Chapter 15
Economics of Land Degradation in India

Gurumurthy Mythili and Jann Goedecke

Abstract Land degradation is increasingly becoming a major concern for Indian agriculture on which two-third of the population depend for their livelihood. Many policies and programs have been initiated in the last two decades to address this problem but the results are meager. Analysis of causes of land degradation and their extents is very important to design suitable policies to overcome the degradation problem. It is in this context, this paper identifies the major socio-economic variables that explain land degradation. It also finds economic and social costs of land degradation and the net benefits from taking up conservation activities and finally draws some lessons on what are the right policy instruments to promote sustainable land management practices. The Total Economic Value (TEV) concept has been used in deriving the costs and benefits. Our findings from state level analysis suggest that 'input subsidies' and 'decreasing land-man ratio' are two major determining factors that increase land degradation. Rationalizing input subsidies will go a long way in improving the management of land resources. At the household level, the number of crops grown and the operating area are significantly influencing land degradation. The analysis of the costs of action versus inaction against land degradation shows that costs of inaction are higher than the costs of action, indicating the benefits that will accrue if sufficient conservation practices are undertaken. Institutions and incentive mechanisms play important roles in changing the behavior of farmers to act in a resource conservative way.

Keywords Total economic value · Costs of inaction · Drivers of land degradation · Land policies

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Introduction

Land degradation poses a considerable challenge to agricultural growth and poverty reduction in India. It is officially estimated that about 44 % of India's land area is degraded. The causes of land degradation are numerous and complex. Proximate factors include the extension of crop cultivation to marginal and low potential lands or to lands vulnerable to natural hazards,[1] improper crop rotations, overuse of agrochemicals, and mismanagement of the irrigation system. Moreover, "shifting cultivation" practiced in many parts of the country is responsible for deforestation and the expansion of agriculture to less productive lands. However, the underlying causes are believed to be poverty among agricultural households, land fragmentation, insecure land tenure, open access nature of some resources, and policy and institutional failures.

To illustrate one of these drivers in more detail, India supports 18 % of the world human population, 15 % of the global livestock population, but endowed with only 2.4 % of world land area. Moreover, the average size of land holdings in agriculture declined from 2.30 to 1.16 ha during 1970–2010 due to increasing population pressure. About 60 % of the land is rainfed and low in productivity, leading to high inter-annual fluctuations in agricultural output. About 200 million rural poor depend on these rainfed areas for their livelihoods.

Intensive farming practices, particularly with wheat and rice, initiated during the Green Revolution in 1970s, have mined nutrients from the soil. Soil degradation is limiting gains in agricultural output and forest production. Land degradation is a big challenge to policy makers who need to balance the multiple goals of poverty eradication, food security and sustainable land management.

The major objective of this study is to scientifically support policy actions in India on sustainable land management, through finding answers to the three research questions below:

(i) What are key causes of land degradation across typical agro-ecological regions of India?
(ii) What are the economic, social and environmental costs of land degradation and net benefits resulting from taking actions against degradation compared to inaction?
(iii) What are the feasible policy and development strategies that enable and catalyze sustainable land management (SLM) actions?

This Economics of Land Degradation (ELD) research seeks to test two hypotheses. Firstly, we test which factors, such as climate and agricultural practices, population density, poverty, absence of secure land tenure, lack of market access and others, are significant causes of land degradation. Secondly, we also

[1]Steep slopes, shallow and sandy soils, fragile arid and semi-arid lands bordering deserts.

hypothesize that the benefit of taking action against land degradation through SLM measures is greater than the costs of inaction.

The chapter begins with a brief introduction to Conceptual Framework and followed by Land use, land degradation status, trend and classifications. The following section focuses on land policies and their influences on land degradation. This is followed by the impacts of land degradation where the survey of past studies, the methodology adopted for our own estimates and the estimates of costs of action vs inaction are highlighted. Then we move to the drivers of land degradation which contains state level and household level analysis. Finally we draw inferences from the findings and policy implications.

ELD Conceptual Framework

The conceptual framework used in the India case study of Economics of Land Degradation broadly follows the ELD framework presented in von Braun et al. (2013). The causes of land degradation are divided into proximate and underlying, which interact with each other to result in different levels of land degradation. The level of land degradation determines its outcomes or effects—whether on-site or offsite—on the provision of ecosystem services and the benefits humans derive from those services. Actors can then take action to control the causes of land degradation, its level, or its effects (ibid.).

Many of the services provided by ecosystems are not transacted through the markets, so different agents do not take into account negative or positive effects on those ecosystems. Since the external costs or benefits are not accounted for in the farmer’s land use decision, this leads to an undervaluation of land and its provision of ecosystem services (ibid.). The failure to capture these values causes higher rates of land degradation. To adequately account for ecosystem services in decision making, the economic values of those services have to be determined (Nkonya et al. 2011). Attributing economic values to ecosystem services is challenging, due to measurement problems. As economic values are linked to the number of (human) beneficiaries and the socioeconomic context, these services depend on local or regional conditions (ibid.). As TEEB (2010) indicates, a global framework that identifies a set of key attributes and then monitors these by building on national indicators could help answering this challenge.

It is also crucial to identify and understand institutional arrangements affecting land management, in order to devise sustainable and efficient policies to combat land degradation. For example, if farmers use excessive water or fertilizer, leading to some forms of land degradation, it must be understood why they do so. Missing or very low prices of irrigation water or fertilizer provide incentives to degrade land and soils in a misleading institutional setup.

The Extent and Types of Land Degradation in India

Cultivable lands (175 million ha) make up almost 60 % of the total Indian territory, 80 % of which is under crops (141 million ha), and another 6 % (10 million ha) is under rangelands (Table A.1 in the Annex and Fig. 15.1). The remaining arable lands are not cultivated. Forests (70 million ha) are the second most important land cover category, making up about a quarter of the total area.

The land use dynamics over the last four decades between 1970s and 2010, point at increasing share of croplands at the expense of rangelands and wastelands,

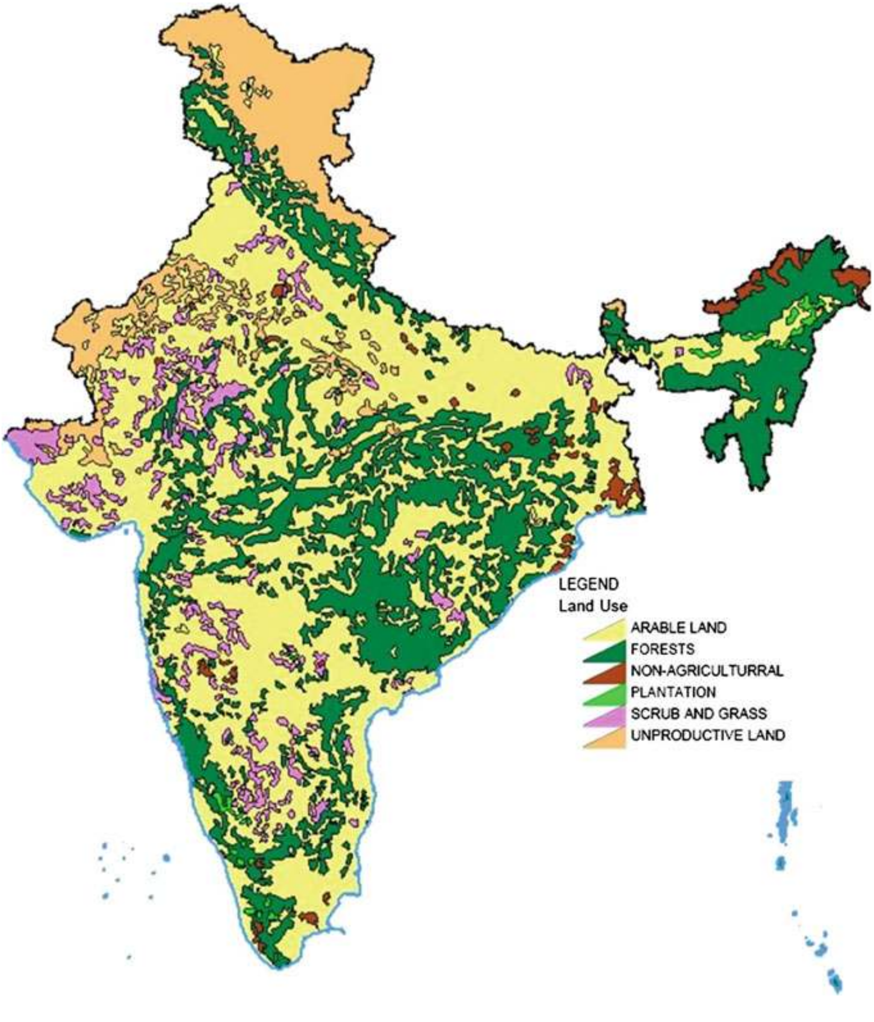

Fig. 15.1 Land use and land cover in India. *Source* National Institute of Hydrology (2009), Accessed from IndiaWaterPortal.org

rapidly growing urbanization and a slight extension in the forest cover (Table A.1 in the Annex). However, the analysis of more recent MODIS satellite data shows that between 2001 and 2009, the forest cover declined all across India by a total of 2.8 million ha, of which the largest shares are in Kerala, Madhya Pradesh, and Andhra Pradesh (Table 15.1).

Similarly, the areas under woodlands and barren lands have also decreased by 3.2 million ha each. On the other hand, the biggest land use change was the increase

Table 15.1 Land use change between 2001 and 2009 in Indian states (without Union territories), in thousand ha

Location	Forest	Shrub	Grassland	Cropland	Wood	Barren	Water
Andhra Pradesh	−324	85	1418	1230	−2330	−48	−32
Arunachal Pradesh	265	−141	80	−5	−41	−144	−13
Assam	−200	−68	−138	19	409	−49	27
Bihar	−148	−221	−115	725	−216	−13	−12
Chhattisgarh	−123	26	−69	521	−358	5	−3
Goa	−1	−8	−14	−7	32	−3	0
Gujarat	10	−787	−105	1331	30	−597	116
Haryana	3	−143	−11	155	0	−5	0
Jammu & Kashmir	427	−253	−595	130	−64	387	−32
Jharkhand	−237	99	−1	472	−332	0	0
Karnataka	−118	−81	1347	−1524	379	−9	6
Kerala	−945	−16	−11	172	820	−1	−19
Madhya Pradesh	−452	−152	481	372	−312	12	51
Maharashtra	−35	−413	473	227	−256	−10	15
Manipur	−123	−25	3	58	88	0	−1
Meghalaya	−110	2	−24	−1	134	0	−1
Mizoram	−291	−2	−15	−25	332	0	0
Nagaland	36	−2	−14	−16	−3	0	−1
Orissa	−268	62	62	772	−599	−19	−10
Punjab	7	−18	−17	24	5	0	−1
Rajasthan	−16	4893	−770	−1400	107	−2815	1
Sikkim	19	−4	15	0	−17	−10	−2
Tamil Nadu	−159	−210	325	774	−736	5	2
Tripura	−240	−7	−29	−14	291	0	−2
Uttar Pradesh	−104	−145	−108	528	−151	−7	−14
Uttarakhand	234	−178	−77	104	−153	80	−10
West Bengal	43	−42	−43	390	−283	−29	−34
India	**−2848**	**2252**	**2048**	**5010**	**−3222**	**−3271**	**32**

Source MODIS land cover
Note “urban” was left out since no change is reported in the considered time period

of the cropped areas by 5 million ha between 2001 and 2009, and increase of 2.2 and 2 million ha of shrublands and grasslands, respectively. These overall figures hide significant regional differences. For example, even though the overall cropland area has increased in India, such states as Karnataka, Rajasthan, have lost about 1.5 million ha of croplands each; whereas such other states as Gujarat, Andhra Pradesh have gained about 1.3 million ha of croplands each. Table 15.1 shows these regional differences in detail.

Geographically, India is divided into six zones: North, South, East, North East, West, Central, and Union territories. The land degradation data (Table 15.2) show that soil erosion due to water and wind occupy more than 70 % of the total degraded area. The water induced soil erosion is the single largest contributor to land degradation, i.e. about two-third of the total, followed by salinity, about 15 %, which is a common problem in the irrigated lands in the country. Region-wise statistics show that central region is the worst affected of all (59 % of its total area), followed by North-Eastern and Southern regions.

Land degradation statistics vary depending on the source and estimation method. One estimate is based on universal soil loss function, as applied in the NBSS and the other, on National Remote Sensing Agency (NRSA). NRSA bases its estimates on remotely sensed satellite data. NRSA estimates are lower than the former estimates by NBSS&LUP-ICAR-2005 and are expected to be more accurate and to give more detailed information.

Table 15.3 provides trends on land degradation using the former method. The NRSA estimates are given in Table 15.4. The trend shows that land degradation declined after 1996. There is a need to evaluate the reasons behind this decline. One potential cause could be the increased public investments to address degradation after 1996. The most important type of land degradation in India is soil erosion (both by wind and water) (on 119 million ha), followed by shifting cultivation, waterlogging and salinity.

According to the NRSA estimates only about 20 % of the territory in India, i.e. 65 million ha of land are considered as wastelands. However, it should be noted that these two estimates do not necessarily contradict each other as they measure different things.

More recent estimates by Le et al. (2014), using remotely sensed NDVI data, show that about 16 % of the Indian territory, i.e. about 47 million ha, showed declining NDVI trends between 1982 and 2006 (Fig. 15.2), of which 29 million ha in croplands and 12 million ha in forested areas.

The levels of soil erosion are classified by the degree of severity in Table 15.5. It shows that moderate erosion of 5–10 tons per ha (per year) is the largest category affecting 43 % of the total area affected by soil erosion. About 1.4 billion tons of soils are lost annually due to moderate erosion, and 1.6 billion tons due to high erosion. The total annual soil losses are estimated at about 5 billion tons.

While water erosion prevails across the country, wind erosion is dominant in the western part of the country, particularly in the state of Rajasthan. Singh et al. (1990) estimated that the annual erosion rate varies from below 5 tons/ha for dense forests, snow-clad cold deserts, and arid regions of western Rajasthan to above 80 tons/ha

Table 15.2 The classification of land degradation in India, by types and regions (in 1000 ha)

Region	Water erosion	Wind erosion	Water logging	Salinity/alkalinity	Several degradation types combined	Total degraded area	Area	Degraded area (%)
North	23,449	9040	4396	3342	335	40,562	101,061	40
North East	4136	–	522	5534	2422	12,614	26,219	48
Central	17,883	–	359	6842	1126	26,210	44,345	59
East	9249	–	3392	2322	194	15,157	41,833	36
West	16,446	443	599	1869	1993	21,350	50,743	42
South	22,330	–	5031	1902	1302	30,565	63,576	48
Union Territories	187	–	–	9	9	205	825	25
INDIA	93,680 (64 %)	9483 (6 %)	14,299 (10 %)	21,820 (15 %)	7381 (5 %)	146,663 (100 %)	328,602	45

Note Figures in parentheses are percentages to total degraded area. States in each region: North: Delhi, Jammu and Kashmir, Himachal Pradesh, Punjab, Haryana, Uttarakhand, Uttar Pradesh. North East: Assam, Sikkim, Nagaland, Meghalaya, Manipur, Mizoram, Tripura, Arunachal Pradesh. Central: Madhya Pradesh, Chhattisgarh. East: Bihar, Orissa, Jharkhand, West Bengal. West: Rajasthan, Gujarat, Goa, Maharashtra. South: Andhra Pradesh, Kerala, Karnataka, Tamil Nadu

Source NBSS&LUP-ICAR-2005 on the Scale of 1:250,000

Table 15.3 Trend in land degradation in India (area in million hectares)

Type	Ministry of agriculture and co-operation		Sehgal and Abrol		NBSS&LUP
	1980	1985	1994	1997	2005
Soil erosion[a]	150.0	141.2	162.4	167.0	119.19
Saline and alkaline soil	8.0	9.4	10.1	11.0	5.95
Water logging[b]	6.0	8.5	11.6	13.0	14.3
Shifting cultivation	4.4	4.9		9.0	7.38
Total degradation	168.4	175.1	175.0	187.8	146.82

Source As in column titles
[a]This includes both wind and water erosion, but water erosion accounts for more than 90 %
[b]Canal areas account for about 50 % of the total water logged area

Table 15.4 Category wise wastelands of India in 1999–2000 (estimated by NRSA)

Category	% of total geographical area
Gullied/or Ravenous land	0.65
Land with or without scrub	6.13
Water logged and marshy land	0.52
Land affected by salinity/alkalinity coastal/inland	0.65
Shifting cultivation area	1.11
Underutilized/degraded notified forest land	4.44
Degraded pastures/grazing land	0.82
Degraded land under plantation crop	0.18
Sands—Inland/coastal	1.58
Mining/industrial waste land	0.04
Barren rocky/stony waste/sheet rock area	2.04
Steep sloping area	0.24
Snow covered and/or glacial area	1.76
Total waste land area	20.17

Source NRSA

in the Shiwalik hills. Severe wind erosion is recorded mostly in the extreme western parts of the country. Almost one-third of the area under soil erosion suffers from low productivity. The topsoil erosion depletes the nutrient content of the soil (State of the Environment 2001).

Statistics from The National Bureau of Soil Survey and Land Use Planning (Sehgal and Abrol 1994) reveal that about 3.7 million ha suffer from nutrient loss and/or depletion of organic matter. Nutrient depletion is fairly widespread in the cultivated areas of the subtropical region. Estimates of loss of nutrients, using the annual soil specific erosion rates provided by the Central Soil and Water Conservation Research and Training Institute, ICAR, show that nearly 74 million tons of major nutrients is lost due to erosion annually in India. On an average, every

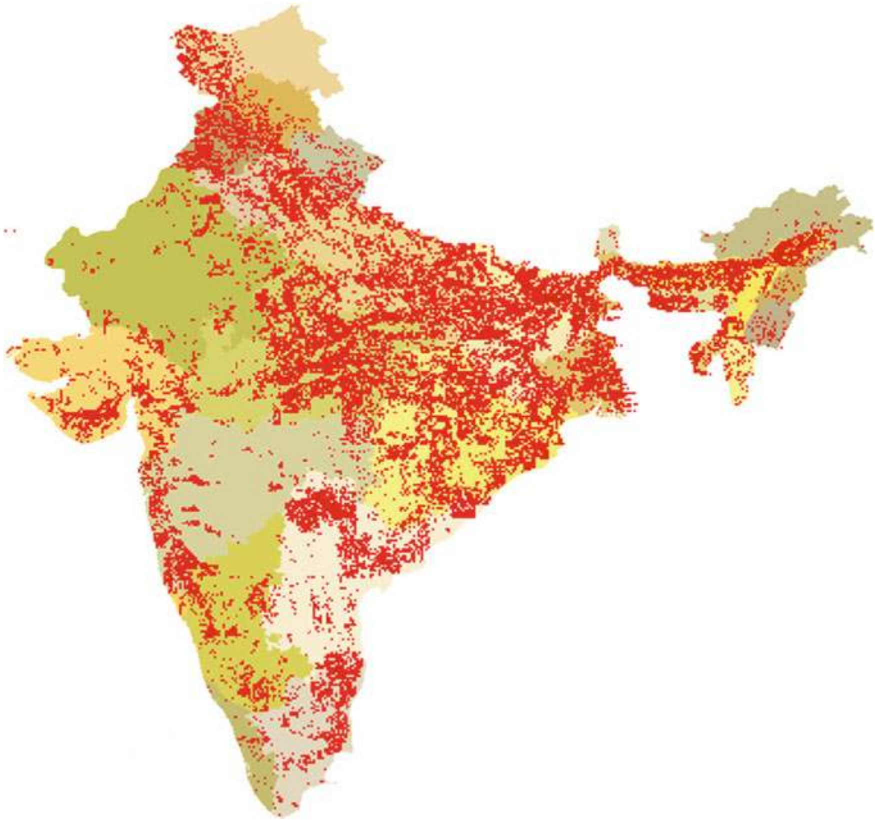

Fig. 15.2 Land degradation hotspots in India. *Source* Le et al. (2014). *Note* Land degradation hotspots are colored in *red*

Table 15.5 Levels of soil erosion of varying severity for India

Severity of erosion	Annual soil loss range (ton/ha)	The share of the total affected area (%)	Annual loss of soil (million tons)
Slight	≤5	24	401
Moderate	5–10	43	1406
High	10–20	24	1610
Very high	20–40	5	640
Severe	40–80	3	666
Very severe	≥80	1	255
Total			4978

Source Singh et al. (1990)

year, the country loses 0.8 million tons of nitrogen, 1.8 million tons of phosphorus, and 26.3 million tons of potassium (State of the Environment 2001). The offsite effect of erosion is the siltation in the reservoirs. Many reservoirs have suffered from reduced storage capacity due to increasing erosion and deposition. Siltation of major river courses due to excessive silt deposits is observed widely in Bihar and Uttar Pradesh since many rivers in these regions are flood-prone. The total area affected due to this problem is about 2.73 million ha (Das 1977; Mukherjee et al. 1985). The rivers Ganga and Brahmaputra carry the maximum sediment load annually, about 586 and 470 million tons, respectively. Between 6000 and 12,000 million tons of fertile soil are eroded annually and much of it is deposited in the reservoirs leading to a reduction in their storage capacity by 1–2 % (State of the Environment 2001).

Salt-affected soils are widespread in the different agro climatic zones of the Indo-Gangetic Plain. Areas with a mean annual rainfall of more than 600 mm are mostly of alkali soils, while saline soils are dominant in the arid, semiarid, and coastal regions (State of the Environment 2001). About 7 million ha is salt-affected, of which 2.5 million ha represents the alkali soils in the Indo-Gangetic Plain. Nearly 50 % of the canal-irrigated area is affected by salinization and/or alkalisation due to inadequate drainage, inefficient water management and distorted subsidized energy pricing (State of the Environment 2001). The regions affected by salinization caused by the rise in ground water are Uttar Pradesh, Haryana, Rajasthan, Maharashtra, and Karnataka. Inadequate planning and management of surface irrigation systems is the major cause of salinity of canal command area (State of the Environment 2001).

Evolution of Land Policies

The land policy is one major factor in the societal efforts to conserve land resources. Looking back, the pre-independence period was characterized by Zamindari and Ryotwari systems where the main motive was collecting land revenue or tax from the users of the land. In this system many non-cultivating intermediaries emerged and the government did not make any effort to abolish the intermediaries. Hence at the time of independence, the major challenge was to reform the agrarian structure and this brought about land reforms in the country. Various programs and policies that have bearing on land resources is given in Annex Table A.2.

In the subsequent Five Year Plans, land Policy was one of the major components. It broadly consists of (1) abolition of intermediaries, tenancy Reform and Redistribution of land (1950–72), (2) Bringing uncultivated land under cultivation (1972–85), (3) Water and Soil Conservation efforts (1985–95), and (4) Improve land revenue administration and land entitlement (1995 till date) (Deshpande 2003). The issues in various plan period and policy focus is given in the Annex Table A.3.

Secured land rights gives the cultivator incentives to use the land in such a way that the long term interest is protected. However the tenancy laws did not meet with success in India as it helped tenants acquire ownership right of only a very small percentage of the cultivated area. There were many forms of concealed tenancy which were difficult to break. If we go through the statistics provided by National Sample Survey, there was a very sharp reduction in tenancy over time. One factor responsible for reduction in tenancy was that many land owners evicted their tenants in response to the tenancy legislation (Deshpande 2003). Even though reduction in tenancy is likely to help reduce land degradation, there is no sufficient information available to conclude if the land vacated by tenants is put to productive use by the land owner or left as fallow land.

In recent land policies, attention was drawn to loss of micronutrient due to irrational and imbalanced use of fertiliser. Rationalising fertiliser subsidies is being considered as one of the objectives in the current policies (Annex Table A.3).

The Impact of Land Degradation

A Survey of Past Studies

In the literature on the costs of land degradation in India, soil loss has been valued using productivity approach, preventive cost approach, and replacement cost approach. The productivity approach basically attempts to value through impacts, viz. through productivity loss. Preventive measures are practices such as conservation agriculture. The replacement cost is cost of restoration of soil to its original state (Mythili 2003).

Econometric techniques have been utilized in a few studies (e.g. Parikh 1989; Parikh and Ghosh 1991) to estimate soil loss by having the yield function as separable in input response function and soil quality multiplier function. Given a measurable soil quality multiplier, potential yield value foregone as a result of decline in soil quality for a given input bundle can be determined.[2] Few studies estimate benefits from soil conservation through watershed development program in terms of productivity gains (e.g. Ninan 2002). This method is known as preventive method. However loss of productivity is widely used in the Indian context to measure the impact (Mythili 2003).

Most of the studies which attempted valuation of degradation failed to recognize the regional level diversities. According to soil types, black and red soils are more vulnerable to land degradation (Sehgal and Abrol 1994). Loss estimates of some major studies are presented in Table 15.6.

Table 15.7 presents state wise estimates of losses due to different types of land degradation based on soil loss, extracted from the study by Vasisht et al. (2003). About 8 states reported more than 20 % loss in the production due to degradation.

[2]The farmers' adaptation mechanism for alteration in the soil quality can also be dealt within the model.

Table 15.6 Impact of soil erosion, salinity and water logging in India—a review

Study	Data period	Type	Loss	Remark
Narayana and Ram Babu (1983)	1976	Soil erosion (water induced)	Annual loss of soil 16.4 tons/ha	
Singh et al. (1990)	1970s	Soil erosion (water induced)	Annual loss of soil 15.2 tons/ha	
Bansil (1990)	1986	Soil erosion (water induced)	Annual loss in production of major crops 13.5 million tons (3.1 % of total production)	Cover agricultural land, other non-wasteland and non-forest land
UNDP, FAO and UNEP (1993)	1993	Soil erosion (water induced)	Annual loss in production 8.2 million tons (1.7 % of total production)	Only agricultural land
Sehgal and Abrol (1994)	1990s	Soil erosion (water induced)	Soil productivity decline ranges from 12 % in deep soil to 73 % in shallow soil	Loss is more in red and black soil as compared to alluvium derived soil
Brandon et al. (1996)	1990s	Soil erosion	Annual loss of 4–6.3 % agricultural production	
UNDP, FAO and UNEP (1993)	1993	Salinity	6.2 million tons of Production loss	As per FAO data
Singh (1994)	1990s	Salinity	About 50 % of canal irrigated area is affected by salinity	
Singh (1994)	1990s	Waterlogging	Productivity loss ranging from 40 % for paddy to 80 % for potato	
Reddy (2003)	1989	Soil erosion	Loss in terms of replacement cost range from 1 to 1.7 % of GDP based on various data estimates. In terms of production loss it is 4 times higher	Erosion data of NRSA and ARPU and Sehgal and Abrol (1994) are used to find cost of erosion

(continued)

Table 15.6 (continued)

Study	Data period	Type	Loss	Remark
Reddy (2003)	1989	Salinity and Alkalinity	Loss of production to the tune of 0.67 million tons which is 0.2 % of GDP	Based on NRSA estimates of area affected
	1994	Salinity and Alkalinity	Loss of production is 3.80 million tonnes equal to 0.3 % of GDP	Based on the degradation area data of Sehgal and Abrol (1994)
Reddy (2003)	1989	Water logging	Production loss of 0.85 mt equal to 0.25 % of GDP	Based on NRSA estimates
	1994	Water logging	Production loss of 8.72 m equal to 0.8 % of GDP	Based on Sehgal and Abrol (1994) estimates
Vasisht et al. (2003)	1994–96	All types	Production loss of 12 % of total value of production	Statewise estimates also computed

Source For some studies: Reddy (2003) and TERI (1998). Others were extracted from the respective studies

Table 15.7 State-wise estimates of economic losses of land degradation in India

State	Degraded land area[a] (1000 ha)	Losses due to degradation as % to total value of production
Andhra Pradesh	15,662	20
Assam	2807	25
Bihar	6291	14
Gujarat	10,336	22
Himachal Pradesh	3008	27
Haryana	1384	15
Jammu & Kashmir	2225	17
Karnataka	7681	18
Kerala	2608	24
Maharashtra	13,328	22
Madhya Pradesh	26,209	20
Orissa	6121	19
Rajasthan	13,586	17
Tamil Nadu	5273	21
Uttar Pradesh	15,253	13
West Bengal	2752	10
Punjab	896	19
All India[b]	187,770	12

Source Vasisht et al. (2003)
[a]Based on the estimate of Sehgal and Abrol (1994)
[b]National Bureau of Soil Survey and Land Use Planning

Methodology of Deriving Costs of Land Degradation

In the present study, the economic impacts of land degradation are calculated using the Total Economic Value (TEV) Framework (MEA 2005). TEV approach captures the total costs of land degradation more comprehensively (Nkonya et al. 2013). We use the data from TEEB database, based on more than 300 case studies around the world, and use value transfer approach to cover the areas for which the data is lacking (Nkonya et al. 2013). The values of the ecosystem services thus obtained were used in calculating the Total Economic Value of the economic impacts of land degradation.

Cost of Inaction Versus Cost of Action

The calculation of costs of inaction and the costs of action against land degradation follows the methodology described in detail in Chap. 6 of this volume. The methodology to assess the cost of inaction is based on the fact that land degradation mainly occurs in two forms (Nkonya et al. 2013). Costs of inaction arise if land use changes from more economically and environmentally productive (considering its ecosystem functions) land uses to those with less productivity. The cost of action against degradation due to land use and land cover change are incurred by re-establishing the high value biome and the opportunity cost, since the benefits given by the biome that is being replaced have to be taken account of.

Estimates of Cost

Our estimates using the TEV approach presented in the methodology section are given in Table 15.8. The total annual costs of land degradation by land use and cover change in 2009 as compared to 2001 in India are estimated to be about 5.35 billion USD.

The biggest share of these costs are occurring in Kerala, Rajasthan, Andhra Pradesh, Orissa and Madhya Pradesh, whereas the lowest land degradation by land use change are in Haryana, Punjab and Goa (Fig. 15.3). These land degradation costs estimates are only due to land use and cover change, and do not yet account for costs of land degradation when land use did not change, i.e. when cropland stayed as cropland between 2001 and 2009, but crop yields were negatively affected by land degradation. As for the per capita costs of land degradation, the highest per capita costs are observed in Mizoram and Arunachal Pradesh and the lowest per capita costs again in Haryana and Punjab. The reason for such low figures for Haryana and Punjab is that there has been very little land use change in these two States. However, these estimates exclude the costs of land degradation other than land use change, which are expected to be more prevalent in these states.

The share of LD in the regional GDP shows that the share is significant in the Northern and North-eastern regions of India (Fig. 15.4).

The estimates in Table 15.9 confirm that the cost of inaction exceeds cost of action in every state. The ratio of action over inaction is in the range 20–40 % in humid regions in general and above 40 % in sub humid and arid regions. Further cost of action for crop and grassland are more or less similar to cost of taking action against deforestation. However when it comes to inaction there are wide variations between the two. Cost of inaction against deforestation, is consistently higher in all the states. Cost of inaction in crop and grass lands is the highest in Madhya Pradesh which is a relatively backward region and the smallest in Punjab & Haryana province. In this region, the land use change is much less and the land degradations mainly occur in the form of loss of productivity due to salinity. This region exposes

Table 15.8 Total economic cost of land degradation in India

State	Gross regional product (GRP) in 2009, in billion USD	GRP per capita, in USD	Annual costs of land degradation, in million USD	Annual per capita cost of land degradation, in USD	The share of land degradation costs in GRP (%)
Andhra Pradesh	102.6	1056	335.0	4.0	<1
Arunachal Pradesh	1.5	973	106.0	76.6	7
Assam	19.4	549	268.3	8.6	1
Bihar	37.1	341	126.1	1.2	<1
Chhattisgarh	20.8	702	255.2	10.0	1
Goa	6.2	2963	9.3	6.4	<1
Gujarat	89.4	1271	201.4	3.3	<1
Haryana	46.5	1615	4.8	0.2	<1
Jammu & Kashmir	10.1	673	250.9	20.0	2
Jharkhand	20.2	543	218.7	6.6	1
Karnataka	72.2	1044	244.4	4.0	<1
Kerala	48.6	1205	517.8	15.5	1
Madhya Pradesh	47.5	571	325.5	4.5	1
Maharashtra	188.6	1481	158.1	1.4	<1
Manipur	1.7	547	122.3	47.6	7
Meghalaya	2.8	900	126.2	42.5	5
Mizoram	1.1	869	193.3	176.1	17
Nagaland	2.1	989	92.8	46.9	4
Orissa	34.3	687	333.3	7.9	1
Punjab	41.9	1252	7.5	0.3	<1
Rajasthan	55.1	681	405.3	5.9	1
Sikkim	1.0	1375	28.7	47.0	3
Tamil Nadu	99.1	1271	254.1	3.5	<1
Tripura	3.2	799	147.3	40.1	5
Uttar Pradesh	109.2	468	130.1	0.7	<1
Uttarakhand	13.9	1186	205.1	20.3	1
West Bengal	84.8	837	84.9	0.9	<1
Total	1224.3	922	5351.3	4.4	<1

Source Authors' calculation based on the data extracted from Government of Punjab, Department of Planning (2014); Indian Ministry of Statistics and Programme Implementation (2014); TEEB dataset; Modis land cover dataset

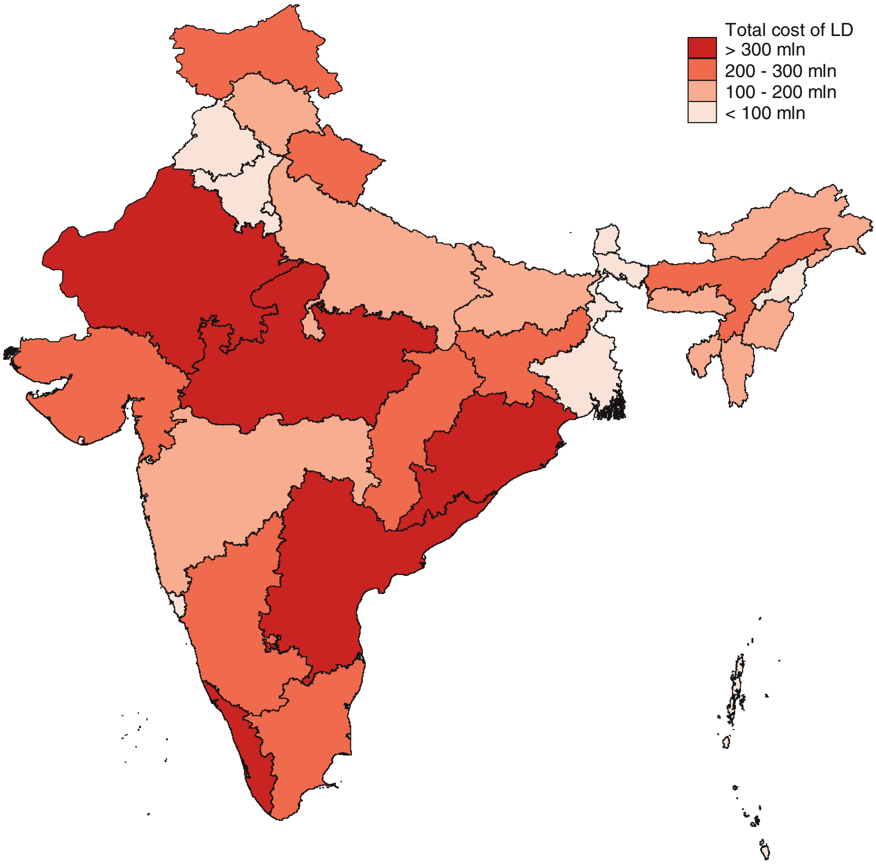

Fig. 15.3 Annual costs of land degradation, in million USD. *Source* Government of Punjab, Department of Planning (2014); Indian Ministry of Statistics and Programme Implementation (2014); TEEB dataset; Modis land cover dataset

a high level of irrigation and fertiliser use. Since this analysis takes into account only land use cover changes, Punjab and Haryana show much less costs of inaction. Goa also shows smaller units of costs of inaction but it has much less activity under crop and grass lands and it mainly derives its income from tourism.

Loss Due to Rangeland Degradation

With regard to Biomass decline of grazing land for livestock, it is estimated by Kwon et al. (Chap. 8 of the book) that 7.70 US million dollars of value (at 2007 prices) is lost in milk and meat production due to decline in grass biomass from

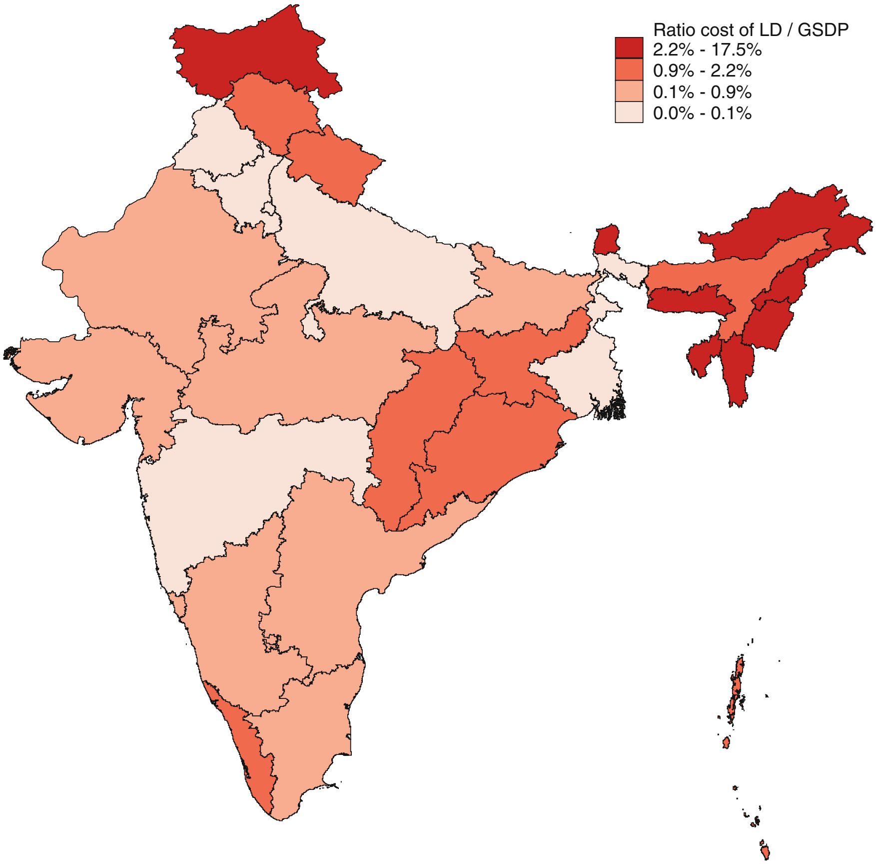

Fig. 15.4 The share of annual land degradation costs in regional GDP (thresholds according to quartiles). *Source* Indian Ministry of Statistics and Programme Implementation; simulations based on TEEB and MODIS land cover datasets, agroecological zones defined according to IISD (2015)

rangeland degradation.[3] Almost 80 % of this decline constitutes loss of milk production as meat consumption is low in India.

This estimate of total loss of livestock products for India by this study is much less in comparison with smaller African countries like Ethiopia and Kenya. However this study did not consider the forest lands which are widely used for grazing in India. In India, about 60 % of livestock grazing area is forest area (Kapur et al. 2010). The loss of rangeland value significantly varies between studies due to varying methodologies. Mani et al. (2012) reported 3–4 billion dollars of livestock value loss at 2010 prices due to grassland degradation.

[3]Only cattle, buffalo, sheep and goat are considered in this study.

Table 15.9 Cost of action and inaction against land degradation, by state (in billion USD)

State	Annual costs of LD, in million USD	Annual costs of LD in terms of provisional ecosystem services only	Cost of action (6 years)	Cost of action (30 years)	Of which, opportunity cost of action	Cost of inaction (6 years)	Cost of inaction (30 years)	Ratio cost of action/inaction (%)	Agro-ecological zone
Andhra Pradesh	334.96	2.29	20.02	20.05	19.88	28.41	38.46	52	Subhumid
Arunachal Pradesh	106.02	0.39	1.46	1.46	1.45	4.09	5.54	26	Humid
Assam	268.28	1.2	5.4	5.41	5.36	12.06	16.33	33	Humid
Bihar	126.14	0.74	4.75	4.76	4.72	7.97	10.79	44	Humid
Chhattisgarh	255.19	1.31	8.89	8.9	8.83	15.11	20.45	43	Subhumid
Goa	9.35	0.04	0.15	0.15	0.15	0.39	0.53	28	Humid
Gujarat	201.42	1.78	11.94	11.96	11.83	18.18	24.61	49	A&S
Haryana	4.75	0.07	0.9	0.9	0.89	1.03	1.39	65	A&S
Jammu & Kashmir	250.94	1.14	2.89	2.9	2.85	9.47	12.82	23	A&S
Jharkhand	218.66	1.07	6.68	6.69	6.63	12.01	16.25	41	Subhumid
Karnataka	244.4	1.34	9.08	9.1	9.02	15.22	20.6	44	Subhumid
Kerala	517.78	1.87	6.1	6.11	6.06	18.34	24.82	25	Humid
Madhya Pradesh	325.53	1.94	15.49	15.51	15.38	23.52	31.84	49	Subhumid
Maharashtra	158.15	1.22	11.77	11.78	11.69	15.81	21.4	55	Subhumid
Manipur	122.34	0.45	1.63	1.64	1.62	4.53	6.14	27	Humid
Meghalaya	126.21	0.46	1.49	1.49	1.48	4.52	6.12	24	Humid
Mizoram	193.25	0.67	2.01	2.01	2.0	6.57	8.9	23	Humid

(continued)

Table 15.9 (continued)

State	Annual costs of LD, in million USD	Annual costs of LD in terms of provisional ecosystem services only	Cost of action (6 years)	Cost of action (30 years)	Of which, opportunity cost of action	Cost of inaction (6 years)	Cost of inaction (30 years)	Ratio cost of action/inaction (%)	Agro-ecological zone
Nagaland	92.82	0.33	1.03	1.03	1.02	3.23	4.37	24	Humid
Orissa	333.26	1.68	11.84	11.86	11.76	19.88	26.91	44	Subhumid
Punjab	7.49	0.05	0.32	0.32	0.32	0.52	0.71	45	A&S
Rajasthan	405.34	2.95	13.78	13.81	13.63	26.3	35.6	39	A&S
Sikkim	28.71	0.11	0.31	0.31	0.3	1.03	1.39	22	Humid
Tamil Nadu	254.08	1.61	10.1	10.12	10.02	16.84	22.79	44	Subhumid
Tripura	147.25	0.53	1.68	1.69	1.67	5.19	7.03	24	Humid
Uttar Pradesh	130.13	0.73	4.25	4.26	4.22	7.57	10.24	42	Subhumid
Uttarakhand	205.11	0.87	3.17	3.18	3.14	8.35	11.3	28	Subhumid
West Bengal	84.89	0.55	4.22	4.22	4.19	6.36	8.61	49	Humid
Total	5152.46	27.38	161.36	161.6	160.11	292.51	395.95	41	

Source Authors' calculation based on the data extracted from Indian Ministry of Statistics and Programme Implementation; simulations based on TEEB and MODIS land cover datasets, agroecological zones defined according to IISD (2015). *Notes* A&S means arid and semi-arid

Focus Group Discussions

Focus Group Discussions were conducted in 8 villages from 2 districts. Ahmednagar in the western Maharashtra and Karnal in eastern part of Haryana were chosen. They both fall in the Hot semi-arid ecological zone. Six villages were selected from Ahmednagar and two were selected from Karnal for ground truthing exercise. The villages are depicted in Fig. 15.5. Table 15.10 presents the basic statistics of the village economy for the year 2013.

The FGD uncovered the following results. As for LUCC, the shrub land and grass land have come down in Hivare bazar of Ahmednagar, the grass land has increased in Karnal in both the villages. The major drivers of land use change are cited as infrastructure development, income increase, easier access to information technology and policies. For Hivare bazar livestock is as important as crops. Livestock population has drastically increased in this region in the last decade and that could be one reason that the grass land has been over exploited which led to its fall. This village also actively engaged in non-farm activities. As against this, villages in Haryana mainly depend on agriculture, uses machinery intensively on farm and as a result, the grassland has not witnessed a fall. About 50 % of the sample villages witnessed moderate to severe deforestation due to expansion of cropland. Almost 75 % perceived change in attitude towards higher interest in preserving cultural heritage.

The off-site eco system valuation from the perception of focal group participants of the village revealed that the benefits far exceed the costs. It was felt that community awareness, governmental policies would help contributing towards conservation of ecosystem. Many have revealed that they would be willing to contribute towards provision of any service that would improve their soil quality.

Drivers of Land Degradation

Survey of Literature

In mid-sixties, before the start of the Green revolution, increases in agricultural production in India were mainly achieved through expansion of the cultivated area, usually at the expense of community lands and forests. Since much of the area was brought under cultivation, or subject to grazing pressure, soil erosion and degradation had been substantial. The later advancements of Green revolution were mostly land saving. Therefore, it was believed that technological innovations will reduce pressure on marginal and sub-marginal lands, and thus, reduce further land degradation. However, the technological innovations were also capital intensive and not sufficiently labor-absorbing. Moreover, in many states, real wages either remained stagnant or declined between mid-1950s and mid-1970s, leading to lack

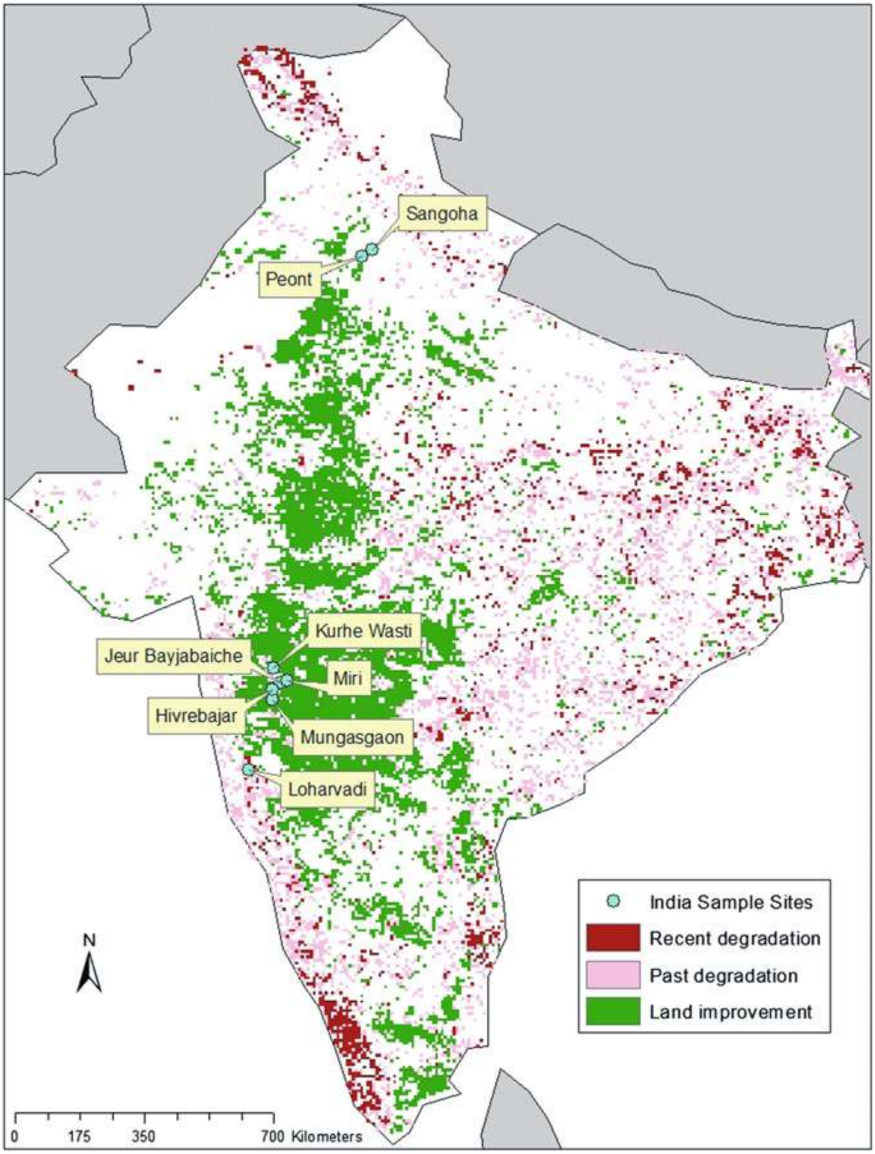

Fig. 15.5 Selected groundtruthing cites. *Source* FGD. Note: *Dark red* indicates pixels that demonstrate both long-term degradation as well as degradation in recent (2000–2006) years, *green pixels* indicate sites with improved land

of substantial increase in the incomes of the poor agricultural households, who continued exploiting forest resources (Hanumantha Rao 1994).

On the investment front, rising demand was not matched with adequate investment to augment the yield potential of the land resources. Degradation could

Table 15.10 Status of the villages in 2013

District	Villages in Ahmed Nagar district						Villages in Karnal district	
Particulars	Loharwadi	Mungusgaon	Hivare Bazar	Miri	Jeur	Pimpri-Gouli	Peont	Sangoha
No. of Households	1500	1450	1350	2000	1200	972	775	1065
Villagers engaged in								
Agriculture (%)	80	95	100	98	80	100	100	100
Crop (%)	80	100	100	98	100	100	100	100
Livestock (%)	5	10	100	90	70	50	50	100
Forest (%)	0	5	75	5	0	20	0	0
Fisheries (%)	0	0	0	0	0	0	0	0
Non-agriculture (%)	0	7	100	10	0	70	0	0

Source Focus group discussions

be perceived as a consequence of the failure to cope with the rising demand for food, fodder, fuel wood and other forest products through necessary investment in technological change and institutional arrangement for managing the resources. The agrarian change in India is different in different regions and hence problem of degradation is different. The regions with intensive cultivation which caused land degradation problems are, Punjab, Haryana, West Uttar Pradesh, and the deltaic regions of Andhra Pradesh and Tamil Nadu. This region is characterised by more intensive application of inputs, irrigation, fertiliser and pesticide, HYV seeds and mechanisation. Increasing demand for labour has resulted in higher wages and hence lower poverty. The other extreme is the region with more extension of area to ecologically fragile lands ranging from arid and semi-arid zones with low and uncertain rainfall, to hilly areas with assured rainfall. They have comparative advantage in animal husbandry, forestry and horticulture. They are characterised by increasing poverty and pressure for land under cultivation. In between these two types lies the majority of area. The progress of irrigation and land augmenting technological change is slow. Expansion of area under cultivation is moderate and mechanisation is slow. They exert pressure on common lands.

The existing studies on the link between land degradation and socioeconomic variables are very few. In fact there is only one systematic attempt on the determinants of land degradation in India (Reddy 2003). But this study deals only with district level and state level data and not at the household level. Some empirical studies have rejected the direct relation between poverty and resource degradation (Nadkarni 1990; Jodha 1986; Reddy 1999). These studies argue that the poor have greater motivation to conserve the resource because their livelihood depends on it; they are often victims of degradation and not the cause of degradation.

Reddy (2003) has conducted an empirical exercise using a regression technique to find the determinants of degradation at the district level and at the state level. The proportion of area degraded under various components to the total geographical area of the region (Source: NRSA) is the dependent variable. The regressors consist of: Socioeconomic, demographic, technological, institutional and climatic factors. At the district level, the period of analysis is 1986–93, while at the state level, the analysis was conducted for the 3 periods, 1981–82, 1988–89 and 1986–93. The state-wise analysis reveals that land-man ratio (defined as rural population per hectare of net sown area) exerts significantly positive influence on degradation, meaning that higher population pressure on agricultural land is not the cause of land degradation. The regions of intensive cultivation are actually less prone to degradation. In the district level analysis, there were 3 different regressions, one each for total degraded, salt affected and water logged area. For the salt affected land, percentage of irrigated area and population density, as expected, imposed a significantly positive influence; output per hectare imposed a negative influence.

From Reddy's (2003) analysis it appeared that better carrying capacity of lands support higher population densities. Hence no direct relationship was revealed between poverty and degradation. Per capita income does not exert any influence on degradation. Output per hectare is inversely related to land degradation indicating that regions with higher productive land are less prone to degradation. Rainfall does not have any bearing on degradation. Even the variable on availability of institutional credit has no impact on extent of degradation.

From a case study of Maharashtra, Joshi et al. (1996) has found that the investment for the mitigation of land degradation always gets the last priority. Farmers are enthusiastically willing to spend family labour time for conservation activities. It has been found that farmers are rational in following soil conservation methods. Absence of direct economic benefit results in non-adoption (Chopra 1996). The solution here would be the creation of incentives by the state. Most of the conservation technologies are capital intensive and hence needs support from the state.

Various programs initiated by the government over time have impacted land management directly and indirectly (Annex Table A.3) and studies on impact of programs on land management have shown that programs such as Wasteland Development Programs and Watershed Development Programs have mitigated degradation.

Empirical Analysis of Drivers of Land Degradation

We analyse the drivers of land degradation both on the macro (comparing states) as well as on the micro (comparing households) level. As the results of existing state-level analyses were based on the data for the period before 2000, it is hence proposed to update the analysis using the data of post 2000 periods. For this purpose, we have selected 13 states[4] of India which have significant land degradation due to soil erosion and the time periods are 2000, 2005, 2007 and 2010, the years for which data are available for soil erosion. The model to estimate follows a panel design and is given by

$$\boldsymbol{Y}_{s,t} = \boldsymbol{\alpha}_s + \boldsymbol{\beta}_1 \boldsymbol{x}_{s,t} + \boldsymbol{\beta}_1 \boldsymbol{z}_{s,t} + \boldsymbol{\varepsilon}_{s,t} \qquad (15.1)$$

where s denotes the observed state and t is the year of observation. Our dependent variable Y is 'waste land' which is the area affected by soil erosion. We regressed this with the host of influencing agricultural variables captured by the vector x, such as number of cultivators per unit of area, cropping intensity, fertiliser consumption or fertiliser subsidy, percentage of irrigated area, and yield. We control for a state-dependent characteristics, GDP, population density, poverty ratio and literacy rate. All the variables except the dummies have been used in logarithmic form in the estimation.

Additionally to the state-level analysis, we also perform an analysis of drivers of land degradation at household level. More specifically, the unit of observation is a

[4]The selected states are: Andhra Pradesh, Bihar, Gujarat, Haryana, Karnataka, Madhya Pradesh (including Chattisgarh), Maharashtra, Orissa, Punjab, Rajasthan, Tamilnadu, Uttar Pradesh and West Bengal.

plot cultivated by a household, where households may own more than one plot. To achieve this, the Cost of Cultivation Survey (CCS)[5] dataset is employed, which is conducted annually, covering 19 Indian states. The dependent variable is the plot level of soil erosion perceived by farmers themselves, serving as a proxy for land degradation, with 4 possible states in ranked order (none, sheet erosion, small gullies, large gullies). For this reason we regress soil erosion on household characteristics and plot specific information in an ordered probit regression framework:

$$Pr(LD_{ij}^{t+1} = k) = \Phi(\mu_k - \beta \mathbf{X}_{ij}^t) - \Phi(\mu_{k-1} - \beta' \mathbf{X}_{ij}^t) \quad (15.2)$$

where

$i = 1,\ldots, N$	households
$j = 1,\ldots, M_i$	plots for the *i*th households
$k = 1,\ldots, 4$	ordered outcomes
$t = 2005$	the base year
$\mu_{-1} = -\infty$	and $\mu_4 = \infty$

Vector X_{ij} contains socio-demographic characteristics of the household and plot-specific information, which is further explained in the next section.

Data and Variables

For the state-level analysis, information on the extent of wastelands per state was obtained from various sources, and is measured in 1000 ha.[6] The variables considered independent for our purposes can be summarized as follows:

Gross agricultural State Domestic Product per capita: The Gross state Domestic Product from agriculture and allied activities was considered at the constant prices of 1999–2000 for this variable. Since the 2010 GSDP was available only at 2004–05 prices, it was converted at 1999–2000 prices using an implicit price deflator.
Number of Cultivators per cultivated area: The Number of cultivators per unit of cultivated area measures the density of farm holdings in the available area. This is measured in number of cultivators per 1000 ha.

[5]Indian Commission for Agricultural Costs and Prices (CACP), Comprehensive Cost of Cultivation scheme for the year 2005–06 and 2006–07, Indian directorate of economics and statistics, Ministry of Agriculture.

[6]Degraded and wastelands of India, status and spatial distribution, ICAR, 2010; Wastelands Atlas of India by National remote sensing agency, 2000; *Degraded and Wastelands of India—Status and Spatial Distribution*, Indian Council of Agricultural Research and National Academy of Agricultural Sciences, New Delhi, June 2010, website (http://www.icar.org.in/files/Degraded-and-Wastelands.pdf). Wasteland atlas of India by National remote sensing agency, 2005; Statistics released by ministry of rural development, Govt. of India.

Fertiliser subsidy: The fertiliser subsidy was available at the national level and it was allocated using the weights of fertiliser consumption share of the state to the all India consumption.
Cropping Intensity: The cropping intensity, measured as ratio of gross cropped area over net sown area, was collected from the database available at Ministry of agriculture, Government of India.
Population density: The population density is measured as population in 1000 km^{-2} of geographical area of the state.
Rural Poverty ratio and the literacy rates: The poverty ratios and the literacy rates have been interpolated for the study years from the available years. Poverty ratio was available for the years 1996–97, 2001–02, 2006–07 and 2011–12 whereas literacy rates were available on the decadal basis for the years 1991, 2001 and 2011. The data were taken from Ministry of Statistics and Programme Implementation and Rural development statistics, National Institute of Rural Development.
Yield: The yield of major food grains is the value added in agriculture per hectare of cultivated area.
Percentage of Irrigated area: The percentage of irrigated area has been calculated by dividing the net irrigated area by net sown area.

To account for spatial differences, dummy variables are used for each region, North, West, East while keeping South as the reference category. Data for all described variables were compiled from different sources.[7]

For the micro level analysis, several items asked for in the CCS are considered as explanatory for the extent of soil erosion. Household demographics include highest education completed, age, time available for work (all given for head of household), a dummy denoting if the head of household is female, size of the household as well as proxies for the household's wealth: the log value of livestock, the number of livestock and the log value of physical assets. Plot specific information entails quality of drainage, the number of different crops grown on the plot, the number of seasons where crops are grown and the total area of the plot, as well as dummies for irrigation, property of land and land use. While those variables are cross sectional as of 2005, the CCS data also includes monthly data on crop inputs between 2005 and 2006, where the intensity in the application of organic manure, chemical fertilizers, and pesticides are of interest. Data on agricultural extension, and sources of farmer's information, were not available in the data. To account for correlation in the dependent variable within villages, standard errors are clustered on the village level.

[7]Source: Yield, The Gross State Domestic Product, Percentage of Irrigated area for the year 2010, Number of Cultivators, Cultivated area and fertiliser consumption has been collected from The Agriculture statistics at a glance, 2003; 2007, 2010 and 2013. The Irrigated area and the net sown area for the years 2000, 2005 and 2007 has been taken from Ministry of agriculture, Govt. of India. Whereas the fertiliser subsidy has been taken from: Lok Sabha Unstarred Question No. 2623, dated 23.07.2009, the statistics released by: Lok Sabha Starred Question No. 121, dated on 11.3.2005, statistics released by: Lok sabha Unstarred Question No. 2484, dated 10.03.2011 and Unstarred question no. 1810, dated 01.12.2011.

Estimation

State Level Analysis

This section reviews the results of the econometric estimation, starting with the state-level panel regression. Table 15.11 presents the basic statistics of the variables considered for the regression.

Since panel methodology has been used to find the estimates, the Hausman test was conducted first to decide if the model follows Fixed Effect or Random Effect model. The Hausman test for testing fixed effect vs random effect did not reject the random effects model. Hence we ran the panel model of random effects with wasteland as the dependent variable and the results are presented in Table 15.12.

Fertiliser subsidy turns out be a major determinant of land degradation. This has also been a talking point recently in the academic literature as well as policy forums and reports and action is being proposed in the plan documents for a phase wise withdrawal of input subsidies. However due to political pressure, lobbying by farmers' group, government is not able to cut down subsidies on fertilizer in a desirable manner. According to the coefficient, a 1 % reduction in subsidy is likely to reduce land degradation by nearly 3 %. Population density and poverty ratio, coefficients of both are statistically significant but signs are other than expected. They show that these two variables cannot be held as reasons for land degradation. The results of poverty ratio-land degradation link also corroborates the results of other studies (e.g. Reddy 2003), that poor are victims rather than a cause of land degradation.

A negative coefficient for yield negates the prevailing argument that more intensive application of inputs in search of better yield in the short run results in soil degradation. The coefficient indicates that efforts to bring in 1 % more yield can in

Table 15.11 Basic statistics for state level variables

Variable	Mean	Std. Dev.	Min	Max
Waste lands	3186	4242	1	15,887
Yield	2062	895	757	4280
GSDP	6112	2626	2496	12,905
Fertiliser subsidy	2584	2136	265	10,104
Density of Cultivators per unit of cultivated area	785	416	96	1850
Irrigated area (%)	51	23	20	98
Cropping intensity	152	39	111	267
Population density	27,831	18,395	5122	70,923
Rural Poverty ratio (%)	24	11	6	48
Rural Literacy rate (%)	63	7	44	77

Source The authors

Table 15.12 Estimates of random effect model

Explanatory variables	Coefficient	Z value
Yield	−0.8765*	−2.68
Fertiliser subsidy	2.937*	8.73
Population density	−3.5083*	−5.11
Sectoral GDP from agriculture per capita	0.5786	0.63
Density of cultivators	0.9026*	2.22
Cropping intensity	1.3688	1.56
% of irrigated area	0.9326	1.03
Poverty ratio	−0.4795	−1.16
Literacy rate	3.9741*	2.02
Dummy variables		
Northern	0.1914	0.28
Eastern	1.8706*	2.86
Western	−0.8709	−1.54
Constant	−6.7865	−0.69
Wald Chi^2	153.23*	
Observations	52	

Source The authors
Note The dependent variable is area affected by soil erosion. All the variables except dummies are expressed in logarithm. Hence the coefficients directly measure elasticities
*Indicates significance at 5 % level

fact reduce soil degradation by about 0.9 %. Inclusion of cropping intensity as a variable has helped in holding the intensity of application constant. Hence the other factors which help in increasing the yield, namely soil conservation measures, better irrigation system, etc. gives a negative coefficient for this variable. The number of cultivators per unit of cultivated area which is a measure of land scarcity, as expected, shows a positive relation. It indicates that a 1 % increase in this measure will lead to nearly 0.9 % increase in soil degradation. The rural literacy rate has given a wrong sign as the increase in literacy leads to increased degradation. However this measure is debatable since quality of education in rural areas varies substantially and is not accounted for in this simple measure of literacy. Variables such as Agriculture value added per capita, cropping intensity, percentage of irrigated area did not give statistically significant coefficients even though they all have their expected sign. The agricultural GDP per capita is an indicator for rural growth. Growth versus resource degradation literature debates on Environmental Kuznets curve (EKC) theory that in the phase of initial growth, more environmental harm will take place which will slowly decline along the growth path and once the threshold level is reached, further growth will be environmental friendly. Hence we can say that the income per capita is yet to reach the threshold level.

The coefficients of regional dummies indicate that, as compared to the southern region, the northern and eastern regions suffer from more degradation, holding everything else constant, and the western region is subject to less land degradation. The northern region allots a larger percentage of land to cereal crops due to which it is likely that over-application of fertilizer and water causes more degradation. Some parts of the eastern region receive a maximum quantum of rainfall. Hence the possibility of water induced soil erosion is higher in this region if the rainfall is not scattered across region or time.

The Household Plot Level Analysis

This section presents the analysis of drivers of land degradation on the household level as described in the methodology. Since soil erosion induced by water is unambiguously the major symptom of land degradation in India, as shown in Table 15.2, it is regarded as a suitable proxy for land degradation in a broader sense. Table 15.13 displays descriptive statistics of all the variables used in the analysis.

The main results are depicted in Table 15.14, first column. They show that the higher the frequency of application of organic manure, as well as chemical fertilizers, the lower the likelihood of soil erosion, given equal characteristics, where the effects are significant at 1 %. The use of pesticides, in contrast, is found to increase the occurrence of soil erosion. The number of different crops grown within the time span of the monthly survey also significantly ($p < 0.001$) drives the extent of soil erosion. The quality of drainage exposes a U-shaped influence on erosion, where a good drainage system fosters erosion and a mediocre one works against it, compared to bad quality drainage. Erosion is rather present on large fields, as shown by the positive significant coefficient of the plot area. Other variables that are negatively associated with erosion are the education dummies (relative to the category "illiterate") and the time of the household head devoted to work on the parcel. Interestingly, land property is positively associated with soil erosion, which might hint at a certain degree of insecurity in land tenure.

The second column of Table 15.14 displays results with state fixed effects, which account for some variation. While some variables display lower coefficients, the main explanatory variables, namely application of manure and fertilizer, respectively, remain significant in their explanatory power. The last two columns run a usual probit, where erosion is measured with two outcomes, "yes" or "no", regardless of the extent. The results are qualitatively similar, with the coefficients for use of manure and fertilizer still on a high level, while use of pesticides does not significantly explain erosion. The positive effect of organic manure application than the effect of fertilizer application is stronger in all four specifications. Thus, the application of manure seems to be more sustainable way in terms of land conservation compared to the utilization of chemical fertilizer or pesticides.

Table 15.13 Descriptive statistics of variables from CACP household survey

Variable	Observations	Mean	Std. Dev.	Min	Max
Erosion					
None	21,044	0.747	0.435		
Sheet erosion	21,044	0.187	0.390	0	1
Small gullies	21,044	0.057	0.232	0	1
Large gullies	21,044	0.009	0.093	0	1
Land use					
Crops	23,139	0.903	0.295	0	1
Fallows	23,139	0.015	0.123	0	1
Other	23,139	0.081	0.273		
Drainage					
Poor	22,263	0.192	0.394		
Middling	22,263	0.327	0.469	0	1
Good	22,263	0.481	0.500	0	1
Education					
Illiterate	22,409	0.196	0.397		
Up to primary	22,409	0.264	0.441	0	1
Up to secondary	22,409	0.279	0.449	0	1
Secondary	22,409	0.140	0.347	0	1
Post-secondary	22,409	0.121	0.326	0	1
Frequency of manure applied	19,891	0.688	1.261	0	32
Frequency of fertilizer applied	19,891	4.399	4.442	0	60
Frequency of pesticides applied	19,891	1.221	2.647	0	50
Total area	22,391	1.034	1.241	0	42
Time available to work	22,424	65.181	35.271	0	101
Female head	22,424	0.033	0.180	0	1
Plot irrigated	22,387	0.566	0.496	0	1
Land owned and managed	22,391	0.976	0.153	0	1
Household size	22,424	6.847	3.597	1	40
Age of household head	22,424	52.616	13.685	0	105
Livestock value (log)	23,129	7.901	3.806	0	12.60
Asset value (log)	23,139	10.059	2.113	0	15.26
Livestock present	23,139	0.182	0.386	0	1
# of crops grown	20,096	1.852	1.265	1	13
# of cropping seasons	20,096	1.583	0.680	1	4

Overall, it emerges that agricultural industry on a larger scale seems to drive land degradation. The larger the cultivated area, and the more crops are grown on it, the more a plot is affected by soil erosion. Sustainable land management practices help to work against this kind of degradation, such as feeding the soil with organic

Table 15.14 Estimation results from the ordered probit model

	(1) Ordered probit	(2) Ordered probit, state FE	(3) Ordinary probit	(4) Ordinary probit, state FE
# of times manure applied	−0.087***	−0.097***	−0.098***	−0.105***
	(−4.629)	(−4.648)	(−4.735)	(−4.495)
# of times fertilizer applied	−0.052***	−0.026***	−0.047***	−0.020*
	(−7.258)	(−3.433)	(−6.304)	(−2.564)
# of times pesticides applied	0.024*	0.016	0.028*	0.017
	(2.455)	(1.623)	(2.441)	(1.412)
Irrigation: plot irrigated	−0.09	−0.05	−0.076	−0.024
	(−1.807)	(−0.943)	(−1.408)	(−0.406)
Tenure: land owned and managed	0.338**	0.038	0.299*	−0.044
	(2.786)	(0.301)	(2.267)	(−0.297)
Land use: crops	0.083	−0.345	0.25	−0.27
	(0.217)	(−0.938)	(0.735)	(−0.801)
Land use: fallows	0.145	−0.235	0.431	0.009
	(0.315)	(−0.534)	(0.933)	(0.019)
Drainage: middling	0.154*	0.147*	0.146	0.154
	(2.230)	(1.968)	(1.886)	(1.768)
Drainage: good	−0.174**	−0.147*	−0.201**	−0.155
	(−2.729)	(−2.091)	(−2.792)	(−1.863)
Education: up to primary	−0.150**	−0.142*	−0.137*	−0.150*
	(−2.776)	(−2.502)	(−2.457)	(−2.514)
Education: up to secondary	−0.04	0.026	−0.027	0.027
	(−0.691)	(0.425)	(−0.428)	(0.420)
Education: secondary	−0.167*	−0.146	−0.154	−0.152
	(−2.276)	(−1.893)	(−1.958)	(−1.826)
Education: post-secondary	−0.154*	−0.115	−0.098	−0.081
	(−2.167)	(−1.518)	(−1.274)	(−1.000)
Total area	0.051***	0.012	0.046**	−0.002
	(3.452)	(0.739)	(2.882)	(−0.095)
Time available to work	−0.003***	−0.001	−0.003***	−0.001
	(−4.751)	(−1.922)	(−4.287)	(−1.467)
Female head	−0.098	−0.211	−0.144	−0.307*
	(−0.848)	(−1.731)	(−1.301)	(−2.497)
Household size	0.001	0.005	0.000	0.004
	(0.183)	(0.677)	(−0.054)	(0.498)
Age (head)	−0.002	−0.001	0.000	0.000
	(−1.044)	(−0.642)	(−0.289)	(0.029)
Livestock value	−0.062*	−0.027	−0.072*	−0.028
	(−2.201)	(−0.941)	(−2.336)	(−0.904)

(continued)

Table 15.14 (continued)

	(1)	(2)	(3)	(4)
	Ordered probit	Ordered probit, state FE	Ordinary probit	Ordinary probit, state FE
Asset value	0.036*	−0.002	0.044**	0.011
	(2.304)	(−0.122)	(2.624)	(0.584)
Livestock present	−0.549*	−0.269	−0.621*	−0.276
	(−2.049)	(−0.998)	(−2.113)	(−0.934)
# of crops grown	0.100***	0.075***	0.093***	0.086***
	(6.294)	(4.532)	(5.159)	(4.617)
# of cropping seasons	−0.041	−0.028	−0.033	−0.022
	(−1.138)	(−0.717)	(−0.830)	(−0.479)
Constant			−0.528	−0.248
			(−1.092)	(−0.430)
μ_1	0.345	−0.25		
	(0.700)	(−0.423)		
μ_2	1.289**	0.759		
	(2.614)	(1.277)		
μ_3	2.252***	1.746**		
	(4.540)	(2.949)		
State fixed effects	No	Yes	No	Yes
Observations	16,649	16,649	16,649	16,649
Pseudo R-squared	0.041	0.100	0.048	0.135

Source CACP, calculation by the authors
t-statistics shown in parentheses
*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$. Standard errors clustered on the village level

manure, or usage of a well-working drainage system, which prevents loss of water and increases water use efficiency. If livestock is held on a plot, this likewise seems to help the soil recover, possibly because the area is then cultivated less intensively. Some of the results' magnitude shrink considerably when controlling for state effects, which points at systematic differences in the surrounding conditions and agriculture practices across regions. For instance, land tenure exhibits no meaningful influence on soil erosion, once state fixed effects are included. This may hint at different legislations regarding land tenure security between states. No effect can be attributed to irrigation, which means that neither rainfed nor irrigated plots are stronger affected per se, and sustainable land management practices are expected to have a desired outcome in both.

Concluding Remarks

Understanding the major causes of land degradation is important for finding solution to mitigate the problem. Our analysis on drivers of land degradation shows that fertiliser subsidy and decreasing land-man ratio are important reasons for increasing land degradation. At the household level, the quality of the drainage system, as well as application of organic manure may significantly reduce soil erosion. A larger operated area, and a higher number of different crops grown, both increase degradation. This hints at sustainable land management practices reducing erosion.

While access to irrigation checks degradation, poor management of irrigation water itself contributes to degradation. Proper management of irrigation water will go a long way in controlling degradation. If wastage of water is tackled, it would help in reducing water logging and salinity problems. Judicious management of forests through the right kind of institutional mechanism would help in checking water and wind erosion, which forms a major share of total degradation.

Water and energy are underpriced which leads to inefficient use of land and water. However, energy pricing is a political pursuit in India. Unless the scarcity of the resource is reflected in pricing, overutilization of the resource continues to occur which in turn increases degradation. Agricultural extension services is another factor that needs to be strengthened for training the users of the land for the adoption of resource conserving technologies.

Creating awareness and ownership rights for cultivators are important steps in the challenge of mitigating land degradation. The solution lies in changing the behaviour of the farmer through the right set of institutional arrangements and market based instruments. Identifying all the stakeholders of land improvement, viz. farmers, farm labour, industries and institutions and how they are impacted by the policies related to the improvement would help in finding a comprehensive solution. This awaits further analysis.

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Annex

(See Tables A.1, A.2 and A.3).

Table A.1 Land use dynamics in India

Classification	Area in million hectares					
	1970–71	1980–81	1990–91	2000–01	2010–11	% Change from 1970–71 to 2010–11
Geographical area (reported)	303.76	304.15	304.86	305.12	305.9	
	(100)					
1. Forest	63.91	67.47	67.8	69.53	70	9.53
	(21.04)					
2. Not available for cultivation	44.64	39.62	40.48	41.48	43.56	−2.42
	(14.7)					
(a) Non Agricultural uses	16.48	19.66	21.09	23.86	26.51	60.86
	(5.43)					
(b) Barren and uncultivable land	28.16	19.66	19.39	17.6	17.05	−39.45
	(9.27)					
3. Other uncultivated land total	35.06	32.31	30.22	27.5	26.17	−25.36
(Excluding fallow land)	(11.54)					
(a) Permanent pastures and other grazing land	13.26	11.97	11.4	10.66	10.3	−22.32
	(4.37)					
(b) Land under Miscellaneous tree crops and groves not included in net area sown	4.3	3.6	3.82	3.46	3.21	−25.35
	(1.42)					
(c) Cultivable Waste land	17.5	16.74	15	13.63	12.66	−−27.66
	(5.76)					
4. Fallow land total	19.88	24.75	23.36	27.73	26.17	31.64
	(6.54)					
(a) Fallow land other than Current fallows	8.76	9.92	9.66	10.27	10.32	17.81
	(2.88)					
(b) Current Fallows	11.12	14.83	13.7	14.78	14.26	28.24
	(3.66)					
5. Net area sown (6–7)	140.27	140	143	141.34	141.58	0.93
	(46.18)					
6. Gross cropped area	165.79	172.63	185.74	185.34	198.97	20.01
	(54.58)					
7. Area sown more than once	25.52	32.63	42.74	44	57.39	124.88
	(8.4)					

Source Indiastat.com. *Note* Figures in the parentheses are percentages to geographical area

Table A.2 Policies/programs that have a bearing on Land Resource

Year	Programs/policies	Specific features
1977–78	Desert Development Program	Restoration of ecological balance by harnessing, conserving and developing natural resources
1980–81	Integrated watershed management in the catchment of flood-prone rivers	Enhance the productivity and tackle menace of floods
1985	National Land Use and Wasteland Development Council	Policy planning concerning the scientific management of the country's land resources development of wasteland
1985	National Land Use and Conservation Board	Formulate a national policy and perspective plan for conservation, management and development of land resources of the country Review of Progress of implementation of ongoing schemes and programs connected with conservation and development of land resources and soils
1985	National Wastelands Development Board	Formulate a perspective plan for the management and development of wastelands in the country Identify the waste land and assess the progress of programs and schemes for the development of wasteland Create a reliable data base and documentation centre for waste land development
1985–86	National Watershed Development Project for Rainfed Areas	Area approach to watershed development improve crop productivity Restore ecological balance
1985–86	Reclamation & development of Alkali & Acid soil	Reclamation of soil
1988	National Land Use Policy	To devise an effective administrative procedures for regulating land use To prevent further deterioration of land resources Restore the productivity of degraded lands Allocate land for different uses based on land capability, productivity and goals
1989–90	Integrated Wastelands Development Project	Adopt soil and moisture conservation measures such as terracing, bunding etc… To enhance people's participation in wasteland development programs
1992	Constitution (74th Amendment) Act, 1992	Regulation of land use and urban planning brought under the domain of urban self-governing bodies

(continued)

Table A.2 (continued)

Year	Programs/policies	Specific features
1992	Policy statement of Abatement of Pollution	Advocate use of mix of policy instruments in the form of legislation, regulation and fiscal incentives
1999	Department of Land Resources	Formulation of Integrated Land Resource Management Policies Implementation of land based development programs
2006	National Rainfed Area Authority	Sustainable and holistic development of rainfed areas

Source http://envfor.nic.in/

Table A.3 Land policy formulation through planning period

Plan period	Issues	Policy focus
First 1951–56	To increase area under cultivation	Land reform for efficient use of land and tenancy rights to cultivate land and abolition of intermediaries
Second 1956–61	Low productivity in dry land	Soil conservation, irrigation development, strengthen extension services
Third 1961–66	Food security, reclaiming cultiwable waste land and ways to tackle low growth regions to increase the growth	Intensive area development program, conducting soil surveys
Fourth 1969–74	Food security, ways to shifting land towards food crops, tackle allocation and technical inefficiency in production	Focus on soil and water conservation in dry regions, technological change, land ceiling Act, institutional changes
Fifth 1974–79	Irrigated land management, Drought-prone areas	Drought prone area and desert area development programs, focus on dry farming
Sixth 1980–85	Underutilisation of land resources	Land and water management programs
Seventh 1985–90	Soil erosion and land degradation, deforestation, degradation of forest land	Specific attention to soil and water conservation
Eighth 1992–97	Dryland and rainfed areas, importance of peoples participation in land management in villages recognised	Soil conservation integrated with watershed programs. Agroclimatic regional planning approach
Ninth 1997–2002	Faster rate of land degradation, revisit of Land reforms, tackling technical inefficiency, long term policy needed	Maintenance of village commons, Decentralised land management, Panchayat Raj institutions

(continued)

Table A.3 (continued)

Plan period	Issues	Policy focus
Tenth 2002–2007	Groundwater depletion and water logging	Rainwater harvesting, groundwater recharging measures and controlling groundwater exploitation, treatment of waterlogged areas
Eleventh 2007–2012	In addition to erosion, salinity and alkalinity, soils losing soil carbon and micronutrients due to irrational and unbalanced fertilizer use	Rationalise subsidies across nutrients, reform delivery method of subsidies, agriculture extension

Source Deshpande (2003) and five year plan documents

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