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Impact of soil conservation measures on vegetation recovery in the catchment of a rapidly silting recreational lake at Chandigarh

S.S. Grewal

Society for Promotion and Conservation of Environment, H. No. 114, Sector 46-A, Chandigarh .
E-mail: drgrewal0114@yahoo.com

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ABSTRACT

Sukhna, a recreational lake developed in 1958 at Chandigarh (North India) by constructing a 12.8 m high earthen dam across three ferocious Shivalik torrents, suffered from pre-mature siltation due to heavy soil erosion from its 4207 ha catchment area. Intensive soil conservation measures were initiated but after 16 years of lake construction which included effective closure imposed by fencing 2540 ha forest area, large scale plantation, construction of more than 180 silt detention earthen dams and equal number of masonry check dams supported by vegetative conservation measures. These measures, carried over a long time, led to vegetation cover development and ecological recovery which formed the subject matter of a comprehensive study conducted during 2008-09 in the catchment of a representative 560 ha micro-watershed. Assessment of vegetation recovery, abundance and species distribution was carried out by physical measurements in plots of different sizes - 10000, 100 and 1 sq m for trees, bushes and grasses spread over three landscape regions and slope classes.

The overall tree density in treated area over control improved in a period of 35 years from 162 to 450 and bush density from 5977 to 8984 ha^{-1}. However, the shade provided by large number of trees and aggressive bushes like *Lantana camara* reduced the number of grass clumps from 173 to 55 sq m^{-1}. Recovery was attributed to improvement in moisture regime, control of biotic pressure and forest fires.

Natural regeneration of tree species was affected by wildlife browsing, invasion of weeds, and at places by shade. The prominent tree species were *Acacia catechu*, *Acacia nilotica*, *Dalbergia sissoo*, *Acacia modesta*, *Prosopis juliflora*, *Acacia latifolia* and bush species of *Lantana camara*, *Murraya koenigii, Carrisa carandus, Adhatoda vasica* and *Ziziphus nummularia.*

Limited manipulation of the bush cover like removal of *Lantana* from safer slopes to promote growth of palatable grasses for wild life is recommended. The vertical cliffs which continue to trigger landslides should be stabilised with location specific bio-mechanical measures. Sukhna lake catchment demonstrate the extent of ecological recovery of degraded forest eco-system within 35 years of integrated soil conservation measures and effective closure.

1. INTRODUCTION

The Shivalik foothills are denuded and degraded and remained a cause of concern for long (Glover, 1944; Gorrie, 1946; Grewal *et al.,* 1990). Sukhna Lake of Chandigarh city was constructed in 1958 across three Shivalik torrents emerging from a highly degraded Shivalik catchment covering 4207 ha. The man-made lake was formed by constructing a 12.8 m high rock-fill earthen dam (Bansal and Grewal, 1986 and 1990). The severity of soil erosion problem in its Shivalik catchment was not realised before the lake was planned and the lake started silting right from first year of its formation. The upper areas of Kansal, Nepli and Ghareri torrents draining into the lake were extremely denuded, degraded and silt loads in the torrents were so high that by the time remedial measures were initiated, lot of silt had already found its way to the lake (Grewal and Juneja, 1984).

Intensive soil and water conservation measures were taken up in a 2540 ha forest catchment of the lake which included effective closure, large scale plantation, construction of more than 180 silt detention earthen dams and equal number of masonry check dams supported by vegetative conservation measures (Sohal, 2000). However, no systematic studies were conducted to assess the impacts of treatment measures on vegetation recovery, species dominance and distribution. The present study was commissioned in 2008-09 to evaluate the impact of soil conservation measures in the catchment of Sukhna Lake on soil, vegetation and ground water. The impact of soil conservation measures on soil properties has already been presented in a separate paper (Grewal, 2013); the impact on vegetation recovery, species dominance and distribution is reported in this paper.

2. MATERIALS AND METHODS

The climate of Chandigarh is semi-arid (1120 mm mean annual rainfall and 1800 mm as pan evaporation) with mean maximum temperature of 41.8°C during June and minimum of 5.1°C during January. Out of the total rainfall of the area, 80% is received during monsoon season from July to September. Average daily pan evaporation ranges between 0.9 and 9.5 mm day^{-1} during December and May, respectively. The Lake area is located at 32°42' N latitudes and 76°54' E longitudes. At the time of its construction, the storage capacity was 1074 ha-m and water spread area varying between 1.52 and 2.28 sq m (SPACE, 2012).

It is important that the changes in the vegetation cover complex in the treated area are compared with a reliable and comparable control. Since the base level observations taken before the start of catchment treatment were not available, the next best alternative was to take observations from untreated contiguous area having similar bio-physical conditions. It is natural that no two watersheds are similar, but taking adjoining area having same soil, slope, aspect, drainage pattern, geological formation and vegetation types except closure and treatment with soil and water conservation measures appeared the best alternative. Such an area was available in the catchment of adjoining Karoran *choe* near Prempura village which was selected as control. Prempura is the first village of Haryana on northern side of Kansal *Choe*.

It was decided that Ghareri *choe* was the most representative of the treated catchment area and hence taken for intensive study. Four landscape regions representing elevations were selected as lower, middle, higher-I and higher-II as area under higher was relatively more. In each region, three slope positions were selected along the topo-sequence *i.e.* lower, middle and high. There were thus four regions, three slopes and three replications which represented the landscape of this micro-watershed. The size of the plot for the study of general landscape features and enumeration of tree species was taken as 100 x 100 m, 10 x 10 m for enumeration of bushes and 1 x 1 m for grasses and litter accumulation. The number of tree species in each block with girth measurements at breast height using vernier calliper were physically recorded. Soil samples and litter samples were collected from 1 x 1 m area from each plot. Two representative sites were taken for soil moisture measurement from 0-120 cm depth before and after rainy season and moisture was determined gravimetrically. Tree plantation records from the UT Forest Department were obtained to determine the number and species planted during the rehabilitation process. This dry-deciduous mixed natural forest was dominated by *A. catechu* and *A. nilotica* on hill slopes and *D. sissoo* along the *choe* beds. *A. catechu* was planted on slopes along staggered contour trenches but *D. sissoo* was planted by digging pits. The fodder tree species were included but suffered high mortality due to wildlife browsing. Simple statistical methods of averages/means were used in the analysis of results.

3. RESULTS AND DISCUSSION

Tree Planting In Sukhna Lake Catchment

The number of trees planted each year from 1989-90 to 1999-2000 was reported by Sohal (2000). In these 11 years, a total of 16.56 lakh seedlings were planted (Table 1).

The rate of planting increased from 1.45 lakh in 1989-90 to 3.20 lakh in 1992-93 but then from 1994-95 onwards, the rate of planting was gradually reduced to only 0.25 lakh in 1999-2000. Most planting was done in middle and upper

Table: 1
Tree seedlings planted in Sukhna Lake catchment from 1989-90 to 1999-2000

Year	1989-90	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98	1998-99	1999-2000	Total
No. of seedling planted (lakhs)	1.45	2.07	2.29	3.20	2.50	2.75	0.70	0.50	0.40	0.45	0.25	16.56

landscape regions in an enrichment mode @ 500 to 700 trees ha^{-1} and also planting of *Eulaliopsis binata* grass tufts. Considering around 70% survival rate, gap filling was also done. In addition, there were considerable additions through natural regeneration (Sohal, 2000).

Since no tree is being removed or harvested because of wildlife sanctuary restrictions, we observed large number of mature kikar (*A. nilotica*) and shisham (*D. sissoo*) trees had died and were in the stage of dying/decaying. A large number of trees were submerged in the storage area of 150 water bodies. Yet the catchment of Sukhna Lake presented the look of greenest area in whole of Shivaliks as seen from LANDSAT imageries.

Distribution of Tree Species

Treated area

In case of treated area, *A. catechu, A. nilotica, Acacia modesta*, *D. sissoo* and *Prosopis juliflora* were the main plant species found in the catchment area. *P. juliflora* was introduced in small pockets on absolutely bare calcareous patches but it proliferated fast and got spread in other areas as well. *A. catechu* was well distributed in all the landscape regions and topo-sequences but its numerical strength gradually increased from 133 to 141 to 196 and 313 trees ha^{-1} when moving from lowest to middle, higher and highest landscape region, respectively (Table 2).

This was mainly because these tree species were planted in larger number in middle and upper areas and medium to heavy textured soils with pH range of 8.9 to 9.3 were best suited to these tree species.

Within the landscape regions, there was no significant trend between upper, middle and lower slope classes. The stocking density of both *A. catechu* (185 trees ha^{-1}) and *A. nilotica* (117 trees ha^{-1}) was the highest and constituted 67% of the total. *D. sissoo* and miscellaneous tree species were more dominant in lower landscape region along the sandy/gravely *choe* beds, where the soils were light textured and moisture regime was better. *Eucalyptus* was mainly planted but other tree species were both of planted and natural origin. Surprisingly, in the highest region of Bade Pathranwala *choe*, *A. catechu* is the only tree species and other tree species were totally absent. This again was due to planting more of *A. catechu* on heavy, calcareous soils in upper areas and species preference for such site conditions. It is interesting to note that in middle landscape region the tree density is lowest (172 ha^{-1}) because the bush density is highest in this region (Table 5) and these prolific bushes checked the population of other tree species which were absent in this region.

The overall stocking density was 450 trees ha^{-1}; with a high variability, minimum of 172 and maximum of 1178 trees ha^{-1}. The maximum number of 1178 trees ha^{-1} was in

Table: 2

Distribution of tree species (no ha^{-1}) on three landscape regions and slope positions in treated area

Landscape Region	Slope position	Density of dominant tree species (no. ha^{-1})					
		Acacia catechu	*Acacia nilotica*	*Dalbergia sissoo*	Eucalyptus	Others	Total/Mean
	Upper	88	-	-	-	178	266
Lower	Middle	188	11	220	-	22	441
Maljhanwala	Lower	122	-	211	11	22	366
	Mean	133	4	144	4	74	358
	Upper	112	11	23	-	--	146
Middle	Middle	123	-	-	--	-	123
Tarkanwala	Lower	189		11	47	-	247
	Mean	141	4	11	16	-	172
	Upper	312	88	-	-	-	400
Higher 1	Middle	221	312	-	-	-	533
Kherewala	Lower	56	901	34	187	-	1178
	Mean	196	434	11	62	-	703
	Upper	Haryana		-	-	-	-
Higher II	Middle	357	-	-	-	-	357
Bade Patharanwala	Lower	266	-	-	-	-	266
	Mean	313	0	0	-	-	312
Overall Mean		185.0	117.4	45.1	22.3	80.1	450.0
Mean Girth (cm)		46.76	59.43	81.75	90.1	40.4	

lower region of Higher-1 Kherewala Landscape where *A. nilotica* was in highest numbers. In general, two-third of the tree species were of *A. catechu* and *A. nilotica.* The high spacial variability in slope, aspect and soil conditions influenced species abundance and distribution.

Control area

In case of control area outside Sukhna Lake catchment, overall tree density was 159 trees ha^{-1} against 450 ha^{-1} in lake catchment (Table 3).

A. nilotica, A. catechu and *A. modesta* were the main tree species. *Butea monosperma* cluster was found only in one block. The number of trees on lower, middle and higher landscape was 188, 181 and 111 ha^{-1} against 358, 172 and 703 trees ha^{-1} on respective slopes in treated lake catchment.

Distribution of Tree Species in Girth Classes

An attempt was made to assess the overall status of the growing stock after 35 years of effective closure, fire protection and soil conservation measures by relating number of tree species with their girth classes. In case of Sukhna lake catchment area, out of 450 trees ha^{-1}, 54 (11.9%) were in 0-20 cm girth class, 122 (27.1%) in 20-40 cm girth class, 148 (33%) in 40-60 cm girth class 56 (12.4%) in 60-80 cm girth class, 35 (7.5%) in 80-100 cm girth class and 36 (8.1%) in more than 100 cm girth class (Table 4 and Fig. 1).

The weighted mean girth of *A. catechu* was 46.7 cm, *A. nilotica* 59.4 cm, *D. sissoo* 81.7 cm, Eucalyptus 90.1 cm and miscellaneous tree species as 40.4 cm. It appears that protection led to vegetation recovery especially in case of dominant tree species of *A. catechu* and *A. nilotica.*

In case of untreated control, out of 159 trees ha^{-1}, 31 (19.2%) were in 0-20 cm girth class, 65 (40.9%) in 20-40 cm girth class, 49 (30.8%) in 40-60 cm girth class, 13 (8.4%) in 60-80 cm girth class and only1 (0.7%) in 80-100 cm girth class. The weighted mean diameter of *A. catechu*, *A. nilotica, B. monosperma*, *D. sissoo*, *Lannea grandis* and *A. modesta* was 40.3, 36.7, 37.9, 90.0, 28.1 and 24 cm, respectively. These are relatively much smaller in girth as compared with the mean girth of trees in treated area.

The weighted mean girth of dominant tree species varied from 40.4 to 90.01 cm in case of Sukhna Lake plots but the same varied from only 24.0 to 40.3 cm (except lone tree of shisham) under control. This clearly showed better tree growth and stocking density in Sukhna Lake catchment area over control. The effect of better tree cover was clearly

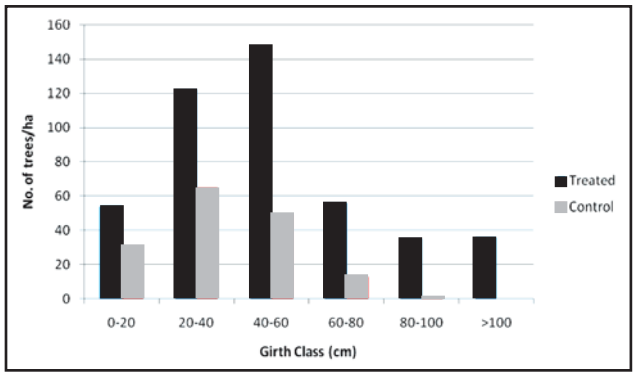

Fig. 1. No. of trees ha^{-1} in different girth classes (cm) in treated and control area

Table: 3

Distribution of tree species (no. ha^{-1}) on three landscape regions and slope positions on untreated area

Landscape region	Slope position	Density of tree species (no ha^{-1})						
		Acacia catechu	*Acacia nilotica*	*Dalbergia sissoo*	*Lannea grandis*	*Acacia modesta*	*Butea monosperma*	Total/Mean
Lower	Upper	44	33	-	11	33	-	121
	Middle	89	11	-	11	11	-	122
	Lower	11	34	-	-	-	277	322
	Mean	48	26	-	7.3	15	92	188
Middle	Upper	77	-	-	3.3	-	-	110
	Middle	99	-	-	3.3	-	-	132
	Lower	-	277	11	11	-	-	299
	Mean	59	92	4	25	-	-	180
Higher	Upper	-	67		-	22	-	89
	Middle	-	99	-	22	33	-	154
	Lower	-	44	-	-	45	-	89
	Mean	-	70	-	7.3	33.3	-	111
Overall Mean		35.6	62.8	1.2	13.4	16.0	30.8	159.6
Mean Girth (cm)		40.3	36.7	90.0	28.1	24.0	37.9	

Table: 4
Distribution of dominant tree species in girth classes in treated and control area

Treatment	Name of tree species	No. of trees in girth classes (cm)							
		0-20	20-40	40-60	60-80	80-100	>100	Total	Weighted mean girth
Treated	*Acacia catechu*	5.0	60.0	79.2	27.5	13.3	-	185.0	46.7
	Acacia nilotica	12.1	51.6	36.6	16.2	1.0	-	118	59.4
	Dalbergia sissoo	0	3.1	11.1	8	2	20.9	45	82
	Eucalyptus species	1		3	1.1	6	11.2	22	90
	Total	18.1	114.7	129.9	52.8	22.3	32.1	370	
	% of total	4.9	31.0	35.0	14.3	6.0	8.8	100.0	
	Miscellaneous species								
	Diostyros leavis								
	Celtis australis	35.4	7.1	18.3	3	12.3	4	80	40
	Prosopis juliflora								
	Ehretia laevis								
	% of total	44.3	8.9	22.8	3.7	115.3	5.0	100.0	
	Grand total	54	122	148	56	35	36	450	
	% of total	11.9	27.1	33.0	12.4	7.5	8.1	100.0	
Control	*Acacia catechu*	6.1	13.6	7.3	8.6			36	40
	Acacia nilotica	6.1	32	22.2	2.4			63	37
	Butea monosperma	3.7	13.6	11	2.4			31	38
	Dalbergia sissoo	-	-			1.2		1	90
	Lannea grandis	4.9	4.9	3.6				13	28
	A. modesta	9.8	1.2	5				16.0	24
	Total	31	65	49	13	1	-	159	
	% of total	19.2	40.9	30.8	8.4	0.7	-	100.0	

reflected in much higher leaf litter built up on the forest floor.

Observation of Management Importance for Sukhna Lake Treated Area

The natural regeneration of dominate tree species of *Acacia catechu*, *Acacia nilotica* and *Dalbergia sissoo* was not taking place as evident from much less number of young recruits in 0-20 cm girth class. On the contrary, natural regeneration of miscellaneous tree species of *Diostyros tomentosa*, *Celtis australis*, *Prosopis juliflora*, *Lannea grandis* is taking place as was evident that 35 plants out of 80 were in 0-20 cm girth class.

Almost 28% trees in treated area (against 9.1% in control) were above the harvestable girth class of 60 cm. Almost half of the trees of *D. sissoo* and *Eucalyptus* fell in >100 cm girth class (against one in control). *P. juliflora* is fast spreading to all bare areas and its natural regeneration was taking place as indicated by sizeable young recruits. Many over mature trees of *A. nilotica* and *D. sissoo* were dead/decaying particularly in water-logged pockets. Young seedlings of all tree species which are palatable to the wildlife were heavily browsed and not growing except on inaccessible spots. Many trees in larger girth classes were fit for harvesting but were not being removed because of wildlife sanctuary restrictions. As a result, the natural regeneration of desirable tree species suffered adversely due to shade effect on young recruits. As the fully grown trees were providing lot of shade, Basuti (*Adhatoda vasica*) and *Murraya koenigii* proliferated fast as under storey bushes.

Wildlife frequented the area so much that all naturally regenerated plants with low height (< 1m) were browsed repeatedly and could not often grow. Where *L. camara* was cleared manually to promote grass growth, *M. koenigii* and Parthenium proliferated vigorously, so grass growth was adversely affected.

Eucalyptus saplings were planted on flat, level alluvium lands in the valley, when the area was acquired. They were never harvested. We counted 2558 fully mature *Eucalyptus* trees in a two ha block of flat land located along the main Ghareri *Choe*. These were even aged trees

having 20 to 44 cm diameter at breast height. Undergrowth of *A. vasica* and *M. koenigii* was also evidenced. A thick layer of slow decomposing leaf litter of *Eucalyptus* was formed on the ground surface. Under such a stand of Eucalyptus trees, no runoff is expected and all the rain water was used *in-situ.* Sanctuary area restrictions do not allow the harvesting of even fully grown/mature trees.

Distribution of Bushes

Treated area

A. vasica was the most dominant bush in the treated Sukhna Lake area where its number was 4982 ha^{-1} followed by *L. camara* (1818 ha^{-1}), *M. koenigii* (1784 ha^{-1}), *Ziziphus nummularia* (200 ha^{-1}) and *Carrisa carandus* (200 ha^{-1}). The total number of bushes was 8984 ha^{-1}, indicating almost every sq m of space have at least one bush (Table 5). In the overall landscape of Ghareri *Choe*, the middle region represented by Maljanwala *Choe* had the maximum mean bush density of 17443 ha^{-1}, followed by higher region represented by Kherewala and Bare pathranwala, where mean bush density was 6267 and 8300 ha^{-1}, respectively. Lowest bush density was in the lower region represented by Tarkhanwala *choe* where average bush density was 3700 ha^{-1} only.

In case of middle region, where bush density was maximum; *A. vasica* and *M. koenigii* were most dominant. *Z. nummularia* and *C. carandus* were almost absent and numerical strength of *C. carandus* was very low. This appears to be the effect of physical removal of *L. camara* by the Forest Department. Moreover, *L. camara, Z. nummularia* and *C. carandus* are light demander but *A. vasica* and *M. koenigii* proliferate more under shade and moist conditions.

L. camara and *A. vasica* gained < 2m height, whereas *M. koenigii*, *Z. nummularia* and *C. carandus* to some extent attained lesser height. This is because of the natural character of the plants. *M. koenigii* being a shade demander, proliferated under shade conditions.

Control area

L. camara was the most dominant bush in the untreated control area where its density was 3811 ha^{-1} (Table 6). This was followed by *C. carandus* (999 ha^{-1}), *Z. nummularia* (789 ha^{-1}) and *D. sissoo* (378 ha^{-1}). Overall bush density was 5977 ha^{-1} whereas in treated area of *Ghareri choe*, bush density was 8984 ha^{-1}. *A. vasica* was the most dominant bush in treated area (4982 ha^{-1} followed by *M. koenigii* (1784 ha^{-1}). But surprisingly, both these species were absent in control area as shade and moisture conditions were not conducive in control area.

While *Z. nummularia* and *C. carandus* bushes were only 200 ha^{-1} each in treated area but their frequency was substantially large *i.e.* 789 and 999 ha^{-1} in untreated control area mainly because of availability of light and drier soil moisture regime. The obvious reason is that in treated area, *M. koenigii* and *A. vasica* proliferated the most because of shade and better moisture regime but in case of untreated control; *Z. nummularia* and *C. carandus* were the two most

Table: 5

Density (no. ha^{-1}) of perennial bushes at three landscape and slope positions in treated area

Landscape region	Slope position	Bushes					
		Lantana *(Lantana camara)*	Basuti *(Adhatoda vasica)*	Ber *(Ziziphus nummularia)*	Karipatta *(Murraya koenigii)*	Karonda *(Carissa spinarum)*	Total
Lower	Upper	2800	0	600	0	0	3400
Maljhanwala	Middle	5100	1600	0	0	0	6700
	Lower	0	0	400	0	600	1000
	Mean	2633	533	334	0	200	3700
Middle	Upper	700	300	0	0	0	1000
Tarkhanwala	Middle	0	30700	0	830	0	31530
	Lower	0	7600	0	1220	0	19800
	Mean	233	12867	0	4343	0	17443
Higher I	Upper	1000	0	0	0	0	1000
(Kherewala)	Middle	2100	0	0	0	0	2100
	Lower	0	14600	700	0	400	15700
	Mean	1033	4868	233	0	133	6267
Higher II	Middle	7500	0	0	6600	1200	15300
(Bade	Lower	800	0	500	0	0	1300
Pathranwala)	Mean	4150	0	250	3300	600	8300
	Overall mean	1818	4982	200	1784	200	8984

prolific plant species because of drier moisture conditions and sufficient light.

It is clear that when forest area was closed and biotic interference eliminated, the bushes quickly regenerated and multiplied. They are very powerful colonisers of degraded slopes and helped controlling soil erosion. But unfortunately, they suppressed the growth of palatable grasses and also Bhabar grass (*E. binata*) having commercial value. Such observations were also made by Dhar (1994). The U.T. Forest Department is trying to eradicate Lantana bushes from few safer slopes to promote the growth of palatable grasses for wildlife. These efforts need to be continued so that menace of Lantana remains under check.

Distribution of Grasses

There were 55 clumps of various grass species per sq m area out of which *Bhabar* (*E. binata*) and *Dholu* (*C. fulvus*) grasses were most prominent and *H. contortus* grass was co-dominant (Table 7). As such, grasses were more prominent in higher/upper reaches where bushes were relatively less prominent. The soil depth is less and erosion intensity is high on higher peaks where numerical strength of trees and bushes was less but of grasses was more since they are not suppressed by taller plant species. While Sarkanda (*Saccharum munja*) was totally absent in these plots, palatable Doob grass (*C. dactylon*) was almost eliminated as it was found only in one out of nine plots.

In some of the plots, where *A. nilotica* was most dominant, *E. binata*, *C. fulvus* and other grasses were eliminated except *H. contortus* which could survive only when number of *A. nilotica* trees reduced and *A.catechu* was present. It was noted that *C. fulvus* grass could come in association of *D. sissoo* and not in other tree species, probably because thin canopy of trees and light during winter months was not a limiting factor.

In case of control, the overall number of grass clumps was 173 sq m^{-1} against only 55 in treated areas where *H. contortus* and *Cynodon dactylon* were most dominant and *C. fulvus* and *E. binata* were co-dominant. Difference was not discernible in grass clumps amongst three regions (unlike treated area). Miscellaneous grasses were very few but *S. munja* was present in some plots on lower region. It was also evident that where bushes were more dominant particularly Lantana, the number of grass clumps diminished indicating that Lantana eliminated natural regeneration of grasses due to shade effect. Due to thicker tree and bush cover, the leaf litter accumulation on the forest floor improved from 2.05 to 4.49 t ha^{-1}.

In a wildlife sanctuary, palatable grasses, some shade and water bodies must be an integral part. In the treated area, there are sufficient number of trees to provide shade, large spread of water bodies over the entire area and enough nestling and hiding places in tall grasses. The removal of *L. camara* from safer places or flatter slopes was attempted by the Forest Department but some re-growth took place and *M. koenigii* and *A. vasica* occupied the vacated land. These efforts to promote palatable grasses and few fodder trees here and there must be continued as a part of management plan of the wildlife sanctuary.

As the degraded forest area was closed to biotic interference, vegetation cover quickly developed and plant species proliferated as per soil, slope, aspect, moisture, shade, temperature and other edaphic conditions (Grewal, 1995). A multi-layered vegetation cover developed over a period of 35 years. The leaf litter on the forest floor further

Table: 6

Density (no. ha^{-1}) of bushes on three landscape and slope positions in control area

		Bushes				
Landscape region	Slope position	Lantana (*Lantana camara*)	Creepers *(Dalbergia sissoo)*	Ber (*Ziziphus nummularia*)	Karonda (*Carissa spinarum*)	Total
Lower	Upper	1500	0	100	1000	2600
	Middle	8900	0	2800	1400	13100
	Lower	10700	0	200	500	11400
	Mean	7033	0	1033	966	9032
Middle	Upper	800	0	0	1100	1900
	Middle	5500	0	0	1100	6600
	Lower	1000	0	900	700	2600
	Mean	2433	0	300	966	3700
Higher	Upper	1300	1100	2500	1000	5900
	Middle	1100	1700	600	1100	4500
	Lower	3500	600	0	1100	5200
	Mean	1967	1133	1033	1067	5200
	Overall mean	3811	378	789	999	5977

checked dispersion of soil particles which take place under the direct impact of kinetic energy of rain drops. This build up of litter layer on soil surface led to the build up of organic matter, increased infiltration rate and hence reduced run off and soil loss (SPACE, 2009; Pankaj *et al.,* 2012). The physical and chemical properties of the soil were changed in favour of plant growth (Grewal, 2013). Soni *et al.* (2002) also reported that significant amount of above ground biomass does accumulate on the soil surface as a result of litter fall from shrubs and this results in addition of mineral elements which are important for long term productivity of disturbed soils.

The impact of afforestation, soil and water conservation measures both biological and mechanical coupled with reduction in socially imposed biotic pressure in Shivalik watersheds generated very useful information (Singh, 1998 and 1999). These measures decreased run off from 40-50% to less than 2% in 5 years. Similarly, soil loss was reduced from the range of 163-419 t $ha^{-1}yr^{-1}$ to less than 5 t $ha^{-1}yr^{-1}$ as measured from silt observation posts. The mean stock density of trees increased from an average of 81 to the range of 729 to 954 trees ha^{-1}. The shrub population improved from 3391 to 4978-8013 ha^{-1} in treated watersheds over a period of 10 years. Similarly, the results of increased tree, bush and grass stocking density and canopy cover after holistic treatment of three Shivalik watersheds in Ambala Shivaliks of Haryana was reported by Dhar (1994). Panwar *et al.* (2012) observed that the soil conservation measures in a treated watershed result in proliferation of bushes such as *L. Camava, M. Koinigii* and *A. catechu* which inhabit the growth of palatable grasses.

4. CONCLUSIONS

The effective closure imposed over a long time and intensive soil and water conservation measures carried over a long time produced very interesting results in terms of vegetation cover development and ecological recovery. Overall tree density improved from 162 to 450. Bush density also increased from 5977 to 8984 ha^{-1}. However, the shade provided by large number of trees and aggressive bushes reduced the number of grass clumps from 173 to 55 sq m^{-1}. which is not a positive sign from wildlife point of view. The

Table: 7

Density (no. ha^{-1}) of dominant grass species and leaf litter accumulation in three landscape regions of treated and control area

Treatment	Landscape region	Density No. sq m^{-1}	Grasses Dominant Species	Leaf litter (t ha^{-1})
Sukhna Lake catchment	Lower	16	*Eulaliopsis binata*	
			Cynodon dactylon	4.01
			Chrysopogon fulvus	
			Heteropogon contortus	
			Miscellaneous	
	Middle	43	*Eulaliopsis binata*	
			Chrysopogon fulvus	4.80
	Higher	105	*Eulaliopsis binata*	
			Chrysopogon fulvus	4.40
			Heteropogon contortus	
	Mean	55		4.40
Control area	Lower	167	*Heteropogon contortus*	
			Cynodon dactylon	
			Chrysopogon fulvus	2.24
			Eulaliopsis binata	
	Middle	156	*Heteropogon contortus*	
			Cynodon dactylon	2.10
			Eulaliopsis binata	
			Chrysopogon fulvus	
	Higher	196	*Cynodon dactylon*	
			Eulaliopsis binata	1.80
			Chrysopogon fulvus	
			Heteropogon contortus	
	Mean	173		2.05

sanctuary area limitations did not allow harvesting of mature trees and shade conditions promoted bush growth. The inferior tree species like *P. juliflora* are proliferating fast on all available bare sites. The tree and bush cover development led to significant leaf litter accumulation on the soil surface having positive ecological impacts. The increased bush invasion and resultant decrease in the presence of palatable grasses calls for careful removal of *L. camara*, the most obnoxious bush from safer slopes.

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