Chapter 2

DEVELOPMENT AND MANAGEMENT OF NATURAL RESOURCES

INTRODUCTION

Inter-relationship and inter-dependence among water, land, vegetation and animal resources determine the nature and kind of livelihood support systems particularly in rural areas. Depletion of the natural resource-base and increasing biomass-demand of the expanding human and livestock population are attracting the attention of all concerned. However, the degeneration of natural resources is assuming alarming proportions. It is, therefore, pertinent to evolve strategies for sustainable natural-resource management systems. It is also imperative to observe the changes taking place in the land-use pattern in general and in the agricultural sector in particular, which will have implications for local bio-diversity and the ecosystem, and food and nutritional security of the local people.

Punjab is endowed with some forests, abundant water and fertile land resources, whereas its earth resources (mines, fossil fuel) are negligible. Agriculture is the mainstay of the state, wherein 42,64,000 hectare is the net sown area with a crop intensity of 186 per cent. Irrigation is through surface canal water as well as underground water pumped through tube wells, and over 94 per cent of the cultivated areas is irrigated. The state has an average rainfall of about 382 mm per year, whereas certain areas in the north of the state get over 1000 mm of rain and in the southern side rainfall is low (150-22 mm).

Punjab has a vast expanse of flat alluvial land while the Shivalik hills in the north have fluvial carvings and deposits of the three rivers, namely, the Ravi, Beas and Satluj, which flow through central Punjab, and the sand dunes in the southwest.

However, in recent years, due to the increase in population and other economic activities, scientists, intellectuals and the general public at large have expressed serious concern that both land and water resources have been overexploited, while their conservation has been slow and inadequate, so much so that there is fear that both land and water may become inadequate to support future development activities.

The natural resource of Punjab have been discussed under the following heads:

1. Land
2. Water
3. Forest
4. Wetlands, barren lands
5. Bio-diversity
6. Energy

LAND

Land is the fundamental base for most human and natural activities and one of the major natural resources on this planet. Production of minerals, as well as agriculture, depends

entirely on the availability and use of suitable land. In Punjab the following activities depend on land.

1. Agriculture
2. Water resource
3. Forest
4. Living species
5. Industry and Commerce
6. Transport
7. Pastures
8. Waste Land and uncultivated land
9. Miscellaneous

The extent of land utilisation usually depends on the type of soil in an area, e.g.,loamy soils support agriculture, whereas sandy and rocky soils, which are not suitable for agriculture are usually put to some other use.

Table 1
Land-use Pattern in Punjab (.000 Hect.)

Area	1960-61	1970-71	1980-81	1990-91	1997-98 (R)	1998-99 (P)	1999-00 (P)	2000-01 (P)
Geographical area	5036	5036	5036	5036	5036	5036	5036	5036
Reported area	5022	5031	5033	5033	5033	5033	5033	5033
Forests	35	123	216	222	305	305	281	279
Barren and unculturable land	-	208	96	83	57	66	46	49
Land put to non-agricultural use	-	416	436	343	337	394	394	384
Culturable waste	-	83	41	35	37	29	20	14
Permanent pastures & other grazing land	-	5	4	10	4	10	6	4
Land under misc. trees, crops & grooves	-	4	4	12	5	13	5	5
Fallow land	313	139	45	110	49	43	38	34
Net area sown	3757	4053	4191	4218	4239	4173	4243	4264
Net area as percentage to total area	75	81	83	84	84	83	84	85
Area sown move than once	975	1625	2572	3284	3594	3567	3604	3671
Total cropped area	4732	5678	6763	7502	7833	7740	7847	7935

Source: *Statistical Abstract of Punjab*, 2001
Note : R: Revised, P: Provisional

The land resource of Punjab comprises of plains developed by alluvium – a material laid by the rivers under the influence of the climate and, in the north, the Shivalik hills which have undulating areas with rocky soil with heavy drainage. Punjab has about 4.2 million

hectare of land under agriculture. In addition, 6.0 per cent area is under forests. The remaining area is for human habitation, industry, roads and railways and other unmarked activities. Hence, there is little scope for bringing more area under cultivation. Table 1 shows changes in the land-use pattern in the state over the period 1960-61 to 2000-01.

The share of non-agricultural land is high in the north-eastern hilly parts and areas along various ravine belts. The share of agricultural land is gradually declining because of soil degradation due to intensive cultivation or to changing course of rivers and population pressure. About two million hectare is degraded land (Table 2).

Table 2
Extent of Degraded Land in Punjab

Waste-land/soil degradation	Area (lakh ha)
Water erosion	
(i) Severe (gullies, ravenous)	1.70
(ii) Slight & moderate (with/without scrubs)	3.40
Water-logged—rising water table	1.22
Marshy-submerged	2.28
Salt-affected (varying degrees of deterioration)	
(i) Canal command areas	3.93
(ii) Outside canal command areas	1.27
Degraded forest/pasture lands	2.00
Coarse/very light textured (loss of nutrients with deep percolation and leaching, poor in fertility)	6.20

Source: Director, Punjab Remote Sensing Centre, Ludhiana

Land Management

The state has been divided into three zones on the basis of soil- and water-management programmes. The northern zone is located in the foothills of the Shivaliks and extends from Derabassi block of Patiala district to Dhar block of Gurdaspur district, covering Ropar, Fatehgarh Sahib, Hoshiarpur and Gurdaspur districts. In these areas, soil erosion due to flash floods is very common. Terracing and leveling of undulating land is necessary to make some headway in developmental activities.

The central zone comprises of the districts of Patiala, Ludhiana, Jalandar, Nawanshahar, Kapurthala and Amritsar. Here, the land is level and there is extensive urbanization, industrialization and agricultural activity. In the agricultural areas, on the one hand alkaline/saline soils are increasing due to water logging and extensive use of underground water, while on the other, soil reclamation work is also going on. More and more land of the ravine beds, covered by the rivers Beas, Ravi and Satluj and their tributaries are being brought under cultivation. Sand scraping is also widespread around the river banks.

The southern zone comprises of the districts of Sangur, Bhatinda, Mansa, Muktsar, Moga, Faridkot and Ferozepur. Sand dunes are common in the southern most area, adjacent to Rajasthan. These are being reclaimed gradually to reach the good soil below for agricultural purposes. Sand scraping is also common. Since the underground water is brackish, the soils are getting sodic relatively fast and such areas are going out of

cultivation. Over 37,000 hectare of land has been reclaimed from gullies up to the year 2000. Maximum reclamation has taken place in the districts of Hoshiarpur followed by Ropar and Patiala, where land in each district has been brought under cultivation during the last two years (Table 3). The pace of land reclamation is slow and needs to be speeded up.

Table 3
District- wise Progress of Gully Reclamation Work on Agricultural Land up to 1999-2000 (Hectare)

District	Up to 1997-98	During 1998-99	During 1999-2000	Total up to 1999-2000
Fatehgarh Sahib	-	-	-	-
Hoshiarpur	23711	-	-	23711
Gurdaspur	2677	-	-	2677
Jalandhar	97	-	-	97
Nawanshahar	-	-	-	-
Kapurthala	191	-	-	191
Amritsar	2	-	-	2
Ludhiana	-	-	-	-
Ropar	9290	64	-	9354
Patiala	1405	-	-	1405
Ferozepur	-	-	-	-
Sangrur	-	-	-	-
Bathinda	-	-	-	-
Mukarsar	-	-	-	-
Faridkot	-	-	-	-
Moga	-	-	-	-
Mansa	-	-	-	-
Total	37373	64	-	37437

Source: *Annual Administrative Report*, Department of Soil & Water Conservation, Punjab

Agricultural Land

Cropping intensity has been increasing since the green revolution and now it is 186 per cent. Wheat and paddy are the dominant crops of the Rabi and Kharif seasons respectively, occupying more than 60 per cent of the net cultivated area in each season. Both these crops are water and nutrient guzzlers. For paddy cultivation puddling of the soil is a prerequisite before transplanting. Repeated puddling leads to soil compaction, sub-division of soil particles and makes these soils impervious. Such soils in the long run become biologically inactive due to changes in the physico-chemical characteristics and thus are likely to become un-cultivable. The following important soil related constraints develop due to nutrient exhaustion of soils of macro- and micro-nutrients and intensive cultivation;

- *Chemical:* Depletion of organic matter; multi-nutrient deficiencies; nutrient imbalance; salinity/sodicity and pollution from agro-chemicals, sewerage and industrial affluent.

- *Physical:* Surface crusts; sub-soil compaction; soil erosion; poor air-water relationship; development of hard pan of fine textured sodic soils.
- *Biological:* Decline in quality and quantity of soil biomass; low biological oxidation and slow rate of decomposition of crop residues.
- *Hydrological:* Shallow water table; negative water balance; water logging; flood hazards; free percolation in coarse soils and poor permeability in fine textured soils.

At present, the organic carbon content has come down to 0.2 per cent from 0.5 per cent since 1960. The macro- and micro-nutrient deficiencies are dominant in 67 per cent of the cultivated area (Table 4). On top of it there are extensive areas where the soils are polluted due to waste-matter dumps containing degradable and non-degradable material, in and around urban areas. Extensive use of agro-chemicals on agricultural land reduce their biological activity, thus affecting the production potential of the soil, besides causing soil and water pollution.

Table 4
Percent Distribution of Blocks According to Fertility Status of Soils in Punjab (on the basis of per cent deficient samples)

Fertility		1970-77		1981-90		
Status	N	P	K	N	P	K
Low	52	16	13	67	44	-
Medium	48	65	58	33	55	43
High	-	19	29	-	1	57

Source: Brar and Chhibba, 1994, Brar, 1979

Soil Conservation

There is excessive pressure on Punjab's lands, on the one hand due to intensive cultivation and on the other, due to population pressure, industrialization, water accumulation and other activities. Land resources are limited and very precious and have to be used with a view to its repeated utilization on a sustainable basis. Conservation of land thus assumes great importance. The present activity of the state Department of Soil and Water Management aims at transforming uncultivated land into cultivated land. There is very little scope for further increase in agricultural production by bringing more area under cultivation. Thus, various soil conservation measures, such as land development, water harvesting technology, water management, conservation irrigation, field drainage, improvement of handicapped areas, utilization of sullage water, improvement of sub-soiling, etc., are essential to obtain maximum returns from the limited and highly valuable material resource, i.e, land, for sustaining agricultural growth/productivity. During the Eighth Plan, 67,472 hectare has been treated under different soil and water conservation measures. It was targeted to cover an area of 1,13,700 hectare during the Ninth Plan (Table 5). The soil and water conservation programme was expected to generate 30.60 lakh mandays of employment during the Ninth Plan. However, little attempt has been made to stop or reduce the misuse of soil by making it biologically dead due to accumulation of industrial affluents, dumping of urban waste and natural soil erosion.

Table 5
Achievements of Soil and Water conservation Works during Plan Periods (Hectare)

	8th Five Year Plan					9th Five Year Plan (Target)
Item of Work	1992-93	1993-94	1994-95	1995-96	1996-97	1997-02
Land development and ravine reclamation	2760	1247	1106	487	405	-
Rehabilitation of watershed	815	220	373	--	315	-
Water harvesting technology	330	--	468	910	1089	-
Water management	6682	380	850	1526	1504	-
Conservation measures	550	--	--	--	--	-
Field drainage	---	--	--	90	--	-
Improvement of subsoiling	213	146	65	62	--	-
Conservation Irrigation techniques	2886	1133	--	--	--	-
Improvement of handicapped areas	--	6071	7438	6858	7000	-
National watershed development	1169	--	2500	2385	1880	-
Tapping of sullage water	570	185	256	315	--	-
Drip Irrigation	--	--	--	314	325	-
River valley project	--	--	--	396	--	-
Flood Prone Rivers	--	--	--	1413	1805	-
Total	15975	9362	13056	14756	14323	113700

Source: *Ninth Five-Year Plan of Punjab (1997-02)*

Records do not reveal the amount of land area, which was once productive and has been going out of cultivation gradually. In addition, there may be small land patches distributed here and there owned by the farmers lying unused because these are uncultivable due to alkalinity or salinity. Similarly, in many paddy-growing farms some areas have become water logged where the second crop cannot be grown in the Rabi season. Such fragmented areas, which have become uncultivable have also to be brought under cultivation after proper reclamation through scientific advice to the farmers, who will adopt the reclamation practices faster as the area belongs to them.

In the northern Kandi region, soil erosion is a problem which needs to be tackled in a systematic and scientific manner, by terracing, planning of perennial grasses and trees, bunding, etc., in contiguous areas. The patchy work done here and there leads to more erosion of soils and washes away the terraces and bunds made in a season, which have to be reconstructed reportedly to be redone again. Only when this is done soil erosion can be checked on a sustainable basis in contiguous large area.

Conserving the natural land on a sustainable basis, particularly when it is fertile, is necessary in a situation when agricultural activity has to increase because of increase in population and an increasing demand for agricultural produce. Conservation and sustainability of land should go hand in hand so that these valuable assets remain of value.

In addition, soil salinity is on the increase in the southern region due to the use of brackish water for irrigation and in the central zone due to seepage and overuse of water. Strategies for improving the organic carbon status of the soil are also very important since it plays a multiple role in maintaining soil health.

Intensive research is needed to ameliorate the deteriorating condition of Punjab's soil and some of the known techniques, such as afforestation, water conservation, etc., should be properly disseminated to the stakeholders. For instance, large quantities of crop residues left in the field by the combined harvester can be recycled for improving the soil structure, decreasing bulk density and increasing porosity and infiltration of these soils in addition to supplementing nutrients. Several agronomic practices, such as raised beds, use of mulches, overhead plastic covers, etc., can greatly reduce environmental stress. Cultivation of crops with minimum tillage or zero tillage is becoming popular in this part of the country, because of the advantage of retaining organic carbon, besides lowering the cost of cultivation. This technique also needs to be continuously refined and evaluated through an inter-disciplinary approach to the cropping system.

In Punjab, an area of 6.98 lakh hectare was affected with alkalinity/salinity of the soil, which included 2.35 lakh hectare severely affected and 4.63 lakh hectare marginally or moderately affected. Out of the total of 6.98 lakh hectare, about 4.90 lakh hectare had been reclaimed up to 1996-97 (Table 6). Subsidized gypsum is supplied to all categories of farmers. *Dhancha* seeds with a limit of Rs. 300 per hectare are supplied free of cost.

These soils are either alkaline (with high pH), saline (with high salt content) or both alkaline and saline. The reclamation process of saline soils involves removal of excess soluble salts out of the root zone. In irrigated and well drained areas, like most of the central plain zone, soil salts are located and drained to suitable areas. Mulching has been found to increase the efficiency of leaching of salts. Alkali soils with high exchangeable sodium can be reclaimed by applying gypsum, press mud, etc. These scientific methods of soil reclamation, when adopted carefully, can minimize the problem and encourage productivity of several salt tolerant crops. Continuing research inputs are needed to improve technologies to manage such soils on a sustainable basis.

Steps taken by government agencies in vast areas which need reclamation from soil salinity or water logging are a slow process. This activity has to be quickened so that more area is brought under cultivation than that which goes out of cultivation.

Table 6
Reclamation of Alkaline/Kallar Land during the Plan Period in Punjab (Hect.)

Total area affected with alkalinity at the beginning of fifth plan	6,98,000
Level achieved upto 1979-80	73,547
Area reclaimed during sixth plan 1980-85	1,56,197
Total area reclaimed upto the end of sixth plan	2,29,744
Area reclaimed during seventh plan 1985-90	1,23,475
Total area reclaimed upto 1989-90	**3,53,219**
Achievements	
1990-91	21,323
1991-92	23,463
1992-93	18,210
1993-94	20,670
Eighth plan 1992-97	**1,10,000**
1994-95	19,000
1995-96	26,000
1996-97	22,400
1997-98 (Target)	20,000
Ninth Plan (Target)	1,00,000

Source: *Ninth Five-Year Plan, Punjab (1997-02)*

Outlays of Rs.1,250.00 lakh and Rs. 250.00 lakh have been made under the 50:50 sharing scheme for `Reclamation of Alkali Soils' in the Ninth Plan and the Annual Plan for 1997-98 to reclaim 100,000 hectare and 20,000 hectare respectively. Allocations of Rs. 1,134.12 lakh and Rs.206.22 lakh have been provided in the Tenth Plan and the Annual Plan for 2002-03 respectively for reclaiming saline land.

Table 7
Expenditure on Soil Conservation Measures during Plan Period (Rs. in Lakhs)

Plan Period	Soil Conservation & Engg. Deptt.	Agriculture Department (Land Reclamation)	Total
Expenditure			
Eighth Plan			
1992-93	577.99	302.71	880.70
1993-94	582.36	264.28	846.64
1994-95	633.80	272.72	906.52
1995-96	582.36	264.28	846.64
1996-97	624.35	53.86	678.21
Outlay			
Ninth Plan	4175.00	1250.00	5425.00
1997-98	625.20	250.00	875.20

Source: *Ninth Five-Year Plan, Punjab (1997-02)*

The state government has been spending money on various soil conservation measures regularly in order to improve degraded land. Expenditure under the sub-head `Soil Conservation' during the Eighth Five-Year Plan, i.e., 1992-93, 1993-94, 1994-95, 1995-96 and 1996-97 and approved outlay for the Ninth Plan and the Annual Plan for 1997-98 is given in Table 7. The total expenditure on soil conservation was Rs. 4,158.71 lakh

during the Eighth Plan. Out of an outlay of Rs 5,425.00 lakh provided in the Ninth Plan, only 35.8 per cent was spent on soil conservation during the plan period.

For water-logged soils, avoidance is the best prescription. Seepage from canal water and overuse of irrigation water for crops have to be checked to avoid water-logging. A proper drainage system has to be developed so that the flow of water is on a gradient to prevent accumulation in the first two to three metre depth of the soil. A project to develop a drainage system in the southern region of the state is under construction. However, a scientific drainage system needs to be refined and reinforced so that the water-logging problem is reduced and eventually eliminated. A mix of scientifically proven methods of minimizing and eliminating water-logging are:

- Planting of contour vegetative hedges particularly on higher slope areas.
- Repair bore-wells with pumping sets for vertical drainage.
- Shallow bore-well with pumping sets for vertical drainage.
- Percolation wells with pump sets.
- Deepening/renovation of village ponds and others.
- Dissemination of these methods to the farmers concerned can greatly help in checking water-logging.

WATER

Water is considered to be an inexhaustible natural resource in the world, but the quantum varies from place to place. Punjab, as the name suggests, is the land of rivers. It is endowed with a good surface water resource through rivers and streams and also has abundant underground water reservoirs. It is a conservative estimate that nearly 80 per cent of the water resources is consumed in the production of food and fibre. Agricultural water-management, therefore, assumes great significance. While surface-water management has been under governmental jurisdiction, underground water is mostly exploited on a private basis.

The use of water has been through an integrated approach on the basis of comprehensive research and investigations. In spite of this, there has been problems of fluctuating sub-soil water level losses and wastage of undeveloped and developed water courses and a general phenomenon of improper drainage. For Punjab, the rivers Sutlej, Ravi and Beas of the Indus basin and the rivers Yamuna and the Ganga basin originating in the Himalayas are the main sources of water for canal irrigation. Storage basins have been constructed over the river Sutlej-Bhakra Dam, on the river Beas–Beas Dam at Pong and on the river Ravi–Thein Dam, whereas for the river Yamuna, the storage dam (Kishau Dam) is yet to be completed. The rivers Sutlej, Beas and Ravi have been interlinked with the transfer of water from the Ravi to the Beas and from the Beas to the Sutlej – the Bhakra canal system and the Yamuna canal system are also interlinked to regulate the water flow. In other words, all the four rivers have been so interlinked that these can operate as a common grid, and this remarkable water management system is greatly responsible for progressive agriculture in the state, as it provides abundant surface water for irrigation.

Surface Water Resources

The three rivers, namely the Sutlej, Beas and Ravi, flowing through the state have a water potential of about 20.06 maf. Although some limitations are imposed by seasonal variations in the flow, large quantities of water are available for irrigation purposes. The river flow is considerably reduced from mid-November to mid-February and the subsequent rise in the level of water is dependent upon the rains. Besides these rivers, there is a network of six major canals, some built during British times and others later on. These are the Upperbari Doab Canal; Bist Doab Canal; Sirhind Canal; Patiala I.B. Circle; Bhakra Main Canal; and Ferozepur Canal Circle. In addition, there are several important water drains and nallahs, as mentioned earlier.

Punjab has a distribution network of 1.45 lakh km of canals including branch canals, and minor distributaries and one lakh km of field canals or water courses. The canal irrigation system irrigated about 1.3 million hectate of land in 1970-71, while only one million hectare was irrigated during 1999-2000 (Table 8). There has been a reduction of over 36 per cent in the canal irrigation area since 1990. This is because only 35-40 per cent of the water entering the canal system reaches the cultivated fields. Normally the optimum efficiency for canal irrigation is 60 per cent. Over the years, maintenance of the canal irrigation system has been neglected and overlooked. Mainly silting of canal beds, unlined channels and distributaries and leakage of bunds due to improper maintenance cause loss of water. Revamping the canal system, particularly by de-silting and lining of channels and distributaries, would generate enough water for the remaining unirrigated land of the state.

Incidentally, the quality of the canal water remains good for most part of the year, except during May and June when the electrical conductivity increases from an average of 400 to 500 moh/cm. The quality of water is also affected by the terrain through which passes it.

The canal irrigation system has also led to much wastage due to seepage. In most of the canals, which are unlined, constant seepage has led to water-logging in most of the command areas and also development of salinity in the soil. Unless the canals are properly cleaned and lined, the problem of water-logging and soil salinity will continue to aggravate and more and more land will become uncultivable. Urgent steps are needed to check the loss of land on account of controllable canal water flow.

Table 8
Net Irrigated Area (.000 ha.) by Different Sources in Punjab

Source	1970-71	1980-81	1990-91	1999-00*	2000-01*
Canals	1292	1430	1669	1051	1002
Tube wells	1591	1939	2233	2938	3017
Other sources	5	13	7	12	2
Total	2888	3382	3909	4001	4021
Share of area irrigated to the net area sown (%)	71	81	93	94	94

Source : *Statistical Abstract, Punjab 1971, 1981, 1991, 2000 and 2001*
Note : * Indicates provisional estimates

Groundwater Resources

Groundwater resources are exploited to supplement surface water resources. In Punjab, underground water resources have been exploited to such a large extent that the crisis of its depletion is becoming a reality. There are 9.35 lakh tube wells in the state to lift underground water for agricultural irrigation and another 1,50,000 in urban and semi urban areas for drinking water, industrial purposes, etc.

During 1970-71, there were only 1.92 lakh tube wells in the state. About 71 per cent crop areas were irrigated by tube wells during 1970-71, increasing to 95 per cent during 1999-2000. While canal irrigation has been declining over the years, tube well irrigation, particularly in the central and northern regions of the state, has been on the increase. The state has over 1.7 million hm of available groundwater potential. Due to over-exploitation of underground water reserves are getting exhausted, so much so that the water table has gone down by five to ten metres during 1973 to 1996 in the central plain zone. It has been estimated that the average decline of the water level is at the rate of 23 cm per year (Table 9). If this trend continues for the next 15 years, more than two lakh submersible pumps would be needed to replace the present pump sets, at an estimated cost of Rs. 2,000 crore meaning thereby an extra expenditure of Rs. 5,000 per hectare of net sown area and in addition a two-fold increase in energy consumption.

Table 9
Rise and Fall in Underground Water Table in Different Districts of Punjab, 1973 through 1994

District	Fall in water table (m)			Rise in water table (m)		
	Blocks	1973-83	1984-94	Saline/semi-saline blocks	1973-83	1984-94
Sub-mountainous Zone						
Gurdaspur	All	+0.2-0.6	-0.7-1.2	-	-	-
Ropar	All	+0.04	-1.8	-	-	-
Hoshiarpur	All	-0.9	-0.9	-	-	-
Central Plains						
Amritsar	All	-0.9	-2.3	-	-	-
Kapurthala	All	-0.7	-1.8	-	-	-
Jalandhar	All	-1.5	-2.5	-	-	-
Ludhiana	All	-0.9	-1.9	-	-	-
Patiala	All	-0.9	-1.9	-	-	-
Patiala	All	-.17	-9.8	-	-	-
Fatehgarh Sahib	All	-1.3	-2.7	-	-	-
Sangrur	All	-5.1	-5.1	-	-	-
South-west Zone						
Mansa	All	-1.6	-1.4	-	-	-
Bhathinda	0.5	+3.5	-1.9	0.5	7.3	4.2
Faridlot	0.5	-1.15	-4.5	0.33	9.0	5.0
Ferozepur	0.75	+0.1	4.5	0.25	7.7	3.0

Source: Directorate of Water Resources, Punjab

According to a PAU estimate (1997) in 63 blocks of the state there is over-exploitation of water of more than 100 per cent of the annual net re-charge, whereas in seven blocks

the exploitation is above 85 per cent. This over-exploitation of underground water is due to the constant increase in the number of tube wells because of poor canal water supply, free electricity, cultivation of high water-consuming crops such as paddy, potato, wheat, sugarcane, fodder, etc., and scant attention to water-use efficiency. The phenomenon of over-exploitation of underground water resources is of concern in the other Indian states as well. During 1984-85 to 1998-99, the number of dark blocks has increased from 253 to 422 in the country. In Andhra Pradesh dark blocks have increased from 0 to 30, in Gujarat from 6 to 26, in Haryana from 31 to 51, and in Punjab from 61 to 97 (*Report, Planning Commission, 2001*). This calls for effective groundwater recharging measures and also regulation of groundwater resources. Extensive research is needed to work out methods of optimal water-use for different crops for different regions and also to improve the surface-water irrigation system.

In the southern region the groundwater is brackish, with high conductivity. Sweet water is found only in deep layers beyond 15 to 20 metres where submersible pumps have to be used. Being the southern and tail-end region of the canal system, both surface and underground water are scarce and hence this area has remained agriculturally less developed. Conjunctive use of sweet water, especially from canals with underground brackish water, has been in the practice for growing various crops in this region. But increase in soil salinity is a constant threat in these areas. Strong research input is needed to develop crop varieties for this area and to maximize the use of available water.

Watershed Management

In the sub-mountain Kandi region of the Shivalik range, soil erosion is rampant due to excessive water-flow during the rainy season and absence of water for drinking and irrigation in the rest of the year. Water conservation has been a need in this area. A watershed development project was initiated in 1990 with the assistance of the World Bank in this region. As a result of developing watersheds, contour vegetative barriers and vegetative reinforcements have been established in 6274 hectare and rain-water conservation has been possible for irrigating over 5000 hectare of land uptil 1995. A total of 2094 villages fall in the Kandi tract, having a population of 14.17 lakh and 30,99,000 hectare of land belonging to the districts of Gurdaspur, Hoshiarpur, Nawanshahar, Ropar and Patiala. As a result of the development of watershed management, the yield of maize crop was 1746 kilogram per hectare, wheat 2098 kilogram per hectare and gram 79.4 kilogram per hectare during 1996-97. The cropping intensity has been 165 per cent. In the project area successful cultivation of crops, forests and grass has been possible, while in non-project areas the conditions are yet to improve. The participation of local people and government agencies have demonstrated that infertile and degraded areas can be conveniently converted into fertile and cultivable areas with their joint efforts and scientific acumen. Continuation of watershed management programmes in the remaining area is necessary for increasing crop productivity. Besides capturing rain, water-sheds can meet the growing demand for irrigation in lean periods. In addition, the basic approach should be to convert the surface flow of water to sub-surface flow for reaching open and groundwater aquifers.

Management of Water-use

Government-managed canal water system, which has a very scientific layout of distribution and delivery mechanism, is now facing criticality in its performance. While

the end user of the canal irrigation system is the biggest sufferer, the influential landlords take advantage of the weakness of the system and usurp the water which otherwise should have reached the tail-enders. By managing the canal system in a scientific manner, the remaining unirrigated area of the state can also receive water for cultivation. Presently more than 50 per cent of the canal water is wasted only because of seepage. This can be easily checked by well-developed scientific procedures.

Water-logging in the canal command areas and areas where the drainage is poor has been a cause of concern, as large areas have gone out of cultivation. Valuable experience has been gained from the management of water-logged areas in the Tikri project (Barabanki district, UP) of National Watershed Development Programmes for Rainfed Agriculture (NWDPRA), where desilting of village ponds and vertical drainage through shallow tube wells have totally eliminated water-logging. In addition, fish culture in desilted ponds and summer cropping of okra, green gram and cucurbits irrigated from shallow tube wells are generating considerable income to the farmers. Such success stories should be emulated for action in the affected areas.

Over-exploitation of underground water needs to be checked and regulated so that only the amount of water required is pumped out and there is no wastage. Withdrawal of free electricity or introduction of partial tariff will reduce considerably the continuous running of tube wells and also check wastage of water. The recharge of underground water is an immediate necessity and concerted steps must be initiated now, failing which water scarcity will become a reality by the end of the next decade. In this context, rain-water harvesting, which is relatively an inexpensive technology, should be adopted on a large scale both in urban and rural areas, with a focus on recharging the depleting underground water and also using it for irrigation purposes. Administrative reforms are also required in the distribution of water and a campaign needs to be launched to sensitize people to save water. Panchayati Raj Institutions can greatly facilitate the task of water management at the village level.

Rain-water Harvesting

To recharge the depleting groundwater table, rain-water harvesting is necessary in urban as well as rural areas. The most prominent area where rain-water harvesting can be done is the Kandi area, or the lower Shivaliks where there are a number of choes. The main method recommended for preventing soil erosion is through check dams. Apart from the check dams, sink holes should be made where the soil is impervious. Sink holes have to be located upstream of the check dams where water has been stored. This area serves also as acquifers of the water table of Punjab in general. The design of these sink holes should be such that they can be cleaned annually. Check dams and sink hole combination not only controls soil erosion, but also checks flash floods in these areas.

Rain-water harvesting in inhabited areas: There are many other ways, though at the micro level, to enhance rain-water harvesting. The most prominent and useful method is rooftop rain-water harvesting. Many states, such as Andhra Pradesh and now Haryana have also made it mandatory for every house, of plot-size 250 sq, yards and more, to have its own rain-water harvesting system. In areas having smaller plot size, and even rural settlements, rain-water harvesting pits can be made at the community level.

A typical rooftop rain-water harvesting system comprises of

a) Roof catchment
b) Gutters
c) Downpipes
d) Rain-water/storm-water drains
e) Filter chamber
f) Ground water recharge structures, like pit, trench, tube well or a combination of the above structures.

Storage tanks: For harvesting roof top rain-water, storage tanks may be used. These tanks may be constructed on the surface as well as underground by utilizing local material. The size of the tank depends upon the availability of run-off and water demand. After proper chlorination, the stored water may be used for drinking purposes.

Recharge pits: Recharge pits are constructed for recharging shallow aquifers. These are constructed 1 to 2 m. wide and 2 to 3 m. deep back and filled with boulders, gravels and coarse sand. The size of filter material is generally as below:

Coarse sand : 1.5 - 2 mm

Gravels : 5 - 10 mm

Boulders : 5 - 20 cm

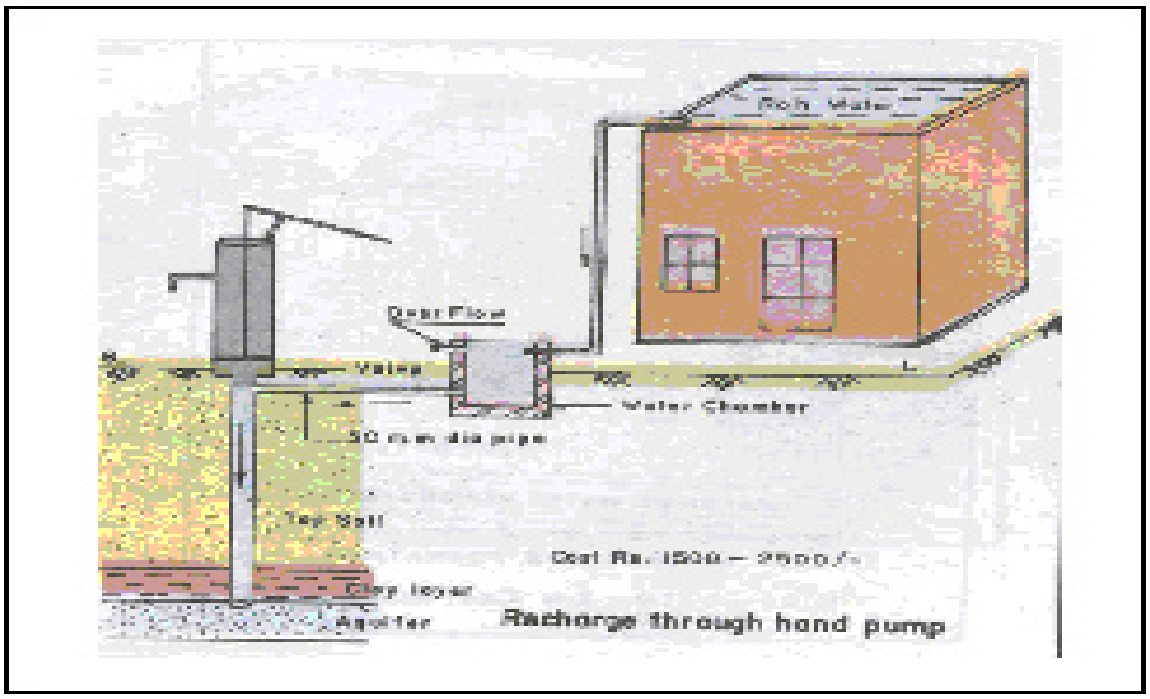
The filter material should be filled in graded form. Boulders at the bottom, gravels in between and coarse sand at the top so that the silt content that will come with the runoff will be deposited on the top of the coarse sand layer and can easily be removed. If clay layer is encountered at shallow depths, it should be punctured with auger hole and this should be refilled with fine gravel of 3 to 6 mm size.

Trenches: These are constructed when permeable strata are available at shallow depths. The trench may be 0.5 to 1 m. wide, 1 to 1.5 m. deep and 10 to 20 m. long, depending upon the availability of water. These are back-filled with filter materials. In case clay layer is encountered at shallow depth, auger holes may be constructed and back-filled with fine gravel.

Abandoned dug wells: Existing abandoned dug wells may be utilized as recharge structures after cleaning and desilting them. For removing the silt content, the run-off water should pass either through a desilting chamber or a filter chamber.

Abandoned hand pumps: The existing abandoned hand pumps may be used for recharging shallow/deep aquifers, if the availability of water is limited. Water should pass through the filter media before being diverted into hand pumps.

Abandoned tube wells: Abandoned tube wells may be used for recharging shallow/deep aquifers. These tube wells should be redeveloped before use as recharge structures. Water should pass through the filter media before it is diverted into recharge tube wells.



Recharge wells: Recharge wells of 100 to 300 mm. diameter are generally constructed for recharging the deeper aquifers and rooftop rain-water is diverted to recharge well for recharge to groundwater. The runoff water may be passed through filter media to avoid choking of recharge wells.

Vertical recharge shafts: For recharging shallow aquifers which are located below clayey surface at a depth of about 10 to 15 m, recharge shafts of 0.5 to 3 m diameter and 10 to 15 m deep are constructed, depending upon the availability of run-off. These are back-filled with boulders, gravels and coarse sand. For lesser diameter shafts, the reverse/direct rotary rigs are used and larger diameter shafts may be dug manually. In the upper portion of 1 or 2 m depth, brick masonry work is carried out for the stability of the structure.

Shaft with recharge well: If the aquifer is available at a greater depth, say 20 or 30 m, a shallow shaft of 2 to 5 m diameter and 5 to 6 m deep may be constructed, depending upon the availability of run-off. Inside the shaft, a recharge well of 100 to 300 mm diameter is constructed for recharging the available water to a deeper aquifer. At the bottom of the shaft filter media are provided to avoid choking of the recharge well.

Lateral trench with bore wells: For recharging the upper as well as deeper aquifers, lateral trench 1.5 to 3 m wide and 10 to 30 m long, depending on the availability of water, with one or more bore wells may be constructed. The lateral trench is back-filled with boulders, gravels and coarse sand.

Agricultural Land

Apart from rooftop rain-harvesting, the agricultural sector should also be encouraged to use different forms of irrigation other than flood irrigation, where much of the water is evaporated. Drip irrigation and sprinkle irrigation should be made compulsory for the

consumption of less water. Even field boundaries should be made higher, at least 2.5-3 ft for checking outflow of water. This could be checked by revenue authorities or patwaris in the villages.

Drain Management

Drains, which are spread almost all over Punjab, may be used effectively for rain-water harvesting. There should be a strict ban on the dumping of city sewage in these drains, whereas check dams must be constructed along with flood gates near waste land. Drains, constructed for the flow of excess surface rain water, must be made to carry this type of water only. Those drains which carry water from agricultural fields containing fertilizers, pesticides, etc., must be used again for irrigation of agricultural fields alone.

FORESTS

Punjab is a predominantly an agricultural state, consequently the forests cover is low. According to the state's Forests Department, approximately about six per cent of the land area is recorded under forests against the norm of 33 per cent prescribed in the National Forest Policy.

Table 10
Forest Cover in India and Punjab (2000)

	India	Punjab
Recorded forest area	75 m ha (54% Reserve forests) (30% Protected forests)	2.90 lakh ha (5.8%)
Actual forest cover	64 m ha (19% of total geographical area)	1.39 lakh ha (2.8% of area)
Well stocked forests	(12% of total geographical area)	51.00 ha
(Cover density> 40%)	38 m ha	(1.0%)
Degraded forests	31m ha (40% of recorded forest area)	12,000 ha (0.23%)
Average productivity	<lm3ha (Potential is: Rainfed: 25-35 m ha irrigated 40-50 m3/ha	-
Growing stock	@ 65m3/ha (110m3/ha world average)	-

Source: *Statistical Abstracts*, Punjab, 2000-2001

The actual forest cover is 2.8 per cent (Table 10). The types of forests in Punjab are given in Table 11. There is hardly any scope to transfer more areas to the Forest Department for raising forests plantation. Out of the total of 1,387 sq. km. land under forest cover during 1997-98, the Shivalik Circle, constituting the districts of Hoshiarpur and Ropar, has the highest area (1,82,907 hectare) followed by the Bist Circle (80,217 hectare) and the South Circle (41,405 hectare). Hoshiarpur and Nawanshahar districts have the maximum land under forest cover. Per capita forest in Punjab is 0.01 hectare as compared to the Indian average of 0.07 hectare (Table 12).

Table 11
Forests of Punjab

Types of Forests	1997-98 (ha)	1998-99 (ha)
A) GOVERNMENT FORESTS		
1. Reserve forests	4336.36	4336.39
2. Protected forests		
i) Demarcated forests	29842.36	29988.38
ii) Un-demarcated forests	7970.05	7970.05
iii) Road strips	16511.17	16524.17
iv) Rail strips	8723.19	8723.19
v) Canal/Drain strips	45024.74	45034.24
Total Protected forests	108071.53	108240.03
3. Unclassed forests	21522.54	21377.34
Total Govt. forests	133930.46	133953.75
B)PRIVATE FORESTS		
4.Under sec. 4 & 5 of Punjab Land Preservation Act, 1900	169899.60	169899.60
5.Under Sec. 38 of Indian Forest Act. 1927	675.33	675.33
Total Private Forest	170574.93	170574.93
Grand Total	304505.39	304528.69

Source: *Annual Administrative Report, 1998-99, Forest & Wildlife Preservation*, Punjab

The function of forests is merely to provide timber, food, fibre and fuel wood. These have a great influence on the environment, the soil, water and, above all, these are the custodians of bio-diversity and wildlife. The survival of all these elements on a sustainable basis is necessary, but the current situation is such that the conservation of existing forests is so urgent that expansion is a far cry. In contrast, however, degradation of forests for economic reasons and extensive poaching of wildlife has been going on unabated, despite the fact that several forests areas have been declared as reserves for wildlife and felling trees is banned. In Punjab, 8,064 cases of illegal felling of trees and poaching of animals were registered during 1997-98, in addition to several hundreds of unreported cases. Management of forests, therefore, assumes great significance.

Table 12
Forest Cover in Punjab and Other States (1997-98)

State	Geographic area (sq km)	Forest area (sq km)	Forest as % to total area	Per capita (ha)
Punjab	50362	1387	2.8	0.01
Haryana	44212	604	1.4	-
Rajasthan	342239	13353	4.0	0.03
Gujarat	196024	12578	6.4	0.03
Arunachal Pradesh	83743	68602	82.0	7.93
India	**3287263**	**633397**	**19.3**	**0.07**

Source: *Statistical Outline of India, 2000-01*

Forests of Punjab have been classified as under:

a) Coniferous (Lower Shivalik Chir Pine) forests
b) Bamboo forests
c) Scrub forests
d) Broad leaf forests

Coniferous forests: These forests are found in the Shivalik hills of the state where Chir is the main species, along with Amla, Khair, Sunan and some scattered trees of Terminalias. Chir wood is of poor quality and its felling in the area is completely banned. These areas are being managed according to the tree section of the working plan, i.e., by a selection-cum-improvement felling system.

Bamboo forests: These forests are also found in the Shivalik hills, mainly in the Dasuya Forest Division and in certain pockets of Hoshiarpur and Gurdaspur Forest Divisions in Dholbaha and Salidhar forests respectively. In the Dasuya Forest Division, Bindravan, Karanpur and Nanad Bir areas are almost pure bamboo forests. The main species is *Dendrocalamus strictus* associated with Rajain, Khair, etc. These forests are being managed under selection-cum-improvement felling system.

Scrub forests: Scrub forests are found in the Shivalik hills and in various Birs of Punjab. *Acacia catechu* is the main species found here. *Acacia nilotica* and *Delbergia sissoo* are found along riverine areas and in the plains. In the Shivaliks, management of these forests is under the Land Preservation Act of 1900 and under the Indian Forest Act of 1927, whose main objective is to stop and reverse the process of soil erosion and improve the moisture regime and groundwater recharging. In the past few years, economically more important tree species have been introduced in these scrub forests, both in the hills and in the plains. These include Eucalyptus, Neem, Siris, Toot, Drek, Ailanthus, Tun, Amla, Poplar, etc. In the plains, the Eucalyptus areas are under clear felling with regeneration. Improvement in felling, thinning and other silvicutural operations are also conducted as and when required. The techniques of management have great scope for improvement.

Broad leaf forests: Eucalyptus, Shisham, Poplar, Mango, Neem, Toot, Teak, Ailanthus and Tun are some of the important species of the broad leaf forests. These types of forests are mainly found in the plains and are being managed under the prescriptions given in the working plans. Generally, the silvicultural system adopted is clear felling with artificial regeneration. The Eucalyptus forests are under the clear felling system with natural regeneration (coppice), supplemented by artificial regeneration. Improvements in felling, thinning and other silvicultural operations are also carried out as and when required.

Regeneration and Afforestation

Regeneration becomes essential as more and more forests get destroyed due to economic reasons, negligence, fires and other known and unknown causes. It has to be conducted at a faster pace than that of degradation, which now appears to be faster. Punjab has much less area under forests than prescribed, hence forest regeneration assumes great significance, for which concerted practical and scientific approaches have to be adopted. The current methods of forest regeneration are:

Mainly natural: Locational factors are very important in the natural regeneration of any forest species. Natural regeneration of Khair, Chil, Shisham, Eucalyptus and Bamboos has been going on in the forests of the state. Natural regeneration of Shisham is being encouraged in the Shivalik hills, as it helps soil conservation. At some places in the plains of Punjab good natural regeneration of Shisham has been noticed. Eucalyptus regenerates naturally through coppice. Natural regeneration is not the only way of afforestation but has also to be supplemented with artificial regeneration.

Mainly artificial: Afforestation with artificial regeneration is the main method adopted to increase the forest cover of the state. Plants of economically important species, viz., Eucalyptus, Khair, Bamboo, Teak and Shisham are raised in polythene bags in different nurseries of the state. At present there are 273 forest nurseries, covering an area of 263.49 hectare, which raise the seedlings of those tree species, which are planted when required for the artificial regeneration of the forests. The number of nurseries and seedlings need to be increased two-to three-folds to augment the forest cover in the state.

Afforestation: During 1998-99, afforestation/treatment was carried out over an area of 10,439 ha by the department under different schemes in operation. Apart from this, individuals and various organizations also carried out afforestation/treatment after purchasing the plants from forest nurseries and other private nurseries of the state. Voluntary bodies and village panchayats should be involved in this work.

Forest Produce and Requirement

Forests are also a natural source for wood, wood products, fruits, biodiversity and provide pasture land for grazing animals. Many communities thrive on forest produce, as this is their only means of livelihood and sustenance. In the process, damage to the forests and pasture lands takes place. However, some of the communities using forest produce are equally responsible for the maintenance of these forests, as they also ensure proper protection and regular regeneration exercises.

Overexploitation of forests for their produce for economic gains has endangered them and is the main cause of their degradation. The forest department is charged with the responsibility of preservation, management and regeneration of forests as well as wild life, but degradation of forests and poaching of wild animals go on unabated. Scientific methods need to be adopted for the sustainability of forests and wild life, and peoples' participation in this task should be ensured for better results.

Table 13
Forest Produce in Punjab

Particulars	Unit	1997-98	1998-99
Timber	Cu.M	73182	67760
Firewood	-do-	2070	2187
Bhabbar grass	Tonne	493	494
Fodder/grazing Sarkanda	Lakh Rs.	24.72	21.98
Plants	Lakh Rs.	50.31	40.93

Source: *Annual Administration Report, 1998-99, Forest & Wildlife Preservation, Punjab*

During 1998-99, 67,700 cubic metre of timber was legally produced by the forest department and 2,187 cu.m was meant for fuelwood. Non-wood forest produce, such as babbar grass, bamboo, sarkanda, fodder and fruits, valued at over Rs. 100 lakh, was also produced and sold (Table 13). This production is variable depending on weather conditions, market demand and the availability of forest produce. The projected annual total demand for wood in the state by the year 2005 is approximately 7.24 million cum. There are 88 plyboard manufacturing units in Punjab whose annual demand is met by trees harvested from 6,000 to 8,000 hectare of land annually. These units are working at 50 per cent capacity. On a six to seven year rotation the area under poplar tree cultivation can be easily increased by about one lakh hectare. Installation of pulp units for paper/rayon in public or private sectors is necessary, and this activity itself will encourage afforestation.

Agro-forestry and Social Forestry

Agro-forestry involves growing trees and crops in combination, while social forestry deals with growing trees in the socially inhabited areas, such as towns, villages, roads, parks, railway tracks etc. Punjab Agriculture University (PAU), after years of research, has identified tree species of Poplar, Eucalyptus, Leucaena, Acacia, Melia, etc., for agro-forestry and developed matching technology for their block and boundary plantation. For boundary plantation, planting of Eucalyptus in the north-south direction and its specific management of crop nutrients and water management have been standardized. Guniea grass, oats and sorghum have been identified as suitable crops for block plantation. Keeping in view the demand for several plywood units in the state, considerable emphasis has been laid on Poplar plantation. Cultivation of fodder crops, as inter-crop in the early stages at Poplar plantation has been found to be profitable and better than wheat-paddy rotation (Table 14).

Table 14
Economics of Poplar with Inter-cropping
(Annual value Rs./ha)

Year	Poplar+Wheat -Kh. Fodder	Poplar+Sugarcane for three years Wheat-Kh fodder for three years	Poplar+Potato+ fodder for three years Wheat-kh. fodder for three years	Paddy-Wheat
I	16778	27385	36498	33023
II	12095	30190	12098	33023
III	5925	16228	11143	33023
IV	43293	45450	45685	33023
V	44580	52658	53683	33023
VI	60435	67603	67813	33023
Overall	183106	239514	226118	198138
Annual	**30518**	**39919**	**37686**	**33023**

Source: Singh, Sukhjinder (2000) M.Sc. Thesis, Department of Economics & Sociology. Punjab Agricultural University, Ludhiana (Unpublished).

Usually farmers cannot spare or tie up the land for longer periods under block forests-tree plantation. Boundary plantation of Poplar, Eucalyptus, Drake, etc., planted in the north-south direction has given better results than when planted in the east-west direction. Marshy and marginal land are more suitable for Eucalyptus cultivation. Trees

planted around farm tube wells alongside farm paths and permanent water channels also add to agro-forestry and do not affect agricultural crops.

Cultivation of Eucalyptus was popular in the state during the eighties. Its cultivation declined due to lack of proper marketing and the agro-forestry movement suffered a setback. A second push for encouraging agro-forestry and social forestry is called for with adequate research backing.

Forest Management

Forest management is the crucial input for saving the forests, their bio-diversity and wildlife, from losses due to illegal felling of trees and poaching of wildlife. Besides, vigil has to be kept to detect forest fires. There are roads and paths passing through the forests and some rest houses have also been constructed. These have to be properly maintained. Protection from cattle on open grazing has to be ensured so that the rejuvenation of trees' undercover is not damaged beyond repair. Several trading operations, such as improvement in felling, Kana/gram stubbing, weeding, debudding, have to be carried out frequently to maintain the health of forest cover. While the wood of Poplar is in great demand there is also need for diversification to grow Teak, Simbal, Bamboo, Shisham, etc., for greater economic returns. Though adequate manpower has been assigned to the forest department, leakages are frequent and sometimes over-burdening.

Afforestation is a process of planting trees and other plant species on a regular basis to maintain appropriate forest cover and increase the forest area. In special area programmes, such as the sub-mountainous zone of Kandi area in the districts of Hoshiarpur, Ropar and Gurdaspur, afforestation is aimed at checking soil erosion and conserving water. An integrated afforestation programme with suitable tree species, grasses and other plants, to rejuvenate and add to the forest area and also to avoid the loss of bio-diversity, for ecological restoration and environmental conservation is on. Since 1997, this programme has covered over 1000 hectares in the Kandi area. The speed with which this work is being done is rather slow because degradation of forests is taking place faster than afforestation. In this context, participation of local stakeholders would be meaningful in not only saving the forests from degradation but also in looking after the planted trees. Involvement of Panchayati Raj Institutions would be meaningful.

Bio-diversity and its Conservation

In India about 45,000 plant species have been recorded, which constitute nearly 12 per cent of the world's total plant species. Out of these 3,000 species are of non-economic value. Many plant species found in the Himalayas and Shivalik ranges are locally used for various medicinal, food and fibre purposes. The medicinal value of some plant species is yet to be determined.

Bio-diversity: Punjab is almost entirely cultivated. The Shivalik in the north and northeast has undulating green forest cover where the maximum wild stock of the state exists. Along with the Shivaliks the wet-lands or patches along rivers are places where wild stock is available. The state can be divided into four main zones as follows:

1. Shivaliks
2. Grassy plains
3. Semi-arid region
4. Wet-lands

Shivaliks: The Shivalik forests are dominated by deciduous and broad-leaves bushes and trees. Quite a number of herbs and shrubs are also found in this region, especially during the rainy season. The lower hills have Shisham and Khair trees. The broad-leaves bushes and trees include Aohatoda, Azadirachta, Bombax, Butea, Albergia, Albizzia, Ficus, etc.. A large number of herbs form part of the ground flora. Thorny bushes and trees include Capparis, Ziziphus, Acacia, Mimosa, Lantana, etc.

The area also provide shelter to a large number of animals, birds, reptiles and insects. The ecosystem is of the climax type. The area has a large number of birds, especially sparrows, finches, weavers, woodpeckers, doves, pigeons, quails, cuckoos, magpie, parakeets, mynahs, etc. Such animals as deer, bluebull, sambhar, hogdeer, chital, etc., are found here, though in very small numbers.

Grassy plains: The grassy plains exist between the Shivaliks and the sandy southern fringes of Punjab. Most of the area is cultivated, dotted by numerous trees and shrubs. Grasses are the dominant natural vegetation. The fauna include several herbivores, such as hares, squirrels, etc., and carnivores, such as cats, foxes, mangoose, snakes, etc. Birds, which mainly feed on insects and grains are to be found in this area.

Semi-arid region: The southern areas of Punjab were characterized by shifting sand dunes, about half a century ago. However, with increasing cultivation and availability of irrigation facilities, the sandy regions have shrunk considerably. Since humidity is very low, thorny bushes are the main flora. Reptiles, such as lizards and snakes comprise the main fauna of the area. Other animals include hares, jackals, squirrels, etc. Black buck and blue bull are found in Abohar sanctuary, protected by local inhabitants.

Wet-lands: Punjab has several inland fresh water reservoirs, such as ponds, lakes and rivers, which provide habitat to a variety of flora and fauna. Aquatic vegetation, such as water hycanith, nelumbium, trapa, hydrilla, etc., exixts in abundance in water bodies, along with varieties of algae and petridophytes, which feed large numbers of amphibians and reptiles, such as snakes, turtles, etc., and 116 species of fish have also been recorded in the water bodies of Punjab. They also attract a large number of migratory birds.

The state of bio-diversity in Punjab is not ecologically sound because of many reasons, such as:

1. The green revolution, which has resulted in food stability, is also responsible for changes in the ecosystem and loss of bio-diversity.
2. The narrow spectrum of traded products from agriculture, forestry and fisheries has resulted in the promotion of a few species only to the neglect of all other varieties.
3. Habitat loss has taken place due to micro-climatic change resulting from extensive land-use changes.
4. There is further loss of bio-diversity, as it has not been evaluated properly and integrated into the management of the resources.
5. Legal provisions are there to check poaching, extensive fishing, deforestation, but implementation is lacking, as well as awareness among the people residing in the neighbourhood.

The Punjab foothills of the Shivaliks, which once supported dense vegetation of diverse plant species, now present a highly degraded look. Perhaps many plant species have become extinct in this area. With the passage of time, depletion of agro-bio-diversity has also been taking place because of changes in the system of agriculture and in traditional crops and varieties in favour of new ones, over-grazing and deforestation. Encroachment for urban habitation, industries and other developmental activities have also caused considerable damage to plant species. Effects of such erosion of bio-physical and ecological systems are now being felt and will be felt more in the future. As there are no bylaws for adequate control, or powers to check unrestricted destruction of plant species and bio-resources, there is a need for legislative measure against indiscriminate removal of plants from non-agricultural land. A bio-informatics cell needs to be set up to record the existing plant wealth and ensure its conservation.

ENERGY

Energy is among the basic requirements of man, besides food, shelter and clothing. Human beings consume almost every form of energy, such as fossilized fuel, sun, wind, water, thermal or biological energy. Punjab mainly consumes fossil fuel as energy, besides hydro power.

Conventional Energy Sources

Natural non-renewable resources: Coal and petroleum are the natural non-renewable fuels used in the state. Punjab has none of these resources and is totally dependent on import from other states of the country, though there are two coal-based thermal power plants at Bhatinda and Ropar. Other sources of energy, such as petrol, diesel, furnace oil, kerosene and LPG are used in the state for transportation, industry, domestic purposes and in agriculture.

Natural renewable resources: Hydro-energy is the most important source of renewable energy in the state. Both large-scale and micro hydro electricity projects have been set up, out of which ten are state owned and three are shared with other states.

Another form of conventional renewable energy used in the state is bio-mass in the form of fuel wood, agro-waste and cattle-dung cakes. According to a report dung-cake consumption during 1978-79 was about three million tonnes in Punjab. It is estimated that by the year 2004-05 it will be about 10 million tonnes.

Non-conventional Energy Sources

In view of the ever increasing demand for energy and depletion of the world's conventional fuel resources, and their impact on the environment, non-conventional sources of energy need to be tapped.

Solar energy: Punjab has approximately 293 days/year of bright sunshine. This provides a large base for tapping natural energy resources. Solar energy can be utilized for the following five purposes:

i) Low-temperature collection system for domestic heating
ii) Concentrating collection system
iii) Photo-electric system
iv) Photo-synthetic system

Wind energy: Wind is also another important source of non-conventional energy. It involves the use of air masses of different densities and temperatures. Utilization of wind energy had been in practice in rural areas of the state before the seventies for winnowing threshed crops. It has now been substituted by machinces. The potential of wind energy utilization is under study for more effective use.

Cogeneration: Production of energy from steams in boilers is also being tried out in some industries of the state. This could be further enhanced by using various weeds as fuel for these boilers. Such weeds as water hyacinth, congress grass and lantana, which otherwise create enormous environmental problems in the state, could be used as fuel.

IMPROVING EFFICIENCY IN NATURAL RESOURCES USE

Land

Land is a valuable asset particularly when it is agricultural land. In Punjab, with 186 per cent cropping intensity, agricultural land is fully exploited and has started showing signs of fatigue in certain areas. Since agricultural soils in Punjab are alluvial deep, varying from sand to silty clay, it has taken centuries to form the fertile surface layer (5 to 10 cm) of the soil. The fertile layer is often washed away by floods and also eroded by wind and water (Table 15). Preservation of the surface layer, with its accompanying nutritional and biological support system, assumes significance as its loss would lead to loss in agricultural productivity.

Table 15
Runoff and Soil loss from Non-arable and Arable Land of Varying Sizes in the Shivalik Foothills of Punjab

		Area (ha)	Run (%)	Soil loss (t/ha/yr)
(A)	Non-arable lands			
(i)	Large catchments	1630-5610	26-42	38-225
(ii)	Small catchments	3 to 80	21-45	11-189
(B)	Arable lands	0.25 to 3	20.35	10.62

Source: Sur H.S. (2000) Director, Zonal Research Station, Bullowal, Saunkhri

Preservation and conservation of agricultural land is the responsibility of the cultivator, who looks after it so that it remains productive. He has to put in an appropriate quantity of nutrients and other ingredients, in place of those taken out in the process agricultural production, to maintain the land's fertility level. Unfortunately, this has not been happening and as a result our soils are becoming less productive because of loss of macro- and micro-nutrients in several areas. Establishment of a network of soil-testing laboratories as a facility to the farmer will go a long way in advising the cultivators about the hunger of the soil and its productivity potential.

Wastelands, another area of concern, are gradually increasing. Adjoining areas of urban habitation are becoming reservoirs of non-biodegradable wastes. The Government of India started an integrated wasteland development project in 1988-89 to develop wastelands based on village/micro watershed areas. However, dumping grounds around urban and factory areas, where affluents are deposited, and those of leftover brick kilns, quarries and old residential sites constitute a large mass of wasteland which is increasing day by day, but their reclamation and re-use has received little attention. Such areas are not only rendered permanently unusable but are also a source of pollution of air, land and groundwater. Attention needs to be paid to such areas too. Saline soils and water-logged soils are usually man made. Reversing the process of water-logging and soil salinity is a long drawn exercise and has to be done on a community basis. On the other hand, prevention of the development of salinity and water-logging is easily possible through proper extension of knowledge to the farmers. Sustainable agriculture, as a means to ecological conservation, calls for special attention to the management of land, which is our natural resource and should be well maintained.

Water

Water being a critical component of the life-support system, the national emphasis is on drinking water, followed by agriculture, industry and power. The basic needs for human beings, bovines and small remnants are 40, 30 and 1.5 litres per capita per day respectively. This does not include the requirements of wildlife. Scarcity of water can cause great hardship, while its abundance, particularly due to rains or floods, can cause havoc. As the underground water in the state is getting depleted, special attention has to be paid to water management and for this rain-water conservation is an important component. Most of the rain-water normally flows away. If, out of this, adequate precipitation is stored in the soil-profile itself as sub-surface water, and wells as groundwater, it will save the soil from erosion and mitigate the impact of droughts and floods. Siltation of reservoirs and canals will also be reduced. Conservation of rain-water is the requirement of the day, so that the depleting underground water is recharged and pressure on withdrawal for irrigation is reduced. Technology to conserve rain-water from rooftops of urban houses and runoff water of open spaces is available and is being used with success in Andhra Pradesh and other places. Water so collected is used for re-charging the underground water basin and also for irrigation and other purposes. In Kandi area where there is high runoff of rain-water, there is also an acute shortage of drinking water. Efforts have to be made to devise means to relocate rain-water of the monsoon season in a manner that it could be used for the sustainability of agriculture, human and plant resources.

Forests

Forests are the lifeline of all development activities and sustenance of human life. Increasing forest cover through proper management, protection and regeneration are essential components of conservation of soil and water resources and above all for regulating climatic aberrations. In Punjab, forests are important for continuing its agricultural activities. In addition, forests of neighbouring states, especially Himachal Pradesh and Jammu and Kashmir, are more important, as the entire water resources and climatic variables are totally dependent on the forest cover of these states. Degeneration of forests in these states has a direct bearing on Punjab's agricultural development programmes. Joint efforts by the three states to preserve and enlarge their

forest cover, through a consortium action-programme, will be of mutual benefit and steps should be initiated in this direction urgently.

COMMUNITY PARTICIPATION IN NATURAL RESOURCES MANAGEMENT

The report of the working group on watershed development, rainfed farming and natural resource management for the Tenth Five Year Plan (2002-2007), that the Planning Commission of the Government of India submitted in September 2001, has emphatically pointed out that many government schemes concerning land, water and watershed development programmes started well but could not be operated on a sustainable basis due to lack of community and stakeholders' participation. Wherever success has been achieved in the conservation of natural resources on a sustainable basis, it has been on account of local participatory activity. Plans and projects of the government, which have secured active participation of the communities, have achieved notable success. The watershed development project in Sukhomanjri (Shivalik hills) has succeeded and attracted attention because of community participation, which created necessary conditions for the development of a sustainable crop-production system, as a result of water- and land-conservation and scientific management.

Active participation of the people and the community in the conservation of natural resources is very important in executing the relevant programmes. It has to be a people's programme to conserve nature through developing micro-planning for execution with the support of the government. People would participate meaningfully when production increased or stabilized and they got their share of the benefits therefrom. Without direct and tangible benefits, participation of the stakeholders would remain passive and just a few big influential farmers would corner a large proportion of the assistance. The role of Panchayati Raj Institutions assumes importance in this context. Programmes of natural conservation need to be re-oriented in favour of the Gram Sabha members, that is, the villagers. Conditions must be created for them to feel that the cattle resources, the forests, the common land, water and waste-land, etc., belong to them and their conservation would mean improved productivity. The participation of women and the landless in the process of decision-making is also equally important to ensure their active co-operation. *Conservation of natural resources needs to be conceived as a means and the production system as an end.*

References

Alexandrates, N., *World Agriculture: Towards 2010, An FAO Study*, FAO and John Eiloy & Sons, N. York. 1995.

Annual Administrative Report, Department of Soil and Water Conservation, Punjab. Various issues.

Annual Administrative Report, Department of Forests and Wild Life, Punjab. Various issues.

Brar, J.S. and Chibbar I.M., 'N.P. and K. Status of Punjab Soils', *Indian Journal of Ecology*, 21(1): 34-38, 1994.

Dhillon, P. Singh, *Water Resources Development and Management in North West India*, Centre for Research in Rural and Industrial Development, Chandigarh, 1988.

Government of India – *Plan Documents.* Various issues.

Government of India, Planning Commission, *Report of the Working Group on Watershed Development, Rainfed Farming and Natural Resource Management for the Tenth Five Year Plan (2002-2007),* Sept. 2001.

Government of Punjab – *Plan Documents.* Various issues.

Government of Punjab, *Statistical Abstracts of Punjab*, Economic and Statistical Organisation, Punjab. Various issues.

Johi, S.S. and Ray S.K., *Future of Agriculture in Punjab,* Centre for Research in Rural and Industrial Development, Chandigarh, 2002.

Kansal, B.D., Dhaliwal G.S. and Bajwa M.S., *Agriculture and Environment,* National Agricultural Technology Information Centre, Ludhiana, 1996.

Kohli, R.K., Aryaand Atul K.S., *Agroforestry and Environment*, IUFRO and DNAES International Meet, Dayanand National Academy of Environmental Sciences, Chandigarh, 1996.

Land and Water Management in India Basin (India). Vol. 1. Land and Water Resources, Indian Ecological Society. PAU, Ludhiana, 1975.

Punjab Agricultural University, Vision 2020, *Punjab Agricultural University Perspective Plan,* 1998.

Punjab Environment, Status Report, 1995, Punjab State Council for Science & Technology, Chandigarh

Singla, G.B., *Agricultural Planning Atlas*, Punjabi University, Patiala, 1996.

Statistical Outline of India, 2001-2002, Tata Services Ltd., Mumbai.