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The Energy and Resources Institute

ECONOMICS OF DESERTIFICATION, LAND DEGRADATION AND DROUGHT IN INDIA

Vol I: Macroeconomic assessment of the costs of land degradation in India

Prepared for

Ministry of Environment, Forest and Climate Change
New Delhi

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MINISTER OF ENVIRONMENT, FOREST & CLIMATE CHANGE

MESSAGE

Land degradation and desertification resulting from a range of issues such as forest degradation and loss, overgrazing, changes in land use, over-cultivation and increasing water stress, is a serious global concern that results in declines in ecosystem productivity and aggravates poverty. Yet land degradation is one of the most serious problems confronting humanity today, and as many as 1.5 billion people in all parts of the world are already directly negatively affected by land degradation. India itself faces several challenges relating to land degradation with 18% of the word population and 15% of its livestock supported by only 2.4% of the global land area. Pressures on agricultural land increase as croplands available per person decreased three fold to 0.12 ha per person since the 1960s.Land degradation now afflicts large expanses of land globally, and is expanding due to anthropogenic pressures, exacerbated by natural climate events. Despite the huge pressures on land and natural capital, there are also signs of many positive gains-for example between 2003/05 and 2011/13, satellite data suggest that areas under salinity and wind erosion in the country have been declining. Land production dynamics have also remained stable within the last 15 years.

Combating land degradation is vital to ensuring resilient livelihoods, in meeting the Sustainable Development Goals (SDGs), while equally playing a role in tackling challengessuch as climate change and loss of biodiversity.

India has shown a strong commitment to sustainable land management with a focus on combating land degradation and desertification. India recently brought out a desertification and land degradation atlas in which the Space Applications Centre, Ahmedabad along with partner institutes carried out an inventory of desertification and land degradation in the country for the period 2003-05 to 2011-13. Regular updated information on the physical extent of land degradation in the country is required in order to track the country's progress towards mitigating desertification and land degradation. Moreover, India is committed to achieving Land Degradation Neutrality by 2030, and has introduced innovative measures such as the Soil Health Card Scheme to help farmers improve productivity through judicious use of inputs, and the provision of LPG connections through the PradhanMantriUjjwalaYojana.

I congratulate the Ministry of Environment, Forest and Climate Change for commissioning a study on the costs of land degradation in India. I wish to thankTERI for their valuable contributions in assessing the scale of land degradation in the country along with the economic inputs, and for assessing the quantum of investment required for undertaking preventive and restorative measures which can help achieve the aspirational goal of land degradation neutral India by 2030. The Economics of Desertification, Land Degradation and Drouht (EDLDD) study report highlights the significant costs imposed by land degradation (82% of total costs) as compared with land use change (18% of total costs) and makes a strong case for reducing land degradation.I am certain that thesalient findings will be extremely useful to India's reporting to UNCCD and for those working on issues pertaining to land degradation in the country.

Date:19.04.2018

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MINISTRY OF ENVIRONMENT, FOREST AND CLIMATE CHANGE

MESSAGE

Desertification, along with climate change and the loss of biodiversity were identified as the greatest challenges to sustainable development during the 1992 Rio Earth Summit. Owing to its saliency therefore, land degradation features prominently in the Sustainable Development Goals (SDGs) under Goal 15 (protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, ***combat desertification, and halt and reverse land degradation*** and halt biodiversity loss) and specifically target 15.3 (***by 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world***). Addressing issues relating to land degradation and desertification is pivotal not only for enhancing human well-being and ensuring food security, but also because degradation of land is closely allied to other global concerns including climate change and biodiversity loss. Consequently, addressing land degradation both strategically and holistically can simultaneously facilitate the achievement of multiple SDGs such as food security, reduce poverty and enhance livelihoods, conserve biodiversity and lead to climate action.

The key to achieving this is sustainable management and restoration of land coupled with conservation that focuses on land and soil, water and biodiversity. India is at the forefront of efforts to reduce land degradation and ensure the sustainable management of land resources and over the years has initiated several programmes and schemes to address this issue. Although a huge challenge, addressing land issues is critical in India given that almost half of the population derive their income from farm related and allied activities. India is also working towards achieving land degradation neutrality which requires integrated land use planning and close coordination between the Ministry of Environment, Forest and Climate Change and line Ministries. The goal of the current Government is reducing poverty and facilitating livelihoods; addressing land degradation closely ties in with achieving this.

I am happy that the Ministry of Environment, Forest and Climate Change commissioned a study to understand the costs of land degradation and to determine the amount of investment required for undertaking preventive and restorative measures. I congratulate TERI on bringing out a detailed report that addresses issues relating to land degradation and desertification in India and which makes a strong economic argument for addressing these concerns. I hope that the results and recommendations act as a framework for guiding action towards mitigating land degradation.

(C.K. Mishra)

Place: New Delhi
Dated: 19th April, 2018

FOREWORD

Degradation of dry lands is one of the most serious environmental problems confronting contemporary Indian society. Degraded dry lands have far reaching consequences- decreased food security, exacerbated environmental degradation, enhanced migration and slowed poverty reduction. Although land degradation results in loss of both ecosystem services and livelihood opportunities, thereby imposing huge costs on society, there have been few studies, especially in India, that comprehensively assess the cost of such impacts.

The Energy and Resources Institute (TERI) takes pride in presenting this report, commissioned by the Ministry of Environment, Forests and Climate Change, Government of India. The report carries out a macroeconomic analysis of some of these costs of land degradation in India. In India, the task is made more complex due to the close linkages between land degradation and vulnerability of livelihoods. Most existing efforts at assessing the economic cost of land degradation in the country have been limited to the loss of provisioning services in the case of agriculture, though recent work has also looked at the provisioning, regulating and supporting (both direct and indirect) services provided by forests. In this study, we cover two major aspects of land degradation- first, the cost of land degradation related to a given land use (e.g. loss of agricultural production or decrease in forest quality) and second, the cost that arises when land moves from a more to a less productive use.

The macro-economic study provides a broad-brush assessment of the costs of land degradation and desertification in India. This is supplemented by case studies which estimate the costs of degradation, and conversely, the benefits of measures to reduce degradation, and provide a more nuanced approach to the issue thus enhancing understanding of the physical, social and economic factors that influence the problem at local level. The case studies carried out in Gujarat, Uttarakhand, Madhya Pradesh, Andhra Pradesh, Uttar Pradesh and Rajasthan, therefore, also individually address the main causes of land degradation and desertification in the drylands of India. These case studies, involving a survey of more than 1000 households across these States, encompass major land degradation causal mechanisms, e.g. salinity, water erosion, vegetal degradation, sodicity, waterlogged saline soils and wind erosion. In addition, these case studies also encompass most ecosystems including rangelands, forests and agricultural lands, as well as issues such as the role of biological invasions in exacerbating land degradation.

The major message to emerge from this report is that it makes strong business and economic sense to mitigate land degradation. This TERI study very conservatively appraises the costs of land degradation at 48.8 billion USD, or 2.5% of India's GDP in 2014/15, and about 15.9% of the GVA from the agriculture, forestry and fishing sectors. Stepping up the reclamation of degraded lands makes business sense for India. Our estimates suggest that the annual costs of degradation exceed the total costs of reclamation projected for 2030. Therefore it costs far less to reclaim land than it does to degrade it!

I am confident that the report will serve as a primary resource for policy makers and researchers, and will spur action to mitigate land degradation and put India on the path to land degradation neutrality.

Dr Ajay Mathur
Director General, The Energy and Resources Institute (TERI)

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EXECUTIVE SUMMARY OF VOLUME-I

Land is a vital resource for producing food, preserving forests and biodiversity, facilitating the natural management of water systems and acting as a carbon store. Appropriate land management can protect and maximize these services for society. Conversely, desertification, along with climate change and the loss of biodiversity were identified as the greatest challenges to sustainable development during the 1992 Rio Earth Summit. The United Nations Convention to Combat Desertification (UNCCD) is one of 3 Rio Conventions which focuses upon Desertification, Land Degradation and Drought (DLDD).

In this study, we determine the costs of land degradation for the country. In addition, six case studies from the dry lands that encompass a range of land degradation causal processes and ecosystems have been carried out for the States of Gujarat, Uttarakhand, Madhya Pradesh, Andhra Pradesh, Uttar Pradesh and Rajasthan to determine the costs of degradation or the foregone benefits of those who are not benefitted by interventions to reduce land degradation-e.g. farmers lacking flap gates and sub-surface drainage to reduce salinity in the coastal rice fields of Andhra Pradesh. This report is divided into two volumes. The first volume introduces the problem and includes a literature review of DLDD in India and analyses the economic approaches used globally to estimate the costs of DLDD. This is followed by a macro-economic assessment of the costs of degradation for the country and an assessment of the costs of reclamation in 2030. Volume 2 discusses and summarises the results of the individual case studies. Here we highlight the results of the macro-economic study.

This study aims to carry out an economic analysis of some of these costs of land degradation in India. In India, the task is made more complex due to the close linkages between land degradation and livelihoods. Most existing efforts at assessing the economic cost of land degradation in the country have been limited to the loss of provisioning services in the case of agriculture though some more recent work has looked at provisioning, regulating and supporting (both direct and indirect) services in the case of forests. It is important to look beyond those directly affected by land degradation - a recent global study attempted to value land degradation using the TEV approach and found that only about 46% of the global cost of land degradation due to LUCC (land use/cover change) is borne by land users while the remaining 54% is borne by consumers of ecosystem services off the farm (Nkonya et al 2016).[1]

We make an attempt in this study to take a wider perspective of land degradation. We cover two major aspects of land degradation- first, the cost of land degradation on a given land use, and second, the cost that arises when land moves from a more to a less productive (as measured by the Total Economic Value or TEV) use. In the first category, we look at losses within agriculture, forestry and rangelands, the sectors where arguably the costs of land degradation are felt the most. In the second category, we look at change within the official nine-category land use classification followed in India, as well as wetlands. The resulting costs of degradation are included in the Table below.

[1] Due to the limited number of available TEV values for different land uses in different eco systems, the study relied heavily on "transferring" the results from micro studies to national and regional and even to a global scale. This is meant not as a critique of the study but to highlight the severe limitations in assessing the costs of land degradation at any appreciable level of aggregation.

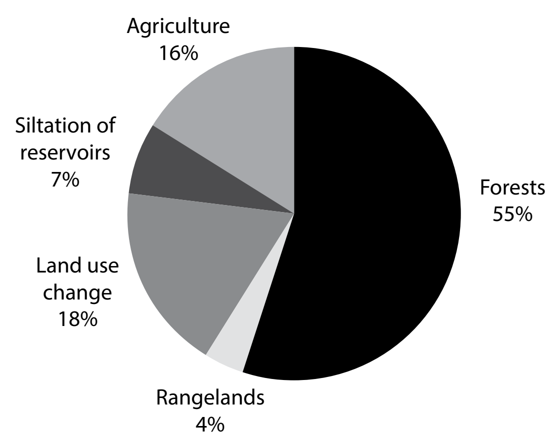
Costs of land degradation and land use change

	Category	Economic cost		
		Annual economic costs of degradation (Value in Rs million in 2014/15 prices)	**% of gross value added from agriculture and forestry (2014/15)**	**% of GDP (2014/15)**
	Loss in agricultural production due to:			
1a	Water erosion			
	Onsite losses in rain-fed agriculture	208496	1.04	0.17
	Offsite losses	228585	1.15	0.18
1b	Sodic soils	162809	0.82	0.13
1c	Saline soils	86753	0.43	0.07
1d	Wind erosion	36675	0.18	0.03
1 (1a + 1b + 1c + 1d)	Total agricultural loss	723319	3.63	0.58
2	Loss due to degradation of rangelands	120245	0.60	0.10
3	Loss due to forest degradation	1758574	8.81	1.41
4 (1 + 2 + 3)	Total due to land degradation	2602138	13.04	2.08
5	Loss due to land use/cover change	575252	2.88	0.46
6 (4 + 5)	**Total cost of land degradation and land use change**	**3177390**	**15.92**	**2.54**

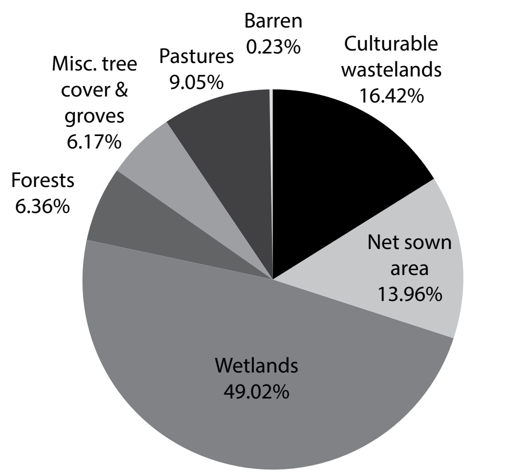
This cost is estimated at 2.5% of India's GDP in 2014/15 and about 15.9% of the GVA from the agriculture, forestry and fishing sectors. Almost 82% of the estimated cost is on account of land degradation and only 18% due to land use change (see Figure below). This result suggests that while loss of productive land for forests, wetlands, rangelands and other ecosystems is a concern, a larger concern is the degradation of existing ecosystems.

This is a serious concern particularly given that India aims to be land degradation-neutral in 2030, where any increases in land degradation are balanced by equivalent gains in land reclamation to ensure no additional net loss of land-based natural capital.

Also it can be seen that the distribution of the economic burden of losses due to different types of land degradation is different from the distribution of the physical extent of degradation itself. For instance, according to recent SAC (2016) figures, water erosion accounts for 37.4% of the total area affected by degradation, followed by vegetation degradation (30.4%), wind erosion (18.9%) and salinity (3.8%). However, ***in terms of the cost of land***



Distribution of the total costs of land degradation in India

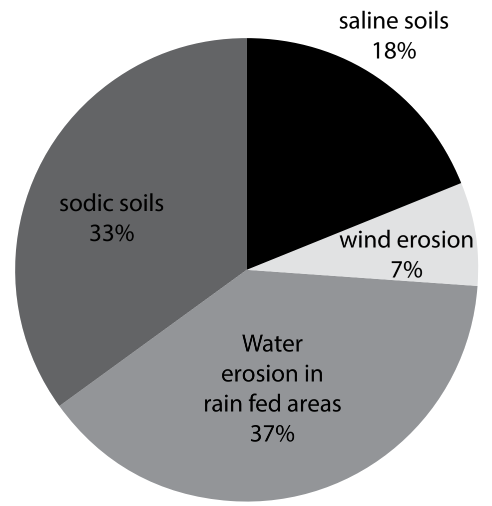


Costs of land use change: distribution by category

degradation and use change, the economic cost of forests degradation accounts for over 55% of the total, although in physical terms it ranks second in its contribution to India's degraded land area. This is on account of the higher cost per hectare of vegetal or forest degradation. ***In contrast, onsite and offsite losses due to water erosion account for about 14% of the total economic cost.***

The figure below gives the costs of land use change by category. The largest value is accounted for by wetlands followed by culturable wastelands, followed by pastures and forests. These losses are partly compensated by a gain in the value of land due to the increase in land area under fallow lands (not shown in the Figure).

Production losses due to agriculture alone are close to 4% of Gross Value Added (GVA) from the agriculture sector in 2014/15 at a very conservative level (See Fig. below) These are conservative figures since the losses have not been estimated for all crops (e.g. cash crops are not included in estimates of soil erosion), regions (e.g. water erosion has been estimated only for rain-fed agriculture), or degradation (e.g. losses due to water logging are not included). Given the scope of this exercise, we find that water erosion in rain-fed areas accounts for the majority share (37%), followed by losses due to sodic soils (33%), saline soils (18%) and wind erosion (7%).



Cost of productivity losses in agriculture: distribution by type of land degradation

Excluding wind erosion, which is concentrated in Rajasthan we find that Gujarat suffers the highest losses on account of land degradation (about 26% of the value of national losses) largely due to losses on account of alkalinity and salinity – it makes up for 34% and 61% of total agricultural losses in the country due to these two factors, while accounting for less than 5% of the losses due to water erosion. This is followed by Uttar Pradesh, which accounts for about 22% of the national losses due to agriculture, mostly because of alkalinity. The other states that have a high share of the value of all Indian crop loss due to degradation are Madhya Pradesh (about 8%), Karnataka and Maharashtra (7% each), and Andhra Pradesh (6%). Rajasthan accounts for about 3% of the losses due to water erosion in rain fed agriculture, salinity and alkalinity but all of the losses due to wind erosion included in this study are borne by the State.

Apart from providing an estimate of the costs of land degradation and land reclamation in the country, our study also flags some important issues. From a policy perspective, the study underscores the gravity of degradation as compared to land use change. Degradation accounts for 81.9% of the total costs of land use change and land degradation. The results underline the costs of forest loss and degradation to the economy, although this may be partly because of the high TEV values for forests in comparison with croplands. ***Overall, forest degradation accounts for 40% of the costs of land degradation in the country and forest loss and forest degradation together account for 56.6% of the total costs of land degradation and land use change in the country***. Therefore, any strategy to ensure that India becomes land degradation-neutral by 2030 must address the critical issue of reducing forest dependence for fuelwood, fodder and non-timber forest products.

Projections of land area that is likely to be degraded in 2030 under two different scenarios are estimated at 94.53 mha and 106.15 mha, respectively. In scenario 1, which is based on the reported estimates for 2003 and 2011 (SAC, 2016), the trend indicates a decrease in area affected by wind erosion and salinity, while area affected by water erosion, water logging and under open forests increase over time. In scenario 2, three distinct time points (1995, 2003 and 2011) with a gap of 8 years between each time point were considered for future projections. In scenario 2, degraded land that is saline and waterlogged is projected to decrease in the future. However, both wind and water erosion, two dominant causes of land degradation, in addition to the area under open forests are projected to increase.

That area affected by water erosion is projected to rise in both scenarios, suggests that India will need to strengthen her reclamation efforts in this area. In both scenarios considered, the area affected by salinity shows a decline, suggesting successful reclamation efforts.

Wind erosion and water logging show conflicting trends in the two scenarios. This difference is accounted for by the use of additional time series data in scenario 2. The addition of a mere data point alters the entire trend of land degradation. This underscores the need to maintain accurate and consistent, longitudinal data to clarify the trends in land degradation in India. Without this, it is hard to assess the efficacy of on-going reclamation programmes, or to give successful policy prescriptions. Wind erosion is the third largest contributor to land degradation in India, but is either increasing or decreasing depending on the data used.

The overall observed and projected increase in land degradation in both scenarios clearly suggests that India needs to scale up reclamation efforts. This makes economic sense, since the ***annual*** costs of land degradation (Rs 3177 billion), outstrip the ***total*** costs of reclamation in 2030 (Rs. 2948 billion in scenario 1 and Rs 3175 billion in scenario 2). If we take 2003, as the baseline year for setting the LDN target, our projections suggest that physical estimates of land degradation in the country outstrip this target in 2011 itself and keep increasing in 2030. To counter this, reclamation efforts will need to be scaled up, particularly for water erosion (in both scenarios), for wind erosion (in scenario 2) and for forests (in both scenarios).

Several definitional and measurement issues must also be addressed to get an accurate picture of the actual costs of land degradation in the country and prevent land mismanagement. Because of a lack of consensus of what constitutes a wasteland or the difference between degraded lands[2] and wastelands, estimates of land degradation for the country vary widely. For example, the Wasteland Atlas, the Atlas of Degraded Areas (ICAR-NAAS, 2010) and the recent Desertification and Land Degradation Atlas (SAC, 2016), provide different estimates due to definitional and other issues. This makes an effective assessment of the extent of land degradation or the costs of reclamation in the country imprecise and open to interpretation. Importantly, this also has policy implications since it fosters inappropriate land use and conversion to other land uses that might exacerbate land degradation. Greater clarity and convergence between agencies in reporting of land-use figures in India will contribute to effective governance of natural resources commensurate with their value, and promote rational policy and decision making.

[2] "land degradation refers to a, "reduction or loss of biological or economic productivity and complexity of rain-fed cropland, irrigated cropland or range, pasture, forests, & woodlands resulting from land use or from a process or combination of processes arising from human activities & habitation patterns."

CHAPTER 1

INTRODUCTION

What of thee I dig out
Let that quickly grow over
Let me not hit thy vitals
Or thy heart
— Atharva Veda 1000 BC

Land is a vital resource for producing food, preserving forests and biodiversity, facilitating the natural management of water systems and acting as a carbon store. Appropriate land management can protect and maximize these services for society. Conversely, desertification, along with climate change and the loss of biodiversity were identified as the greatest challenges to sustainable development during the 1992 Rio Earth Summit. The United Nations Convention to Combat Desertification (UNCCD) is one of 3 Rio Conventions which focuses upon Desertification, Land Degradation and Drought (DLDD). The Convention addresses specifically the issue of land degradation in arid, semi-arid and dry sub-humid areas of dry lands which are home to some of the most vulnerable people and ecosystems in the world.

Dry lands where land degradation is referred to as desertification are considered especially vulnerable to degradation (Adeel et al., 2005). The United Nations Convention to Combat Desertification (UNCCD) defines dry lands to include arid, semi-arid and dry-sub humid areas (other than polar and sub-polar regions) areas, which together cover approximately 34.9 percent of the Earth's terrestrial surface and are home to about 34% of the world population (Safriel and Adeel, 2005)[3]- see Figure 1. About 72% of the global dry land area occurs within developing countries, the proportion increasing with aridity and reaching almost 100% for hyper-arid areas. Consequently, the majority of dry land peoples (87% to 93%, depending on how the former Soviet Union countries are categorized) live in developing countries (Safriel and Adeel, 2005). Rangelands and croplands jointly account for 90% of dry land areas globally and are often interwoven, supporting an integrated agro-pastoral livelihood (Safriel and Adeel, 2005).[4]

Degradation of dry lands is recognized as one of the most serious historic and contemporary environmental problems confronting society. UNCCD defines land degradation as a "*reduction or loss, in arid, semi-arid, and dry sub-humid areas, of the biological or economic productivity and complexity of rain-fed cropland, irrigated cropland, or range, pasture, forest, and woodlands resulting from land uses or from a process or combination of processes, including processes arising from human activities and habitation patterns, such as: (i) soil erosion caused by wind and/or water; (ii) deterioration of the physical, chemical, and biological or economic properties of soil; and (iii) long-term loss of natural vegetation*". Land degradation is caused by "complex interactions of physical, biological, political,

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[3] The UNCCD defines dry lands in terms of the Aridity Index (AI) which is the ratio of average annual precipitation and the potential evapo-transpiration. Areas with $0.05 < AI < 0.65$ are included under dry lands. Within these, areas with $0.05 < AI < 0.2$ are classified as arid, areas with $0.2 < AI < 0.5$ as semi-arid, and areas with $0.5 < AI < 0.65$ as dry sub-humid (UNCCD undated). The UNCCD classification of dry lands excludes hyperarid regions ($AI < 0.05$) , which represent approximately 6.6 percent of the Earth's land surface. Several definition of dry lands, including that adopted by the Convention on Bio-diversity, includes hyperarid regions (Sorensen 2007), taking the extent of drylands to 41.5 % of the world's terrestrial area and the affected population to 35.5% of the world population (Safriel and Adeel, 2005)

[4] These figures include the hyper arid regions

social, cultural and economic factors," according to the preamble of the Convention. But four human activities are considered the most immediate causes: over-cultivation, over-grazing, deforestation and poorly drained irrigation.

There are conflicting assessments on the extent of the land degradation, ranging from 15% to 63% of global land and 4% to 74% of its subset of global dry lands (Safriel, 2007). Recent estimates suggest that up to 25% of land is highly degraded, 36% is slightly or moderately degraded but stable and 10% is increasing (FAO, 2011 as cited in UNCCD, 2017). Vegetation productivity globally has declined consistently between 1981 and 2003 (Bai et al., 2008 as cited in UNCCD, 2017).

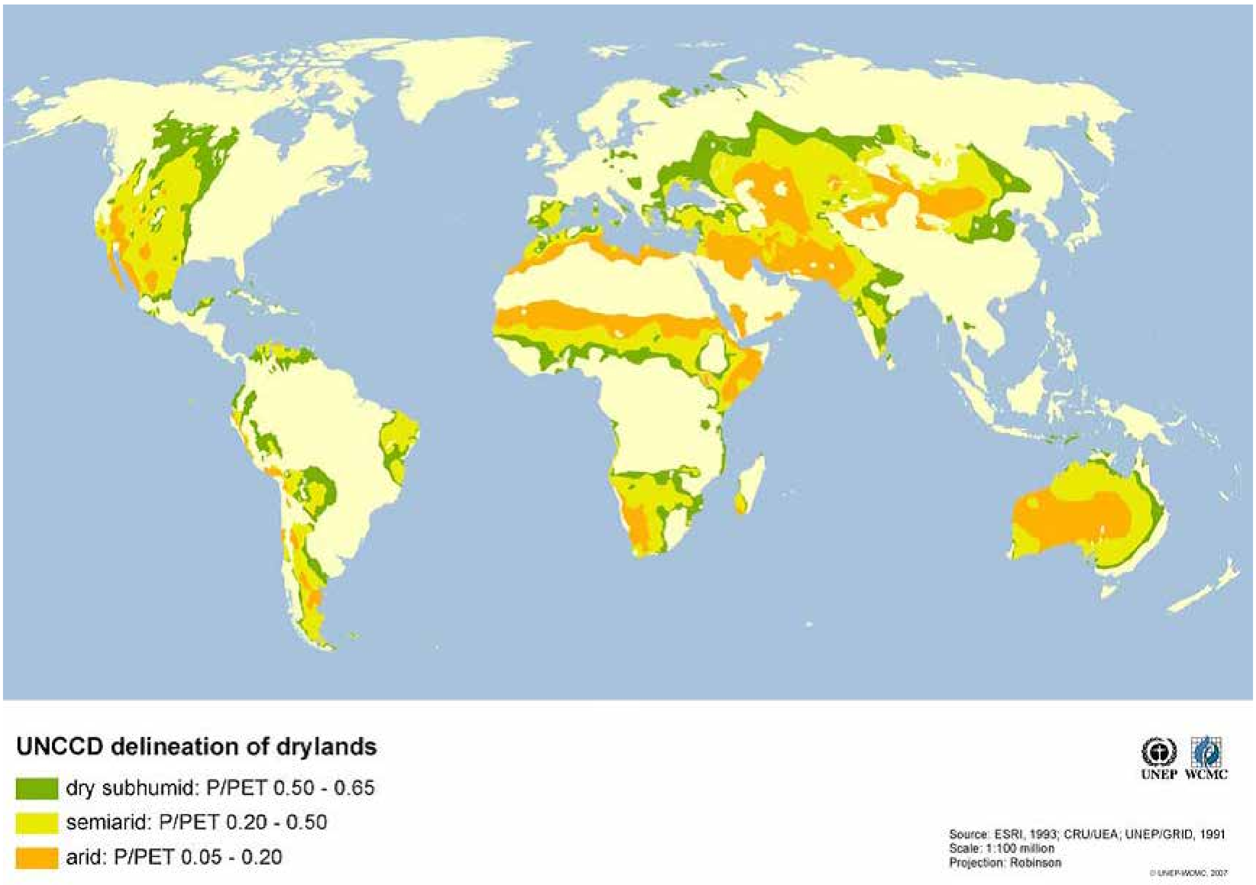

Figure 1.1 UNCCD delineation of drylands

Source: Sorensen (2007)

The resulting loss of services from land degradation, including that of food provision, is not just a concern in itself but can in turn unleash a vicious circle of environmental degradation, impoverishment, migration and conflicts, often also putting the political stability of the affected countries and regions at risk. Scientific studies indicate that around 12 million hectares of land are transformed into new man-made deserts every year (UNCCD, 2011) and that one quarter of the world's agricultural land is highly degraded (FAO, 2011). The regional distribution of drylands is provided in Fig 1.2 The underlying biophysical and anthropogenic causes of land degradation are multiple and overlapping. Drylands suffer from extreme variability in precipitation, water stress, high evapotranspiration brought on by high air temperatures and low humidity, as well as low soil fertility due to low deposition and decomposition of organic matter (UNEP, 2012; FAO, 2008). This predisposition of drylands to degradation is further influenced by human-induced environmental changes and pressures, and the complex nature of these interactions. Overgrazing by livestock, deforestation and degradation, water stress, land use change including widespread conversion of forests and rangelands to croplands, are all significantly impacting productivity in the innately vulnerable ecosystems of drylands.

The causes of desertification, in general, may be clubbed into proximal and distal reasons. The proximal are biophysical in terms of the vulnerability of soils due to topography and climatic factors such as temperature, rainfall and wind, but also due to unsustainable land management practices. The distal reasons which precipitate or exacerbate land degradation are far more systemic including weak institutions and poor governance, policy and market failures, demographic and socio-economic factors as well as the impacts of globalization.

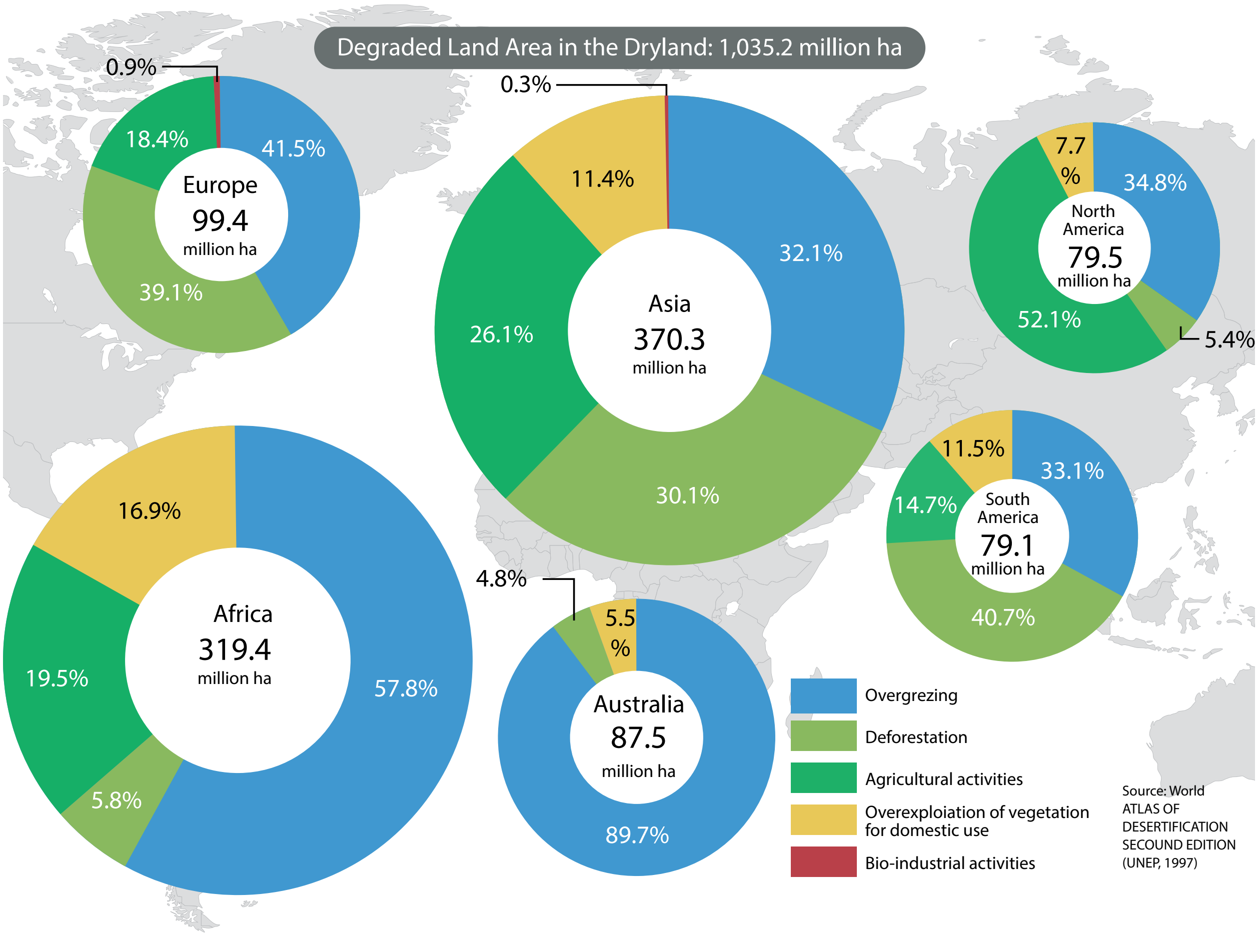

Figure 1.2 Regional distribution of drylands

Source: UNEP, 1997

Owing to its saliency, land degradation features prominently in the Sustainable Development Goals (SDGs) under Goal 15 (protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss)[5] and specifically target 15.3 (by 2030, combat desertification**,** restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world) and the important indicator of progress towards these targets, namely, the "proportion of land that is degraded over total land area." UNCCD (2017) defines Land Degradation Neutrality (LDN), as, "a state whereby the amount and quality of land resources necessary to support ecosystem functions and services and enhance food security, remain stable or increase within specified temporal and spatial scales and ecosystems." This definition emphasizes the importance of ecosystem services, and the need

[5] SDG 2 (end hunger, achieve food security and improved nutrition and promote sustainable agriculture), and SDG 5 (achieve gender equality and empower all women and girls) are also relevant. The Millennium Development Goals also addressed land degradation, although more indirectly through MDG 1 (eradicate extreme poverty and hunger) and MDG 7 (ensuring environmental sustainability). Other MDGs were also relevant: MDG 3 (Promote gender equality and empower women) because rural women bear a large responsibility for cultivating crops, raising livestock, and collecting water and firewood in developing countries, all of which are linked to the sustainability of land; MDG 8 (Develop a Global Partnership for Development) because some of the least developed countries suffer from the worst LDD and stand to gain from international cooperation on the issue.

to maintain or enhance the "stock of natural capital associated with land resources and the ecosystem services that flow from them."

The status of land degradation and desertification in India has been assessed by several organizations, providing a range of disparate estimates. As per a 2016 study carried out by Space Applications Centre, India has a total geographic area (TGA) of 328.72 million ha, out of which the total area undergoing the process of land degradation is estimated at 96.4 million hectares, which constitutes 29.32 percentage of India's total land area. There has been an increase of 1.87mha undergoing land degradation/desertification between 2011-13 and 2003-05. During this period 1.95mha has been reclaimed and 0.44 mha converted from high severity to low severity. At the same time, 3.63 mha of productive land has degraded and 0.74 mha has shifted from low to high severity degradation status. During this period, the states showing increases in degradation are Delhi, Tripura, Nagaland, Himachal Pradesh and Mizoram (11.03-4.34%) whereas Odisha, Rajasthan, Telengana, and Uttar Pradesh have improved their degradation status (-0.11 to -1.27%).

The dry lands in India according to SAC (2007) comprise of arid areas covering 50.8 million hectares (15.8 %), semi-arid areas covering 123.4 million hectares (37.6 %) and dry sub-humid areas covering 54.1 million hectares (16.5 %). In these drylands, the area undergoing desertification is 82.64 million ha, while in 2003-05 it was 81.48 m ha. This suggests an increase of 1.16 mha area under desertification of which the most significant process in the arid region is wind erosion, while vegetation degradation and water erosion are the primary causes in semi-arid and dry sub-humid regions (SAC, 2016). In arid regions, 30.54 mha are undergoing desertification increasing to 35.4 mha in the semi-arid region and dropping to 16.7mha in the dry sub-humid parts of India (SAC, 2016).

Overall 19 classes of degradation have been identified which describe degradation emerging from (i) water erosion, (ii) chemical degradation including acid soils as well as salt affected soils, (iii) wind erosion and also (iv) physical degradation comprising of areas characterized with mining and industrial waste or waterlogging (ICAR and NAAS, 2010). Differential usage of spatial methods, definitions of land use and causal processes and coverage of issues under land degradation have produced very different figures of land degradation over the years from 94.53 mha in 2003-05 (SAC, 2016), to 120 mha (ICAR and NAAS, 2010) to 105 mha (SAC, 2007), and more recently 96.4 mha (SAC, 2016). By and large, however, while India has almost 70% of its area in the dry lands, the area under desertification is about a quarter of the land mass, while land degradation covers about a third of the land area (SAC, 2016).

India is in the process of aligning its New National Action Programme to Combat Desertification (NNAP-CD) with the UNCCD 10 Year Strategy. The NNAP-CD will strive toward achieving the aspirational goal of land degradation neutral India by 2030. An inter-ministerial effort, this will help mainstream DLDD issues in the national development priorities and be incorporated in relevant sectoral planning, budgeting and implementation frameworks. A major constraint in balancing trade-offs between competing land uses and designing interventions to combat DLDD is the lack of adequate understanding of the economics of desertification, or of land degradation in general. To address this lacuna, the Ministry of Environment, Forests and Climate Change has engaged TERI to undertake a study on the economics of land degradation with the following terms of reference.

1.1 Terms of Reference

1. Examine economic valuation studies and data available from secondary literature and published sources.
2. Review Government's programmes and schemes relating to DLDD issues, targets, financial allocations and achievements.
3. Select 6 case study sites for micro-economic assessment in arid, semi-arid and dry sub-humid regions of the country, identify the data requirements, and sources of information.
4. A macro-economic assessment for the entire country and scenario development (till 2030).

5. A micro-economic assessment for 6 case study sites for full economic assessment and scenario development (till 2030).

We divide the report into 2 volumes. Volume I encompasses the introduction, a literature review, and concludes with a detailed macroeconomic review for the country, followed by recommendations. Volume II incorporates a micro-economic assessment of six case studies spanning six states in India. Volume II discusses the approach adopted in identifying causal processes, states, districts and sites to assess land degradation, desertification and drought in the country. This is followed by a micro-economic assessment of the six case study sites in India.

CHAPTER 2

Assessing the Economic Cost of Desertification, Land Degradation and Drought: A review

2.1 Introduction

Desertification, Land Degradation and Drought (DLDD) adversely affects a wide range of products and services that land provides and results in declines in economic returns from land. The loss due to these declining returns from land degradation imposes a cost on the land owners/users as well as on society as a whole. The economic impacts of desertification can be divided into three main categories: direct impacts, which affect the land users; indirect impacts, which could affect people far away from where the degradation occurs; and economy-wide impacts, which arise due to complex links across economic sectors and the resulting "multiplier effect" (Low, 2013). These impacts could be on-site or off-site with some impacts being non-visible or difficult to quantify. The direct, indirect and multiplier effects of desertification can widely affect poverty and national income (Low, 2013). The impact on the agricultural market (or any sector that depends directly on terrestrial ecosystem services and benefits) also has intersectoral, economy wide "multiplier" effects. For example, Diao and Sarpong (2007) predict that land degradation could lead to 5.4% increase in the poverty rate in 2015 compared to the case of no soil loss.

The first estimate of the global direct cost of desertification was $26 billion per annum, made by UNEP in 1980, shortly after the UN Plan of Action to Combat Desertification was agreed to at the UN Conference on Desertification (UNCOD) in 1977. It was based on reports (including by Dregne 1983) of yield declines on lands with differing degrees of severity of desertification.[6] Estimates of the direct costs of national land degradation as a proportion of national income have also been made for single countries, with many studies referring to conditions in the 1980s (Table 2.1). The estimates cover a wide range. The US estimate, for example, was $27 billion in monetary terms, which slightly exceeded UNEP's (1980) estimate for the global direct cost of desertification. When expressed as percentages of Agricultural Gross Domestic Product (AGDP) the direct costs range from 2% of AGDP for Ethiopia and 4% of AGDP for India, to as much as 20% of AGDP for both Burkina Faso and the USA and 2-30% for Mali. However, there is need for some caution since such estimates are "often more illustrative than definitive, due to the paucity of empirical data and measurement problems" and due to "serious methodological difficulties (Low, 2013)."

Table 2.1 Estimates of national direct costs of land degradation in the 1980s as a proportion of Gross Domestic Product (GDP)

Country	Per cent GDP	Per cent Agricultural GDP	Reference
Burkina Faso	9	20	Lallement (1989)*
Ethiopia	-	9	Bojö and Castells (1995), based on Hurni (1988)*

[6] The two main methods used to estimate the costs of land degradation are the replacement cost method and the loss of production. The replacement cost method estimates the amount of soil nutrients lost each year by soil erosion in terms of the cost of replenishing nutrients artificially. and the cost of buying fertilizers to replace these nutrients. The loss of production method converts the loss of soil into a reduction in crop production.

Country	Per cent GDP	Per cent Agricultural GDP	Reference
India	2	4	Reddy (2003)*
Mali	0.9-12.5	2-30	Bishop and Allen (1990)*
USA	0.4	20	Pimentel *et al.* (1995)*
China		2.7	Liu (2006)
China		1.4%	Zhang *et al* (1996)
Latin American countries		8- 14	Morales *et al.*, 2011

***As compiled in Low (2013)**

Estimates of the offsite costs of land degradation are less common than those of direct costs. One of the most commonly studied offsite costs is the siltation of rivers, reservoirs and irrigation canals which reduce their effectiveness and increases the probability of flooding. For instance, Hansen and Hellerstein (2007) found that lower soil erosion level in the USA in 1997, relative to 1982, had resulted in the conservation of $154 million worth of reservoir benefits. The analysis of the cost of DLDD and the benefits of the control measures is important for investment decisions of the land owner/user and government on measures to control degradation or sustainable land management.

2.2 Economic valuation studies

The economic impacts of DLDD have been documented by several studies, and costs of such impacts are assessed at different levels-local, national and global. Low (2013) and Nkonya (2011) presented a comprehensive review of studies assessing the cost of DLDD in different countries or regions across the globe. Loss of crop yield or land productivity, one of the direct onsite impacts, has been the most studied impact in terms of assessment of cost. Land ecosystems provide a range of services like regulation of water supplies, maintaining water quality and flow, flood control, nutrient recycling, pollination, genetic resources, flood control, carbon storage and recreational activities. Although land degradation results in loss of these services as well as have several other onsite and off-site impacts, there have been few studies that comprehensively assess the cost of such impacts. Adhikari and Nadela (2011) opined that most literature estimated the cost of soil erosion[7] which only partially accounts for the cost of land degradation. There are also several studies assessing the benefits of land degradation control measures or sustainable land management practices. See Box 2 for a description of some of these studies and their citations.

The initial work analysing costs of land degradation (e.g. Burt, 1981 and McConnel, 1983) used optimal control models that aimed at maximizing net present value of agricultural output to estimate the optimal rate of land degradation. Although these models have several advantages in explaining land degradation or conservation decisions at farm level, they are very data intensive and involve complex estimation procedures. Hence in subsequent years the cost-benefit approach has emerged as a popular tool for comparing land degrading and land conservation management practices. It provides a coherent framework for 'integration of information on the biophysical and economic environments faced by the farmers' (Lutz et al, 1994). The cost-benefit analysis (CBA) involves quantification or measurement of all cost and benefits associated with land degradation and conservation practices. This approach takes into account the temporal distribution of costs and benefits by using an appropriate discount rate. The range

7 Adhikari and Nadela (2011) differentiated between land degradation, soil degradation and soil erosion. They defined 'land degradation' as the reduction in the soil's ability to contribute to crop production; 'soil degradation' as the reduction in soil quality that encompasses the physical, chemical and biological attributes of the soil; 'soil erosion' is as a process that results in the physical loss of top soil, in a reduction of rooting depth and in the removal of nutrients due to an agent, such as wind and water.

of valuation methods that emerged in recent years to value both the marketed as well as non-marketed ecosystem goods and services (TEEB, 2010) have aided in expanding the scope of cost and benefit analysis of land degradation and conservation measures.

2.2.1 Direct Economic Costs

Costs may be direct or indirect. Direct costs may be divided into on-site and off-site, that is whether the impacts are felt at the site (e.g. on the farm due to loss of productivity) or off-site-e.g. soil erosion that leads to siltation of reservoirs downstream. Direct onsite costs of DLDD are borne directly by the users of land due to declining land productivity and resulting losses of income (Low, 2013). Indirect costs of land degradation, according to Nkonya (2011), "represent their impacts across all sectors of the economy-for instance through price transmission mechanisms or transactions on the input markets-as well as their human impacts (migration, food security, poverty)".

UNEP attempted the first global estimate of direct costs of desertification in 1980 and pegged it at $26 billion per annum (Low, 2013). Drenge and Chou (1992) estimated the annual global cost in terms of income forgone due to land degradation as $ 42 billion in 1990 US dollars. A number of studies estimating the direct costs of land degradation emerged at national, regional and local level, though most of them focused on on-site impacts in terms of productivity loss of the land. The estimated direct costs of land degradation vary widely across countries (see Table 2.2) and also within the same country, and are not comparable (Yesuf et al, 2005; Low, 2013).

Table 2.2 Direct Costs of Land Degradation

Author(s)	Country	Costs	Unit	% of GDP	% of agricultural GDP	Notes
Dregne and Chou 1992	World	42	US$ billion			
Huang and Rozelle 1995	China	700	US$ million		< 1%	
Solorzano et al. 1991	Costa Rica				5-13% of annual value added in agriculture	
FAO 1986	Ethiopia				< 1%	
Sutcliffe 1993	Ethiopia	155	US$ million		5%	
Bojo and Cassells 1995	Ethiopia	130	US$ million		3%	
Convery and Tutu 1990	Ghana	166.4	US$ million		5%	
Magrath and Arens 1989	Indonesia, Java	340-406	US$ million	GDP growth per year	3% (Berry, Olson, and Campbell 2003)	
Cohen, Brown, and Shephard 2006	Kenya			3.80%		
Bojo 1991	Lesotho	0.3	US$ million		< 1%	
Eaton 1996	Malawi				3%	

Author(s)	Country	Costs	Unit	% of GDP	% of agricultural GDP	Notes
Bishop and Allen 1989	Mali	2.9-11.6	US$ million		< 1%	
van der Pol 1992	Mali	59	US$ million			
McIntire 1994	Mexico				2.7-12.3%	10% discount rate
McKenzie 1994	South Africa				4%	
Norse and Saigal 1992	Zimbabwe	99.5	US$ million		8%	
Grohs 1994	Zimbabwe	0.7-2.1	US$ million	< 1%	0.36%	In 1988/1989 dollars
Stocking 1986	Zimbabwe	117	US$ million		9%	In 1986 dollars
Berry, Olson, and Campbell (2003)	China			4–12 per cent of the GDP is lost due to environmental degradation,		85 per cent resulting from soil erosion, nutrient loss and changes in crops
	Ethiopia	139	US$ million	4%	0.2-0.5%	Direct effects
	Mexico	3.2	US$ billion			
	Rwanda	23	US$ million		3.50%	Direct effects
Bishop 1995	Mali	1.1-7.3	US$ million	1.51%	3.38% (3-13% in Yesuf et al. 2005)	beta=0,004, beta-factor: sensitivity to soil erosion, values for different betas calculated
	Malawi	13	Mil. US-$		2,4% (17-55% in Yesuf et al., 2005)	Beta = 0.004
Young 1993	South and Southeast Asia				7%	
	India				5%	
	Pakistan				5%	
Pimentel et al 1995	USA	27	US$ Billion	0.4	20	

Author(s)	Country	Costs	Unit	% of GDP	% of agricultural GDP	Notes
Drechsel and Gylele 1999	Mali				5.5-6.5%	
	Madagascar				6-9%	
	Malawi				9.5-11%	
	Ghana				4-5%	
	Ethiopia				10-11%	
Lallement 1989	Burkina Faso			9	20	
Sonneveld 2002	Ethiopia				2.93%	
Reddy 2003	India	75	Billion Indian Rupees	2	4	
Diao and Sarpong 2007	Ghana	4.2	US$ billion (20062015)	18	5%	Sustainable Land Management (SLM) practices would generate an aggregate economic benefit of US$6.4 billion over the 20062015 period.
Wang et al., 2012	China	10	US$ Billion			
Morales, Dascal, Aranibar Morera, 2012	Latin America					
	Paraguay				6.6%	
	Guatemala				24%	
World Bank (2013)	India					
	Cost of soil salinity, waterlogging and nutrients loss	715	Rs. billion		1.1 % of GDP in 2010	
	Loss of fodder and livestock income due to due to rangeland degradation	405	Rs. billion		0.6% of GDP in 2010	

Author(s)	Country	Costs	Unit	% of GDP	% of agricultural GDP	Notes
Costanza et al. (2014)	Global	9.4 annually	US$ trillion			
Bouza et al. (2016)	Argentina	75	US$ Billion (2007 prices)	16%		
Mirzabaev et al. (2016)	Central Asia	6	US$ Billion (2009 prices)	3%		
	Kazakhstan	3.06	US$ Billion (2009 prices)	3%		
	Kyrgystan	0.55	US$ Billion (2009 prices)	11%		
	Tajikistan	0.5	US$ Billion (2009 prices)	10%		
	Turkmenistan	0.87	US$ Billion (2009 prices)	4%		
	Uzbekistan	0.83	US$ Billion (2009 prices)	3%		
Deng and Li (2016)	China	37	US$ Billion (2007 prices)	1%		
Gebreselassie et al. (2016)	Ethiopia	4.3	US$ Billion			

Source: Nkonya et al (2011); World Bank (2013) Low (2013); UNCCD, (2013), Costanza et al. (2014); Nkonya (2016)

The wide variation in the costs are explained by factors such as use of different data sets, diversity in estimation methods, and varied methodological approaches and assumptions even for similar estimation methods (Low, 2013; Yesuf et al, 2007). For example, Reddy (2003) shows that the total cost of degradation which includes costs of erosion, salinity and alkalinity, and water logging when estimated by using a loss of production method is around three times higher than the estimates based on replacement cost method. The study also suggests that the estimated total cost of degradation varies from 4 % to 5.6 % of the GDP (loss of production method) depending on the extent of degradation as reported by different studies. Yesuf et al (2005) reviewed some studies that estimated cost of land degradation for Ethiopia and found that the estimates varied between 2 to 7 percent of the agricultural GDP though all four studies reviewed used loss of production method.

2.2.1.1 Approaches to determine on-site direct costs

The common methods used in the literature for estimation of direct on-site costs of land degradation are

- Replacement cost approach
- Productivity change approach

2.2.1.1.1 Replacement Cost Approach

This method measures the impact of land degradation by assessing the incremental expenditure on chemical fertilizers applied for replacement or to maintain or repair the soil nutrients lost through degradation. This method has several limitations and is criticized on several grounds. The method assumes perfect substitution between chemical fertilizer and lost soil nutrients (Nkonya, 2011), and zero degradation (Barbier, 1998). Costs of additional fertilizer used fail to capture the value of lost organic components of the soil or micro-organisms and related biodiversity (Kumar, 2004) and hence could be an underestimate of the real value of lost top soil. Without defining the linkage between lost nutrient and agricultural production, this method is likely to overestimate the value of lost soil nutrient as other factors like rainfall have more significant impact of agricultural production (Bojo, 1996; Nkonya, 2011). The replacement cost has been estimated in varied ways. Reddy (2003) has used the market prices of chemical fertilizers (NPK) at the rate of 3.01 units of NPK for every unit of nutrient loss. Pimentel et al (1995) included the cost of energy for application of fertilizers along with the cost of fertilizer.

2.2.1.1.2 Productivity Change Approach

Productivity change or loss of production is widely used to measure the direct cost of land degradation. This assumes that impacts of land degradation are manifested in terms of reduced productivity of land. The cost of degradation is estimated as the market values of the differential productivity of the degraded and non-degraded land. Though the method looks simple and straight forward, the challenges involved in implementing the method is finding an appropriate benchmark productivity to compare or establishing a counterfactual. The limitation of this method includes use of crop prices that are subject to policy distortions for estimating the costs (Crosson, 1998 as cited in Nkonya, 2011) and difficulties in accounting for farmers' response to degradation given the complex erosion-productivity relationship (Kumar, 2004; Nkonya, 2011).

Some of the ways in which productivity loss has been estimated in physical terms include agro-ecological and soil erosion models (Martınez-Casasnovas and Ramos, 2006; Cruz et al, 1988; Barry et al, 2011), field-based experiments, plot surveys and analysis of sediment loads (Sharda and Dogra 2013), subjectively elicited yield data from farmers (Herath 2001) and benefits-transfer approach using findings from other similar studies (Reddy 2003). Once the yield-land degradation function is established, the most commonly used approaches for placing an economic value on agricultural land degradation is by using the value of production losses.

2.2.1.2 Off-site Impacts of DLDD

Apart from the onsite economic costs, DLDD also leads to several off-site impacts hence imposing a cost on people living away from the site of degradation. Water erosion results in siltation of rivers, canals, reservoirs, thus adversely affecting the water quality and availability in these water bodies and may also cause flooding. Similarly wind erosion causes dust storms adversely affecting the health conditions, transport infrastructure and maintenance costs of building and transport systems. Both wind and water erosion also affects the floral and faunal biodiversity of water and terrestrial ecosystems. However, there have been limited studies assessing the costs and benefits of such off-site impacts due to data and methodological constraints including the lack of market prices for many of these impacts. Low (2013) summarized some of the studies estimating off-site costs (Table 2.3).

Table 2.3 Review of studies estimating off-site costs of land degradation (in chronological order)

Author	Country	Degradation process	Type of off-site cost	Off-site cost	Unit	Note
Clark 1985		Soil erosion	Total off-stream damage	1,100-3,100	US$ million	in 1980 dollars
			Total in-stream damage	2,100-10,000	US$ million	in 1980 dollars
Cruz et al. 1988	Philippines—Pantabangan Reservoir	Soil erosion	Reduction in service life of reservoir	1.11	Philippine pesos per hectare	
			Reduction in active storage and irrigation	12.99	Philippine pesos per hectare	
			Reduction in active storage and hydropower	2.91	Philippine pesos per hectare	
			Opportunity cost of dead storage for irrigation	575.55	Philippine pesos per hectare	
	Philippines—agat Reservoir	Soil erosion	Reduction in service life of reservoir	0.1	Philippine pesos per hectare	
			Opportunity cost of dead storage for irrigation	365.61	Philippine pesos per hectare	
Magrath and Arens 1989	Indonesia, Java	Soil erosion	Irrigation system siltation	7.9-12.9	US$ million	
			Harbor dredging	1.4-3.5	US$ million	
			Reservoir sedimentation	16.3-74.9	US$ million	
Grohs 1994	Zimbabwe	Soil erosion	Sedimentation (productivity change approach)	0.6	Zimbabwean dollars	in 1989 dollars
			Sedimentation (replacement cost approach)	0.8-8.8	Zimbabwean dollars	In 1989 dollars
			Sedimentation (defensive expenditure)	1.0-12.5	Zimbabwean dollars	In 1989 dollars

Author	Country	Degradation process	Type of off-site cost	Off-site cost	Unit	Note
Pimentel et al. 1995	United States	Water erosion	Recreational	2,440.0	US$ million per year	On- and off-site costs of erosion in United States: US$44 billion per year or $100/ha
			Water-storage facilities	841.8	US$ million per year	
			Navigation	683.2	US$ million per year	
			Other in-stream uses	1,09.08	US$ million per year	
			Flood damages	939.4	US$ million per year	
			Water-conveyance facilities	244.0	US$ million per year	
			Water-treatment facilities	122.0	US$ million per year	
			Other off-stream uses	976.0	US$ million per year	
		Wind erosion	Exterior paint	18.5	US$ million per year	
			Landscaping	2,894.0	US$ million per year	
			Automobiles	134.6	US$ million per year	
			Interior, laundry	986.0	US$ million per year	
			Health	5,371.0	US$ million per year	
			Recreation	223.2	US$ million per year	
			Road maintenance	1.2	US$ million per year	
			Cost to business	3.5	US$ million per year	
			Cost to irrigation and conservation districts	0.1	US$ million per year	
Richards 1997	Bolivia—Taquina watershed	Soil erosion	Flood prevention	2.30	US-Mil. $	Annual benefit after initiation of conservation measures

Author	Country	Degradation process	Type of off-site cost	Off-site cost	Unit	Note
			Aquifer recharge	7.80	US-Mil. $	Annual benefit from years 7-20 after initiation of conservation measures
Feather, Hellerstein, and Hansen 1999	United States	Soil erosion	Recreation	80	US$ million	Benefit
			Wildlife viewing	348	US$ million	Benefit
			Hunting	36	US$ million	Benefit
Pretty 2000	United Kingdom	Soil erosion	Damage to roads and property	4.00	Million pounds	Calculated for various off- and in-stream damages
			Traffic accidents	0.10	Million pounds	
			Footpath loss	1.19	Million pounds	
			Channel degradation	8.47	Million pounds	
Krausse et al. 2001	New Zealand	Soil erosion	Sedimentation	27.4	NZ-Mil. $	Calculated for various off- and in-stream damages; in 1998 dollars
Vieth, Gunatilake, and Cox 2001	Sri Lanka - Upper Mahareli Watershed	Soil erosion	Reduction in irrigated area	0.080	US-Mil. $	In 1993 dollars
			Reduction in hydropower production	0.288	Mil. $	In 1993 dollars
			Cost of water purification	0.080	Mil. $	In 1993 dollars
Hansen et al. 2002	United States	Erosion	Dredging	257	US$ million per year	In 1998 dollars; not included: sediment dredged by lake or ocean action

Author	Country	Degradation process	Type of off-site cost	Off-site cost	Unit	Note
Tegtmeier and Duffy 2004	United States	Soil erosion	Cost to water industry	277.0-831.1	US$ million	In 2002 dollars
			Cost to replace lost capacity of reservoirs	241.806,044.5	US$ million	In 2002 dollars
			Water-conveyance costs	268.0-790.0	US$ million	In 2002 dollars
			Flood damages	190.0-548.8	US$ million	In 2002 dollars
			Damage to recreational activities	540.1-3,183.7	US$ million	In 2002 dollars
			Cost to navigation (shipping damage, dredging)	304.0-338.6	US$ million	In 2002 dollars
			In-stream impacts (fisheries, preservation value)	242.2-1,218.3	US$ million	In 2002 dollars
			Off-stream impacts (industrial uses, steam power plants)	197.6-439.7	US$ million	In 2002 dollars
Rodrigues, 2005	Brazil	Soil Erosion	Sedimentation	38.39 to 165.73	US$ million	
Colombo et al. 2005	Spain—Andalusian region	Soil erosion	Landscape desertification: small/medium improvement	17.428-22.88	Euro	Implicit price
			Surface and groundwater quality: medium/high quality	21.865-29.352	Euro	
			Flora and fauna quality: improvement to medium/good quality	14.992-17.765	Euro	
			Jobs created (number)	0.102	Euro	

Author	Country	Degradation process	Type of off-site cost	Off-site cost	Unit	Note
Hansen and Hellerstein 2007	USA	Soil Erosion	Impact of soil conservation on reservoir services	154 million in reservoir benefits	US$	Across the 2111 US watersheds, a one-ton reduction in soil erosion provides benefits ranging from zero to $1.38. In a policy application, the lower soil erosion level in 1997, relative to 1982, was shown to have conserved $154 million in reservoir benefits
Nkonya et al. (2008)	Kenya	Soil Erosion, loss of vegetation	Carbon sequestration, siltation (cost of treatment and purification of water)	24	KES per hectare	
Basson (2010)	Global	Soil Erosion	Siltation of water reservoirs.	18.5 billion annually	US$	

Source: Nkonya et al (2011), Hansen and Hellerstein 2007; Telles et al. (2011); Basson (2010)

One of the major challenges of assessing off-site impacts is paucity of data on biophysical aspects and lack of market prices for many such costs and benefits (Low, 2013). Some papers have looked at the opportunity cost of sedimentation of reservoirs due to soil erosion in terms of potential irrigation and hydroelectricity benefits forgone, cost of water purification, flood damages and so on (Cruz et al, 1988; Pimentel et al, 1995; Hansen et al, 2002, Vieth et al, 2001; Nkonya et al, 2008). Some of the studies also look at the costs of damage to public and private infrastructure due to soil erosion (Pimentel et al, 1995; Pretty, 2000). Only a few studies have estimated the offsite economic costs or benefits like carbon sequestration, biodiversity, and tourism (Feather et al, 1999; Nkonya et al, 2008; Colombo et al, 2005). There have been a few studies that made comprehensive assessments of both direct and indirect costs. Though the estimates are not comparable, for most studies the off-site costs are estimated to be higher than the on-site costs, particularly for developed countries (Vieth et al, 2001). However, the estimates of some of the studies suggest otherwise. For instance, Pimentel et al (1995, included a range of offsite costs due to wind and water erosion, estimated the offsite cost be 38 % of the total costs ($17 billion of $44 billion) of land degradation for USA. Vieth et al (2001) studied the costs and benefits of soil conservation measures in Upper Mahaweli Watershed in Sri Lanka and found that the estimated on-site costs accounts to 97 % of the total costs. The offsite costs in this study included the costs of lost hydro power, lost irrigation and the cost of water purification. Various methods are used in the literature for estimating the off-site costs and benefits.

1. Non-market valuation techniques like contingent valuation (willingness to pay or accept), choice experiments, hedonic prices, travel cost
2. Avertive behavioural responses and damage cost approach
3. Replacement cost approaches

2.2.1.2.1 Contingent Valuation (CV) Methods

In Contingent Valuation (CV) an individual's willingness to pay or accept is measured in a hypothetical market scenario by asking how much money the individual would be willing to pay for an increase in provision of the ecosystem goods or services from land. The monetary value of the non-marketed good and services are assessed based on the stated values of the individual responses. This method is criticized for the associated possible biases which may lead to over-estimation or under-estimation of the values (Mitchel and Carson, 1989).

2.2.1.2.2 Choice Experiment

Choice experiment is a similar stated preference method where the individual is asked to choose the most preferred option from a set of proposed options with varied attributes. The value of the ecosystem good or service is obtained based on the willingness to pay response of the individuals for change in attributes. This method like CV has some limitations too and is subject to biases in arriving at the right values. Colombo et al (2006) used choice experiments to estimate the compensating surplus in an evaluation of a soil conservation programme.

2.2.1.2.3 Hedonic Pricing

In this method, the realized market prices in terms of property or rental values are used to ascertain the value of ecosystem goods and services. The assumption is that the differences in the market values are attributable to the different levels of land degradation or conservation. This method results in over-estimation or under-estimation of values when the land markets do not function well or the buyers have imperfect information on the costs and benefits of land's productive capacity (King and Sinden, 1988; Bishop 1995). Holmes (1988) used the hedonic function to estimate the cost of water purification (as cited in Nkonya, 2011). Travel cost approach is a similar method where the values are estimated based on the realized market prices in terms of travel expenses incurred by the individual to enjoy certain ecosystem services like visiting a national park or places of scenic beauty.

2.2.1.2.4 Avoided Cost or Damage Cost Approach

In this method the cost of degradation or benefits of conservation are assessed by estimating the cost of the activities that could have been avoided had the degradation not occurred or by estimating the cost of the damage due to degradation. For example, the impact of water erosion on reservoir or canal or rivers has been estimated by cost of removals of the siltation or sediments from these water bodies or cost of loss of hydropower or cost of loss of damage due to floods (Cruz etal, 1998, Vieth et al, 2001; Hansen and Hellerstein, 2007). There have been several studies that adopted this method for estimating the off-site costs and benefits like water treatment (Vieth et al, 2001; Nkonya, 2008), flooding and ground water recharge (Richards, 1997), and loss of recreational services (Feather et al, 1999; Clark, 1985).

2.2.1.2.5 Replacement cost approach

This method is also used for estimating the off-site cost and is measured by the cost of providing the least cost alternative. Clark (1996) estimated the cost of replacing hydro-electricity lost due to reservoir sedimentation by electricity generated from fossil fuel.

2.2.1.2.6 Benefit-transfer approach

The estimation of non-marketed costs and benefits through all these methods are time consuming, require lots of resources and involves complex estimation procedures. So benefit-transfer approaches are often adopted wherein results obtained from studies undertaken in comparable sites or sites with similar contexts are used to estimate the costs and benefits.

Table 2.4 summarises the different costs associated with land degradation and the methodology adopted in the literature to assess these costs.

Table 2.4 Measuring Costs of DLDD

Ecosystem service affected	Scale	Impacts	Direct (D)/ Indirect Costs (I)	Valuation methodology
Productivity of farming	On-site	Loss of agricultural yield	D	Production-function based approaches
		Soil nutrient depletion due to erosion	D/I	Replacement costs of inputs such as fertilizers
		Malnutrition	D	Disability Adjusted Life Year (DALY)
		Salinity	D	Avoided cost of desalination
Livestock farming / Pastoralism	On-site	Loss of milk, meat and hides	D	Productivity function based approaches
Water quantity & water quality	On-site / off site	Flash floods	D	Avoided damage costs
		Declining fish populations	D/I	Production function
		Health	D/I	Disability Adjusted Life Year Health treatment expenditure
		Siltation of rivers and reservoirs	D/I	Replacement cost (Dredging cost of reservoirs) Value of reduced hydropower production Value of reduced irrigation
		Aquifer depletion	D	Replacement cost (increased pumping costs or drilling a deeper replacement pump) Embedded time (opportunity cost of additional time spent to collect water)
Dust storms	On-site / off site	Health	I	Disability adjusted life year Health treatment expenditure
		Discomfort	D	Expenditure on averting behavior / damage mitigation
		Reduced labour productivity	D/I	Value of reduced output

Ecosystem service affected	Scale	Impacts	Direct (D)/ Indirect Costs (I)	Valuation methodology
Biodiversity	On-site	Decrease in wild food availability	D	Opportunity cost of additional time spent 'gathering, hunting or fishing' Substitute goods values
		Loss of emblematic species	D	Stated preference methods
		Loss of genetic resources	I	Stated preference methods
Carbon storage and sequestration	On-site	Reduced climate mitigation	I	Market prices for C02e
Eco-tourism and recreation	On-site	Decrease in visitor numbers	D	Stated Preference Travel Cost Hedonic pricing (hotels)

Source: Low (2013)

All these costs lead to a multitude of other 'indirect' costs throughout the economy as the impacts are closely interrelated to each other in a variety of ways (Low, 2013). For instance, declining income of the farmers and increase in food prices due to loss of agricultural production caused by land degradation would have a spiralling impact on the entire economy- 'knock on effects' (Low (2013). Similarly, reduced production of electricity due to reservoir sedimentation which directly impacts those industries or activities that use electricity as an input could also impact the entire economy. There have been few studies assessing these comprehensive economy-wide impacts. However, some studies like Coxhead (1999), Alfsen et al (1996), and Diao and Sarpong (2007) explored the knock on effects on the economy (Low, 2013). Kirui (2016) estimated that LD in Tanzania and Malawi amounts to the equivalent of 15% and 10% of their respective Gross Domestic Products (GDP). Similarly, Mirzabaev et al. (2016) found that Kyrgyzstan and Tajikistan are losing the equivalence of about 10% of their GDP annually to LD. Diao and Sarpong (2011) showed that LD over the last decade increased the national poverty rate by 5.4% in Ghana. An important aspect of land degradation, mostly brought out by macro-economic general equilibrium models is the influence of policies. For instance Coxhead and Shively (1995) show that while technological progress in corn results in less area under corn and reduced land degradation, a subsidy to grain millers induces rapid agricultural land degradation.

2.2.3 Cost-benefit analyses of Sustainable Land Management (SLM) practices

Though cost-benefit analysis or economic valuation of SLM practices helps better decision making (see Box 1), this approach has its limitations too. Some of the issues highlighted in Requier-Desjardins et al (2011), Low (2013), and Nkonya (2011) are as follows:

- Internal rate of economic return as an indicator should not be used for comparing the economic performance of different kinds of SLM techniques.
- Valuation of SLM projects are usually undertaken to assess the positive results of interventions and do not take into account the considerations from an institutional perspective or whether the intervention could be undertaken at a larger scale to enrich the results.
- The implementation of SLM measures assumes that the beneficiaries don't have other options or alternatives to improve their living standards. Therefore it is assumed that the local farmers won't incur any opportunity cost of those actions which may not always be the cases. Similarly, it is assumed that there is no transaction costs involved in the implementation and evaluation of SLM measures.

- There has not been any comprehensive assessment that takes into account all the benefits. For instance, the economic benefits like rise in water table, improvement in the status of women (due to gain in from reduction of time for collection of water and fuel wood and consequent investment in income generating activities) and reduction in migration etc. though identified and described has not been quantified.
- Choice of appropriate discount rate determines the study outcomes. Most of studies (particularly on Sahel) used discount rate as high as 10 % whereas the eco-system valuation studies usually use 3-5 %.
- The rates of erosion used in the estimation vary significantly across the studies. The erosion rate is most cases are obtained from USLE , the Wischmeier and Smith's Empirical Soil Loss Model [8] rather than actual rates measured in the field.

Box 1: Sustainable Land Management – Some success around the world

In Zimbawe, water harvesting combined with conservation agriculture increased farmers gross margins 4 to 7 fold and increased returns on labour 2-to-3 fold compared to standard practices. These practices have had the greatest success in zones with lower rainfall (Winterbottom, et.al, 2013).

From 1991 to 2004, Brazil's grain production more than doubled from 58 million tons to 125 million tons as a result of widespread adoption of conservation agriculture and introduction of improved crop varieties (Winterbottom, et.al, 2013)

In China, the adoption of no-till systems of wheat production and raised yields and reduced production costs, results in an average increase of 30% net economic returns over 4 years (Rosegrant, 2014).

In western Kenya, 60,000 smallholder farmers in western Kenya are benefiting from carbon credits generated by applying sustainable land management farming techniques. So far they have achieved a reduction of 24,788 mt C02, which is equivalent to emissions from 5,164 vehicles in a year. By using SLM practices, yields of some crops increased by 15-20% (World Bank, 2014).

Over 5 million hectares of degraded land in the Sahel have been restored through a practice known as 'farmer-managed natural regeneration.' This has resulted in an additional half a million tons of grain production each year and enough fodder to support more livestock. To date, it has improved food security of about 2.5 million people (CGIAR, 2013).

Research in Malawi indicates that agroforestry practices generally increase yields from 1 tonne/hectare to 2-3 tonnes/hectare even if farmers cannot afford inorganic fertilizes (Winterbottom, et.al, 2013.

An initiative by the International Fund for Agricultural Development (IFAD) that mobilized local community participation has helped restore around one-third of the Syrian steppe that had become badly degraded due to severe drought and intensive grazing (IFAD in UNCCD, 2011).

Sustainable land management, including closing yield-potential gaps and reaching 95% of potential maximum crop yields could result in an additional 2.3 billion tons of crop production per year, equivalent to a potential gain of US 1.4 trillion (Economics of Land Degradation Initiative, 2013)

Food and Agricultural Organization (FAO) implemented the "Acacia Operation Project-Support to food security, poverty alleviation and soil degradation control in the gums and resins producer countries" in 6 countries in sub-Saharan Africa (Burkina Faso, Chad, Niger, Kenya, Senegal and Sudan). The project resulted in the restoration of 13240 ha. (FAO in UNCCD, 2011).

A national afforestation program in which degraded and public lands are eligible for financing has been established in Romainia. In 2005 and 2006 over 5000 ha of degraded lands were afforested at € 5000/ha.

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[8] USLE, The Universal Soil Loss equation developed by ARS scientists W. Wischmeier and D. Smith, predicts average annual soil loss caused by sheet and rill erosion. The USLE for estimating average annual soil erosion is: A = RKLSCP where
A = average annual soil loss in t/a (tons per acre)
R = rainfall erosivity index
K = soil erodibility factor
LS = topographic factor - L is for slope length & S is for slope
C = cropping factor
P = conservation practice factor

- SLM projects when implemented in common land should take into account the livelihood concerns as conservation and livelihood objectives could be contradictory.
- Studies have used methods and approaches with varied assumptions which make it difficult to compare the results.

What most studies either do not look at or address only qualitatively for obvious reasons is the social dimension- issues of poverty, food security, migration and livelihoods – of land degradation. Quantification of social impacts is hindered by the difficulties in establishing the causal mechanisms between social and biophysical observations. Requier-Desjardins et al (2011) argue that any attempt at understanding the costs and benefits of land degradation should describe and conceptualize underlying social processes and contexts (institutions, social and economic policies.). Such an approach will ensure that essential information is not omitted when translating such impacts into economic (monetary) costs. Moreover, while assessing the costs and benefits justifies the actions at macro and micro level, it does not necessarily lead to implementation of favourable policies and programmes or adoption of sustainable land management (SLM) practices at farm level. This is evident from the continuation of land degrading activities despite highly positive net present values or profitability of several available SLM technologies (Knowler, 2004). So devising effective incentive mechanisms through sectoral and macro-economic policies is critical to ensure more action on the ground.

CHAPTER 3

A Review of Desertification, Land Degradation and Drought in India

3.1 Introduction: Defining the issue

In this chapter, we review the scale and extent of desertification, land degradation and drought in the country, analyse the proximal and distal reasons for land degradation, review the literature on the economic costs of land degradation, and analyse the efficacy of programmes to mitigate degradation and restore degraded lands. The objective of this chapter is to set the context for a macro-economic assessment of land degradation in India and for six micro-economic case studies that encompass a range of land degradation causal factors and major land uses in the country (e.g. forests, rangelands and agriculture).

Before we, however, discuss the causal mechanisms for land degradation in the country, it is important to understand how land, land degradation and desertification are related to each other and how they are defined. We use these definitions in our estimates of land degradation both at the macroeconomic level and at the scale of our microeconomic case study assessments.

According to UNCCD (1996), land is defined as, *"The terrestrial bio-productive system that comprises soil, vegetation, other biota, and the ecological and hydrological processes that operate within the system (UNCCD, 1996, Part1, Article 1e)."* Relating to this definition of land, land degradation has been defined by UNCCD as the, *"Reduction or loss of biological or economic productivity and complexity of rain-fed cropland, irrigated cropland or range, pasture, forests, & woodlands resulting from land use or from a process or combination of processes arising from human activities & habitation patterns such as*

- Soil erosion caused by water and/or wind
- Deterioration of physical, chemical, biological or economic properties of soil
- Long-term loss of natural vegetation

Land degradation (LD) can be broadly divided into physical, chemical & biological degradation (Nkonya et al, 2013)

- Physical degradation is erosion, soil organic carbon loss, change in soil's physical structure-e.g. compaction, waterlogging. Globally soil erosion is the most important LD process resulting in removal of topsoil. Soil productivity is depleted through reduced rooting depth, loss of plant nutrients and physical loss of topsoil
- Chemical degradation refers to leaching, salinisation, fertility depletion, acidification, nutrient imbalances
- Biological degradation implies the loss of vegetation, rangeland degradation and loss in biodiversity including soil organic matter

Thus the definition of land and by its extension land degradation refers not only to soil but the negative impacts on the entire bio-productive system.

Other definitions are also commonly used. For example, the latest studies on land degradation often address the loss of ecosystem services that result from land degradation, and the consequent impacts for human welfare. This is in contrast to the definitions provided above which address LD purely in physical, biological or chemical terms rather than the consequences for human welfare. In 2006, the Global Environment Facility (GEF) funded the Land Degradation assessment in Drylands (LADA) project under which a global assessment of land degradation (GLADA) was attempted. Land degradation (LD) has been described by LADA as 'the reduction in the capacity of the land to provide ecosystem goods and services over a period of time' (Nachtergaele et al., 2010). This linking of loss of ecosystem services with a reduction in human welfare relates to the Millennium Ecosystem Assessment (MEA, 2005) which strongly highlighted these interconnections. This approach is important because land degradation can occur due to both anthropogenic reasons and because of natural events. When largely human-induced, land degradation becomes an important social issues people not only cause land degradation but bear the brunt of its impacts (Blaikie and Brookfield 1987).

Desertification is nothing but a special case of land degradation that is defined as, "Land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities (UNCCD, 1996, Part1, Article 1a). Although several definitions of desertification have emerged from the late 1970s, the definition given above is now widely accepted.

3.2 Proximal and distal causes of land degradation

The causes of desertification, in general, may be divided into proximal and distal reasons (Fig 3.1). These are explained below.

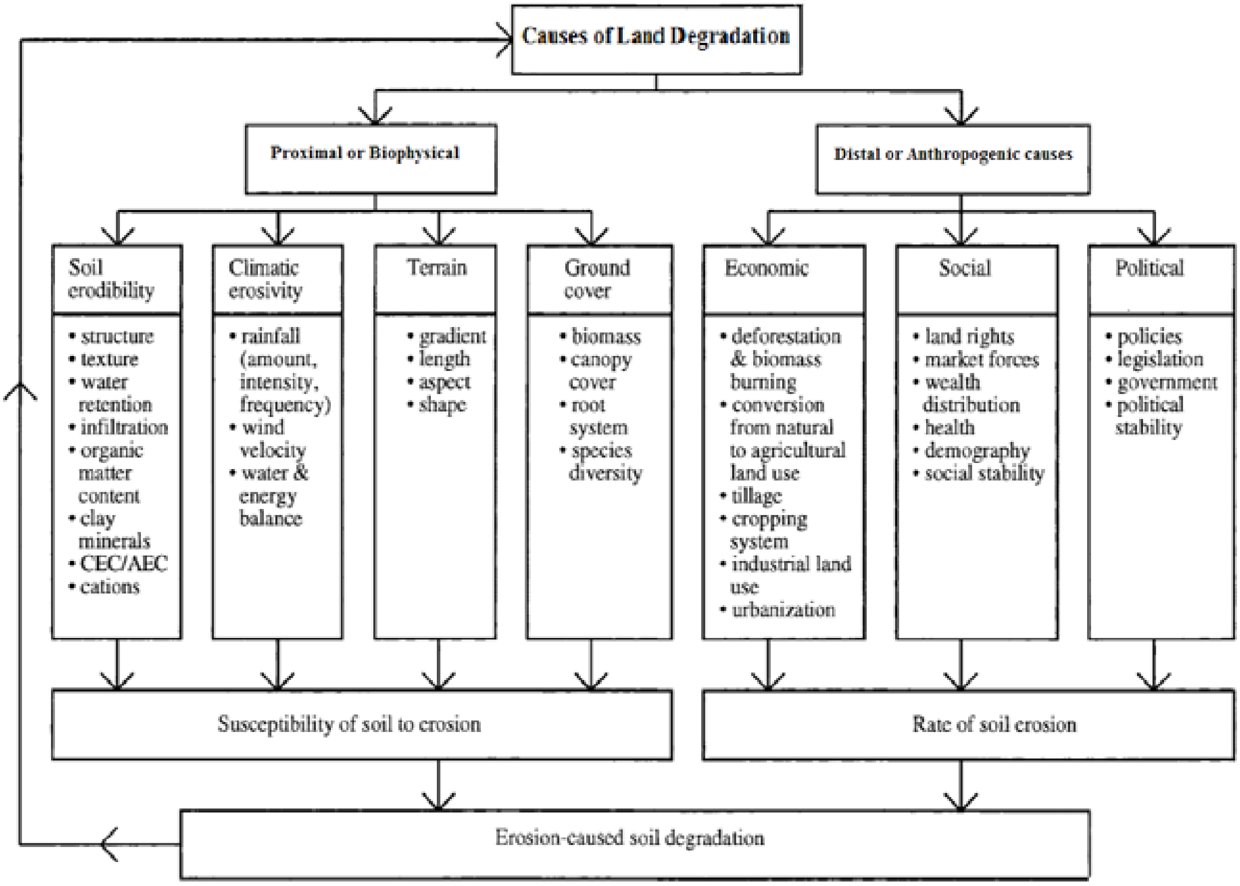


Figure 3.1 Diagrammatic depiction of the causes of land degradation

Source: Lal (1995)

The proximal are biophysical in terms of the vulnerability of soils due to topography and climatic factors such as temperature, rainfall and wind, but also due to unsustainable land management practices. Unsustainable forest management results from deforestation, degradation, overgrazing, and conversion to other land uses, forest fires, excessive fuel wood collection and unsustainable harvests of non-timber forest products (Nachtergaele et al., 2010, Meyfroidt and Lambin, 2011, GLASOD). The GLASOD (global assessment of soil degradation) assessment cites deforestation as the cause for 98% of areas affected by soil erosion as well as an important contributor to salinisation. In the Indian context, forest degradation rather than deforestation is one of the major reasons for land degradation.[9]

Unsustainable agricultural practices result from extensive and frequent cropping, excessive fertilizer and pesticide use and shifting cultivation with short fallows. Decreases in soil fertility often result from prolonged cultivation and erosion, and extensive application of fertilizers is used to maintain crop yields. Expansion of canal irrigation to arid and semi-arid areas has caused widespread salinization and water logging. Mining and quarrying also inevitably result in land degradation (Sahu and Dash, 2011) particularly if inadequate land restoration measures are taken. Mine overburden and waste are erosion-prone, choking drainage and producing acid drainage water.

The distal reasons which precipitate or exacerbate land degradation are far more systemic (Nkonya et al., 2011). These include weak institutions and poor governance, policy and market failures (e.g. subsidizing fertilizer use), land fragmentation and uncertain tenure, demographic and socio-economic factors as well as the impacts of globalization.

Escalating demands for products in areas far removed from where they are produced is often responsible for inappropriate policies and land use practices. This makes the externalization of environmental and social costs a huge risk in this age of globalisation. For example, significant proportions of flower imports to the European Union come from the drylands in Kenya and Israel (MEA, 2005). Another outcome of globalization is the acquisition of land in other countries for the production of food, timber and minerals-such land acquisition stands at about 100 million hectares globally (HLPE 2011) leaving less land, and altering land use patterns for local populations.

Insecure land tenure has long been acknowledged as a major reason for land mismanagement. In Africa, where trees are cut for fuel, there is little incentive to plant new ones given the absence of ownership by the people, in Uganda, for example. The promise of ownership of trees to the people in Niger has helped promote agroforestry amongst the landless, and women, as well as on communal land. According to the UNCCD (2014), security of land tenure for women can raise farm production by 20-30% and boost total agricultural production by 2.5 to 4% in some countries. Tenurial rights over resources need not, however, be private. Poor governance that fails to recognize or promote traditional, community-based land management systems, decentralisation and institutions based on traditional knowledge can aggravate land degradation. Private tenures, for example, are often inappropriate in dryland settings as they fail to provide pastoralists with access to ecosystem services (MEA, 2005). Good governance in drylands therefore, necessitates the institution of multiple tenurial and land use systems, appropriate to the context and the biophysical resource base.

Policies impact behaviour. Costa Rica since 1997 has invested in promoting payments for ecosystem services (Pagiola 2008). Likewise, more than one-third (with actual adoption rate in parentheses) of crop area in Argentina (58 percent), Paraguay (54 percent), Uruguay (47 percent), and Brazil (38 percent) is under conservation agriculture (Kassam et al., 2009). Farm subsidies also indirectly impact land degradation (Heffer and Prud'homme 2009) by promoting over application for example of fertilizers (Mulvaney, Khan and Ellsworth 2009).

3.3 Areal estimates of desertification and land degradation in India

Fig.3.2 indicates the location of the drylands in India. The drylands constitute the arid, semi-arid and dry sub-humid regions of the country. The total area under desertification is 82.64 mha (Table 3.1). Table 3.2 provides an estimate of land degradation in each of these regions by category of degradation.

[9] See section on the economics of forest degradation in India

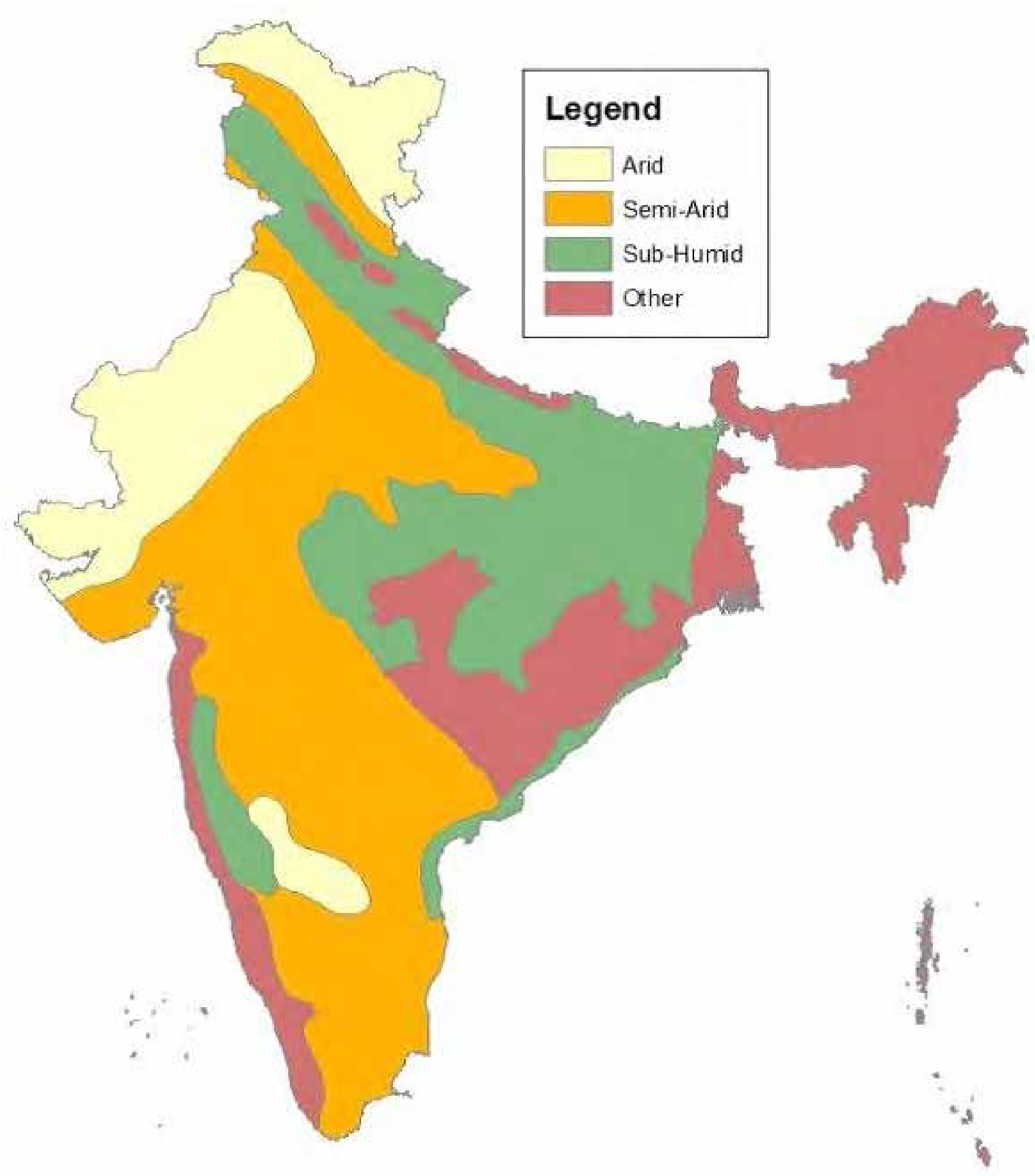


Figure 3.2 The Drylands of India

Source: Agro-ecological subregions of India, NBSSLLP (ICAR), Nagpur

Table 3.1 Area under desertification in India (in 2011/13)

Zone	Area (mha)
Arid	30.54
Semi-arid	35.4
Dry sub-humid	16.70
Total	**82.64**

Source: SAC, 2016

Table 3.2 Cause and extent of desertification in each category of dry land

Process of Degradation	Area under Desertification (mha)							
	2011-13				2003-05			
	Arid	Semi-Arid	Sub-Humid	Total	Arid	Semi-Arid	Sub-Humid	Total
Vegetation Degradation	2.86	13.48	6.65	22.99	2.81	13.39	6.34	22.54
Water Erosion	3.03	17.51	8.97	29.51	3.12	17.07	8.91	29.1
Wind Erosion	17.63	0.56	0	18.19	17.72	0.57	0	18.29
Salinity Alkalinity	2.52	0.86	0.09	3.47	2.52	1.07	0.21	3.8
Water Logging	0.02	0.08	0.31	0.41	0.02	0.08	0.25	0.35
Mass Movement	0.84	0.11	–	0.95	0.76	0.11		0.87
Frost Shattering	2.94	0.46	0.01	3.41	2.74	0.43	0.01	3.18
Man Made	0.04	0.14	0.16	0.34	0.04	0.14	0.14	0.32
Barren	0.25	0.28	0.05	0.58	0.25	0.28	0.05	0.58
Rocky	0.3	0.97	0.02	1.29	0.29	0.97	0.02	1.28
Settlement	0.11	0.93	0.44	1.48	0.07	0.75	0.33	1.15
Grand Total	30.54	35.4	16.7	82.64	30.35	34.85	16.28	81.48

Source: SAC, 2016

Estimates of land degradation for India have fluctuated widely over the years based on differences in assessment methodologies and varying definitions of what constitutes wastelands and degraded areas (Table 3.3). These estimates varied from 148 M ha in 1976 (National Commission on Agriculture, 1976) to 175 M ha in 1978 (Ministry of Agriculture (Soil and Water Conservation Division) to 187 M ha and 147 M ha according to NBSS&LUP estimates in 1994 and 2004 respectively. Far lower estimates of 123 M ha were provided by the National Wasteland Development Board in 1985 (Gautam and Narayan, 1988).

Table 3.3 Land degradation assessment by different organizations

Agency	Estimated Extent (M ha)	Criteria for delineation
National Commission on Agriculture (NCA, 1976)	148.09	Based on secondary data
Ministry of Agriculture (1978) (Soil and Water Conservation Division	175.00	Based on the NCA's estimates. No systematic survey was undertaken
Society for Promotion of Wastelands Development (SPWD) (Bhumbla and Khare, 1984)	129.58	Based on secondary estimates
NRSA (1985)	53.28	Mapping on 1:1 million scale based on the remote-sensing techniques
Ministry of Agriculture (MOA, 1985)	173.64	Land degradation statistics for states
Ministry of Agriculture (MOA, 1984)	107.43	Elimination of duplication of area. Area reclaimed counted

NBSS&LUP (1994)	187.70	Mapping on 1:4 million scale based on the Global Assessment of Soil Degradation (GLASOD) Guidelines
NBSS&LUP (2004) (revised)	146.82	1:1 million scale of map
Department of Environment (Vohra, 1980)	95.00	
National Wasteland Development Board (1985)	123.00	

Source: Gautam and Narayan (1988).

Variation in approaches resulted in very different figures for NBSS&LUP and the NRSA. While the former estimates are derived from soil maps on a 1: 250,000 scale, the NRSA data used remote sensing on 1:50,000 scale for mapping non-agricultural areas (Table 3.4).

Table 3.4 NBSS&LUP soil degradation classes, derived from 1:250,000 soil map (1985-1995) and NRSA Wasteland classes (1986-2000)

NBSS&LUP soil degradation classes, derived from 1:250,000 soil map (1985-1995)			NRSA Wasteland classes (1986-2000) (remote sensing on 1:50,000 scale for mapping non-agricultural areas)		
Classes	**Codes**	**Area (in mha)**	**Wasteland class**	**Area (in m ha)**	**%**
Water Erosion	W		Gullied/ravinous land	2.06	0.65
Loss of top soil	Wt	83.31	Land with/without scrub	19.40	6.13
Terrain deformation	Wd	10.37	Waterlogged/marshy land	1.66	0.52
Wind Erosion	E		Land affected by salinity	2.04	0.65
Loss of top soil	Wt	4.35	Shifting cultivation area	3.51	1.11
Loss of top soil/ terrain deformation	Et/Ed	3.24	Degraded notified forest land	14.07	4.44
Terrain deformation/ overblowing	Ed/Eo	1.89	Degraded pastures/grazing land	2.60	0.82
Chemical Deterioration	C		Degraded land under plantation	0.58	0.18
Salinization	Cs	5.89	Sandy area	5.00	1.58
Loss of nutrients (En) – (Acid soils)	En	16.03	Mining/industrial wasteland	0.12	0.04
Physical Deterioration	P		Barren rocky/stony/sheet rock	6.46	2.04
Water logging	Pw	14.29	Steep sloping area	0.77	0.24
Others			Snow covered/glacial area	5.58	1.76
Ice caps/Rock outcrops/Arid mountain	I/R/M	8.38			
Total		**147.75**	Total	63.85	20.16

Source: NRSA and MoRD 2000 as cited in ICAR-NAAS (2010)

In 2010, the estimates of NBSS&LUP and NRSA (now NRSC) were harmonised providing a figure of 120.4 m ha of degraded and desertified areas in India (Table 3.5, Fig 3.3). However, in 2016, an updated atlas on degradation was been published (SAC, 2016). Since our study was initiated in May, 2015, it is the harmonised atlas of 2010 and to an extent the atlas published by SAC (2007) that has formed the basis of selection of our study states and sites (see Volume II). The SAC (2016) atlas became available only at the conclusion of our study.

Table 3.5 Harmonised degradation and desertification status of India

Process of degradation/desertification	Area (mha)	% of geographical area
Water erosion	30.24	25.12
Wind erosion	4.54	3.77
Acid soil	17.93	5.45
Alkali/Sodic soil	3.7	1.13
Saline soil	2.73	0.83
Waterlogged Areas	0.91	0.28
Mining/Industrial	0.26	0.08
Total	**120.4**	**36.63**

Source: ICAR-NAAS (2010)

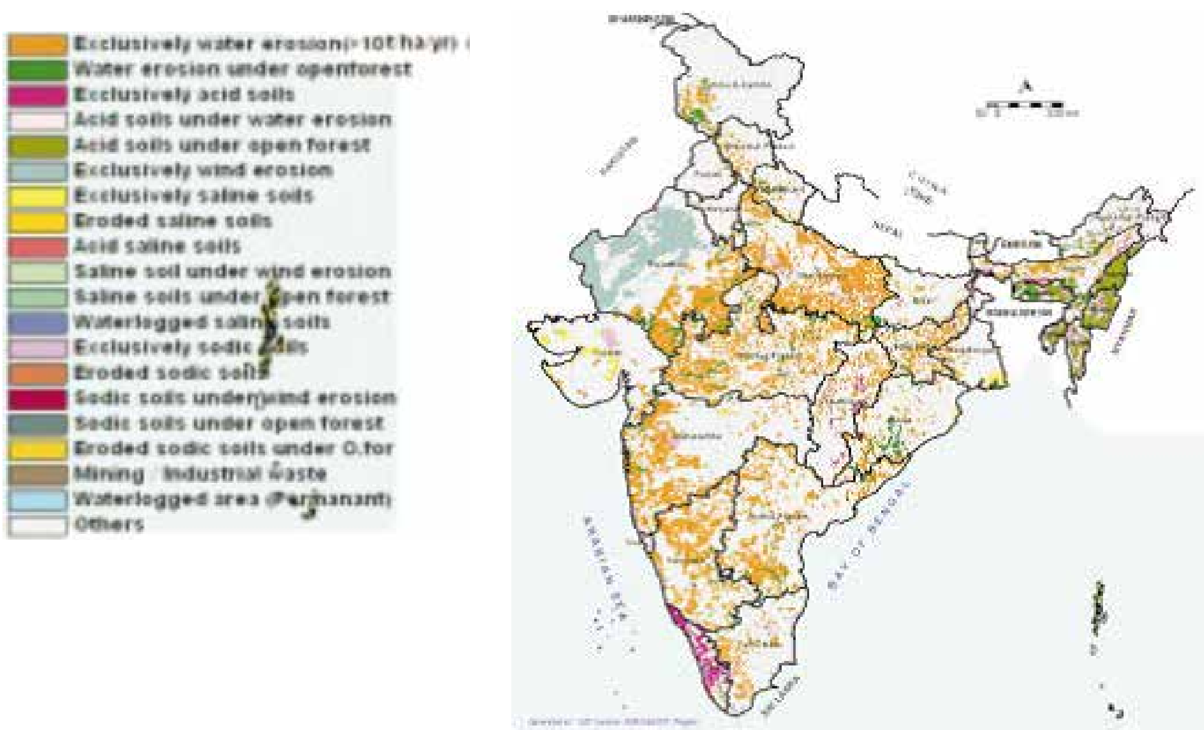


Figure 3.3 Degraded and wastelands of India

Source: ICAR-NAAS (2010)

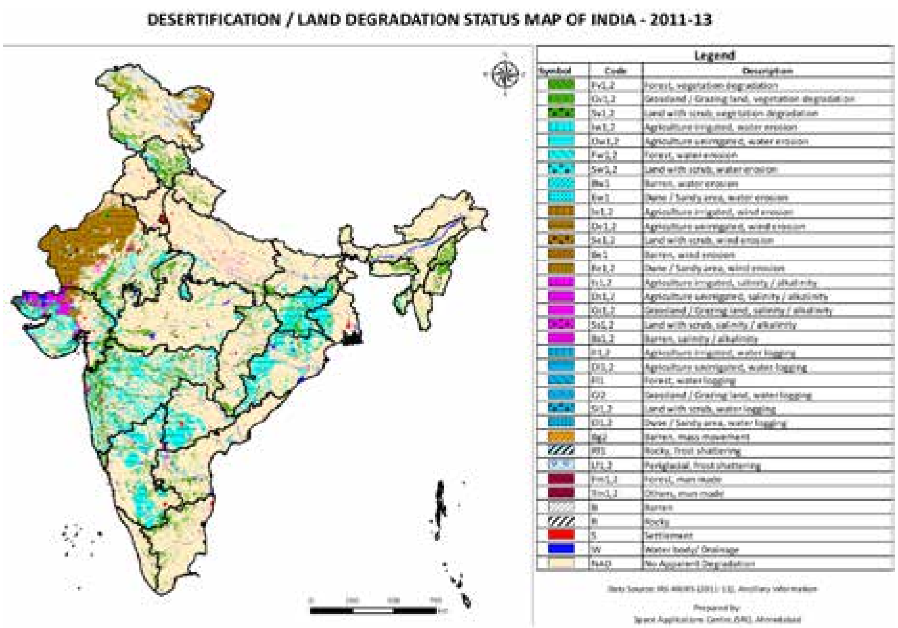
The Space Applications Centre (SAC) in 2016 estimated that India had 96.54 m ha under desertification and land degradation in 2011/2013, an increase of 1.87m ha since 2003/05 (Table 3.6). Based on these latest figures, almost 30% of the country is impacted by desertification and land degradation (SAC, 2016) of which water erosion accounts for 10.98% followed by vegetation degradation at 8.91% of India's geographical area.

Table 3.6 Degradation and desertification status of India

Process of Desertification/ land degradation	2011/13		2003/05		Change (in mha) between 03/05 and 11/13
	Area (mha)	**Area (%)**	**Area (mha)**	**Area (%)**	
Vegetation Degradation	29.3	8.91	28.28	8.6	1.02
Water Erosion	36.1	10.98	35.61	10.83	0.49
Wind Erosion	18.23	5.55	18.35	5.58	-0.12
Salinity	3.67	1.12	4.01	1.22	-0.34
Water Logging	0.65	0.2	0.6	0.18	0.05
Frost Shattering	3.34	1.02	3.11	0.95	0.23
Mass Movement	0.93	0.28	0.84	0.26	0.09
Manmade	0.41	0.12	0.37	0.11	0.04
Barren/Rocky	1.89	0.57	1.88	0.57	0.01
Settlement	1.88	0.57	1.48	0.45	0.4
Total Area under Desertification	**96.4**	**29.32**	**94.53**	**28.76**	**1872523**
No Apparent degradation	226.73	68.97	228.68	69.57	-1954372
Total Geographical Area (mha)	328.72				

Source: SAC, 2016

A. 2011-2013



B. 2003-05

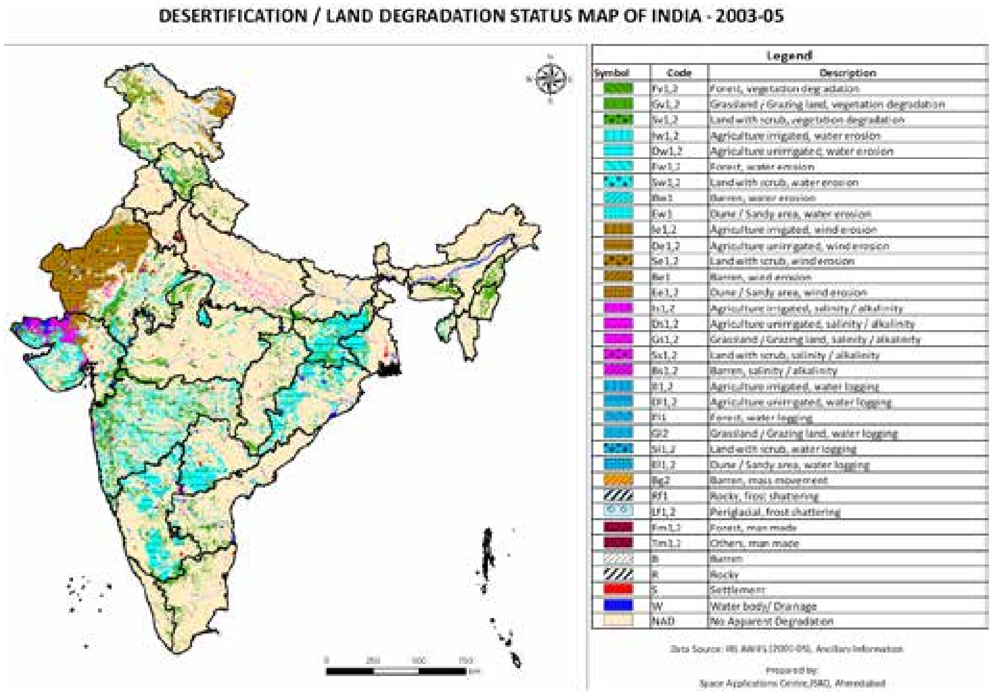


Figure 3.4 Desertification/Land degradation status map of India a. 2011/13 and b. 2003/05

Source: SAC (2016)

In terms of vegetal degradation, earlier SAC (2007) figures provided a value of 31.66 M ha which has decreased to 29.3 M ha in the latest estimate (SAC, 2016). According to SAC (2007) much of this vegetal degradation occurred in NE India. However, ICAR (2010) did not include a separate category of vegetal degradation and the State of India report (FSI, 2015) also does not refer to any increase in forest degradation or decreases in forest cover. However, SAC (2016) indicates an increase in 1.02 m ha in vegetal degradation from 2003-2005, and it is the second most important cause of degradation in India[10]. Moreover, according to Le et al. (2014) using NDVI data, about 16% of India (47 million ha) showed declining NDVI trends between 1982 and 2006 of which 12 million ha is forests and 29 mha comprises croplands.

3.3.1 Change in land use patterns

Details of changes in land use patterns are provided in Chapter 4. Here we include the results of land use changes presented by Mythilli and Goedecke (2016) using MODIS data (Table 3.7). According to Mythilli and Goedecke (2016), MODIS data indicates a decline in forest cover between 2001 and 2009. Kerala, Madhya Pradesh and Andhra Pradesh account for the largest share of this decline in forest area. There has also been a decrease in woodlands[11] and barren lands by 3.2 million ha. However, croplands, followed by grasslands and shrublands have seen the greatest increase in areas over this time period

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[10] But this has declined from the figures provided in SAC (2007)

[11] According to this study, a forest is defined as, "Woody vegetation with height >2 m and covering at least 60 % of land area. Forest trees divided into three categories: (i) Deciduous Broadleaf—broadleaf trees that shed leaves in annual cycles. (ii) Deciduous Needleleaf—as deciduous broadleaf but with narrow leaves. (iii) Evergreen Broadleaf Forests—broadleaf trees that remain green foliage throughout the year. (iv) needleleaf evergreen— like evergreen broadleaf but with narrow leaves". A woodland is defined as, "Biome with tree cover of 5–10 %, with trees reaching a height of 5 m at maturity". According to the Forest Survey of India (FSI), any 1 ha area with a canopy density >10% is considered to be a forest.

(Table 3.7). Degradation of India's agricultural lands, forest lands and rangelands are of serious concern due to increasing populations coupled with declining agricultural productivity. In case of forests, widespread loss of myriad ecosystem services and biodiversity have enormous social, biological and economic implications for India's more than 270 million (Milne et al., 2006) forest-dependent people.

Table 3.7 Land use change between 2001 and 2009 in Indian States (without Union Territories), in thousand ha (using MODIS data)

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
Total	-2848	-2252	2048	5010	-3222	-3271	32

Source: MODIS land cover as cited in Mythilli and Goedecke (2016)
Note. "urban" was left out since no change is reported in the considered time period.

3.3.2 Types of land degradation

The major types of land degradation are described below (harmonised atlas of ICAR and NAAS, 2010).

Water erosion

Soil erosion due to water is the primary cause of land degradation in the country. Water erosion results in loss of top-soil or deformation of terrain through various processes such as gully, rill, sheet and splash erosion. The severity of soil erosion depends on several factors such as intensity of rainfall coupled with the type of slopes, soils and land use categories ICAR-NAAS (2010). A map of soil erosion due to water is provided in Fig 3.5. The top ten states with the largest percent of the State's geographical area under water erosion are provided in Fig 3.6. Uttar Pradesh and Madhya Pradesh are the most impacted by water erosion.

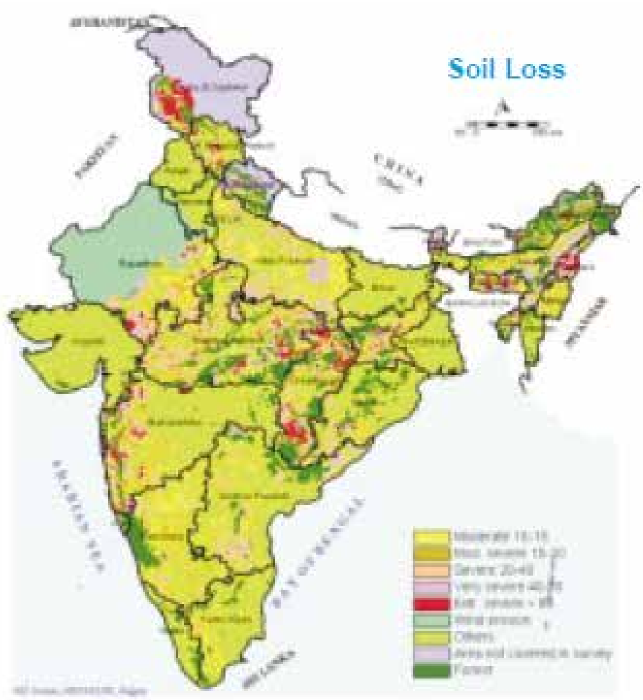

Figure 3.5 Soil loss by water erosion in India (> 10 tonnes/ha/year)

Source: Maji et al. (2008) as cited in ICAR-NAAS (2010)

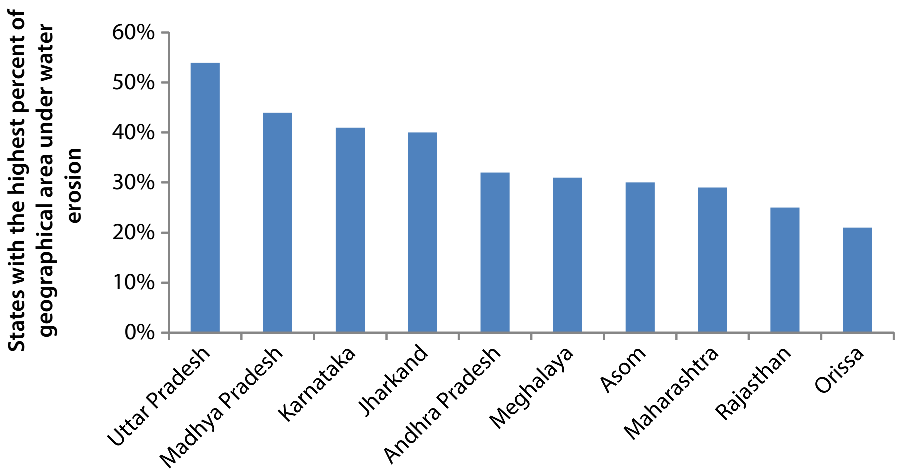

Figure 3.6 Top ten states that are most impacted by water erosion

Source: ICAR-NAAS (2010)

3.3.3 Acid soils

Acid soils are also important in the country, particularly those soils with pH <5.5 which have major impacts on soil productivity (Fig. 3.7 Acid soils are particularly important in the North-Eastern Region of the country (Fig 3.8). However, soils with higher pH that are acidic (5.5-6.5) allow crop production and support thick vegetation in the North East. Addition of lime can help reduce the acidity of soils.

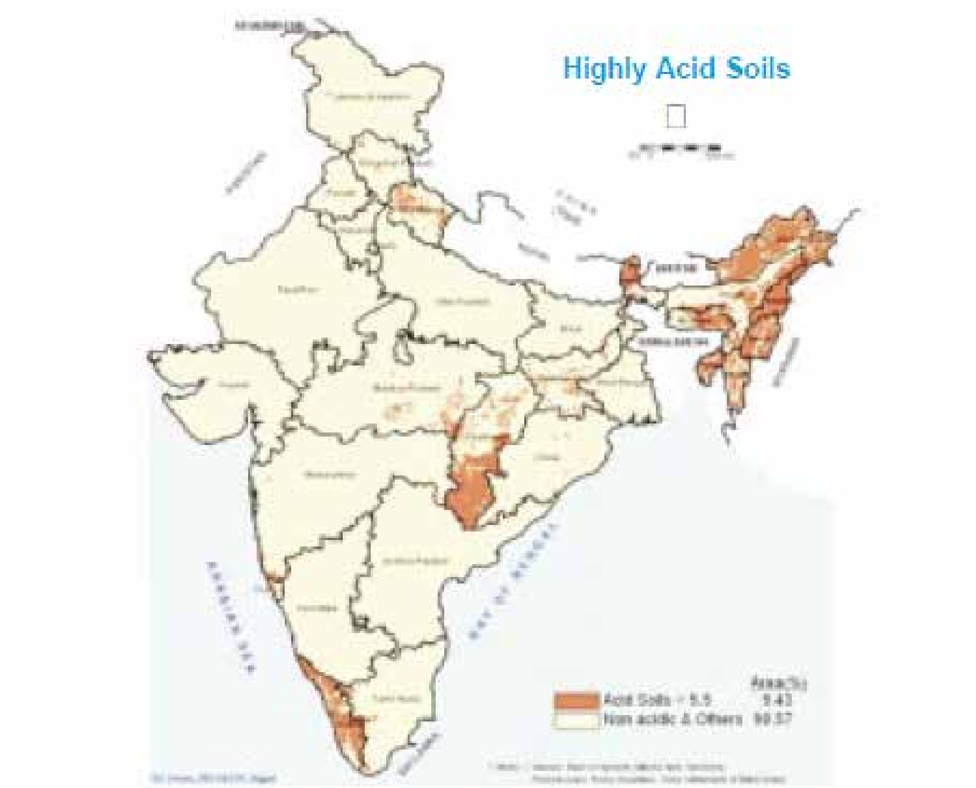

Figure 3.7 Acid soils of India

Source: Maji et al. (2008a) as cited in ICAR-NAAS (2010)

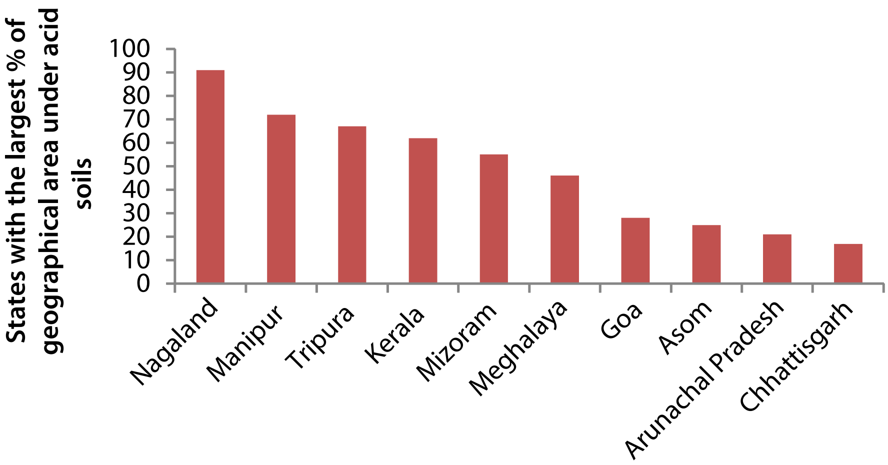

Figure 3.8 Top ten states that are most impacted by acid soils

Source: ICAR-NAAS (2010)

3.3.4 Saline and sodic soils

Salinity affects mainly coastal states (Fig 3.9) including Gujarat (8% of State's geographical area) and West Bengal (5%) apart from the Andaman and Nicobar islands (9%) followed by Orissa, Rajasthan, Maharashtra and Haryana each with 1% affected area. However, Uttar Pradesh (6%) and Haryana (4%) followed by Punjab, Gujarat and Tamil Nadu (3% each) are the most impacted by sodic soils which adversely impacts crop productivity due to changes in physical structure and nutrients.

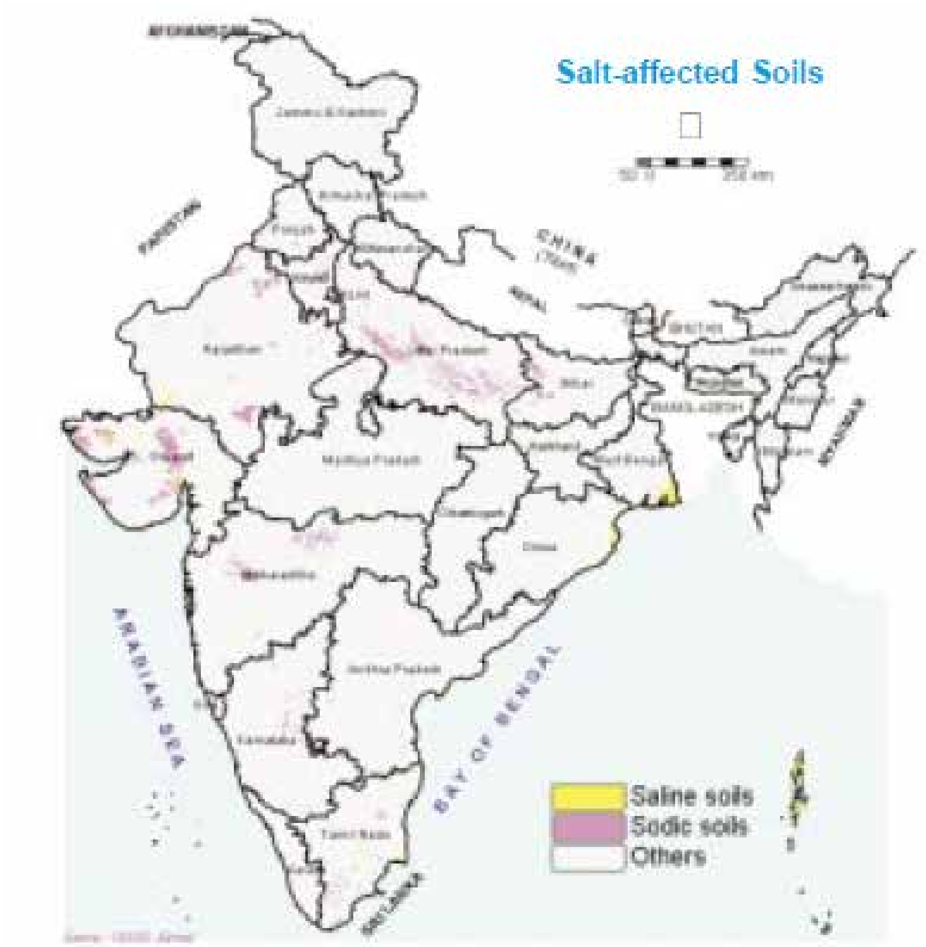

Figure 3.9 Salt-affected soils of India

Source: CSSRI, Karnal as cited in ICAR-NAAS (2010)

According to the latest atlas produced by SAC (2016), the States of Rajasthan, Maharashtra, Gujarat, Jammu & Kashmir, Karnataka, Jharkhand, Odisha, Madhya Pradesh and Telangana in descending order contribute around 23.95% (2011-13) and 23.64% (2003-05) of desertification/land degradation with respect to total TGA. The remaining states each contribute less than 1% to desertification/land degradation. In terms of the TGA of individual states however, Jharkhand, Rajasthan, Delhi, Gujarat and Goa have more than 50% of the state's area under desertification/land degradation, whereas states with less than 10% area under desertification/land degradation are Kerala, Assam, Mizoram, Haryana, Bihar, Uttar Pradesh, Punjab and Arunachal Pradesh. The change analysis carried out for 2011-13 and 2003-05 indicates that around 1.95 mha land has been reclaimed and 0.44 mha land has been converted from high severity to low severity degradation, indicating improvement. On the other hand, 3.63 mha of productive land has degraded and 0.74 mha land has converted from low severity to high severity degradation. Further, during this time frame, high desertification/land degradation changes are observed in the states of Delhi, Tripura, Nagaland, Himachal Pradesh and Mizoram (11.03-4.34 %), whereas Odisha, Rajasthan, Telangana and Uttar Pradesh have shown improvement (-0.11 to -1.27 %).

3.4 Literature review of land degradation studies for India

Relatively few studies in India have attempted to value land degradation in India, Reddy (2003) used both the loss of production and replacement cost approach to estimate the value of degradation in

India. Some studies have estimated the benefits from soil conservation through watershed development programmes in terms of productivity gains (preventative method), e.g. Ninan, (2002). A recent study by Mythili and Goedecke, (2016) used the Total Economic Value Framework (TEV) to estimate the costs of land degradation for the country resulting from land use change. Table 3.8 provides a review of some studies carried out on the costs of land degradation in India, while estimates of the impacts of soil degradation in physical terms are provided in Table 3.8.

Table 3.8 Studies carried out on the costs of land degradation in India

Study	Data period	Type	Method/Details	Results
TERI (1998)		Onsite: Loss of production due to erosion by water and wind; loss of nutrients, salinization and water logging Offsite: Loss of production due to reduced area under irrigation due to siltation of reservoirs	Loss of Production disaggregated for 3 levels of severity of land degradation and 11 crops) Value transfer	Rs. 39-232 bn = approx 11%-26% of the potential yield of the eleven crops considered
Naryana 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)	Cover agricultural land, other non-wasteland and non-forest land	Annual loss in production of major crops 13.5 million tons (3.1 % of total production)
UNDP, FAO and UNEP (1993)	1993	Soil erosion (water induced) Salinity	Only agricultural land As per FAO report	Annual loss in production 8.2 million tons (1.7% of total production) 6.2 million tons of Production loss
Sehgal and Abrol (1994)	1990s	Soil erosion (water induced)	Loss is more in red and black soil as compared to alluvium derived soil	Soil productivity decline ranges from 12% in deep soil to 73% in shallow soil
Singh (1994)	1990s	Salinity Water logging		About 50% of canal irrigated area is affected by salinity Productivity loss ranging from 40% for paddy to 80% for potato
Brandon et. Al (1996)	1990s	Soil erosion	Annual loss of 4-6-3% agricultural production	

Study	Data period	Type	Method/Details	Results
Reddy (2003)	1989	Onsite: all categories of land degradation (water and wind erosion, salinity, alkalinity, waterlogging, degradation due to cultivation practices, industry- and mining related degradation etc.)	Loss of production Replacement cost Value transfer Loss of production using a district-level production function	Loss of production: Rs 75 bn (1988) - Rs 449 (1994) Replacement cost: Rs 25 bn (1988) Rs 185 bn (1994)
Vasisht et. al. (2003)	1994-96	All types	State-wise estimates also computed	Production loss of 12% of total value of production
World Bank (2013)		Onsite: Cost of soil salinity, waterlogging and nutrients loss loss of fodder and livestock income due to due to rangeland degradation	Loss of production (Soil salinity and waterlogging) considering only wheat Replacement Cost (nutrient loss) Value transfer	Rs. 715 billion Rs. or 1.1 % of GDP in 2010 Rs. 405 billion or 0.6% of GDP in 2010
Sharda et al (2010), Sharda and Dogra (2013)		Onsite: Loss of production of major cereal, oilseed, and pulse crops cultivated on rainfed areas of India due to soil erosion by water.	Loss of production Experimental data of a crop integrated with the rainfed area of that crop under each erosion intensity category for three major soil groups (alluvial, black and red) in a state	At state level, productivity loss in rainfed cereals :0.2–10.9 q/ha oilseeds 0.1–6.3 q/ha pulses 0.04–4.4 q/ha India suffers a loss of 1.63 q/ha in productivity of rainfed crops, valued at Rs. 2,484/ha. Annual production losses of 13.4 Mt valued at Rs. 205 bn in 2011/12
Mythili and Goedecke, (2016)	2001-2009	Change in land use and land cover	Total Economic Value Framework (TEV). Value transfer from TEEB (2010)	Annual costs of land degradation due to land use and cover change in 2009 compared with 2001 is 5.35 billion USD. Share of land degradation costs in GRP is < 1%

Source: Reddy (2003), TERI (1998), World Bank, 2013, Sharda et al 2010, Sharda and Dogra, 2013 and also adapted from Mythili and Goedecke, 2016.

Table 3.9 Studies on the impact of soil erosion, salinity and water logging in India

Study	Data Period	Type	Loss	Remarks
Naryana 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	

Study	Data Period	Type	Loss	Remarks
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	Water logging	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) area used to find cost of erosion
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

Study	Data Period	Type	Loss	Remarks
Vasisht et. Al. (2003)	1994-96	All types	Production loss of 12% of total value of production	State-wise estimates also computed

Source: For some studies – Reddy (2003) and TERI (1998). Others were extracted from the respective studies. As cited in Mythili and Goedecke (2016)

Mythili and Goedecke (2016) used the TEV approach to estimate the costs of degradation (Table 3.10). According to this study, the annual costs of land degradation due to land use and cover change in 2009 compared with 2001 is 5.35 billion USD. The share of land degradation costs in GRP is <1%.

Table 3.10 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	1056.0	335.0	4.0	<1
Arunachal Pradesh	1.5	973.0	106.0	76.6	7
Assam	19.4	549.0	268.3	8.6	1
Bihar	37.1	341.0	126.1	1.2	<1
Chhattisgarh	20.8	702.0	255.2	10.0	1
Goa	6.2	2963.0	9.3	6.4	<1
Gujarat	89.4	1271.0	201.4	3.3	<1
Haryana	46.5	1615.0	4.8	0.2	<1
Jammu & Kashmir	10.1	673.0	250.9	20.0	2
Jharkhand	20.2	543.0	218.7	6.6	1
Karnataka	72.2	1044.0	244.4	4.0	<1
Kerala	48.6	1205.0	517.8	15.5	1
Madhya Pradesh	47.5	571.0	325.5	4.5	1
Maharashtra	188.6	1481.0	158.1	1.4	<1
Manipur	1.7	547.0	122.3	47.6	7
Meghalaya	2.8	900.0	126.2	42.5	5
Mizoram	1.1	869.0	193.3	176.1	17
Nagaland	2.1	989.0	92.8	46.9	4
Orissa	34.3	687.0	333.3	7.9	1
Punjab	41.9	1252.0	7.5	0.3	<1
Rajasthan	55.1	681.0	405.3	5.9	1
Sikkim	1.0	1375.0	28.7	47.0	3
Tamil Nadu	99.1	1271.0	254.1	3.5	<1
Tripura	3.2	799.0	147.3	40.1	5
Uttar Pradesh	109.2	468.0	130.1	0.7	<1
Uttarakhand	13.9	1186.0	205.1	20.3	1
West Bengal	84.8	837.0	84.9	0.9	<1
Total	**1224.3**	**922.0**	**5351.3**	**4.4**	**<1**

Source: Mythili and Goedecke, (2016) based on authors' calculation using data extracted from Government of Punjab, Department of Planning (2014); Indian Ministry of Statistics and Programme Implementation (2014); TEEB dataset; Modis land cover dataset

According to this study, the largest share of these costs of degradation are borne by Kerala, Rajasthan, Andhra Pradesh, Orissa and Madhya Pradesh while Haryana, Punjab and Goa show the lowest values. These figures, however, are based on estimates of land use and cover change and not for example on decreases in yields or productivity that results from land degradation. According to this study, north-eastern states show the highest per capita costs, particularly Mizoram and Arunachal Pradesh while Haryana and Punjab show the lowest per capita costs because the latter two states show little land use change. The share of land degradation in the regional GDP is highest for the Northern and North-eastern regions of the country. ***This macroeconomic estimate differs from ours (see chapter 4) , as we have looked at changes in crop productivity resulting from water, wind erosion and salinity, apart from loss and degradation of forest cover in estimating land degradation. This is in addition to land use and land cover change Moreover, our assessment is based on official figures provided by the government for land use change and not on MODIS data***.

Mythili and Goedecke, (2016) also calculated the cost of inaction versus cost of action for land degradation. The costs of inaction arise if land use changes from economically and environmentally productive 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 costs, given that the benefits of the biome that is being replaced need to be accounted for. Mythili and Goedecke, (2016), found that for each State in India, the cost of inaction exceeds the cost of action (Table 3.11) and the ratio of action over inaction ranges from 20-40% in humid regions and above 40% in sub humid and arid regions. They find that the costs of action are more or less equivalent for crops and grasslands as against deforestation. Nevertheless, the cost of inaction against deforestation is higher in all the states. The cost of inaction in crop and grasslands is high in Madhya Pradesh and the smallest in Punjab and Haryana. This is because in the latter two states, landuse change is low-instead degradation results from loss of productivity due to salinity brought about by high irrigation and fertilizer use. Goa also shows low costs of inaction since much of its incomes derive from tourism rather than productivity or livestock production.

In the rangelands, the loss of productivity according to Kwon et al. (2016) is estimated at a loss of 7.7 million USD (at 2007 prices) of milk and meat production due to declining grass biomass yields from rangeland degradation. More than 80% of this decline is due to loss of milk production as meat consumption is low. This study, however, does not consider forestlands which constitute more than 60% of livestock grazing areas (Kapur et al., 2010). According to Mani et al. (2012) due to grassland degradation there is 3-4 billion dollars of livestock value loss (at 2010 prices).

Reddy (2003) used a regression to understand the determinants of land degradation at the district and state levels. His dependent variable was the proportion of area degraded (due to various causal reasons) to the total geographical area of the region. The independent variables were socio-economic, demographic, technological, institutional and climatic factors. Reddy (2003) found that the rural population per ha of net sown area exerts a positive influence on degradation and therefore, regions of intensive cultivation fare better in terms of degradation than others. At the district level regressions conducted for salt affected, water logged and total degraded areas, output per ha imposed a negative influence while percentage of irrigated area and population density had a positive influence on land. ***Therefore, Reddy's studies did not show a relationship between high population density, poverty and degradation. Per capita income was not related to degradation. Moreover, more productive lands were less prone to degradation (inverse relation of output per ha to land degradation).***

Similar results that reject the relation between resource degradation and poverty have been obtained by Nadkarni, 1990, Jodha, 1986 and Reddy, 1999. Mythili and Goedecke (2016) also determined the drivers of land degradation at state and household level. They regressed the dependent variable (area affected by soil erosion) with likely influencing agricultural variables-e.g. number of cultivators per unit of area, cropping intensity, percentage of irrigated area, yield, fertilizer consumption and subsidy. At household level, the dependent variable (plot level of soil erosion with 4 possible states

Table 3.11 Cost of action and inaction against land degradation, by state (in billion USD)

State	Annual cost of L.D. 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	21.52	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

State	Annual cost of L.D. 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
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	6.57	8.9	23	Humid
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	4.226	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, agro ecological zones defined according to IISD (2015). As cited in Mythili and Goedecke, (2016).
Note. A&S means arid and semi-arid

in ranked order (none, sheet erosion, small and large gullies) were regressed against socio-demographic characteristics of households and plot-specific information. Taken together, Mythili and Goedecke, (2016)'s study suggests that agricultural industry on a larger scale drives land degradation. The larger the cultivated area and the more the crops grown, higher is the soil erosion. However, sustainable land management (SLM) prevents this, for example through the application of organic manure or use of drainage systems that enhance water use efficiency and prevent water loss. Higher levels of livestock also improve the soil condition.

3.5 Programmes and policies to reduce land degradation in India: a review of efficacy

3.5.1 India's approach to DLDD

To address the issues of desertification, land degradation and drought, India is implementing sustainable land management practices through various approaches, although it does not have a specific policy or legislative framework for combating desertification. However, India became a signatory to the UNCCD on 14 October 1994 and ratified it on 17 December 1996, while in 2010, the National Action Programme to Combat Desertification (NAP) was submitted to UNCCD that focuses on the status and impacts of desertification and initiatives taken for combating desertification. India is also preparing its New National Action Programme to Combat Desertification (NNAP-CD) keeping in view (a) The 10 year (2008-2018) Strategy of UNCCD (Decision 3/COP 8), (b) the fact that India has already undertaken a number of schemes and programmes in the recent past to address the issue of DLDD and (c) the aspirational goal of achieving land degradation neutrality. The concerns of land degradation, drought and desertification, are moreover, reflected in various policies (e.g., National Water Policy 2012; National Forest Policy 1988; National Agricultural Policy 2000; Forest (Conservation) Act 1980; Environment (Protection) Act 1986; National Environmental Policy 2006; National Policy for Farmers 2007; National Rainfed Area Authority (NRAA)- 2007), National Forest Policy as well in the objectives of sustainable land management (SLM), sustainable forest management (SFM) and sustainable agriculture[12].

Over the years several different ministries have been instrumental in implementing programmes against desertification, land degradation and drought including the Ministry of Agriculture, Cooperation and Farmers' Welfare, Ministry of Rural Development, Ministry of Water Resources and Ministry of Environment, Forests and Climate Change amongst others. Starting with the first Five Year Plan (1951-1956) which focussed on 'land rehabilitation', subsequent Five Year Plans have initiated long-term programmes for the dry lands, for drought prone areas and to enhance rainfed agriculture and reduce soil erosion. In addition, these programmes dovetail with other schemes so that convergence is achieved. While the programmes of DoLR were designed to address areas characterised by difficult terrain and preponderance of community resources, those of the Ministry of Agriculture aimed at increasing production and enhancing productivity in largely privately-owned cultivated areas.

A brief review of the centrally sponsored schemes that India has been implementing since the first Five Year Plan is provided below.

Soil Conservation in the Catchment of River Valley Projects (RVP) and Flood Prone Areas (FPR)

This scheme was launched in 1962-1963. The scheme aims at controlling the siltation of reservoirs, enhancing productivity of catchment areas through integrated planning of watersheds by appropriate measures such as vegetative hedges, contour/ graded bunding, agro-forestry, horticulture, plantation, silvi -pasture developments, pasture development, afforestation, drainage line treatments, water

[12] http://envfor.nic.in/division/unccd-india

harvesting structures and percolation tanks, covering all land uses, i. e. agricultural land, forest lands and wastelands. Only "Very High" and "High" categories of watersheds identified by Soil and Land Use Survey of India (SLUSI) formerly known as All India Soil & Land Use Survey (AISLUS) are taken for treatment under the scheme. Till 2013 about 7. 91 million ha have been covered under RVP and FPR (Pandey, 2015).

Reclamation and Development of Alkali & Acid Soils (RADAS)

The Centrally Sponsored Scheme of Reclamation and Development of Alkaline and Acid Soil was launched during the 7th Five-year-plan and is continuing in the states of Haryana, Punjab and Uttar Pradesh. It aims to improve physical conditions and productivity status of alkaline soils in order to ensure crop production. The major components include provision of irrigation and farm development like land levelling, bunding and deep ploughing, community drainage systems, application of soil amendments and organic manure. About 0.91 million ha area was covered by this programme till 2013 (Pandey, 2015).

Watershed Development Projects for Shifting Cultivation Areas (WDPSCA)

The scheme for watershed development in shifting cultivation areas was launched during 1987 -1988 covering all seven states of the north-eastern region and in the states of Andhra Pradesh and Orissa with 100% central assistance. The scheme targeted 25, 000 families practicing shifting cultivation and focussed on soil conservation and watershed management in shifting cultivation areas. The area covered by this scheme till 2013 was 0.59 million ha (Pandey, 2015).

National Watershed Development Project for Rainfed Areas (NWDPRA)

This programme was launched in 1985-86 by the Ministry of Agriculture as the National Watershed Development Project for Rainfed Agriculture which was then redesigned in the early nineties as NWDPRA, focusing on integrated watershed management and sustainable farming systems. The new programme included measures such as conservation of arable lands and development of multi-tiered vegetation consisting of grasses, shrubs and trees. The area covered by this scheme till 2013 was 11.03 million ha (Pandey, 2015).

Drought Prone Area Programme (DPAP), Desert Development Programme (DDP) and Integrated Wasteland Development Project.

The Drought Prone Area Programme (DPAP) was initiated in 1973 to '74 while the Desert Development Programme (DDP) was initiated in 1977 - 1978. These programmes adopted the watershed approach in 1987. An area of 15.2 million ha under DPAP and 9.0 million ha under DDP has been covered since the programme's inception till 2011 -2012. The Integrated Wasteland Development Projects Scheme (IWDP) of the National Wasteland Development Board in 1989 also aimed at developing wastelands on a watershed basis. An area of 10. 2 million ha was covered under IWDP from its inception to 2011 -2012. While DDP focused on reforestation to arrest the extension of hot and cold deserts, DPAP concentrated on non-arable lands and drainage lines for in situ soil and moisture conservation, agro-forestry, pasture development, horticulture, and alternate land uses. IWDP, on the other hand, adopted pasture development, soil, and moisture conservation as prominent activities on wasteland under government, community or private control. The common theme was sustainable management of land and water resources.

These flagship programmes of the Ministry of Rural Development were brought under a single umbrella- Integrated Watershed Management Programme (IWMP) in 2008 to ensure greater inter-sectoral integration and a dovetailing of strategies. The Integrated Watershed Management Programme (IWMP) focuses on sustainable land management practices. Till 2013, 59.19 mha were covered under IWMP with a financial outlay of around Rs 29,000 crores for the Twelfth Financial Plan.

The IWMP has now been brought under the PMKSY, the Pradhan Mantri Krishi Sinchayi Yojana which is managed by the Ministry of Agriculture, Cooperation and Farmers' Welfare and has been formulated by amalgamating ongoing schemes viz. Accelerated Irrigation Benefit Programme (AIBP) of the Ministry of Water Resources, River Development & Ganga Rejuvenation (MoWR,RD&GR), Integrated Watershed Management Programme (IWMP) of Department of Land Resources (DoLR) and the On Farm Water Management (OFWM) of Department of Agriculture and Cooperation (DAC). PMKSY has been approved for implementation across the country with an outlay of Rs. 50,000 crores in five years. For 2015-16, an outlay of Rs.5300 crores has been made which includes Rs. 1800 crores for DAC; Rs. 1500 crores for DoLR; Rs. 2000 crores for MoWR(Rs. 1000 crores for AIBP; Rs. 1000 crores for PMKSY.

The key features of the Integrated Watershed Management Programme are:

- Delegating powers to States: States are empowered to sanction and oversee the implementation of watershed projects within their area of jurisdiction and within the parameters set out in the guidelines.
- Dedicated institutions: There would be dedicated implementing agencies with multi-disciplinary professional teams at the national, state, and district levels for managing the watershed programmes.
- Financial assistance to dedicated institutions: Additional financial assistance are provided for strengthening the institutions at the district, state, and national levels to ensure professionalism in management of the watershed projects.
- Duration of the Programme: Project duration has been enhanced to 4-7 years contingent on the nature of activities spread over 3 distinct phases, namely, preparatory phase, work phase, and consolidation phase. Under the preparatory phase, appropriate mechanisms for adoption of participatory approach and empowerment of local institutions are developed. A Detailed Project Report (DPR) of the project is prepared with the help of local communities. This is followed by Entry Point Activities (EPAs) to establish credibility of the WDT and create rapport with the local people. The duration of this phase is one to two years. The work phase is the key phase of the programme, during which the work prescribed in the DPR is implemented. The duration of this phase is two to three years. The third and final phase of the programme is the consolidation and withdrawal phase with the duration of one to two years.
- Budget Allocation: The budget distribution for a particular watershed programme includes the administrative cost of 10 %; monitoring and evaluation - 2%, preparatory phase - 10%, work phase - 75% and consolidation and withdrawal phase - 3%. The unit cost of watershed development work is Rs. 12,000 per hectare in plain areas and Rs. 15,000/- per hectare in hilly areas.

Role of the Mahatma Gandhi National Rural Employment Guarantee Act (MNREGA)

Apart from the programmes listed above, convergence with various schemes in order to reduce desertification, land degradation and drought, has been encouraged, for example through MNREGA which ensures 100 days of unskilled manual work each financial year to every household in rural areas. Moreover, more than 60% of the work carried out under MGNREGA relates to natural resource management to mitigate DLDD in India through public infrastructure development and by creating individual/ community assets. These include water conservation and water harvesting structures to augment and improve groundwater with special focus on recharging ground water including drinking water sources, watershed management, renovation of traditional water bodies, afforestation, tree plantation and horticulture in common and forest lands, road margins, canal bunds, tank foreshores and coastal belts and land development activities in common land. At the community/ individual level, initiatives include land development provision of suitable infrastructure for irrigation including dug wells, farm ponds and other water harvesting structures, improving livelihoods through horticulture, sericulture, plantation, and farm forestry, and development of fallow or waste lands of households.

Under MGNREGS it is now mandatory to undertake at least 60% work in a district for creation of productive assets directly linked to agriculture and allied activities through development of land, water and trees. An assessment of projects indicates that 42% of activities under MGNREGS relate to water conservation, 13% to land development and another 13% to individual land. Moreover, action has been initiated to ensure convergence of IWMP and MGNREGS to achieve the goals of the MPKSY in rainfed areas, as well as developing a greening plan under MGNREGA, focus on participatory planning and a command area approach in irrigated areas to mitigate waterlogging, salinity and efficient use of water.

Green India Mission (GIM)

The Green India Mission (GIM) under the National Action Plan on Climate Change focuses on sustainable land management and restoration of areas degraded through deforestation, degradation, over-extraction of fuelwood and fodder and overgrazing. The mission objective is increased forest cover on 5 mha of forest/non-forest land and improved quality of forest cover on another 5 mha (a total of 10 mha). The specific targets are:

- qualitative improvement of forest cover/ecosystem in moderately dense forests (1.5 m ha), open degraded forests (3 m ha) , degraded grassland (0.4 m ha) and wetlands (0.1 m ha);
- eco-restoration/afforestation of scrub, shifting cultivation areas, cold deserts, mangroves, ravines and abandoned mining areas (1.8 m ha);
- bringing urban/ peri-urban lands under forest and tree cover (0.20 m ha); and d) agro-forestry /social forestry (3 m ha).
- The Mission also targets improvement of forest- based livelihoods for about three million households living in and around forests.

In the last fifty years, the Government of India through various ministries has invested more than US$ 4 billion for watershed development. Moreover, in the 11th Plan document, the Government of India placed a high priority on raising agricultural productivity to achieve annual growth of more than 4.1 %. This led to the Sustainable land and Ecosystem Management (SLEM) Programme, which is a joint initiative of the Government of India and the Global Environmental Facility (GEF) under the latter's Country Partnership Programme (CPP) with the following objectives

- Prevention and/or control of land degradation by restoration of degraded (agricultural and forested) lands and biomass cover to produce, harvest, and utilize biomass in ways that maximize productivity, as well as by carbon sequestration, biodiversity conservation, and sustainable use of natural resources;
- Enhancement of local capacity and institution building to strengthen land and ecosystem management;
- Facilitation of knowledge dissemination and application of national and international good practices in SLEM within and across states; and,
- Replication and scaling up of successful land and ecosystem management practices and technologies to maximize synergies across the UN Conventions on Biological Diversity (CBD), Climate Change (UNFCCC), and Combating Desertification (UNCCD) conventions.

3.5.2 Assessing the efficacy of these programmes to prevent DLDD

The achievements of these programmes till March (2013) are provided in Table 3.12 while the programme-wise degraded lands developed till March 2013 (in mha) is shown in Fig 3.10. Currently the IWMP accounts for 65% coverage of degraded land (Fig.3.10).

Table 3.12 Achievement and investment in various land degradation programmes till 2013

S. No	Name of Scheme	Area treated (million ha)	Investment (Rs crore)
Department of Agriculture, Cooperation and Farmers' Welfare			
1	NWDPRA	11.03	4499.9
2	RVP & FPR	7.91	3581.7

3	WDPSCA	0.59	505.8
4	RADAS	0.91	195.1
5	**EAP**	2.41	4351.5
	Total (DAC)	**22.85**	**13133.9**
Department of Land Resources (DoLR)			
	IWMP (DPAP, DDP AND IWDP)	59.19	18442.1
	Grand Total	**82.04**	**31576.1**

Source: Pandey (2015)

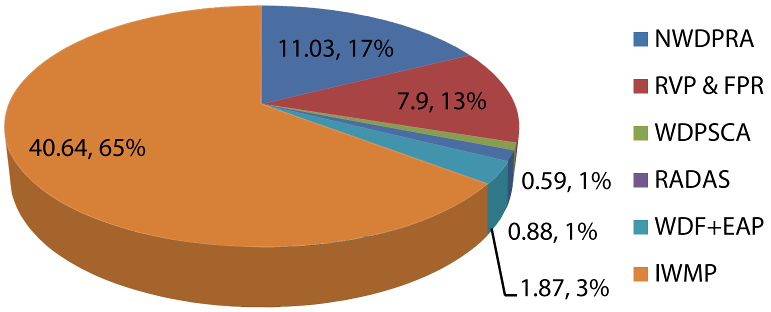

Figure 3.10 Programme-wise degraded land developed up to March 2013 (in mha)

Source: Pandey (2015)

These programmes have had many positive impacts as detailed later including prevention of soil erosion, reduction of peak rate of runoff and sediment yield, creation of water resources, enhancement of ground water, improvement of soil fertility, increased cropped area, cropping intensity and diversification as well as additional employment opportunities in rural areas (Pandey, 2015). Several new interventions have also been introduced such as promotion of agroforestry including the provision of soil testing kits, resource conservation technologies for reclamation of problem soil, rainwater conservation and development of secondary storage structures under PMKSY amongst others. The plan for degraded land development by 2030 is provided in Table 3.13.

Table 3.13 Plan for degraded land development by 2030 (leftover degraded land)

Name of Department	Programme for 15 years (2015-2030)	
	Physical (mha)	**Financial (Rs crore)**
Department of Agriculture, Cooperation and Farmers' Welfare	30	60000
Department of Land Resources	82	164000
Total (Rs.)	112	224000

Source: Pandey (2015)

Watershed programmes in India have constituted an important approach to reduce land degradation and enhance agricultural productivity in rainfed areas, as well as enhance the socio-economic and livelihood status of people. They aim to achieve this through soil and water conservation activities that enhance water storage, reduce erosion and enhance the nutrient and carbon content of soil. Increasing agricultural yields and reduced land degradation provide a collateral benefit of enhancing human welfare of agriculture-dependent communities living in rainfed areas as well as contributing to the food security of the country (Ahmad et al., 2011). Rainfed areas constitute about 65% of arable land in India and 55% of the country's agricultural output thereby supporting 40% of the nation's population (Ahmad et al., 2011) and hence are the focus of watershed programmes. This is in contrast to India's Green Revolution which focuses on areas in the plains through promotion of fertilizers, pesticides and irrigation, but which represents only 40% of India's arable lands.

More than Rs 100,000 million have been spent per annum since the 1980s on watershed and other projects. These programmes (See Table 3.14 for a chronological listing of programmes and Table 3.15 for a listing of some other programmes across States) have contributed significantly to sustainable land management- influencing ground water levels, surface water, irrigation facilities, water regeneration capacity, land use pattern, cropping pattern, livestock production, employment generation, income generation and debt reduction (e.g. Farrington et al. 1999, Kerr, 2000).Watershed development activities have also shown significant positive impacts on the water table, the perennial nature of water in wells, water availability for cattle and other domestic uses and are increasingly tapping innovations in farming systems[13] (See Box 3). Reddy et al. (2004) for example, carried out an evaluation of 37 watersheds in different agro-eco regions of the country in 2001 and found that watershed villages showed an increase in all factors sampled[14] compared to non-watershed villages. However, they found no difference based on the implementation agency.

Box 3: Tapping innovations in farming systems to reduce land degradation

The Mallapoor village in Uthnoor mandal, Adilabad district in Telengana is an example of the use of innovations for sustainable land management and climate-resilient livelihoods. In this village, the local people had shifted to growing cotton with some soya and red gram rather than mixing cotton crops with millets that had been their traditional practice. In 2010-2011, however, the local people set aside 25% of their agricultural land for millet-based, mixed-cropping systems. This along with measures like soil moisture retention and other activities under watershed development programmes has had multiple benefits-increased productivity, reduced costs through the halving of chemical fertilizers and pesticide use, and increases in application of livestock manure. In general there have been increases in cotton, food as well as fodder through plantation of tree crops. Their resilience to climate-induced changes was evident in 2013-2014 when a poor monsoon led to widespread crop losses in neighbouring villages, while Mallapoor was buffered by their mixed cropping strategies. According to people of this village, adoption of sustainable land management has increased cotton yields from 5-6 quintals per acre to 8 quintals in a bad year and 9-10 quintals in a good rainfall year.

Table 3.14 Chronology of government WSD programs and guidelines in India

Year	Program/ Policy/ Guideline	Major Objective(s)	Relevant Institution	Financial allocations	Targets and achievements
1973-74	Drought Prone Area Programme (DPAP)1	Promote economic development and mainstreaming of drought prone areas through soil and moisture conservation measures.	Ministry of Rural Development (MoRD)	209533.63 Lakhs INR (Funds released)	Since the adoption of watershed approach in the year 1995-96 till 2005-2006, 24363 projects have been sanctioned to treat 121.82 lakh hectares of drought prone area.

[13] For example, the XII Five year plan of the Government of India proposed a National Programme of Rainfed Farming that underlined the need for including 'untapped agronomic and management innovations' in farming systems

[14] physical (ground water, soil erosion, runoff reduction, etc.), biological (afforestation, cropping intensity, productivity levels of dryland crops) and socio-economic parameters (additional benefit-cost ratio, additional annuity value, etc. and additional employment and reduction in outmigration of labour, participation of farmers in watershed programmes

Year	Program/ Policy/ Guideline	Major Objective(s)	Relevant Institution	Financial allocations	Targets and achievements
					A total of 5717 projects are deemed complete and 16882 projects are ongoing. Total area treated is 65.74 lakh hectares. (Source: Department of Land Resources)
1977-78	Desert Development Programme (DDP) 2	Minimize adverse effects of drought and desertification through reforestation.	Ministry of Rural Development (MoRD)	3817.68 Crores INR (sanctioned) 1568.79 Crores INR (Funds released)	Total area treated under DDP so far is 35.31 Hectares. (Source: Department of Land Resources)
1989-90	Integrated Wasteland Development Programme (IWDP) 3	Regenerate degraded non-forest land through silvipasture and soil and water conservation on the village and micro-watershed scale.	Ministry of Rural Development (MoRD)	161454.20 Million INR	50149 watershed projects sanctioned Covered an area of 56.21 M ha 33464 watershed projects completed out of 45062 projects due for completion (74%) 680 million man days generated (Source: Department of Land Resources)
1989	Integrated Afforestation and Eco-Development Scheme (IAEPS) 4	Restore and regenerate the ecological balance of degraded forests on a watershed basis using a participatory approach.	Ministry of Environment, Forest and Climate Change (MoEF&CC) and State Forest Department	Financial Targets (in crores INR): 1992-93 – 32.62 1993-94 – 42.97 1994-95 – 51.57	Physical targets and achievements: Target (in ha) 1992-93 – 60,000 1993-94 – 64,000 1994-95 – 94,710 Achievements (in ha): 1992-93 – 56622 1993-94 – 61345 (Source: Ministry of Environment forest and Climate Change)
1990-91	National Watershed Development Project for Rainfed Areas (NWDPRA)5	Promote sustainable natural resource management, enhance agricultural production, restore the ecological balance, reduce regional disparities, and create sustained employment opportunities in rainfed areas.	Ministry of Agriculture (MoA)	43207.80 Million INR	Watershed based interventions have led to increase in groundwater recharge, increase in number of wells and water bodies, enhancement of cropping intensity, changes in cropping pattern, higher yields of crops and reduction in soil losses. (Source: Department of Land Resources)

Year	Program/ Policy/ Guideline	Major Objective(s)	Relevant Institution	Financial allocations	Targets and achievements
1992	Indo-German Watershed Development Programme6	Rehabilitate micro-watersheds for the purpose of regeneration of natural resources and sustainable livelihoods, using a participatory approach.	National Bank for Agriculture and Rural Development (NABARD) and the Watershed Organisation Trust (WOTR)	13.88 Million INR	The Programme has resulted in the following policy impacts: Setting up of the National Water Development Fund (WDF) at NABARD in 1999 (see above). Integration of innovative elements of IGWDP into National Watershed Development Programmes (e.g. capacity building concepts). (Source: Ministry of Environment forests and Climate Change)
1994	Guidelines for Watershed Development7	Provide common guidelines for WSD focused on the watershed scale and having a participatory focus (Represented around a third of the GOI's investment in micro-watersheds and sought to leverage the success of NGOs).	Ministry of Rural Development (MoRD)		
1999-2000	Watershed Development Fund8	Provide financial support to scale up successful participatory WSD projects in 100 priority districts; promote a more unified strategy to WSD.	Ministry of Agriculture (MoA) and National Bank for Agriculture and Rural Development (NABARD)	200 crores INR	Various Watershed Development Programmes: National Watershed Development Project for Rainfed Areas (NWDPRA), Soil Conservation in the Catchments of River Valley Project & Flood Prone River (RVP & FPR), Reclamation & Development of Alkali & Acid Soil (RADAS), Watershed Development Project in Shifting Cultivation Areas (WDPSCA) are being implemented. (Source: Department of Land Resources)
2001	Common Guidelines for Watershed Development (Revised)9	Update the 1994 WSD guidelines to have a more participatory and project- specific focus with greater flexibility in implementation. Applicable to IWDP, DPAP, DDP, and other programs notified by GOI.	Ministry of Rural Development (MoRD)		

Year	Program/ Policy/ Guideline	Major Objective(s)	Relevant Institution	Financial allocations	Targets and achievements
2002	National Afforestation Programme10	Develop forest resources using a participatory approach and build capacity of fringe communities. Formulated by the merger of IAEPS and three other forestry programs to reduce the multiplicity of schemes	Ministry of Environment, Forest and Climate Change (MoEF&CC)	29235.70 Million INR	42535Joint Forest Management Committees and 800 Forest Development Agencies have been included in the programme since inception. 1888264 hectares area has been afforested atan expenditure of Rs. 29235.7 million. (Source: Ministry of Environment, Forest and Climate Change)
2003	Hariyali Guidelines11	Integrate community institutions more meaningfully in DPP, DPAP, and IWDP and simplify procedures.	Ministry of Rural Development (MoRD)		
2005	Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS)12	Enhance livelihood security in rural areas by providing at least 100 days of guaranteed wage employment a year to every household whose adult members volunteer to do unskilled manual work (e.g. soil and water conservation, afforestation, and land development).	Ministry of Rural Development (MoRD)		Employment provided to households: 2.34838 Lakhs
2006	Parthasarathy Committee report13	The Parthasarathy Committee was established as a Technical Committee to evaluate the DPAP, DDP, and IWDP. In 2006, the Committee released a report that served as a review of India's Watershed Program. The Committee's report serves as the basis of the Neeranchal Guidelines and the NRAA.	Ministry of Rural Development (MoRD)	Maximum expenditure norm per hectare (INR): For year 1995 – 4000 For year 2000 – 6000 April 1, 2006 Onwards - 12000	Mitigating the adverse effects of extreme climatic conditions such as drought and desertification on crops, human and livestock population for the overall improvement of rural areas. Restoring ecological balance by harnessing, conserving and developing natural resources, i.e., land, water and biomass. (Source: Department of Land Resources)

Year	Program/ Policy/ Guideline	Major Objective(s)	Relevant Institution	Financial allocations	Targets and achievements
2006	National Rainfed Area Authority (NRAA)14	Create common guidelines for all WSD schemes under the different ministries for the development of rainfed farming systems.	Planning Commission		Developed common Guidelines for the Watershed Developments projects, Vision document for the national perspective plan for rainfed areas. Formats of State Strategic Plan circulated to all the states. (Source: Ministry of Agriculture and Farmers welfare)
2008	Common Guidelines for Watershed Development (Neeranchal) released15	Promote a fresh framework to guide all WSD projects in all departments and ministries.	National Rainfed Area Authority (NRAA) and Planning Commission		
2009	Integrated Watershed Management Programme (IWMP)16	Consolidated three programs: IWDP, DPAP, and DPP. Programs adopted a cluster approach focusing on a cluster of micro-watersheds (1000 ha to 5000 ha scale).	Ministry of Rural Development (MoRD)		
2009	Policy and institutional reform for mainstreaming and up-scaling sustainable land and ecosystem management in India	Prevention and/ or control of land degradation by restoration of degraded (agricultural and forested) lands and biomass cover and make sustainable use of natural resources in selected project areas;	Indian Council of Forestry Research and Education (ICFRE)	1.00 Million USD. Funding by Global Environmental Facility	A draft report on baseline study at national and eight selected states namely: Madhya Pradesh, Uttar Pradesh, Andhra Pradesh, Rajasthan, Nagaland, Uttarakhand, Kerala and Odisha have been finalized. Emerging trends based on baseline study were recorded and interpreted. The draft report of all the thematic areas was prepared for policy and institutional reform mainstreaming and up-scaling sustainable land and ecosystem management (Source: India's Fifth report to UNCCD)
2010	Enrichment of land degradation datasets with soil datasets of different states of India.	Enrichment of land degradation maps with soil/ soil loss parameters and finalisation of state wise enriched land degradation maps of India.	National Bureau of Soil Survey and Land Use Planning, Nagpur	0.60 Million rupees Funding by National Remote Sensing centre	Enriched land degradation maps at state level.

Year	Program/ Policy/ Guideline	Major Objective(s)	Relevant Institution	Financial allocations	Targets and achievements
2011	Revised Common Guidelines for Watershed Development released17	Provide amendments to the 2008 guidelines based on clarifications and suggestions from concerned ministries, departments, state governments, and NGOs.	NRAA and Planning Commission		
2013	Revisions added to 2008 Common Guidelines (known as Neeranchal Guidelines)18	Add new features to the 2008 Common Guidelines to ensure momentum to the IWMP while strengthening its innovative features.	Ministry of Rural Development (MoRD)	Unit cost for watershed development of Rs. 6000 per hectare was worked out during April 2001. During 11th Plan it has been suitably revised from Rs. 6000 per ha. to Rs.12,000/ha. in plains and Rs.15,000/ ha in difficult/hilly areas	All the works/activities that are planned for the treatment and development of the drainage lines, arable and non-arable lands in the watershed area are completed with the active participation and contribution of the user groups and the community at large. (Source: Ministry of Rural Development)
2015	Pradhan Mantri Krishi Sinchayee Yojna (PMKSY)	IWMP brought under this programme. The objective of the programme is to extend irrigation ('water to every field') and improving water use efficiency ('more crop per drop'). PMKSY has been formulated amalgamating ongoing schemes viz. Accelerated Irrigation Benefit Programme (AIBP) of the Ministry of Water Resources, River Development & Ganga Rejuvenation (MoWR,RD&GR), Integrated Watershed Management Programme (IWMP) of Department of Land Resources (DoLR) and the On Farm Water Management	Ministry of Agriculture Cooperation and Farmers' Welfare	For 2015-16, an outlay of Rs.5300 crore has been made which includes 1800 crore INR for DAC; 1500 crore INR for DoLR; 2000 crore INR for MoWR. 1000 crore INR for AIBP; 1000 crores INR for PMKSY).	Physical progress for irrigation potential created is 20,900 hectares. In terms of capacity it is 8286099 cum.

Year	Program/ Policy/ Guideline	Major Objective(s)	Relevant Institution	Financial allocations	Targets and achievements
		(OFWM) of Department of Agriculture and Cooperation (DAC). PMKSY has been approved for implementation across the country with an outlay of Rs. 50,000 crore in five years. For 2015-16, an outlay of Rs.5300 crore has been made which includes Rs. 1800 crore for DAC; Rs. 1500 crore for DoLR; Rs. 2000 crore for MoWR(Rs. 1000 crore for AIBP; Rs. 1000 crores for PMKSY).			

Source: Ministry of Agriculture and Farmers Welfare

Table 3.15 (a) Listing of some state-specific schemes to reduce land degradation

S. No.	Schemes
1	Efficacy and economics of water harvesting devices in controlling run-off losses and enhancing biomass productivity in Aravalli ranges. Main objective was to study the potential impacts of different rain water harvesting (RWH) devices in controlling run off losses in different topographical conditions and to study the viability of rain water harvesting devices for their adoption in large scale utilisation of data in assessing land degradation and rehabilitation programme. The Implementing Agency is Arid Forest Research Institute (AFRI), Jodhpur. It covers District Banswara in Rajasthan and the committed amount is **1.56 million INR**. It has resulted in preparation of RWH structures enhanced water availability increased vegetal production and soil organic carbon.
2	**Study of characteristic features pertaining to bio drainage potential of some selected tree species.** The main objectives were to understand the perspective of trees in providing drainage under a given agro-ecological conditions and identify potential tree species for bio drainage in the region, to evaluate the capacity of plants to tolerate water logging and soil salinity and understand their adaptability mechanism also to provide useful data and parameters that can guide planning and design of bio drainage schemes and their management at regional level. The implementing Agency is Arid Forest Research Institute (AFRI), Jodhpur. The project is implemented in Rajasthan with the committed amount of 4.45 million INR. As a result of this project *Prosophis juliflora*, *Tamarix dioica* and *Saccharum munja* have come up in the area with recession of ground water table as natural succession and contributed significantly for further lowering of ground water table and increasing productivity.
3	Development of economically viable and integrated agro forestry models for Arid Region. The project was implemented in Rajasthan and Budget allocated was **1.06 Million INR**. The main objective was to study the effect of different tree species on soil fertility and soil physical characteristics. It was found that performance of *Ziziphus mauritiana* species was found the best among horticulture species, while *Colophospermum mopane* was the best in silvicultural species.

S. No.	Schemes
4	**Effect of fertilizer application on growth and yield of 10 years old *Salvadora persia* and *Aacia ampliceps* plantations under silvipastoral system on arid salt affected soil.** Main objective of the project was the improvement of productivity of salt affected degraded lands by introduction of silvipastoral systems. The project was implemented by Arid Forest Research Institute (AFRI), Jodhpur in the state of Rajasthan with the allocated budget of **0.66 Million INR.** After treating the *Salvadora persica* with the fertilizer it was recorded that the fruiting has increased from 36% to 78%.
5	Productivity and biometric studies on some important species in semi-arid regions for their sustainable management. The project was started with the objective to develop growth and yield models for sustainable management of plantations of selected species in semi-arid areas of Rajasthan by Arid Forest Research Institute (AFRI), Jodhpur. Funded by Rajasthan State Forest Department **(0.55 Million INR**). Outcome of this work shall help the State Forest Departments, planters and other interested groups in management and planning.
6	Enhancing productivity of saline wastelands in Kachchh through improved tree planting techniques and silvipastoral study. The objective was to study the relationship between survival rates of different tree and grass species and plantation techniques with reference to highly saline areas, to find out the best planting technique and optimum level of amendments and fertilizers and also to improve the productivity of degraded lands by introduction of silvipastoral system. The study was carried out by Arid Forest Research Institute (AFRI), Jodhpur, in the state of Gujarat with the allocated budget of **0.76 Million INR**. In this study, *Salvadora persica* proved to be the best plant surviving in the extremely harsh conditions of high salinity.
7	Identification of soil vegetation relations and indicator species for assessment and rehabilitation in lower Arravali of Rajasthan. The main objective was study of vegetation structure and indicator species on dominant soil types and utilization of the data in assessing land degradation and rehabilitation programme. The project was implemented by Arid Forest Research Institute (AFRI), Jodhpur in Barnasknatha, Sabakantha in Gujarat and Banswara, Rajsamand and Pali in Rajasthan with the allocated budget of **1.17 Million INR**. It has helped in identifying indicator species suitable for ecosystem health and hill slope hydrology and useful in adopting management strategies in rehabilitation and control of land degradation.
8	Nationwide mapping of land degradation at 1:50,000 scale. Objective was Preparation of a land degradation map of the five districts (Jaislamer, Bikaner, Ganganagar, Hanumangarh, Churu districts) of western Rajasthan as a part of Nation-wide mapping at 1:50,000 scale by Central Arid Zone Research Institute, Jodhpur with funding of **3.25 Million INR** by Global Environmental Facility. As a result of this project, land degradation map for five districts of western Rajasthan (Churu, Hanumangarh, Ganganagar, Bikaner and Jaisalmer) has been prepared using multi-temporal resourcesat-1 LISS-III data of kharif (2005), rabi (2006) and zaid seasons (2006) and field survey.
9	**Plantation and green belt development around Chandrapura Thermal Power Station, Chandrapura, Dhanbad.** Main objectives were the establishment of permanent Hi-Tech Nursery and Plantations along the ridges and slopes and maintenance of these plantations. Institute of Forest Productivity is the Nodal Agency for this project and the project area is Chandrapura region in the district of Dhanbad, Jharkhand with the allocated budget of **7.30 Million INR**. Project resulted in establishment of a high-tech nursery and raising of planting stocks at Chandrapura of *Acacia mangium, A. auriculiformis, Albizia lebbeck, Alstonia' scholaris, Azadirachta indica, Bombax ceiba, Bauhinia variegata, Delonix, regia, Dalbergia sissoo, Eucalyptustereticornis, Gmelma arborea, Melia azedarach, Sesbania grandiflora, Pongamia pinnata, Syzygium cum ini, Terminalia arjuna, Swietenia mahagoni, Spathodeacampanulata, Peltophorumferrugineum* and *Anacardium occidentale* etc.
10	**Uttarakhand decentralised watershed development project.** Objective was to improve the productive potential of natural resources and increased incomes of rural inhabitants in selected watersheds through socially inclusive, institutionally and environmentally sustainable approaches. The project was implemented by Uttarakhand Watershed management Directorate, the allocated budget was **77.60 Million USD** funded by World Bank Group. This has resulted in a 10% increase in house hold real income due to project intervention in targeted villages.

S. No.	Schemes
11	**Sustainable land, water and biodiversity conservation and management for improved livelihoods in Uttarakhand.** The main objective of this project was to improve the productive potential of the natural resources and increase incomes of rural inhabitants in selected watersheds through socially inclusive, institutionally and environmentally sustainable approaches. It was implemented by Uttarakhand watershed management Directorate funded by Global Environment facility. The allocated amount was **7.49 Million USD**. It resulted in Sustainable watershed management mainstreamed into village-level watershed development plans including parts of micro-watersheds lying outside the boundaries of the village and improved biodiversity in qualitative and quantitative terms at watershed level.
12	**Reversing environmental degradation and rural poverty through adaptation to climate change in drought stricken areas in southern India: A hydrological unit pilot project approach.** The geographical boundary of the project is the State of Andhra Pradesh (AP) in India. It is implemented by Bharathi Integrated Rural development Society with an allocated budget of **1.30 Million USD** funded by Global Environment Facility. It provided a platform for land based climate change adaptation measures suitable to drought prone areas developed; adoption of a package of methods, tools and institutional approaches in support of District and State level natural resource management initiatives to address the impacts of drought.
13	**Integrated land and eco-system management to combat land degradation and deforestation in Madhya Pradesh.** Main objective was to Address the regulatory and institutional constraints to mainstreaming of biodiversity conservation into agricultural activities surrounding protected areas and integration of biodiversity and land degradation concerns into national level policies and regulatory. The project was implemented by Madhya Pradesh Forest Department with an allocated budget of **260.00 Million USD** funded by Global Environment facility. It resulted in the rehabilitation of degraded bamboo forests (11,515 ha) treated so far by 789 poor families, 200,000 medicinal plant species for home garden were distributed.
14	**Participatory natural resource management project, Madhya Pradesh.** The project was started with the objective to enhance the capacities and self-help potential of the villagers to enable them to manage successfully the implementation and the continuation of the watershed project and to create income possibilities for tribal families. The project was implemented by Watershed Organisation Trust, Pune (Maharashtra) covering 4 villages in the district Jabalpur (Kundam and Jabalpur Block), 2 villages in the district Mandala (Niwas Block) and 2 villages in the district Katni (Dheemarkheda Block) with an allocated budget of **0.67 Million Euro**. The main achievement of this project was that all inhabitants of the area benefited from the regeneration of the ecological balance, from improved working and income possibilities and a strengthening of local markets.
15	**Natural resource management along watershed lines.** The objective was to enhance capacities of communities living in the selected cluster of villages for creating income possibilities through restoration, conservation of natural resources and improvement of their livelihood basis. The project was implemented by Watershed Organisation Trust, Pune (Maharashtra) and covered 4 Villages from Mandala District (Bijadandi block - Kalpi Cluster), Madhya Pradesh. The financial allocations were **16.15 Million INR** funded by RBS Foundation, India. The overall impact of the project interventions at the village level resulted in mitigating the problems of water scarcity, food insufficiency, unemployment, drudgery, low and unstable income flows, absence of local collective leadership, illiteracy and health.
16	**Integrated watershed management project (Mahaboobnagar District, Andhra Pradesh).** Objective was to improve rural livelihoods through participatory watershed development with focus on integrated farming systems for enhancing income, productivity and livelihood security in a sustainable manner. The Nodal agency is Watershed Organisation Trust, Pune (Maharashtra) covering 7 villages from Mahboobnagar. Allocated funds are **91.8 Million INR** funded by Government of Andhra Pradesh. As a result of this project all members of the Watershed Committee and staff have been imparted training to improve their knowledge and upgradation of technical/management skills for the successful discharge of their responsibilities. There is an increase in the groundwater table due to enhanced recharge by watershed interventions.

S. No.	Schemes
17	**Centrally sponsored programme of soil conservation in the catchments of River Valley Project & Flood Prone River (RVP&FPR).** Main objectives of programme are to prevent land degradation by adopting multi-disciplinary integrated approach for soil conservation and watershed management in catchment areas; to improve land capability and moisture regime in watersheds, to promote land uses to match land capability; and to prevent soil loss from catchments to reduce siltation of multipurpose reservoirs and enhancing in-situ moisture conservation and surface rainwater storages in catchments to reduce flood peaks and volume of runoff. The project is implemented by Department of Agriculture & Cooperation, Ministry of Agriculture. Allocated budget is **34306.84 Million INR** funded by Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India. These watershed interventions are effective in prevention of soil erosion, land degradation and conservation of rain water.
18	**Swan River integrated watershed management project, Una Himachal Pradesh.** The project is implemented by Himachal Pradesh Forest Department with the allocated budget of **2140 Million INR**. The major achievements include enhancement of forest cover and agriculture production, Reduction in soil erosion and improvement in moisture regimes and thereby improvement in ecological conditions of Swan River Catchment, Reduction in and intensity of flooding and Reclamation of private & government land.
19	**Sustainable participatory management of natural resources to control land degradation in the Thar Desert ecosystem.** Main objective was to help arrest land degradation that is compromising the functions and service of the Thar Desert ecosystem and the livelihoods of its inhabitants and to decrease the trend and severity of degradation, improve biodiversity, promote resilience to climate change including variability, and enhance the carbon stored at above-ground and below-ground levels. Jal Bhagirathi Foundation is the implementing agency with a financial allocation of **14.70 Million USD** funded by United Nations Development Programme and Government of Rajasthan. The main achievements are that over 10,000 ha of agricultural land has come under sustainable land management practices; 2,500 farmers adopted coping mechanism for climate variability and change, improved land and water management practices applied on 500 ha degraded coastal land; productivity in 90 ha of saline land enhanced through land shaping; innovative SLEM approaches and techniques in agriculture.
20	**Gujarat forestry development project Phase II.** Main objective is to restore degraded forests and improve livelihood for and empower the local people who are dependent on forests by promoting sustainable forest management including JFM plantation and community/tribal development, thereby improving environment and alleviating poverty. The project is implemented by Gujarat State Forest Department with financial allocation of 20923 Million Japanese Yen funded by Japan Bank for International Cooperation. Major achievements include Conservation of the existing dense forests with their biodiversity and wildlife in the project area and restoration of the degraded forests and augmenting productivity of forests.
21	**Tripura forest environmental improvement and poverty alleviation project.** Focuses on restoring degraded forests and improving the livelihoods of the people, especially the tribal population engaged in traditional shifting cultivation. Nodal Agency is Tripura Forest Department covering 66180 Hectares of Area with allocated amount of **7725 Million Japanese Yen** funded by Japan Bank for International Cooperation and Government of Sikkim.
22	**Sikkim biodiversity conservation and forest management project.** The main components of the project include: forest and biodiversity conservation, inventory and monitoring of biodiversity, study of impacts of climate change and grazing in the Himalayan ecosystem, management plans and conservation of flagship species habitats, enhancement of working plans and establishment of forest management zones, inscription process of Khangchendzonga Biosphere Reserve on the world heritage list, ex-situ conservation and promotion of biodiversity conservation, knowledge generation and dissemination of biodiversity and best practice information; promotion of ecotourism; community participation and joint forest management and organizational strengthening of the Forest Department. The Nodal Agency for implementation is Sikkim Forest, Environment and Wildlife Management Department with allocated budget of **2800 Million INR** funded by Japan Bank for International Cooperation and Government of Sikkim. The project has resulted in

S. No.	Schemes
	inventorization of biodiversity, report on status of flagship wildlife species and their habitats, climate change impacts on vegetation and impacts on biodiversity and also development of ecotourism in 10 forest fringe villages through formation of a cadre of guides and support staff from within the village community.
23	**Odisha Forestry Sector Development Project.** The project aims to promote sustainable forest management, and poverty alleviation through creation of livelihood options, infrastructure for income generating activities duly linked with forest conservation in the project area. It is implemented by Odisha Forest department and covers an area of 200000 ha. The financial allocation is **13937 Million Japanese yen** and **1008.80 Million INR** funded by Japan Bank for International Cooperation and Government of Odisha. The project includes restoration of degraded forests (196,650 ha in 11 divisions), coastal plantations (2,810 ha in 2 divisions), biodiversity management (ecotourism development in five sites, establishment of community reserves/heritage sites), community/tribal development (entry point activities, income generation activities, livelihood improvement and formation of 2,275 VSSs and 4,550 SHGs).

Source: Elucidation of India's Fifth National Report to UNCCD

Table 3.15 (b) Additional listing of some state-wise programmes to reduce DLDD

S. No	Project/Programme	Area	Investment
1	Efficacy and economics of water harvesting devices in controlling run-off losses and enhancing biomass productivity in Aravali ranges.	District Banswara, Rajasthan	▯ 1.56 million
2	Study of characteristic features pertaining to bio-drainage potential of some selected tree species	Rajasthan state	▯ 4.45 million
3	Mycorrhizal dependency and productivity of economic important medicinal plants (Mehandi & Ashwagandha) of arid zones	Rajasthan, Gujrat and Dadar Nagar Hawali	▯ 0.20 million
4	Development of economically viable and integrated agroforestry models for arid region.	Rajasthan	▯ 1.06 million
5	Effect of fertilizer application on growth and yield of 10 years old *Salvadora persica* and *Acacia ampliceps* plantations under silvipastoral system on arid salt affected soil	Rajasthan	▯ 0.66 million
6	Productivity and biometrics studies on some important species in semi arid regions of Rajasthan for their sustainable management	Rajasthan	▯ 0.55 million
7	Enhancing productivity of saline wastelands in Kachchh through improved tree planting techniques and silvipastoral study	Gujrat	▯ 0.76 million
8	Characterization and classification of forest soils of Rajasthan	Rajasthan	▯ 0.75 million
9	Identification of soil-vegetation relations and indicator species for assessment and rehabilitation in lower Aravalli of Rajasthan	Banasknaths, Sabakantha in Gujrat and Banswara, Rajsamand and Pali in Rajasthan	▯ 1.17 million
10	Impact of *Prosopis juliflora* on biodiversity, rehabilitation of degraded community lands and as a source of livelihood for people in Rajasthan State	Rajasthan	▯ 0.80 million

S. No	Project/Programme	Area	Investment
11	Enrichment of land degradation datasets with soil datasets of different states of India	Whole country	▯ 0.60 million
12	Policy and institutional reform for mainstreaming and up-scaling sustainable land and ecosystem management in India	Different states and Union territories of India	1.00 million USD
13	Nationwide mapping of land degradation at 1:50000 scale	Jaisalmer, Bikaner, ganganagar, Hanuman garh and Churu districts of Rajasthan	▯ 3.25 million
14	Plantation and green belt development around Chandrapura Thermal Power Station, Chandrapura, Dhanbad	Chandrapura region in the district of Dhanbad, Jharkhand	▯ 7.30 million
15	Uttarakhand decentralized watershed development project (UDWDP)	Uttarakhand	77.60 million USD
16	Sustainable land, water and biodiversity-conservation and management for improved livelihood in Uttarakhand	Uttarakhand	7.49 million USD
17	Reversing environmental degradation and rural poverty through adaptation to climate change in drought stricken areas in Southern India: A hydrological unit pilot project approach	Rudravarnam Mandal, Kurnool, Uppununthala Mandal, Mahabubnagar, Marakpur mandal, Chittor, Kasinayana mandal, Kadapa, Ardheevu mandal, Prakasam, Thiparthy mandal, Nalgonda, Gooty mandal, Anantpur Districts	1.30 million USD
18	Integrated land and eco-system management to combat land degradation and deforestation in Madhya Pradesh	Madhya Pradesh forest department- community forest management project, Bhopal and the DFO north Betul, west betul, West Chhindwara, South Chhindwara, East Chhindwara, Sidhi, Singroli and Umariya	260.00 million USD
19	Participatory natural resource management project, Madhya Pradesh	4 villages in district Jabalpur, 2 villages in district Mandala and 2 villages in the district Katni	0.67 million Euro
20	Poverty reduction through community based natural resource management for livelihood opportunities in rural areas	7 villages from Aurangabad district	▯ 28.07 million
21	GRAMODAYA sustainable livelihood project	30 villages from Dhule District (Sakri block)	▯ 75.44 million
22	Natural resource management along watershed lines	4 villages from Mandala district, Madhya Pradesh	▯ 16.15 million

S. No	Project/Programme	Area	Investment
23	Participatory natural resource management and village development project, Rajasthan	11 villages from Udaipur District, Rajasthan	0.59 million Euro
24	Wasundhara Sunahara kal participatory village development project based on natural resource management	7 villages, Pune District	₹ 35.22 million
25	Sukhi Baliraja initiatives	24 villages from Wardha District	₹ 163.60 million
26	Climate change adaption in rural Maharashtra	49 villages from Maharashtra (Ahmednagar and Aurangabad districts), Madhya Pradesh (Mandla District) and Andhra Pradesh (Kurnool and Mahboobnagar district)	₹ 318.23 million
27	Integrated watershed management project (Kurnool District, Andhra Pradsh)	8 villaages from Kurnool District (Atmakur block), Andhra Pradesh	₹ 126.23 million
28	Integrated watershed management project (Mahaboobnagar District, Andhra Pradesh)	7 villages from Mahaboobnagar district (Amangal block, Andhra Pradesh)	₹ 91.80 million
29	Public-Private-Civil Society Partnership (PPCP) under MREGS in Jalna District, Maharashtra	56 villages from Jalna district (Jafrabad and Bhokardan block), Maharashtra	₹ 36.54 million
30	Public-Private-Civil Society Partnership (PPCP) under MREGS in Amravati District, Maharashtra	18 villages from Amravati District (Nandgaon Khandeshwar block), Maharashtra	₹ 11.67 million
31	Participatory natural resource management along watershed lines in Rajasthan	2 villages – Dungarpur District and Block, rajasthan	₹ 6.32 million
32	Watershed development fund	3 villages from mahaboobnagar district (Narayanpeth block), Andhra Pradesh	₹ 30.85 million
33	Climate change adaptation in rural Maharashtra	25 villages from Ahmednagar district of maharashtra (Sangamner and Akole block) Maharashtra	₹ 318.23 million
34	Community mobilization for the poverty alleviation through integrated watershed development	3 villages from Ahmednagar district of Maharashtra (Akole block) Maharashtra	₹ 30.95 million
35	National afforestation programme		₹ 29235.70 million

S. No	Project/Programme	Area	Investment
36	Integrated watershed management programme (IWMP)	Whole country	▯ 161454.20 million
37	Centrally sponsored programme of soil conservation in the catchments of river valley projects and flood prone river (RVP & FPR)	27 states namely except Goa	▯ 34306.84 million
38	Centrally sponsored programme of national watershed development project for rainfed areas (NWDPRA)	Programme is being implemented in all states & two union territories (Andaman & Nicobar Islands and Dadra &b Nagar Haveli)	▯ 43207.80 million
39	Swan river integrated watershed management project, Una Himachal Pradesh	District Una, Himachal Pradesh	▯ 2140.00 million
40	Sustainable rural livelihood security through innovations in land and ecosystem management		14.70 million USD
41	Sustainable rural livelihood security through innovations in land and ecosystem management	Whole country	96.07 million USD
42	Gujarat forestry development project – Phase II	Gujarat	20923.00 Million Japanese Yen
43	Odisha forestry sector development project	Odisha	13937.00 million Japanese Yen and Rs. 1000.80 Million
44	Sikkim biodiversity conservation and forest management project	Sikkim	▯ 2800.00 Million
45	Rajasthan forestry and biodiversity project – Phase II	15 Districts of Rajasthan	15749.00 Million Japanese Yen
46	Tripura forest environmental improvement and poverty alleviation project	Entire state	7725.00 Million Japanese Yen
47	Indo-German watershed development programme- Phase III	29 WS projects (64 villages) from Dhule, Nagpur, Nandurbar, Nashik and Wardha	▯ 13.88 million

Source: [1] Bhandari et al. 2007; 2 Press Information Bureau, 2005; 3 Department of Rural Development, 2013 and Rural Development Department, Haryana, 2013; 4 Forests and Environment Department, 2013; 5Department of Agriculture and Cooperation, 2012; 6 NABARD, 2007; 7 Turton and Farrington, 1998; 8NABARD, 2006; 9 Department of Land Resources, 2012; 10 National Afforestation & Eco-Development Board 2009; 11 Department of Land Resources, 2003; 12 MoRD, 2013; 13 Mani, 2009; 14 GOI, 2011; 15 GOI, 2011; 16 Department of Land Resources, 2013; 17 GOI, 2011; 18 Planning Commission, 2012 as cited in Gray and Srinidhi, (2013) and Ministry of Agriculture, Cooperation and Farmers' Welfare (2016).

Moreover, these programmes have evolved from the 1970s when the focus was on technical interventions with low net returns and inequity in the distribution of benefits, to ecosystem-based approaches today that have a strong participatory component and focus on social approaches as well (Gray and Srinidhi, 2013). This participatory approach has been recognised in the WSD guidelines (GOI 2011) and various Five Year Plans.

Despite huge advances in the approach followed, and the enormous investment in these programmes, knowledge of their efficacy in terms of reducing land degradation, enhancing productivity, contributing to poverty alleviation as well as which interventions are the most appropriate and effective, remain largely unknown. Evaluations by third parties and by the Government, according to Gray and Srinidhi (2013) lack consistency in methodology and data collection approaches and this is buttressed by the Parthasarathy Technical Committee report (DoLR 2006) which found an inconsistency in the data quality across projects. An issue with these programmes is their lack of sustainability in the long-term (Sharma, 2005); many farmers benefit from these projects only through short term paid labour opportunities (Joy, 2003). The other issue is that many watershed programmes have failed to arrest land degradation and in case of water management have focussed on the supply side rather than in reducing or managing demand. This has negative repercussions for down-stream users (KAWAD, 2001). A major issue with watershed and land degradation programmes is that over the last thirty years they have been implemented and administered by different ministries based on a multitude of programmes and policies (Gray and Srinidhi, 2013). This has led to a fragmented approach.

As early as 1994, a Technical Committee under the Chairmanship of Prof. C.H. Hanumantha Rao, was appointed to assess the Drought Prone Areas Programme (DPAP) and the Desert Development Programme (DDP). The Committee concluded that "programmes have been implemented in a fragmented manner by different departments through rigid guidelines without any well-designed plans prepared on watershed basis by involving the inhabitants. Except in a few places, the achievements have been sub-optimal. Ecological degradation has been proceeding unabated in these areas with reduced forest cover, reducing water table and a shortage of drinking water, fuel and fodder" (Hanumantha Rao Committee, 1994, Preface). This committee recommended a common set of operational guidelines, objectives, strategies, and expenditure norms for watershed development projects integrating the features of the three programmes under the MoRD. Accordingly, the Guidelines for Watershed Development were framed and brought into force with effect from April 1, 1995. However, the MoRD revised the 1994 Hanumantha Rao Committee guidelines in 2001 and yet again in 2003 under the nomenclature, "Hariyali Guidelines".

As many as nine guidelines have been issued for watershed projects over more than twenty years. The Twelfth Five Year Plan, several years later echoes the conclusion of the Hanumantha Committee report and underlines the absence of a unified approach with this pithy comment, "Each of these [programmes] is conceived and implemented in departmental silos and there is no unified mechanism for coordination and convergence. As a result, these programs do not lead to 'area development'; potential synergies are lost; and investments, interventions, and results remain sub-optimal" (Planning Commission 2012).

The Parthasarathy Technical Committee report (DoLR 2006) suggested widespread reforms to the watershed programme in particular including;

- The adoption of a cluster approach including micro-watershed ranging in size from 4,000 to 10,000 ha rather than the earlier 500 ha;
- Initiation of a 3-phase programme, which included an initial preparatory phase of two years focused on building local capacities and institutions;
- Enhancement of the per hectare norm to Rs 12,000 from the prevailing Rs 6,000;
- A focus on capacity building including the involvement of the NGO sector, enhanced emphasis for on monitoring, evaluation, learning and social audit and the building of a livelihoods perspective into the programme;
- Setting up of a full time implementation structure especially at district level.

These recommendations led to the setting up of a National Rainfed Areas Authority (NRAA) in November 2006. The NRAA, in coordination with the Planning Commission, issued a new set of Common Guidelines for Watershed Development Projects in February 2008, which are applicable to all watershed development projects in all Departments/Ministries of the government. The predominant focus, however, of these watershed development projects has been on soil and water conservation.

Gray and Srinidhi (2013) point out that one of the issues with these programmes is the general absence of any economic valuation studies. They emphasize the importance of these analyses not only to address some of the issues described above, but primarily because Benefit-Cost Analyses can help justify expenditure, target interventions and guide decision making.

Table 3.16 Overview of recent economic valuations of watershed development in India

Author(s)	Region	Methodology	What was valued	Key Results
Chatuverdi, V., 2004. Cost-benefit analysis of watershed development: An exploratory study in Gujarat. Development Support Centre. Research Report., Ahmedabad	Gujarat	Benefit-cost analysis of eight WSD projects over a ten-year period, using questionnaire based surveys and focus group discussions, exploring the distribution of benefits.	Benefits include returns from agriculture and horticulture; Costs include investments undertaken in soil and moisture conservation and water harvesting only	▪ Average benefit-cost ratio was 8.56. ▪ The average benefit from the WSD project (calculated as the difference between profit before and after watershed development) in normal rainfall years was greater than in drought years. ▪ Profit for marginal farmers is much lower than for small or big farmers. Profits were also higher for well-owners than for non-well-owners.
Joshi, P.K., Jha, A.K., Wani, S.P., Joshi, L., Shiyani, R.L., 2005. Meta-analysis to assess impact of watershed programme and people's participation. Comprehensive Assessment Research Report 8. Colombo, Sri Lanka: Comprehensive Assessment Secretariat.	India	Meta-analysis of 311 WSD case studies	The study attempted to document efficiency, equity, and sustainability benefits. Four important indicators were identified to demonstrate sustainability benefits. These included: (i) increased water storage capacity, which augmented irrigation; (ii) increased cropping intensity; (iii) reduced runoff, which enhanced groundwater recharge; and (iv) reduced soil loss.	▪ Mean benefit-cost ratio of a WSD program in India was 2.14 ▪ The internal rate of return was 22 percent. ▪ The performance of the WSD program was best for programs that targeted low and medium income groups, were jointly implemented by the state and central government, had effective people's participation, and had rainfall ranging between 700–1,000 mm. ▪ Lack of appropriate institutional support is impeding the tapping of potential benefits associated+ with these programs.

Author(s)	Region	Methodology	What was valued	Key Results
Sahu, S. 2008. Cost benefit analysis of participatory natural resource management: A study of watershed development initiative in Indian village. Munich Personal RePEc Archive. Paper no. 17134.	Rajasthan	Benefit-cost analysis projecting benefits for 30 years.	Benefits from agricultural and livestock production, self-help group savings, and wage employment; Costs include intervention capital and administrative costs.	▪ Benefit-cost ratio ranged from 1.97 to 2.34
Palanisami, K., Kumar, D.S., Wani, S.P., Giordano, M., 2009. Evaluation of watershed development programmes in India using economic surplus method. Agricultural Economics Research Review. Vol 22, July–December 2009:197–207.	Tamil Nadu	Economic surplus used to measure the aggregated social benefits of a research project and distributional impacts for a cluster of 10 watersheds.	Costs include capital and Operation and Maintenance (O&M) costs of WSD interventions towards watershed. Benefits are based on consumer and producer surplus from being able to consume products at a lower market price and being able to sell products at a higher market price.	▪ Benefit-cost ratio of 1.93 ▪ People's participation (e.g. in Panchayati Raj Institutions, local user groups, and NGOs) along with institutional support from different levels of government should be ensured to make the program more participatory, interactive, and cost-effective. ▪ Internal rate of return of 25 percent.
Kale, G., Manekar, V.L., Porey, P.D., 2012. Watershed development project justification by economic evaluation: a case study of Kachhighati Watershed in Aurangabad District, Maharashtra. ISH Journal of Hydraulic Engineering. Vol. 18 (2): 101–111	Maharashtra	Benefit-cost analysis; Present value analysis assuming sustainability of the project will be a minimum of 35 years.	Costs include capital and administrative costs of all WSD interventions; Benefits include increased income from agriculture, livestock, and fodder production, and savings from self-help groups.	▪ Benefit-cost ratio based on the total present value of costs (TPVC) and the total present value of benefits (TPVB) is calculated as7.1658. ▪ Average annual benefit-cost ratio based on present values during the first 5-year block period (1997–2001) is 3.1397, whereas that in the second 5-year block period (2002–2006) after the implementation of project is 5.2870. ▪ Economic evaluation as a tool is found effective for the financial validation of watershed projects.

Source: Gray and Srinidhi (2013)

Table 3.16 provides an overview of some economic valuation studies that have been carried out in India with their B-C values, and an analysis of strengths and weaknesses of the watershed programmes they evaluate. Use of B-C analysis for watershed programmes is essential given the scale of investments made in such programmes by the Government of India as well as bilateral and corporate funders (Kale et al., 2012). However, most of the current economic valuations of land restoration programmes still do not emphasize the co-benefits in terms of carbon sequestration, for example, or biodiversity enhancement. Gray and Srinidhi (2013) evaluated a Kumbharwadi watershed project in Maharashtra, and found that it generated a positive B-C analysis including for co-benefits over a 15 year time frame. They found total present value costs from 1998 through 2012 ranged from $2.69 to $3.95 million. Total present value benefits, excluding the avoided social cost from carbon sequestration, ranged from $9.02 to $10.13 million for the same period. The NPV of the WSD project in Kumbharwadi ranged from $5.07 to $7.43 million, which equates to benefits of $5,573 to $8,172 per hectare treated or $29,650 to $43,479 for each of Kumbharwadi's 171 households. The benefit-cost ratio ranged from 2.28 to 3.76.

Gray and Srinidhi (2013) however, highlight the following points regarding these DLDD projects:

- Lack of consistency in data reporting of social, environmental and economic indicators due to an a) absence of knowledge of which indicators are required for such economic valuations and b) inadequate funding for monitoring and evaluation. Therefore, the recommend the need for funding agencies to standardize data collection processes and reporting protocols.
- Lack of consistency in data collection as impact assessments are carried out by different agencies from those implementing the project and hence project implementers view these evaluations as an external issue.
- Failure to evaluate non-market and societal co-benefits that provide a more holistic picture of these programmes
- Lack of post-project monitoring and impact assessments to evaluate the contribution of these projects to building resilience to drought and long-term restoration of ecosystems.

Although these programmes have been effective, several challenges remain. Rather than adopting a uniform approach, site-specific strategies are often required to deal with fragile ecosystems. For example, mountainous systems such as the Himalaya and Shivalik suffer from high intensity soil erosion and run off of rain water from the catchment area. Landslides are very common throughout the region. All these factors make it difficult to implement conservation programmes. For example, in the hill states, most farm lands are not suitable for regular agricultural cultivation, for which the land has to be tilled every six months. Majority of the fields are not terraced and farming is rainfed. This results in soil erosion and run off of rain water, depriving farm lands of soil nutrients and moisture. Ideally these lands are only fit for growing tree crops, horticulture or forestry. Moreover, per capita land holdings are small. The average land holding in Uttarakhand is 0.89 ha and some states possess even smaller farm lands. The problem is further complicated when these small farmlands are not located at one place. Thus, to adopt any one method for soil and moisture conservation in these farmland becomes difficult and at times, even impossible. The 'prescriptive' target driven approach of these programmes dilutes their impact on the ground.

These programmes often fail to factor in other drivers of degradation such as increasing populations of people and cattle, which has an adverse impact on natural resources of the watershed. Positive steps to mitigate degradation are undermined by an increase in population. Other factors impact these programmes such as road construction, ill-effects of forest fires, and invasive species. Road construction in the hills for example impacts conservation activities carried out under IWMP due to debris accumulation. Forest fires which result in high intensity soil erosion and excessive run off during the monsoon or invasion by species like *Lantana* are not factored into these programmes. Again, these issues suggest a lack of convergence amongst departments in ensuring the success of programmes to limit DLDD.

Socio-economic activities are key to preventing land degradation, desertification and drought. Activities targeting local communities need to be strengthened and training programmes on skill and micro-enterprise development targeted at appropriate beneficiaries. Moreover, without establishing market linkages, these programmes tend to fail; consequently value addition must become a priority. Activities also need to be more participatory-since the approach is so top-down, dictated by guidelines and targets, the programme lacks enthusiastic participation of beneficiaries.

Paucity of funds is also an issue. For example seed money of a paltry Rs 25,000 to each Self-Help Group is insufficient especially when the profits have to be shared by all its members. This seed money is also merely a loan to be repaid and is of little benefit. Delays in fund flow to the Gram Panchayat level are another issue which is compounded by lack of clarity of contributions of the State and Central Governments. Flexibility in implementation must also extend to the funding norms (currently fixed to Rs. 12,000- per ha and Rs. 15,000/ per ha respectively for plain and hill areas).

The IWMP programme, in particular lacks a uniform executing agency, actively invested in the programme and includes DFOs or CEOs or DRDAs and even NGOs who have their own work to execute and therefore, are not able to provide required time and human power for execution of the IWMP.

In general, programmes to reduce land degradation, desertification and drought would benefit from an integrated approach ensuring convergence of various ministries and departments, flexibility in planning, implementation and funding to account for site-specific needs and a focus on ensuring sustainability. Moreover, an integrated approach to the management of various ecosystems including forests, rangelands, wetlands and agro-ecosystems given their close interconnections would also be ideal for appropriate land use planning. These issues are also discussed in detail in Chapter 4.

CHAPTER 4

Macro-economic assessment of the cost of land degradation in India

4.1 Introduction

Land degradation is evident across all terrestrial biomes[15] and has multiple and far-reaching consequences, some of which may not be yet fully understood. The range of services that land provides and which are affected by its degradation can be broadly classified as provisioning (e.g. food, fuel, fibre, water etc.), regulating (e.g. climate regulation, flood or drought control, decrease in soil erosion, nutrient recycling etc.), cultural (spiritual, aesthetic, and educational), and supporting (e.g. soil formation, primary productivity, biogeochemistry). These services can also be bundled in terms of the Total Economic Value (TEV) of ecosystems to society, encompassing both use and non-use values (Table 4.1). Following from this broad conceptualization of the utility of land, the costs of its degradation can be direct (e.g. loss of agricultural productivity, wood and fodder production, tourism opportunities, ecosystem services, biodiversity, soil fertility, nutrients, carbon sequestration capacity and groundwater recharge) or indirect, including offsite costs (e.g. increased dust storms, changes in stream flow and reliability of irrigation, lowered drinking water quality, siltation of water systems and higher incidence of respiratory (from dust storms), food/water-borne (from lowered water quality), and infectious (from population migration) diseases, increase in poverty, food insecurity and malnutrition, conflict over natural resources and involuntary migration) (ELD Initiative, 2015).

Table 4.1 Conceptualizing the Total Economic Value of Ecosystem Services

		Provisioning services	Regulating services	Cultural services	Supporting services
Use value	**Direct use** (value of consumptive outputs of land e.g. food, timber)				
	Indirect use (value of services provided by land e.g. pollination or dispersal)				
	Option (value of keeping land use flexible for future direct and indirect uses)				
Non-use value	**Existence** (value allocated to land simply because it exists)				
	Bequest (value attached to the possibility of bequeathing land to future generations)				

Note: The figure combines the TEV classification (along the rows) with the classification of ecosystem services adopted by the Millennium Ecosystem Assessment (MEA 2005). The shaded boxes show the relevant services/values for each row/column

[15] This encompasses a range of habitats including inland wetlands

This chapter aims to carry out an economic analysis of some of these costs of land degradation in India. The challenge of quantifying all of these impacts is enormous, not least because of limitations in understanding the complex underlying dynamics, especially of higher order impacts. In India, the task is made more complex due to the close linkages between land degradation and livelihoods. Most existing efforts at assessing the economic cost of land degradation in the country have been limited to the loss of provisioning services in the case of agriculture though some more recent work has looked at provisioning, regulating and supporting (both direct and indirect) services in the case of forests. It is important to look beyond those directly affected by land degradation - a recent global study attempted to value land degradation using the TEV approach and found that only about 46% of the global cost of land degradation due to LUCC (land use/cover change) is borne by land users while the remaining 54% is borne by consumers of ecosystem services off the farm (Nkonya et al 2016).[16]

We make an attempt in this study to take a wider perspective of land degradation. We look at the cost of degradation both due to land use change and degradation within static land uses, with a focus on the four land uses where the direct impact of land degradation is arguably felt the most- agriculture, rangelands, forests, and wetlands. This study is buttressed by six micro-economic case studies encompassing the arid, semi-arid and dry sub-humid regions of the country with a focus on agro-ecosystems, rangelands and forests.

We begin by reviewing the status of degradation for each of the four land use categories (agriculture, rangelands, forests, and wetlands) to set the context for the economic assessment of land degradation. This is followed by a discussion on the conceptual approach to assessing the cost of land degradation. This approach is informed by a detailed review of existing literature for India, and builds on some of the existing research. Section 3 discusses the results and the final section concludes by highlighting some data and definitional issues.

4.2 The current status of land use and degradation in India

In this section, we discuss the status of degradation across primary land uses in India, and analyse trends in each of these sectors in terms of resource use, pressures and challenges faced. This is to set the context for the next sections that analyse the costs wrought by overexploitation of resources and changes in land use.

4.2.1 Land use and land cover change in India

The latest land use statistics for the country (year 2012/13) indicate that the largest area of land use is net sown area (46%) followed by forests (23%) and areas under non-agricultural uses (9%) (Figure 4.1).

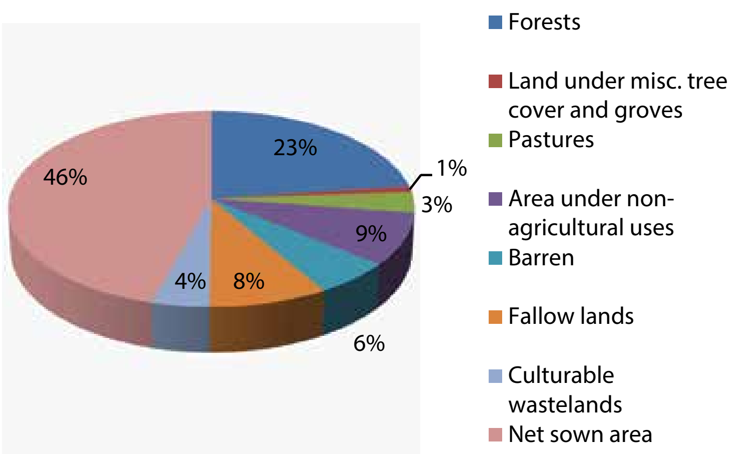

Figure 4.1 Percentage of land area under various land uses in 2012/2013

*% of land area reported for land utilization statistics.

Source: Directorate of Economics and Statistics, Ministry of Agriculture and Farmers Welfare

The change in land use over the last six decades is depicted in Figure 4.2. The following trends stand out:

- An increase in the area under forests in the initial decades followed by stabilization of forest cover in the last few decades. The area under forests

[16] Due to the limited number of available TEV values for different land uses in different eco systems, the study relied heavily on "transferring" the results from micro studies to national and regional and even to a global scale. This is meant not as a critique of the study but to highlight the severe limitations in assessing the costs of land degradation at any appreciable level of aggregation.

has increased from about 40 million hectares in 1950/51 to about 67 million hectares in 1980/81 with a near stabilization in the area since then. However, as discussed later in this section, there is not enough information to distinguish how much of this increase is on account of native forests rather than plantations. These are studies to suggest that native forests in India have actually declined by 1.5%–2.7% per year (Puyravaud et al., 2010a; b).The second issue of concern is that while forest cover may have stabilized over the last few years, the share of dense forests is low with the majority of the forest being in the open and scrub categories (10.4% of geographical area), which are considered as degraded.

- An initial increase in net sown area (119 mha in 1950/51 to 143 in 1990/91) followed by a gradual decline (140 mha in 2012/13), even though agriculture continues to account for the lion's share of land use in the country. If we account for an additional area added by reclamation of culturable wastelands (about 2.4 million ha), it is estimated that a total net sown area has decreased during the two decades between 1990/91 and 2010/11 (Sharma, 2015).
- Likewise, there has been a decline in the area under pastures (14 mha in 1960/71 to about 10 mha in 2012/13) after an initial increase post-independence (7 mha in 1950/51 to 14 mha in 1960/71). The Planning Commission (2011) mentions that grazing lands have been transferred to developmental projects, planted over, given as land grants to the landless and brought under irrigated cultivation. They attribute this to the lack of a pasture management and grazing policy. Given such extensive pressures on pasturelands, their conversion to alternative land uses and their support of livestock in excess of their carrying capacity, the Planning Commission (2011) estimated that the country by 2020 faces an estimated shortage of 728 million tons of green fodder and 157 million tonnes of dry fodder.
- A marked decline in the area under barren and unculturable lands, miscellaneous tree cover and groves, and culturable wastelands. Together these three categories of land use have come down from 28% of the land use in 1950/51 to about 11% in 2012/13. One reason for the decline in wastelands could be their restoration and conversion to more productive land uses because of improved land and watershed management (e.g. conversion of culturable wastelands to agriculture). However, an important concern in this case is the definition of wastelands. There appears to be no consensus on what classifies as wasteland or degraded areas. Definitions of what constitutes wasteland often appear to hark back to John Locke's colonial formulations[17]. That is, wastelands were basically uncultivated lands, lying 'idle' or held 'in common' often associated with 'wildness, wilderness and savagery.' [18] By this definition, many highly productive landscapes such as grasslands and marshes can be considered to be wastelands, and are converted to other land uses, including agriculture. The Wasteland Atlas of India for example includes waterlogged areas and marshes that support diverse flora and fauna and contribute to ground water recharge, as well as snow covered/glacial areas that are the sources of rivers (Vanak et al. 2013).
- An increase in permanent fallow lands (19 mha in 1970/71 to about 26 mha in 2012/13) after an initial decrease post-independence (28 mha in 1950/51 to 19 mha in 1970/71). One of the reasons for this increase is the degradation of land resulting from waterlogging and soil salinity or because of absence of irrigation facilities. More than 80 per cent of total fallow land is in Andhra Pradesh, Rajasthan, Jharkhand, Tamil Nadu, Maharashtra, Karnataka, and Uttar Pradesh (Sharma, 2015).

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[17] As described in Whitehead (2010)

[18] There are several definitions of wastelands, some of which are provided below.
The definition of wasteland from the Cambridge Advanced Learner's Dictionary is 'An empty area of land, especially in or near a city, which is not used to grow crops or built on, or used in any way and/or a place, time or situation containing nothing positive or productive, or completely without a particular quality or activity'.
The Technical Task Group Report of the National Wastelands Development Board defines wasteland as a land which is presently lying unutilized due to different constraints
ICAR proposed that wastelands are lands which due to neglect or due to degradation are not being utilized to their full potential. These can result from inherent or imposed disabilities or both, such as location, environment, chemical and physical properties, and even suffer from management conditions
According to Integrated Wasteland Development Programme, wasteland is a degraded land which can be brought under vegetative cover, with reasonable effort, and which is currently underutilised and land which is deteriorating for lack of appropriate water and soil management or on account of natural causes.

- A progressive increase in area under non-agricultural uses (9 mha in 1950/51 to 26 mha in 2012/13), due to urbanization and industrial and infrastructural expansion. Although, the area under non-agricultural uses accounts for only 9% of the total, it is this land use that showed the highest growth rate at the all India level. Almost all States have witnessed an increase in area under non-agricultural use from 1991-92 to 2011/12. In parallel the net sown area during this period decreased in several States. For example, Odisha lost more than 17 lakh ha net sown area, Bihar (including Jharkhand) 12.4 lakh ha, Maharashtra (7.6 lakh ha), Tamil Nadu (7.1 lakh ha), Karnataka (3.1 lakh ha), Andhra Pradesh (2.7 lakh ha) and West Bengal (2.6 lakh ha). Not surprisingly, therefore, the perception of widespread acquisition of fertile lands by corporates causing displacement of farmer communities is now a politically volatile issue in India (Sharma, 2015).[19]

Decreasing the rate of conversion of productive land to non-farm uses is important in a primarily agrarian society like India, and in the interest of long-term food security for the country given escalating climatic vulnerabilities. This is important because adding to the loss of agricultural land are issues of land degradation and farmland fragmentation. According to the Government of India, the average farm size has roughly halved to 1.15 ha in 2010-11 when compared to 2.28 ha in 1970-71 (GoI, 2014). Small and marginal holdings (< 2 ha) accounted for over 85 % of land holdings in 2010-11 versus 69.9% in 1970-71 and the operated area at 44.6 per cent in 2010-11 compared with 20.9 per cent in 1970-71. The proportion of marginal holdings (<1 ha) increased from 51 % to 67.1 % in this period.

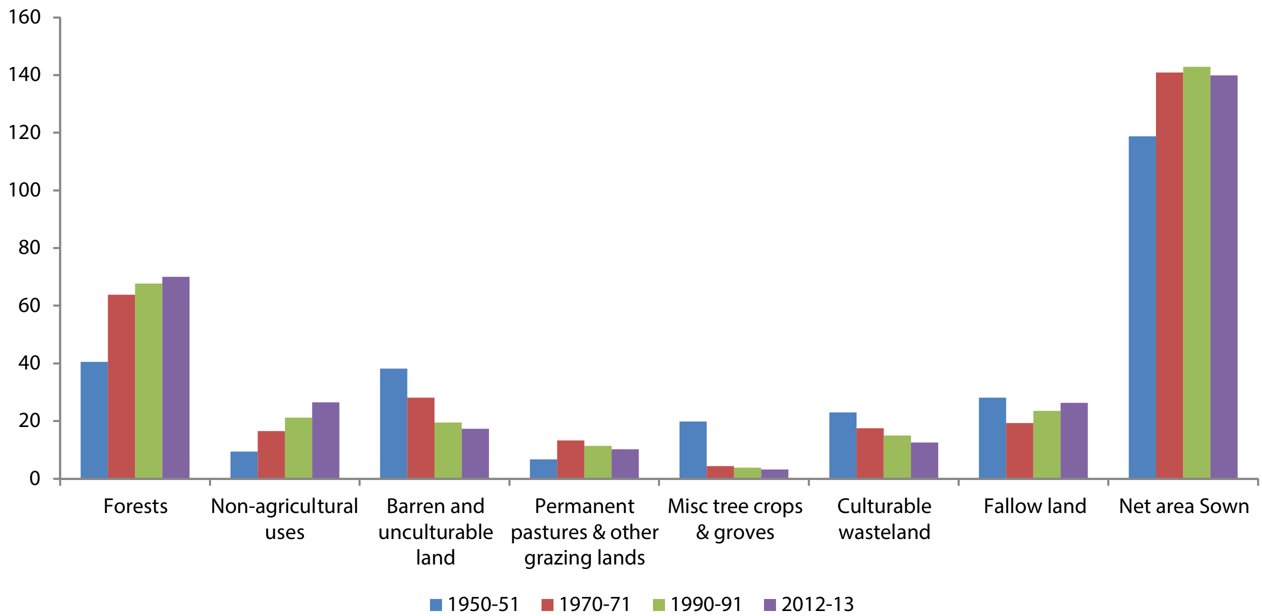

Figure 4.2 Land use change 1950/51- 2012/13

Source: Directorate of Economics and Statistics, Ministry of Agriculture and Farmers Welfare

4.2.2 Forests

Forests are a category of land use in India governed under the provisions of the Indian Forest Act (1927) and are referred to as Recorded Forest Area (RFA) (FSI, 2015). The Recorded Forest Area of the country is 76.4 million hectares covering 23.26% of India's geographical area. The total forest cover[20] of India, however, is 70.17 million hectares constituting 21.34% of India's geographical area while the tree cover

[19] In contrast, the net sown area increased in some states during this period by about 20 lakh ha in Rajasthan and 9.5 lakh ha in Gujarat (Sharma, 2015). However, Gujarat is the only state to add about 3 lakh ha to its total agricultural land in the last two decades.

[20] Forest cover and RFA are different, as per the definition used by FSI, Forest cover includes all land, one hectare and above, with tree canopy density of 10% or more irrespective of ownership and legal status. Such lands may not necessarily be within recorded forest area. It also includes orchards, bamboo and palm.

is 9.2 million hectares or 2.82% of India's geographical area (FSI, 2015). Apart from the area recorded under forest and tree cover, India has 4.1 million hectares of scrub forests (degraded forests with canopy cover <10%) (FSI, 2015).

India's forest cover has stabilised as indicated by India's State of Forest Reports (Figure 4.3). However, the India State of Forest Reports do not provide disaggregated data on plantations and natural forests, a must to understand whether forest cover is stabilizing due to increases in native forest cover or because of plantations or both, and to what extent. The real status of India's natural forests will only become clear once this disaggregation is done. This is important because some studies utilising FSI data suggests that native forests in India have actually declined by 1.5%–2.7% per year (Puyravaud et al., 2010a; b).

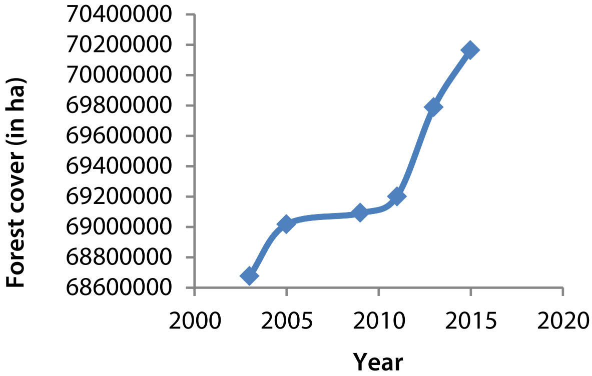

Figure 4.3 Increase in India's forest cover between 2003 and 2015

Source: FSI (2009-2015)[21]

While forest cover has stabilised, degradation is definitely an issue-as compared with 2.61% of Geographical Area (8590400 ha-8.6 mha) under Very Dense Forests (VDF), 9.59% of GA (31537400 ha-31.5 mha) is under Moderately Dense Forests (MDF), while as much as 9.14 % of GA (30039500 ha-30mha) is under Open Forests (OF) and 1.26% of GA (4136200 ha-4.1mha) is under Scrub. Apart from VDF and MDF forests, the other two categories (OF and scrub) can be considered to be potentially degraded (some percentage of scrub forests may include savannah grasslands or other forest types where further densification is ecologically untenable) resulting in a potentially total degraded area of 34175700 ha (10.4% of GA or 48.7% of India's forest cover)[22]. Moreover, some of the MDF forests also have the potential to move into the Very Dense Forest class[23]. According to the latest SAC atlas (2016), vegetal degradation has increased to 29.3 m ha as compared with 28.28 mha accounting for 8.91% of India's geographical area. Thus vegetal degradation ranks second to water erosion in terms of area degraded in India. ***If we consider the national target of 33% of India's area under forest and tree cover cover (108479679 ha), then currently 20.79 % of this target area either constitutes degraded forest (10.4% of GA or almost 50% of current forest cover) or is currently not under forests (34176179 ha or 10.4 % of GA).***

Other measures also suggest that India's forests are degraded-for example only 48% of RFA has adequate regeneration, while 24% has inadequate regeneration and 10% has no regeneration. Likewise, the growing stock[24] of the country's forests shows a declining trend since 2003, (despite a minor uptick since 2013) with a percentage decrease of 12.2% since 2003 (Figure 4.4), (FSI 2003-2015). A trendline

[21] The revised figures based on changes in methodology have been taken from FSI (2009) onwards

[22] Scrub forests are officially defined by the Forest Survey of India as degraded forests with canopy cover <10% (FSI, 2015).

[23] FSI's forest cover change matrix shows constant movement from open and scrub forests upwards and similar degradation from more dense to less dense categories, hence we assume that much of the open forests can potentially be densified further and are currently degraded.

[24] Growing stock is the volume of total standing biomass in forests and degradation can be measured in terms of erosion of growing stock since a better-stocked forest has higher production potential (TERI, 1998). Forest productivity is defined as the net annual increment per unit forest area expressed in cubic metres per ha.

for growing stock suggests that this decreasing trend may continue in 2030, the target year for India to be land degradation-neutral (Figure 4.5).

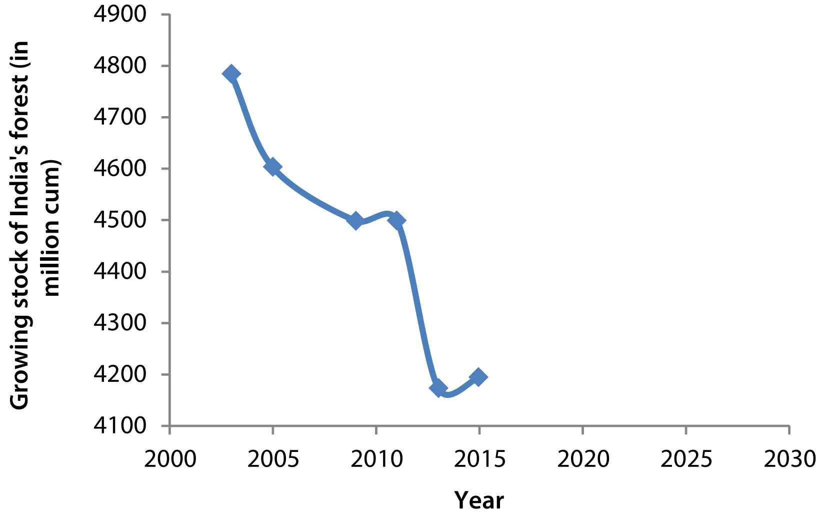

Figure 4.4 Declining growing stock of India's forests between 2003 and 2015

Source: FSI (2003-2015)

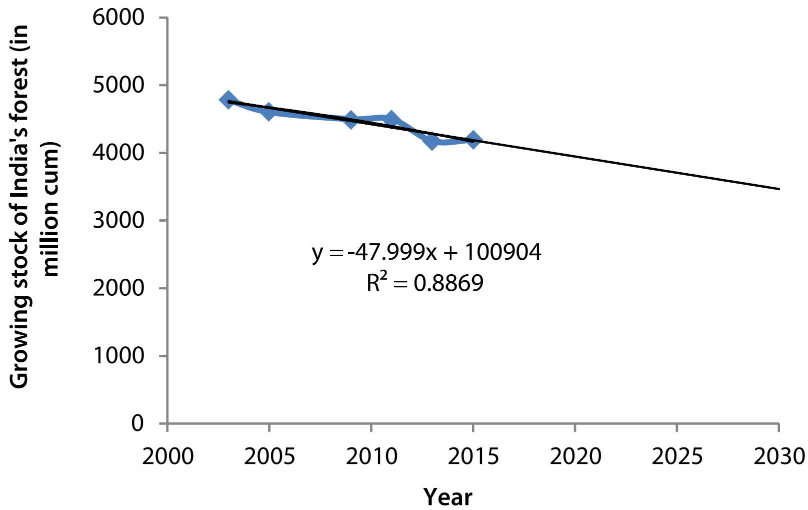

Figure 4.5 Trendline for growing stock in 2030

The many causal reasons for the degradation of India's forests include diversion of forest lands for development projects and degradation resulting from extensive dependence on forest resources. About 1 million ha of forest area has been diverted for 14,997 developmental projects since 1980 when the Forest Conservation Act was enacted (NBAP, 2008). Population pressures and concomitant increases in the collection of fuelwood and fodder, and grazing in forests by local communities take their toll on the forests. Several recent sources suggest that the major reason for degradation of India's forests stems from extraction of fuelwood (Rath, 2002; Sagar & Singh 2004; Davidar et al. 2007, 2010; Puyravaud et al. 2010a and 2010b), despite the diversified nature of woodfuel use. Other factors include fires which adversely affect regeneration in some cases, invasive species, and natural calamities like droughts, diseases, cyclones, and landslides. Fire prone areas account for 54% of the recorded forest area of which heavy fires affect 1.3% and moderate and mild fires impact about 6.5% and 46%, respectively. The extent of forest area impacted by surface fires is 3.69% (FSI, 2013).

Substantial amounts of fodder are consumed from forests with an estimated 38.49% of total livestock in India (200 million) directly dependent on forests for grazing (FSI, 2011a). According to the Planning Commission (2008), 78% of the forest area has degraded due to heavy grazing. World Bank estimates suggest that about 247 million people in the country rely mostly on natural forests for part of their subsistence or cash livelihoods, and two-thirds of these (167 million) use fuelwood as an energy source (Milne 2006). FSI (2011) estimates of people dependent on fuelwood from forests are higher at 199.6 million, although more than 853 million people in India are believed to use fuel wood from various sources. These 200 million people utilise 58.7 million tonnes annually from forests. The forestry sector was estimated to contribute to 2.2% of the country's GDP in 2001 (Chopra et al., 2003).

Photo 4.1 Fuelwood collection and grazing in India's forests

First pic: Siddharth Edake; 2nd pic Pia Sethi

4.2.3 Rangelands and pasturelands

Rangelands[25] support livestock, millions of pastoralists are dependent on them, and they constitute an important ecological, social and economic resource. Despite this they have shown a decrease of 287000 ha since 2001-2003. India supports 16% of the world's cattle population on just 0.5% of the world's grazing area. More than 50% of this livestock population (500 million) is supported by rangelands[26] (Planning Commission, 2011), although according to FSI (2011a), the figure is closer to 60%. The importance of rangelands to the exchequer can be gauged from the fact that livestock contribute about 8.5 - 9% to the country's GDP (Planning Commission, 2006).

Grasslands have traditionally been an undervalued resource, classified as wastelands or 'forest blanks' and converted to other land uses. In the past even village common lands used for grazing were considered to be wastelands. Several natural grasslands such as the sholas of the Western Ghats, the wet grasslands of the terai and the dry grasslands of the Deccan have been converted to plantations, while grasslands in Maharashtra are being converted for watershed programmes. Not surprisingly, these depleting grasslands now support populations of some of India's most threatened wildlife such as the Great Indian Bustard, the Lesser Florican and the Nilgiri Tahr. This decline of pasturelands continues despite the fact that grasslands are important ecosystems in their own right, with fossil

[25] The primary difference between rangelands, pasturelands and grasslands relates to vegetation and their management. Rangelands are those lands on which the native vegetation is predominantly grasses, grass-like plants, forbs, or shrubs suitable for grazing or browsing use. Rangelands include natural grassland, savannas, many wetlands, some deserts, tundra, and certain forb and shrub communities. Thus rangelands are a broader term encompassing grasslands. Pastures are those lands that are primarily used for the production of adapted, domesticated forage plants for livestock.

[26] Forest supports the remaining 50% of India's livestock

records suggesting that C3[27]-grasses existed in India 50 million years ago, and C4-grasslands may have been widespread on the Indian subcontinent 7 million years ago (Vanak et al., 2013). One of the recommendations under the forestry sector's mid-term review of 11th Plan (Planning Commission, 2012 a) was that 'grassland and other ecologically important eco-systems need to be conserved' (para 22.65).

Savannah grasslands in particular have seen widespread declines. Semi-arid savannas are restricted to only a handful of sites spread across Andhra Pradesh, Karnataka, Madhya Pradesh and Maharashtra and cover approximately 20,000 square kilometres. Even in colonial times, large areas of savannahs were converted to agriculture through canal irrigation that subsequently led to salinization and land degradation (Vanak et al., 2013).

Photo 4.2 Plantations in natural grasslands of the Terai region

Existing grasslands are subject to extreme grazing pressures. According to Shankar and Gupta (1992) while the carrying capacity of livestock in the semi-arid grasslands is 1 adult cattle unit (ACU) per ha, the stocking rates are as high as 51 ACU. Similarly in arid areas while the carrying capacity is 0.2-0.5 ACU per ha, the stocking rate is 1 to 4 ACU per ha (Raheja 1966). Many of the grazing lands have also been invaded by non-palatable invasive alien species like *Lantana*, *Eupatorium*, *Parthenium*, *Prosopis juliflora*, *Leucaena*, which impacts their productivity (Planning Commission, 2011). *Prosopis juliflora*, for example, introduced as a measure to reduce salinity has now spread extensively across the Banni grasslands of Gujarat[28]. Additionally, erosion of traditional grassland management practices and loss and encroachment of common village lands is impacting the viability of India's pasturelands. The Planning Commission (2011) mentions that under the centrally sponsored scheme 'Area Oriented Fuel and Fodder Project' under National Afforestation & Ecodevelopment Board (NAEB) during the 11th Plan period, the forest department managed grazing lands legally classified as forest. However, this programme focussed on afforesting these areas rather than enhancing fodder management on village community lands. Compounding these issues is the absence of a grassland protection and grazing-fodder management policy at both national and state levels.

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[27] "This refers to the different pathways that plants use to capture carbon dioxide during photosynthesis. All species have the more primitive C3 pathway, but the additional C4 pathway evolved in species in the wet and dry tropics. The first product of carbon fixation in C3 plants involves a 3-carbon molecule, whilst C4 plants initially produce a 4-carbon molecule that then enters the C3 cycle." http://www.dpi.nsw.gov.au/content/agriculture/pastures/pastures-and-rangelands/native-pastures/what-are-c3-and-c4-native-grass

[28] See Vol II for a case study of the Banni grasslands and the costs of degradation

Estimates of pasturelands/rangelands and grassland in the country vary. While the Directorate of Economics and Statistics, Ministry of Agriculture and Farmers Welfare provides a figure of 10.5 m ha of pasturelands for 2001, the Planning Commission (2011) gives a figure of 38mha for 1997. Moreover, according to the Planning Commission (2008), the total recorded pasture land in the country shrunk by more than 30% since independence.

The exact extent of grasslands in the country probably remains unclear for several reasons. One is because of their frequent misclassification as forests. For example, dry savannahs are often classified as dry tropical forests even though savannahs are distinguishable from savannahs by the presence of a C4-grass-dominated understory and trees adapted to the occurrence of fires, unlike trees of tropical dry forests (Ratnam et al., 2011). Secondly, satellite-based delineation of grasslands is not a straightforward exercise. According to Vanak et al. (2013), "Unlike forested areas of India, which are easily delineated using even coarse scale satellite imageries, the spectral signature of grasses is easily confused with rain-fed agriculture, and horticulture, forestry plantations and isolated trees in agricultural fields are easily confused with woodlands. Thus, multiple methods at multiple scales are needed to classify savanna systems." A third reason could be definitional in nature; while rangelands and grasslands refer to lands with native vegetation, the term pasturelands is narrower in scope including lands primarily used for livestock. Furthermore, it is possible that the figures for pasturelands (such as those cited by the Planning Commission (2011) include grasslands in forests.

The Planning Commission (2011) underlines the need to undertake surveys of grazing lands since current figures are largely ''guestimates". For example, according to the Planning Commission (2011), only 12.15 million ha of land in the country is classified as permanent pastures/ grazing lands, while grazing is estimated to occur on about 40% of the land area in the country, most of which are not designated as grazing lands.

4.2.4 Wetlands

Wetlands are amongst the most productive ecosystems on earth. Wetlands provide a wide range of ecological, economic and ecosystem services apart from supporting a rich diversity of faunal and floristic assemblages. Yet wetlands perhaps best exemplify the concept of contested environments, where conflicting objectives of development put pressure on an already undervalued natural resource. The contribution of wetlands to the economy is poorly understood and it is this lack of importance given to wetlands vis-à-vis other natural ecosystems such as forests that make them particularly prone to drainage and diversion to other land uses particularly agriculture or development. Pollution from both households and industry is also an issue as is overexploitation (Bassi et al. (2014). Defined as temporarily or permanently inundated areas, wetlands provide ecosystem goods and services ranging from fisheries, to aquatic biodiversity, to hydropower generation and ground water recharge.

An unappreciated role of wetlands is in their contribution to carbon sequestration and storage. Wetlands cover about six to nine per cent of the Earth's surface and contain 20-25 per cent of global terrestrial carbon (350-535 Gt C) (Gorham, 1995). Being highly productive ecosystems they sequester carbon and also store carbon-rich organic sediments. Anaerobic conditions of wetlands resulting from inundation result in slow decomposition and consequently significant accumulation of carbon stores over long periods of time even where productivity is low (Commonwealth of Australia, 2012). Their drainage is a major source of greenhouse gases though global estimates of drainage vary from 6 percent (Armentano and Menges, 1986) to 50 percent (Moser et al., 1996)[29], with most conversion in temperate and tropical regions.

In India, wetlands are broadly categorised into inland wetlands (both natural and human made) and coastal and marine wetlands. Diverse types of wetlands are found in India ranging from estuarine (including deltas, tidal marshes, and mangrove swamps), lacustarine (lakes), riverine (along rivers and streams), palustarine ('marshy'- marshes, swamps and bogs) and coastal wetlands including rock shores

[29] As cited in http://www.ipcc.ch/ipccreports/sres/land_use/index.php?idp=196

and coral reefs. The current Wetland Atlas for India (2011) also includes rivers and streams within the ambit of wetlands.

Estimates of area under wetlands have varied widely over the years. The Space Applications Centre carried out a mapping exercise for wetlands at 1:250,000 scale in 1998 (SAC 1998) and found that the extent of inland wetlands was 3. 6 million ha and that of coastal wetlands was 4 million ha. Also detected were an additional 80,000 wetlands smaller than the minimum-mapping unit. Assuming that these wetlands occupy 675979 ha area, the total wetland area excluding rivers, canals and rice in the country in 1998 was 8.26 mha. SACON (2004) updated the mapping of SAC (1998) at 1:50,000 scale and provided a figure of 7 million ha under inland wetlands.

An updated Wetland Atlas for 2011 (SAC, 2011) provides a figure of 10.56 million ha under inland wetlands (including rivers and streams that were not included by SAC, 1998). Coastal wetlands cover an area of 4.14 million ha leading to a total figure of 14.7 million ha under wetlands including an additional area of 0.55 m ha under wetlands <2.25 ha in size. However, ISRO (2016) provides different estimates which are discussed later in the report.

4.2.5 Agriculture

India continues to be predominantly rural with close to 69% of its population still residing in rural areas as per the 2011 Census. Agriculture remains the mainstay of employment with agricultural workers constituting about 55% of the country's working population (in 2011), of which 45% are cultivators and 55% agricultural labourers. However the contribution of the agriculture, forestry and fishing sector to GDP in 2013/14 (2004/05 prices) was only 14% (lower than 19% in 2004/05) (estimated from Agricultural Statistics at a glance, 2014. Ministry of Agriculture and Farmers Welfare).

In terms of land use statistics, agriculture uses roughly 46% of the land area reported for land use statistics (and 43% of total geographical area) in the country with net sown area adding up to 139.93 million hectares and gross cropped area adding up to 194.39 million hectares in 2012/13 (based on land use statistics from Ministry of Agriculture and Farmers Welfare). While net sown area has more or less plateaued, even showing a slight dip since the 1990s, gross cropped area has increased overtime, reflecting the higher intensity of cropping (111% in 1950/51 to 139% in 2012/13)- see Figure 4.6. The pressure on land resources can be gauged from the fact that the country supports 18% of the word's human population and 15% of the world's livestock population on 2.3% of the world's land area. The ratio of total population to arable land in India is 7.8 as compared to a global average of 4.9 (estimated from Agricultural Statistics at a Glance, 2014. Ministry of Agriculture and Farmers Welfare).

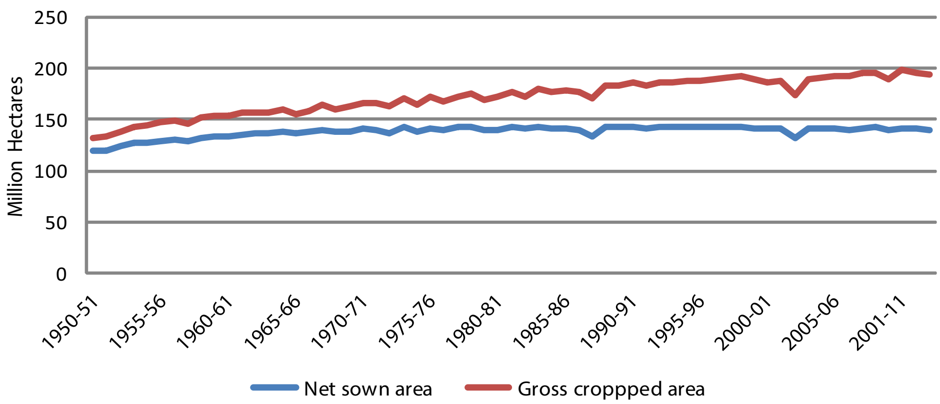

Figure 4.6 Area under agriculture (mha)

Degradation of land under agriculture and its implications have been widely documented in the form of declining crop productivity, lower yield as compared to other countries, changing cropping patterns and land use intensity, high input use and declining profit (see Bhattacharya et a 2015 and TERI 2010 for a discussion on the issue, and reviews of related literature). It is now widely acknowledged that the Green Revolution of the 1960s, which ensured food security for the country, has not been an unmixed blessing. As the Economic Survey 2015/16 puts it "Indian agriculture, is in a way, a victim of its own past success—especially the green revolution". The resulting intensification and extensification of agriculture has been characterized by an increase in cropping and irrigation intensity and indiscriminate use of chemical fertilizers, pesticides and insecticides. This, together with inappropriate agricultural practises - such as excessive tillage and use of heavy machinery, poor irrigation and water management techniques, non-adoption of adequate soil conservation measures and poor crop cycle planning have led to over-exploitation and contamination of soil and water resources in many parts of the country.

Population pressures add to the problem of land degradation in the country. Declining landholding size referred to earlier, has adverse implications for soil fertility and is one of the important causes of low agricultural productivity in the country (TERI, 2010). The extension of cultivation to land of lower potential and fertility, with greater natural degradation hazards such as steep slopes, areas of shallow or sandy soils, or with laterite crusts, arid or semi-arid land bordering deserts, which are fragile or marginal lands, in many parts of the country has also contributed to land degradation (GoI 2001- State of Environment report, 2001). In arid, semi-arid and sub-humid tracts of the country, large areas have been rendered barren due to saline-sodic soils because of unhealthy land management in respect of irrigation, drainage and crop husbandry (GoI, 2001, State of Environment Report 2001). The expansion of canal irrigation has been associated with widespread waterlogging and salinity/sodification problems in command areas, such as in the Indo-Gangetic plains and the Indira Gandhi Nahar Project. An estimated 6.43 mha of land has been affected by varying degrees of salinity and sodicity in different parts of the country (ICAR-NAAS, 2010).

Burning of wheat and rice straw and other agricultural residue has also contributed to loss of soil fertility, apart from causing air pollution. Open field burning of straw after harvesting is a common practice in states like Punjab, Haryana and Uttar Pradesh in order to ensure early preparation of fields for the next crop. Punjab alone produces around 23 million tonnes of rice straw and 17 million tonnes of wheat straw, annually. This straw is rich in nitrogen, phosphorus and potassium. However, instead of recycling it back into the soil by mulching, it is burnt in the fields. It is estimated that the resulting loss of NPK from the soil, is about 50 per cent of the total fertilizer consumption in the state. (GoI 2009- state of environment 2009)

Various institutional and policy failures compound the challenge of land degradation in agriculture. On the policy front, there are no clear policy guidelines for conversion of prime agricultural land into other uses. Policies relying on heavy subsidization of inputs, particularly chemical fertilizers, electricity, and water, have disproportionately benefitted richer farmers and irrigated areas, have encouraged indiscriminate overexploitation of the land and water resource base of agriculture (State of Environment Report 2009) and have become politically entrenched (Badiani et al., 2012, Dubash, 2002). On the institutional front, tenancy reforms have been unable to respond to land quality variations and overcome the consequences of land fragmentation (TERI 2010). Finally, the lack of effective institutional convergence among the multiple agencies dealing with land resources at various tiers of governance remains a major challenge in tackling land degradation in India.

4.3 Conceptual approach to assessing the economic costs of land degradation in India

In an ideal scenario, an economic analysis of the cost of land degradation should include a) all land uses and b) all major indirect and offsite costs to ensure that the assessment captures the costs to society, beyond direct private costs. Nkonya et al (2016) propose a useful two dimensional conceptualization of the cost of land degradation, namely the loss in TEV due to land use/cover change (LUCC) and the cost of degradation of land that does not experience any change of use (static land use). A review of the literature, discussed in more detail later, suggests that existing research focuses on static-land use costs of degradation dominated by first-order direct output losses in agriculture. There is some more recent work on the loss of ecological values but almost entirely in the context of forests.

Following Nkonya et al (2016) , we cover two major aspects of land degradation- first, the cost of land degradation on a given land use, and second, the cost that arises when land moves from a more to a less productive (as measured by the TEV) use. In the first category, we look at losses within agriculture, forestry and rangelands, the sectors where arguably the costs of land degradation are felt the most. In the second category, we look at change within the official nine-category land use classification followed in India, as well as wetlands. The second category of estimates are rough approximations due to constraints in information, and at this stage must be seen more in terms of bringing to the fore this aspect of land degradation that has hitherto received scant attention.

The broad framework of the study is outlined in Figure 4.7. The detailed methodology for estimating each of these impacts is discussed in more detail in subsequent sections.

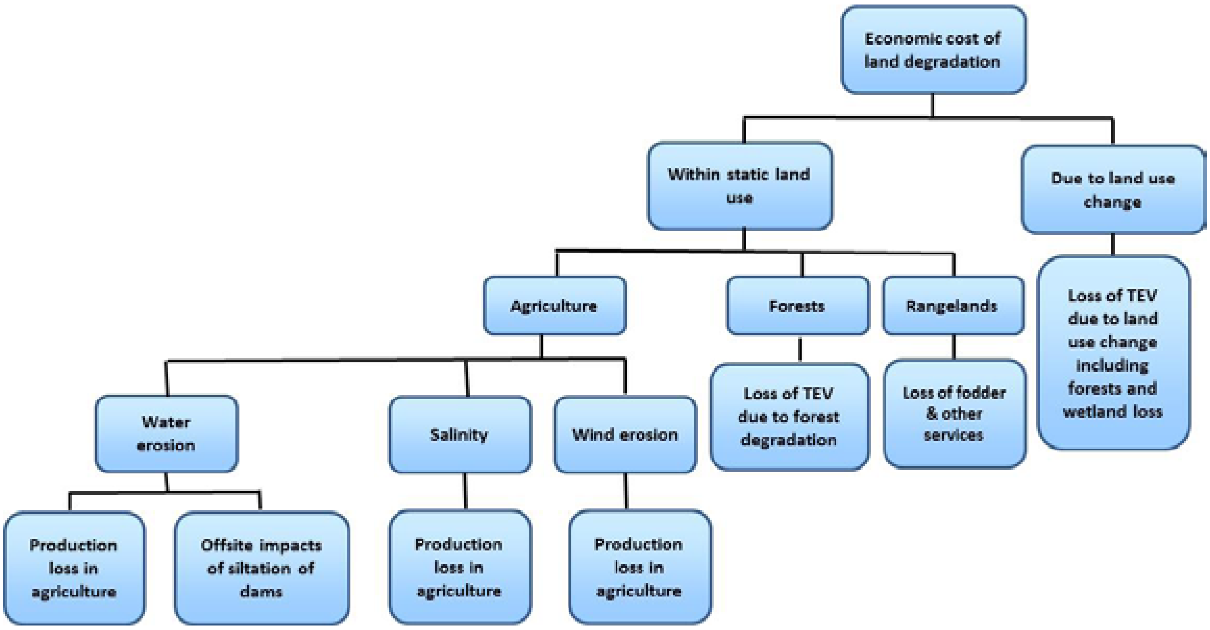

Figure 4.7 Framework for assessing the cost of land degradation used in this study

4.4 Degradation within static land use

4.4.1 Forests

FAO (2002) defines forest degradation as, "the reduction of the capacity of a forest to provide goods and services". We have used this definition as the conceptual basis of our assessment of the monetary losses resulting from forest degradation. The economic costs of deforestation and degradation include both direct losses (e.g of provisioning or consumptive direct use services) of timber, fuelwood and non-timber forest products, and non-consumptive direct use values such as recreation; indirect use losses (loss of flood protection, carbon sequestration other ecosystem services) as well as non-use values associated with loss of forests such as biodiversity.

Bahuguna and Bisht (2013) estimate that the minimum value of goods and services provided by forests annually in India are about INR 6.96 lakh crores. Most studies assessing the value of forests, biodiversity and ecosystem services focus on provisioning services (Negi and Semwal, 2010; Joshi and Negi, 2011; Mahapatra and Tewari, 2005; Purushothaman et al., 2000; Narendran et al., 2001; Murthy et al., 2005; Sarmah and Arunachalam, 2011; Appasamy, 1993). One study addresses the nutrient recycling role of forests (Kiran and Kaur, 2011) while Badola et al., (2010) addressed the regulating role of a single forest ecosystem and Kadekodi and Ravindranath (1997), and Singh (2007) that of the forests of India. The recreational value of services has been assessed by Badola et al. (2010) and Hadker et al. (1997) for Corbett Tiger Reserve, Uttarakhand and Borivili National Park, Maharashtra, respectively. Only about ten studies from India capture a range of ecosystem services (Chopra, 1993; Parikh et al., 2008; Verma, 2000; Verma et al., 2010; Verma et al., 2007). Recently, 12 studies have been carried out as part of the TEEB-India Initiative (TII) (MoEFCC and GIZ, 2014) to assess the ecosystem services of forests (and also wetlands and coastal ecosystems).

Very few studies address the economics of forest degradation in India, and those that do again restrict themselves to provisioning services. The losses of ecosystem services, for example, through deforestation and forest degradation are not often assessed. To date we are only aware of six major studies that have estimated the costs of forest degradation in India. Many of these form part of a larger assessment of the economics of land degradation in the country, and utilise different approaches. These include a study conducted by TERI (1998), studies conducted by Gundimeda et al. (2005, 2006), Kumar et al. (2006), a World Bank study (2013) and a recent assessment by Mythilli and Goedecke, (2016). We briefly review the methodology and the results of each study before describing our approach to estimating the costs of deforestation and degradation.

TERI in 1998 carried out a study on land degradation in which they included the economic losses resulting from forest degradation. This study only included the loss of provisioning services that results from forest degradation, namely the economic loss of industrial wood and fuelwood. In this study they estimated the real forest area versus the recorded forest area using the following formula.

Real forest area = (total growing stock/potential growing stock) X recorded forest area. Their study estimated that the real area is 48 million ha (63%) versus a recorded area of 77 million ha. Therefore unproductive forest constitutes 37%.

They estimated the total physical loss to be the difference between the total physical product or service derivable from the recorded area and from the real forest area.

The study estimated foregone production of industrial wood at 45 billion rupees annually and fuelwood production at 12 billion rupees annually leading to a total loss of 57 billion rupees per year.

Gundimeda et al. (2005a) determined the value of timber, carbon fuelwood and Non-Timber Forest Products in India's forests. They found an overall decrease of 168 Mcum of timber accompanied by a net carbon release of roughly 58 MtC. They estimated that a decrease in stock of timber was responsible for wealth depletion of over INR 380 billion (1% of GDP). The details are provided in Appendix 1 (Table1).

Gundimeda et al. (2006) also estimated the value of biodiversity in India's forests and found the consumer surplus for Indian and foreign tourists was US 558 and 3638 respectively and the total NPV of ecotourism for India is Rs 4307390 million or Rs 91,641 per ha. The States with the highest loss of biodiversity as percentage of NSDP were Mizoram (147%), Assam (55.5%), Himachal Pradesh (15.6%) and Kerala (12.3%). The overall loss in value was Rs 147460.00 million rupees per year. Kumar et al. (2006) calculated the values of ecological services provided by Indian forests (viz soil conservation, water augmentation and flood prevention).

The World Bank (2013) study assessed both degradation (static land use) and deforestation (land use change). They used various estimates to arrive at a deforestation figure of 0.6 million hectares annually between 2006-2009, and an estimate of degraded forest area in 2003 of 24.4 million ha. From these two figures they estimated the total degraded forest area in 2009 at 28 million hectares. Using various estimates of use values limited to (i) Timber, (ii) Non-timber forest products, (iii) Fodder, (iv) Eco-tourism (v) Carbon sequestration (vi) Soil erosion prevention and (vii) Water recharge (Appendix 1 (Table 2), they valued the losses by assuming that degraded forests provide between 20 to 80% of the direct use values but none of the indirect values that are associated with dense forest functions. However, according to estimates provided by Gundimeda (2001), degraded forests are associated with a 20% loss of accumulated carbon in the range of 21-59 tC/ha in India, valued at a cost of carbon USD20 per ton of $C0_2$. The losses are estimated at between 0.1 to 0.3% of GDP (Appendix 1Table 2). However, if related to the GDP of the poor (17% of the country's total GDP in 2010), then losses in the forestry sector are 0.6% to 1.7%.

Mythilli and Goedecke (2016) estimated the cost of land degradation including forests as part of a suite of land use classifications. However, their definition of forests based on MODIS data for the period 2001-2009 is different from that used by the Forest Survey of India (FSI) and they have assessed deforestation (that is the change from one land use category to another) and not forest degradation per se.

Land degradation in the forestry context may refer to a) the conversion of forests to non-forests, i.e. the change in Land Use Land Cover (LULCC) ('deforestation') and/or b) degradation which refers to a shift from a more dense forest class to a less dense forest one (e.g. from very dense to moderately dense forests or from moderately dense forests to open forests or from open forests to scrub forests), the 'static' land use scenario. In this study, we determine forest degradation resulting from both these categories. While the values of deforestation are derived directly from the Forest Survey of India change matrix (FSI 2009-2015), forest degradation is assessed using FSI data for 2015. Here we discuss the method used for deriving estimates of forest degradation while estimates relating to deforestation are discussed in the section on land use change.

In order to estimate the costs of forest degradation (shift from a higher forest density class to a lower value), we adapt the Millennium Ecosystem Assessment (MEA, 2005) definition of land degradation to the forestry context in India, and then apply the Total Economic Value (TEV) approach to determine the value of forest degradation (see Nkonya et al. 2016). The following steps were followed:

- The costs of forest degradation due to conversion from one density class to another was derived from the equation for cost of land degradation due to LUCC (as outlined in Nkonya et al., 2016) in the following way

$$CF_{CD} = \sum_i^k \Delta a_{ij} * (P_i - P_j)$$

where,

- CF_{CD} is the cost of forest degradation due to change in forest density class
- a_{ij} = land area of forest density class i being replaced by forest density class j, where i,j=1,...k
- P_i is the TEV per unit of area for forest density class i, the underlying assumption being that change in area from one density class to another can be valued by the difference in TEV values of these density classes under different levels of forest degradation

Currently, the forest and tree cover of India stands at 24.16% (FSI, 2015) much below the goals of the National Forest Policy of 1988 which allows for a forest and tree cover target of 33% for the country and 66% for hill areas. The current situation for India's forest cover is provided in Table 4.2. However, this forest policy target does not disaggregate these targets by forest and tree cover or by density class, which makes it difficult to use them for the purposes of this study. However, given the country target of 33%, we make some tenable assumptions to estimate the costs of forest degradation for the country under two alternative scenarios which are discussed in subsequent sections.

Table 4.2 Forest and tree cover of India in 2015

Class	Area (in ha)	Percent of Geographical Area
Forest cover		
Very Dense Forest	8590400	2.61
Moderate Dense Forest	31537400	9.59
Open Forest	30039500	9.14
Total Forest Cover *	70167300	**21.34**

Class	Area (in ha)	Percent of Geographical Area
Tree Cover	9257200	2.82
Total Forest and Tree Cover	79424500	**24.16**
Scrub	4136200	1.26
Non-forest	254422800	77.4
Total Geographical Area	328726300	**100.00**

Source: FSI (2015)

Forest Degradation- Conservative Scenario 1

In this scenario, we include both open forests (30.04 mha) and scrub forests (4.14 mha) (that is forests of canopy density <40%) within the category of potentially degraded forests (total 34.18 mha) (FSI, 2015) and then consider the benefits lost from their current status (that is we estimate the costs of forest degradation resulting from the area of forests lying under scrub and open forests, rather than under moderately dense forests). ***In this scenario, we assume that the potentially degraded forests of this country should at least be in the moderately dense category*** to a) meet the needs of India's >250 million forest-dependent people given the many ecosystem services provided by moderately dense forests and b) the conservation and climate mitigation objectives of the country given that India has an NDC (Nationally Determined Contribution) target of creating an additional carbon sink of 2.5 to 3 billion CO_2 equivalent through additional forest and tree cover by 2030.

It can of course be argued that all open and scrub forests with canopy densities below 40% and 10% may not be degraded (e.g if the forests include savannah grasslands or say areas of desert national park) which cannot achieve higher canopy densities. However,

1. Our figures of 30.04 mha of open forests being degraded tie in well with SAC (2016) figures of 29.3 m ha under vegetal degradation[30].
2. FSI change matrix itself shows upgradation from open forests to moderately dense forests and very dense forests (and vice-versa) indicating that these forests can and regularly achieve higher canopy densities (Appendix 6).
3. This assumption would be unnecessary if disaggregated changes in figures were provided by FSI for native forests versus plantations. In the absence of more accurate data, we need to make these assumptions.

We therefore, conservatively assume a moderately dense figure (40-70% canopy density) and do not assume that all of India's open and scrub forests should be in the very dense category, given the enormous pressures wielded by India's population on her land resources, the unviability of such an objective being achieved by 2030.

Forest Degradation- Highly Conservative Scenario 2

In this even more conservative scenario, we only consider open forests (30.04 mha) to be degraded (FSI, 2015), and then estimate the benefits lost from degradation (that is we estimate the costs of forest degradation resulting from the current area of forests lying under open forests rather than the next higher category of moderately dense forests.) In this scenario, we do not consider scrub forests to fall within the definition of forests. This dovetails with India's definition of forests which is "an area with a minimum coverage of 1 ha, with at least 10 % crown cover (FSI, 2009)." By this definition, scrub forests are not classified under forests since they have less than 10% forest cover. Moreover, scrub forests can also include grassland areas (Anmol Kumar, 2017, pers comment).

[30] Although, their estimates also include grasslands

In order to estimate the costs of this forest degradation for the country, we compared the TEV of different density classes and estimated the cost (or equivalently the benefits forgone) due to forest being in the scrub and open density classes rather than in the moderately dense class. Verma et al (2014) assessed the TEV and rates of Net Present Value (NPV) applicable to different classes/categories of India's forests (Table 4.3). This was done for 14 different forest types (based on Champion and Seth's, 1968 classification, and for four different FSI density classes (Very Dense Forests, Moderately Dense Forests, Open Forests and Scrub[31]). The TEV estimates incorporate the array of goods and services comprising timber, bamboo, fodder, fuelwood, NWFP, carbon sequestration, soil conservation, water recharge, pollination and seed dispersal, and water purification. We have used those values for which Verma et al. (2014) provide the TEV (see Table 4.3). The figures used are, however, likely to be an underestimate. Verma et al. (2014) for example, does not provide the TEV for bioprospecting and carbon storage across the country, although an NPV is given.

Table 4.3 Total Economic Value of forests (after adjusting for double counting and simultaneous delivery of ecosystem services) as given by Verma et al. (2014)

Tropical Economic Value - Rs/ha/yr	VDF	MDF	OF	Scrub
Tropical Wet Evergreen Forests - North East	178,772	93,991	81,716	22,988
Tropical Wet Evergreen Forests - Western Ghats	197,052	138,537	53,832	27,464
Tropical Semi Evergreen Forests - North East	102,971	80,975	42,447	24,170
Tropical Semi Evergreen Forests - Eastern Deccan	240,290	195,825	104,140	93,733
Tropical Semi Evergreen Forests - Western Ghats	159,497	105,316	63,064	34,818
Tropical Moist Deciduous Forests	147,493	101,457	57,112	26,102
Littoral & Swamp Forests	240,606	161,884	92,650	63,943
Tropical Dry Deciduous Forests	107,810	77,390	46,804	29,565
Tropical Thorn Forests	61,365	54,008	43,238	29,289
Tropical & Subtropical Dry Evergreen Forests	126,952	91,131	51,781	21,928
Subtropical Pine/Broadleaved Hill Forests	108,322	83,875	47,420	17,256
Montane & Moist Temperate Forest	165,691	127,735	63,635	18,541
Sub Alpine & Dry Temperate Forest	139,036	114,532	54,901	13,563
Alpine Scrub	120,739	89,210	41,483	18,038
Country Average	**149,757**	**108,276**	**60,302**	**31,528**

Legend: VDF: Very Dense Forests; MDF-Moderately Dense Forest; OF: Open Forests

Source: Verma et al. (2014). FSI (2011) data used by Verma et al. (2014)

These values account for double counting and simultaneous delivery of ecosystem services. Therefore, according to Verma et al. (2014) the total economic value for forests is estimated based on a notional assumption of percentage of full value relevant for each of the forest goods and services to arrive at a more compatible and simultaneous delivery of ecosystem services. The assumptions used by Verma et al. (2014) are listed in Appendix 2.

[31] Very dense forests (VDF) are defined as those with canopy density of 70% and above;
Moderately dense forests (MDF) have a canopy density of between 40-70%
Open forests (OF) have a canopy density between 10 to 40%
Scrub constitutes areas with a canopy density below 10% . Verma et al. (2014) redefine scrub as forests with less than 10% canopy cover (LTF) although they use scrub in the draft version of the report.

We have calculated an average of the TEV to arrive at a figure for the country for each density class. Ideally, a weighted average should have been used to account for the area under each forest type. However, this requires updated information on the area under each forest type which is available only for 2011 (FSI, 2011) in the Forest Atlas of India. Unfortunately, forest type estimations of area under each density class have not been updated since 2011.

Table 4.4 provides the change in TEV resulting from degradation from one density class to another, that were used to value a change in area between the corresponding density classes.

Table 4.4 Change in TEV resulting from conversion from one forest density class to another class of lower density (in Rs/ha/year)*

VDF to MDF	VDF to OF	VDF to scrub	VDF to NF	MDF to OF	MDF to scrub	OF to scrub	MDF to NF
41480.7	89455.2	118228.4	149,757	47974.5	76747.7	28773.2	108,276

Legend: VDF: Very Dense Forests; MDF-Moderately Dense Forest; OF: Open Forests; NF: Non-Forests
*We assume that the TEV of a non-forest that has been converted from a forest is 0 given the loss of ecosystem services that results
Source: Adapted from Verma et al. (2014)

Depending on the scenario considered, the costs of degradation range from Rs 1441 billion- Rs 1759 billion (see Table 4.5).

Table 4.5 Costs of forest degradation

Forest Density Class	VDF	MDF	OF	Scrub	Total
Country average of TEV (Rs/ ha/year)	149,757	108,276	60,302	31,528	
Area of each class of forest (in ha			30039500	4136200	
TEV lost per ha for conversion from MDF (rupees)			47974.5	76748	
Scenario I Costs of degradation (benefits foregone) resulting from forests in the scrub and OF categories rather than in the MDF category (Conservative scenario)					
Costs (in million rupees)			1441130	317444	1758574
Scenario II Costs of degradation (benefits foregone) resulting from forests in the OF category rather than in the MDF category (Very conservative scenario)					
Costs (in million rupees)			1441130		1441130

4.4.2 Rangelands

Rangelands are an important, but highly undervalued land use category. Rangelands provide a range of services including direct use values (e.g. subsistence pastoral use, bio-medical, genetic, harvesting by-products, outdoor recreation), indirect use values (ecosystem functions such as soil conservation/ retention, water supply and retention, nutrient recycling, waste treatment, pollination, wildlife habitat, air quality, climate regulation) and non-use values (e.g. socio-cultural goods and services that contribute to health, aesthetics, spiritual and cultural values and to traditional knowledge) (Hatfield and Davies, 2006, Heidenreich, 2009). However, our understanding of the TEV of the goods and services provided by indigenous grasslands is very limited. In a review focused on temperate grasslands, Heidenreich (2009) did not find any empirical valuation research for temperate grasslands and Joshi et al, undated reach a similar conclusion in the context of grasslands in the Hindu-Kush region. Limited work on estimation of the value of rangeland ecosystems has been conducted in the USA, Canada, South America, and Australia, which suggest the total economic value of temperate grassland can range widely from USD 190 to USD 1,618 per hectare per year depending on location, extent, function, and significance to the human population in the vicinity.

In a recent study, Kwon et al (2016) estimate the global impact of grassland degradation on livestock productivity (from 2001 and 2011) at about 6.8 billion USD. The authors estimate the extent of degraded grasslands using satellite data and use this information along with estimates of the corresponding productivity of grasslands to estimate the cost of milk (and similarly meat production) as follows:

$$CLD_M = \sum_{i=1}^{l} [DMI_{t=2001} - DMI_{t=2010}]\, \theta_m x_t P_m$$

$$DMI_t = biom_t \gamma \kappa$$

Where, DMI_t = dry matter intake (tons) in year t in pixel i; θ_m = conversion factor of grass DMI to the fresh weight of milk; P_m = price of milk per ton; $biom_t$ = grass biomass production (DM) in year t; γ = contribution of grass to total feed intake; x_t = number of milking cows in pixel i; and κ = share of above ground grass biomass actually consumed by livestock.

Using this methodology, Kwon et al (2016) estimate the value of loss in milk and meat production due to decline in grass biomass in India at 7.70 US million dollars (at 2007 prices) (considering only cattle, buffalo, sheep and goats). 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 in this study is much lower than smaller African countries; however, the study acknowledges that it does not consider forest lands, which account for as much as 60% of the livestock grazing area according to some estimates.

In another recent estimate, World Bank (2013) estimated the loss of grass yield due to rangeland degradation in two ways. In the first method the reduction in fodder production is valued at the price of fodder and is estimated at Rs 400-800 billion. This is based on an assumed productivity of 0.55 TDM/ha (tonnes of dry matter per hectare) on degraded rangelands as against original productivity of 3.5 TDM/hectare, and fodder price of 4000-8000 Rs. per ton of DM. In the second method the loss of fodder is converted into a loss of livestock based on estimates of the feedstock requirements of each animal cattle unit (ACU). This loss is then monetized using the value of GDP from the livestock sector per ACU. This approach gives a value of Rs 170-256 billion. For their final estimation, they consider the average value from these two approaches, which is about Rs 405 billion, equivalent to 0.6% of GDP in 2010.

Clearly, the current estimates of the value of rangeland degradation span a wide range, from approximately from Rs 500 million as per estimates of Kwon et al , 2016 to Rs 535 billion as per World Bank, 2013 (in 2014/15 prices).

We assess the cost of rangeland degradation, in terms of the loss in fodder and ecological services provided by rangelands, based on the following assumptions:

4. 50% of the rangelands in the country are degraded. This is a conservative estimate since there are number of studies that suggest that nearly all pastoral systems in the country are highly degraded (Roy and Roy undated, Government of India, 2011).
5. Per hectare productivity of a degraded grassland is assumed to be 1.5 tonnes of green fodder as compared to 3.6 tonnes in healthier grasslands. Roy and Roy undated survey a number of studies on the productivity of grasslands in India. They conclude that while the potential harvestable biomass in the grasslands of India varies from 2.2 to 5.0 t/ha, the actual situation is much bleaker with a harvestable above ground yield of only 0.5- 2.0 t/ha. We used the average of these ranges to

estimate the productivity of healthy and degraded grasslands in India. This figure also ties in closely with the estimates (1.2 to 1.5 t/ha of green forage supply from pastoral sources) used by the Indian Grassland and Fodder Research Institute to project fodder supply for a Vision 2050 exercise (IGFRI, 2013).

6. Green forage was converted into dry matter (DM) by applying a factor of 0.25, following (IGFRI, 2013). This translates into 0.3t of DM in degraded pastures as against 0.9 t of DM in healthier pastures.
7. Price of Dry Matter was assumed to be Rs 5000/tonne (based on http://www.dairyknowledge.in). This is on the conservative side of the price range of Rs 4000-8000 Rs. per ton of DM used by World Bank (2013)
8. For ecosystems services, we assume that pastures provide the same value of services as scrub forests and that these services are not available in degraded pastures.

Our results suggest that the loss of fodder due to degradation of grasslands is Rs 13.44 billion while the loss of other (other than fodder) services provided by grasslands is to the tune of Rs. 106.80 billion, thus resulting in a total estimated cost of about Rs. 120.25 billion in 2014/15.

4.4.3 Agriculture

Agriculture has received the most attention in the context of land degradation, being at the heart of several land degradation problems in terms of causes and impacts. The most studied aspects of land degradation in agriculture include soil erosion due to water and wind, salinity, alkalinity, water logging and chemical degradation.

Two approaches are mostly used to value the on-site agricultural effects of soil erosion. The first measures the impact on soil as a resource from the perspective of key soil characteristics such as soil nutrient content. The value of soil nutrients lost due to degradation is estimated in terms of the cost of replacing these nutrients with artificial fertilizers. The second method is based on the effects of erosion on the quantity and value of agricultural production. Production loss is also the most commonly used technique for estimating the cost of other forms of land degradation in agriculture such as salinity and alkalinity.

World Bank (2013) estimated the cost of land degradation in India as part of a larger study on the economic loss of environmental health and natural resources. The study followed the production loss method (for agricultural losses due to salinity and water logging) and the replacement costs (for agricultural losses due to erosion), both approaches relying on loss norms available from existing literature, as follows:

1. **Cost of erosion**
   » Estimated fertilizer required to replace leached out nutrients (each N, P and K in tonnes) * price of N, P and K respectively
2. **Cost of salinity**
   » Area under wheat affected by different levels of salinity (ha) * average productivity of wheat * average loss of productivity of wheat under corresponding levels of salinity (around 5% per unit salinity for levels over 6 dS/m.) * net income from a hectare of land under wheat[32]
   » Area affected by extreme salinity (assumed to be half of the area uncultivable due to waterlogging and salinity) * net income from a hectare of land under wheat
3. **Cost of water logging**
   » Area under paddy affected by waterlogging (ha) * average productivity of paddy * average loss in productivity in paddy due to water logging (40%) * net income from a hectare of land under paddy
   » Extent of waterlogged wasteland * net income from a hectare of land under paddy

[32] Assumption that such land is only used for wheat production

The value of total agricultural loss, thus derived, was to the tune of ***1% of India's GDP in 2010.***

Gundimeda et al (2005a) estimated the cost of land degradation due to soil erosion (both onsite cost of erosion of topsoil and offsite cost of sedimentation of waterways) and other factors. The onsite cost of soil erosion was estimated using the replacement cost of the constituent nutrients lost. The authors used available information on different soil erosion zones of India and estimated the erosion rate contributed by each State using the share of the agricultural area in each State to the total in India. The amount of nutrients lost were then estimated based on assumptions about the proportion of nitrogen, phosphorus, and potassium per unit of top soil eroded (assumed to be 1.39%), and then valued, respectively, in terms of the equivalent levels of urea, single superphosphate and murate of potash using the price of fertilizer. For offsite impacts, the authors estimated the sediment loads in various major rivers (including all tributaries) based on existing information on geographical area under major rivers in all states, and sediment load per square kilometre per year. The contribution of agriculture to the sediment load of each state was estimated on the basis of the proportion of land degraded as a result of agricultural activities in the total geographical area of each state. An average cost of Rs 122 per tonne of sediment was taken as the basis for estimating the cost of de-sedimentation of water bodies in the country.

For other (than erosion) forms of land degradation, the authors applied the loss in production method. Using an estimated NPV of agricultural land, the authors used norms for loss of production due to specific factors (salinity- 25% loss in productivity, water logging considering only paddy- 40% loss in productivity, gullies and marshy land- 100% loss in productivity, degraded pasture and uplands with or without scrubs- 100% loss in productivity), to estimate the value of output lost. As an alternative, the authors estimate the value of degraded land using the maintenance cost approach, by using estimates of the expenditure incurred by the government from the Ninth Plan onwards during 1998–2002 in repairing and rehabilitating degraded land.

The study found that depletion and degradation (in terms of replacement cost of soil nutrients, cost of sedimentation of water bodies, and cost of rehabilitating degraded lands) amounted to about ***1.34% of India's GDP in 2002/03***. Of this, the direct onsite costs (replacement cost of soil nutrients and cost of rehabilitating degraded lands) were about 1.27% of India's GDP in 2002/03.

Reddy (2003) estimated crop losses due to degradation of (non-forest) lands in India. The author relied primarily on NRSA data for the period 1988-89 for the extent of land degradation due to various factors (water erosion, wind erosion, salinity and alkalinity, and water logging.) in the country.[33] Economic costs were estimated based on two alternative methods- the loss of production and the cost of replacing nutrients lost due to degradation, using existing norms. Their methodology is summarized below:

1. **Cost of soil erosion**
   - **Nutrient replacements cost:** Area affected by erosion (ha) * average loss of top soil (tonnes per hectare-19.6 tonnes per ha)* % loss of NPK per tonne of top soil lost (1.39%) * replacement factor (based on the average efficiency in the application of artificial NPK- 33%)* market price of NPK
   - **Production cost:** Area affected by erosion (ha) * average production of foodgrains (tonnes/ha) *average loss in production of foodgrains (30.4%)* market price of foodgrains
2. **Cost of salinity**
   - Area affected by salinity (ha) * average production of crops (tonnes/ha)* average loss in production of crops (25%)* market price[34]
3. **Cost of water logging**

Area affected by waterlogging (ha) * average production of paddy (tonnes/ha) * average loss in production of paddy (40%) * market price of paddy

[33] Total area degraded in 1988/89 as per NRSA was 35.49 (erosion- 31.5 million ha, salinity/alkalinity- 1.9 million ha and water logging- 1.2 million ha). The authors also used estimates of Sehgal and Abrol (1994) which added up to 187.8 million ha (erosion - 166.1 million ha, salinity/alkalinity- 10.1 million ha, and water logging -11.6 million ha)

[34] It is not clear from the paper which crops have been considered for the loss estimation

The results of the study are summarized in Appendix 3. In addition, Reddy (2003) also estimated economic costs based on a production function estimated at the district level (for 217 districts),, as follows

- Y = f (Deg, FS, GIA, Fert, Credit, U) ,
- where, Y: value of production in Rs/ha; Deg: % geographical area degraded; FS: average farm size in ha; GIA: % gross area irrigated; Fert: fertilizer consumption per ha; Credit: availability of institutional credit/ha; U: error term

The study found a wide range of estimates of the cost of land degradation in India ranging from about 0.45% of GDP using the production function approach to about 1-2% of GDP using the replacement cost. Much higher values in the range of 4-6% of GDP were obtained by applying production losses based on average productivity losses for different forms of degradation.

TERI (1999) considered both onsite and offsite impacts of land degradation. Onsite impacts were estimated for erosion, nutrient depletion and salinization/water logging while offsite impacts reflected the cost of sedimentation of reservoirs due to soil erosion. The costs were estimated by applying yield reduction factors to the productivity of different crops under different types of land degradation and multiplying these with corresponding affected area (at the national level).[35] The study also estimated the offsite impacts of erosion in terms of siltation of downstream irrigation reservoirs. This was based on an estimate of 11% of storage capacity being silted up over the years and the assumption that a fall in reservoir capacity corresponded to a proportionate fall in the total irrigated area. This reduction in the irrigated area was distributed among crops in proportion to their share in the canal command area and the cost of siltation was estimated as the value (at support prices) of the difference in productivity between irrigated and un-irrigated areas, i.e.

Offsite loss in physical output = (average productivity in irrigated areas – average productivity in un-irrigated areas)* loss in irrigated area

The study estimated that Rs 89-232 billion were lost due to soil degradation, roughly equal to 0.63%-1.65% of India's GDP in 1997/98 (0.56% and 1.57% excluding offsite costs) and 2.43% and 6.31% of GDP from agriculture and livestock (2.13% and 6.01% excluding offsite impacts) in the same year.

The above review indicates that the cost of degradation as % of GDP as estimated by different studies is in the range of 1-2%, with the exception of some of the cost scenarios of Reddy (2003).[36] These estimates are mostly based on average loss norms for soil nutrients or agricultural productivity due to degradation, with limited differentiation of these norms due to crop, region or soil type (though some studies e.g. TERI 1999 and Gundimeda et al 2005 take into account some differentiation). In practice, however some regions and soil types are more vulnerable due to degradation than others. For example, Sehgal and Abrol (1994) found that the loss of productivity due to soil erosion was more pronounced in red soils followed by black soils and alluvium soils.

In order to address this limitation, the present analysis uses output loss factors that are region, crop and soil specific, being based on crop experiments for different soil types in different regions of the country. As discussed in Chapter 1, water erosion is the predominant form of land degradation in the country. While estimates differ, according to the Space Applications Centre (SAC) study in 2016, water erosion accounts for 10.98% of the degraded area, followed by vegetal degradation (8.91%), wind erosion (5.55%) and salinity (1.12%). According to the harmonised figures (ICAR-NAAS, 2010) water erosion accounts for 25.12% of the geographical area followed by wind erosion (3.77% of geographical area), acid soils (5.4 % of geographical area), alkali/sodic soils (1.13%) and salinity (0.83%). Accordingly, loss in agricultural production due to water erosion, salinity and sodicity and wind erosion are considered in this assessment.

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35 Yield reduction factors available from two sources were used- one, Brandon Hommann and Kishor (1995) which are crop specific (11 crops) and based on studies in the Indian sub-continent, Africa and North America and (2) those by Sehgal and Abrol (1994) which are aggregate rather than crop-specific, based on field data.

36 The high cost scenario of Reddy (2003) is based on an assumption of 30% loss of output due to soil erosion and the higher end of estimates for degraded area. Other studies that use the production loss method for estimating losses due to soil erosion use a range of loss factors (about 5%-40%) depending on the severity of erosion and the type of soils (e.g. TERI, 1998).

Production loss in agriculture due to water erosion

We rely on the work done by Sharda et al (2010) (IISWC- Indian Institute of Soil and Water Conservation) to estimate the value of production losses in agriculture in rain-fed areas due to water erosion. Their study estimated average EPLFs (erosion productivity loss factors) for relevant crop and soil combinations based on 147 experiments conducted between 1974-2005 which compared no-conservation (farmers' practice) with conservation best practices (e.g. agronomic, mechanical or land configuration measures) covering various edaphic, topographic and agro-climatic conditions; and major soil types (alluvial, black and red) in the country. Broadly, the steps followed in the study were as follows:

- Categorization of erosion category by extent of erosion (slight, moderately slight, moderate, moderately severe, severe) and soil type in each state under the assumption that the potentially eroded area among the three major soil groups is in the same proportion as the actual area under the three soil groups of that state for each erosion category
- Estimation of average EPLF (erosion productivity loss factor) for relevant crop (categorized under cereals, pulses and oil seeds) and soil combinations based on experiments
- Extrapolation of the experimental crop- soil- and erosion category- wise EPLFs for other erosion categories and soil groups using loss factors by Sehgal and Abrol (1994)
- Estimation of production loss using crop- and erosion class–specific rainfed area and average crop yield in the state under the assumption that degraded rainfed areas of a state and its distribution among different erosion categories is in the same proportion as the potentially degraded area of that state, covering each erosion category. The rainfed area of a crop in a state was estimated by subtracting the irrigated area from the total cultivated area under a crop. The estimation was based on the following formula:

  $L_R = E_R * P * \delta$...(1)

  subscript `R' denotes rain-fed areas;
  L = production loss ;
  E = potentially eroded area ;
  P = average productivity; and
  δ = erosion productivity loss factor
- Valuation of productivity loss at the minimum support prices in 2004/05

For the purpose of this study, we converted the value of losses derived by Sharda et al (2010) into 2014/15 market prices by using the WPI and a crop-specific factor of the ratio of wholesale price to the support price.

Table 4.6 Losses due to water erosion in rain-fed agriculture for all India

Crop	Potential eroded rain-fed area ('00 ha)	Production loss (t)	Monetary loss (Rs. million) in 2014/15 prices*
Cereals	435489	8909483	**97725**
Oilseeds	205507	2811192	**62124**
Pulses	185556	1727367	**48647**
Total	**826552**	**13448042**	**208496**

Source: Sharda et al 2010, last column - estimated for the present study using 2005/06 values in Sharda et al (2010)

As can been seen from Table 4.6, cereals account for the largest share (about 47%) of losses due to water erosion in rain-fed areas. This is followed by oilseeds (30%) and pulses (23%). Looking at the distribution of these costs across States (Annexure 2), MP (17% of the all India value of total cost) and Karnataka (16%) suffer the highest losses, followed by Maharashtra (12%) and Andhra Pradesh (10%).

Offsite impacts of soil erosion

There is some literature on the offsite impacts of soil erosion in terms of sedimentation of water bodies but these have been at specific project sites and their extrapolation to a larger geographically scale is fraught with untenable assumptions.

Two approaches have been used in the literature to estimate economy-wide offsite costs of soil erosion. The first approach is to estimate the opportunity cost of lost storage in terms of the resulting loss of benefits (irrigation, power, drinking water, flood control etc.). This is the approach taken by TERI (1999), as discussed above. There are two limitations with the approach. First, it is not the loss of total storage but the loss of live storage that is relevant to assess the cost of foregone benefits. Most modern dams are designed so that they can afford to lose some storage capacity without their performance being impaired – through the provision of "dead storage" which lies beneath the elevation of the dam's lowest outlet. However sediments do not build up evenly along a horizontal plane, so that some "live storage" is usually lost before the dead storage is filled. The Central Water Commission has recently published a compendium of siltation of reservoirs in India, which provides data on the loss in total storage capacity but does not distinguish between dead and live storage. Our discussion with the Central Water Commission and the National Hydro Power Corporation suggests that while some loss of live storage does take place, there are regular efforts to ensure that it is kept minimal, especially in the new dams. In any case, using loss of total rather than live capacity would present a misleading picture of the cost of sedimentation of dams. Secondly, even if this information were available, the relation between the loss of capacity and loss of benefits is not necessarily linear. In addition to the purpose of the dam (multi-purpose versus single purpose), the loss of benefits would also depend on a number of dam- specific attributes such as size and height.

The second method that has been used for the estimation of offsite impacts of soil erosion is in terms of the cost of de-sedimentation of water bodies in the country. As discussed above, Gundimeda et al (2005a) use an average cost of Rs122 per tonne of sediment as the basis for estimating this cost. Our discussion with CWC and NHPC suggest that most dams provide for sediment management through provisions like hydraulic flushing / sluicing through low level outlets which can preserve the long-term capacity of reservoirs by controlling sediment deposition. The choice of the most efficient method depends on reservoir geometry, flow and sediment characteristics and reservoir operation schedule. Once these systems are made integral to the dam engineering, desilting becomes a part of the dam operations and estimating a separate cost for it is not possible.[37] Mechanical desiltation of large dams is rarely done due to very high costs.

An alternative method to estimate the cost of capacity lost due to sedimentation is in terms of the cost of creating equivalent capacity. This would obviate the need to address issues such as the dam purpose but it still leaves the challenge of assessing the loss in dead vs. live capacity. This would also require some estimates of the cost of dam construction differentiated by region and technology.

In order to come up with the cost of sedimentation while addressing some of these limitations, we follow TERI (1998) with some modifications:

- Assume that only 25% of the total loss of capacity is attributable to live storage
- Assume that the total irrigation intensity in the command area remains unaffected, thus a fall in reservoir capacity leads to a proportional fall in total irrigated area;
- Offsite loss in physical output = (average productivity irrigated areas – average productivity in un-

[37] In some cases, removal of sediments is not an option. For example, reservoirs covered under the Indus Valley Treaty cannot be desilted. Also, mechanical desilting is prohibitively expensive and usually not undertaken.

irrigated areas) * loss in irrigated area; where loss in irrigated area = 25%* % loss in storage capacity due to siltation

- Monetary loss in output = loss in physical output * weighted average price of crops (with area under different crops as weights)

Since information on difference in productivity between irrigated and un-irrigated areas was available only for food grains, we use the productivity and prices of food grains as a proxy to measure losses due to sedimentation of dams in the country. Our estimates suggest that Rs 228.59 billion are lost each year due to sedimentation of dams considering irrigation losses alone. Losses due to forgone power supply, drinking water or flood control benefits from dams are additional, and thus these estimates should be seen as highly conservative.

Production losses in agriculture due to sodicity and salinity[38]

Productivity losses due to salinity are based on the work done by Sharma et al (2015) at the Central Soil Salinity Research Institute. In their study, salt affected soils are grouped under two categories, namely alkali/sodic and saline soils based on three parametres- electrical conductivity of saturation paste extract, exchangeable sodium percentage and pH. Production and monetary losses due to soil salinity and sodicity were estimated for 240 districts covering 14 states of India. All major *Kharif* (June to October) and *Rabi* (November to March) crops cultivated in each district of salt-affected states in India were considered for estimation of losses except few oilseed crops due to unavailability of data. On the whole, 19 crops including 7 cereals and millets, 5 oilseeds, 4 pulses and 3 commercial crops were considered for computation of production losses in India. The following steps were followed:

- Categorization of saline and sodic area by extent of the problem as per Table 4.7. Crop-wise area in *Kharif* and *Rabi* seasons in a given district was used to apportion the potential salt-affected area under a given crop category due to limited data on crop-wise salt-affected area.

Table 4.7 Different categories of salt-affected lands based on the degree of salinity/sodicity

Degrees of degradation	Salinity ECe (dS/m)	Sodicity pHs	ESP
Slight	4.0-8.0	8.5-9.0	<15
Moderate	8.1-16.0	9.1-9.8	15-40
Severe	>16	>9.8	>40

Estimation of loss factors for 'slightly' and 'moderately' affected areas for different cereals, oilseeds, pulses and commercial crops, based on experiments conducted by Central Soil Salinity Research Institute (CSSRI) and various other research institutes conducted under salinity/sodicity and control conditions. Crop production in severely salt-affected lands was assumed to be zero.

Estimation of production loss using crop- and salinity class area and average crop yield using the following formula

$$PLFS_{ij} = (C_{ij} - T_i) * (S_i/100) \qquad \ldots\ldots(2)$$

where,

» $PLFS_{ij}$ = Production loss factor of i^{th} crop for j^{th} land category in saline (sodic) regions
» C_{ij} = EC_e (ESP) value of i^{th} crop for j^{th} land category in saline (sodic) regions
» T_i = Threshold value of EC_e (ESP) for i^{th} crop
» S_i = Slope value of EC_e (ESP) for i^{th} crop

[38] Sodic soils have high sodium content while saline soils have high salt content including of Calcium, Magnesium and carbonates

Estimation of production losses for an individual crop in saline (sodic) region using the by following formula; losses were added regions (districts, states and all India)

$$LS_{ij} = A_{ij} * P_i * PLFS_{ij} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

where,

- » LS_{ij} = Production losses of i^{th} crop for j^{th} land category in saline (sodic) region
- » A_{ij} = Salinity (sodicity) affected area of i^{th} crop for j^{th} land category
- » P_i = Average district level yield of i^{th} crop
- » $PLFS_{ij}$ = Production loss factor of i^{th} crop for j^{th} land category in saline (sodic) region
- » Valuation of production losses at three years moving average of market prices (2012 to 2014)

The results for sodicity and salinity are summarized in Tables 4.8 and 4.9 respectively.

Table 4.8 Agricultural losses due to sodicity

Crop	Crop area under sodic soils (ha)	Production losses (t)	Monetary loss (Rs. million) (in 2014/15 prices)
Cereals	4503289	5952677	86148
Oilseeds	789763	286809	11606
Pulses	684659	287339	8792
Cash crops	689910	4655904	56263
Total	6667621	11182729	162809

Source: Sharma et al (2015); Estimated losses were converted into 2014/15 prices using the WPI

Table 4.8 suggests that over 50% of the value of losses due to sodicity are borne by cereals, followed by cash crops which account for about 35% of the value of losses due to sodicity in the country. At the State level, UP carries the largest burden of this cost at over 50%, followed by Gujarat (34%).

Table 4.9 Agricultural losses due to salinity

Crop	Crop area under sodic soils (ha)	Production losses (t)	Monetary loss (Rs. million) (in 2014/15 prices)
Cereals	2745306	2353757	32775
Oilseeds	770022	588764	24798
Pulses	650441	237304	7474
Cash crops	641860	2481444	21706
Total	4807629	5661269	86753

Source: Sharma et al (2015); Estimated losses were converted into 2014/15 prices using the WPI

The value of losses due to salinity are distributed across crops with cereals accounting for 38% of these costs, oilseeds 29%, cash crops 25% and pulses 9%. Looking at state-wide distribution of the total cost, Gujarat accounts for the lions share at 61%, followed by West Bengal at about 15%.

Production losses in agriculture due to wind erosion

We rely on Santra et al (2016) at the Central Arid Zone Research Institute for the assessment of crop production loss due to wind erosion. Their study attempts to quantify the indirect impact of wind erosion on crop production. Wind erosion severity classes were first mapped in western Rajasthan using satellite imagery and field observations; following which crop yield data, soil loss data and associated nutrient contents from study sample locations were collated to estimate the yield loss. According to the area statistics from the harmonized atlas of degraded and wastelands of India, about 12.40 Mha are affected by wind erosion in India (2007 figures). Spatial distribution of the area affected by wind erosion shows that most of the severely and very severely affected areas are in western Rajasthan. It has been estimated that 76% of Western Rajasthan is affected by wind erosion and deposition form of land degradation.

The study is based on the following methodology:

- Extent of wind erosion severity was mapped using spatial analysis. Field indicators such as terrain properties and average annual rainfall pattern and remote sensing signatures of land surface were considered for categorization of land degraded by wind erosion which were further verified through visual interpretation of LISS-III and IRS LISS-IV images.
- Assessment of productivity of major crops in western Rajasthan under different categories of wind erosion severity was based on tehsil level area and production data under the different severity classes. Land use/land cover was overlaid with wind erosion index and wind erosion severity grid to select fifteen tehsils representing irrigated and rainfed croplands for which crop productivity data was extracted from the district statistical database.
- Annual soil loss data was measured at different study locations under each severity category using wind erosion samplers or erosion pins. Wind eroded soil masses were collected during each dust storm event as well as periodically. The data on mass-fluxes of aeolian sediments were then fitted in power decay mass-height profile, which was found the best model for the Indian Thar desert (Mertia et al., 2010) as shown in Eq. (4):

  $$q\,(z) = az^{b} \quad \ldots\ldots\ldots(4)$$

  where,

  - q is the mass flux (M L^{-2} T^{-1}) of aeolian sediments at height z (L) from surface;
  - 'a' and 'b' are empirical constants of the equation
- Total aeolian mass transport rate (M L^{-1} T^{-1}) up to a standard height of 2 m was computed through integration of (4) with lower limit of z = 0.01 m to upper limit of z = 2 m. The calculated mass transport rate was converted to soil loss (kg ha^{-1}) by dividing the aeolian mass transport rate with the distance (L) of non-eroding boundaries from the sampling point and multiplying with the duration of wind erosion event (T)
- Loss of soil nutrient along with eroded soil was calculated from measured soil loss data and the nutrient concentration in eroded soil as follows:

  $$Nutrient\ content\ in\ eroded\ soil\ (kg/ton) = \frac{Nutrient\ content\ in\ native\ soil\ (kg/ha)) * nutrient\ richness\ factor}{2.25 * 1000} \quad \ldots\ldots(5)$$

  - For estimating the yield loss due to depletion of nutrient resources through wind erosion, soil test crop response (STCR) equations for arid regions of India were used. Based on the targeted yield approach, the STCR equations can be represented in following general form:

  $$F = b_1 * Y + b_2 * Nu \quad \ldots\ldots\ldots(6)$$

  Where,

  - F is amount of fertilizer required (kg ha^{-1}) to get the target yield of Y (q ha^{-1}) if the nutrient present in soil is Nu (kg ha^{-1}),
  - b_1 and b_2 are coefficient
- STCR equations for selected six crops for this study were collated as in Appendix 4. These STCR equations were developed for the arid region using targeted yield approach by All India Coordinated Research Project (AICRP) on STCR.

- For calculation purpose, two situations were assumed for which the amount of fertilizer applied (F) was similar but the nutrient contents are different (N1 and N2) due to depletion of soil nutrient through wind erosion, which ultimately lead to different yields (Y1 and Y2). These two situations can be represented by Eq. (7) and Eq. (8), respectively.

$$F = b_1 * Y_1 + b_2 * N_1 \ldots\ldots(7)$$

$$F = b_1 * Y_2 + b_2 * N_2 \ldots\ldots(8)$$

- Where, Y_1 and Y_2 are crop yields under soil nutrient concentrations of N_1 and N_2, respectively. Subtracting Eq. (7) from Eq. (8) and rearranging, we get

$$Y_1 - Y_2 = -b_2/b_1\,(N_1 - N_2) \ldots\ldots(9)$$

In words, $Yield\ loss\ (q\ ha^{-1}) = -(b_2/b_1) * nutrient\ loss\ (kg\ ha^{-1})$

- Following (9), the corresponding factor (b_2/b_1) for N, P_2O_5 and K_2O content under each selected crop were calculated.
- Economic loss through crop production loss was calculated considering the minimum support prices of each crop for 2012-2013. Since MSP values were not reported for cluster bean and moth bean, market price estimation was taken at the time of harvest and total economic loss has been estimated by averaging the economic loss per hectare for each crop and the area under cultivation under that crop in the year 2011-12.

The value of crop losses due to wind erosion is estimated at Rs 36675 million in 2014-15 market prices.[39]

4.5 Degradation due to land use change

Mythilli and Goedecke (2016) estimate the cost of change in land use in India from economically and environmentally more productive (in terms of the TEV) land use and land cover to less so, considering movement within seven land use classes (forests, shrubs, grasslands, croplands, wood, barren land and water). The TEV values of wood, grass, forest, shrub and water are global averages taken from the TEEB database; the TEV for barren land is based on estimates from Kenya while crop values are India-specific averages.[40] The authors estimate that the total annual cost of land degradation due to land use and cover change in 2009 as compared to 2001 are about 5.35 billion USD, equivalent to less than 1% of India GDP in 2009. The TEV used by the authors for different land use classes are provided in Table 4.10.

Table 4.10 TEV of different land use classes used by Mythilli and Goedecke (2016)

Land use category	TEV (USD per ha per year)
Water	8498
Barren	160
Wood	1588
Grass	2871
Forest	5264
Shrub	1588
Crop	1586

Source: Personal communication with the authors

[39] Adjusting for the conversion of support prices to wholesale prices

[40] Based on personal communication with the authors. The results are therefore rough approximations, but are still based on the best numbers available.

We followed a similar approach to Mythilli and Goedecke (2016) to estimate the cost of land use change in India. We multiplied the change in land use under a given category by its corresponding TEV and added the resulting loss/gain in TEVs across land use classes to derive the net loss/gain in TEV due to land use change. The land-use specific TEV estimates we used were mostly borrowed from Mythilli and Goedecke (2016). However, our study differs from them in three main respects:

We use the official nine category[41]-land use classifications followed in India to ensure the analysis is replicable and consistent/comparable with other aspects of this study. According to the official land use statistics of India, out of a geographical area of 329 million hectares, statistics are available only from 305 million hectares. This means some areas (to the extent of 7%) are still not covered or classifiable under the current classification. The reporting area is classified into the following categories- forests, area under non-agricultural uses, barren and un-culturable land, permanent pastures and other grazing lands, land under miscellaneous tree crops, etc, culturable waste land, fallow lands other than current fallows: current fallows; and net sown area. The definitions of each of these classes are detailed in Appendix 5.

The second departure in our assessment is with respect to the treatment of change in land use under forests. As can be seen from official statistics (Table 10), the area under forests has increased over the years. Unfortunately, in the absence of disaggregate data, it is not clear if the addition in forests is due to plantations or regeneration in natural forests or both. Further, it is the loss of dense forests that is of relevance rather than all forests given that forests in other density classes provide a small proportion of ecosystems services that dense forests do. For example, the value of Open Forests is only 40% of Very Dense Forests or 55 % of Moderately Dense Forests in terms of ecosystem services provided, and those of scrub forests even lower. Moreover, plantations are not a perfect substitute for natural forests in terms of all ecosystem services provided. Thus we focus on the conversion of dense forests to non-forests rather than all forests to non-forests. We use Verma et al. (2014)'s TEVs for dense forests which are India specific.

The third departure in our assessment is for wetlands. According to ISRO (2016) Bhuvan data, the area under inland wetlands (which is not included in the official nine-category land use classification of India) has decreased from 9935.08 sq km to 7913.62 sq km. while the area under rivers/streams/canals has decreased from 60228.19 sq. km to 59096.89 sq. km. We use these figures to estimate the decrease in area under wetlands. To estimate the costs of wetland degradation we use the TEV for water given by Mythilli and Goedecke (2016) (Table 4.10).

4.5.1 Overall Land Use Change

As can be seen from Table 4.11, there has been a considerable decrease in the area under culturable wastelands, followed by net sown area, pastures and under miscellaneous tree crops in the period between 2001/02 and 2012/13. Most of this decrease is accounted for by the net increase in area under non-agricultural uses (which comprises all land occupied by buildings, roads and railways or under water, e.g. rivers and canals, and other land put to uses other than agriculture). We discuss below, how the change in TEV was estimated for each of these classes of land use.

Table 4.11 Land use classification (all India) '000 ha

Year	Geo-graphi-cal Area	Reporting area for land utilisation statistics	Forests	Misc. tree cover & groves	Pas-tures	Non-agricul-tural uses	Barren	Fallow lands*	Cultur-able waste-lands	Net sown area
2001-02	328726	305127	69720	3442	10528	23914	17414	25856	13520	140734

[41] We have clubbed two categories of current fallows, and fallow lands other than current fallows resulting in eight categories of land use for the purposes of this study

2012-13	328726	305936	70007	3157	10240	26454	17284	26283	12578	139932
Change 2001-2013[42]		809	288	-284	-287	2540	-130	427	-942	-802

* Includes both current fallows and fallow lands other than current fallows.
Source: Directorate of Economics and Statistics, Ministry of Agriculture and Farmers Welfare, http://eands.dacnet.nic.in/LUS_1999_2004.htm

4.5.2 Forests

To estimate the conversion of dense forest area to non-forest area, we used the forest cover change matrix resulting from conversion of one density class to another between 2005-2015 (excluding year 2007-2009), which is the period for which comparable data in terms of density classes and assessment methodologies is available. It must be noted, however, that along with forest degradation, forest cover is also upgrading simultaneously including conversion from non-forests and scrub to open forests, moderately dense forests and to very dense forests. We therefore used the net decrease in area under forests from one density class to the next (or to non-forests) to obtain a picture of the costs of forest degradation/deforestation (Table 4.12).

An analysis of the forest change matrix using Forest Survey of India (FSI) data shows that during 2005 and 2015, net forest degradation/deforestation was observed only in 2 cases (see Table 4)-from Very Dense Forests to Non-Forests (loss of 28,400 ha) and from Moderately Dense Forests to Non-Forests (loss of 3,25,900 ha)-both of which could be classified as deforestation. First, the change in area from very dense forests to non-forests was far higher than the area under non-forests that were converted to very dense forests; second, far more area was converted from moderately dense forests to non-forests than were upgraded from non-forests to moderately dense ones. We utilise these changes to estimate the costs of deforestation during 2005 to 2015. Deforestation from 2005 to 2015 is estimated at 354300 ha or 0.3 million ha (Table 12). The detailed forest cover change matrix from 2005-2015 for all forests classes is provided in Appendix 6.

Table 4.12 Estimate of net conversion to non-forests derived from forest cover change matrix from 2005-2015

Forest cover change (in ha)	2005-2007	2009-2011	2011-2013	2013-2015	Total forest change from 2005 to 2015 (in ha)
VDF to NF	7600	4500	10600	25700	48400
NF to VDF	3600	700	0	15700	20000
Net conversion of VDF to NF	-4000	-3800	-10600	-10000	-28400
MDF to NF	213000	188800	150500	225400	777700
NF to MDF	144100	144200	65700	97800	451800
Net conversion of MDF to NF	-68900	-44600	-84800	-127600	-325900
Net change (Deforestation)					354300 ha (0.3 million ha)

Legend: VDF: Very Dense Forests; MDF-Moderately Dense Forest; OF: Open Forests; NF: Non-Forests
Source: FSI (2009-2015)

[42] As can be seen from Table 10, the net land us change in the country does not add up to zero due to an additional 809 thousand ha of land brought under land use reporting

The costs of deforestation (or conversion from dense forests to non-forests) are provided in Table 4.13 and amount to Rs 39.54 billion. Using the annual TEV per hectare of VDF and MDF and assuming that the TEV of the non-forest land use to which VDF and MDF is converted is negligible in comparison, the total economic loss due to the net conversion of VDF to NF amounts to Rs 4.25 billion and that due to the net conversion of MDF to NF is Rs 35.29 billion, thus resulting in a total estimated loss of Rs 39.54 billion due to conversion of dense forest to non-forest uses.

Table 4.13 Costs of conversion of dense forests to non-forests

Forest Density Class	VDF	MDF	OF	Scrub	Non-Forest	Total
Country average of TEV (Rs/ha/year)	149,757	108,276	60,302	31,528	0*	
Costs of deforestation (Benefits foregone) resulting from VDF and MDF forests being converted to Non-Forests						
TEV lost per ha for conversion from VDF to NF and MDF to NF (rupees)	149,757 (VDF to NF)	108,276 MDF to NF)				
Net conversion of VDF to NF (in ha)						28400
Costs of deforestation for conversion of VDF to NF (in million Rs)						4253.10
Net conversion of MDF to NF (in ha)						325900
Costs of deforestation for conversion of MDF to NF (in million Rs)						35287.12
Costs of deforestation (in million rupees) (Total forests converted to Non-Forests)						39540.25

*Assumed to be 0 for forests converted to Non-Forests

4.5.3 Wetlands

Estimates of wetland area provided by SAC (1998, 2011) do not indicate change in wetland status over a period of time. We therefore utilise ISRO (2016) Bhuvan statistics to obtain an estimate of changes in wetland areal extent from 2005/06 to 2011/12 (Figure 4.14). These statistics indicate a decrease in extent of inland wetlands and rivers and streams, both categories relevant to this study of land use degradation. This change was extrapolated for a 10 year period by using an estimated average annual change in area under wetlands (Table 4.14) and valued using the TEV for water as suggested by Mythilli and Goedecke (2016) (see Table 4.10). Appendix 7 provides state-wise detailing on change of wetland areas from 2005/06 to 2011/12.

Table 4.14 Change in area under wetlands from 2005/06 to 2011/12

Type of Wetlands	2005-06	2011-12	Change (Value)	% Change
Inland Wetlands (sq. km)	9935.08	7913.62	-2021.46	-20.35%
Coastal Wetlands (sq. km)	10639.57	15048.75	4409.18	41.44%
River/Stream/Canals Wetlands (sq. km)	60228.19	59096.89	-1131.3	-1.88%
Reservoir/Lakes/Ponds Wetlands (sq. km)	48135.68	53948.37	5812.69	12.08%
Total wetland area (sq. km)	128938.52	136007.63	7069.11	5.48%

Source: ISRO (2016)

For estimating the change in TEV of land due to land use change for other categories of land use (other than forests and wetlands), we used the change in area as per Table 4.15 and estimated the corresponding loss in annual TEV from Table 4.10. Given that the TEV of land uses that have experienced a net decline is higher than that of land under buildings and infrastructure, there is a net loss of TEV due to change in land use in the country (Table 4.15).

Table 4.15 Change in TEV due to change in land use /cover (Rs million in 2014/15 prices)

Forests	Misc. tree cover & groves	Pastures	Barren	Fallow lands	Culturable wastelands	Net sown area	Wetlands	Total
-39540	-30821	-56272	-1420	46249	-102047	-86764	-304637	-575252

Notes: The period for change in land use underlying these estimates is 2001/02 to 2012/13 (the latest year for which land use statistics were available) except in the case of forests which is based on change over 2005-2015, due to the availability of detailed forest cover change matrix for this period. In the case of wetlands (inland and rivers/streams/canals), the change in area was available for 2005/06 and 2011/12, The average annual change during this period was estimated, based on which the change in area under wetlands was extrapolated for 10 year uptil 2015. The TEV for each land use class is based on Mythilli et al (2016)- see Table 9 above- except for forests where India and density class specific estimates based on Verma et al (2014) were used. Land under misc. tree cover & groves was valued using TEV for woodlands; pastures using the value for grasslands, barren lands using the value for barren lands; fallow lands and culturable wastelands using the value for shrubs, net sown area using the value of croplands; and wetlands using the value for water respectively. Area under non-agricultural uses (other than area under rivers and canals, which comprises all land occupied by buildings, roads and railways and other land put to uses other than agriculture) was implicitly given a TEV of zero.

Source: Estimated by authors

4.6 Results and discussion

The final estimates of the costs of land degradation and land use change are given in Table 4.16.

Table 4.16 Costs of land degradation and land use change

	Category	Economic cost		
		Annual economic costs of degradation (Value in Rs million in 2014/15 prices)	% of gross value added from agriculture and forestry (2014/15)	% of GDP (2014/15)
	Loss in agricultural production due to:			
1a	Water erosion			
	Onsite losses in rain-fed agriculture	208496	1.04	0.17
	Offsite losses	228585	1.15	0.18
1b	Sodic soils	162809	0.82	0.13
1c	Saline soils	86753	0.43	0.07
1d	Wind erosion	36675	0.18	0.03
1 (1a+1b+1c+1d)	Total agricultural loss	723319	3.63	0.58
2	Loss due to degradation of rangelands	120245	0.60	0.10
3	Loss due to forest degradation	1758574	8.81	1.41
4 (1+2+3)	Total due to land degradation	2602138	13.04	2.08
5	Loss due to land use/cover change	575252	2.88	0.46
6 (4+5)	**Total cost of land degradation and land use change**	**3177390**	**15.92**	**2.54**

* Using forest degradation scenario I

This cost is estimated at about 2.5% of India's GDP in 2014/15 and about 15.9% of the GVA from the agriculture, forestry and fishing sectors. Almost 82% of the estimated cost is on account of land degradation and only 18% due to land use change (Figure 4.8). This result suggests that while loss of productive land for forests, wetlands, rangelands and other ecosystems is a concern, a larger concern is the degradation of existing ecosystems. Also it can be seen that the distribution of the economic burden of losses due to different types of land degradation is different from the distribution of the physical extent of degradation itself. For instance, according to recent SAC (2016) figures, water erosion accounts for 37.4% of the total area affected by degradation, followed by vegetation degradation (30.4%), wind erosion (18.9%) and salinity (3.8%). However, in terms of the cost of land degradation and use change, the economic cost of forests degradation accounts for over 55% of the total, although in physical terms it ranks second in its contribution to India's degraded land area. This is on account of the higher cost per hectare of vegetal or forest degradation. In contrast, onsite and offsite losses due to water erosion account for about 14% of the total economic cost.

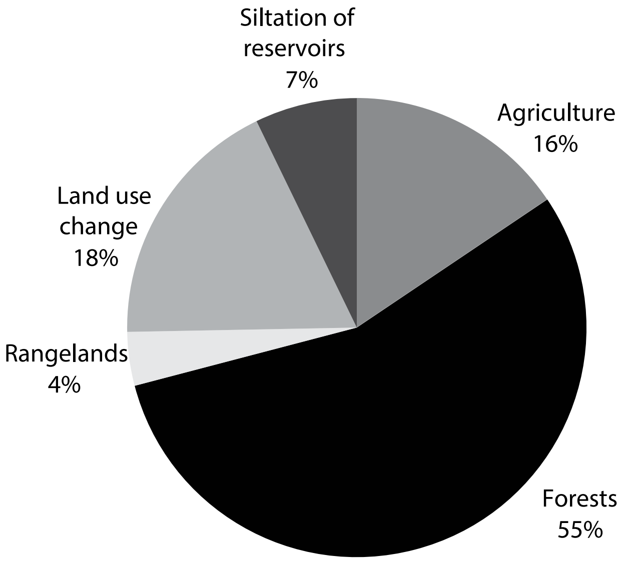

Figure 4.8 Distribution of the total costs of land degradation in India

Figure 4.9 gives the costs of land use change by category. The largest value is accounted for by wetlands followed by culturable wastelands, followed by pastures and forests. These losses are partly compensated by a gain in the value of land due to the increase in land area under fallow lands (not shown in the Figure). Refer to Table 4.11.

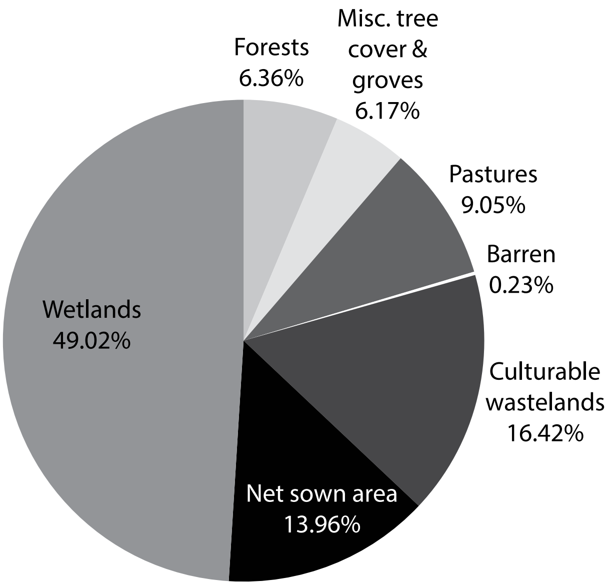

Figure 4.9 Costs of land use change: distribution by category

4.6.1 Forests

In case of forest resources, our estimated area of degradation (34 mha) is similar to that estimated by World Bank (2013) (28 mha). However, our estimates of the cost of degradation and deforestation (Rs 1481 billion - 1798 billion annually) are much higher than those estimated by World Bank (2013) (Rs 70- 196 billion annually). The difference is largely attributable to the higher TEV used by Verma et al. (2015) as compared with those estimated by the World Bank. The results also clearly indicate that costs of degradation for India (Rs 1441 billion to 1758.6 billion) are far higher than the costs of deforestation

(Rs 39.5 billion) given that India's forest cover has stabilised but degradation due to removal for fuelwood, fodder and non-timber forest products continues. At present the costs of deforestation account for only about 2.19% - 2.67% of the total costs of vegetal degradation (depending on the scenario considered). The remaining is accounted for by the degradation of forests.

4.6.2 Rangelands

Rangelands account for 4% of the total costs of land degradation in the country. However, these estimates are conservative at best, given the large variation in estimations of rangelands and pasturelands. India's land use statistics define permanent pasture and other grazing land as "grazing land whether it is permanent pastures and meadows or not." This definition is very unclear. For example are alpine pastures (bugyals) included in this category or within forests? Moist Alpine Scrubs, a forest type, for example includes Alpine pastures that comprise 8.06% of this forest category (FSI, 2015). Similarly Sub-Alpine forests include alpine pastures (FSI, 2015). Therefore, accurate figures of the extent of grassland degradation and consequently its impacts on livestock productivity are difficult to estimate with any degree of certainty. India urgently needs a detailed assessment to be conducted for the grasslands of the country including village pasturelands.

4.6.3 Wetlands

Wetlands account for 49% of the total costs resulting from land use change or Rs 304637 million. This is not surprisingly, since they have been described as the most productive ecosystems on earth and yet suffer from widespread diversion. Moreover, wetlands are not included as a category of land use in India's land use classification. This is despite their comprising an important category of land use providing numerous ecosystem services such as ground water recharge, fisheries and biodiversity. Until their value is recognized, they will continue to be diverted for alternative land uses especially agriculture, real estate and industrial development.

4.6.4 Agriculture

Production losses due to agriculture alone are close to 4% of Gross Value Added (GVA) from the agriculture sector in 2014/15 at a very conservative level (Fig. 4.10). These are conservative figures since the losses have not been estimated for all crops (e.g. cash crops are not included in estimates of soil erosion), regions (e.g. water erosion has been estimated only for rain-fed agriculture), or degradation (e.g. losses due to water logging are not included). Given the scope of this exercise, we find that water erosion in rain-fed areas accounts for the majority share (37%), followed by losses due to sodic soils (33%), saline soils (18%) and wind erosion (7%).

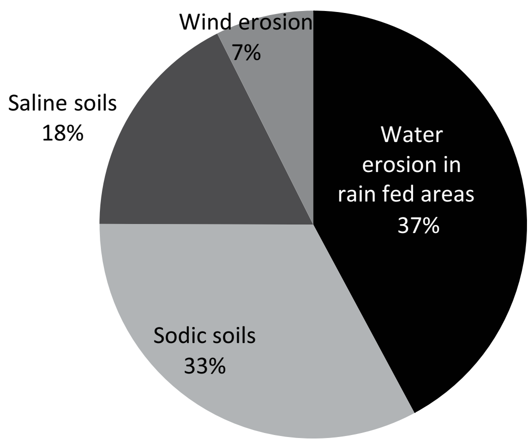

Figure 4.10 Cost of productivity losses in agriculture: distribution by type of land degradation

Excluding wind erosion, which is concentrated in Rajasthan we find that Gujarat suffers the highest losses on account of land degradation (about 26% of the value of national losses) largely due to losses on account of alkalinity and salinity – it makes up for 34% and 61% of total agricultural losses in the country due to these two factors, while accounting for less than 5% of the losses due to water erosion. This is followed by Uttar Pradesh, which accounts for about 22% of the national losses due to agriculture, mostly because of alkalinity. The other states that have a high share of the value of all Indian crop loss due to degradation are Madhya Pradesh (about 8%), Karnataka and Maharashtra (7% each), and Andhra Pradesh (6%). Rajasthan accounts for about 3% of the losses due to water erosion in rain fed agriculture, salinity and alkalinity but all of the losses due to wind erosion included in this study are borne by the State.

4.7 Projecting land degradation in 2030-a scenario analysis

In this section we develop future scenarios upto 2030- for land degradation in India, based on which we estimate future investments that will be required to reclaim degraded land if action is not taken now. These projections for land degradation are based on extrapolation of available past data, which has some serious limitations. Except in the case of forests, long- term trend analysis is not available under a common methodology (resolution) or even a single source. For example Table 4.17 provides various estimates of land degradation/desertification and area under wastelands over the years. These estimates underline several issues

- The classification of land degradation categories fluctuate over the years. For example, the ICAR-NAAS (2010) atlas which harmonises the NBSSLUP soil degradation classes and the NRSA wasteland classes does not include vegetal degradation as a discrete category. However, the recent Space Applications Centre (SAC) atlas has a separate category of vegetal degradation.
- Acid soils are listed as a separate category in the ICAR-NAAS (2010) atlas, but there is no mention of acid soils in the recent SAC (2016) atlas. Have all of India’s acid soils been reclaimed or are they now clubbed with another category? The situation remains unclear.
- ICAR-NAAS (2010) atlas has a separate figure for mining/industrial land degradation but SAC (2016) has a general category called man-made which includes several other man-made causes of degradation including city waste. Hence the contribution of mining for example to land degradation is unclear.
- It is not known if the category waterlogged areas includes marshy lands (SAC, 2016) which are a separate category in the NRSA wasteland classes.
- Wasteland classifications are completely different from land degradation ones including for example gullied/ravenous land. While the ICAR-NAAS (2010) atlas harmonised these figures, the wasteland atlas of India (NRSC, 2011) continues to use these classifications (Table 4.18).
- Several productive lands such as marshy areas are classified as wastelands. Moreover, shifting cultivation (jhum lands-e.g. abandoned jhums) lands are also classified as wastelands. These are a stage in forest regeneration following movement of shifting cultivators to another area. Is it justifiable to classify marshy lands or shifting cultivation lands regenerating to forest, as wastelands?
- There is a lack of consistency between SAC (2016) data (including figures from 2003/05 and 2011/13) and SAC (2007 data). Increases in degradation from 2003/05 to 2011/13 are accompanied by a dip in SAC (2007) data and vice-versa.

Table 4.17. Estimates of land degradation for India

Process of Desertification/ land degradation	2011/13 (SAC, 2016)	2003/05 (SAC, 2016)	SAC, 2007 data	ICAR (2010)- Harmonised data (mha)	NBSS&LUP soil degradation classes, derived from 1:250,000 soil map (1985-1995)	NRSA Wasteland classes (1986-2000) 1:50,000 scale	1980-1982 (NRSA as cited in Reddy, 2003)	1988-89 (NRSA as cited in Reddy, 2003)	1986-1999 (NRSA as cited in Reddy, 2003)	Area estimated by working group of MOWR in 1991	Waterlogged areas (both irrigated and non-irrigated) National Commission on Agriculture 11976	Waterlogged areas (both irrigated and non-irrigated) Ministry of Agriculture 1984-86
	Area (mha)	Area (mha)										
Vegetation Degradation (degraded notified forest land according to NRSA (1986-2000)	29.3	28.28	31.66			14.07						
Water Erosion	36.1	35.61	33.56	30.24	93.68							
Wind Erosion (Sandy area according to NRSA 1986-2000)	18.23	18.35	17.56	4.54	9.48	5						
Salinity/ alkalinity)	3.67	4.01	5.26	2.73**	5.89	2.04	3.9	1.99	2.05			
Water Logging	0.65	0.6	0.98	0.91	14.29	1.66	0.88*	1.22	1.66*	2.46	8.53	6
Frost Shattering	3.34	3.11	10.21									
Mass Movement	0.93	0.84	4.45									
Manmade	0.41	0.37	0.15									

Process of Desertification/ land degradation	2011/13 (SAC, 2016)	2003/05 (SAC, 2016)	SAC, 2007 data	ICAR (2010)- Harmonised data (mha)	NBSS&LUP soil degradation classes, derived from 1:250,000 soil map (1985-1995)	NRSA Wasteland classes (1986-2000) 1:50,000 scale	1980-1982 (NRSA as cited in Reddy, 2003)	1988-89 (NRSA as cited in Reddy, 2003)	1986-1999 (NRSA as cited in Reddy, 2003)	Area estimated by working group of MOWR in 1991	Waterlogged areas (both irrigated and non-irrigated) National Commission on Agriculture 11976	Waterlogged areas (both irrigated and non-irrigated) Ministry of Agriculture 1984-86
Barren/ Rocky (Barren rocky/stony/ sheet rock according to NRSA, 1986-2000)	1.89	1.88	1.65			6.46						
Settlement	1.88	1.48										
Acid Soil (ICAR category)				17.93	16.03							
Alkali/Sodic soil (ICAR category)				3.7								
Mining/ Industrial				0.26		0.12		0.12	0.13			
Ice caps/Rock outcrops/Arid mountain (Snow covered/ glacial area according to NRSA, 1986-2000)					8.38	5.58						
Gullied/ ravinous land						2.06	4.33	2.02	2.06			

Process of Desertification/ land degradation	2011/13 (SAC, 2016)	2003/05 (SAC, 2016)	SAC, 2007 data	ICAR (2010)- Harmonised data (mha)	NBSS&LUP soil degradation classes, derived from 1:250,000 soil map (1985-1995)	NRSA Wasteland classes (1986-2000) 1:50,000 scale	1980-1982 (NRSA as cited in Reddy, 2003)	1988-89 (NRSA as cited in Reddy, 2003)	1986-1999 (NRSA as cited in Reddy, 2003)	Area estimated by working group of MOWR in 1991	Waterlogged areas (both irrigated and non-irrigated) National Commission on Agriculture 11976	Waterlogged areas (both irrigated and non-irrigated) Ministry of Agriculture 1984-86
Land with/ without scrub						19.4	10.8	26.5	19.4			
Waterlogged/ marshy land								0.82				
Shifting cultivation area						3.51	2.4	2.82	3.51			
Degraded pastures/ grazing land						2.6			2.6			
Degraded land under plantation						0.58			0.58			
Steep sloping area						0.77						
Total Area under Desertification	**96.4**	**94.53**	**105.48**	**120**	**147.75**	**63.85**	**22.31**	**35.49**	**31.99**			
No Apparent degradation	226.73	228.68										
Total Geographical Area (mha)	328.72											

Table. 4.18. Category-wise total area under wastelands (sq. km.) during 2008-09 vis-à-vis. 2005-06 and change in different categories

S.No.	Cateogry	Total WL			% to TGA		
		2005-06	2008-09	Change	2005-06	2008-09	Change
1	Gullied and/or ravinous land-Medium	7005.47	6145.96	-859.51	0.22	0.19	-0.03
2	Gullied and/or ravinous land-Deep/very deep ravine	1714.8	1266.06	-448.74	0.05	0.04	-0.01
3	Land with dense scrub	93372.62	86979.91	-6392.71	2.95	2.75	-0.2
4	Land with open scrub	91645.83	93033	1387.17	2.89	2.94	0.05
5	Waterlogged and Marshy land-Permanent	2532.46	1757.07	-775.39	0.08	0.06	-0.02
6	Waterlogged and Marshy land-Seasonal	2994.22	6946.31	3952.09	0.09	0.22	0.13
7	Land affected by salinity/alkalinity-moderate	5451.63	5414.53	-37.1	0.17	0.17	0
8	Land affected by salinity/alkalinity-Strong	1737.81	1391.09	-346.72	0.05	0.04	-0.01
9	Shifting cultivation area-Current Jhum	5625.07	4814.68	-810.39	0.18	0.15	-0.03
10	Shifting cultivation area-Abandoned Jhum	4608.44	4210.46	-397.98	0.15	0.13	-0.02
11	Under utlized/degraded forest-scrub dominated	85787.78	83699.71	-2088.07	2.71	2.64	-0.07
12	Agricultural land inside notified forest land	16381.53	15680.26	-701.27	0.52	0.5	-0.02
13	Degraded pastures/grazing land	7197.14	6832.17	-364.97	0.23	0.22	-0.01
14	Degraded land under plantation crops	314.14	278.53	-35.61	0.01	0.01	0
15	Sands-Riverine	2439.86	2111.96	-327.9	0.08	0.07	-0.01

S.No.	Cateogry	Total WL			% to TGA		
		2005-06	2008-09	Change	2005-06	2008-09	Change
16	Sands-Coastal sand	719.31	654.47	-64.84	0.02	0.02	0
17	Sands - Dessert sand	5280.07	3934.8	-1345.27	0.17	0.12	-0.05
18	Sands-Semi-stablized to stablized (>40m) dune	11188.21	9279.75	-1908.46	0.35	0.29	-0.06
19	Sands-Semi-stablized to stablized moderately high (15-40m) dune	15627.63	14273.03	-1354.6	0.49	0.45	-0.04
20	Mining Wastelands	506.58	593.65	87.07	0.02	0.02	0
21	Industrial wastelands	63.99	58	-5.99	0	0	0
22	Barren rocky area	69372.54	59482.29	-9890.25	2.19	1.88	-0.31
23	Snow cover and/or glacial area	40694.8	58183.44	17488.64	1.29	1.84	0.55
	Total	**472261.94**	**467021.16**	**-5240.78**	**14.91**	**14.75**	**-0.17**

Given these disparities in data, projections for 2030 are indicative at best. In the development of our projections, one scenario uses two point data (2003/05 and 2011/13 (SAC, 2016) on land degradation. However the two data points – 2003 and 2011, are too close to meaningfully assess trends in a long-term process, which land degradation is. For the second scenario, we use a longer time series but the data is from different sources, possibly using different methodologies. Our analysis, thus, needs to be seen in the light of these limitations.

We separately study the following five main classes of land degradation – water erosion, wind erosion, water logging, salinity/alkalinity, and forest degradation. Together these factors account for 28.2% of the geographical area (91.7% of India's degraded land) in the country if we include both open and scrub forests (corresponding to the forest conservative scenario 1 described earlier) and 27% of India's GA (91.3% of India's degraded land) if we include only open forests (forest very conservative scenario 2)[43]. We prepare two sets of projections for land degradation.

Scenario 1

For water erosion, wind erosion, water logging, and salinity/alkalinity, we employ the only multi-point data available from a single source (SAC, 2016). Since this is only a two-point data set (2003 and 2011), these projections are based on the assumption that the linear trends observed over this eight year period will continue over the next 19 years, till 2030. The projections for forest degradation are based on an analysis of the four-point trend observed for the categories of forests that may be considered degraded-scrub and open forests- over the period 2005-2013. We do not use older FSI data due to changes in resolution and methodology. These projections are shown in Figure 4.11 (with four sub-graphs for the four types of land degradation) and Figure 4.12 (two sub-graphs for forests). For forests, we also project trends for dense forests (moderately dense and very dense) since it is difficult to interpret the trends for degraded forests (open and scrub) in the absence of available trends for dense forests (because dense forests are converted to open forests and scrub).

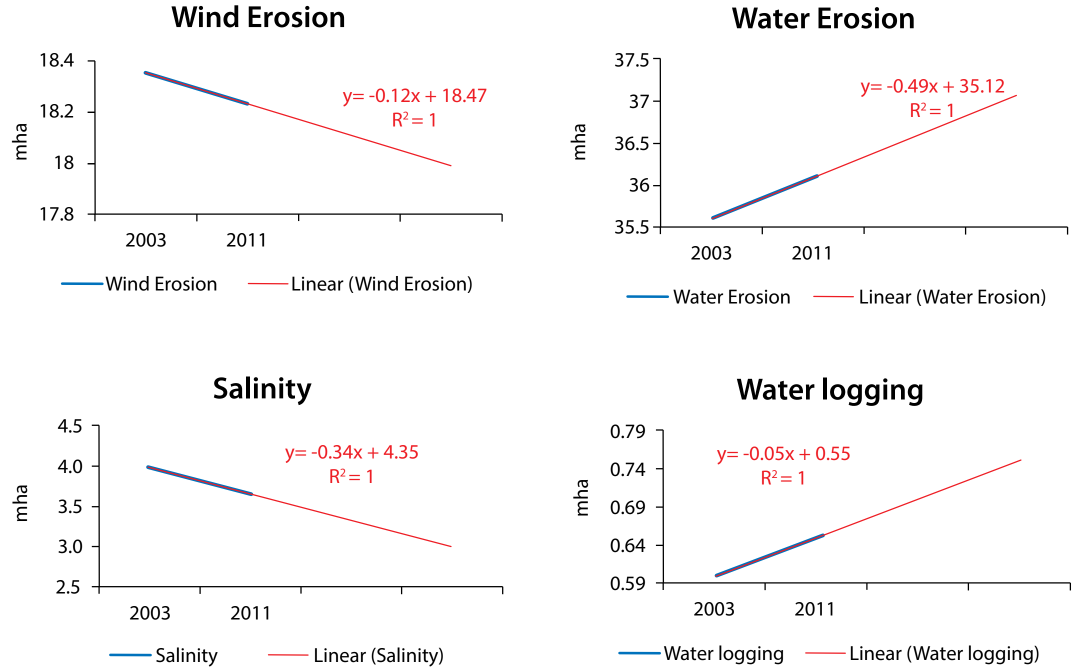

Figure 4.11 Past trend and future projections (till 2030) of different types of land degradation in Scenario 1 (in mha)

[43] We use SAC (2016) figures for all classes of erosion listed above except forests for which we use FSI (2015) data for open and scrub forests which we assume to be degraded. We adjust the total degraded area accordingly

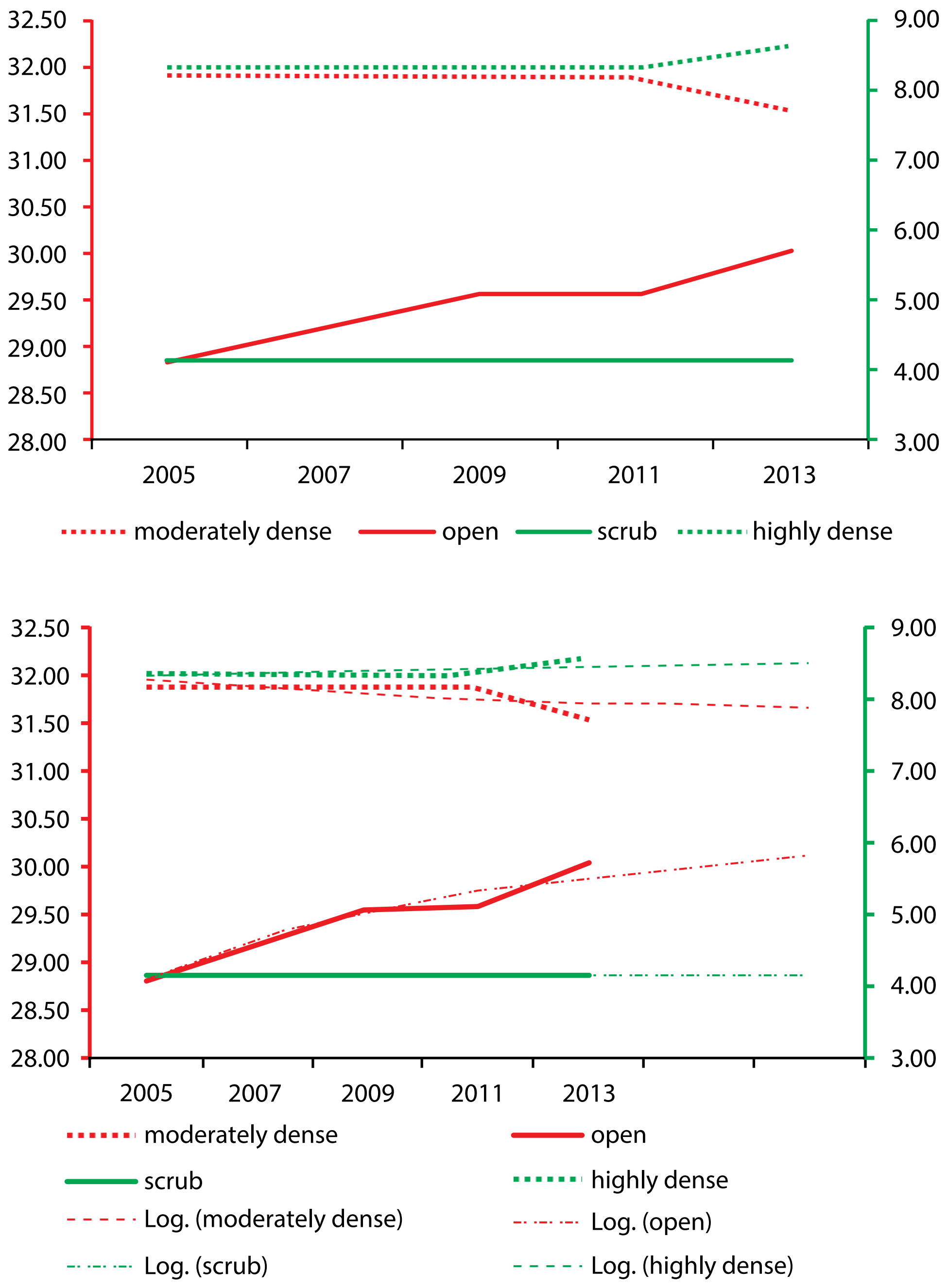

Figure 4.12 Past trend and projection of forest degradation (till 2030) (in mha)

The data indicates a decreasing trend for wind erosion and salinity, while water erosion and water logging increase over time. In the case of forests, the area under scrub forest decreases over time, while that under open forests increases over time. Scrub forests can upgrade to open forests, while dense forests can downgrade to either open or scrub forests. Our analysis of moderately dense forests indicates their decrease over time, probably due downgradation to open forests (hence the trend of increasing area under open forests), as well as upgradation to dense forests (hence an increasing trend for dense forests). Upgradation of scrub forests and reduced conversion of other categories to scrub probably explains the decreases in scrub forests over time. A logarithmic trend appears to best fit the past data points and has been used to project the future scenario. The trend suggests that the decline in area under scrub land and the increase in area under open forest will occur at a decreasing rate.

Scenario 2

Recognizing the need for a longer time horizon to study the issue of land degradation, we also analyse a second set of estimates which are based on three data points, although from different sources – mid 1990s (Harmonized Atlas produced by ICAR-NAAS in 2010[44]), 2003 and 2011 (SAC, 2016) for the four classes of land degradation. These are shown in Figure 4.13. The projections for forests made in Scenario1 is retained in Scenario 2.

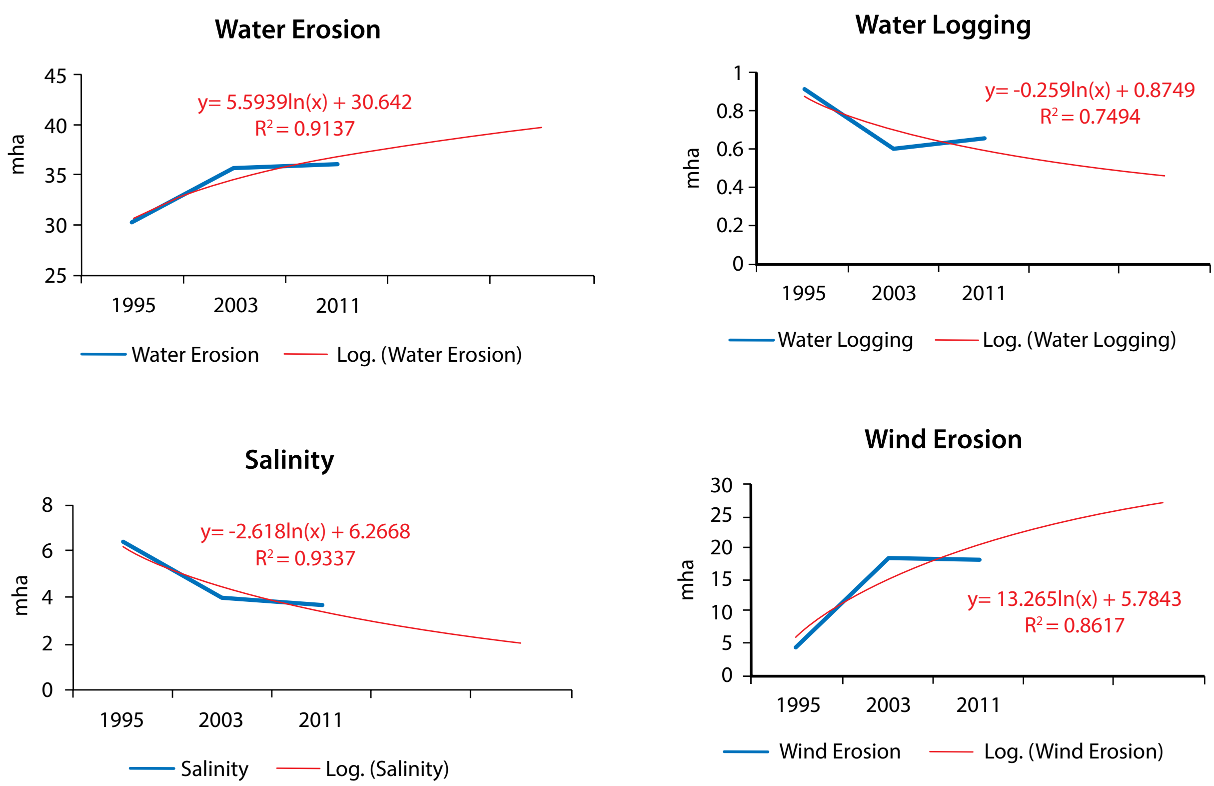

Figure 4.13 Past trend and future projection (till 2030) of different types of land degradation in Scenario 2 (in mha)

Using the three point series, a logarithmic trend line appears to best fit the past data in each case. As can be seen from the figures, the trend suggests that area affected by water logging and salinity fall, while areas affected by water and wind erosion rise. In summary, in scenario 2, degraded land that is saline and waterlogged is projected to decrease in the future, suggesting successful reclamation efforts. However, both wind and water erosion, two dominant causes of land degradation are projected to increase, underlining the need to scale up reclamation efforts in India.

Discussion

Figure 4.14 depicts the aggregate picture that emerges under both scenarios. Land degradation is projected to increase in both scenarios. A more disaggregated examination (Figure 4.15) shows that except for water logging, all other categories of land degradation are expected to be larger in scenario 2[45.] Further, in both scenarios, there in an increase in area under water erosion, in addition to the increase in the area under open forests, which contributes to this overall rise in land degradation. This increase overwhelms the decrease in area under salinity seen in both scenarios.

[44] The Harmonized Atlas sought to reconcile two data sets- NBSS&LUP soil degradation classes, derived from 1:250,000 soil map (1985-1995) and the NRSA Wasteland classes (1986-2000) 1:50,000 scale We chose 1995 as the year corresponding to the harmonized estimates.

[45] The same values for forest degradation were taken in both scenarios and hence degraded forest area remains the same.

However, it is interesting that the pattern of change in the cases of area affected by water logging and wind erosion is different under the two scenarios. While wind erosion decreases in scenario 1, it increases in scenario 2, with a reverse pattern exhibited by waterlogging in the two scenarios. This difference is accounted for by the use of additional time series data in scenario 2. Waterlogging drops substantially from 0.91 mha in1995 to 0.65 mha in 2011 but increases marginally from 0.6 in 2003. Similarly, wind erosion escalates from 4.54 mha in 1995 to 18.23 in 2011 but drops marginally from 18.35 m ha in 2003. The addition of a mere data point alters the entire trend of land degradation. This underscores the need to maintain, accurate and consistent, longitudinal data to clarify the trends in land degradation in India. Without this, it is hard to assess the efficacy of on-going reclamation programmes, or to give successful policy prescriptions based on accurate long-term trends and projections. Wind erosion is the third largest contributor to land degradation in India, but is either increasing or decreasing depending on the data used.

Consistent increases in the area under water erosion, however, suggest that despite substantial investments over time in the watershed programme (Rs 315.8 billion till 2013; Pandey, 2015), the impacts have been less than successful. Salinity/alkalinity has nevertheless decreased in both scenarios, underlining the success of measures to reduce salinity/alkalinity, particularly in Uttar Pradesh which accounts for almost 50% of the dip in saline degraded area (SAC, 2016).

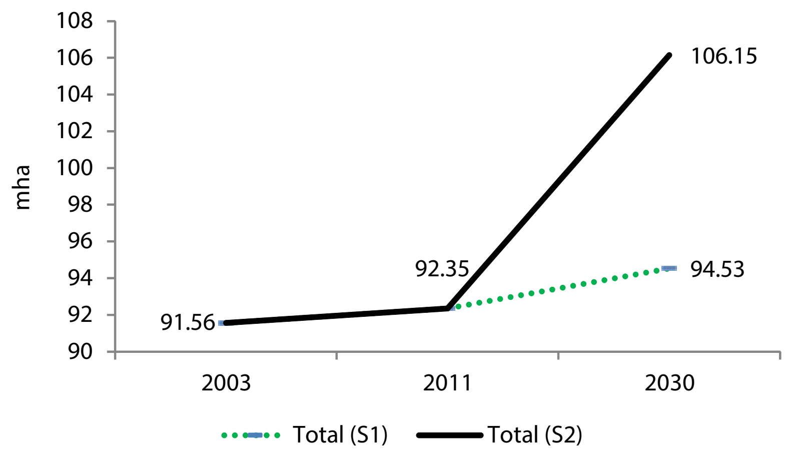

Figure 4.14 Total area (in mha) under land degradation in past and future scenarios (S1 and S2)

Note: S1 and S2 denote Scenario 1 and 2 respectively

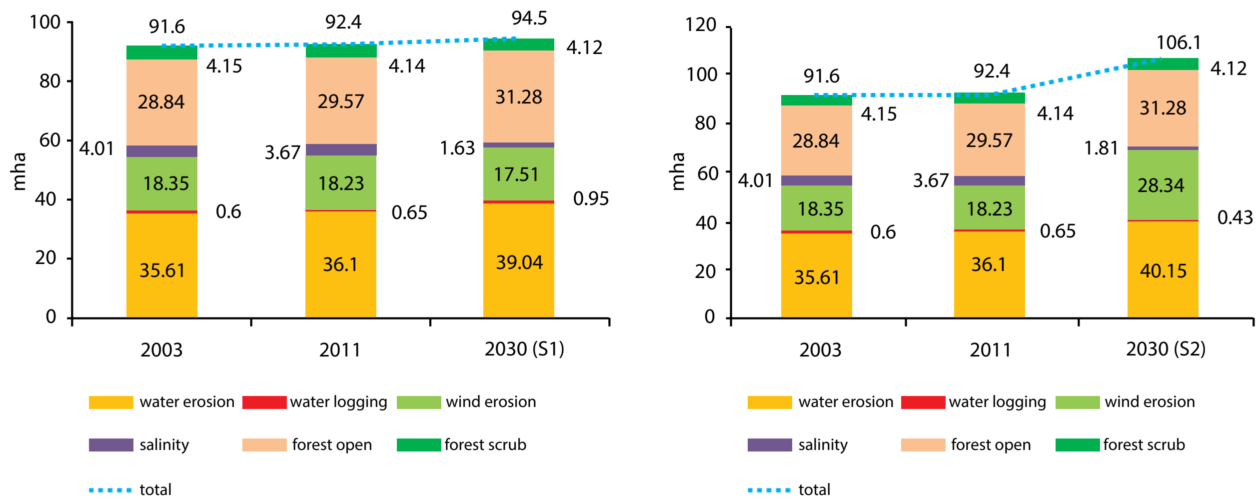

Figure 4.15 Area (in mha) under different types of degradation in past and future scenarios (S1 and S2)

Note: S1 and S2 denote Scenario 1 and 2 respectively

4.8 Land degradation neutrality by 2030

India aspires to be land degradation-neutral by 2030. UNCCD (2017) defines Land Degradation Neutrality (LDN), as, "a state whereby the amount and quality of land resources necessary to support ecosystem functions and services and enhance food security, remain stable or increase within specified temporal and spatial scales and ecosystems". This definition emphasizes the importance of ecosystem services, and the need to maintain or enhance the "stock of natural capital associated with land resources and the ecosystem services that flow from them." A pictorial graphic of the way LDN is envisaged by UNCCD and will be calculated is shown in Fig. 4.16. The baseline is the same as the LDN target and becomes the target to be achieved in order to maintain neutrality. While LDN is the minimum objective, countries may have a more ambitious target. Using this hypothetical example, and our projections and scenarios described above, we pictorially represent this situation for India including the total for both the scenarios described above. We take year 2003 values as the hypothetical baseline or the LDN target given that it is the only consistently estimated two-time period data for land degradation, currently available in the country. As indicated in Figure 4.17, current projections suggest that LDN will not be achieved but that physical estimates of degradation will exceed 2003 values unless reclamation efforts are scaled up. Our figures suggest that the total area of land degradation outstripped the baseline or LDN in 2011 itself.

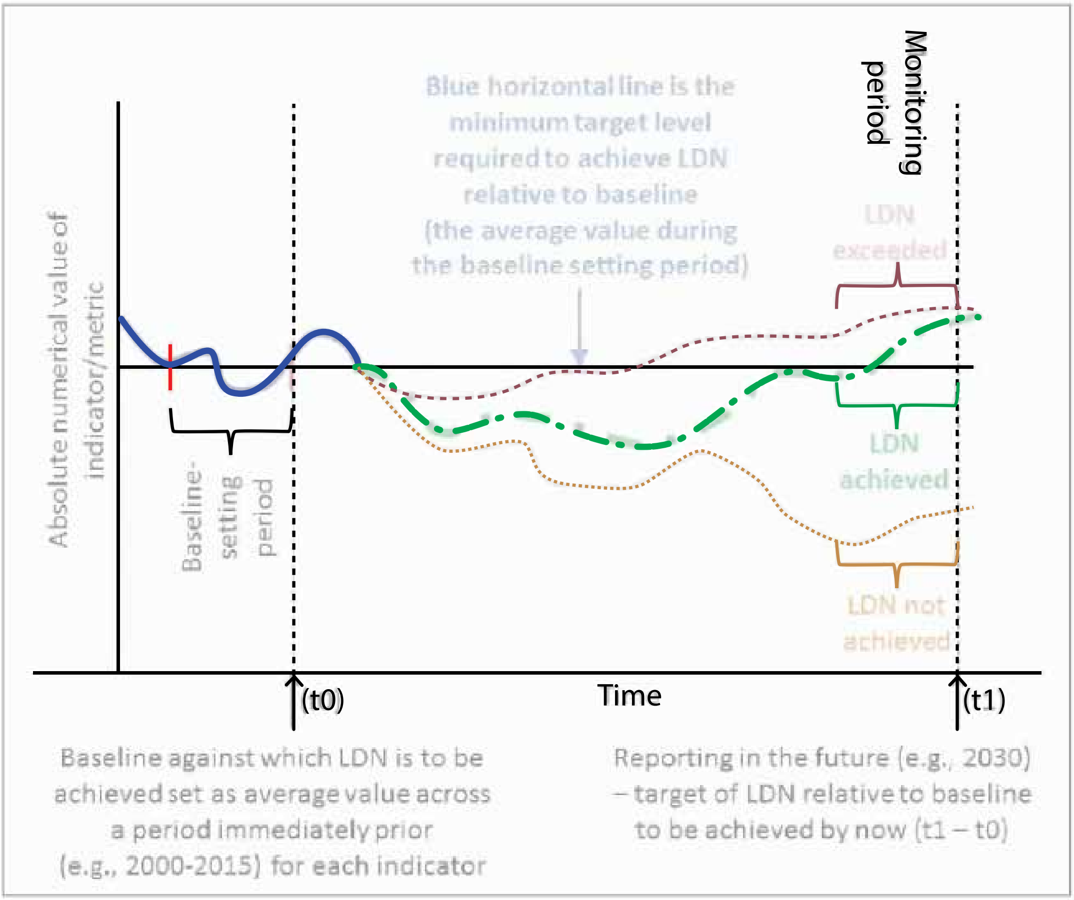

Figure 4.16 Alternative hypothetical trajectories for a hypothetical indicator/metric, showing paths that achieve, exceed or do not achieve LDN.

Source: UNCCD (2017)

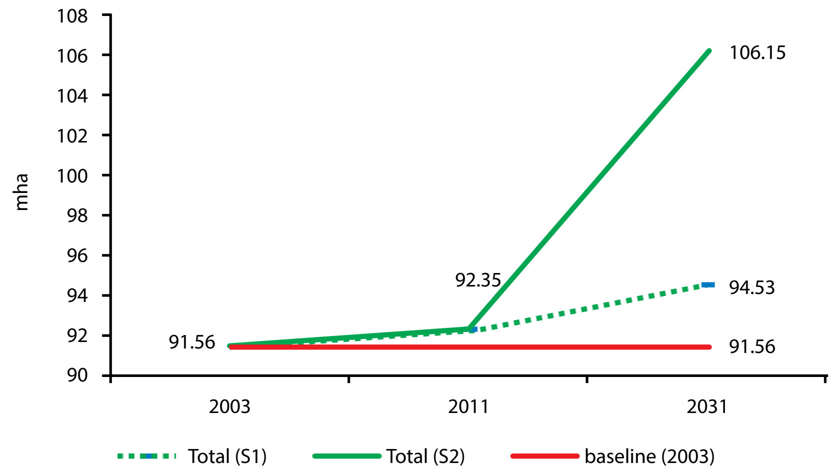

Figure 4.17 An example of LDN for India with the baseline set as year 2003 and projections for total physical estimates of degradation for 2030.

4.9 Costs of reclaiming India's degraded land in 2030

In order to estimate the investments required to reclaim degraded land, we have used per hectare reclamation cost norms for different types of land degradation available from different government projects and programmes. These are summarized in Table 4.19. These estimates were converted into common 2014/15 prices and multiplied by the respective projected area under the different types of land degradation to arrive at the estimated investment (in 2014/15 prices) to reclaim degraded land in 2030. Based on the above methodology, total investment required along with projected area to be reclaimed and per unit investment requirement (at 2014-15 price) is provided in Table 4.20.

Table 4.19. Cost norms for reclamation of various categories of degraded lands

	Category	Amount (Rs/ha)	Year	Source
1	Saline/alkaline	60000	2016	http://agricoop.nic.in/sites/default/files/rps_guidelines%20 (2).pdf
2	Wind erosion		2005	Source: Chouhan, T.S. 2005. Degree, Extent and treatment of desertification hazards in India Sociedade & Natureza, vol. 1, núm. 1, mayo, 2005, pp. 901-919 Universidade Federal de Uberlândia
a)	arid	11000		
b)	semi-arid	11000		
c)	sub-humid	12000		
3	Water erosion		2016	Pradhan Mantri Krishi Sinchayee Yojna (2015)
a)	plains	12000		
b)	hills	15000		
4	Forests		2009	NAP, 2009 guidelines

a)	artificial regeneration (for open and scrub forests)	37085		
b)	natural regeneration (used as proxy for moderately dense forests)	27163		
5	Waterlogging		2013	http://wrmin.nic.in/writereaddata/CAD-WL-20140331.pdf (XII plan)
a)	surface drainage	20000		
b)	SSD-Sub Surface Drainage	50,000		

Table 4.20 Required investment to reclaim degraded land in 2030

1	2	3	4	5	6
	Projected area in 2030 (in mha)		Cost of reclamation per ha (in 2014/15 prices)	Total investment (in Rs billion)	
	Scenario 1	Scenario 2		Scenario 1	Scenario 2
water erosion	39.04	40.15	15000	586	602
wind erosion	17.51	28.34	20812	364	590
water logging	0.95	0.43	50,000	48	22
salinity	1.63	1.81	60000	98	109
forests-scrub	4.12	4.12	52326	216	216
forests-open	31.28	31.28	52326	1637	1637
Total	94.53	106.15		2948	3175

Due to the higher projected degraded area in Scenario 2, the total investment required for reclamation is higher in this scenario (3175 billion INR) compared to scenario 1 (2948 billion INR). The annual cost of degradation determined earlier in this chapter is pegged at 3177 billion INR. Thus, irrespective of the scenario used, the total investment required to reclaim India's degraded land is lower than the annual costs of land degradation. These results clearly indicate that it makes economic sense to reduce land degradation and ensure that India is land degradation neutral by 2030 or earlier.

4.10 Conclusion

We conclude with some key policy and definitional issues. Our estimates should be seen as highly conservative. First, as pointed out earlier, in the case of agricultural losses not all crops, regions and types of degradation are included. These are partial estimates and therefore conservative as suggested. Second, in the case of forests, much of the scrub and non-forest areas that are upgraded to very dense or moderately dense forests are likely to be plantations, and plantations cannot replace natural forests in terms of all ecosystem services provided. Moreover, estimates of forest degradation from other sources provide far higher figures of forest degradation for the country. For example MODIS satellite data shows that between 2001 and 2009, 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 (Mythilli and Goedecke, 2016). Moreover, recent 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 of which 12 million ha is in forested areas and the remaining 29 million ha in croplands (Le et al., 2014).

From a policy perspective, the study underscores the gravity of degradation as compared to land use change. Degradation accounts for 81.9% of the total costs of land use change and land degradation. The results underline the costs of forest loss and degradation to the economy, although this may be partly because of the high TEV values for forests in comparison with croplands. Overall, forest degradation accounts for 40% of the costs of land degradation in the country and forest loss and forest degradation together account for 56.6% of the total costs of land degradation and land use change in the country. Therefore, any strategy to ensure that India becomes land degradation-neutral by 2030 must address the critical issue of reducing forest dependence for fuelwood, fodder and non-timber forest products.

Firewood and other biomass-based fuels lie on the lowest rung of the energy ladder, and people tend to switch to modern fuels with an increase in household income, given that firewood is a "normal" option for lower income households but an inferior one for households with higher income (Arnold, Kohlin, and Persson 2006). Urbanization and rising incomes have seen a reduced demand in firewood, although charcoal is the fuel that the urban poor often shift to (Arnold, Kohlin, and Persson 2006). For example, in Hyderabad, fuelwood usage by households dropped by 60% over a 13-year period although the population trebled during that time (ESMAP 1999). Consequently, a major focus for reducing forest degradation is encouraging rural households dependent on forests to switch to alternative fuel sources or at the minimum utilise fuel efficient devices. The latest scheme of LPG subsidization for BPL households is a positive measure but requires a relook to ensure its sustained uptake and success.[46]

India will also need to reduce forest degradation to meet the INDC targets of an additional carbon sink of 2.5 to 3 billion tonnes of carbon dioxide equivalent through additional forest and tree cover by 2030, particularly since forest degradation directly impacts the emission and sequestration of greenhouse gases, and inadequate land is available to meet these targets through plantations alone.

The study shows that the loss of agricultural production accounts for about 16% of the total costs of land use change and land degradation in India and costs the equivalent of close to 3% of the value added by the agriculture and forestry sector in 2014/15. Addressing agricultural production is imperative. This is especially important since the maximum share (over 40%) of this cost is borne by farmers in rain-fed areas, which are intrinsically less advantaged than those in irrigated areas. It is not surprising, that the bulk of funds spent for land degradation focus on watershed programmes for water-induced soil erosion (but see below). Till March 2013, 58.4 % of total expenditure for land degradation focussed on water erosion and accounted for 72% of the land area treated in the country (Pandey, 2015, pers. communication, Department of Agriculture and Cooperation). However, it is important that in addition to watershed initiatives to encourage soil conservation, the pricing of agricultural inputs and outputs is rationalized in order to ensure food security, nutritional balance and equitable prosperity of farmers in the country.

Projections of land area that is likely to be degraded in 2030 under two different scenarios are estimated at 94.53 mha and 106.15 mha, respectively. In scenario 1, which is based on the reported estimates for 2003 and 2011 (SAC, 2016), the trend indicates a decrease in area affected by wind erosion and salinity, while area affected by water erosion, water logging and under open forests increase over time. In scenario 2, three distinct time points (1995, 2003 and 2011) with a gap of 8 years between each time point were considered for future projections. In scenario 2, degraded land that is saline and waterlogged is projected to decrease in the future. However, both wind and water erosion, two dominant causes of land degradation, in addition to the area under open forests are projected to increase.

[46] In particular, while the scheme addresses the high up-front costs of LPG by waiving these off for BPL households, the continued use of LPG post connection remains doubtful with the cost per subsidised cylinder (14.2Kg) at approximately Rs 400-450 still being high for BPL households (https://www.iocl.com/products/indanegas.aspx, CEEW 2014:http://ceew.in/pdf/CEEW-Rationalising-LPG-Subsidies-Reaching-the-Underserved-5Dec14.pdf).

That area affected by water erosion is projected to rise in both scenarios, suggests that India will need to strengthen her reclamation efforts in this area, despite substantial expenditure to date on the watershed programme. In both scenarios considered, the area affected by salinity shows a decline, suggesting successful reclamation efforts.

Wind erosion and water logging show conflicting trends in the two scenarios. This difference is accounted for by the use of additional time series data in scenario 2. The addition of a mere data point alters the entire trend of land degradation. This underscores the need to maintain, accurate and consistent, longitudinal data to clarify the trends in land degradation in India. Without this, it is hard to assess the efficacy of on-going reclamation programmes, or to give successful policy prescriptions. Wind erosion is the third largest contributor to land degradation in India, but is either increasing or decreasing depending on the data adopted.

The overall observed and projected increase in land degradation in both scenarios clearly suggests that India needs to scale up reclamation efforts. This makes economic sense, since the ***annual*** costs of land degradation (Rs 3177 billion), exceed the ***total*** costs of reclamation (Rs. 2948 billion in scenario 1 and Rs 3175 billion in scenario 2).If we take 2003, as the baseline year for setting the LDN target, our projections suggest that physical estimates of land degradation in the country outstrip this target in 2011 itself and keep increasing in 2030. To counter this, reclamation efforts will need to be scaled up, particularly for water erosion (in both scenarios), for wind erosion (in scenario 2) and for forests (in both scenarios).

Several definitional and measurement issues must be addressed to get an accurate picture of the actual costs of land degradation in the country and prevent land mismanagement. As mentioned earlier, because of a lack of consensus of what constitutes a wasteland or the difference between degraded lands[47] and wastelands, estimates of land degradation for the country vary widely. For example, the Wasteland Atlas (NRSC, 2011) and the Atlas of Degraded Areas (ICAR-NAAS, 2010) provide different results due to definitional issues. This makes an effective assessment of the extent of land degradation in the country imprecise and open to interpretation. Importantly, this also has policy implications since it fosters inappropriate land use and conversion to other land uses that might exacerbate land degradation. For example, the classification of village grazing land as wasteland and their conversion for development, shifts cattle grazing onto forest areas consequently enhancing forest degradation. A study by International Centre for Research in Semi-Arid Tropics, Hyderabad, indicated that since the 1950s, the area under Common Property Resources has gone down by 31-55 per cent in 82 villages in seven states (Jodha, 1986). Inappropriate policies and mismanagement of land leads to conflict over resources, and India needs to urgently rationalize its definitions of what does or does not comprise productive land. This should be based on good science but importantly must consider socio-economic, cultural and traditional land management methods and issues within its ambit.

Another issue is the need for updated and accurate statistics on the areal extent of various ecosystems. For example in the forestry sector, as highlighted earlier, clear estimates of how much of India's forest cover lies under plantations versus natural forests remains unavailable. Estimates of degraded forest areas vary between FSI (2015) at 30.04 mha of open forests (excluding scrub forests of 4.14 mha) and SAC (2016) at 29.3 mha of degraded vegetation. There is a need for finer scale assessments of forest quality in addition to remote sensing assessments of forest cover, in order to establish forest health of the country. The same holds true for grasslands and a grassland atlas of the country is clearly warranted along with a policy for grasslands, grazing and fodder.

Finally, it is necessary that land-use statistics are rationalized and estimates of areas various land uses, particularly forests, wetlands, and grasslands, are harmonised by ensuring that various agencies for example the. Forest Survey of India and the Space Applications Centre work together.

Greater clarity and convergence in reporting of land-use figures in India will contribute to effective governance of natural resources commensurate with their value, and promote rational policy and decision making.

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[47] As mentioned earlier in this report, "land degradation refers to a, "reduction or loss of biological or economic productivity and complexity of rain-fed cropland, irrigated cropland or range, pasture, forests, & woodlands resulting from land use or from a process or combination of processes arising from human activities & habitation patterns."

CHAPTER 5

Recommendations

5.1 Introduction

Land is a vital resource for producing food, preserving forests and biodiversity, facilitating the natural management of water systems and acting as a carbon store. Appropriate land management can protect and maximize these services for society. Conversely, desertification, along with climate change and the loss of biodiversity were identified as the greatest challenges to sustainable development during the 1992 Rio Earth Summit. The United Nations Convention to Combat Desertification (UNCCD) is one of 3 Rio Conventions which focuses upon Desertification, Land Degradation and Drought (DLDD).

In this study, we determined the costs of land degradation for the country. The annual economic costs of land degradation and land use change in the country have been estimated at Rs 3177390 million or 317739 crore which is 2.54% ***of India's GDP in 2014/15 and about 15.9% of the GVA from the agriculture, forestry and fishing sectors. Almost 82% of the estimated cost is on account of land degradation and only 18% due to land use change***

Also it can be seen that the distribution of the economic burden of losses due to different types of land degradation is different from the distribution of the physical extent of degradation itself. For instance, according to recent SAC (2016) figures, water erosion accounts for 37.4% of the total area affected by degradation, followed by vegetation degradation (30.4%), wind erosion (18.9%) and salinity (3.8%). However, ***in terms of the cost of land degradation and use change, the economic cost of forest loss and degradation accounts for over 55% of the total of which degradation accounts for 40% and forest loss the remaining. However, in physical terms, forest degradation ranks second in its contribution to India's degraded land area***. This is on account of the higher cost per hectare of vegetal or forest degradation. In terms of agricultural production losses, water erosion in rain-fed areas accounts for the majority share (37%), followed by losses due to sodic soils (33%), saline soils (18%) and wind erosion (7%).

5.2 Recommendations

We give below a series of recommendations based on our review and analysis of both the physical estimates and the economic costs of land degradation. Ultimately, assessing the economic costs of land degradation depends on accurate physical estimates of the areal magnitude of the problem.

- The study underscores the gravity of degradation as compared to land use change. Degradation accounts for 81.9% of the total costs of land use change and land degradation and hence ***efforts in India must focus on a) reducing further degradation of existing ecosystems and b) enhancing restoration efforts of degraded ecosystems.***
- Forest degradation accounts for the major share of land degradation costs of India highlighting the need to prevent forest degradation. Therefore, any strategy to ensure that India becomes land degradation-neutral by 2030 ***must address the critical issue of reducing forest dependence for fuelwood, fodder and non-timber forest products***: factors that drive forest degradation in India given that almost 300 million people depend on the forests for various needs. ***A major focus for reducing forest degradation is encouraging rural households dependent on forests to switch to***

alternative fuel sources or at the minimum utilise fuel-efficient devices. The latest scheme of LPG subsidization for BPL households is a positive measure but requires a relook to ensure its sustained uptake and success.

- Our figures of losses in agricultural production are very conservative. Nevertheless, the study indicated that the loss of agricultural production accounts for about 16% of the total costs of land use change and land degradation in India and costs the equivalent of close to 3% of the value added by the agriculture and forestry sector in 2014/15. Addressing issues of decreases in agricultural production is imperative for an agrarian country like India. This is especially important since the maximum share (over 40%) of this cost is borne by farmers in rain-fed areas, which are intrinsically less advantaged than those in irrigated areas. ***Therefore, studies need to focus on ways to minise land degradation and maximise land reclamation in rainfed areas, and an evaluation of the success of the watershed programme in doing so (see point below). Additionally, studies on the costs of agricultural production losses in irrigated lands (resulting from waterlogging, enhanced salinity and water erosion) are required. Moreover, the pricing of agricultural inputs and outputs is rationalized in order to ensure food security, nutritional balance and equitable prosperity of farmers in the country***
- Projections of land area that is likely to be degraded in 2030 under two different scenarios are estimated at 94.53 mha and 106.15 mha, respectively. The area affected by water erosion and area under open forests (as compared with moderately dense and very dense forests) is projected to rise in both scenarios, suggesting that India will need to strengthen her reclamation efforts in these sectors). Till March 2013, 58.4 % of total expenditure for land degradation focussed on water erosion and accounted for 72% of the land area treated in the country (Pandey, 2015, pers. communication, Department of Agriculture and Cooperation). Nevertheless, consistent increases in the area under water erosion continue, despite substantial investments over time in the watershed programme (Rs 315.8 billion till 2013; Pandey, 2015***A detailed impact evaluation is required of the contribution of the watershed programme to reducing water erosion (and enhancing water tables) in India given that this is one of the primary programmes in India to reduce land degradation.***
- The overall observed and projected increase in land degradation in both scenarios mentioned in the point above clearly suggests that ***India needs to scale up reclamation efforts.*** This makes economic sense, since the ***annual*** costs of land degradation (Rs 3177 billion), exceed the ***total*** costs of reclamation (Rs. 2948 billion in scenario 1 and Rs 3175 billion in scenario 2).
- In both scenarios considered above, the area affected by salinity shows a decline, suggesting successful reclamation efforts particularly in the State of Uttar Pradesh which accounts for almost 50% of the dip in saline degraded area (SAC, 2016). ***The success of these programmes must be replicated in areas such as Punjab and Haryana that are impacted by waterlogging which results in enhanced salinity and sodicity.***
- Consistent, longitudinal, all India and State-level physical estimates of land degradation in the country are lacking, making it hard to establish trends over a period of time. Currently, there is only one consistently estimated, two time period data for land degradation in the country (estimated for 2003/05 and 2011/13) (SAC, 2016), but these are too close in time to make any meaningful analysis. Assessing trends from different sources is difficult since the classification of land degradation categories fluctuate across sources or over the years. For example, the ICAR-NAAS (2010) atlas which harmonises the NBSSLUP soil degradation classes and the NRSA wasteland classes does not include vegetal degradation as a discrete category. However, the recent Space Applications Centre (SAC) atlas has a separate category of vegetal degradation. Without consistent estimates of degradation over time, it is hard to assess the efficacy of on-going reclamation programmes, or to give successful policy prescriptions. For example, because of huge discrepancies between different sources (all official), our two projected scenarios for 2030 indicate that wind erosion either increases or decreases, depending on the data used. This is unfortunate, because wind erosion is the third largest contributor to land degradation in India, ***and it is important to understand country trends over time***.

- Setting of the Land Degradation Neutrality (LDN) targets to ensure that India becomes LDN in 2030 crucially requires long-term, consistently estimated, datasets. If we take 2003, as the baseline year for setting the LDN target (if we employ the only multi-point data available from a single source (SAC, 2016), our projections suggest that physical estimates of land degradation in the country outstrip this target in 2011 itself and keep increasing in 2030. ***Hence reclamation efforts will need to be speed up if India is to become LDN by 2030.***
- Several definitional and measurement issues must be addressed to get an accurate picture of the actual costs of land degradation in the country and prevent land mismanagement. Because of a lack of consensus of what constitutes a wasteland or the difference between degraded lands[48] and wastelands, estimates of land degradation for the country vary widely. For example, the Wasteland Atlas (NRSC, 2011) and the Atlas of Degraded Areas (ICAR-NAAS, 2010) provide different results due to definitional issues. This makes an effective assessment of the extent of land degradation in the country imprecise and open to interpretation. Importantly, this also has policy implications since it fosters inappropriate land use and conversion to other land uses that might exacerbate land degradation. For example, the classification of village grazing land as wasteland and their conversion for development, shifts cattle grazing onto forest areas consequently enhancing forest degradation. Inappropriate policies and mismanagement of land leads to conflict over resources. ***Therefore, land-use statistics must be rationalized and estimates of areas of various land uses, particularly forests, wetlands, and grasslands, need to be harmonised by ensuring that various agencies for example the. Forest Survey of India and the Space Applications Centre work together***.
- ***There is an urgent need for updated and accurate statistics on the areal extent of various ecosystems.*** For example in the forestry sector, as highlighted earlier, clear estimates of how much of India's forest cover lies under plantations versus natural forests remains unavailable. There is a need for finer scale assessments of forest quality in addition to remote sensing assessments of forest cover, in order to establish forest health of the country. The same holds true for grasslands; current estimates of grasslands in the country, according to the Planning Commission (2011), are 'mere guestimates''. ***Therefore, a grassland atlas of the country is clearly warranted along with a policy for grasslands, grazing and fodder***. This atlas must address issues, such as frequent misclassification of grasslands as forests. For example, dry savannahs are often classified as dry tropical forests. ***Similarly consistent estimates and definitions of wetlands are required, for example between the Wetland Atlas (SAC, 2011) and estimates of ISRO (e.g. ISRO, 2016).***
- ***There is also a need to add wetlands to the official nine category-land use classification of the country (Directorate of Economics and Statistics, Ministry of Agriculture and Farmers Welfare).*** The current classification includes forests, area under non-agricultural uses, barren and un-culturable land, permanent pastures and other grazing lands, land under miscellaneous tree crops, etc, culturable waste land, fallow lands other than current fallows: current fallows; and net sown area

[48] "land degradation refers to a, "reduction or loss of biological or economic productivity and complexity of rain-fed cropland, irrigated cropland or range, pasture, forests, & woodlands resulting from land use or from a process or combination of processes arising from human activities & habitation patterns."

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Appendices

Appendix 1. Annual forest use value estimates and losses utilises by World Bank (2013)

Table 1. Estimated annual use values per hectare of forest in India used by World Bank (2013) (Billion Rs. except where indicated)

Annual Use Values per ha (range)	Low	High
Direct		
Timber	17.2	17.2
Non-timber values	21.0	21.0
Fodder	94.4	188.8
Ecotourism	51.2	51.2
Carbon sequestration	266.8	339.5
Total Direct	**450.6**	**617.5**
Per Hectare, Rs.	6471.3	8871.2
Indirect		
Soil erosion	15.5	15.5
Water recharge	6.4	6.4
Total indirect	21.9	21.9
Per hectare Rs.	314.5	314.5
Total use values	**472.5**	**539.6**
Total per hectare, Rs.	**6785.9**	**9185.7**

Source: Staff estimates applying secondary data from FSI (2009, 2011), GAISP (2005-2006), FAO (2009), Gundimeda (2005), Haripriya (2001), Pearce et. al (1999), 3rd National Report on Implementation of UN Convention to Combat Desertification (2003), World Bank (2006), World Bank (2012), dwww.indg.in as cited in World Bank (2013).

Table 2. Estimation of annual forest value loss in Rs. per hectare, except where indicated

Losses	% loss	Low	High
Direct Values	80-100%	198	248
Timber	20-100%	60	301
Non timber values	0%	1356	2712
Ecotourism	100%	51	51

Losses	% loss	Low	High
Carbon sequestration	20%	766	975
Total Direct		2432	4287
Average % loss		42%	53%
Total Direct, Rs. Bn.		60.5	106.7
Indirect Values			
Soil erosion	0-100%	0	1783
Water recharge	0-100%	0	765
Total indirect		0	2548
Average % loss		0	100
Total Indirect values in billion Rs.		0	63.4
Total degradation losses in billion Rs		60.5	170.2
Total deforestation losses (20% carbon losses only) in billion rupees		9.14	25.47
Total		69.7	195.6
% GDP		0.11%	0.30%
% GDP for the poor		0.60%	1.68%

Source. Staff estimates applying secondary data from GAISP (2005-2006), Gundimeda (2005), Gundimeda (2001) as cited in World Bank (2013)

Appendix 2. Assumptions for percentage of full value relevant for each forest good and service

Goods / service	% of full value relevant
Bamboo	70%
Fodder	100%
Timber	50%
NWFP	70%
Carbon Sequestration	80%
Fuelwood	100%
Bioprospecting	70%
Pollination & seed dispersal	70%
Water recharge	80%
Soil conservation	80%
Water purification	50%
Carbon storage	80%

Source: Verma et al. (2014)

Appendix 3. State level losses due to water erosion (in rain fed areas), sodicity, and salinity

State	Losses due to water erosion in rain-fed agriculture			Agricultural losses due to sodicity			Agricultural losses due to salinity			Total value of agricultural losses due to land degradation
	Potential eroded rainfed area ('00 ha)	***Production loss (t)***	***Monetary loss (Rs. million) in 2014/15 prices***	***Crop area under sodic soils (ha)***	***Production losses (t)***	***Monetary loss (Rs. million) (in 2014/15 prices)***	***Crop area under sodic soils (ha)***	***Production losses (t)***	***Monetary loss (Rs. million) (in 2014/15 prices)***	***Monetary loss (Rs. million) (in 2014/15 prices)***
India	**826552**	**13448042**	**208496**	**6667621**	**11182729**	**162809**	**4807629**	**5661269**	**86753**	**458058**
Andhra Pradesh	54546	1174316	20320	536750	102225	2862	88195	399252	5061	28243
Arunachal Pradesh	1750	70677	992							992
Assam	27350	637860	7933							7933
Bihar	27013	122266	1695	197948	501211	5492	84776	52463	572	7759
Chattisgarh	42842	1006165	13008							13008
Delhi	112.58	607	7							7
Goa	439	40747	489							489
Gujarat	52584	515357	9850	958165	2107449	55830	2904203	2724735	53272	118952
Haryana	7497	14946	145	358860	600285	7106	95765	118418	1340	8592
Himachal Pradesh	6690	136073	1594							1594
J&K	5726	69504	809							809
Jharkhand	17900	315335	4042							4042
Karnataka	78821	2105057	32429	163631	15321	327	1881	262	8	32764
Kerala	1248	59740	714				17134	4123	77	792

State	Losses due to water erosion in rain-fed agriculture			Agricultural losses due to sodicity			Agricultural losses due to salinity			Total value of agricultural losses due to land degradation
Madhya Pradesh	129546	2033076	34484	245802	32027	956				35441
Maharashtra	136770	1603528	24598	698691	1348	40	287573	921175	5366	30004
Manipur	1333	72884	831							831
Meghalaya	950	45275	569							569
Mizoram	647	26209	352							352
Nagaland	2185	130387	1761							1761
Orissa	51855	1055294	15425				273276	197141	2881	18306
Punjab	1672	5291	63	301731	143964	1057				1120
Rajasthan	52621	504761	10266	290337	21323	433	411241	168250	3938	14637
Sikkim	841	28196	378							378
Tamil Nadu	18928	348070	6689	379293	102936	1157	15235	44280	336	8182
Tripura	1590	25029	106							106
UP	60977	801357	12650	2536413	7554640	87547	36829	140765	582	100779
Uttarakhand	6240	167740	2068							2068
West Bengal	35879	336203	4230			0	591521	890405	13319	17549

'Sources: Sharda et al, 2010 (Losses due to water erosion in rain-fed agriculture), Sharma et al, 2015 (losses due to sodicity and salinity),
All estimates were converted to common 2014/15 prices using the WPI series

Appendix 4: Soil Test Crop Response (STCR) equations developed for arid region using targeted yield approach by All India Coordinated Research Project (AICRP) on STCR

Crop	Fertilizer required (kg ha^{-1})	Coefficient of STCR equations			
		Target yield (q ha^{-1})	**Soil N content(kg ha^{-1})**	**Soil P_2O_5 content(kg ha^{-1})**	**Soil K_2O content(kg ha^{-1})**
Bajra	N	10.05	-0.89		
	P_2O_5	6.02		-1.66	
	K_2O	8.2			-0.52
Mustard	N	27.25	-0.969		
	P_2O_5	22.11		-5.69	
	K_2O	21.54			-0.59
Wheat	N	8.54	-0.63		
	P_2O_5	6.93		-3.72	
	K_2O	7.21			-0.55
Groundnut	N + 0.18 ON	1.82	-0.26		
	P_2O_5 + 0.6 OP_2O_5	2.08		-1.48	
	K_2O + 0.33 OK_2O	2.43			
Moth bean	N	8.61	-0.29		
	P_2O_5	8.91		-1.66	
	K_2O	17.58			-0.53
Cluster bean	N	5.38	-0.46		
	P_2O_5	5.07		-2.46	
	K_2O	4.86			-0.34

N = Nitrogen, P_2O_5 = Phosphorous Pentoxide, K_2O = Potassium Oxide, ON = Nitrogen through organic sources, OK_2O = Potash through organic source, OP_2O_5 = Phosphate through organic source

Appendix 5. Concepts & Definitions for land use change

1. **Geographical Area**: The latest figures of geographical area of the State/Union Territories are those provided by the Office of the Surveyor General of India.
2. **Reporting Area for Land Utilisation Statistics** : The Reporting area stands for the area for which data on land use classification of area are available. In areas where land utilization figures are based on land records, reporting area is the area according to village papers, i.e. the papers prepared by the village accountants. In some cases, the village papers may not be maintained in respect of the entire area of the State. For example, village papers are not prepared for the forest areas but the magnitude of such area is known. Also there are tracts in many States for which no village paper exists. In such cases, ad-hoc estimates of classification of area are derived to complete the coverage.

3. **Forest Area** : This includes all land classified either as forest under any legal enactment, or administered as forest, whether State-owned or private, and whether wooded or maintained as potential forest land. The area of crops raised in the forest and grazing lands or areas open for grazing within the forests remain included under the "forest area".
4. **Area under Non-agricultural Uses**: This includes all land occupied by buildings, roads and railways or under water, e.g. rivers and canals, and other land put to uses other than agriculture.
5. **Barren and Un-culturable Land**: This includes all land covered by mountains, deserts, etc. Land which cannot be brought under cultivation except at an exorbitant cost is classified as unculturable whether such land is in isolated blocks or within cultivated holdings.
6. **Permanent Pasture and other Grazing Land**: This includes all grazing land whether it is permanent pasture and meadows or not. Village common grazing land is included under this heading.
7. **Land under Miscellaneous Tree Crops, etc.**: This includes all cultivable land which is not included in 'Net area sown' but is put to some agricultural uses. Land under casuring trees, thatching grasses, bamboo bushes and other groves for fuel, etc. which are not included under 'Orchards' are classified under this category.
8. **Culturable Waste Land**: This includes land available for cultivation, whether taken up or not taken up for cultivation once, but not cultivated during the last five years or more in succession including the current year for some reason or the other . Such land may be either fallow or covered with shrubs and jungles which are not put to any use. They may be accessible or unaccessible and may lie in isolated blocks or within cultivated holdings.
9. **Fallow Lands other than Current Fallows**: This includes all land which was taken up for cultivation but is temporarily out of cultivation for a period of not less than one year and not more than five years.
10. **Current Fallows:** This represents cropped area which is kept fallow during the current year.
11. **Net Area Sown:** This represents the total area sown with crops and orchards.
12. Area sown more than once in the same year is counted only once.
13. **Total Cropped Area:** This represents the total area sown once and/or more than once in a particular year, i.e. the area is counted as many times as there are sowings in a year. This total area is known as gross cropped area. Area Sown more than once: This represents the areas on which crops are cultivated more than once during the agricultural year. This is obtained by deducting Net Area Sown from Total Cropped Area.
14. **Irrigated Area:** The area is assumed to be irrigated for cultivation through such sources as canals (Govt. & Private), tanks, tube-wells, other wells and other sources. It comprises the following:
    - **Net Irrigated Area:** It is the area irrigated through any source once in a year for a particular crop.
    - **Total Net Un-irrigated Area:** It is the area arrived at by deducting the net irrigated area from net sown area.
    - **Total/Gross Irrigated Area:** It is the total area under crops, irrigated once and/or more than once in a year. It is counted as many times as the number of times the areas are cropped and irrigated in a year.
    - **Total/Gross Un-Irrigated Area:** It is the area arrived at by deducting the gross irrigated area from the gross sown area.
    - **Cropping Intensity:** It is the ratio of Net Area Sown to the Total Cropped Area.

Definition of Some Commonly used Terms

- Total Cultivable Area: This consists of net area sown, current fallows, fallow lands other than current fallows, culturable waste and land under miscellaneous tree crops.
- Total Un-Cultivable Area: It is the area arrived at by deducting the total cultivable area from the total reported area.

- Total Cultivated Area: This consists of net area sown and current fallows.
- Total Un-Cultivated Area: It is the area arrived at by deducting the total cultivated area from the total reported area. Agricultural Land/Total Culturable Land: Same as cultivable area.

Appendix 6. Detailed forest cover change matrix from 2005-2015

Forest cover change (in ha)	2005-2007	2009-2011	2011-2013	2013-2015	Total forest change from 2005 to 2015 (in ha)
VDF to MDF	12700	22900	25500	62300	123400
MDF to VDF	22000	31100	43300	289700	386100
Net	9300	8200	17800	227400	**262700**
VDF to OF	4500	2100	4500	14500	25600
OF to VDF	3500	2000	400	36200	42100
Net	-1000	-100	-4100	21700	**16500**
VDF to Scrub	500	0	0	400	900
scrub to VDF	0	0	0	1500	1500
Net	-500	0	0	1100	**600**
VDF to NF	7600	4500	10600	25700	48400
NF to VDF	3600	700	0	15700	20000
Net conversion of VDF to NF	-4000	-3800	-10600	-10000	**-28400**
MDF to OF	194800	190300	178600	243800	807500
OF to MDF	182100	292900	82000	258000	815000
Net	-12700	102600	-96600	14200	**7500**
MDF to Scrub	4200	8100	200	9300	21800
Scrub to MDF	1500	8200	300	13000	23000
Net	-2700	100	100	3700	**1200**
MDF to NF	213000	188800	150500	225400	777700
NF to MDF	144100	144200	65700	97800	451800
Net conversion of MDF to NF	-68900	-44600	-84800	-127600	**-325900**
OF to scrub	18600	35500	6000	59600	119700
Scrub to OF	16100	48800	60600	149600	275100
Net	-2500	13300	54600	90000	**155400**
OF to N-F	414900	340600	185200	562200	1502900
NF to OF	566300	349100	813000	982500	2710900
Net	151400	8500	627800	420300	**1208000**
Scrub to NF	28200	17500	69600	167400	282700
NF to scrub	46400	33500	45000	260100	385000
Net Change (total)	18200	16000	-24600	92700	**102300**

Legend: VDF: Very Dense Forests; MDF-Moderately Dense Forest; OF: Open Forests; NF: Non-Forests
Source: FSI (2009-2015)

Appendix 7: Country-wide and state-wise changes in area under wetlands (2005/06-2011/12)

Type of Wetlands	2005-06	2011-12	Change (Value)	% Change
INDIA				
Inland Wetlands (sq. km)	9935.08	7913.62	-2021.46	-20.35%
Coastal Wetlands (sq. km)	10639.57	15048.75	4409.18	41.44%
River/Stream/Canals Wetlands (sq. km)	60228.19	59096.89	-1131.3	-1.88%
Reservoir/Lakes/Ponds Wetlands (sq. km)	48135.68	53948.37	5812.69	12.08%
Total wetland area (sq. km)	128938.52	136007.63	7069.11	5.48%
STATE-WISE				
Andaman & Nicobar Island				
Type of Wetlands	**2005-06**	**2011-12**	**Change (Value)**	**% Change**
Inland Wetlands (sq. km)	15.7	16.35	0.65	4.14%
Coastal Wetlands (sq. km)	102.49	97.32	-5.17	-5.04%
River/Stream/Canals Wetlands (sq. km)	63.6	34.34	-29.26	-46.01%
Reservoir/Lakes/Ponds Wetlands (sq. km)	7.87	7.61	-0.26	-3.30%
Total wetland area (sq. km)	189.66	155.62	-34.04	-17.95%
Andhra Pradesh				
Type of Wetlands	**2005-06**	**2011-12**	**Change (Value)**	**% Change**
Inland Wetlands (sq. km)	191.17	470.23	279.06	145.97%
Coastal Wetlands (sq. km)	1187.73	1067.5	-120.23	-10.12%
River/Stream/Canals Wetlands (sq. km)	5928.36	5920.46	-7.9	-0.13%
Reservoir/Lakes/Ponds Wetlands (sq. km)	11568.29	11464.06	-104.23	-0.90%
Total wetland area (sq. km)	18875.55	18922.25	46.7	0.25%
Arunachal Pradesh				
Type of Wetlands	**2005-06**	**2011-12**	**Change (Value)**	**% Change**
Inland Wetlands (sq. km)	5.04	5.42	0.38	7.54%
Coastal Wetlands (sq. km)				
River/Stream/Canals Wetlands (sq. km)	1553.1	1572.73	19.63	1.26%

Type of Wetlands	2005-06	2011-12	Change (Value)	% Change
Reservoir/Lakes/Ponds Wetlands (sq. km)	35.12	37.11	1.99	5.67%
Total wetland area (sq. km)	1593.26	1615.26	22	1.38%
Assam				
Type of Wetlands	**2005-06**	**2011-12**	**Change (Value)**	**% Change**
Inland Wetlands (sq. km)	1801.49	1496.65	-304.84	-16.92%
Coastal Wetlands (sq. km)				
River/Stream/Canals Wetlands (sq. km)	7026.81	6750.84	-275.97	-3.93%
Reservoir/Lakes/Ponds Wetlands (sq. km)	63.94	73.67	9.73	15.22%
Total wetland area (sq. km)	8892.24	8321.16	-571.08	-6.42%
Bihar				
Type of Wetlands	**2005-06**	**2011-12**	**Change (Value)**	**% Change**
Inland Wetlands (sq. km)	2046.92	1840.48	-206.44	-10.09%
Coastal Wetlands (sq. km)				
River/Stream/Canals Wetlands (sq. km)	4564.8	4324.55	-240.25	-5.26%
Reservoir/Lakes/Ponds Wetlands (sq. km)	173.19	171.65	-1.54	-0.89%
Total wetland area (sq. km)	6784.91	6336.68	-448.23	-6.61%
Chandigarh				
Type of Wetlands	**2005-06**	**2011-12**	**Change (Value)**	**% Change**
Inland Wetlands (sq. km)		0.02		
Coastal Wetlands (sq. km)				
River/Stream/Canals Wetlands (sq. km)	0.78	0.75	-0.03	-3.85%
Reservoir/Lakes/Ponds Wetlands (sq. km)	1.43	1.52	0.09	6.29%
Total wetland area (sq. km)	2.21	2.29	0.08	3.62%
Chhattisgarh				
Type of Wetlands	**2005-06**	**2011-12**	**Change (Value)**	**% Change**
Inland Wetlands (sq. km)	0.04	0.5	0.46	1150.00%
Coastal Wetlands (sq. km)				

Type of Wetlands	2005-06	2011-12	Change (Value)	% Change
River/Stream/Canals Wetlands (sq. km)	1803.08	1786.38	-16.7	-0.93%
Reservoir/Lakes/Ponds Wetlands (sq. km)	1415.31	1559.54	144.23	10.19%
Total wetland area (sq. km)	3218.43	3346.42	127.99	3.98%
Dadra Nagar Haveli				
Type of Wetlands	**2005-06**	**2011-12**	**Change (Value)**	**% Change**
Inland Wetlands (sq. km)	0.04	0	-0.04	-100.00%
Coastal Wetlands (sq. km)			0	
River/Stream/Canals Wetlands (sq. km)	19.54	8.05	-11.49	-58.80%
Reservoir/Lakes/Ponds Wetlands (sq. km)	0.5	12.82	12.32	2464.00%
Total wetland area (sq. km)	20.08	20.87	0.79	3.93%
Daman and Diu				
Type of Wetlands	**2005-06**	**2011-12**	**Change (Value)**	**% Change**
Inland Wetlands (sq. km)	3.33	7.62	4.29	128.83%
Coastal Wetlands (sq. km)	17.57	7.65	-9.92	-56.46%
River/Stream/Canals Wetlands (sq. km)	3.03	4.58	1.55	51.16%
Reservoir/Lakes/Ponds Wetlands (sq. km)	0.47	0.57	0.1	21.28%
Total wetland area (sq. km)	24.4	20.42	-3.98	-16.31%
Delhi				
Type of Wetlands	**2005-06**	**2011-12**	**Change (Value)**	**% Change**
Inland Wetlands (sq. km)	5.84	4.1	-1.74	-29.79%
Coastal Wetlands (sq. km)				
River/Stream/Canals Wetlands (sq. km)	25.39	27.15	1.76	6.93%
Reservoir/Lakes/Ponds Wetlands (sq. km)	3.73	3.79	0.06	1.61%
Total wetland area (sq. km)	34.96	35.04	0.08	0.23%
Goa				
Type of Wetlands	**2005-06**	**2011-12**	**Change (Value)**	**% Change**
Inland Wetlands (sq. km)	50.86	54.44	3.58	7.04%

Type of Wetlands	2005-06	2011-12	Change (Value)	% Change
Coastal Wetlands (sq. km)	13.09	20.18	7.09	54.16%
River/Stream/Canals Wetlands (sq. km)	80.02	69.02	-11	-13.75%
Reservoir/Lakes/Ponds Wetlands (sq. km)	33.22	30.18	-3.04	-9.15%
Total wetland area (sq. km)	177.19	173.82	-3.37	-1.90%
Gujarat				
Type of Wetlands	**2005-06**	**2011-12**	**Change (Value)**	**% Change**
Inland Wetlands (sq. km)	915.36	981.08	65.72	7.18%
Coastal Wetlands (sq. km)	6301.99	8851.59	2549.6	40.46%
River/Stream/Canals Wetlands (sq. km)	2843.95	3060.56	216.61	7.62%
Reservoir/Lakes/Ponds Wetlands (sq. km)	3383.48	4901.07	1517.59	44.85%
Total wetland area (sq. km)	13444.78	17794.3	4349.52	32.35%
Haryana				
Type of Wetlands	**2005-06**	**2011-12**	**Change (Value)**	**% Change**
Inland Wetlands (sq. km)	20.62	29.2	8.58	41.61%
Coastal Wetlands (sq. km)				
River/Stream/Canals Wetlands (sq. km)	271.71	251.63	-20.08	-7.39%
Reservoir/Lakes/Ponds Wetlands (sq. km)	55.82	60.72	4.9	8.78%
Total wetland area (sq. km)	348.15	341.55	-6.6	-1.90%
Himachal Pradesh				
Type of Wetlands	**2005-06**	**2011-12**	**Change (Value)**	**% Change**
Inland Wetlands (sq. km)	13.84	3.51	-10.33	-74.64%
Coastal Wetlands (sq. km)				
River/Stream/Canals Wetlands (sq. km)	999.4	1013.92	14.52	1.45%
Reservoir/Lakes/Ponds Wetlands (sq. km)	408.67	430.3	21.63	5.29%
Total wetland area (sq. km)	1421.91	1447.73	25.82	1.82%
Jammu & Kashmir				

Type of Wetlands	2005-06	2011-12	Change (Value)	% Change
Type of Wetlands	**2005-06**	**2011-12**	**Change (Value)**	**% Change**
Inland Wetlands (sq. km)	471.24	670.28	199.04	42.24%
Coastal Wetlands (sq. km)				
River/Stream/Canals Wetlands (sq. km)	1900.75	2072.37	171.62	9.03%
Reservoir/Lakes/Ponds Wetlands (sq. km)	1190.47	1237.67	47.2	3.96%
Total wetland area (sq. km)	3562.46	3980.32	417.86	11.73%
		Jharkhand		
Type of Wetlands	**2005-06**	**2011-12**	**Change (Value)**	**% Change**
Inland Wetlands (sq. km)	0.37	13.16	12.79	3456.76%
Coastal Wetlands (sq. km)				
River/Stream/Canals Wetlands (sq. km)	1258.27	1312.9	54.63	4.34%
Reservoir/Lakes/Ponds Wetlands (sq. km)	569.53	695.92	126.39	22.19%
Total wetland area (sq. km)	1828.17	2021.98	193.81	10.60%
		Karnataka		
Type of Wetlands	**2005-06**	**2011-12**	**Change (Value)**	**% Change**
Inland Wetlands (sq. km)	26.64	22.82	-3.82	-14.34%
Coastal Wetlands (sq. km)	40.39	23.85	-16.54	-40.95%
River/Stream/Canals Wetlands (sq. km)	1953.77	1967.7	13.93	0.71%
Reservoir/Lakes/Ponds Wetlands (sq. km)	5264.83	5216.27	-48.56	-0.92%
Total wetland area (sq. km)	7285.63	7230.64	-54.99	-0.75%
		Kerala		
Type of Wetlands	**2005-06**	**2011-12**	**Change (Value)**	**% Change**
Inland Wetlands (sq. km)	84.8	267.58	182.78	215.54%
Coastal Wetlands (sq. km)	0.84	86.45	85.61	10191.67%
River/Stream/Canals Wetlands (sq. km)	695.71	555.12	-140.59	-20.21%
Reservoir/Lakes/Ponds Wetlands (sq. km)	512.18	627.9	115.72	22.59%
Total wetland area (sq. km)	1293.53	1537.05	243.52	18.83%

Type of Wetlands	2005-06	2011-12	Change (Value)	% Change
Lakshadweep				
Type of Wetlands	**2005-06**	**2011-12**	**Change (Value)**	**% Change**
Inland Wetlands (sq. km)				
Coastal Wetlands (sq. km)				
River/Stream/Canals Wetlands (sq. km)				
Reservoir/Lakes/Ponds Wetlands (sq. km)	0.02	0.02	0	0.00%
Total wetland area (sq. km)	0.02	0.02	0	0.00%
Madhya Pradesh				
Type of Wetlands	**2005-06**	**2011-12**	**Change (Value)**	**% Change**
Inland Wetlands (sq. km)				
Coastal Wetlands (sq. km)				
River/Stream/Canals Wetlands (sq. km)	2864.27	3237.63	373.36	13.04%
Reservoir/Lakes/Ponds Wetlands (sq. km)	3581.56	5311.01	1729.45	48.29%
Total wetland area (sq. km)	6445.83	8548.64	2102.81	32.62%
Maharashtra				
Type of Wetlands	**2005-06**	**2011-12**	**Change (Value)**	**% Change**
Inland Wetlands (sq. km)	2.46	2.28	-0.18	-7.32%
Coastal Wetlands (sq. km)	843.17	910.99	67.82	8.04%
River/Stream/Canals Wetlands (sq. km)	3967.56	3896.22	-71.34	-1.80%
Reservoir/Lakes/Ponds Wetlands (sq. km)	5188.76	5997.88	809.12	15.59%
Total wetland area (sq. km)	10001.95	10807.37	805.42	8.05%
Manipur				
Type of Wetlands	**2005-06**	**2011-12**	**Change (Value)**	**% Change**
Inland Wetlands (sq. km)	266.87	287.32	20.45	7.66%
Coastal Wetlands (sq. km)				
River/Stream/Canals Wetlands (sq. km)	142.27	145.18	2.91	2.05%
Reservoir/Lakes/Ponds Wetlands (sq. km)	132.22	116.7	-15.52	-11.74%

Type of Wetlands	2005-06	2011-12	Change (Value)	% Change
Total wetland area (sq. km)	541.36	549.2	7.84	1.45%
		Meghalaya		
Type of Wetlands	**2005-06**	**2011-12**	**Change (Value)**	**% Change**
Inland Wetlands (sq. km)	58.7	55.4	-3.3	-5.62%
Coastal Wetlands (sq. km)				
River/Stream/Canals Wetlands (sq. km)	276.87	273.42	-3.45	-1.25%
Reservoir/Lakes/Ponds Wetlands (sq. km)	16.41	17.98	1.57	9.57%
Total wetland area (sq. km)	351.98	346.8	-5.18	-1.47%
		Mizoram		
Type of Wetlands	**2005-06**	**2011-12**	**Change (Value)**	**% Change**
Inland Wetlands (sq. km)				
Coastal Wetlands (sq. km)				
River/Stream/Canals Wetlands (sq. km)	225.66	136.07	-89.59	-39.70%
Reservoir/Lakes/Ponds Wetlands (sq. km)	6.07	25.47	19.4	319.60%
Total wetland area (sq. km)	231.73	161.58	-70.15	-30.27%
		Nagaland		
Type of Wetlands	**2005-06**	**2011-12**	**Change (Value)**	**% Change**
Inland Wetlands (sq. km)	0.04	0	-0.04	-100.00%
Coastal Wetlands (sq. km)				
River/Stream/Canals Wetlands (sq. km)	175.7	181.1	5.4	3.07%
Reservoir/Lakes/Ponds Wetlands (sq. km)	19.42	21.14	1.72	8.86%
Total wetland area (sq. km)	195.16	202.24	7.08	3.63%
		Odisha		
Type of Wetlands	**2005-06**	**2011-12**	**Change (Value)**	**% Change**
Inland Wetlands (sq. km)	458.93	464.71	5.78	1.26%
Coastal Wetlands (sq. km)	1132.64	1130.32	-2.32	-0.20%
River/Stream/Canals Wetlands (sq. km)	3023.79	3028.8	5.01	0.17%

Type of Wetlands	2005-06	2011-12	Change (Value)	% Change
Reservoir/Lakes/Ponds Wetlands (sq. km)	2487.89	2580.92	93.03	3.74%
Total wetland area (sq. km)	7103.25	7204.75	101.5	1.43%
		Puducherry		
Type of Wetlands	2005-06	2011-12	Change (Value)	% Change
Inland Wetlands (sq. km)		0.86		
Coastal Wetlands (sq. km)	5.87	4.26	-1.61	-27.43%
River/Stream/Canals Wetlands (sq. km)	17.56	7.25	-10.31	-58.71%
Reservoir/Lakes/Ponds Wetlands (sq. km)	26.45	16.55	-9.9	-37.43%
Total wetland area (sq. km)	49.88	28.92	-20.96	-42.02%
		Punjab		
Type of Wetlands	2005-06	2011-12	Change (Value)	% Change
Inland Wetlands (sq. km)	129.91	114.63	-15.28	-11.76%
Coastal Wetlands (sq. km)				
River/Stream/Canals Wetlands (sq. km)	687.3	731.86	44.56	6.48%
Reservoir/Lakes/Ponds Wetlands (sq. km)	85.74	83.94	-1.8	-2.10%
Total wetland area (sq. km)	902.95	930.43	27.48	3.04%
		Rajasthan		
Type of Wetlands	2005-06	2011-12	Change (Value)	% Change
Inland Wetlands (sq. km)	210.75	245.33	34.58	16.41%
Coastal Wetlands (sq. km)				
River/Stream/Canals Wetlands (sq. km)	3252.95	3343.57	90.62	2.79%
Reservoir/Lakes/Ponds Wetlands (sq. km)	2650.61	3166.33	515.72	19.46%
Total wetland area (sq. km)	6114.31	6755.23	640.92	10.48%
		Sikkim		
Type of Wetlands	2005-06	2011-12	Change (Value)	% Change
Inland Wetlands (sq. km)				
Coastal Wetlands (sq. km)				

Type of Wetlands	2005-06	2011-12	Change (Value)	% Change
River/Stream/Canals Wetlands (sq. km)	43.61	41.21	-2.4	-5.50%
Reservoir/Lakes/Ponds Wetlands (sq. km)	13.54	17.74	4.2	31.02%
Total wetland area (sq. km)	57.15	58.95	1.8	3.15%
Tamil Nadu				
Type of Wetlands	**2005-06**	**2011-12**	**Change (Value)**	**% Change**
Inland Wetlands (sq. km)	41.48	49.93	8.45	20.37%
Coastal Wetlands (sq. km)	906.2	868.94	-37.26	-4.11%
River/Stream/Canals Wetlands (sq. km)	1792.59	1702.88	-89.71	-5.00%
Reservoir/Lakes/Ponds Wetlands (sq. km)	6502.21	6745.25	243.04	3.74%
Total wetland area (sq. km)	9242.48	9367	124.52	1.35%
Tripura				
Type of Wetlands	**2005-06**	**2011-12**	**Change (Value)**	**% Change**
Inland Wetlands (sq. km)	7.68	5.52	-2.16	-28.13%
Coastal Wetlands (sq. km)				
River/Stream/Canals Wetlands (sq. km)	50.64	50.63	-0.01	-0.02%
Reservoir/Lakes/Ponds Wetlands (sq. km)	54.42	55.34	0.92	1.69%
Total wetland area (sq. km)	112.74	111.49	-1.25	-1.11%
Uttar Pradesh				
Type of Wetlands	**2005-06**	**2011-12**	**Change (Value)**	**% Change**
Inland Wetlands (sq. km)	2713.96	2307.48	-406.48	-14.98%
Coastal Wetlands (sq. km)				
River/Stream/Canals Wetlands (sq. km)	6102.8	7255.18	1152.38	18.88%
Reservoir/Lakes/Ponds Wetlands (sq. km)	1334.84	1803.41	468.57	35.10%
Total wetland area (sq. km)	10151.6	11366.07	1214.47	11.96%
Uttarakhand				
Type of Wetlands	**2005-06**	**2011-12**	**Change (Value)**	**% Change**
Inland Wetlands (sq. km)		0.05		

Type of Wetlands	2005-06	2011-12	Change (Value)	% Change
Coastal Wetlands (sq. km)				
River/Stream/Canals Wetlands (sq. km)	900.53	1092.55	192.02	21.32%
Reservoir/Lakes/Ponds Wetlands (sq. km)	168.94	196.17	27.23	16.12%
Total wetland area (sq. km)	1069.47	1288.77	219.3	20.51%
West Bengal				
Type of Wetlands	**2005-06**	**2011-12**	**Change (Value)**	**% Change**
Inland Wetlands (sq. km)	391	337.11	-53.89	-13.78%
Coastal Wetlands (sq. km)	87.59	139.22	51.63	58.95%
River/Stream/Canals Wetlands (sq. km)	5712.02	3240.29	-2471.73	-43.27%
Reservoir/Lakes/Ponds Wetlands (sq. km)	1178.53	1260.15	81.62	6.93%
Total wetland area (sq. km)	7369.14	4976.77	-2392.37	-32.46%

Definitions

Wetland / water bodies

All submerged or water-saturated lands, natural or man-made, inland or coastal, permanent or temporary, static or dynamic, vegetated or non-vegetated, which necessarily have a land-water interface, are defined as wetlands. It consists of:

Inland Wetlands: These are the areas that include ox-bow lakes, cut-off meanders, playas, marsh, etc. which are seasonal as well as permanent in nature. It also includes manmade wetlands like waterlogged areas (seasonal and perennial).

Coastal Wetland: These include estuaries, lagoons, creek, backwater, bay, tidal flat/mud

flat, sand/beach, rocky coast, mangrove, salt marsh/marsh vegetation and other hydrophytic River /Stream / Canals: Rivers/streams are natural course of water flowing on the land surface along a definite channel/slope regularly or intermittently towards a sea in most cases or in to a lake or an inland basin in desert areas or a marsh or another river. Canals are artificial water course constructed for irrigation, navigation or to drain out excess water from agricultural lands.

Water Bodies: This category comprises areas with surface water in the form of ponds, lakes, tanks and reservoirs.

Source: ISRO (2016)