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GOVERNMENT OF INDIA
MINISTRY OF AGRICULTURE
(DEPARTMENT OF AGRICULTURE & COOPERATION)
Krishi Bhawan, New Delhi - 110 001

D.O.No.12-12/89-LRC

27th March 1989

Dear Dr. Lee,

I thank you very much for your letter No. 42.768/ML/lw dated 23rd February 1989 regarding the proposal of making a preliminary review of the current state of affairs concerning water resources protection in developing countries. We, as the landuse and conservation subject matter people are concerned with watershed degradation which includes deforestation, soil erosion, land degradation, sedimentation and hydrologic deterioration. The last item is the changes in water regime both in soil profile, channel system, groundwater storages. The experiences in the field as well as research institutes indicate that through the process of watershed degradation starting from deforestation to land degradation, significant alteration occurs in hydrological aspects of the contributing areas. These are manifested by the disappearance of water points, lowering of groundwater, occurrence of water-stress conditions, flash floods and low dry weather flow thus extending the dry season significantly. Recently on request from the Institution of Engineers (India) I had prepared a write-up entitled 'Soil Conservation for Perspective Water Management, Environment and Land Productivity. Some of the information and approaches given in this paper be considered for deciding upon the parameters in carrying out this preliminary review as indicated in your letter.

I am moving on to a different Ministry i.e. Ministry of Environment & Forest, and my address will be as follows:

D.C. Das
Scientist 'SG'
Department of Environment & Forest,
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With best regards,

Encl: as above.

Yours sincerely,

DCDas.
(D.C. Das)

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SOIL CONSERVATION FOR PERSPECTIVE WATER MANAGEMENT, ENVIRONMENT AND LAND PRODUCTIVITY.

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National Seminar on 'New Perspectives in Water Management,- Sponsored by Indian National Academy of Engineering and Central Water Commission, New Delhi - 110 022.

Land being limited its availability for meeting the requirements of primary production systems as well as social priorities is declining with the rising population and enlarging aspirations of the communities. So is the case with the essential critical input-water for all land uses. Watershed degradation is further causing shrinkage of this natural resources base. Consequently environment is getting inhospitable and natural calamities are causing serious dislocation and biological resource base is getting poorer. The interaction of factors and the policies towards retarding this trend for various regions of the country have been brought out vis-a-vis/with a number of soil and water conservation programmes on the basis of integrated watershed management and in compliance to the National Land Use Policy Outline.

"To meet the consumption needs of a growing population by increasing productivity of the integrated land resource in the country;

To prevent any further deterioration of the land resource by appropriate preventive measures;

To restore the productivity of the degraded land by an appropriate package of practice;" (National Land Use Policy Outline. 2.4.1-2.4.3)

INTRODUCTION

1.1 In the context of continuing technological development and persisting planning endeavour India is experiencing many cruel paradoxes. Some of these are :

i) Growing affluence in some quarters while abject poverty with subsistence living over extensive areas .

ii) Higher production including foodgrains while wide spread under-feeding and malnutrition.

iii) Multi-dimensional activities for generating work opportunities contrasted by continuing and increasing unemployment/underemployment and migration from rural scene to urban locations.

iv) Numerous innovations for building up grass root level organisations with no perceptible gain in arresting the loss of community value sense - collective rights and liabilities for the traditional and newly created assets.

The contradictions are of special concern as the country has reasonably good natural endowments mainly land stock and water complemented by a long list of useful crops and cultivated plants, good and paying livestock breeds favourable photosynthesis period and traditionally good vegetation and wild animals to sustain primary production systems.

1.2 Following the Independence, the country has taken commendable strides in a number of fields to promote economic growth and better standard of living. Between 1950-51 and 1986-87 production of foodgrains has risen from 51 million tonnes to over 150 million tonnes and consumption of fertilisers has gone from 0.66 million tonnes to 9.0 million tonnes. Irrigation was made available to about 42 million hectares from the net sown areas against 21 million hectares (MOA, 1987). There have been more and more villages provided with electricity, better education facilities and other social amenities. Nevertheless, the contribution of agriculture to the total country's economic growth has been declining. Its share to national income dropped from 50% in 1950-51 to 40% in mid seventies and to 30% by 1986-87. During 1980-81 though 1986-87 rate of decline in its share to national income has been 1% annually (MOA, 1987). There seems to be some difficulty in reconciling to the fact that the economic growth and distribution of income as well as employment opportunities are not always meeting the planning objectives of equity and social justice.

1.3 The problems that the country is beset with and the potential technology that can solve these problems relate to a number of environmental issues. These may be examined in three parts viz.

i) Land stocks or physical resources base - watershed degradation comprising deforestation, soil erosion and land degradation and hydrologic deterioration etc. vs. desirable land use and water management.

ii) Biological resources - extinction of flora and fauna vs. their protection and conservation while meeting the rising demands for biomass.

iii) Pollution covering both water and air through various human interventions such as urbanisation and economic exploitation like mining, fishing, excessive use of fertilisers, insecticides, pesticides etc. vs. increased economic and developmental activities.

1.4 The land based activities which are the prime concern of soil and water conservation, are directly related to first environmental issue and indirectly influence the other two as well. In all problem analysis it would be essential to understand the nature's linkages between land surface and soil profile on the one hand and water cycle, representing quantum of water and its distribution over time and space, on the other. In an alternate perception the challenges are to maintain land productivity (making nutrients available to plants and regeneration of fertility) as well as availability of water to all users and replenishing the supply. These two perceptions concern same cause and effect model. In the ultimate analysis water is available to the user, either humanbeing or animals or plants through the medium of soil. Similarly, the replenishment of water either to the ponds and lakes or streams and rivers or deeper profile and groundwater are finally through the medium of land surface and soil profile. It is, therefore, very significant to realise that a favourable and sustainable relationship between land cycle and water cycle will be the key to the understanding of the environmental problems as well as seeking lasting solutions leading to the secured livelihood with safer environment. The vital promotional role that the communities of plants and animals, commonly called forests, in achieving this objective is illustrated in figure 1.

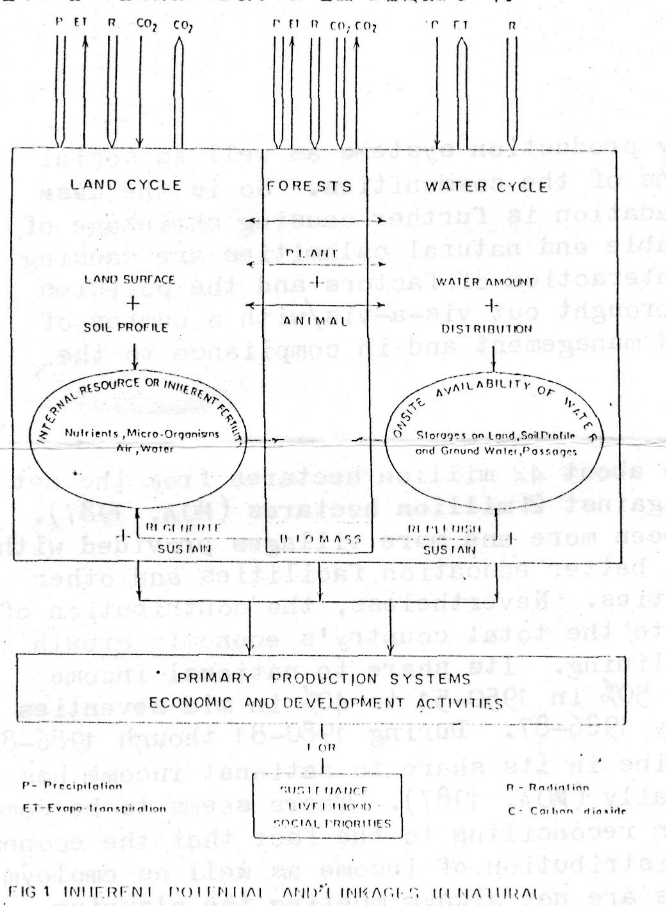


FIG 1 INHERENT POTENTIAL AND LINKAGES IN NATURAL RESOURCES BASE FOR LANDUSE PLANNING

1.5 In this presentation attempt has, therefore, been made to highlight the inter-related perceptions of a safer environment and sustained land productivity through a new perspective in water management.

2. PROBLEM IDENTIFICATION

The problems are manifold and present in variable combinations in different parts of the country. They are due to the bio-physical set up as well as socio-economic implications. The linkages of these in resource planning is shown in fig. 2.

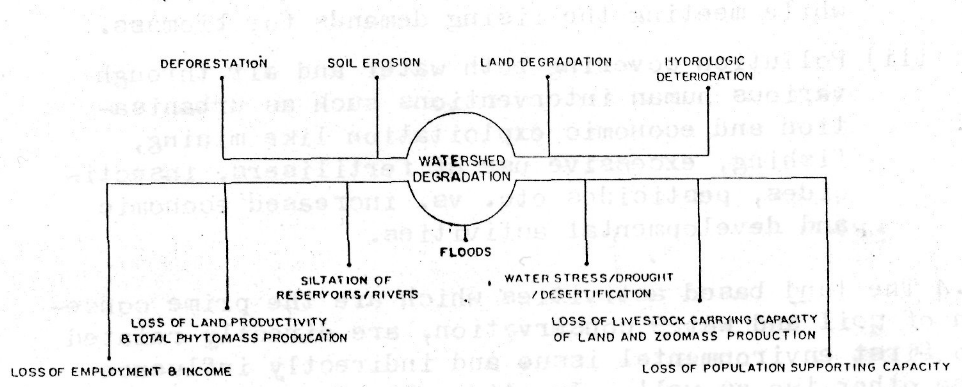


FIG 2. PROBLEM OF INDIA'S LAND RESOURCES- INTERLINKS FOR ORIENTING PLANNING PROCESSES

Land Use Shifts and Demands :

2.1 The nine-fold utilisation classification systems provide the changes of land use and shifts to mee-t the varying demands of the communities. The changes that have taken place during the last 4 decades are indicated hereunder (NLCB 1988a)

Area in million hectares

Land Utilisation class	1950-51	1980-81
1. Reporting area for land utilisation statistics.	284.3	304.16
2. Total cropped area	131.89	173.10
3. Net sown area	118.75	140.30
4. Current fallows	10.68	14.81
5. Culturable wasteland	22.94	16.70
6. Fallows other than current fallow	17.44	9.79
7. Miscellaneous trees	19.83	3.49
8. Permanent pasture and grazing land	6.68	12.00
9. Forest	40.48	67.42
10. Non-agriculture Non-forest	9.36	19.48
11. Barren land	38.16	20.17

It would be seen that rise in areas under urbanisation and other non-agricultural uses has been 108% while that for net sown area, current fallows and total cropped area range between 18 and 32%. Area under forests also increased by 67%. Maximum decrease has been registered under miscellaneous tree cover (82%), followed by barren and non-agricultural lands (47%), while decrease in fallows other than current fallows (44%) and culturable wastelands (27%). Arable lands have been steadily shrink-ing both for cultivation as well as forests. Area under real forest cover has also been declining due to deforestation.

2.2 The human population rise is projected to be 42.8% while livestock population will rise by 48% by 2000 AD. Relative increase of the population of goat is expected to be further even though NCA (1976) had anticipated a decline. The demands for foodgrains will rise by 80.45%, fuelwood 61.65% and fodder 50.09%. Some specific enhanced requirements of some major land based commodities and area requirement are given in Table 1. Total phytomass that will have to be produced, would be about 2000 million tonnes at the least. The effective and optimum utilisation of unit land and water will thus be judged from its ability to give highest aggregate return of phytomass in different utilisable forms.

Availability of Land and Land Budget:

2.3 The problem of availability of land is not only in respect of land under crops but also in terms of fodder development and grazing resource base as will be seen hereunder :-

Available Area per capita of Human Population

(ha/person)

	1950	1980	2000AD
Total	0.89	0.50	0.33
Cultivable land (including forest and trees).	0.48	0.20	0.15

Available Area per Animal Head:

			(Projected)
Excluding Forest	0.37	0.15	0.10
Including Forest	0.51	0.32	0.24

Table-1: PROJECTIONS OF HUMAN & LIVESTOCK POPULATION VIS-A-VIS LAND BASED COMMODITIES AND AREA REQUIRED BY 2000 A.D.

Projections of Demand

1. Population NCA(1976) 1000 millions

FAO(1982) 1036 "

2. Livestock NCA(1976) 324.41 "

NLCB(1988) 582

(Pigs & poultry not included. NCA's projection about goat did not come true. Instead of decreasing it has risen from 67.52 million in 1971 to 95.25 in 1981).

3. Foodgrain 225 Million tonnes
4. Sugar & gur 30 "
5. Vegetable oil NCA (1976) 10.2 "
6. Cotton 17.2 Million bales
7. Tea 695 Million Kgs.
8. Coffee 159 "
9. Tobbacco 590 "

(Requirement of Tuber & Bulb crops, fruits etc. excluded).

10. Fodder - On dry weight equivalent basis

i) By NCA(1976)(On 2% body weight basis) 796 million tonnes

ii) By NWDB(1986) for higher productivity 1233 "

iii) By NLCB(1988a) based on livestock committee report(1982)-average daily feed rate of 4 kg/head. 850 "

11. Fuelwood NCA(1976) 225 million cub.m.

12. Industrial Wood " 64.4 "

In terms of Gross Phytomass the total may be over 2000 million tonnes.

Projected Area for Agricultural Sector, NCA(1976).

i) Foodgrains 123.1 million ha

(increase in areas under Barley, Maize, Jowar and decrease in areas under wheat and paddy).

ii) Commercial Crops 48.6 million ha

(including likely 25.5 m.ha.under oilseeds, 5 m.ha under sugarcane).

iii) Horticultural Crops 12.8 Million ha.

iv) Plantation Crops 2.8 Million ha.

v) Green Fodder 16.5 Million ha.

vi) Industrial wood forest 48.0 Million ha.

Total cropped area 200 million ha. NCA
Total net sown area 150 " " "
Net irrigated area 84 " " "
Net irrigated area 110 " " NLCB
(To ensure quantum jump in agril. production).

Table-2: ESTIMATED PROBLEM AREAS DUE TO SOIL EROSION UNDER VARIOUS LAND UTILISATION CLASSES AND DIFFERENT TYPES OF LAND DEGRADATION ON TWO TIME FRAMES.

(Area in lakh ha)

	Soil Erosion in land Utilisation Classes	With Land Utilisation Statistics for 1976-77 Problem Area	1981-82 Problem Area@@
	1	2	3
1.0	Cultivable Land		
1.1	Rainfed Non-paddy	821.1	778.8
1.2	Current Fallows	35.7	33.7
1.3	Fallows other than current Fallows	48.4	47.8
1.4	Permanent pastures-Grazing land	47.9	41.6
1.5	Misc. Tree Crops and Groves	7.9	7.2
1.6	Cultivable Waste Land	85.7	82.9
	Sub-Total of 1	1046.7	992.0
2.0	Forest Land		
2.1	Reserve Forest	39.0	39.0
2.2	Protected Forest	92.8	92.8
2.3	Unclassed Forest	63.1	63.1
	Sub-Total of 2	194.9	194.9
3.0	Area Not Available for Agriculture and not under Forest		
3.1	Non-Agricultural uses	35.1	39.0
3.2	Barren and Unculturable	44.0	40.3
	Sub-Total of 3	79.1	79.3
4.0	Degraded Lands		
4.1	Gullies and Ravines	39.7	39.7
4.2	Shifting Cultivation	28.5	49.1
4.3	Waterlogged Area	59.9	85.3
4.4	Alkali Soils	69.9	35.8
4.5	Saline Soils	(alkali 2.5)	
4.6	Coastal Sandy Saline Areas	16.3	55.0++
4.7	Riverine Lands and Torrents	27.3	27.3
4.8	Desert	187.9	178.0
	Sub-Total of 4	429.5	470.20
	Grand Total 1 to 4	1750.2	1736.4

++ Regarding Saline and coastal saline sandy soils - reports in respect of some States/ parts seem to be in-complete. 5.5 million ha. is according to NCBAD's report while as per NCA it ranges between 5 to 8 million ha.

Sources other than NCA's Report 1976 :

i) NCBAD - National Committee on Backward Area Development P.C. 1981.

ii) RBA - Rastriya Barh Ayog, 1980.

iii) Report of Working Group on a) Land Reclamation and Development and b) Soil & Water Conservation for formulation of the VII Five Year Plans, 1984.

iv) Figures provided by State Govts. till 84-85.

v) Task Force on Shifting Cultivation, Deptt. of Agri. & Coopn., 1983.

2.4 Thus considering various options the National Land Use Policy Outline envisages a desirable Land Budget as follows : (NLCB, 1988 b)

(Million ha)

Category	1980 A.D.	2000 A.D. (Projected)
1. Net sown Area		
(a) Rainfed	101.0	40.0
(b) Irrigated	39.0	110.0
2. Forests	67.4	115.0
3. Pastures/grasslands	12.0	22.0
4. Urbanisation	19.5	25.5
(Settlements + non-Agril. than forest uses)		
5. Other non usable	90.1	16.5
Total :	329.0	329.0

Eroded and Degraded Lands:

2.5 The total geographical area is about 329 million hectares. As per latest assessment using various estimates, studies and reports, the distribution of areas subjected to soil erosion and various types of land degradation for the 2 time frame are presented in table-2. Current distribution of 173.64 million hectares problem lands is given at figure 3. There has been some rise in the waterlogged areas and also area under shifting cultivation and also those affected by salts. This rise is mainly due to the additional information provided by Rashtriya Barh Ayog, National Committee for Backward Area Development, Task Force on Shifting Cultivation and Reports from the States (Das, 1985;NLCB, 1988a).

Water the Critical Input:

2.6 Water is a critical and essential input for all activities relating to agriculture i.e. primary production systems. It is required to enhance the productivity of land whether it is under crops, fodder including grazing base, raising horticultural and plantation crops besides forestry. Water is also the single key factor which determines the environment, regulating the health of soil and also availability of nutrients for uptaking. It determines the antecedent status of dryness and wetness of the soil profile indicating the forthcoming situations of water stress or run off resulting in prolonged dry spells or floods affecting productivity and production besides the social amenities. Water as a natural resource, therefore, will have to be looked into in its integrated contribution at variou-s steps of conservation, development and management of land vis-a-vis the production programmes. A single point approach of applying water to the growing crop taking as the only concern, will be self-defeating to enhance and sustain the land productivity even to achieve the quantum jump in agricultural production particularly food crops. (Das, 1988a)

Availability & Budget :

2.7 The global distribution of fresh water indicates that less than 3 per cent of total quantity is of fresh water. However, 1/5th of this amount is available in the liquid form. This limited amount is fortunately replenishable and, therefore, call for an effective planning and utilisation of water resources from harnessing to management and in some cases re-utilisation. More than 98 per-cent of this scarce commodity is in the form of ground water, 1 per cent is in the lakes and ponds while 0.1 per cent each is in the rivers and atmosphere. The soil profile carry 0.2 per cent and the rest, a negligible amount is held by various biological forms. India receives annually 420 m.ha.m. of water supply which includes 20 m.ha.m. from rivers flowing from other countries. This amount is accountable as follows :-

1. Immediate evaporation	70 m.ha.m.	(16.67%)
2. Soil Body holds	165 m.ha.m.	(39.2%)
3. Surface water in rivers, ponds, lakes etc.	135 m.ha.m.	(32.14%)
4. Ground water	50 m.ha.m.	(11.90%)

2.8 In the final utilisation an estimated 200 m.ha.m. (47.62%) is disposed off from the soil body through evapotranspiration while 150 m.ha.m. (35.71%) flows into the sea and other countries like Bangladesh and Pakistan.

2.9 Further, India's water wealth is about equal to that of USA although the area is only 40 per cent of that of USA. In spite of this, availability of water for different uses has been becoming more scarce over time as well as space. Recurring drought over extensive areas have been causing serious damages to the production and its stability (NLCB, 1988c). The problem is being felt in the humid and sub-humid regions where more villages have been listed as those without water, such as in U.P., Madhya Pradesh etc. On the other hand, examination of climatic parameters indicates that in spite of over abundance of rains and river flows in many areas, dry period is getting extended. It stretches as long as 10 to 11 months in the semi-arid Rajasthan, 5 to 7 months in foot hills of Himalayas and other hill-s with annual rainfall as much as 1200 to 1500 m.m. and 4 months in humid North-East and South-West. It has also been realised that with unfavourable temperature and physiography, the ability of soil body to conserve, hold and make available the water input for bare minimum biological activities becomes difficult. This is a key matter for all primary production systems such as crop, fodder, livestock etc. (CES, 1985, 1988)

Utilisation:

2.10 Utilisation of available water, particularly, those which has been harnessed artificially has been mainly for agriculture. Per capita utilisation of water in other parts of the world has been rising sharply. By early 70's the utilisation per capita per day rose from 5 gallons to 65 gallons in Europe while in USA it jumped to 155 gallons. The corresponding consumption rate for India is not available. However, analysis of water supply in major cities like Bombay, Calcutta, Bangalore and Hyderabad indicates that demand is increasing steadily whereas potential of supply developed has not been keeping pace accordingly (NLCB, 1988c). The world's per capita availability of water is expected to reduce further by 21% by 2000 AD and the reduction is likely to be more in Africa, Asia (India included) (Framji, 1988). Estimated annual requirement at time frames namely 1974, 1985, 2000 and 2025 AD are given hereunder:-

Million hectares

Years	Irrigation	Other uses (cities/ industries/villages)	Total
1974	25	3	28
1985	36	18	54
2000	50	25	75
2025	77	28	105

The total requirement increased steadily from 28 million hectares meters in 1974 to 54 million hectares meters in 1985. The increase by 2000 AD will be steep and it will be the figure of 105 million hectare by 2025 AD. However, this estimate might fall short of the actual rise in the requirement considering the growing aspirations of the people and the thrust towards development and economic growth of the rural sector for which fresh estimates would be necessary. The NLCB envisages more rapid growth of irrigation even though its perception of 110 m.ha. by 2000 AD is difficult to achieve. The increase in the case of non-irrigation uses as estimated at present rate of use is likely to be far more to meet the rising aspirations of communities for better standard of living. Notwithstanding what will be the effects on various sectors, shortage of water in coming years is a distinct possibility.

Land-Water Plant Interaction:

2.11 Availability of water is directly related to the ability to prolong the supply throughout the year in the face of limited natural supplies within 3-4 months over most of the country. World at large and India in particular has become conscious about the possibility of acute water shortage and resultant effect on production. However, an adequate realisation is yet to come of the fact that availability of water depends upon how we manage our land surface under different uses and develop and regulate the hydrologic profile depth to augment supplies to our channels/streams and wells. Because whether to users like man, animal and plants or to rivers, lakes and groundwater, water becomes available only after it has routed through land surface and soil profile. The water flow in the river system in the North, though get adequate augmentation through snow melting particularly in post monsoon period, in the rest of the country such flows depend on inter-flows from the land mass. Interaction of land surface, soil profile, plant-s and animals are key to maintain such supply for the beneficial uses taking advantage of natural physiographic linkages amongst mountain slopes, plateaus and plains. In short, a permanent and beneficial relationship between land cycle and water cycle with supporting plant and animal system is a necessity not only at macro level but over extensive areas of micro level as well (Fig.I) (Das, 1988a). This is more necessary as the country is open to very extensive and recurring water-stress conditions even in humid and sub-humid areas (Das, 1988, a,b).

Water Use and Enhancement of Population Supporting Capacity :

2.12 The potential population supporting capacity depends upon the aggregate production of biomass from the same unit of land stock. Admittedly notwithstanding the quality of land and percipitation it receives, the minimum amount of water would be essential to achieve the highest optimum biomass production on sustained basis. This quantum would determine the population supporting capacity. The analysis carried out by the international agencies have shown that notwithstanding the extent of irrigation and complementary inputs the rainfed land production is estimated to fall by about 38.6% and the total land productivity by about 12.4% in 16 countries of South Asian region including India. The loss of productive rainfed lands is expected to be about 35.6% if positive steps are not taken to arrest the process of soil erosion and restore the degraded lands immediately (Higgins et al, 1982). Estimated Population Supporting Capacity (PSC) for irrigated and rainfed areas was worked out for 1980-81, 1990-91 and 2001 AD with projected population and with corresponding likely increase per capita grain consumption. PSC for irrigated land is expected to increase to 0.95% per hectare while rainfed areas increase is estimated to be by 0.72% per ha. and the enhancement in latter case will be mostly through the measures which will ensure land resources conservation, development and management and with particular reference to in-situ water conservation, water harvesting and or use of incident rainfall. The enhancement of PSC for the rainfed areas would also demand relatively much lower investment and would be dispersed over extensive areas of the country. This would benefit about 70% of the net sown areas and the cultivable lands which could be put under productive land management systems to meet the increased demand of fodder or the tree or plant growth (Suraj Bhan and Das, 1985). Socially this would be very relevant to small and marginal farmers and landless labourers, nomadic tribes and the weaker sections.

IrrigatedAgriculture:

2.13 In the programme of enhancing production, irrigation will continue to play critical role. However, the question of utilisation of created irrigation potential and achieving real increase in per unit area productivity must be addressed more seriously to have a real breakthrough. Besides, the question of its sustainability and socio-economic effects will have to be definitely taken note of. A number of irrigation systems have not taken the human aspects into consideration in terms of their traditional and preferred settlements, loss of productive lands through sub-mergence and water logging, diseases arising from the prevalence of water borne germs and water related factors, socio-economic disruption particularly for the communities with small and marginal production base. Surface irrigation systems have variable application efficiencies ranging from 35% to 70% and conveyance efficiencies from 30% to 90%. The overall efficiencies are falling mostly between 10% and 30%. (Framji, 1988). In the developing countries of Asia efficiencies are mostly about 30% compared with about 37% to 40% in the developed countries. The first step towards global conservation would, therefore, be to raise irrigation efficiencies to improve water management and on-farm management while dater water logging & salinity.

Rainfed Agriculture:

2.14 In the context of agriculture, except the net irrigated area or other areas either for crop production or livestock management are rainfed. In such areas, through out the world and over the centuries, water harvesting has been a major strategy and methodology to support profitable land husbandry with adequate stability. In spite of large number of historical evidences throughout the world including India it/does not seem to carry conviction due to either large proje-ct preference or short term compulsion to achieve immediate increase in crop production. Even today, in many parts with plenty or scarce water, both city water supply (as in Bermuda Islands) and farms (as in Australia) depend entirely on rain water harvesting. Contrary to common belief the quantum of water that could be harvested from precipitation even in areas with low rainfall is quite large and proves to be very economically viable besides having security to severe water shortage conditions. Dependability of water harvesting methods is also to be re-assuring. It rests in their small size, flexible, dynamic multiple option, collectivity, low cost, low risk, compatibility with variable farming systems and ability to provide stability to these systems. (UNEP, 1983)

Fodder Development, Grazing and Water Use :

2.15 In the extensive rural areas of the country, livestock is a very important segment of the economy providing source of livelihood particularly to the economically weaker sections and in the ecologically fragile regions. Unlike developed countries farmer-s are practising highly inter-dependent and integrated system of agriculture with varying and variable number and types of animal heads to meet multiple demands. However, while the livestock management largely depends on grazing lands besides forest, which are mainly collectively owned and not adequately conditioned in terms of production potential due to the scarcity of moisture and irregular regeneration of the plant population. Under these circumstances, water resources management both through conserving, augmenting, is key to avoid over-grazing and to ensure regeneration of desired level of phytomass for consumption of the livestock. Water points have been a crucial factor for livestock management whether it is

Table-3:
STATEMENT SHOWING SOIL CONSERVATION REGIONS VIS-A-VIS AGRO-CLIMATIC REGIONS AND RESPECTIVE AREAS COVERED.

Soil Conservation Regions (SCR)			Agro-Climatic Regions (ACZ)		
Sl.No.	SCR	Areas Covered	Sl.No.	ACZ	Areas Covered
1	2	3	4	5	6
1.	North Himalaya (excluding cold desert areas)	Snow clad mountains, temperate arid, semi-arid and sub-humid areas of Jammu & Kashmir hill areas and Kandi areas of Himachal Pradesh.	I.	West Himalayan region:	Jammu & Kashmir and Ladakh, parts of Himachal Pradesh and hills of Uttar Pradesh, West Punjab.
2.	North-Eastern Himalayas	North-Eastern hills of Sikkim, Arunachal Pradesh, Meghalaya, Manipur, Mizoram, Assam, Nagaland, Tripura and West Bengal.	II.	Eastern Himalayan region:	Arunachal Pradesh, Himalayan West Bengal, Assam and associated hills, Nagaland, Manipur, Tripura.
3.	Indo-Gangetic & other(Western) Alluvial Plains.	Punjab, Haryana, North Eastern Rajasthan, Uttar Pradesh and Bihar plains, Chambal command in Rajasthan, command areas in Gujarat.	IV.	Middle Gangetic Plain region:	North Bihar plains, South Bihar plains, Eastern Uttar Pradesh.
			V.	Upper Gangetic Plain region:	Central Uttar Pradesh, North Western Uttar Pradesh, South Western Uttar Pradesh.
			VI.	Trans-Gangetic Plain region:	Delhi, Punjab northern plains, Southern and Central Punjab, Haryana, Rajasthan Sriganganagar area.
4.	Assam Valley and Gangetic Delta.	Plains of Assam, Tripura North Bengal & Gangetic delta areas of West Bengal.	III.	Lower Gangetic Plain region:	West Bengal Plains.
5.	Desertic & Semi-arid Region.	Western-Central Rajasthan, contiguous areas of Haryana and Gujarat, Runn of Kutch.	XIII.	Gujarat Plain hills region:	Gujarat plain and hills.
			XIV.	Western dry region:	Western dry areas.
6.	Mixed Red, Black and Yellow Soils.	Districts of Pali, Bhilwara, Ajmer, Chittorgarh, Udaipur, Jhalawar and Southern Uttar Pradesh (including Bundelkhand area) and Northern Madhya Pradesh (Mukhelkhand)	VIII.	Central Plateau and hills regions:	Bundel Khand of Uttar Pradesh Northern plains and plateau of Madhya Pradesh, Central plateau and hills of Madhya Pradesh, Vindhya hills and plateau of Madhya Pradesh, Rajasthan plains and hills, Rajasthan plateau.
7.	Black Soils (excluding shallow, medium and deep black soils)	South-Eastern Rajasthan, part of Western Madhya Pradesh contiguous large tracts of Maharashtra, Andhra Pradesh, Karnataka and small part of Tamil Nadu.	IX.	Western Plateau and hills region:	Khandesh, Marathwada and Vidharba of Maharashtra, Malwa plateau of Madhya Pradesh.
8.	Eastern Red Soils.	Bulk of West Bengal, Bihar, Orissa and Eastern Madhya Pradesh including Chota-nagpur and Chhatisgarh area, part of Andhra Pradesh plateaus and uplands.	VII.	Eastern Plateau and hills regions:	Bihar-Chhotanagpur plateau, West Bengal plateau, Orissa inland, Chhatisgarh area of Madhya Pradesh, Wain Ganga and Hill Division of Maharashtra.

10 CSRs are regrouped 20 Land Resources Regions (LRR) of ICAR

Here the name depicts the most critical bio-physical attributes e.g. Soil, hilly topograph drainage etc.

Names of Agro-climatic Zones (ACZ) generally reflects first topography. This does not necessarily indicate the cretical attribute demanding attension for physical development.

1	2	3	4	5	6
9.	Southern Red	Bulk of Kerala, Tamil Nadu hills and plains, Karnataka, Andhra Pradesh and part of Maharashtra - hills & plateaus.	X.	Southern Plateau and hills region:	Telangana, Rayalseema and Chittoor of Andhra Pradesh, Tamil Nadu inland, Southern and northern plateau of Karnataka.
			XI. (Hill only)	East Coast Plains and hills region:	Coastal Orissa, Coastal Andhra Pradesh, Tamil Nadu, East Coast, Delta of Tamil Nadu, Southern part of Tamil Nadu and Pondicherry.
10.	East West Coasts and Island Region.	East and West Coast from Orissa to Saurashtra and Islands.	XI. (Part by coasts only)	East Coast Plains and hills Region:	Coastal Orissa, Coastal Andhra, Tamil Nadu, East Coast, Delta of Tamil Nadu, Southern part of Tamil Nadu and Pondicherry.
			XII.	West Coast Plain and ghats region:	West Coast and Nilgiri Divisions of Tamil Nadu, Kerala, Coastal and Western Hills of Karnataka, Konkan of Maharashtra and Goa.
			XV.	Island region:	Andaman, Nicobar, Lakshadweep, Minicoy and Aminidivi islands.

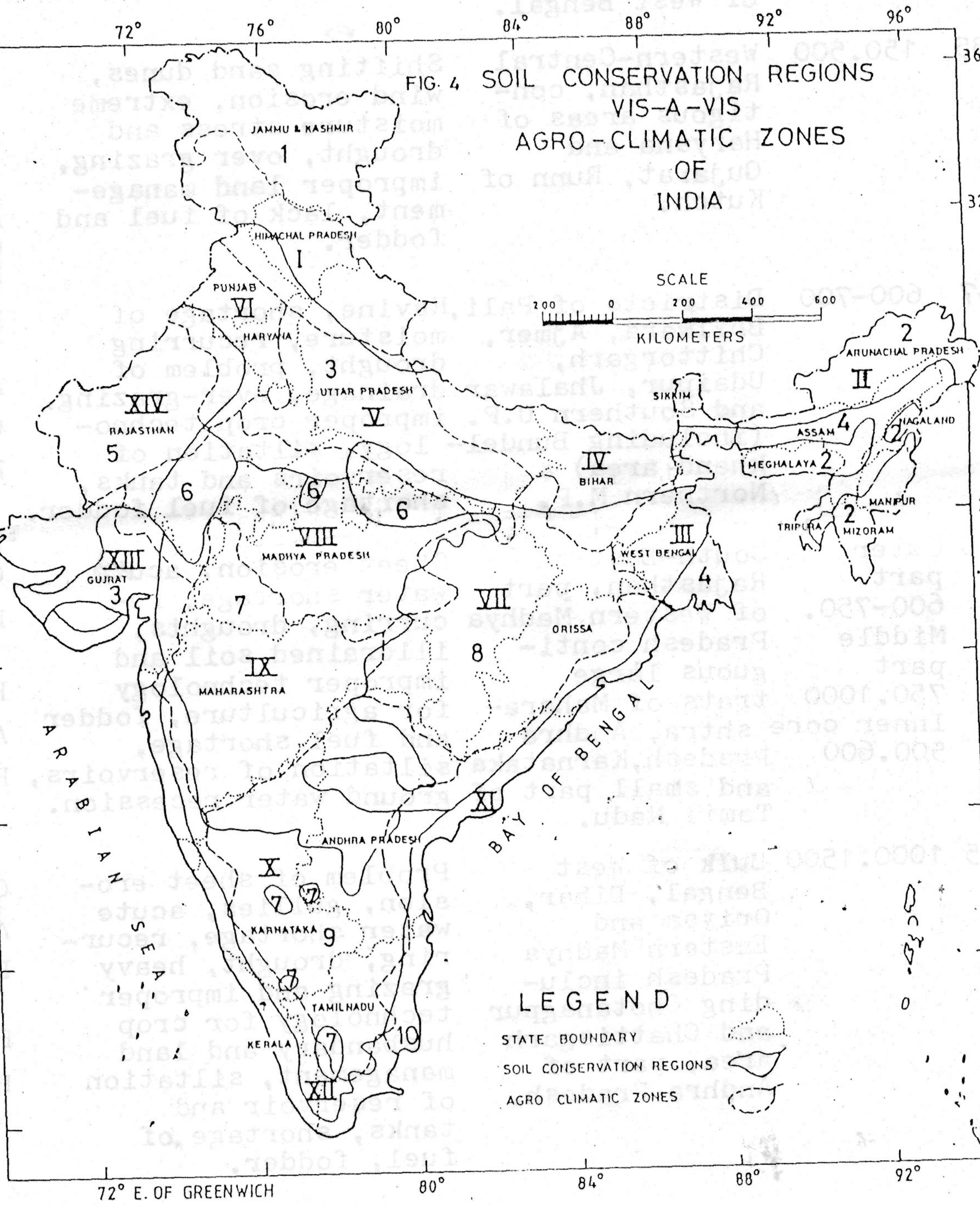


FIG. 4 SOIL CONSERVATION REGIONS VIS-A-VIS AGRO-CLIMATIC ZONES OF INDIA

Table-4: DISTRIBUTION OF DIFFERENT SOIL CONSERVATION PROBLEMS IN VARIOUS SOIL CONSERVATION REGIONS OF INDIA.

S.No.	Soil Conservation region of (SCR)	Area (in ha.)	Rainfall (mm)	Important Area	Problems	Land Husbandry Priorities
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1,	North Himalaya (excluding cold desert areas) (ACZ - I)	25.53	500.2500	Snow clad mountains, temperate arid, semi-arid and sub-humid areas of J & K hill areas and Kandi areas of H.P.	Soil erosion along hill slopes, landslip/slides, torrent, management of ravine lands and siltation of reservoirs over grazing and deforestation, mining drying of Springs.	Forestry Livestock & Fodder Development Hort./Plantation. Cropping Fishculture
2.	North-Eastern malayas (ACZ - II)	17.70	1500.2500	North-Eastern hills of Sikkim, Arunachal Pradesh, Meghalaya, Manipur, Mizoram, Assam, Nagaland, Tripura and West Bengal.	Shifting cultivation, land-slides, rorrents and gullies, problem of riverine lands, siltation of reservoirs and stream beds, flood, loss of flora, fauna.	Afforestation Hort./Plantation. Cropping Livestock Fishculture
3.	Indo-Gangetic Alluvium soils (ACZ - IV, V & VI)	50.90	700-1000	Punjab, Haryana, North-Eastern Rajasthan, U.P. and Bihar plains, Chambal command in Rajasthan, Command areas in Gujarat.	Sheet erosion, ravines, floods, stream bank erosion, waste lands, water logging and riverine lands, prolonged dry spells and failure of rains, shortage of fuel and fooder.	Cropping Horticulture Livestock & Fodder Dev. Fishculture Afforestation.
4.	Assam Valley and Gangetic Delta (ACZ - III)	11.18	1500-2500	Plains of Assam, Tripura, North Bengal and Gangetic delta areas of West Bengal.	Gully erosion, stream bank erosion, waterlogging, coastal salinity.	Cropping Afforestation Fishculture Afforestation.
5.	Desertic areas (ACZ - XIII & XIV)	23.85	150.500	Western-Central Rajasthan, contigous areas of Haryana and Gujarat, Runn of Kutch.	Shifting sand dunes, wind erosion, extreme moisture stress and drought, over grazing, improper land management, lack of fuel and fodder.	Horticulture Livestock & Fodder. Afforestation. Agro-Hort. Cropping Fishculture.
6.	Mixed Red, Black and Yellow Soils (ACZ - VIII)	11.57	600-700	Districts of Pali, Bhilwara, Ajmer, Chittorgarh, Udaipur, Jhalawar and Southern U.P. (including Bundelkhand area) & Northern M.P.	Ravine, shortage of moisture, recurring drought, problem of drainage, over-grazing, improper crop technology, siltation of reservoirs and tanks, shortage of fuel fodder.	Livestock & Fodder Afforestation Cropping Horticulture
7.	Black Soils (excluding shallow, medium and deep black soils) (ACZ - IX)	67.45	Outer part 600-750. Middle part 750.1000 Inner core 500.600	South-Eastern Rajasthan, part of Western Madhya Pradesh contiguous large trats of Maharashtra, Andhra Pradesh, Karnataka and small part of Tamil Nadu.	Sheet erosion, acute water shortage, recurring, droughts, illdrained soil and improper technology for agriculture, fodder and fuel shortage, siltation of reservoirs, ground water recession.	Cropping Livestock & Fodder Horticulture Afforestation Fishculture
8.	Eastern Red Soils (ACZ - VII)	57.45	1000.1500	Bulk of West Bengal, Bihar, Orissa and Eastern Madhya Pradesh including Chotanagpur and Chattisgarh area, part of Andhra Pradesh.	Problem of sheet erosion, gullies, acute water shortage, recurring, drought, heavy grazing and improper technology for crop husbandary and land management, siltation of reservoir and tanks, shortage of fuel, fodder.	Cropping Afforestation. Livestock & Fodder Fishculture. Horticulture.

(1)	(2)	(3)	(4)	(5)	(6)	(7)
9.	Southern Red Soils (ACZ - X, XI hills)	34.77	Around 750 in most parts in Kerala upto 2500	Bulk of Kerala, Tamil Nadu hills and plains, Karnataka, Andhra Pradesh and part of Maharashtra.	Problem of sheet erosion, gullies, acute water shortage, recurring drought, lack of fodder and fuel, improper crop husbandary, siltation of reservoirs and tanks, ground water recession.	Cropping Afforestation. Livestock & Fodder Hort./ Plantations Fishculture.
10.	East West Coasts (ACZ - XI (Coasts) XII & XV)	19.20	East Coast about 1000 and rest heavy rain fall	East and West Coast from Orissa to Saurashtra.	Problem of coastal salinity, soil erosion, coastal sand dunes, wind erosion and flooding of cultivated lands by sea water or rain water, shortage of fuel, fodder.	Fishculture Afforestation Cropping Hort./Plantation Livestock & Fodder

NOTE : Common problems in all the regions are poor productivity, very inadequate employment opportunities and low income. In addition, small holdings scattered in parcels do not permit many a time scientific management principles.

ACZ - Agro Climatic Zones - I to XV.

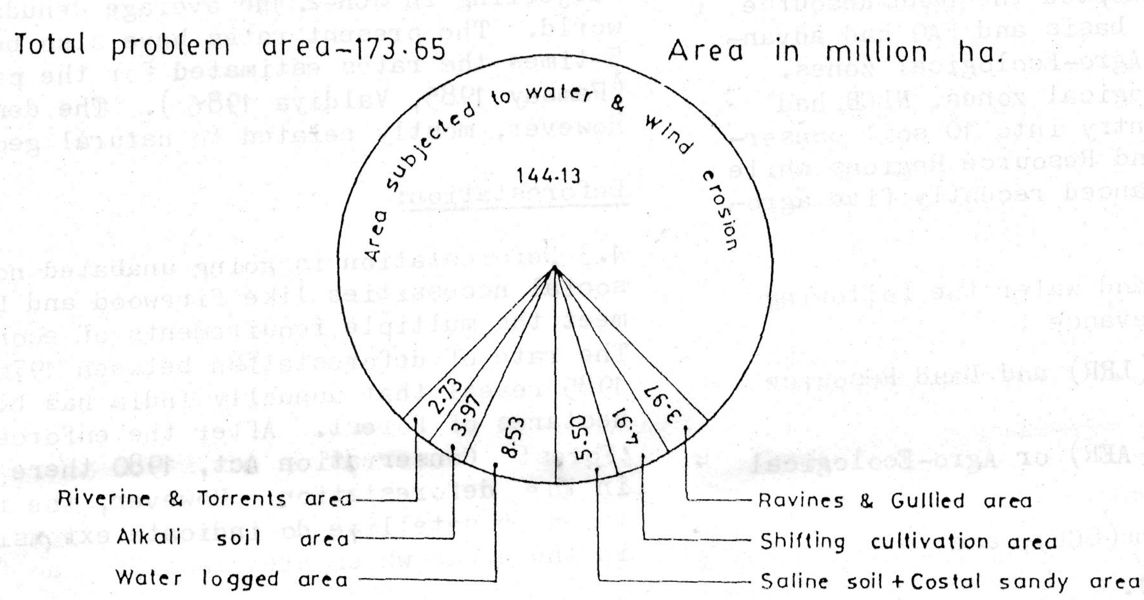


FIG. 3. DISTRIBUTION OF AREA SUBJECT TO SOIL EROSION AND DEGRADED OR SPECIAL PROBLEMS AREAS.

(Estimated with 1981-82 land utilization statistics and degradation data up to 1984-85) pasture based migratory one or part of settled farming system. Best of the grazing lands or pastures cannot support livestock unless complemented by minimum watering facilities. Such watering points and facilities are vanishing through silting and privatisation.

Zonation:

3.1 For integrated planning of land resource to meet the requirements of primary production sectors and also socio economic development sectors it is very essential to carry out the exercise of delineation of the entire country into identified areas/zones based on some parameters representing problems, potentials as well as socio-economic compulsions. Further, macro level planning involves inter-departmental and inter-sectoral coordination while micro level planning takes care of the mechanism prevailing to implement the programmes and provide follow up support to them. This type of delineation/zonation further attempts to consider the country in terms of small units with similar bio-physical attributes and production potentials for food, fodder, fuelwood raw material for industries and social priorities amenities. Many attempts have been made to delineate the country into a number of zones or regions and sub zones of areas for development and utilisation of natural resources mainly land including soil, water and vegetation. Physiographically India has been divided into 4 major divisions and in consideration of the drainage systems there are six water resources regions. The Central Soil and Water Conservation Research & Training Institute, ICAR, had delineated the country into 20 Land Resource Regions (LRR) and 126 Land Resource Areas (LRA). Considering the sedimentation problems the entire country has been delineated into seven hydrologic zones while based on erosion hazard considering geology and physiography India has been delineated into five first order physiographic regions. (Singh, R.L. 1971, Khosla, A.N. 1949, Ahmed, F. 1973, Bali, J.S. 1969, quoted from Das, 1977). At the international level, USDA had adopted the Land Resource Regions and Land Resource Area basis and FAO had advanced Agro-Ecological Regions or Agro-Ecological zones. ICAR had also adopted Agro-Ecological zones. NLCB had used the delineation of the country into 10 soil conservation regions-regrouping 20 Land Resource Regions while the Planning Commission had advanced recently five agro-climatic zones.

3.2 For planning based on land and water the following delineation appear to be of relevance :

i) Land Resources Regions (LRR) and Land Resource Areas (LRA);

ii) Agro-ecological Regions(AER) or Agro-Ecological Zones(AEZ);

iii) Soil Conservation Regions(SCR); and

iv) Agro-climatic Zones(ACZ).

LRR and LRA are oriented to watershed management and when criticality of physical conditions and feasibility of bio-physical modifications govern the decisions as well as the scale of socio-economic development.

3.3 Agro-ecological regions (AER/AEZ) are primarily oriented to take into consideration the ecological aspects with heavy bias to plant performance and nature conservation. FAO had, therefore, used this delineation taking into consideration soil map and climatic growth parameters besides rainfall. ACR as in vogue seems to be predominently advanced for agricultural production where growth functions of various crops take support from the inputs mainly rainfall, irrigation and input supply. From fig. 4 and Table 3 the specific differences are in respect of black soil regions, eastern and southern red soil region and mixed soil region which are also rain-shadow ones, seen. Similarly, there is some difference in respect of Indo-Gangetic and the west alluvial soil regions. The differences, however, are not great and reconcilable. The major reason for such differences is greater emphasis given in LRR and SCR on the bio-physical base for its development utilising the principles of watershed management. The land husbandry, however, will have a greater diversity depending upon the sub-units and climatic limitations, as well as household requirements and other socio-economic forces operating on these units and sub-units. The multiple problems prevailing in various soil Conservation Regions have been examined and their criticality as well as extent assessed. These are individually discussed later while sum total problems of each of the 10 regions are given in Table 4.

Watershed Degradation:

4.1 Watershed degradation has been defined as the loss of value of land and water including its production potential and distortion in hydrological behaviour (FAO, 1986). The processes involved are :- (Das, 1987).

i) Denudation;

ii) Deforestation;

iii) Soil Erosion;

iv) Sedimentation;

v) Land Degradation;

vi) Biological Degradation; and

vii) Hydrological Deterioration.

Denudation:

4.2 The rate of lowering of earth surface or denudation has been observed to be two times for Satluj catchments in the SCR-1 to 20 times for the slide prone slopes of Darjeeling in SCR-2. The average denudation rate for the world. The present rates have also been found to be about 5-times the rates estimated for the past 40 million years (Ramsay 1985, Valdiya 1986). The denudation process, is, however, mostly related to natural geological phenomenon.

Deforestation:

4.3 Deforestation is going unabated not only to meet their social necessities like firewood and fodder but also to meet the multiple requirements of economic development. The rate of deforestation between 1976 and 1980 and 1981-1985 reveal that annually India has been losing 1.47 lakh hectares of forest. After the enforcement of Central Forest Conservation Act, 1980 there has been some change in the deforestation. However, the recent photographs taken by satellite do indicate extensive gaps and blanks in the areas which are classified as forests.(FAO, 1986)

Soil Erosion:

4.4 The process of soil erosion due to wind, water and sea is extensively prevalent throughout India. In order to understand the potentially eroding areas the parameters determining the erosivity of the agents and characteristics of soil as a measure of soil's erodibility need to be studied. There are many parameters prevailing and tried by various investigators and development planners. None of these are fool-proof which can reflect erosion proneness of all site conditions existing throughout the country. Some of the parameters of erosivity chosen here are Intensity Ratio (IR) and Rainfall Factor(R). A storm becomes erosive when it produces enough impact through the combination of mass, energy and intensity or rate of delivery to detach and displace soil particles. Attempts have been made to try the definitions like 'Intense' or 'Excessive' rain as used in USA and finally the norm of minimum volume of 0.5" or 12.5 mm has also

Table-5 : SOIL EROSION AND PARAMETERS OF ERODIBILITY AND EROSIVITY for SOIL CONSERVATION REGIONS OF INDIA (SCR)

S. No.	Soil Conservation Region - SCR	Rainfall mm.	Mean annual temp.	Intensity Ratio (IR)*	Rainfall Factor 'R' or EI annual	RH** DR+ K@	Land Use	Maximum Soil loss t/ha/yr (% slope)
1	2	3	4	5	6	7	8	9
1.	Northern Himalayan Region(A,B,C)	200-2500	10-20	2.05 Dehradun	Dehradun-622 Chandigarh-569	2.13 Dehradun K = 0.15	Dehradun, cultivated Fallow Maize up & down	107 (8%) 28 (8%)
2.	North-Eastern Himalayan Region (G,H)	1500-2500	10-20	-	Shillong-407 Imphal-229	-	Shillong Shifting Cultivation Bare fallow.	83 84
3.	Indo-Gangetic and other Alluvial Plain Region (D,E,F,L)	700-1100 Some areas in the West get less than 400.	20-28	2.04 Agra 2.16 Baroda	New Delhi-364 Lucknow-484 Allahabad-458 Gaya-559 Vasad-519 (Gujarat)	7.0 relaimed ravine-Agra 5.0 Baroda 3.46 Ahmedabad 6-91% Kanpur K=0.11 Vasad K=0.2 (Agra)	Agra Bare fallow	16
4.	Assam Valley and Gangetic Delta Region (I,P)	1500-2500	20-25	-	N.Lakhimpur-1181 Guwahati - 635 Calcutta-774 Agartala-1281	-	-	-
5.	Rajasthan Desert, Runn of Kutch and contiguous semi-arid region.	150-500	25-28 & greater than 28 in extreme West	-	Jaipur-344 Jodhpur-126 Bhuj-120	DR 33-83% Rajasthan DR-31.4% Kutch	-	-
6.	Mixed Red, Black & Yellow Soil Region.	600-700	20-28	1.83 Kota	Kota-354	1.31 Kota 4.57 Sawai Madhopur K=0.11 Kota	Kota Bare fallow	9
7.	Black Soil Region (N)	Outer part between 600-750 Inner part 500-600	20-28	2.36 Bellary	Indore-413 Bhopal-563 Bagra Tawa-514 Bellary-293	6.34-Dharwar	Bellary Cultivated fallow	64
8.	Eastern Red Soil Region (O)	1000-1500	20-25	1.73 Midnapur	Jamshedpur-629 Raipur-606 Jagaddalpur-534	1.78-4.10 Raipur 2.5-21.60 Gullied area of Midnapur. 4.23-Santhal Pargana Kharagpur-1.1	-	-
9.	Southern Red Soil Region (R)	around 750	20-25 (10-15 in the Nilgiris)	1.73 Ootacamund	Bangalore-429 Hyderabad-215 Ootacamund-315 Kodaikanal Town-432 Trichuapally-545	1.00-Hyderabad 1.00-Chickmangalore K=0.04 Ootacamund	Ootacamund Potato up and down Hyderabad Cultivated fallow	39(25%) 5(3%)
10.	East-West Coastal and Islands Region (Q,S,T)	East coast about 1000	20-25	-	Trivandrum-820 Mangalore-1457 Vishakapatnam-533 Madras-753 Sagar Island-1065	-	-	-

* Intensity Ratio - $\frac{\text{Intensity for 5 minutes for 10 years recurrence}}{\text{Qualifying intensity for 5 minutes = 7.63 cm/ha}}$

** Rilling Hazard Ratio - $\frac{\text{Erosion ratio of soil of an area}}{\text{Limiting safe value of erosion ratio or 10}}$

R= Rainfall, Factor in universal soil loss equation or Energy x Intensity factor (EI)*.

@K= Erodibility factor in universal soil loss equation t/ha/EI.

+DR= Dispersion Ratio

A,B........S,T : Land Resources Regions of ICAR.

been tried. Considering the varied distribution patterns and the sudden bursts for short periods followed by prolonged low intensity rains, it has been realised that storm intensity of 5 minutes explains better the incidence of run off and soil loss. These erosive rains could be termed as 'Important Rains' combining the implication contain in the definition of 'Intense', 'Excessive' and the minimum volume of 0.5" or 12.5 mm. Such rains could be defined as follows :- (Das et al, 1967)

"A rainfall is important (to cause runoff and soil loss) when it has a minimum amount of 12.5 mm and a delivery rate, equal to or greater than US Weather Bureau qualifying rate for duration not less than 5 minutes."

4.5 In view of this important relevance to the intensity as a single factor the parameter of Intensity Ratio has been developed following the definition of USA, Weather Bureau for Excessive Rains. IR is defined as follows :-

Intensity Ratio :

$$\text{or IR} = \frac{I_5 \text{ for a return of 10 years for a place}}{\text{US Weather Bureaus Qualifying Intensity for duration of 5 minutes.}}$$

$$= \frac{I_5 \text{ for 10 years return period}}{7.63}$$

Intensity data are still not readily available but intensities for durations lower than 60 minutes can be determined from 1 hour rainfall which can be obtained from iso-hyetal maps prepared by IMD with long data series (Khuller et al, 1975). It however, cannot give quantitative estimates of likely soil loss.

4.6 Another important development has been in the use of a product of rainfall energy and intensity which is generally known E.I product or Erosion Index when used for the whole year. In the Universal Soils Loss Equation (USLE) this factor has been defined as R or 'Rainfall Factor'. Some location-wise values of 'R' have been made available by the Central Soil and Water Conservation, Research and Training Institute. (Ram Babu et al, 1978). The equation developed for extrapolation for the areas where no rainfall exists needs to be more representative. In Table-5 both values of IR as well as 'R' factor for 10 Soil Conservation Regions have been provided. It will be seen that coastal and Islands as well as ~~in~~ Assam valley and Gangetic Delta Region are having 'R' factor value between 1065 and 1457. The information for different elevations and in North and North-Eastern Himalayas are not available. In general leaving aside Soil Conservation Region No.5 and 6 other regions are having 'R' value (400) and therefore capable of causing erosion. IR values whenever more than one the areas could be considered having erosivity. From that point of view Doon Valley, Indo-Gangetic and other alluvial plains, Soil Conservation Regions of mixed soils, black soils, Eastern and Southern red soils are all having erosive rains. Bellary in the arid Black cotton soil region is a critical place. With R factor of 293 it does not make storms highly erosive rains. It has however, got the highest IR i.e. 2.36. This explains relatively high soil loss of 64 t/ha/yr from slopes of below 3%.

4.7 For comparison of erodibility there are a number of indices and parameters. These range from simple soil characteristics to complex indices like erosion ratio, dispersion ratio and erodibility factor (K). The seriousness of erosion would be realised with the beginning of rill formation. In Australia, therefore, rilling distance has been considered to determine the spacing of barrier to break the slope length. Following conceptual model of USLE a ratio viz. Rilling hazard ratio (RH) or factor has been worked out particularly in developing a rational and dynamic formula for determining spacing of bunds, terraces and trenches (Das, 1977). The value of RH for a number of places have also been obtained and presented in Table-5. The soils having RH value greater than 1 can be considered erodible. From this point of view, eastern red soil with extensive gullied areas registers highest RH value of 21.6 while the values for ravines of Agra, black soils, of uplands of West Bengal and alluvial plains of Gujarat have recorded RH value 4 and above therefore, have erodible soils. Dispersion ratio indicates that soils of desert area are also highly erodible.

4.8 The actual soil loss as obtained from various reports indicates that cultivated fallow land, shifting cultivation, bare fallows have registered as high as 107 ton per hectare per year from 8% slopes in Doon Valley due to high IR, 'R' values and high RH ratio. The areas subjected to shifting cultivation have also caused high soil loss in North Eastern Himalayan region having R values near 400. The black soils and mixed soils with milder slopes below 3% have also caused high soil loss ranging from 64 tonnes per hectare per year to 9 tonnes per hectare per year. Up and down cultivation of potatoes on 25% slopes resulted 39 tonnes per hectare per year in Ooty even though soils have RH value only 1, K 0.04 and R value below 400. However, Intensity Ratio (IR) for Ootacamund has been 1.73 which indicates that short duration high intensity rains coupled with steepness of slope have been the cause for high soil loss. It may also be mentioned here that permissible soil loss and soil loss tolerance range for 7 to 12.5 tonnes, depending upon land use, geo-morphology and climate. However, for a developing country like India, where land has been under use for centuries and very little depth is available in relatively more fragile areas such as hills, dryland etc., soil loss tolerance should be adopted still on lower side.

Sedimentation:

4.9 Problems of sedimentation or fragmented materials are wide spread in the drainage systems as well reservoirs. Erosion is the pre-requisite process of sedimentation and all eroded materials are potential sediments. The severity of sediment problems can be realised from (i) Silt loads in the streams and small watersheds. (ii) Silt loads in the tributories and main stem of rivers and (iii) Sediment yields in the reservoirs. Under the Centrally Sponsored Scheme of Soil Conservation in the Catchments of River Valley Projects and Integrated Watershed Management in the Catchments of Flood Prone Rivers about 392 Watersheds are being guaged and runoff sampled for silt load studies. The maximum silt production rates of these watersheds for each of the catchments lying in different soil conservation regions are presented in Table-6. These watersheds range in areas between less than 1 km and 9000 sq. km. But most of the watersheds are of the size below 50 sq. km. The length of data varies from 1 year to 19 years. An examination of silt production rates in Table 6 reveals that watersheds in North Himalayan Region (barring Pohru) recorded high silt loads. Mahi in mixed soils region; Dantiwada in desert area and Chambal in black soils, have registered highest silt production rates of 224, 155.3 and 105.3 tonnes per hectare per year respectively. Red soil region of both eastern and southern India are also having highly eroding watersheds. (Pandey et al, 1987).

4.10 Sediment production rates in some major or important reservoirs or rivers have also been given in Table 6. The sediment production rate is governed by the gross erosion potential and the transportation of the eroded material through drainage systems. Examination of the assumed SPR vs observed SPR for the reservoirs in all the regions indicates that the rate of siltation has been 1.45 to 7.5 times of the design or assumed ones. The exception appears to be only Muchkund catchment. However, Himalayan catchments appear to be most eroding and yielding highest sediments in the respective reservoirs. The reservoirs in SCR of black soils, red soils are also registering very

Table - 6 : Sediment Production Rates (SPR) from Watershed / Catchments in Different Soil Conservation Regions of India

Soil Conservation Regions - SCR	Catchment	Reservoir or river	SPR-ha-m/100 sq.km/yr. Assumed	Observed (year)	Very high and high priority watershed area percent	Maximum Watershed Silt Production Rate ha m/100 Km^2/Yr	Tonnes/ha/Yr
1	2	3	4	5	6	7	8
1. North-Himalayan	1. Beas	1. Pong	4.29	23.59(1970)	42.4	55.7	(78.0)
	2. Sutluj	2. Bhakra	4.29	6.22(1979)	43.8	65.2	(91.2)
	3. Ramganga	3. Ramganga River	4.29	17.30(1974)	33.6	5.9	(8.3)
	4. Pohru			7.71	33.9	0.1	(0.1)
	5. Upper-Yamuna including Giri-Bata					28.5	(39.9)
	6. Upper Ganga					-	-
2. North Eastern Himalayan	7. Teesta			98.20*	42.4	-	-
	8. Gumti	4. Gumti		3.56(1973)	78.2	-	
3. Indo-Gangetic + Western Alluvial Plains.	9. Sukhna lake	6. Sukhna lake		98.50	1971	34.8	(76.7)
	10. Sahibi (Aravalli Range)					8.5	(11.8)
	11. Gomati					24.2	(33.8)
4. Assam Valley and Gangetic Delta Region	12. Pagladiya (at border of Bhutan)	River		31.10	56.6	1.9	(2.7)
	13. Roop narayan River						
5. Rajasthan Desert, Runn of Kutch and contiguous semi arid region	14. Dhantewoda	5. Dhaniwada	3.61	6.32	19.1	110.9	(155.3)
6. Mixed Black Red, Yellow Soils Region	15. Mahi	22. Mahi		1.29 8.99 (1973)	56.4	160.0	(224.0)
7. Black Soil Region	16. Chambal	15. Gandhinagar	3.61	5.29(1976)	21.5	75.2	(105.3)
	17. Matatila	16. Matatila	1.43	3.50(1972)	42.6	14.1	(19.7)
	18. Ukai	17. Ukai	1.47	4.96(1975)	21.9	11.4	(15.9)
	19. Tawa	18. Tawa	3.61	2.67(1980)	39.3		
	20. Pochampad				30.00	3.0	(4.2)
	21. Nizamsagar	19. Nizamsagar	0.29	6.34(1973)	15.30	7.0	(9.8)
	22. Nagarjuna	Sajar			21.60	4.2	(5.9)
	23. Tungabhadra	20. Tungabhadra	4.29	6.11(1972)	18.3	1.5	(2.1)
	24. Bhod	21. Bhod	3.61	15.11(1970)	22.3	-	-
8. Eastern Red Soils Region	25. Sone						
	26. Hirakud	7. Hirakud River	2.52	6.60(1978)	34.1	56.8	(79.6)
	27. Kengal Mandira			7.76	12.87	5.9	(8.3)
	28. Mayurakshi	8. Mayurakshi	3.61	20.09(1972)	42.2	4.1	(5.8)
	29. Kabgsabati	9. Kabgiabati	3.27	6.73(1972)	42.0	11.2	(15.6)
	30. Damodar Barkar	10. Maithon	1.62	12.15(1979)	56.50	33.5	(46.9)
		11. Panchet	2.47	9.92(1974)			
	31. Machkund/Sileru	12. Machkund	3.90	2.19(1978)	42.2	3.6	(5.1)
	32. Punpun					1.2	(1.7)
	33. Ajay						
9. Southern Red Soils Region	34. Lower Bhavani	13. Lower Bhavani		3.69 (1977)	31.8	13.5	(18.9)
	35. Kundah	14. Kundah		3.90 (1977)	7.1	12.6	(17.6)
10. East-West Coast and Islands Region	36. Daman-Ganga (West Coast)	River		15.72	49.4	-	-

*Observation taken at the river section; Catchments at Sl.5,6,10,11,13,25,32 and 33 are of Flood Prone Rivers (FPR) high sediment production rates. In India many of the reservoirs are losing storage capacity at the rate of 0.5 to 1.5 per cent per year. Data on siltation of 3 small reservoirs in the Himalayas reflects of extensive watershed degradation in these catchments. The alarming siltation in Gumti reservoirs in Tripura is due to the extensive shifting cultivation on steep slopes whereas that in Hari Ka Pond and Sukna lake in Shivaliks are due to extensive soil erosion and torrent problems.

4.11 The regional problems of sedimentation could be compared with the percent of total area surveyed and categorised as very high and high priority. In the Himalayan regions such critical areas range from 34% to 78% of the total area. The mixed black soil, black soil and yellow soil regions recorded 56% as the critical areas. In the black soil region it ranges from 13% to 54%. The data given in Table 6 indicate that for different reasons the problem of sedimentation is serious in all the region and thus package of practices will have to be chosen accordingly keeping in view the specific types and cause of high silt yield.

Land Degradation:

4.12 The problem of land degradation cover sand blowing, salt affliction, water logging, sedimentation, mining etc. The problems of land slides and slips are generally extensive and severe in the North and North-Eastern Himalayan region. Sometimes these include even terrace land, cardamom plantation, forest slopes, but mostly along the roads and degrading drainage lines. Watershed survey in Darjeeling and Kalimpong areas reveal that overgrazing, concentrated run off along livestock trail and cultivation of slopes greater than 20° without terracing are additional and immediate causes besides geological attributes. The erelationship of human intervention to the aggravated land slide conditions has been painstekenly studied in the Doon Valley for the period 1919 to 1982 (Sastry et al)

4.13 Torrents and stream erosion are extensively present along the foothills throughout the Himalayan Region. Numerous streams rushing down the hill slopes are variously known such as 'Chos', 'Khuds', 'Kholas', 'Johras' or 'Nalas'. The seriousness of the problem can be visualised from the observed SPR for some of the torrents which range from 22.4 to 39.0 ha. m/100 sq.km./yr (MOI, 1985).

4.14 Mining on hill slopes disrupts the natural physiographic linkage amongst mountain slopes, plateus and plains. The productive soil base and hydrological response are also getting affected. The extent of problems can be visulated from the fact that for every tonnes of ore about 2 tonnes of mine spoils must be removed and dumped. Surface mining is extensive in Eastern Red soil region, particularly for coal and other products. Throughout the country there are 4052 working mines (excluding oil, gas and some rare minerals) and these include 478 coal mines. Ironically these are generally in rich forest and agricultural areas. The associated land degradation is through deforestation, ash dumps and over-hurden, subsidence (Baliga, 1985).

4.15 In India arid zone covers 12% of the country's total area. About 32 million hectares is under hot aridity while 7 million ha. of cold aridity. A host of physical and social factors cause a creep of desertic conditions - expansion of sand covers, dunes, shifting sand, salt allliction, loss of vegetation etc. (Shankaranarayanan, 1985).

4.16 Water-logging and salinity is a problem which has registered spectacular increase with the expansion of irrigation from canal and groundwater. The problem of alkalinity is mostly predominant in the States of U.P., Punjab and Haryana. It is emerging as a serious problem in many of the command areas. The problem of salinity is more common in desert region, black soil region and coasts. In the drier Indo-Gangetic alluvial region and along the coast there has been persistent salinisation of groundwater. The estimates of these areas need to be made more precisely.

Shifting Cultivation :

4.17 Shifting cultivation is a serious problem throughout the North Eastern Region, Himalayan Region and in the hill districts of Eastern red soil regions particularly Orissa and Andhra Pradesh a total area of about 419 million ha. is affected by this problem while annually 1 million ha. is subjected to this practice. Nearly 6.22 lakh families depend on this practice.

Biological Degradation:

4.18 Intensive and unregulated utilisation of land surface by cultivating, grazing or exploitation of plant material have caused the extinction of many natural flora and fauna and affected the regeneration capacity. In the cultivated areas total loss of natural fauna has been neglivible while in the areas subjected to shifting cultivation these species and some mammalian animals have become extinct particularly in the North-Eastern Himalayan Region and many of the species have been declared as endangered ones. This has happened as the follows or Jhoom cycle has been steadily becoming shorter and shorter. In the high altitudes as well as arid and semi-arid areas fodder scarcity and prolonged dry periods had led to the overgrazing and this has caused deterioration in the plant communities. This is manifested by emergence of fewer plants, species and also invasion by unpalable species such as Lantana, Parthinium, Euopotorium, Water hyacinth etc. over extensive areas. (CES, 1985, ICAR, 1983).

Hydrological Deterioration:

4.19 The hydrological deterioration of various regions has increased through different types of interventions. The complexity of the deterioration is due to dual role played by the land surface as well as profile in holding the larger part of the incident rainfall for subsequent utilisation on site and in enhancing the soil moisture storage for beneficial uses. The hydrological response variations of any watershed or area may, therefore, be examined in terms of

a) Changes in watershed retention/alter run off volume (to)

b) Land/use changes/alter stream flow duration characteristics and modify peak flow. (to)

Some information for various regions vis-a-vis problems of soil erosion and land degradation are highlighted in the following paragraphs.

4.20 The studies carried out in Doon Valley and in the Shivaliks reveal that burning, cutting of trees and over grazing increased peak discharge of various small watersheds by 69.32 and 32 per cent respectively. Contour trenching and afforestation reduced peak by 73% while combination of closure, afforestation and gully control works reduced it by 63%. Narrow base terracing or bunding reduced peak by 40% from a watershed (54.63 ha.) at Dehradun (CSWCRTI from Das and Singh, 1979).

4.21 Analysing the observed run off data collected from experimental watersheds of ICAR Research Stations at Dehradun and Chandigarh, the values of run off coefficient 'C' as used in Rational Formula were determined. For cultivated fields it ranged from 0.29 to 0.50, pasture 0.15 to 0.45 and forest 0.10 to 0.40 at Dehradun. The value of 'C' for rugged Shivalik hills was as high as 0.70 (Das et al 1973 from Das & Singh, 1979).

4.22 In the Southern red soil region particularly in the Nilgiris having areas ranging from 7.51 km square to 334.62 km sq. showed that catchment areas of rainfall amounts could not explain variations in watershed retentions. However, watershed retention was found very significantly related to percentage area under forests, grassland, terraced lands and land under plantation crops of tea and coffee (Raghunath et al 1970).

4.23 Resulta also established the variable water yield responses and watershed retention vis-a-vis variations in the distribution under forest, grass, tea and coffee and agriculture. Extensive bench terracing and planting of grassland by Euvalyptus , globulous and Acacia mollissima were found to enhance annual watershed retention by about 28 cms (Raghunath et al, 1970).

4.24 The studies on rainfall disposition carried out in the Nilgiris showed that continuous growing of annual crop on henches helped in large total absorption and utilisation of rainfall (63 per cent of annual rainfall) as compared to 29 per cent from the degraded grasslands and 41 per cent under natural forest conditions. The greater ability of the cultivated benches in utilising larger portion of incident rainfall rests on continuous depletion of retention storage and thus providing large cummulative retention opportunity coinciding the incidence rains. In case of deteriorated grassland, though compacted surface offered steady minimum intake rate to absorb considerable portion of (71%) incident rainfall into the profile. The profile however could not promote voluminous movement of absorbed water through percolation into deeper layers due to loss of conductivity as a result of compaction or continuous depletion by evapotranspiration due to over-saturation condition. Therefore, along the compacted profile of a shorter depth fast / and voluminous inter-flow resulted. In case of forest land, even though larger volume infiltrated into the profile, owing to its deeper extraction zone and greater detention storage, considerable portion was retained / in the profile (Das et al, 1970).

Recharge of Wells and Profile:

4.25 The drying up springs or streams with deforestation mining and intensive cultivation on hill slopes have been noticed by many investigators. To offset these problems of lack of moisture in the profile and groundwater extensive programmes have been taken up to re-charge the profile and also through bunding, Nala plugging, ponding etc. Evidences collected through evaluation studies carried by Agricultural Finance Corporation (AFC, 1988) indicate 3 silt trap-cum-bundhies in Matatila catchment helped in digging down stream 20 more wells. This availability of wells helped in restoring about 21 ha. of land and increased land value by Rs.2000/- per hectare. In the seven sample watersheds in the same catchment 359 water harvesting structures of various descriptions increased number of wells by 214, raised water table ranging from 16 to 22%, helped in reclaiming 508 hectares and irrigating additional over 200 hectares of land. In Lower Bhavani catchment of Tamil Nadu, 66 silt detention dams, 13 percolation ponds and 23 permanent erosion control structures have been constructed to induce recharge to ground water and stabilise water tables of 1608 wells having a total command area of 2031 ha. A specific study indicated that the rise ranged from 34 to 65%. But the rise in water table was progressively decreased as the distance of the well from the percolation pond increased upto 900 meters (NLCB, 1988d).

5. Droughts & Floods :

5.1 The cummulative effects of various degradation processes affecting the stability of environment particularly the natural bio-physical systems are manifested through the incidence of drought and floods. These are concurrent effects of a number of human interventions for production of land based commodites and also meeting socio-economic needs besides the natural causes like uplift pressures, fragile geo-morphology etc. They are again sequential on time-scale and, therefore, very difficult to identify the relationships which could hold on all occasions and sites. In understanding the problems of drought and floods one would thus consider the factors namely, land and soil properties, plant characteristics and hydrologic principles in addition to fluctuations and erratic distribution of rainfall.

Droughts :

5.2 Climatic Crop Growth Index (CCGI) incorporates the varying crop tolerance (manifested by evapo-transportation demand) vis-a-vis shifting water stress conditions (created due to low/erratic rainfall). Crop tolerance also reflects the flexibility of the plant physiology vis-a-vis variations in soil suc-tion keeping the evapo-transportation demand constant. Thus expressing actual rainfall or expected rainfall as the ratio of potential evapo-transportation provides us a parameter to see what type of plant growth can be expected under such conditions of stress to abundance. The specific equivalent rainfall limits, are as follows : (Das 1988b)

Nil Growth

Pi 0.4 (0.769P.E.)=0.307 PE influential rainfall required for a break season; severely restrictive growth.

Pd 0.8 (0.769 P.E.)=0.615 PE the minimum rainfall for satisfactory growth of drought tolerant crops; restricted growth.

Ph 1.2 (0.769 P.E.)=0.922 PE: the minimum rainfall for satisfactory growth of average crops and pasture; just enough growth for some.

Pa 1.6 (0.769 P.E.)=1.220 PE, the rainfall creating conditions for good growth for most crops, plants and dense growth for many.

Pa_2 2.4 (0.769 P.E.)=1.844 PE: the rainfall for abundant and dense growth of paddy; surplus mousture.

Consequent drought classes with increasing intensity are as follows :

	Incident rainfall between
i) Moderate drought	: Pa and Ph.
ii) Large drought	: Ph and Pd
iii) Severe drought	: Pd and Pi
iv) Disastrous drought	: Pi and less.

5.3 Based on meteorological data for 94 stations of India, located in various Soil Conservation Regions of India, the values of these rainfall limits for all stations were calculated and examined with the published long term normal rainfall (Pn) and potential evaportranspiration computed by Penman method (computed). Ratios such as Pi/Pn, Pd/Pn, Ph/Pn and Ph/Pn were computed to facilitate delineation of the country on a single map and with the classification of droughts of different intensities as below : (Rao atal, 1970 from Dec. 1986)

Moderate drought	: when Pa/Pn >I
Large drought	: when Ph/Pn >I
Severe drought	: when Pd/Pn >I
Disastrous drought	: when Pi/Pn >I

Distribution of Area under four categories of droughts have been determined as follows :

Drought Classes	Prone Area (million ha.)	per cent of total geographical area
Moderate drought	76.2	23.90
Large drought	47.0	14.30
Severe drought	116.8	35.60
Disastrous drought	19.7	6.05
Total :	259.7	79.85

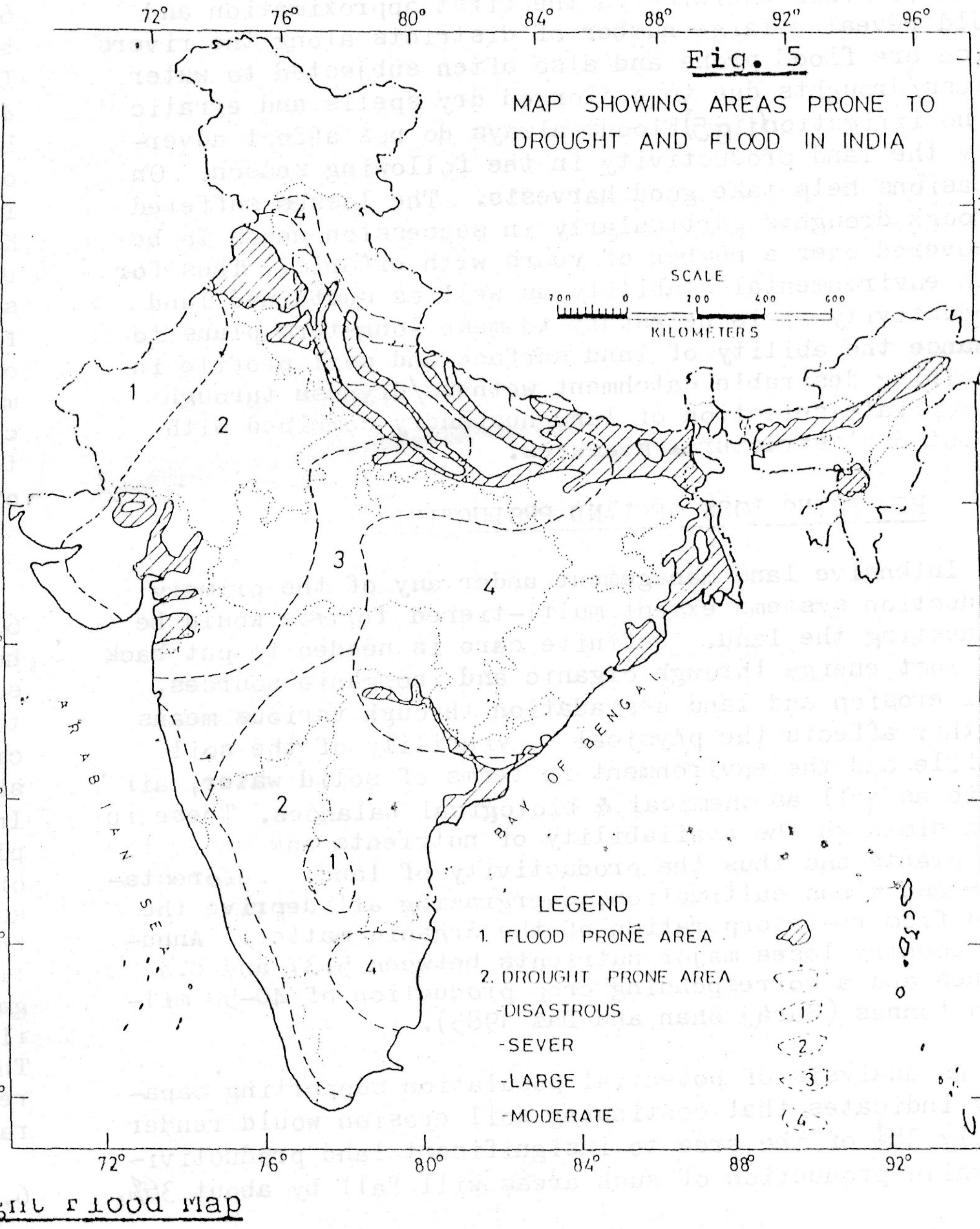
Table - 7 : RUNOFF FLOOD AND DROUGHT PRONENESS OF SOIL CONSERVATION REGIONS OF INDIA

S. No.	Soil Conservation Region.-SCR	Runoff Potential Hydrologic Soil Group.	Flood Hazards: Severity Recurrence.	Flood Hazards: Important areas	Drought Proneness by Climatic Crop Growth Index CCGI: Drought Class-Definition.	Important. Areas.
1	2	3	4	5	6	7
1.	Northern Himalayan Region (A,B,C)	B	Occassional	Small area of Sirmour Distt. (HP), T.Garhwal & Garhwal, Pilibhit, Saharanpur(UP)	- None	But Ladakh, Lahul Spiti - cold deserts.
2.	North-Eastern Himalayan Region (G,H)	B and C	Large annual	Lohit, Siang, Distts. bordering Assam(Ar.P)	Moderate $P_a/P_n > 1$	Along north Western foot hills - Hoshiarpur, Ropar(Punjab); Ambala(Haryana); Saharanpur, Muzaffarnagarn, Bijnor, Nainital, Garhwal(U), Champaran. Darbhanga, Muzaffarpur, Purnea (Bihar); Mald Dinajpur(W.B.).
3.	Indo-Gangetic and other (Western) Alluvial Region (D,E,F,L)	North West-C Rest-B	Severe Annual Some times more than once in a year.	Malda, Dinajpur, Murshidabad, Burdwan & parts of Birbhum, Bankura Midnapore (WB). Entire north Bihar upto Bhagalpur, Munghyr, Patna, Gaya, North of Sahabad(Bihar); Azamgarh, Faizabad, Gonda, Barabanki, Bairoach, Basti, Mirzapur, Allahabad, Falipur, Kanpur, Etawah, Aligarh, Etah, Bulandshahr, Muzaffarnagar, Meerut, Bijnor, Moradabad, Budaun, Aurangabad, Lucknow, Unnao, Rae-Bareilly, Pratapgarh(UP). Delhi, Rohtak, Karnal, Jind, Ambala (Haryana), entire Punjab, Ahmedabad, Khaira, Mehsana (Guj.)	Large $P_h/P_n > 1$	Sirmour (HP), Moradabad, Budayun, Shahjahanpur, Gazipur, Pratapgarh, Rae-Bareilly(UP); Patna, Monghyr, Gaya, Sahabad (Bihar), Plains of Punjab, Haryana, Western U.P. to Aligarh through Mainpuri, Kanpur, Farrukhabad and Alwar, Jaipur, Tonk, Sikar (Rajasthan).
4.	Assam Valley and Gangetic Delta	Assam Valley-C Gangetic Delta-A	Severe More than once every year.	All Assam except N.Cachar, 24 Parganas, Howrah, Hooghly, Calcutta, Midnapur (W.B.)	None	- -
5.	Rajasthan Desert, Run of Kutch and contiguous semi-arid region.	Western Part-A Rest-B	Very Occassional flash floods.	Luni basin, Jaipur, Tonk, Swai Madhopur.	Severe $P_d/P_n > 1$ Disastrous $P_i/P_n > 1$	Agra, Mathura, Eta(UP), Mahindergarh, Hissar, Bhatinda (Haryana), Jalore, Churu, Jhunjhunu(Raj.), Most of Gujarat bordering Rajasthan. Barmer, Jodhpur, Bikaner, Jaisalmer, Ganganagar(Raj.) Kutch (Gujrat).
6.	Mixed Red Black & Yellow Soil Region(M)	B		Rewa, Bhind, Gwalior Datia(M.P.), Banda, Hamirpur (U.P.), Dungarpur(Rajasthan).	Severe $P_d/P_n > 1$	Mirzapur, Banda, Jalaun, Hamirpur, Jhansi (U.P), Rewa, Satna, Bhind, Datia, Chattarpur, Damoh(M.P.), Sirohi, Udaipur, Chittorgarh Dungarpur, Banswara, Pali, Bhilwara (Rajasthan).

Contd....

1	2	3	4	5	6	7
7.	Black Soil Region (N)	D			Moderate $P_d/P_n > 1$	Sidhi, Narasingpur (M.P.), Nagpur (Maharashtra).
					Large $P_h/P_n > 1$	Shivpuri, Guna, Vidishi, Hoshangabad(M.P.), Akola, Buldhana, Ahmednagar (Maharashtra).
					Severe $P_d/P_n > 1$	Budni, Jhalwar (Raj.), Rajgarh, Ratlam, Dhar, Jhabua (M.P.), Dhule, Jalgaon, Osmanabad, Sholapur, Ywatmal (Maharashtra), Raichur, Gulbargh, Bijapur, Dharwar (Karnataka), Nizamabad, Warangal, Khamam, Medak, Kurnool(A.P.)
					Disastrous $P_i/P_n > 1$	Bellary, Chitradurga(Karnataka), Anantapur (A.P.).
8.	Eastern Red Soil Region(C)	Mostly - B A belt behind Coast- C	Annual	Bankura,Midnapur (W.B.),Mayurbhanj, Keonjhar,Cuttack (Orissa),Adilabad, Karimnagar(A.P.)	Moderate $P_a/P_n > 1$	Chotanagpur(Bihar),Purulia,Bankura, Birbhum, Midnapur(W.B.), Entire Orissa except coasts; Raipur, Bastar Sarguja, Durg, Bilaspur (MP), Godavaries, Krishna, Nalgonda, Hyderabad (A.P.).
9.	Southern Red Soil Region(R)	Mostly-B A-belt behind Coast & patches-C Pockets-D		Khamam, Krishna (A.P.)	Moderate $P_a/P_n > 1$	Salem, Arcots,Dharmpur, Chingleput. Madras, Tanjore, Trichurapally (T.N.)
					Severe $P_d/P_n > 1$	Tirunelveli, Ramanathapuram, Madurai (T.N.), Bidar, Kolar, Shimoga, Tumkur (Karnataka), Nellore, Cudappah, Chittoor(A.P.).
10.	East-West Coastal and Islands Region (Q,S,T)	A	Severe Annual	Krishna, East Godavari, Vishakhapatnam (A.P.),Cuttack, Puri(Orissa), Surat, Bulsar Broch (Guj.)		

A - T are Land Resources Regions



Drought Flood Map

The delineation takes into consideration the situation as existing without irrigation development made so far. Even in areas where irrigation has been extended, particularly canal irrigated areas, availability of irrigation right on the time of water stresses gets affected by the inflow into the reservoirs and in turn the capability of catchments to produce water yields.

Floods :

5.4 Floods are as old as the known history of the country is. The Flood Atlas of India (CWC-1987) indicated that an area of 40 million hectares is prone to floods. Annually an average area of 8 million ha. including 3.7 million hectares of crop land is affected by floods. The maximum area damaged in any single year was 18.6 million hectares which included 10 million hectares of crop yields. The distribution of flood affected areas reveals that most of the problems are in the Indo-Gangetic alluvial region, Assam Valley and Deltaic region. In terms of the States, Assam, Bihar, Orissa, U.P. and West Bengal are the worst affected States. The average annual damage to crops, houses and public utilities is about Rs.627 crores and a population ranging from 10-17 million have a lingering fear in their minds as the same monsoon could be a source of damage and destruction for them.

5.5 Though floods are basically due to unusually heavy rainfall over short durations, many of the human interventions that affect adversely the ability of land surface and soil profile to absorb, hold and utilise and make delayed release of the rain-water as depicted in figure 1, also act as immediate causes.

5.6 The examination of maps delineating areas prone to droughts and floods vis-a-vis 10 soil conservation regions and the districts reveals the exact extent of the problem areas subjected to water stresses and excess water. The region-wise situation has been depicted in table 7. This exercise is the first approximation and would reveal a large number of districts along the rivers which are flood prone and also often subjected to water stress/droughts due to prolonged dry spells and erratic or no irrigation (fig 5) Floods always do not affect adversely the land productivity in the following season. On occasions help take good harvests. The losses suffered through droughts particularly in succession needs to be recovered over a number of years with efforts. Thus for both environmental stability as well as sustained land productivity it is necessary to make long-term plans to enhance the ability of land surface and soil profile in obtaining desirable catchment wetness/dryness through appropriate selection of land husbandry combined with promotional structural measures.

REVERSING LOSS OF LAND PRODUCTIVITY:

6.1 Intensive land management under any of the primary production systems except multi-tiered forests would be exhausting the land. Definite care is needed to put back the lost energy through organic and inorganic sources. Soil erosion and land degradation through various means further affects the physical viability of the soil profile and the environment in terms of solid water, air ratio as well as chemical & biological balances. These in turn diminish the availability of nutrients and water to the plants and thus the productivity of land. Deforestation and clean cultivation, overgrazing all deprive the land from re-incorporation of the organic matter. Annually country loses major nutrients between 5.37 and 8.4 tonnes and a corresponding crop production of 40-50 million tonnes (Suraj Bhan and Das 1985).

6.2 An analysis of potential population supporting capacity indicates that continuing soil erosion would render nearly 38% of the area to insignificant land productivity while production of such areas will fall by about 36%. Therefore, in spite of increasing total productivity of the irrigated lands of the 16 countries, including India, studied the country's production is likely to decline by about 12%. The study further indicates the high level of package of practices should include permanent and effective soil and water conservation measures besides other inputs to reverse the threat (Higgins et al, 1982).

6.3 In the NE Himalaya under shifting cultivation (slashing, burning and dibbling of mixed crops) loss of nutrients over succeeding years on 65% slope was very high. This is aggrevated as Jhum cycle or fallow years get shorten. The reduction of productivity of different crops in descending order were cassava, maize, fox tail, millet and paddy (Awasthi, 1986). In the same region under terraced cultivation, the initial levels of carbon, cations and nitrogen were found to be lower than fields under shifting cultivations even with 5 years' fallow cycle. These levels further declined in succeeding years (Mishra and Rama Krishna, 1983).

6.4 Various soil conservation measures like vegetation or structures would have some effect and cost for construction as well as maintenance. The economics of such measures need to be re-assessed in terms of aggregate production in the Integrated farming systems particularly in ecologically fragile regions of hills and dry lands. The studies in the North Eastern hills do indicate the feasibility of taking up in combination e.g. agro-horti-forestry systems combined with terracing on smaller area to enhance the capacity of each hectare of land to support additionally more number of animal heads and to provide greater productivity and income to the people concerned. (Das and Maharjan, 1986). Similarly the development of management of ravinous area could yield 3 million tonnes of foodgrains per year besides putting nearly 60% of such lands under fuel, fodder reserves to meet chronical shortage of these items (NCA 1976).

6.5 Recently studies carried out on farm forestry have been carried out at Agra, Kota, Vasad and Dehradun (CSWRTI, 1987). As Agra, 2 rows of Subabul were planted after 4,6,8 and 10 rows of bajra or 8,12,16 and 20 rows of wheat. Leaves of Subabul were turned into the soil before sowing of wheat. Three years' average yield data showed that the increase in wheat yield ranged from 3 to 4.8 q/ha. At Kota, the study over 7 years showed that cultivation of pigeon pea + black gram was possible as inter crops with subabul under rainfed condition and without reduction in fodder yield. At Vasad, effects of tree growth (subabul) on irrigated crop yield were mixed one. The yield of summer bajra was not affected while yield of bidi-tobacco crop decreased by 17%. Eucalyptus tree however, reduced tobacco yield by 46% and bajra by 31%. At Dehra Dun, yield of cowpea crop was reduced by 75% and 79% respectively when grown on plots with Subabul and Eucalyptus (CSWCRTI, 1987).

6.6 Many of the traditional practices follow types of land husbandry, which are comparable to recent terminologies such as Agro-forestry, Agro-horticulture, Agro-silviculture, Silvipastoral etc. The principle is to cultivate crops along with growing non crop plants - grass, bush, shrub and trees. In India 'Khejri' is an age old practice. In West Africa's Sahil region Sorghum and millets are planted in fields inter spersed with permanent inter crop of *Acacia albida* trees. These fields produce more grains, support more livestock and require shorter fallow periods between crops than fields sown to grain crops only. The trees help enhancing productivity by reincorporating organic matter, through fixation of nitrogen, drawing nutrients from deeper soil layers to the top layers etc. This is known as regeneration of land fertility or inherent fertility of land in resource poor areas such as rainfed areas (Wolf, 1986).

6.7 These practices are quite common throughout India.

Growing "Khejri" with agricultural crops is an age old practice in Rajasthan. Even in the areas under shifting cultivation legumenous fodder trees/plants are grown and preserved so that their leaves can be lopped and incorporated in the soil to obtain and sustaining her crop production. The species used are many but more common ones are Parika roxburghil, Bauhinia purpurea, Dalbergia tamrin-difolia, etc. In Arunachal Pradesh, leaves of Ouercus griffithi are used for this purpose. While in Central and Western Himalayas, Grewia optiva, Bauchinia purpurea, Celtis australis (kharik), Giugya pinnata (Ramshinge) etc. are grown on terraces and un-terraced slopes along with crops. In other tropical parts a number of pasture grasses yield well year after year and without any extra nitrogen from outside and inspite of grazing and burning which remove nitrogen. Results of USA, Nigeria, Ghana etc. indicate that accumulation of Nitrogen per hectare per year could be anywhere between 45 kg to 700 kgs (ICAR, 1983, Das & Maharjan, 1986).

6.8 All these measures have also another positive dimension in terms of mousture conservation through water harvesting, recharging deeper soil profile, ground water and replenishing seasonal nalas and streams (Das, 1988a). Thus the measures protects and regenerate eco-system secure environment too.

STRATEGY, APPROACH & PACKAGE OF TECHNOLOGY

7.1 The complexity of problem lands and utilisation of available water has to be understood and tackled on the basis of integrated watershed management at macro, meso and micro levels. The geographical information system would have to be supplemented by the details of socio-economic demands of target groups to fulfill the objectives of higher and sustained production, generating more remunerative and acceptable employment opportunities with a sense of social equity and justice and securing a safer environment.

7.2 Package of treatments have been worked out for ten soil conservation regions of India for low, medium and high rainfall conditions as well as for agricultural, non-agricultural and all other lands along with drainage system. (NLCB, 1988d). The broad components are as follows:

- Agricultural Land : Bunding/terracing, land shaping, contour cultivation in between bunds, planting of vegetation, water escapes, other outlets etc. Improved crop technology is superimposed through respective Departments.
- Non-agricultural Land : Closures, afforestation and raising of utility trees, grassland development, contour staggered trenching, stone walls.
- Structural Measures : Water harvesting and silt detention structures and other conservation structures for treating problems like gullies, stream banks, land slides and slips, mine spoils etc. which may be both in agricultural and non-agricultural land.
- Restoration of Degraded Lands : Reclamation of ravines and gullies or as all integral of water harvesting structures and are coupled with plantation of trees and shrubs.

7.3 Social and management parameters are to be identified for developing grassroot level organisations to promote the desirable combination of land management systems in compatible manner and commensurate to the requirement of concerned communities. This would also ensure greater participation of the beneficiaries particularly for sharing liabilities and benefits and also demand similar coordination among the line departments to implement the principles and directives contained in the National Land Use Policy as well as national water policy. Finally, monitoring and evaluation will demand identification of key indicators for collection of data, building up of time-series and development of appropriate maps and graphs for concurrent appraisal and subsequent evaluation studies. The results of studies obtained so far by agencies like Agricultural Finance Corporation of India, Administrative Staff College of India, Hyderabad, Indian Institute of Management, Ahmedabad have established positive and significant role of soil and water conservation measures.

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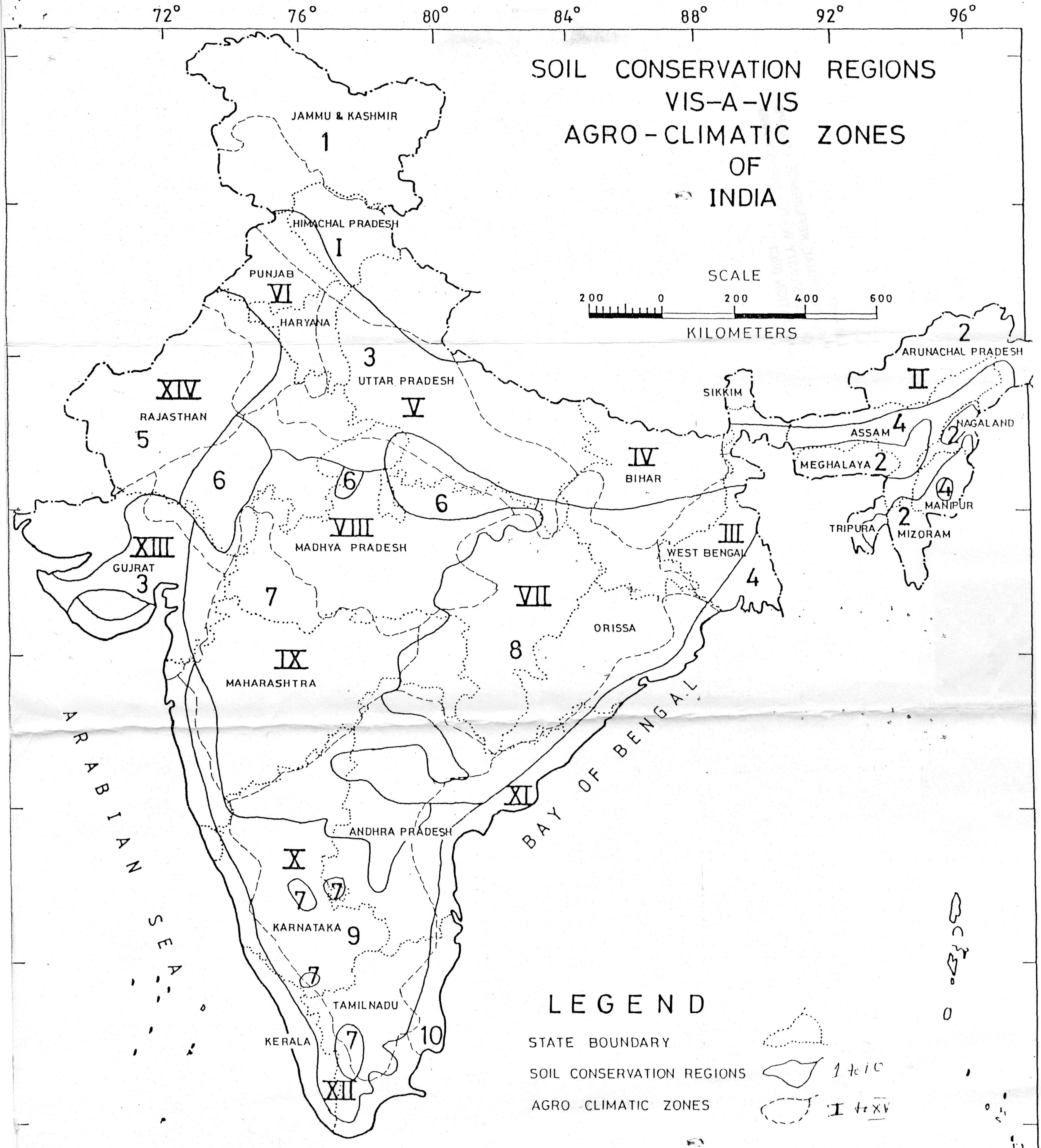
SOIL CONSERVATION REGIONS
VIS-A-VIS
AGRO-CLIMATIC ZONES
OF
INDIA
SCALE
200 0 200 400 600
KILOMETERS
72°
76°
80°
84°
88°
92°
96°
72° E. OF GREENWICH
JAMMU & KASHMIR
HIMACHAL PRADESH
PUNJAB
HARYANA
UTTAR PRADESH
RAJASTHAN
SIKKIM
ARUNACHAL PRADESH
NAGALAND
ASSAM
MEGHALAYA
MANIPUR
TRIPURA
MIZORAM
BIHAR
WEST BENGAL
GUJRAT
MADHYA PRADESH
ORISSA
MAHARASHTRA
ANDHRA PRADESH
KARNATAKA
TAMILNADU
KERALA
ARABIAN SEA
BAY OF BENGAL
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LEGEND
STATE BOUNDARY
SOIL CONSERVATION REGIONS
AGRO CLIMATIC ZONES