

SPATIO-TEMPORAL CHANGES IN THE NATURAL HILLY ECOSYSTEM : A CASE STUDY OF THE CHANDIGARH SIWALIK HILLS

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ABSTRACT : Ecosystems as the manifestations of physical - chemical - biological processes, experience changes both through time and space. Environmental issues are largely specific to different ecosystems but as the spatial ecosystems are not closed ecosystems, these interact with one another in multiple ways. Natural Hilly Ecosystem (NHE) of Inter State Chandigarh Region is largely constituted by the Chandigarh Siwalik Hills. Issues like changes in vegetal cover including forests, loss of biodiversity, soil loss, impact on ground and surface waters, etc. are examined for NHE. The total forest cover in the Chandigarh Siwaliks has definitely shrunk. There has been extirpation of some valuable timber species and there has been disappearance of certain faunal elements. Water induced soil erosion in the hills of NHE has contributed to the problem of land degradation. The changes in the ecosystem have introduced or accelerated disorders in the availability of water, intensification of the rate of soil erosion and transformation of dense forests into scrubs. Changes in ground water conditions are evident and the process of ground water recharge is weak. The study also touches upon interactional aspects with other ecosystems. The issue of depletion of and pollution in the groundwater cuts across boundaries of individual ecosystems. The propositions made in the present study easily lend themselves to be applied in the context of interactive systems comprising highlands and lowlands.

INTRODUCTION

Ecosystems, being not simply random aggregations of discrete phenomena but manifestations of physical-chemical-biological processes, experience changes both through time and space. The environmental issues which thus emerge are also largely specific to different ecosystems. However, as the spatial ecosystems are not closed systems and interact with one another in multiple ways, it becomes necessary to focus attention on the interactional aspects of the ecosystems as well.

The natural hilly ecosystem (NHE) provides

a protective life-support environment. As a result of developmental activities taking place both within the NHE and in its close proximity, this ecosystem is facing the problem of deformation of its landscape, exhaustion of its floral and faunal wealth and changes in its water resources. Besides, interruptions of its traditional economic activities and modification of its social landscape also form an integral part of the changes in the natural hilly ecosystem.

The present paper addresses itself to these issues using the Chandigarh Siwalik Hills as a case study. The Chandigarh Siwalik Hills constitute a large part of the NHE in the Inter-

State Chandigarh Region* which sprawls over the union territory of Chandigarh and the adjoining territories of Punjab, Haryana and Himachal states. (Fig. 1). The NHE of the present study lies to the north and northeast of the urban landscape of the capital city of Chandigarh. Besides the hills proper, the NHE also includes the entire range of physiographic features which rise above the piedmont plain because of similarity of geological history and vegetation cover. The small cultivated pockets around human settlements are sparsely and intermittently located in this system, that is, the Natural Hilly Ecological System (NHE) and within that the focus is on Chandigarh Siwalik Hills (the other constituents of the NHE are the Morni Hills and an outer Kalesar Hill (Fig. 2). The Chandigarh Siwalik Hills extend between the Ghaggar and Satluj rivers. Across the Ghaggar to the east are located the other two constituents of this NHE. Investigations of changes in vegetal cover, the nature and intensity of soil erosion, the geomorphic changes revealed by the measurement of slope gradients all indicate the overall spatial and temporal changes being experienced by this ecosystem.

CHANDIGARH SIWALIK HILLS : SOME SALIENT FEATURES

The Chandigarh Siwalik Hills comprise mainly a chain of low hills, part of elongated belt extending over some 36 km. in length and 9-12 km in width covering roughly an area of 320 square kilometres. In elevation the Chandigarh Siwalik Hills range between 300-625 metres above mean sea level. These hills are characterised by a highly dissected 'badland' topography; ephemeral streams of different

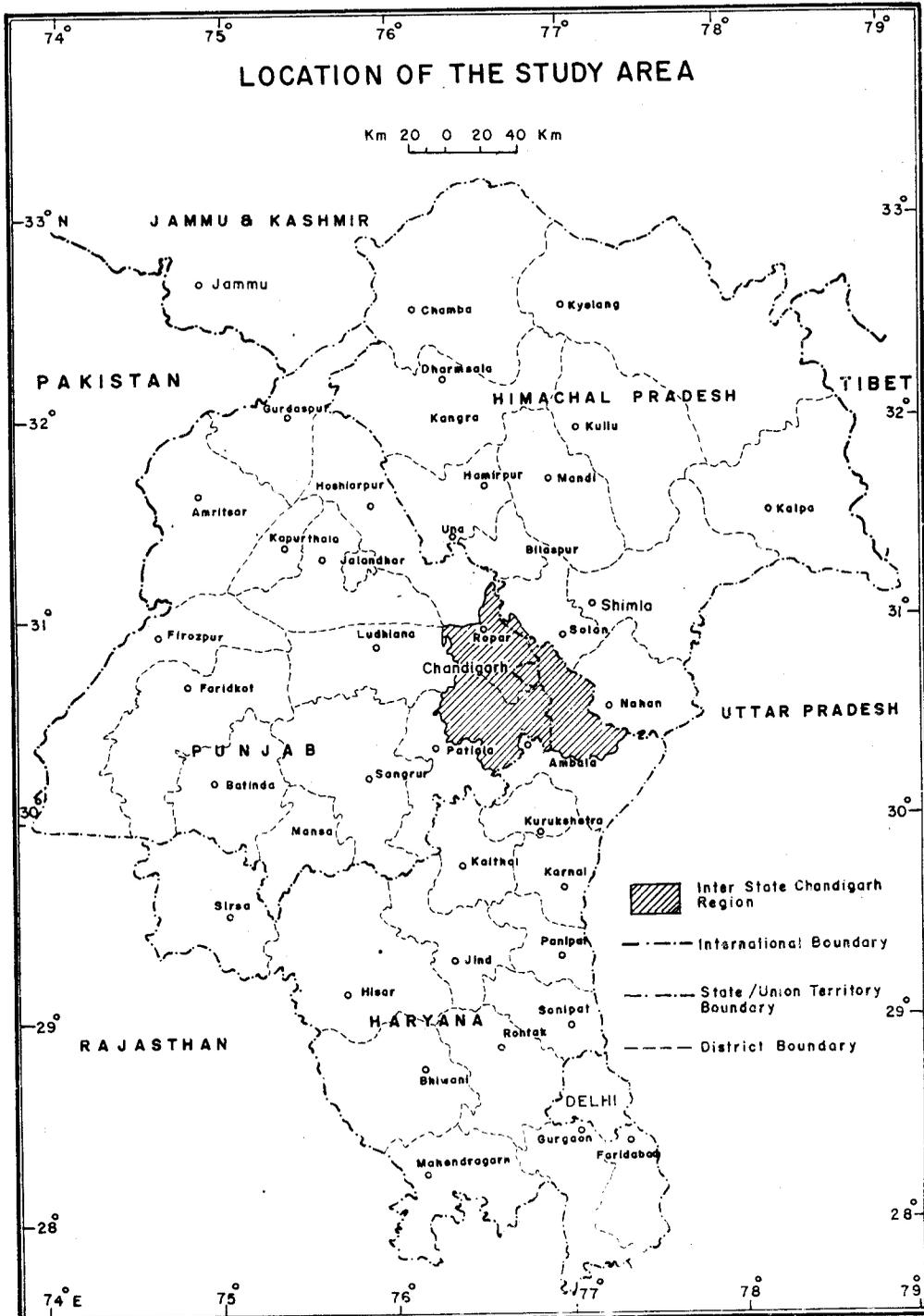
genetic types; erosional landform features including rills, gulleys, scarps, cuestas, spurs, hogback ridges, amphitheatrical basins; depositional features such as choe-terraces, choe-valley lowlands including floodplain scroll and shingle bars (Singh, 1990a). Broad open folds, which constitute a water-divide stand out among the structural features of this ecosystem.

CHANGES IN FLORA : SOME GENERALITIES

Available studies on the vegetation of northwest India (Puri, 1960; Puri et al 1983) indicate that the Siwalik Hills especially the submontane zone had sal (*Shorea robusta*) forests in plenty. In the foothills scattered trees of simbal (*Salmalia malabarica*), dhak (*Butea monosperma*), katha (*Acacia catechu*) alongwith luxurious growth of grasses were found in plenty. Besides, shisham (*Dalbergia sissoo*) and katha (*Acacia catechu*) were the main trees in the riverine tracts. In the pre-Independence period the flora of the northwest Siwalik Hills was rich as indicated by references to their use for feeding the animals (Gorrie, 1946). There are also references to chir pine forests which were later cut down. Evidences of existence of thick dhak forests in the piedmont zone of the Siwalik Hills around late 1940s have also been observed. Due to growing population pressure and several developmental activities the forests have been cut down almost entirely during the post-Independence period. The physiognomy of the hills has been changing fast since the fifties at an unprecedented rate.

Within the ecosystem there are marked regional variations with regard to changes in the vegetal

* The Inter-State Chandigarh Region in the present study covers the Union Territory of Chandigarh which forms its core; Kharar and Ropar tahsils of Ropar districts; Rajpura tahsil of Patiala district, Fatehgarh Sahib tahsil of district of the same name; Kalka and Naraingarh tahsils of Kalka district; and parts of Naiagarh tahsil of Solan district.



Source: SOI State Map of Chandigarh, Delhi, Haryana, Himachal Pradesh & Punjab

Fig. 1

Fig.No.1 : Location of the study area.

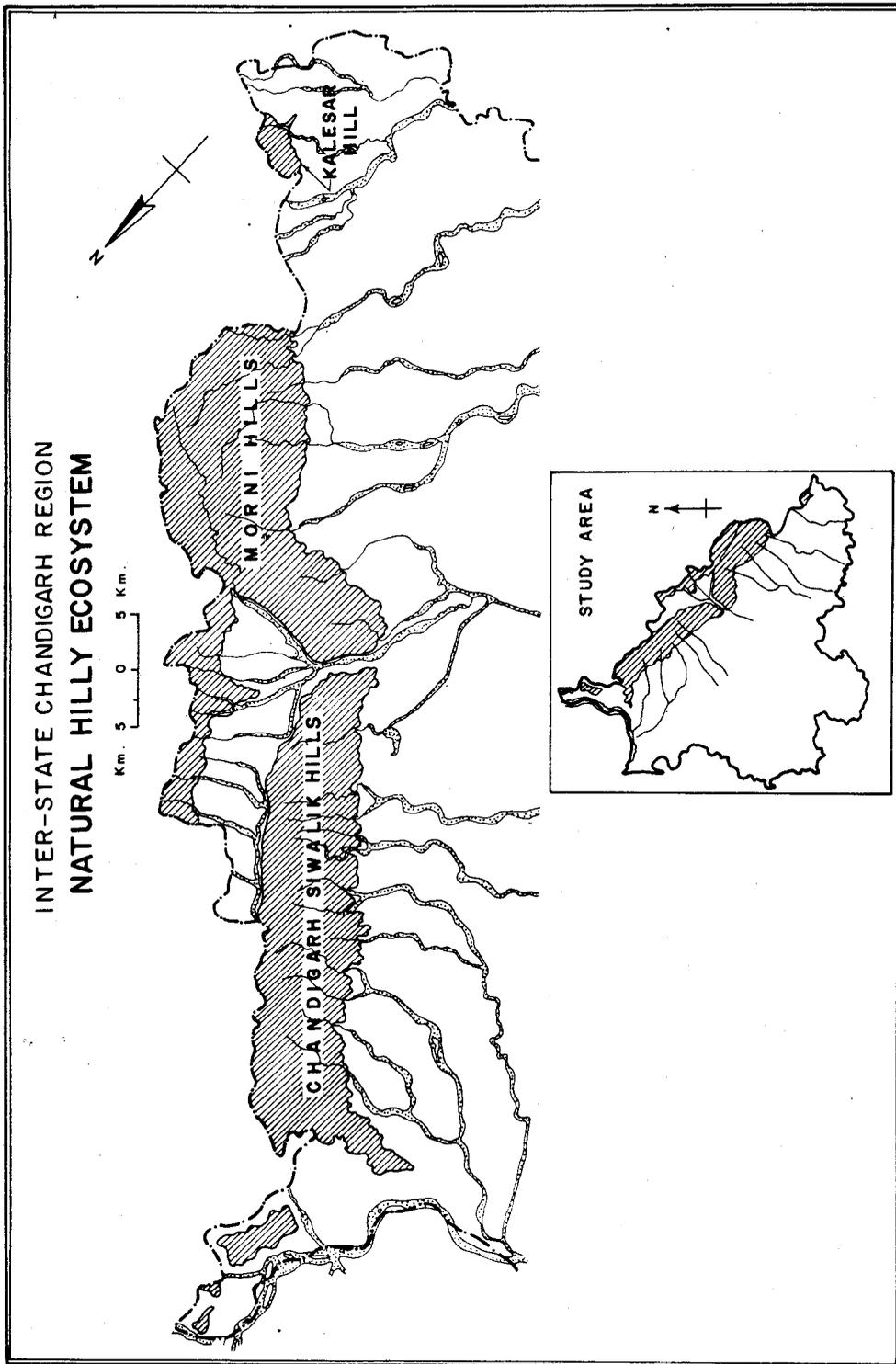


Fig. 2

Fig.No. 2 : Natural Hilly Ecosystem

cover. By and large, the upper reaches of the Siwalik Hills which are closed to the biotic activity under Section 5 of Punjab Land Preservation Act 1900 are still better vegetated. By comparison, the lower reaches which are controlled under Section 4 of the same Act are open to human activities and exhibit sparse vegetation. In the plantation stock of these hills dhak, Eucalyptus and bhabar grass are important which have been introduced as a measure for conserving soils and also because of their importance in rope making and paper manufacturing.

A study of landform-vegetation relationship in the Chandigarh Siwalik Hills revealed that the relationship is not consistent which may be attributed to the recent geological formation of the hills and their ecological degradation associated with increased biotic interference which has a history of about two hundred years but which acquired a glaring manifestation since the sixties (Singh, 1990b). This study

confirmed certain relationships with regard to vegetation and soil-structure.

CHANGES IN VEGETAL COVER

Marked variations in the quality and extent of forest cover have been observed for the period covering about three decades (Table 1).

'Dense Forest' defined by a crown density of more than 40 per cent have registered a significant increase in absolute and relative terms. The percentage under this density class increased from 8.43 in 1966 to 23.46 in 1991. By contrast Open Forest showed decline from 80.45 to 68.20; Scrub from 11.12 to 8.34 during the same reference years. It is evident that the loss has been mainly confined to lower density classes while area under dense forest has not been adversely affected. It may also be noted that year to year variations are not consistent and more over since the data sources are different the comparisons are only broad and may be used only for comprehending the

Table -1

Chandigarh Siwalik hills : Changes in Vegetal Cover,* 1966-91 (Area in square kilometres)†					
Year	Dense Forest (crown density above 40%)	Open Forest (crown density 10-40 %)	Scrub (crown density below 10%)	Total Forest Cover	Non-Forest
1966 ¹	24.25 (8.43)	231.50(80.45)	32.00 (11.12)	287.75(89.78)	32.75(10.22)
1983 ²	20.75 (8.27)	223.25 (88.94)	7.00(2.79)	251.00 (78.32)	69.50(21.68)
1986 ³	10.25 (4.43)	192.00(82.94)	29.25(12.63)	231.50 (72.23)	89.00(27.77)
1988 ⁴	62.25 (23.12)	192.75 (71.59)	14.25 (5.29)	269.25 (84.01)	51.25 (15.99)
1991 ⁵	64.00(23.46)	186.00(68.20)	22.75(8.34)	272.75(85.10)	47.75(14.90)

*Forest cover by density classes

Total area of the Chandigarh Siwalik Hills is 320.50 sq km.

Figures in parentheses indicate percentages for (i) forest cover by density classes to the total forest cover and (ii) total forest cover and non-forest to the total area of the ecological system.

Based on : 1. SOI topographical maps 53A, 53B and 53F surveyed in 1964-66; Landsat MSS-FCC as on December 4, 1983; 3 Landsat TM-FCC as on November 18, 1986; 4, Landsat TM-FCC as on October 2, 1988; and 5, Landsat TM-FCC as on November 16, 1991.

general trends.

The NHE as a whole was dominated by Open Forest (54.39%) in 1966 while Dense Forest covered 31.88% of the total forest cover. In Chandigarh Siwaliks the corresponding figures were 80.45 and 8.43. Large scale degradation of forests took place in the NHE during 1966-1983. Further degradation occurred in the subsequent years and by 1986 there was overall fall in forest areas in the Chandigarh Siwaliks. During 1986-1988 the area registered improvement in area under forest and nearly five-fold increase in area under Dense Forest. In the subsequent period between 1988-1991 these hills showed further improvement as far as forests were concerned.

The Chandigarh Siwalik Hills in 1991 supported 85.10 per cent forests area. However, overall vegetation changes since 1966 have been quite uneven. For the study area, the proportion of areas under stable forest, afforestation, deforestation and non-forest (Table 2) has also changed.

Decline in area under stable forest is quite a disturbing trend and so is the decrease in area affected by deforestation particularly when we compare the figures for 1966-1986 and 1966-1991 periods. Also to be noted, with some

satisfaction, is the increase in area under various afforestation and reforestation schemes. Nonetheless the total forest cover in the Chandigarh Siwaliks has definitely shrunk.

In respect of composition of tree species the study area is characterised by small to medium sized trees with stem diameter ranging from 10-20 cms. to 20-30 cms. Large trees of 70-80 cms. or more diameter are practically non-existent. In addition to the native species of khair, sisham, babul and undergrowth bamboo, plantation of khair on the semi-arid southern slopes of the hills has been introduced. Under afforestation/reforestation programmes Eucalyptus is the only all purpose quick growing tree which has been introduced on a large scale. The introduction of this exotic element has been fairly widespread despite the warnings that Eucalyptus plants adversely affect the underground water resources by stopping the percolation and drainage process. Also the greater biomass production for which Eucalyptus is generally favoured, takes place at the cost of soil fertility especially through heavy nutrient deficit.

LOSS OF BIODIVERSITY

During the last about 100 years large scale destruction of forests in this NHE has resulted

Table 2

**Chandigarh siwalik hills : Vegetational
CHANGES, 1966-1991* (Area in square kilometers)**

Period	Stable Forest	Area affected by deforestation	Area under afforestation/ reforestation	Total Forest Cover	Non Forest
1966-86	157.25	106.00	33.00	296.25	24.25
1986-91	124.00	48.25	92.25	264.50	56.00
1966-91	130.25	72.00	86.25	288.50	32.00

* Based on superimposed mapping of data for relevant periods

T Area undergoing degradation of forest due to biotic interference

in extirpation of some valuable timber species such as chir pine and sal. Similar has been the fate of dhak trees which even 50 years ago grew well in the Siwalik foothills.

Together with the depletion of forest cover this ecosystem has also been witness to fast disappearing fauna. Wild bear and tigers which could be occasionally spotted in the foothill riverine forests in the forties are almost extinct now.

SOIL LOSS

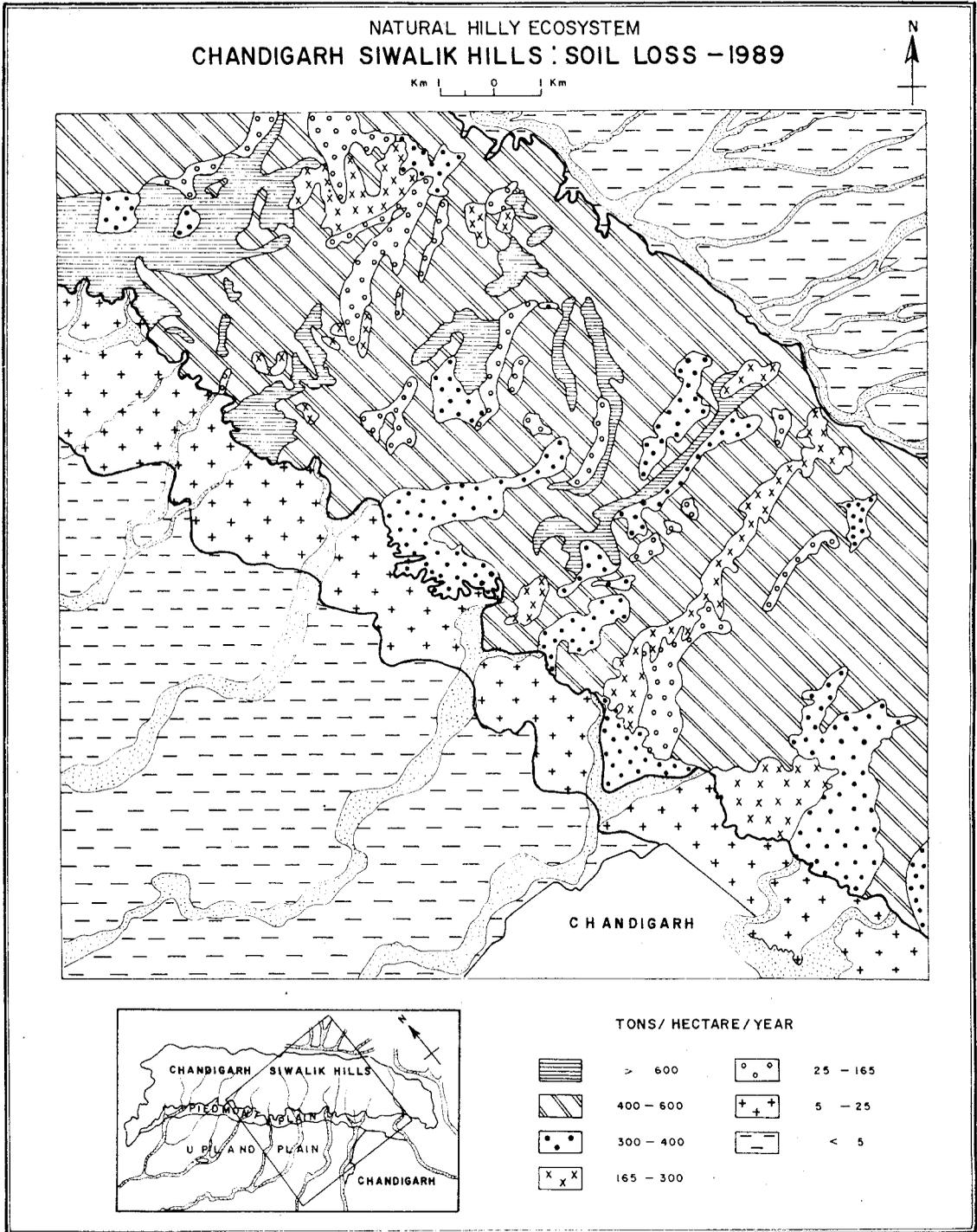
As observed in several studies erosion in the Siwaliks is nearly a century old problem (Glover, 1946). The process got accelerated with the growth of Chandigarh City and other urban settlement in the Inter-State Chandigarh Region. The adjoining Siwalik Hills have suffered on account of ever increasing demand for wood, fodder and other construction material. The soil cover of the hills has thus been exposed to the process of erosion which has been continuously increasing at an accelerated rate causing, among other things, the problem of heavy siltation in the water bodies including the seasonal streams and the famous Sukhna Lake.

Water induced soil erosion in the hills contributed to the problem of land degradation. It has been estimated that the Siwalik Hills experience severe erosion of soil to the tune of 20 tons per hectare per year (Singh et.al 1990). Likewise, efforts to quantify the soil loss at selected sites in the Siwalik Hills revealed the alarming magnitude of the problem as also the relationship between soil loss, slope gradient and vegetation cover. It was found that vegetation cover is the most crucial factor which controls soil erosion (Fig. 3). Besides vegetation cover topographic attributes particularly slope and texture have also influenced the rates of soil erosion in the hills.

SOCIO-ECONOMIC DIMENSIONS

With the rapid growth of Chandigarh Conurbation in 1970s and 1980s the demand for timber increased tremendously. Also the intensifying pressure of population in the hills itself was a major cause of shortage of firewood. The local contractors and brick-kiln owners extracted wood from the NHE in an unabated manner. The construction of roads through the deforested hills affected the natural process of run off causing more frequent landslides and accelerated the phenomenon of gully erosion. The local population of the hills is poor and is confined to pockets of non-forested lands. Cultivation is limited largely to areas in the vicinity of rural settlements and still continues to be primarily of subsistence nature due to poor unirigated less productive thin soils. Cattle, mainly goats and cows are an integral part of the life and economy of the backward hill people. The large number of cattle prove a burden on the forests and have caused great damage to the vegetal cover. The firewood and fodder requirements of the people in this ecosystem are almost entirely met from the forests. The villagers of the hills often lop forest trees to store firewood for the winter months. For most months of the year the people collect dry and fallen twigs and sometimes cut even root suckers of valuable trees such as shisham. Frequent crop failures associated with inadequate rains and absence of irrigation keep people dependent on unorganised cattle rearing activities especially goat keeping which take their toll from vegetal cover of the hills. As per the estimates of the National Productivity Council the number of animals grazing in the forests and high altitude pastures is sixteen times higher than the permissible limit.

In brief, reduction in the number of native forest species, introduction of exotic species producing xerophytic vegetation, continuing



Based on IRS IA LISS-2, Feb 1, 1989 and modified from Saha et. al. (1991)

Fig. 3

Fig.No. 3 : Chandigarh Siwalik Hills : Soil Loss - 1989

denudation of the hill slopes making them highly vulnerable to erosion are salient features of this NHE. In ecological terms these changes have introduced or accelerated disorder in the availability of water, intensification of the rate of erosion and transformation of dense forests into scrubs. Changes in the vegetal cover due to biotic interferences during short period have their own bearing on the variable and constant natural factors operating in the ecosystem over a long period (Fig.4).

IMPACT ON GROUND AND SURFACE WATER CONDITIONS

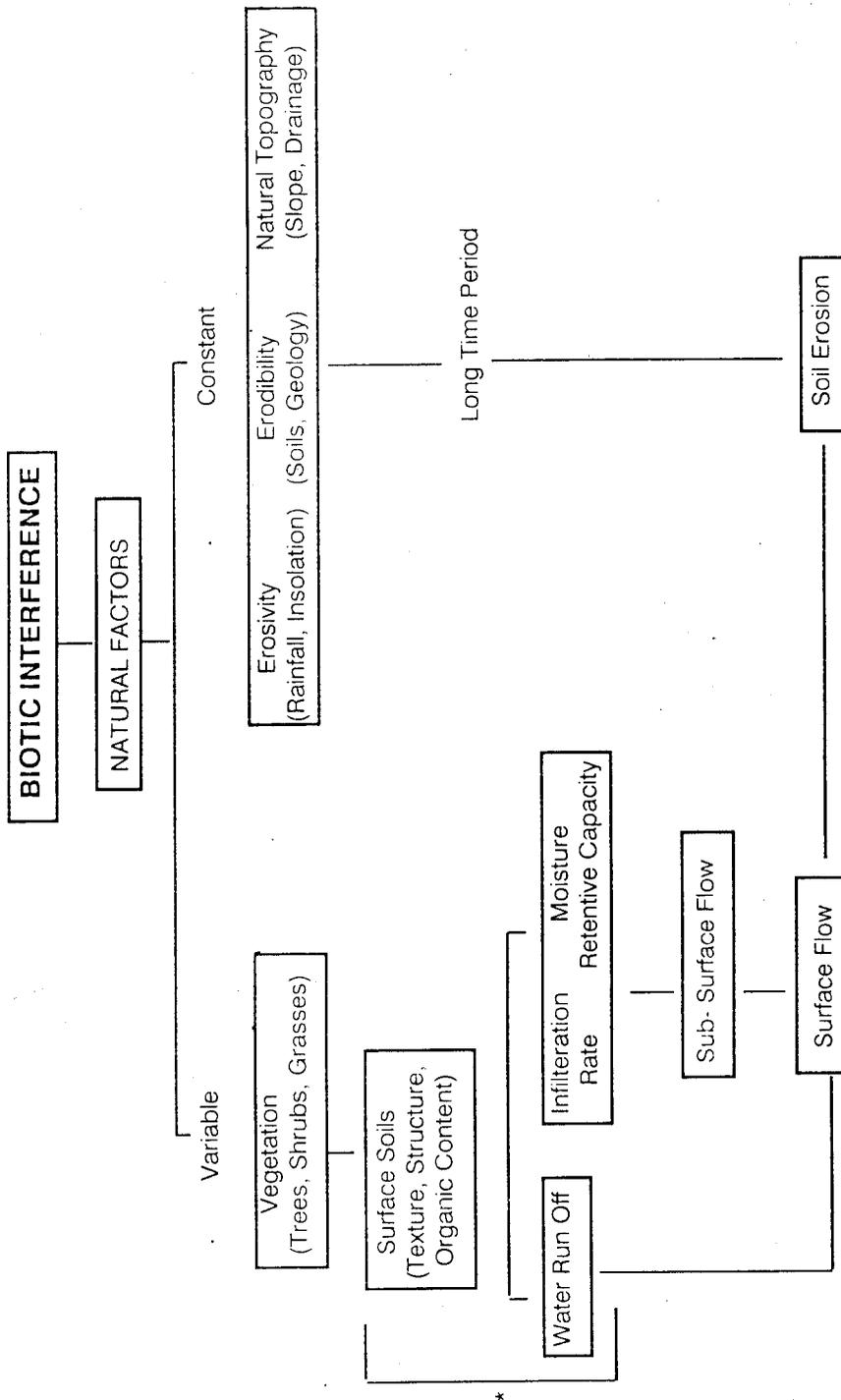
In the NHE the negative effects of heavy rainfall particularly in areas of denuded forest covers have necessitated engineering works which are not cost effective. In any case these have failed to check water and soil loss. Changes in groundwater conditions have also been observed. The process of groundwater recharge is weak. With the decline in the infiltration capacity associated with deforestation in the NHE as also along the banks of the streams debouching from the hills, run-off is fast. This leaves limited water to percolate into the soils and substratum. The water regime of the ecosystem has been further affected by planting of Eucalyptus. The surface water conditions in the ecosystems adjoining the hills have been impacted through excessive sediment load moving down the streams. However, the introduction of both vegetative and mechanical measures in the early eighties has brought down the rate of annual average sedimentation in a section of hills which constitutes the catchment basin of the artificial Sukhna Lake of Chandigarh City.

CONCEPTUALISING THE INTERACTIVE DIMENSIONS : CONCLUSIONS

Ecosystems are localized but highly complicated

interactive complexes exhibiting a wide variety of interrelations between their living communities and their abiotic surroundings. They are also capable of a certain degree of self regulation. In fact, ecosystems evolve through the interwoven influences originating in the lithosphere, the atmosphere, the pedosphere and the biosphere. In the emergence and evolution of ecosystems many interactions follow chain reaction. If the feedbacks are positive the effects are growth-stimulating. However, negative feedbacks will be disturbing not only for an ecosystem itself but also for other interactive ecosystems as well (Schreiber, 1982). Due to the multi-directional physical and functional interconnections between different ecosystems in a given ecosphere the consideration of the interactive dimension becomes imperative in spatial ecological studies.

In the present study the focus has remained on one ecosystem only, that is, the Natural Hilly Ecosystem represented by the Chandigarh Siwalik Hills. The Inter-State Chandigarh Region-the larger ecosphere, of which the NHE is one constituent also covers three other ecosystems: Semi-Natural Drainage Ecosystem (SNDE); the Heterotrophic Urban-Industrial Ecosystem (HUIE); and the Domesticated Agro-Ecosystem (DAE). As stated earlier the four ecosystems are functionally distinct but integrated. In a detailed study of these ecosystems the interactive dimensions, in all its details, have been identified. Our analysis shows that the spatio-temporal changes in the NHE are as much causally related with the dynamics of other ecosystems as they have shaped and transformed the structures in the adjoining ecosystems. It has been found that the impact on vegetal cover, soils and geohydrology of the NHE finds its continuity in the SNDE and the DAE. The changes in



* Changes in properties of constant Natural Processes in short Time Period.

Fig. 4

Fig.No. 4 : Biotic Interference

these ecological parameters are themselves related with the development scenario of the HUIE especially the fast growth of population and proliferation of development activities in the Chandigarh Conurbation in the seventies and eighties. Similarly the loss of biodiversity in the NHE has both backward and forward linkage with the other three ecosystems.

The accumulation of waterborne particles taking place in the NHE continues through the DAE and the process is further intensified through mixing of non-degradable and biodegradable pollutants from the HUIE and DAE into the streams of the SNDE. The problem of sedimentation being witnessed in the SADE and water-features of the HUIE its genesis in the NHE. While the ecological equilibrium in the HUIE has been affected by the course of developmental activities, these have as much contributed to land degradation in the adjoining ecosystems : in the NHE due to timber and fuel wood extraction; in the SNDE by extraction of gravel and sand from the rivers and streams as also discharge of urban waste waters;

in the DAE by removal of large volumes of fertile topsoil by the brick-kiln industry; in the DAE and the SNDE as a result of dumping of garbage at some locations. The issue of depletion and pollution in the underground water also cuts across boundaries of individual ecosystems. The propositions made in the present study easily lend themselves to be applied in the context of interactive system comprising highlands and lowlands.

For stimulating similar studies what we urgently need is a scientific basis of environmental monitoring and its rational organization. Monitoring should cover both observation of and control over the environment. A planned and progressive improvement in the quality of environment and its preservation may only follow and not precede comprehensive understanding of the ecosystems per se as also their interactive dimension. The Natural Hilly Ecosystems also have to be viewed in the context of their interaction with their other spatial counterparts. Their development, safety and protection can be ensured through a holistic and not segmented perspective.

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