastructure 510,762 private houses, 2,649 government building were fully damaged and 3,617 government buildings were partially damaged(MoHA, 2015a). Among injured, thirty percent of the injured suffers from heads, limbs and spinal injuries. Official record of the MoHA shows that the earthquakes disrupted the lives of

nine million people – almost a third of the population and have significant impact on national economy. Ministry of Home Affairs official statistics shows that as of May 10, 2015, so far 202,157 houses have been fully destroyed and 214,202 houses partially destroyed by the recent quake in the earthquake hit districts. Moreover, data shows that 7,532 schools were destroyed in 49 districts(Pathak, 2015). In most of the destructive earthquakes most attention is paid to rescue, relief, recovery and reconstruction works with much attention paid to social, economic and built environment and service delivery aspects. There is very less attention paid to the environmental aspects especially the assessment of damage of earthquake to the environment and recovery measures to be adopted.

Why environmental assessment?

Natural disasters create serious problems all around the world. Among them earthquakes are the most destructive natural events. Environmental degradation created by natural disaster including earthquake may have long term as well as short term impacts to people impacted by it. Earthquake and environmental degradation are inherently linked, but little attention is paid to their interaction, particularly at local levels(Tran and Shaw, 2007). In order to assess the environmental implication of earthquake we need to develop our understanding and application of the modern technologies to assess the impacts. By developing a framework it helps to assess the real impacts of the earthquake and design human responses, and provide inputs to better disaster preparedness. Until now, there is a big gap understanding disaster and its implication on environment and natural resources and creating enabling environment by developing appropriate environment management policies and programs. In order to bridge the gap, an understanding and assessment of earthquake related environmental impacts and its likely issues to be considered while undertaking any environmental assessment is the need of this time, where such disaster hit the world almost every day like recent Gorkha earthquake in Nepal. In light of this need, this article tries to develop a framework that includes the possible issues which may be taken into consideration during the assessment process itself. Such an assessment may also help to identify, prioritize environmental impacts, and minimize adverse environmental damage by developing appropriate national policy, strategy and actions plans during recovery and reconstruction phase.

Environmental impacts of earthquake: an overview

Earthquakes, also called temblors, can be so tremendously destructive impacts on all sectors including environment. Collapsing buildings claim by far the majority of lives, but the destruction is often compounded by landslides, avalanches, fires, floods, or tsunamis. Smaller temblors that usually occur in the days following a large earthquake complicate rescue efforts and cause further death and destruction. Various environmental impacts of earthquake have been recorded in different countries. For

example, the 1934 great Bihar-Nepal earthquake of magnitude 8.2 created landslide, fissures and reported of new springs emerging and increase of water in the rivers(Pandey and Molnar, 1988). A study of Nakagawa River basin to understand earthquake-induced landslides on sediment yield in a mountain watershed of the 1923 Great Kantō earthquake of Japanese main island of Honshu, found that sediment discharge contains landslide debris that was originated by the Kanto Earthquake that occurred over 80 years ago(Koi and others, 2008). This research finding suggests that the earthquake induced landslide may have long-term impact on sediment yield and river morphology. Likewise, on 26 December 2004 the Indian Ocean undersea earthquake of magnitude 9.3 in the Richter scale has devastated the coastal areas of all the 13 coastal districts of Tamil Nadu, and the Union Territory of Pondicherry. The killer waves, on their way, gorged beaches, crushed coral reefs, smashed thousands of hectares of mangrove forests and refashioned coastlines. Study shows that tsunami created by earthquake triggers high sedimentation; siltation and smothered corals indicate the potential threat posed not only to the fragile coral reef ecosystem, but also to the coastal region of the mainland(Kumaraguru and others, 2005). On March 11, 2011 an earthquake measuring magnitude-9.0 in the Richter scale struck Japan on east of the city of Sendai, Miyagi prefecture and subsequent tsunami created by quake entirely destroyed the coastal cities, destroyed coastal forests and also with an unexpected nuclear power plant accident(Ohta, 2012). Although the forests were destroyed but it served to reduce the power and speed of tsunami and contributed to weakening the disaster(Ohta, 2012).

On May 12, 2008 great Sichuan Earthquake also known as Wenchuan earthquake, measuring 8.0 in magnitude hit large region of Sichuan, China that largely destroyed natural mountainous ecosystems functions in the earthquake-hit areas(Wang and others, 2012). A study of Wenchuan earthquake suggests that it severely damaged ecosystem services. Further it showed that there were catastrophic debris flow events in the earthquake affected area which destroyed hundreds of newly built houses. The heavy monsoon on the earthquake hit zone triggered landslides, erosion, and gully formation(Ni and others, 2012), which may have implication for rebuilding and reconstruction phase.

Beside destruction and damage to built infrastructure and settlements, earthquake has direct implication on forest, biodiversity and ecosystem services. Study shows that biodiversity of total groundwater copepod abundance was significantly declined after the L'Aquila earthquake(Galassi and others, 2014).The 2008 Sichuan Earthquake severely damaged ecosystem and habitat of giant panda (*Ailuropoda melanoleuca*). A comparison of remote sensing data before and after earthquake shows that 354 km^2 (23%) of panda habitat in this region was destroyed, 249 km^2 of which was inside nature reserves(Xu and others, 2009). Moreover the study result indicated that earthquake led to 190.86 km2 of landslide and destroyed 86.97 km2 of forest, 39.33

km2 of shrub, 77.99 km2 of grassland and 33.59 km2 of farmland, respectively. During this earthquake ten hundreds of species were killed and their gene was lost, habitat destroyed(Chen and others, 2012; Vina and others, 2011). The Wenchuan earthquake of 2008 had significant losses to tree and shrub species diversity and richness in earthquake-damaged areas. It is observed that remnant vegetation was found in the majority (80%) of damaged areas, suggesting the potential for forest recovery(Zhang and others, 2011).

It is observed in many earthquakes around the word that earthquake has impact on forests. The 1994 Arthur's Pass earthquake (M_W6.7) in the central South Island, New Zealand induced landslide that caused 74% of the total stem biomass mortality, and such mortality was observed greatest on steep slopes. Data from permanent plot(20x20 m) showed 24.0 ± 5.9 % tree mortality and 22.5 % ± 4.0% tree injury, however, low intensity damage to forest was observed(Allen and others, 1999). A similar study of the 2004 Indian Ocean earthquake on 26 December with a magnitude of 9.3, with its epicenter under the sea had severe impact on the coral reef within the Nicobar and Andaman reefs and damage to mangrove forests due to uprooting and prolonged inundation(Bahuguna and others, 2008).

Critique argues that earthquake-induced crustal deformation and ground shaking can alter stream flow and water levels in wells through consolidation of surficial deposits, fracturing of solid rocks, aquifer deformation, and the clearing of fracture-filling material. Furthermore, stream flow and water levels in wells is related to earthquake magnitude. Changes in stream flow and groundwater levels in wells can occur hundreds to thousands of kilometers from the epicenter of the earthquake(Montgomery and Manga, 2003). Scholar suggests that earthquakes affect groundwater hydrology both in short term as well as well as in mid-terms. For example, 2009 L'Aquila earthquake of 6.3 on the Richter scale in Italy showed some mixed results. Study showed that some springs were disappeared, immediate discharge increase in some cases, a progressive increase of the water table elevation by one meter and a sudden lowering of the water table in the recharge area in other case(Falcone and others, 2012). However, it is argued that hydrological responses depend on several factors, such as earthquake magnitude, distance from the epicentre, and local geological conditions(Wang and Manga, 2010).

A study by Wu and others (2010) using remote sensing satellite multispectral images indicated that the Wenchuan earthquake affected the land use/cover, environment, fragmentation of habitats, damage to vegetation and created danger of flooding downstream of the lakes (Wu and others, 2010). Moreover, it is observed that massive landslide has been associated with the 2005 M_w 7.6 Kashmir earthquake(Kaneda and others, 2008). The 2008 Wenchuan earthquake (M_s = 8.0), directly caused more than 15,000 geohazards in the form of landslides, rockfalls, and debris and caused more than 10,000 potential geohazard sites, especially for rockfalls, reflecting the susceptibility of

high and steep slopes(Yin and others, 2009). It is argued that when landslide trigger it affects the character and quality of rivers, streams and groundwater flow, reduce forests cover, reduce habitats for wildlife and fish(Geertsema and others, 2009).

Methodology

In order to understand the relationship between earthquake and environmental impacts, extensive literature review was conducted especially looking at environmental impacts in the post disaster scenario in different parts of the world. The methodology employed for rapid assessment of the damage to environment including biodiversity and ecosystem services were the review of published articles, grey literature, personnel observation, field visits, interviews, newspaper reporting and government reports. In order to provide a guide for undertaking rapid environmental assessment as well as a detailed assessment of the earthquake, issue under different thematic area were identified. The basis for the identification of issues for assessment were mainly guided by the existing knowledge on this particular discipline and also looking on the environmental impacts of the earthquake in the aftermath of the recent Gorkha earthquake.

Result

Environmental impact of Gorkha earthquake: a preliminary review

Food and Agriculture Organization (FAO) of the United Nations conducted a quick assessment of forest loss caused by recent Gorkha earthquake in six districts of Nepal (Dhading, Dolakha, Gorkha, Nuwakot, Rasuwa, Sindhupalchok) using post-earthquake satellite imagery from the Google Crisis Response, comparing pre- and post-earthquake satellite images. This study suggests that 1.9 percent (240 km²) of the total forest area of the priority districts was damaged. Extrapolating the loss of forest base line data to all 14 affected districts (except Kathmandu, Bhaktapur and Lalitpur having negligible forest area) total loss of forest found to be 23, 375 hectares. Study further indicated that most damage to the forest was by landslide, especially on steep slopes, within river valleys(NPC, 2015).

The earthquake had severe impact on food security and livelihoods of people as two-thirds of Nepalese depend on subsistence agriculture for their living. As the earthquake struck on the wheat harvest season the production of wheat will be decreased due to disturbances in harvesting and damage to the crop(FAO, 2015). Similarly, there was significant loss of stored crops, seeds, loss of agricultural tools, animal losses and damage to irrigational canal and agriculture infrastructure.

A quick post disaster need assessment (PDNA) conducted by National Planning Commission (NPC) suggests that seven protected areas (PAs) affected by recent earthquake as well as two Ramsar sites i.e. *Gosaikunda* and *Gokyo*. The seven PAs

account for almost half of the total area under protected area that provide important habitats for several endangered fauna of global significance such as red panda, snow leopard and musk deer. Endangered fauna may have been impacted by earthquake; however, without a detailed assessment, the extent of damage cannot be quantified.

Institution plays a great role in conservation and management of natural resources. Scholar argues that the quest for sustainability cannot be reached top-down and that institutions on a local level are crucial in that development, through collective action(Congleton, 2007; Ostrom, 2005). The recent *Gorkha* earthquake had severely affected local resource governance institutions of the protected area, wildlife, forest, natural resources, and community forest user group (CFUG). Out of a total 894 office buildings affected under MoFSC, 569 buildings were completely damaged. Moreover, 407 Community Forest User Group (CFUG) office buildings were also damaged that may have direct implication for sustainable natural resource governance at local level. Survey report shows that forestry and national park staffs and infrastructures have been damaged by quake. There is a chance of increased poaching and smuggling of the endangered species in the affected areas in the absence of collective institutions. Similarly, eco-tourism infrastructure including mountaineering and trekking routes, bridges and hotels were damaged. The entire village of *Langtang*, which was located along a popular trekking route near the base of Mount *Langtang*, was completely buried by ice and rocks shaken loose by devastating earthquake(NPC, 2015). Moreover, the Gorkha earthquake and subsequent powerful aftershock brought destruction throughout the *Khumbu* region. The quake triggered a massive avalanche on Mount Pumori that swept through Everest Base Camp, killing more than 18 people with several seriously injured.

Nepal posses hundreds of glacier lakes and they are being expanded in a faster rate due to global warming. Study conducted by ICIMOD indicates that many glacier lakes may pose threat of outburst and among them Tsho Rolpa, Imja, and Thulagi are in critical condition. There is a reporting that Tsho Rolpa Lake has developed cracks by recent earthquake, however detail study is need to confirm it. As gauge readers at Tsho Rolpa and meteorological stations at *Langtang* and *Beding* were completely damaged due to earthquake there is a risk of not getting up to date weather information which has implication for disaster response preparedness.

Satellite imagery, aerial photographs and visual observation showed that numerous landslides have been emerged from earthquake, especially in hill slopes. A quick survey by PDNA suggests that a total area of 5150 ha has been affected by landslide. Due to the impact of devastating earthquake on May 24, 2015 a massive landslide has blocked Kali Gandaki River at Baisari in Bhagwati VDC of Myagdi district early Sunday morning that buried 25 houses in Baisari. The blockage of river created an artificial dam of 300 meter high. Many districts including parts of Syangja, Parbat, Myagdi, Baglung,

Gulmi, Palpa and Nawalparasi districts were in considered in danger if the dam broke suddenly. Luckily, without massive disaster the artificial dam began to overflow 15 hours after the debris blocked the river without human casualty. This is just an example of the landslide triggered by recent earthquake. In the upcoming monsoon season it is believed that there will be dozen of such incidents as thousands of landslides has been appeared after the earthquake in the hills and mountains of Nepal(ekantipur, 2015a; ekantipur, 2015b).

Alternative Energy Promotion Centre (AEPC) record shows that about 146,767 units of Improved cook stoves (ICS), 16,721 domestic biogas installations and 70,000 solar installations were reported destroyed during earthquake that have direct impact on carbon emission. An estimate shows that more than a billion bricks will be required for the reconstruction, that demand for coal imports of 1.577 million tons leading to around 39,000 tons of CO^2 emissions. In addition, brick firing will emit around 2800 tons of suspended particulate matters. Moreover, as most of the chimney of the brick kiln in Kathmandu valley has been broken and they are operating without repair that may have direct impact on health of people living nearby and further exacerbate the air pollution problem in Kathmandu valley.

The risk of chemical pollution is also high. The lead contained in paint of destroyed houses poses risk of lead contamination as such debris are dumped into pen space or nearby water bodies. There is not any record of damage to the storage of hazardous chemicals and entering to the environment. However, during debris management, due attention has to be paid if there is any sign of such hazardous chemicals and substances buried under the debris.

Issues to be considered during environmental assessment

Environmental Assessment (EA) is intended to help to survey the environmental impacts, hazards and risks of a particular event on a particular location during a specific period of time(UNHCR, 2009). Moreover, environmental assessment also serve as a valuable tool for a more comprehensive assessment that enables improving understanding resulting risk, especially in the environment sector. It is argued that collection and analysis of data is necessary to understand nature of damage to the environment and its likely and significant impact on livelihoods and economy. Environmental assessment not only helps to identify current environmental problems but also helps to formulate goals and priorities for early identification of mitigation, and enhancement option, ways to avoid or minimize adverse environmental impacts and approaches for recovery.

Various techniques and methods can be applied for the collection of data and information like field observation, sample collection, laboratory analysis, measurement, record of GOs and NGOs, use of GIS and remote sensing techniques, news reporting,

telephone interview and other secondary information. Any impact or changes in the environmental condition can be analyzed comparing with baseline information before the earthquake. This paper tries to identify some of environmental issues that need to be considered while carrying any kind of assessment after the earthquake or in any other kind of disaster situation. The table presented below provides a simple checklist of issues that may be considered while carrying out environmental assessment after post earthquake situation.

Table 1: Issues for environmental assessment of earthquake

S.No.	Sector	Environmental issues	Quantity/Area
1.	Forest	Damage to forest by landslide	Area affected
		Damage to forest by fire	Area affected
		Damage to forest by avalanches	Area affected
		Damage to forest by Tsunami	Area affected
		Damage to loss by GLOFs	Area affected
2.	Biodiversity	Species affected	Number of species affected/lost
		Habitat destruction	No. of wild life species lost their habitat
		Damage to national park/protected area affected	No. of national park/protected area/conservation area affected
		Endangered species affected	No. of endangered species affected
3.	Ecosystem services		
3.1	provisioning services	Food	No. of people/ community affected
		Water	No. of people affected by the unavailability of water for drinking and irrigation
		Timber	No. of population without supply of timber
		Fibre	No. of people without supply of fibre
3.2	regulating services	control of climate	No. of communities, villages affected from micro climatic changes
		floods	Area impacted by floods and damage to crops, settlements and life and property
		wastes	Amount of waste generated
		disease	No. of people affected by diseases
		water quality	Number of people without safe drinking water
3.3	cultural services	recreational	Area/No. of picnic spot, open space damaged/destroyed
		aesthetic	Area without vegetation,
			Area of landslide and no. of affected populations
		spiritual benefits	No. of species lost

S.No.	Sector	Environmental issues	Quantity/Area
			No. of temple/ stupa/ churches/ mosque destroyed Total population affected without religious places of offerings
3.4	supporting services	soil formation, photosynthesis, nutrient cycling	Indirect cost of damage/restoration Cost of photosynthesis, pollination, nutrient transfer, benefit to agriculture and implication to food security
4.	Land degradation	landslide soil erosion gully formation watershed degradation Agriculture land destroyed by landslide	Areas affected by landslide Area affected by soil erosion No. of gullies formed Area of watershed affected Area of agriculture land destroyed by landslide
5.	Flooding	Sedimentation/siltation Loss of crops Damage to reservoir/lake, development infrastructure	Area affected by sedimentation No. of people, settlement affected by flooding No. of reservoir, dam, lakes damaged/affected by floods No. of development infrastructure damaged/affected by flooding
6.	Agriculture	Impact to agriculture land destroyed by landslide, floods, Tsunami, avalanches Fertility lost by damage to agricultural land	Area of agriculture land destroyed by landslide, floods, Tsunami, avalanches Fertility lost by damage to agricultural land
7.	Climate change	GHG emission through deforestation, landslide, GLOFs, avalanches, loss of forest, use of coal, fossil fuel	Quantity of GHG emission through deforestation, landslide GLOFs, avalanches, loss of forest Quantity of GHG emitted due to use of coal, fuel-wood and fossil fuel
8.	Land Use	Conversion of forest land	Area of forest converted to other uses
9.	Water source	Damage to springs Affected river/streams without water Damage to irrigation canal/drinking water schemes and affected population	No. of springs destroyed/affected No. of river/streams without water No. of irrigation canal/drinking water schemes destroyed/affected and affected population
10.	Wetland	Impact to wetland Species affected by the damage of wetland Impact to wetland services	Area/No. of wetland affected/destroyed No. of species affected by the damage of wetland Area affected that depend services from wetland

S.No.	Sector	Environmental issues	Quantity/Area
		Population/communities affected through the impact on wetland	No. of people/community affected through the impact on wetland
11.	Pollution	Air pollution	Population affected by air pollution
		Solid waste/sewage/debris	Quantity of solid waste generated No. of sewerage system damaged and affected population Quantity of debris generated
		Noise pollution	Level of noise pollution and affected population
		River/groundwater pollution	No. of river/stream polluted
		Use of plastic	Quantity of plastic waste generated
		Hazardous waste	Quantity of hazardous substances/chemicals release to the environment
12.	Alternate/renewable energy	Damage to renewable/alternative energy system	No. of solar, wind, biogas plant damaged/destroyed No. of improved cooking stoves damaged/destroyed
13.	Ecotourism	Impact on ecotourism	No. of ecotourism site affected/damaged No. of trekking routed./trails damaged No. of hotels/home stay affected
14.	Fire	Forest fire House fire	Area of forest destroyed by fire No. of houses destroyed by fire

Source: author

Discussion

There is concern that what will be the rate of recovery of environment resources including forests, biodiversity, ecosystem services, water resources, landslide and erosion after the devastating *Gorkha* earthquake of April 12, 2015. It is argued that there will be immediate impact of the earthquake on environment sector having direct bearing on the ecosystem services provided by the environmental resources and negative impact to people directly dependent on these resources. Without a systematic assessment of environmental damage of the earthquake there is always a risk that such damage and its impact on local livelihoods, well-being and national economy will be overlooked during national development planning. A study conducted in China after the Wenchuan earthquake shows that after four years of the earthquake once denuded sites found to be 30- 70% recovery of vegetation cover in only one year(Zhang and others, 2011). Nature always heals the damage that has been made to environment due to natural disasters. However, as the natural healing process is slow, impact on the affected population and social and economic implication of loss of environmental and ecosystem services will be high at least in the short run. The impact of such disaster like earthquake will be high

and irreparable, if we do not act timely to restore the damage and assist people on their endeavor aiming to restore and improve the natural resources base during for reconstruction and recovery.

Conclusion and recommendation

Preliminary report clearly shows that devastating *Gorkha* earthquake has adverse impacts on forest, biodiversity and ecosystem services, agriculture, water resources and development infrastructures that may have severe consequences on social security, economic growth, food security and livelihoods and well-being of people directly dependent on these resources. Moreover, development infrastructures like irrigation canals, drinking water sources, roads, electricity, reservoirs were destroyed that has impact on national economy and living standard of people. Some hydroelectricity power plant were destroyed and several dams and glacier lakes are in danger of outburst which may further trigger landslides, flood, and damage to agricultural land, forest, biodiversity, and ecosystem services. A complete understanding of earthquake disaster scenario on environment is essential before any such event happen, not only for preventive measures to be applied but equally important for assessing social, economic and environmental loss and damage of the earthquake and subsequent corrective measure to be undertaken. At this stage there is sufficient evidence that the recent Gorkha earthquake had negative impact on environmental resources, however, the extent of damage can be verified only after the full assessment of the environmental implication of the earthquake. It is suggested that the restoration of earthquake-damaged ecosystems needs effective restoration policy and planning(Jing and others, 2012). In nutshell, the environmental assessment may help to formulate comprehensive national environmental policy, strategy and action plan to address the challenges of catastrophic impact of earthquake and provide an opportunity for further research.(ekantipur, 2015a)

References

Allen, R.B., P.J. Bellingham, S.K. Wiser 1999. Immediate damage by an earthquake to a temperate montane forest. Ecology 80(2):708-714.

Aydan, Ö., R. Ulusay 2015. A Quick Report on the 2015 Gorkha Earthquake(Nepal) and its Geo-Engineering Aspects. The International Association for Engineering Geology and the Environment (IAEG), France. 1-26 p.

Bahuguna, A., S. Nayak, D. Roy 2008. Impact of the tsunami and earthquake of 26th December 2004 on the vital coastal ecosystems of the Andaman and Nicobar Islands assessed using RESOURCESAT AWiFS data. International Journal of Applied Earth Observation and Geoinformation 10(2):229-237.

Bilham, R., P. Bodin, M. Jackson 1995. Entertaining a great earthquake in Western Nepal: Historic inactivity and geodetic tests for the present state of strain. Journal of Nepal Geological Society 11(1):73-78.

Chamlagain, D. 2009. Earthquake scenario and recent efforts toward earthquake risk reduction in Nepal. Journal of South Asia Disaster Studies 2(1):57-80.

Chen, L., F. Wu, W. Yang, J. Zhang 2012. A comparison on ecosystem services before/after "5.12" Wenchuan earthquake. Acta Ecologica Sinica 32(5):271-273.

Congleton, R.D. 2007. Elinor Ostrom, Understanding Institutional Diversity. Public Choice 132(3):509-511.

Díaz, S., J. Fargione, F.S. Chapin, D. Tilman 2006. Biodiversity loss threatens human well-being. PLoS biology 4(8):e277.

ekantipur. 2015a Blocked Kali Gandaki river flows again (with photos). May 24, 2015 Online reporting. http://www.ekantipur.com/2015/05/24/top-story/blocked-kali-gandaki-river-flows-again-with-photos/405627.html.

ekantipur. 2015b Landslides block Kali Gandaki; dam burst unlikely (Update). May 24, 2015 reporting. http://www.ekantipur.com/2015/05/24/top-story/landslides-block-kali-gandaki-dam-burst-unlikely-update/405582.html.

Falcone, R.A., V. Carucci, A. Falgiani, M. Manetta, B. Parisse, M. Petitta, S. Rusi, M. Spizzico, M. Tallini 2012. Changes on groundwater flow and hydrochemistry of the Gran Sasso carbonate aquifer after 2009 L'Aquila earthquake. Italian Journal of Geosciences 131(3):459-474.

FAO. 2015. Nepal earthquakes.http://www.fao.org/emergencies/crisis/nepal-earthquake/en/. Food and Agricuklture Organization (FAO) of the United Nations, Rome, Italy.

Galassi, D.M., P. Lombardo, B. Fiasca, A. Di Cioccio, T. Di Lorenzo, M. Petitta, P. Di Carlo 2014. Earthquakes trigger the loss of groundwater biodiversity. Scientific reports 4.

Geertsema, M., L. Highland, L. Vaugeouis 2009. Environmental impact of landslides. Landslides–Disaster Risk Reduction: Springer. p 589-607.

Hamdani, N.H., S.A.H. Shah 2005. Earthquake 2005: Some Implications for Environment and Human Capital, MPRA Paper No. 9519. University of AJ &K, Muzaffarabad, Pakistan.

Jing, X.F., Y.L. Chen, H. Chen, Z.Y. Cai 2012. Discussion on the Reconstruction of the Wenchuan Earthquake-Damaged Ecosystems. Applied Mechanics and Materials 209:1668-1673.

Kaneda, H., T. Nakata, H. Tsutsumi, H. Kondo, N. Sugito, Y. Awata, S.S. Akhtar, A. Majid, W. Khattak, A.A. Awan 2008. Surface rupture of the 2005 Kashmir, Pakistan, earthquake and its active tectonic implications. Bulletin of the Seismological Society of America 98(2):521-557.

Koi, T., N. Hotta, I. Ishigaki, N. Matuzaki, Y. Uchiyama, M. Suzuki 2008. Prolonged impact of earthquake-induced landslides on sediment yield in a mountain watershed: the Tanzawa region, Japan. Geomorphology 101(4):692-702.

Kumaraguru, A., K. Jayakumar, J.J. Wilson, C. Ramakritinan 2005. Impact of the tsunami of 26 December 2004 on the coral reef environment of Gulf of Mannar and Palk Bay in the southeast coast of India. Current Science 89(10):1729-1741.

Millennium Ecosystem Assessment. 2005. Ecosystems and human well-being: Island Press Washington, DC.

MoHA. 2015a. Incident Report of Earthquake 2015. Government of Nepal, Ministry of Home Affairs. http://drrportal.gov.np/.

MoHA. 2015b. Nepal Earthquake 2072 : Situation Update as of 11th May. Ministry of Home Affairs, Kathmandu, Nepal. http://drrportal.gov.np/document/documentdetail/14.

Montgomery, D.R., M. Manga 2003. Streamflow and water well responses to earthquakes. Science 300(5628):2047-2049.

Ni, H., W. Zheng, Y. Tie, P. Su, Y. Tang, R. Xu, D. Wang, X. Chen 2012. Formation and characteristics of post-earthquake debris flow: a case study from Wenjia gully in Mianzhu, Sichuan, SW China. Natural Hazards 61(2):317-335.

NPC. 2015. Nepal Post Disaster Needs Assessment (PDNA). National Planning Commission (NPC), Kathmandu, Nepal.

Ohta, T. 2012. The role of forests in the Great East Japan Earthquake and sustainable forest management and its usage.

Ostrom, E. 2005. Understanding institutional diversity Princeton University Press: Princeton University Press, Princeton.

Pandey, M.R., P. Molnar 1988. The Distribution of Intensity of the Bihar-Nepal Earthquake of 15 Jan.1934 & Bounds on the Extent of the Rupture Zone. Journal of Nepal Geological Society 5(1):22-44.

Pathak, B. 2015 An Impact Assessment of a Great Earthquake in Nepal. TRANSCEND Media Service.

Tran, P., R. Shaw 2007. Towards an integrated approach of disaster and environment management: A case study of Thua Thien Hue province, central Viet Nam. Environmental Hazards 7(4):271-282.

UNHCR. 2009. FRamework for Assessing, Monitoring and Evaluating the environment in refugee-related operations: Module III Rapid Environmental Assessment. United Nations High Commissioner for Rufugees (UNHCR). p 1-33.

Vina, A., X. Chen, W.J. McConnell, W. Liu, W. Xu, Z. Ouyang, H. Zhang, J. Liu 2011. Effects of natural disasters on conservation policies: the case of the 2008 Wenchuan earthquake, China. Ambio 40(3):274-284.

Wang, C.Y., M. Manga 2010. Hydrologic responses to earthquakes and a general metric. Geofluids 10(1-2):206-216.

Wang, Y., B. Fu, P. Xu 2012. Evaluation the impact of earthquake on ecosystem services. Procedia Environmental Sciences 13:954-966.

WFP. 2015. Nepal: Earthquake, Nepal Situation Report #6. World Food Programme (WWF).

Wu, F., B. Yu, M. Yan, Z. Wang 2010. Eco-environmental research on the Wenchuan Earthquake area using Disaster Monitoring Constellation (DMC) Beijing-1 small satellite images. International Journal of Remote Sensing 31(13):3643-3660.

Xu W, Wang X, Ouyang Z, Zhang J, Li Z, Xiao Y, Zheng H. 2009. Conservation of giant panda habitat in South Minshan, China, after the May 2008 earthquake. Frontiers in Ecology and the Environment 7(7):353-358.

Yin, Y., F. Wang, P. Sun 2009. Landslide hazards triggered by the 2008 Wenchuan earthquake, Sichuan, China. Landslides 6(2):139-152.

Zhang, J., V. Hull, W. Xu, J. Liu, Z. Ouyang, J. Huang, X. Wang, R. Li 2011. Impact of the 2008 Wenchuan earthquake on biodiversity and giant panda habitat in Wolong Nature Reserve, China. Ecological research 26(3):523-531.

❑

Need of Genetic Improvement of Honeybee Colonies in Nepal

Suroj Pokhrel, Ph.D.[1]

Abstract

An intensive review of available literatures was made to find the need of genetic improvement of Apis cerana Fab. and A. mellifera Lin. colonies in Nepal in 2015. Nepal is enriching in honeybee biodiversity with different 5 species and a number of subspecies/ ecotypes, with a wide genetic variability. There are several sub species/ecotype of native A. cerana and the sub species of A. mellifera Lin. kept by bee keepers is unidentified. Honeybees are cross breed by nature and use of genetic variability on selection and breeding could have great advantages for beekeepers. The study found that the adoption of good beekeeping practices that includes selection of best suited species/sub-species, colony selection and reselection for ***"line breeding"*** *of each domesticated species in each apiary level with individual colony should be a routine job of individual beekeepers. It may have significant role to minimize the negative behavior, imparting good colony characters, with pulling all good genes in a colony and contribute to raise the productivity of honey and hive products in Nepal. Moreover, identification of ecotype, development of breeding stocks, maintenances of parent lines,* ***hybrid breeding*** *that includes, drone and queen rearing, artificial insemination, queen banking and proper re-queening should be initiated for advance beekeeping in Nepal.*

Keywords*: breeding, crossbreed, ecotypes, honeybee, insemination*

Introduction

Origin, evolution and species diversity

Honeybees are notably the most plesiomorphic living species originated about 35 million years ago in South and Southeast Asia (Smith *et. al.*, 2000). The evolutionary sequences of these species started with Synapis or Electrapis to *Apis florea* Fab., *A. dorsata* Fab. *A. laboriosa* Smith, *A. cerana* Fab. and *A. mellifera* Lin. during miocene to post glaciatious period. Several geographical races have been reported from different regions of the world (Ruttner, 1987.). In Nepal there exist four native honeybee species: three open nesting honeybees (*A. florea, A. dorsata* and *A. laboriosa*) and one close nesting, half way domesticated type (*A. cerana*) with different geographical races and one more exotic species *A. mellifera* which is imported and promoted in Terai of Nepal from 1996 (Pokhrel, 2005).

A. cerana also known as the Asiatic hive bee occurs from 60 m to 3500 m in Nepal. The average honey production of a full grown *A. cerana* colony in Nepal is 8.1 kg/year (Pokhrel, 2005_a). It is a best pollinator of crop plants and wild flora in Nepal. Biometric analysis of the samples of bees from Nepal comprise distinct allopatric populations of *A. cerana* occurs in the foothills and mountains of the Himalayas. The morphometric

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measurement suggests that *A. cerana* from Nepal can be classified into three sub-species: *A. cerana cerana* found in the western hills, *A. cerana himalaya* distributed in the eastern hills and *A. cerana indica* in Terai, Inner Terai and central hills of Nepal. *A. cerana cerana* is known as a golden honeybee and is superior among the ecotypes in terms of production. Whereas, *A. cerana indica* is known as black and poor bee which produces a small amount of honey (Pokhrel, 2014). There have been reported 100000 colonies of these bees in wall/log hives, modern hives and hollow tree trunk in forest of Nepal.

A. mellifera was originated in Eastern Africa and spread to Northern Europe. It is the most commonly domesticated species and the third insect to have its genome mapped. There are many subspecies of this bee that have adapted to various local geographic and climatic environments, and in addition, hybrid strains such as the Buckfast bee have been bred in Europe (Ruttner, 1987.). It was imported in Nepal in 1996 and kept by the Terai beekeepers. Presently there are about 25,000 *mellifera* beehives in Terai. This bee has high floral fedality and provides better opportunity to uni-floral honey production. It is a good producer of honey and propolish. The average honey yield of *A. mellifera* colony in Nepal is 28.7 kg/colony/year (Pokhrel, 2005_a). It is a good pollinator of crop plants. However, it is facing the highest level of interspecies competition on nectar and pollen collection with the native honeybees (*A. cerana* and *A. dorsata*) in Terai and Inner Terai because of their similar body sizes (Pokhrel, 2013).

Negative behavior of domesticated honeybees

A. cerana usually swarms two times; once in summer (March-May) and once in winter (November-December) with higher frequency (Verma, 1990). Absconding is a common behavior of this bee which is inter-related with Varroa and other pest incidence. It produces hissing sound, shakes the body, and produces alarm pheromone and stings to its enemies for defense. These behaviors vary situation to situation with different degree with sub-species/eco-types and are related to the production and productivity of the hive products (Pokhrel, 2009).

A. mellifera is the carrier of *Tropilaelaps clareae* Delfinado and Baker to *A. dorsata* colonies. Adaptation of *A. mellifera* against the native predators, co-existence with other honeybee species and need of specific colony management practices eg feeding, migration, queen management are the emerging issues to promote this species (Pokhrel and Thapa 2008).

Good colony characters

Different species of honey bees have different good characters with different degree with their sub-species/eco-types and with individual colonies. Based on these good characters colony selection should be made (Pokhrel, 2009). The good characters include:

1. Better productivity of the hive products eg. *A. cerana* c*erena* gives 3 folds honey yield than *A. cerena indica*.
2. Good defense behavior: eg *A. cerana* are good defensive to hornets and wasps than *A. mellifera.* Stingless honeybees losses their defense capacity, allow robbing to others.
3. Quick colony recovery in honey flow seasons. eg. some of the colonies maintain lower population during off seasons and recover quickly during unset of honey flow seasons. These colonies definitely have better productivity.
4. Good domestication behaviors like minimum swarming, absconding behavior no have robbing tendency and low stinging behavior are the prerequisite for the better domestication. Supersedureness discourages absconding and swarming.
5. Adaptation to harsh weather conditions in different geography is a good colony character.

Honeybees are cross breed by nature

Honeybees are cross breed by nature (Pokhrel, 2001). Many neighboring colonies practices drone rearing upon them receive swarming impulse from the neighboring swarming prune colonies. Subsequently, the colonies start preparation of swarming starting from queen cells building and queen rearing. Queen rearing needs comparatively shorter period (16 days) than drone rearing (24 days) (Pokhrel, 2005a). Usually the mature drones of 22-24 days after their emergence are eligible for mating. Whereas, the queen ready to mate from 2 days of her emergence and ends after 25 days.

The mating time of the queen differs on their body sizes. Larger queen usually mates late afternoon where, smaller one mates earlier, before noon. This has been adopted to escape from their predators (Pokhrel, 2005a). Eligible drones from all the hives around 26 km periphery, fly to drone congregate area for mating, which is several miles up in the sky. Queen bee fly from the hive and detect the drone congregate area with the help of her oligomorphic organ located in her antennae. Upon entering the queen in the drone congregate area the drones attempt mating. She gets multiple mating with several drones from different colonies with different genetic background (John *et.al*.,2015). Thus, honeybees are notably crossbreed in nature.

The sperms received by the queen from multiple mating with different drones (some time up to 50 drones) will be collected in her spermatheca (special sac of reproductive organ). These sperms are used to fertilize the eggs from which the diploid female (worker or queen) produces. Eggs not fertilized with these sperms produces drones which are haploid in nature.

Supersedure in honeybees' colonies

Superseding is a kind of inbreeding phenomenon of honeybee colonies, where the old

queen appears egg laying together with her daughter queen in the same colony, some time with different or the same face of a brooded comb. There is some disadvantage of this inbreeding, which may cause an increase in non-viable brood (more pop-holes in areas of sealed brood). However, in practice, supersedure is probably to be welcomed over 5-7 years period, after which new brood is necessary either by natural swarming or queen introduction (Brown, 1985). Moreover, Coda (1997) states that these superseding colonies are rare treasure, i.e. a supersedure strain and an old queen still laying together with her daughter queen on an adjacent frame is a pearl of great price and this is a strain which is well worthy for future propagation. Supersedure queen (outside the main swarming season) are also more liable to mate with brother drones, so that there is the likelihood of perpetuating the existing good (or bad) characteristics (Brown, 1985). Coda (1997) found that all the supersedure daughter queens would not be the same but there was every chance that some of them would inherit the longevity and possible supersedure characteristics of their parent mothers. House (1997) guessed that some five percent of colonies with 2 year old queens are in the state of supersedure each year which are special strain of the bees. Pokhrel, 2005_a also reported some 6 percent of *A. mellifera* colonies superseding each year in Chitwon, Nepal.

Taranov (1959) advised to take out the surplus young bees from the superseding colonies and set a new colony to prevent supersedure. We can propagate this new-found treasure in the normal way by taking out the old lady and raising queens from her eggs by whatever means of queen-rearing by dividing the colony into a number of nuclei, giving one ripe queen cell to each nucleus and strengthening the colony by the addition of brood bees or honey and pollen stores from other strong colonies. The old queen can be left on the parent stand making sure that it is well provisioned and strengthen it further if necessary (Coda, 1997). Young queens produced by supersedure can be very good, and there are great practical advantages that no bees are lost from the work force by swarming, and that there has been no check in the egg-laying.

Polaczek, (1996) argued that already small reduction in the fitness of a queen in smaller colonies can influence the colony developing in a bad manner, so that re-queening is necessary. However, supersedure provides a young queen in the colony, which can be most profitable as she imparts a positive development of honeybee colony like rapid population growth and imparting higher storage of the hive products. Pokhrel (2005a) found that the supersedure colonies supersede in September-November in Chitwan, Nepal. These colonies rarely swarms and have ability to defend against brood mite, can store more hive products and rear more broods in sub-sequent winter honey flow in Terai Nepal. Liakos *et. al.* (2003) also reported that the highest number of sealed brood (worker and drone) of *A. mellifera macedonica* colonies appeared during the spring of the second year, compared to that of the first year, because of replacement of the queens by supersedure which were normally found the highest during the end of May to early June and decreasing till the end of December.

Justification and objective of the study

Hence, different species, sub species and individual colonies reserves different positive and negative behaviors. Pulling all good genes with minimizing bad characters is the theme of honeybee breeding and colony selection. *A. cerana* have different ecotypes with genetic variability in Nepal. We do not know the exact subspecies of *A. mellifera* we imported in Nepal. We do not have genetic map of these bees. Negative selection of these colonies for selling as the breeding stocks is a serious threat of beekeeping, resulted lower productivity of hive products in Nepal. Hence, improvement on this is most urgent.

Materials and method

Documentation and publication on improving honey genetics of bee colonies in Nepal has been demanded by the beekeepers and federation of Nepal Beekeepers in 2014. Based on the experiences, literature review, consultation to experts and beekeepers information were collected and synthesized to prepare this report.

Results and discussions

Negative practice of colony selection in Nepal

Species and sub species identification

Honeybees have geographic distribution by their subspecies/eco-types. However, beekeepers do not know about the subspecies of honeybees (*A. cerena* and *A. mellifera*) they are keeping. All most all the beekeepers are unknown about the sub-species wise characteristics of the colonies in Nepal (Pokhrel, 2005a).

Cross mating and colony characters

Beekeepers know about the mating behavior of queen bee. However, they are not aware about, why different colors of workers appear in same hive in different seasons. The adult bees from different drones, differently colony, different in colors, may have different good or bad characters. However, it does not carry any meaning in a honeybee colony. But it's upon the character of the mother queen, her inherent characters derives from her mother and father.

Colony division practices

Beekeepers in Nepal are adopting colony division practice with emergency queen. Even, they do not select the shape and size of the emergency queen cells. This resulted inferior queens. In addition, the beekeepers are not known about the genetic character of the drones, they mate with emergency queen that may impart the inferior quality to the queen (Pokhrel, 2005a).

Queen and drone production practices

Some of the beekeepers in Nepal are practicing artificial queen rearing. However, another aspect of colony improvement is drone rearing which is totally neglected. In the other hand, the perfectness in queen rearing skill frequently questioned. Together with that, the parent colony selection for queen rearing is also very weak. All these reflected negative impact on productivity of hive products in Nepal.

Negative colony selection and colony sale

All beekeepers in Nepal sale the colonies which is less attractive for the production of hive products. They sale weak colonies, less defensive to enemies, suffered from brood mites, diseased, having slow colony recovery characters and prone to stinging. The new beekeepers are always purchasing such colonies for to use as breeding stocks and use for colony multiplication. This negative selection of the breeding stock/primary colonies in Nepal is a bottle neck for colony improvement and reflecting low honey productivity (Pokhrel, 2009).

Suggested method of genetic improvement

Genetic improvement is a way of uniting the quality genes of honeybees for to have better yield of hive products, providing better pollination services, pest resistance, domesticating and better honey flow colony recovery etc., with the better queen in parent and production colonies. It is possible by different steps given below:

Selection of species and sub species

Geographical allocation of the honey bee species both wild and domesticated in Nepal is necessary. Among domesticated honeybees *A. cerena* are most suited in hills and *A. mellifera* in Terai. However, inter migration of colonies in both the regions is equally feasible. Moreover, the genetic character at subspecies and individual colony/queen level is a matter to be considered on colony improvement (John. *et.al*. 2015).

Colony selection and maintenance

The good characters of a colony/sub species are the basses for colony selection. It is a routine job of each beekeeper should follow regularly. Selection at once dose not works longer, like in livestock. Each colonies they changes their queen, when she exhausted the sperms in her spermatheca. Workers kill the imperfect queen through balling. Then they rear another queen from the fertilized egg of the past queen. Here, it is not sure the new queen mate with her brothers. Cross mating is a greater chance that may incorporate inferior gene leading colony deformations. Thus, genetically maintenance of the colonies is a serious issue that should be considered.

Breeding and colony maintenance

Breeding and colony maintenance is a difficult task in beekeeping. It indicates the overall development and performance of a honeybee colony.

Genetic mapping

Colony selection is the pre-requisite for honeybee breeding. The colonies with good characters need to have their genetic mapping at sub species/ecotype level. Genetic mapping shows the loci of gene in chromosome/that needs transfer while breeding.

Parent line selection and maintenance

Once the parent line selected, maintenance of the breed is another task. It is for maintaining the mother stocks for queen and drone rearing. Hence, the quality of the queen denotes all colony character and it is guided from her inherent characters from both the mother queen and father drones (up to 50 in numbers).

Drone and queen rearing

The colonies used for drone and queen rearing should be strong enough with full of mature broods and good storage of hive products. It is possible only in the unset of flow season, usually in November or may be in April/May in Nepal. The characters of the queen less colony used for drone and queen rearing have no value on maintaining colony characters. However, the brood taken from the mother colony for drone and queen rearing carries a significant meaning on honeybee breeding and colony improvement.

The queen and drone rearing colony should made queen less before 24 hours. Drone rearing should start a week earlier than the queen rearing. Hence, the brooding period of drone takes about 7/8 more days than the queen. Drones get ready for mating only after 22-24 days of their emergence. Moreover, the queen gets ready for mating from 2-25 days of her emergence. Drone rearing needs especial foundation comb to be inserted in between the brooded combs of the parent colony. After laying eggs from the parent queen, the comb should be taken out and re inserted between the sealed brooded comes (taken from queen right colonies) in a prepared drone and queen rearing colony. After 22-24 days of emergence of the drones, they can be used for semen collection or can be used for natural mating in a controlled or isolated yard.

For queen rearing, the normal comb foundation will be inserted in between the brooded combs of the queen right parent colony. After developing the comb, the queen will lay eggs in both the faces. After 3rd day of the laying larvae will emerge out. The rearing comb should be taken out from the parent colony and used for pick up the larvae for queen rearing. The queen cup holed in a cell bar should be kept in between brooded come of queen less, queen rearing colony. The one day larvae with the help of grafting needle can be transfer in a primed queen cell. After grafting, the cell bar should be

replaced in between the sealed brooded frames in queen rearing colony. After the cell capping around in 12/14 days, the matured queen cell should be separated and used for colony division.

Crossing and Selection

Nepal is enrich in honeybee bio-diversity. These are three wild honeybees: *A. florea*, *A. laboriosa, A. dorsata*, and one half way domesticated *A. cerana*, all native honeybees in Nepal. There are several ecotypes of *A. cerena* with a wide genetic variability in Nepal. It is a boon for honeybee breeder. However, the precious sub species *A. cerana*, cerana found in south Jumla-Kalikot has been neglected and need to exploit on *A. cerena* breeding. The good characters of this species need to transfer to other widely distributed eco-types: *A. cerana* indica and *A. cerana* himalaya (Pokhrel, 2009). There are several methods of genetic improvement of honeybee colonies:

1. Line breeding: It is a most common method of honeybee breeding in world. In Europe in 1930's, a 4-year selection project, using simple line-breeding resulted in an increase in honey production from 148 to 398 pounds per colony. Two important features of this project were culling the poorer queens and grafting from the best queens (John *et.al*., 1915). It is a most feasible method of honeybee breeding for the beekeepers and GoN farms in Nepal. It is a method commonly adopted for breeding and selecting with in relatively small, closed population. Steps for line breeding are:

- Colony selection based on colony characters.
- Drones and queen rearing from the best selected colonies.
- Allow natural mating of the queen with drones reared from selected colonies.
- Re-queening
- Repeat routinely the procedure of colony selection, drone and queen rearing and re-queening

It slowly improves the genetic characteristics of the species and the particular colony. But there is a minor chance of losing vigor because of possible inbreeding. However, this method can assist to establish a perfect stocks and preparing new queen line that is a variety.

2. Hybrid breeding

When inbred lines or races of bees are crossed, the hybrid progeny often are superior to either parent for one or many traits. This phenomenon is called hybrid vigor or heterosis. Hybrid-breeding programs in bees are complicated than line-breeding. At least, three inbred lines must be to have new hybrid. There is a need to mate hybrid queen to inbred drones so that both queen and workers in production colonies can be hybrids.

Four-line hybrids also are possible and commercially available. A systematic scheme for 4 line hybrid breeding is illustrated below (Fig. 1):

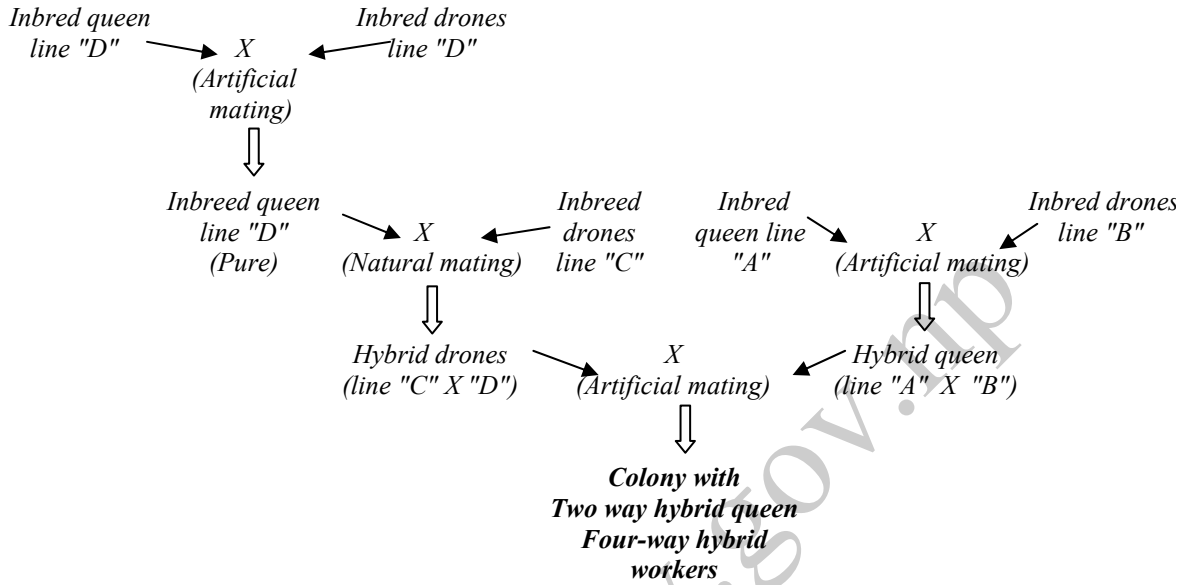

Fig. 1: A systematic scheme for 4 line hybrid breeding of honey bees

All the queens produced in this way will be uniform in appearance, needs to requeen each year. Whereas the worker bees will be variable in appearance, unless the color markings of the parent lines are very similar (John. *et.al.,* 1915).

Artificial insemination/isolated mating

Bee breeding with artificial/ instrumental insemination begins in 1940s (John *et.al.,* 1915). Artificial insemination is a modern technique for honeybee breeding. Mature drones of age 20-24 days should be captured. After head massage with gentle press on their abdomen can brings the semen sac with genitalia out. With the help of a syringe the fresh semen can be collected and used for artificial insemination. Semen from 5-10 drones may be sufficed for a queen at a day. The semen can be preserve for a long time and can be transported but it needs sophisticated. The queen needs to give the anesthesia with carbon dioxide for artificial insemination. A hand microscope can make eases for opening the genital with a forceps and transferring the semen in vagina by the semen collected syringe. Afterward she can be safely released in the colony. All the process should be finished within few minutes. The inseminated queen then should be caged with attendant workers and ample food and replaced in the queen less colony. She may go for mating flight before starting egg laying within 2-3 days, because of her unawareness on she is inseminated. Insemination should be repeated for 3-4 times with 2 days intervals. In the other hand, the mating process can be in controlled mating yard or may be in a isolated distance where, with the targeted drones there are not any other

colonies of the same species within 20 kilometers periphery. But isolation mating carries limited value (John *et.al,* 2015).

Queen banking/requeening

The mated or inseminated queen from the mating nuclei can be caged with ample food and attendant workers and can be banked in a single hive for emergency uses and sale. This makes assurance of quality queen to requeening as per necessary (Pokhrel, 2014).

Mutations

More than 30 specific visible mutations have been observed in bees. Most of them are recessive. These mutations are valuable for pest resistance and behavioral changes (John *et.al.*1915).

Colony division

The mated or inseminated queen, each can be used for colony division/colony propagation. It should be carried out in honey flow season with favorable climate.

Conclusion and recommendation

Different species, sub species and individual colonies of honeybees reserves different positive and negative behaviors. Better productivity, good defensive behavior, minimum robbing swarming and absconding, quick colony recovery in honey flow seasons, better adaptation to harsh weathers and low stinging are the good colony characters. Genetic variability of domesticated honeybees *A. cerana* and *A. mellifera* could have great advantages for beekeepers for their colony improvement through selection and breeding. Pulling all good genes with minimizing bad characters is the theme of honeybee colony selection and breeding. Here are some recommendations for honeybee colony improvement in Nepal:

- Negative selection of honeybee colonies for selling as the breeding stocks should be immediately stopped.
- Selection of best suited honeybee species/sub-species followed by colony selection and reselection for **"line breeding"** of each domesticated species should be a routine job of individual beekeepers.
- Identification of ecotypes, development of breeding stocks, maintenances of parent lines for **hybrid breeding** that includes, drone and queen rearing, artificial insemination, queen banking and proper re-queening should be initiated for advance beekeeping in Nepal.

References

Brown, R. 1985. Beekeeping: A seasonal guide. B.T. Bastsford Ltd., London. 192 pp.

Coda, M.M. 1997. Long-lived supersedure strains. Online Communication (hhtp://www.bibba.com).

House, M. 1997. Ted Hopper guide to bees and honey. Regent Rub. Service, China. pp. 51-52, 126-137.

John, R.H and E.R. Thomas 2015, Breeding and Genetics of honeybees. Beekeeping in United States.

Liakos, V., C. Batzios and M. Kokkinis. 2003. Adult bee's population capped brood production and pollen storage in colonies of Apis mellifera macedonia in Greece. In: Final Program and Book of Abstract, XXXVIII Apimondia, International Apicultural Congress, Ljubljana, Slovenia, August 24-29, 2003. 353: 726.

Pokhrel, S. 2001. Impact of supplement diets on brood and honey production of cross breed honeybee, Apis mellifera L. Master's thesis, Tribhuvan University. 123 pp.

Pokhrel, S. 2005. Behavior and Management of Domesticated and Wild honeybees (Apis spp.) in Chitwan, Nepal. Ph.D. dissertation. Tribhuvan University. 240 p.

Pokhrel, S. 2009. Publications and collections of Suroj Pokhrel. Crop Development Directorate, Department of Agriculture, Kathmandu, Nepal. 1171pp

Pokhrel, S. 2013. Honeybees. Biological Diversity and Conservation. In Jha, P.K., F.P. Neupane, M.L. Shrestha and I.P. Khanal (ed). Nepalpedia. Nepal Academy of Science and Technology. 2:373-381

Pokhrel, S. 2014. The good environment for beekeeping. SMARIKA, National Science day. In: Suroj Pokhrel and et. al. (ed). Ministry of Science and technology. 2:5-11

Pokhrel, S. and R.B. Thapa. 2008. Beekeeping in Chitwan: Problems and Possible Solutions. Journal of Plant Protection Society. 1:122-136.

Polaczek, B. 1996. Over wintering of spare queens in small unit. Pszczlinicze Zeszytynaukowe. XL (2):241-242.

Ruttner, F. 1987. Biogeography and Taxonomy of Honeybees. Springer-Verlog, London PP 1-279.

Smith, D.R., L. Villafuerte, G. Otisc, M.R. Palmer 2000. Biogeography of Apis cerana F. and A. nigrocincta Smith: insights from mtDNA studies. Apidologie. 31:265-279.

Taranov, G.F. 1959. The production of wax in the honeybee colonies. Bee World 40:113-121.

Verma, L.R. 1990. Beekeeping in Integrated Mountain Development: Economic and scientific Respective; Oxford and IBH publishing Co. India, pp 36410.

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Air Pollution in Lumbini, the World Heritage Site

Nabina Maharjan[1] and Suroj Pokhrel[2]

Abstract

Lumbini, the birth place of Lord Buddha, UNESCO World Heritage Site and the pride of Nepal is the most pristine place for Buddhist as well as culture lover of the world. Recent scientific studies witness damage on most of the ancient structures inside the Lumbini protected zone as a result of air pollution created by industries surrounding the site. The black spots on the Ashoka Piller seen from visual inspection during the field visit in 2014 also support the arguments presented by scientific communities. Hence it can be concluded among various pollutions, air pollution is one of the major environmental pollution that is affecting world cultural and religious heritage along with the world civilization.

Keywords: *Ashoka pillar, monuments, pollution, sulphur*

Introduction

The Ancient Monument Preservation Act 2013 BS of Nepal describe ancient monuments as temples, monuments, houses, abbey, cupola, monasteries, stupa, bihar and others that have historical and scientific value in terms of national and international points. The European Union on the other hand describes cultural heritage as "our debt to the past and promise to the future" its protection is very important (Chapuis, 2009). The ancient monuments plays important role in understanding valuable cultures of past and has been considered as the segment of DNA of indigenous people of a community (Guruswamy *et. al.* 1999).

Degradation in the quality of any components of environment due to natural to anthropogenic causes is termed as pollution of the particular aspects. Such as Air pollution is degradation in quality of air because of pollutants from industries or other natural processes which make it unfavorable to be used in normal condition.

Air pollution and its impact on historically important monuments, statues and others are becoming common issues that have attracted world archeologists as well as environmentalists. Many studies globally showed that the monuments carrying cultural as well as religious values have been damaged by air pollution arising from various industries as well as other man made activities (Tidblad, *et. al.* 2012; Sablier and Garrigues, 2014).

Air pollution is one of the important threats to the world cultural heritage (EU, 2009). Air pollution imposes negative impacts on both material as well as economic resources.

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Air pollutants such as SO_x, NO_x, CO_2, and many others enhance corrosion in the monuments damaging the aesthetic beauty of the cultural valuables (Themistocleous, *et. al.* 2012).

Additionally air pollution may cause collapse of the stone statue causing joints and binding of the monuments weak and fragile. Due to air pollution from nearby industries, Taj Mahal in India has suffered from Marble cancer (Burke, 2010). Similarly atmospheric pollution was considered one of the important factors for lost of nearly half of the European tangible cultural heritage (Chapuis, 2009).

Nepal is the country well known for its rich cultural, religious and biological diversity. Among the cultural legacy of the country, Lumbini situated in the Rupandehi district, is the most important religious site. It is the secret place for world Buddhist community as this is the birth place of Lord Buddha. The area has been enlisted as the UNESCO cultural world heritage site since 1997. The Lumbini area consists of numbers of temples, monuments and monasteries along with the Ashok Pillar. The place consists of the remaining dated back to more than 2600 years. The place is culturally and religiously important, and one of the major assets that introduce Nepal to the international community. Hence conserving such place is important to maintain the status of the country as it is related to the name and fame of the country. Studies related to these issues are very few in context of Nepal.

The Lumbini protected zone (LPZ) consists of the religious and cultural heritage covers area of 15 km aerial distance from north east, waste and south within Nepal (Pouedl, *et. al.* 2013). The area is covered by 57 industries of which 30 were brick factories, 11 cement factories, 11 steel production factories and remaining others (Pouedl, *et. al.* 2013). As per Industrial Promotion Board, the industries emitting carbon were not allow operating in the LPZ and should be established 800 m away from both side of Lumbini-Bhairahawa road (Pouedl, *et. al.* 2013).

There have been various researches related to the impact of air pollution on the archeological or historical important monuments, monasteries, statues and others. As air pollution is very common along with the industrial development, their consequences in the cultural and archeological heritage have not been raised. Hence this article is believed to provide the collection of such studies which would help in the formulation of the rules and regulations to conserve cultural and religious heritage of the country.

Methodology

For the study many national as well as international articles, books, online documents related to the subject matter were reviewed and analyzed carefully. A field visit to the Lumbini Protected Zone was conducted to visualize the real scenario in and around the Lumbini in 2014.

Result and discussion

Causes/Sources of air pollution in Lumbini

The study conducted from 2010 to 2013 in the Lumbini area shows remarkable evidences that the sulphur production from the nearby industries is one of the major reasons for the degradation of cultural and religious structures of the Limbuni area (Meucci, 2013; Pouedl, *et. al.* 2013). The industries around the LPZ might be one of the major sources of air pollution in the area along with the transboundary sources of air pollution. The marker stone of the area was found with gypsum, the pollutant derived from air dust and from the atmospheric pollution rich in sulphur dioxide (Meucci, 2013). The major anthropogenic source of sulphure dioxide includes burning of fossil fuel which contains sulphur such as coal, oil and gases (Smith, *et. al.* 2011).

Effect of air pollution in Lumbini

The very popular monument inside the Lumbini religious site is the Ashoka Pillar which has been damaged by various reasons. The Ashoka pillar stands as the very distinct example of the presence of industries around the area. The pillar has many black spots as a result of sulphur produced from the nearby industries (Meucci, 2013; Pouedl, *et. al.* 2013). The black spots on the surface of the Ashoka pillar consist of chlorites and feldspars which is considered major player in the degradation process of the Pillar (Meucci, 2013). Furthermore the exterior of the native sculpture in the area has also found with calcite, dolomite and gypsum (Meucci, 2013).

Legal bindings

Environment Protection Act (2053) and Environment Protection Regulation (2054) emphasize on protection of surrounding environment and polluting environment is considered offence. The Ancient Monument protection act (1956) of Nepal talks about protection of ancient monument of age more than 100 years and gave power to Government of Nepal to any action for the protection and prevention of cultural heritage from being misused. The Act gave power to protect the ancient heritage but it failed to address damage caused by pollution due to rapid industrial growth along with haphazard urbanization. Industrial Enterprises act 1992 (amended 2010) speaks about rules and regulations that governs industries of the country. It talks about the development and expansion of the industries in the environmentally sustainable. The amendment of the Act also emphasize on the implementation of environment friendly technologies. None of the above mentioned legal documents talk about the distance that should be made by industries form the cultural or religious heritage site.

Conclusion and recommendation

Hence the related national and international studies provide enough proofs that haphazard industrial development without environmental concerns are damaging the

ancient cultural heritage of the world. Concern about environment is very important to carryout development activities. Based on the3 conclusion above, following recommendations are made:

1. Use of air pollution control system should be made compulsion in the industries around the world heritage site
2. The industries around the area should be routinely monitored and penalties should be made for those not following the rules
3. Strictly only green vehicles such as rickshaw, cycle or electric vehicles should be allow to drive inside the heritage site
4. Green belt of at least 10 meters should be maintained around the industries
5. Industries should switch to cleaner energy such as CNG (Compressed Natural Gas), LPG (Liquefied Petroleum Gas) and others.
6. The Ashoka pillar can be covered by glass frame for temporary protection but for long term the source of air pollution affecting the pillar should be permanently removed.
7. Study related to the effect of transboundary air pollution source on the monuments in Lumbini Protected Zone is lacking, hence such studies are recommended.

Acknowledgement

We would like to acknowledge Department of Environment for its support to conduct the field visit along with the members of the Lumbini Development Trust and Vikshu Bibekananda for their valuable support to prepare this article.

References

Burke, J. 2010. The Guardian in 6 January, 2015, from http://www.theguardian.com/world/2010/dec/02/taj-mahal-threatened- pollution. Downloaded on 6th January 2015.

Chapuis, M. 2009. Preserving Our Heritage, Improving our Environment. European Commission, Belgium.

Government of Nepal 1956. Ancient Monument Protection Act. Accessed in 2 January 2015 from http://www.lawcommission.gov.np/index.php?option=com_remository&Itemid=25&func=startdown &id=1087&lang=en. Downloaded on 2nd January 2015.

Government of Nepal 1997. Environment Protection Act. Accessed in 2 January 2015 from http://www.lawcommission.gov.np/index.php?option=com_remository&Itemid=18&func=fileinfo&id=9&lang=en. Downloaded on 2nd January 2015

Government of Nepal 1997. Environment Protection Act. Accessed in 2 January 2015 from http://www.lawcommission.gov.np/site/en/content/environment-protection-act-2053-1997. Downloaded on 2nd January 2015.

Government of Nepal 1992. Industrial Enterprises Act. Accessed in 2 January 2015 from http://www.lawcommission.gov.np/index.php?option=com_remository&Itemid=25&func=startdown &id=28&lang=en .Downloaded on 2nd January 2015.

Guruswamy, L., J.C. Roberts and C. Drywater 1999. Protecting the Cultural and Natural Heritage: Finding Common Ground. Tulsa Law Journal: 713-744.

Meucci, C. 2013. Conservation of Archaeological remains.UNESCO, Kathmandu.

Poudel, D., A. Kala, B. Suman , R. Sharmila, P.S. Dambar, B. Saroj, S. Anjana, G. Sunil, Y. Prahalad 2013. Environmental Impact Assessment of Industrial Development around Lumbini, the Birth Place of the lord Buddha, World Heritage Property.IUCN, UNESCO, Kathmandu.

Sablier, M. and P. Garrigues 2014. Cultural Heritage and its Environment: an Issue of Interest for Environment Science and Pollution Research. Environmental Science Pollution research: 5769-5773.

Smith, S.J., J.V. Aardenne, Z. Klimont, R.J. Andres, A. Volke and S.D. Arias 2011. Anthropogenic sulfur dioxide emissions. Atmospheric Chemistry and Physic 1850 (2005): 1101-1116.

Themistocleous, K., A. Nisantzi, A. Agapiou, D.D. Alexakis, D.G. Hadjimitsis, V. Lysandrou, S. Perdikou, A. Retalis and N. Chrysoulakis 2012. Long Term Monitoring of Air Pollution on Monuments and Cultural Heritage Sites in Cyprus Using Satellite Remote Sensing. Heritage in the Digital Era: 145-167.

Tidblad, J., V. Kucera, M. Ferm, K. Kreislova, S. Bruggerhoff, S. Doytchinov, A, Screpanti , T. Grøntoft, T. Yates, D. Fuente de la, O. Roots, T. Lombardo, S. Simon, M. Faller, L. Kwiatkowaski, J. Kobus, C. Varotsos, C. Tzanis, L. Lrage, M. Schreiner, M. Melcher, I. Grancharov, N. Karmanova 2012. Effects of Air Pollution on Materials and Cultural Heritage: ICP Materials Celebrates 25 Years of Research. International Journal of Corrosion1:6.

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Instruction for submitting paper to the *Journal of Environment Sciences* (JoEnvSc)

For the first time Department of Environment (DoEnv) is going to publish the Journal of Environment Sciences (JoEnvSc). JoEnvSc shall publish original (not published or submitted for publication elewhere) research and review articles written in english from the Nepal and other interested scientists/experts in the field of environment sciences. Besides the research or review articles, research notes may also be published in JoEnvSc. Research findings from a single season or location may be accepted as Research Note if the findings are of exceptional interest.

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Abstract

Every manuscript (article) must have a short abstract (not more than 250 words), which should be complete itself but it should be concise and clear without any cited references. Abstract should highlight rationable, objectives, year of experiment (review) materials and methods, important results and conclusion written in a manner so that is suitable for dirrect reproduction in some abstracting journals. Key words (not more than 5 words) should be written below the abstract in alphabetical order.

Introduction

It should give appropirate background and explain the things that are proposed. It should include short introduction to justify the research and relevant reviews and with paper literatue reviewed citations state the objectives clearly (not more than 200 words)

Methodology

This should include description of experimental materials, procedures and statistical design used as well as method/s to analyze results. New methods should be described in detail and for methods developed by earlier researcher/s, only reference may be cited. However we prefer detail methodology. Report the location, georeferences (altitude, latitude and longitude etc. and date of experiment conducted.

Results and discussion

Results and discussion will be either under separate or under combined headings (around 500 words). Table and figures should be illustrated below the text. Results should be presented in a concise manner. Discussion part should not repeat the results but should explain and interpret the data based on the published relevant studies. Insert graph/s and table/s whereever necessary and number them sequentially within each paper/article

Conclusion and recommendation

The conclusion, recommendation and possible impact (if any) should be consized and based on the supporting data.

Units of measurement and statistical analysis

All units and measures whould be in the metric system or in the International System Units (SI) and should be abbreviated for technical values. Currency exchange rates should be in US$ along with the local currency for the appropriate date for any prices cited. For statistical analysis use analysis of variance (ANOVA) to separate means. Authors are encouraged to use valid statistical tools/software to analyze the data.

Acknowledgement

Acknowledge the person/s and or institution/s, if necessary, who actually helped to achieve the objectives of the research.

References

Only the papers closely related to the authors' work should be referred in the text by author's family name and the year of publication and be cited in an alphabetical order. The style of the reference citation should be as below:

Journal

- *Ahmad, R. 1989. A note on the migration of Apis dorsata in the Andanman and Nicobar Islands. Bee World 70 (2): 62-65.*
- *Deodikar, G.B., A. L. Ghatge, R. P. Phadka, D. B. Mahindra, K. K. Kshirsagar, S. Muvel and C. V. Thaker. 1977. Nesting behavior of Indian honeybee III. Nesting behavior of Apis dorsata Fab. Indian Bee J. 30: 1-12.*

Book

- *Crane, E. 1990. Bees and beekeeping: Sciences, practice and world resources. Heinemenn Newnes, Oxford, UK. 274 pp.*
- *Pokhrel, S. 2010. Behaviours of honey bee species and colony management in Nepal. LAMBERT Academic Publishing GMBH and Co. KG. 234p.*

Contribution to Book/ Proceedings

Frisch, K.V. 1967. The dance language and orientation of bees. In: Morse R.A. and F.M. Laigo (eds.). 1969. Apis dorsata in the Philippines. The Beknap Press, Harvard Univversity,. Cambridge, USA 93 pp.

Sihag, R.C. 1998. Eco-biology of the giant honeybee (Apis dorsata) in semi-arid sub-tropical climates of India. In: M. Mastsuma, L.R. Verma, S. Wongsiri, K.K Shrestha (eds.), Asian bee keeping: Progress of research and development. Oxford and IBH publishing Co. Pvt. Ltd. pp. 50-52.

Singh, A.K. 2000. Species of honeybees and their importance. In: R. Singh, P. Kumari and H. Chand (eds.), Manual on honeybee management. Apiary Unit, Rajendra Agricultural University, Bihar, Pusa. pp 20-21.

Thesis/Desertation

Pokhrel, S. 2005. Behavior and Management of Domesticated and Wild Honeybees (Apis spp.) in Chitwan, Nepal. Ph.D. dissertation. Tribhuvan University. 240 p.

Proceeding

Mahindra, D.B., K.S. Muvel, K.K. Kshirsagar, C.V. Thakar, R.P. Phadke and G.B. Deodikar. 1977. Nesting behavior of Apis dorsata. Proc. Int. Beekeep. Conger. 26: 299-300.

Singh, Y. 1980. Beekeeping in Uttar Pradesh-A review. In: Proc. Intl. Conf. Apic. Trop. Climmate. 2:211-226.

Annual report

- *ACAP. 2013. Conservation Education & Extension Programme (CDP): Improved Sanitation Support. In: Annual Report-2013. National Trust for Nature Conservation, Khumaltar-Lalitpur, Nepal. PP.9-10.*
- *CCD. 2014. Annual Report.*

Web material

- *Pretty, J. 2003, Genetic modification: Overview of benefits and risks. Accessed in 5 June, 2005 from http://www.essex.ac.uk/ces/. Downloaded on 20th Nov. 2009.*

Table

Each table with a number and proper title heading (caption) should be prepared and presented above the table. Use simple grid table without complex formatting structures. Use single (*) and double asterisks (**) to indicate statistical significance and have priority in this order to show 5 and 1% levels of significance, respectively. Do not repeat information in the text presented in charts or graphs. Use 10 font size and bold table heading.

Figure

Do not repeat data both in table and figures. Either use table, or graph or figure. Each Figure and/or graph with a number and the proper title heading should be drawn or prepared below the graph/figure.

Page limit

The page limit for the main research articles is not more than ten typed pages in single space including tables, figures and references.

Format for review or features articles

The review or feature article is much different from the main research articles in that contains detailed description of certain topics researched or investigated earlier by concerned scientists or technicans. As in the main research article, it should contain abstract not exceeding 250 to 300 words. Each topics should have an appropriate heading and/or sub-headings with relevant tables and figures numbered separated but sequentially for each review article. At the end of each article, all discussed items should be summarized and the conclusion should be drawn. All the relevant references

should be cited. Authors are requested to choose modern topics of interests to the readers. The review of feature articles should not be of more than 10 pages.

Format for research notes

It is same as of full research paper expect the duration of study for research note could be of one year/season study.

Special attention

- Use standard abbreviation such as **g** for gram and **cm** for centimeter and so on.
- Use realistic formatting not the artistic formatting without giving any jargons and complexity.
- For table, graph and figures use title case such as **Figure 1. Protected areas in Nepal.**
- Do not merger unnecessary rows and column in the table to make more complex formatting.
- Try to be realistic and straight forward to describe findings.
- Do scientifically whatever you want to do.

Font:

- Times New Roman
- Main title: 14 font bold, Sub title: 12 font bold, 3rd title: 12 font bold and italic, Fourth title: 12 font non bold and italic, whole text 12 font not bold.
- Main title: Capatilized Each Word. Other title: Sentence case, Text: Sentence case.