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Cost of Land Degradation in India

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Abstract

This study attempts to make two main contributions to economic and ecological literature in the Indian context. The first one is to compute the economic cost of land degradation in India. The second one is to develop a systematic database on the valuation of terrestrial ecosystem services focussing on India-specific studies in referred as well as gray literature. To develop the database on the valuation of land ecosystem services, the extensive literature survey was conducted using standard search protocol. The survey outcome was segregated into 3 categories, namely forestland, grassland, and croplands. The survey outcome units are arranged systematically and standardized into monetary 2012 US Dollar values. These values enable to provide the direct and indirect value of economic costs of land ecosystem biome. The Total Economic Value (TEV) estimated for cropland, grassland, and forestland based on standardized respective ecosystem service values. The meta-analysis shows that the average TEV values (\$/ha/y 2012 prices) are 7057, 4726 and 6343 for the forest, grass, and cropland terrestrial ecosystem biomes respectively. Regulatory service values are higher than other ecosystem values in the terrestrial land biome. The study also analyzes the economic cost of land degradation using the physical data from the Desertification and Land Degradation Atlas of India for the periods 2003-05 and 2011-13. The result shows that the total annual economic cost of land degradation is Rs. 4904 crore at all-India level. The distributional analysis suggests that the economic cost of land degradation ranged from Rs. crore -1519 to 1866 across Indian states. The cost of land degradation reported here are lower than those available in the literature (Reddy, 2003; Mythili, 2015) due to couple of reasons including use of TEV concept for valuation of ecosystem services lost due to land degradation, and systematic development of valuation database using India specific studies

Key words: *Land Use Cover Change; Land Ecosystem Services; Land Degradation; Total Economic Value*

JEL Codes: *Q15; Q51; Q57*

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INTRODUCTION

The land is one of the most complex biological resources. Land organisms are extremely diverse and contribute to a wide range of ecosystem services that are essential to the sustainable function of natural and managed ecosystem (Barrios, 2007). The land organisms can have a direct and indirect impact on land productivity. The economic importance of land productivity is well recognized in the literature. In ancient and medieval economies, the productivity of agriculture and other extractive industries played a dominant role in the analyses of and writings on the economy. Pre-classical economists believed that surplus production would come from land productivity under certain conditions (Gilbert, 1987). Physiocrats believed that land was the primary source of value. The classical economists emphasized labor as the major source for backing the production of wealth. Adam Smith considered the produce of land as the principle source of revenue and wealth of every country (Smith, 1776). In the 19th-century land source became a factor of production in economic analyses. In the 20th century, the concept of land productivity analysis touched diverse disciplines such as agriculture, real estate, resource, environmental and ecological economics (Hubacek et al, 2006). The present literature on land productivity is taking the discussion forward by considering ecosystem services provided by land and their loss due to land degradation (TEEB, 2010).

Most of earlier land productivity theories focused on different dimensions of land productivity but have all emphasized the importance of land productivity for economic progress (Hubacek et. al., 2006). The over usage of land would lead to land degradation. Over time, the definition of land degradation has become more complex as the nature and scope of land degradation has expanded. Land degradation refers to "a reduction in the capability of the land to support a particular use" (IPCC, 1995). Land includes not only the soil resource, but also the water, vegetation, landscape, and micro-climatic components of an

ecosystem. Land degradation refers to “a temporary or permanent decline in the productive capacity of the land or its potential for environmental management” (FAO, 1995). The climate and soil science literature has started estimation of the economic cost of land degradation in the early 1980s across the globe.

Significance of Land Degradation

Historically, most studies used Land Use Cover Change (LUCC) database to estimate the extent of land degradation. These studies implicitly argued that land degradation leads to declining provision of land ecosystem services (Oldmen, 1992). Globally, land degradation is considered as one of the major problems facing the world (UNEP, 1992). Based on expert opinion, Oldmen (1992) reported that the physical extension of agricultural soil degradation as a percentage of total geographical area in Africa, Asia, South America, Central America, North America, and Europe was 65, 38, 45, 74, 26, and 25, respectively. The soil erosion costs globally were estimated as \$26 billion per year, with \$12 billion attributed to developing countries (UNEP 1986). All forms of land degradation in South Asia were estimated to cost \$9.8 billion to \$11 billion per year (UNOP, FAO, and UNEP 1993). Dia and Sapro (2007) predicted that land degradation would reduce agricultural income by \$4.2 billion over 2006–2015, which forms about 5 percent of agricultural GDP during the period. Further, soil loss could contribute to 5.4 percent increase in the poverty rate in 2015 compared to the case of no soil loss.

The impact of land degradation is more severe in developing and rain-fed countries of South Asia and the Sub-Saharan countries. At the macro-level in India, studies indicate that the estimated cost of land degradation is about 4.5 percent of the Gross Domestic Product (GDP) in 1992 (Reddy, 2003). Reddy (2003) argued that at the aggregate level, India lost about Rs. 76,430 million due to land degradation in 1994. Further, Reddy (2003) estimated the costs due to water logging effect were about Rs 129,575 million. More recently, World Bank reported that

the average annual cost of land degradation is 1.1 percent of GDP in 2010. According to the National Remote Sensing Agency, the economic cost of land degradation was Rs. 75,183 million. Mythili and Goedecke (2016) estimated the annual economic loss due to land degradation to be Rs. 245,785 million. Kerala, Jammu and Kashmir, Rajasthan, Tamilnadu, Chhattisgarh and Madhya Pradesh, Andhra Pradesh and Assam states contributed significantly to total cost of land degradation in India (Mythili and Goedecke, 2016). The process and type of land degradation differ across states due to different climatic and anthropogenic reasons. At the micro-level, Satyanarayana et. al. (2008) suggest that 1.86 tons (/hectare/year) of rice production is lost due to land degradation in Andhra Pradesh. Besides agricultural losses, some studies suggest that 0.8 - 2.2 Petagram (pg) of carbon storage (/hectare/year) capacity would be lost due to land degradation (Robert et. al., 1994).

Land Ecosystem Services

The assessment of land degradation analysis has become more rigorous and comprehensive globally now. The literature adapted the widely accepted Total Economic Value (TEV) approach to analyze the economic value of the land ecosystem. Land ecosystem provides a range of services that are of fundamental importance to human well-being, health, livelihoods, and survival (Costanza et. al., 1997; Millennium Ecosystem Assessment (MEA), 2005; TEEB Synthesis, 2010). Multifunctional ecosystems provide various services on all spatial and temporal levels. The ecosystem services are benefits which people derive from terrestrial ecosystems and include provisioning services such as food, water, timber; regulating services such as climate and water quality regulation; cultural services such as recreation and spiritual benefits; and supporting services such as gene pool (MEA, 2005). The global estimates suggest that the average annual Total Economic Values (TEV) (\$/ha/2012 year prices) are 7184, 5564, 7435, respectively for forestland, grassland, and cropland (De Groot, 2014).

Indian Context

As outlined above, the land degradation literature in the 1980s and 1990s attempted to assess land degradation impact in monetary terms in India (see, for example, NRSA, 1989; ARPU, 1990; and Reddy, 2003 etc.). These studies assessed only partial loss associated with land degradation by considering agricultural production loss and replacement cost. In line with the evolution of land degradation studies world-wide, the depth and scope of assessment of costs associated with land degradation have widened in India. Mythili and Geodecke (2016) have analyzed land degradation costs systematically through Total Economic Value (TEV) approach, developed by Nkonya et.al. (2011). TEV approach would facilitate accounting of losses due to erosion of direct and indirect ecosystem services. Given the overwhelming emphasis of the existing studies (following TEV approach) on provisioning services, one could argue that the ecosystem services loss due to degradation is still in infancy in India. The present study is an attempt to further extend the literature in this field. Following the TEV approach, this study (i) uses the detailed land degradation data of India published recently by the ISRO (2016), and (ii) combines it with total economic values of different terrestrial biomes that are estimated from detailed meta-analysis of various published studies in India.

The paper is structured as follows: The next section provides an overview of the literature pertaining to land degradation extent, cost and methodologies. The third section discusses the methodological approach followed for assessing economic cost of land degradation in India. The fourth section presents the cost of land degradation estimates for India. Finally, the last section discusses the results and concludes.

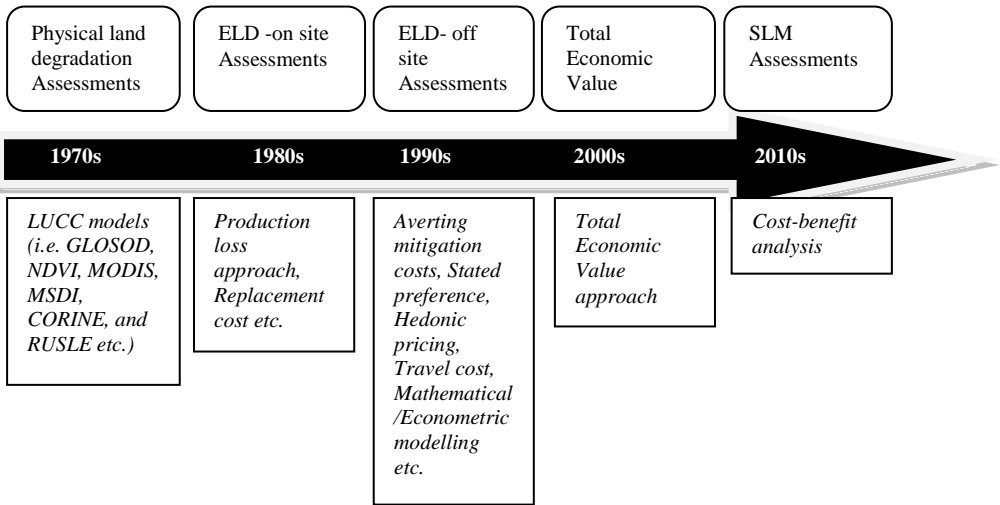
LITERATURE REVIEW

The concept of land degradation started in the early 1970s in geography literature at the global level. Oldmen et. al. (1990) initiated The Global Assessment of Land Degradation (GLASOD) under United Nations

Environment Programme (UNEP) to assess the human-induced causes of land degradation. Later on many assessments have been done on the basis of Land Use Change Models (LUCC) (example, CORINE, PESERA, NDVI, MODIS, MSDI, CORINE, and RUSLE, etc.), which have helped to understand the causes, severity, extent, degree, the impact of fertility and productivity change of the land at global level as well as the national levels (Taimi, 2008). These models analysed changes in the extent of dry lands, rangelands, forests, deserts and grasslands to assess the severity of land degradation. Subsequently numerous studies are done on the basis of typology of land degradation, i.e., salinity, soil erosion, water logging, chemical degradation, wind erosion, and vegetation degradation etc. The analysis of land degradation concept in economics is borrowed from the other areas like geography. LUCC models were able to identify and assess the severity of land degradation but not the economic cost of land degradation.

The economic cost of land degradation in economics literature started in the 1980s. Economic literature broadly uses two methods to analyze the ELD, namely, direct and indirect cost approaches. Production loss and replacement costs are the main methodological approaches for assessing the direct cost of the severity and extent of land degradation. The land degradation costs have mainly been estimated in terms of the impacts on agricultural output and nutritional status (see Bejranonda et. al., 1999). Figure 1 provides a schematic overview of the evolution of the literature in the field of economics of land degradation (ELD).

Figure 1: Evolution of ELD Analysis in Economic Literature at the Global Level



The direct cost/on-site approaches analyze through the LUC models and data sets. These approaches assess only the on-site economic loss of land degradation and do not take into account the off-site losses due to land degradation. After 1980, numerous approaches (i.e. mitigation cost, stated preference, travel cost and mathematical modelling etc.) were available to analyze the off-site economic cost of land degradation. The scope of these methods was to account for the impact of soil conservation, mitigation cost and social value of land degradation, and people's valuation of land attributes etc. Value transfer methods are widely used to analyze national level indirect costs of land degradation. Over time ELD analysis covered implications of land degradation on poverty, migration in developing countries (Duraiappah et al, 1998). An early 21st century the ELD analysis had attempted to analyze through TEV approach which captures the average annual economic cost of land degradation (Nkonya et. al., 2011). The TEV

analysis is able to analyze direct and indirect loss of land degradation. Numerous studies following TEV approach to analyze the economic cost of land degradation at local and global level started appearing over the past two decades.

More recently, the phenomenon of land degradation analysis started adopting even broader scope at the global level. The concept of sustainable land management (SLM) and adaptation of sustainable land management approaches to improve land fertility are the recent trend in the economic analysis. The cost benefit analysis method is widely used to assess the difference between the output under improved land management practice and the status quo land management (ELD Initiative, 2014). Numerous experimental case studies have been taking place at micro-level to analyze ELD. Sustainable land management case studies would be able to analyze the benefits of fertility improvement and establishing opportunities for further development.

In the 1980s the land degradation literature has assessed land degradation impact in monetary terms developing countries like (see, for example, NRSA (1989), ARPU (1990) and Reddy (2003) etc.), India at the macro level. These methods assessed only the provisioning services of land degradation. Moreover, they have focused mostly cropland degradation. Over the period the understanding and assessment of land degradation is more in-depth level. After a decade Mythili and Goedecke (2016) have analyzed systematically through Total Economic Value (TEV, developed by Ephraim Nkonya et.al. 2011) approach. The economic cost of land degradation analysis through TEV is far below from global- level assessments now. There is a scanty of literature and TEV data points are available to analyze ELD through TEV approach. To fulfill the TEV data point's gap in the literature this study will undertake the Meta-analysis.

IMPLICATIONS OF LD IN INDIA - ECOSYSTEM SERVICE APPROACH

Land degradation is the continuous degradation of land under the influence of natural and anthropological causes in arid, semi-arid and dry sub-humid conditions. The processes of desertification and land degradation are observed to have accelerated during recent years. As per the United Nations Convention for Combating Desertification (UNCCD), degradation 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, 1994). Here "land" means the "terrestrial bio-productive system" and "land degradation" means "reduction or loss of 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; 1) Soil erosion caused by wind and/or water; 2) Deterioration of the physical, chemical and biological or economic properties of soil; and 3) Long term loss of natural vegetation" (UNCCD, 1994; ISRO, 2016).

From the above definition, it is clear that land degradation has diverse and widespread implications. The degraded land will provide fewer ecosystem services to the human well being. However, earlier studies have carried out only partial assessments. Direct/onsite assessments like production loss and replacement cost approaches have been followed to analyze the economic cost of land degradation (for example, Reddy, 2003). Mythili and Goedecke (2016) have attempted to analyze systematically the implications of land degradation through Total Economic Value approach. The economic cost of land degradation assessed through TEV service approach would be able to provide realistic estimates.

Analytical Approach

This study utilizes the TEV approach proposed by Nkonya et. al. (2011) which assigns a value to both tradable and non-tradable ecosystem services to estimate the cost of land degradation in a region. In principle land degradation can be accounted in two ways, one is land degradation as a result of the land use cover change (LUCC). The loss of ecosystem services could be due to LUCC that leads to the replacement of biomes with higher ecosystem value by those with a lower value (i.e. LUCC that leads to a loss in the total value of ecosystem services). The second one is deterioration of land quality in a given biome over time. This study restricts itself to the first process of land degradation.

Ideally, when land use change induced land degradation takes place, interaction functions within the ecosystem and provision of services would change non-linearly. To identify marginal change of ecosystem value supply is very complex and difficult. When land use change taking place value of some services will improve and some of would respond negatively. For example, when forest land is converted into agricultural land, the market value of provisioning service may increase but the market value of regulating service may decline. Moreover, the willingness to pay for an ecosystem service could be non-linear depending on the nature of change of demand for that service as supply changes.

LUCC is a continuous and long-term process. Conversion of one biome to other biome is a time taking process and even if the land does not change completely from one biome to another, it may change in its quality. For simplicity, this study takes the annual average LUCC values as marginal value over the period of time.

The cost of land degradation due to LUCC is given by:

$$\text{Annual LD} = \sum_{i=1}^k ((z_i^{t1} * p_i) - (z_i^{t2} * p_i))/T \quad (1)$$

For $i = 1, 2, \dots, k$ (Biomes)

Where; Annual LD = Annual cost of land degradation due to LUCC

z_i^{t1} = land area of biome i reported degraded in the first period

z_i^{t2} = land area of biome i reported degraded in the second period

p_i is the TEV per unit of area for biome in 2012 prices, and

i = biome.

T = time period

The total average annual land degradation value means the annual average cropland, grassland and forest land use cover change aggregation. In other words, the combined average annual LUCC of cropland, grassland and forest land over the period. The TEV value is combined with average aggregate LUCC value in order to estimate the economic cost of land degradation. By definition, land degradation leads to conversion of land from high-value biome to low-value biome. Thus, LUCC involves the movement of biomes from higher TEV to lower TEV. To obtain the net loss of ecosystem value, the second term in the equation nets out the value of the biome replaced by the lower value one.

Land Degradation Data in India

This study uses the land degradation reported recently in the Desertification and Land Degradation Atlas of India, by the India Space Research Organization (ISRO, 2016). This data set provides present status and trends of the land degradation across the country. It comprises of three elements, viz., Land Use, Process of Degradation and Severity Level. This data provides the status of various categories of land use viz., Agricultural irrigated, non-irrigated, forest, grazing land, barren land, rocky area, sandy area, and glacial. This data classifies the process of desertification into vegetation degradation, water erosion, wind erosion, salinity, water logging, mass movement, frost heaving and mass movement. The degradation of land use change is reported at the state

level in the Atlas at two levels, i.e., low and high levels of degradation. This forest/plantation process of degradation considered as forest land degradation, irrigated and non-irrigated land has considered cropland, and grassland/grazing land and land with scrubs are taken as grassland. Low and high-level degradation process has aggregated into one category in all categories of degradation i.e. cropland, grassland and forest land to avoid complexity in ELD analysis. This paper uses only grazing, forest, and cropland desertification data for economic cost of terrestrial land degradation in India. ISRO (2016) provides land degradation data for two time periods: 2003-05 and 2011-13. This study uses land degradation data corresponding to both the periods.

TEV of Land in Different Biomes - Approach

The Total Economic Value (TEV) framework is one of the most widely used frameworks for identifying, categorizing and estimating different ecosystem biome services. TEV attempts to account comprehensively for all terrestrial ecosystem services, categorizing these into direct values (i.e. provisioning services), indirect values (i.e. regulative), option values and existence values (see Figure 2). Ideally, values of goods and services should reflect the best alternative use for resources (true opportunity cost), or the true willingness to pay for the goods and services, excluding external government interventions and including all the externalities (Kadekodi, 1999). However, conventional analysis, based mostly on limited information of marketable value, often fails to capture complete benefits (Verma, 2008; Verma and Kumar, 2008). This is because many of these goods and services do not enter into the market, and for those that enter only a part of the total benefits are actually recorded by market transactions.

Figure 2: TEV Framework

		Use value	Direct use value
Total Value	Economic	Non Use value	Indirect use value
			Option value
			Existence value
			Altruistic value
			Bequest value

Source: TEEB, 2010.

Many of these benefits are also misattributed (Panayotou, 1998). For example, the water regulation services provided by forest biomes may appear as higher profits in water using sectors and not as benefits provided by the forest ecosystem. A first of its kind initiative on the valuation of ecosystem services and biodiversity, known as TEEB (The Economics of Ecosystems and Biodiversity), estimates that the benefits of halving global deforestation by 2030 due to climate change alone are about US\$ 3.7 trillion (TEEB, 2010). Unknown of market price or unaware of indirect market service is leads to undervaluation ecosystem services that provide ecosystem services. For example, some studies estimated cropland ecosystem value is higher than forest land ecosystem value (De Groot, 2014) due to many of the cropland service market values are known whereas many of the forest ecosystem service market price unknown, and even unaware of.

Ecosystem Service Data Collection

There is no readily available data set available on the monetary value of terrestrial land ecosystem service in the Indian context. Therefore, it is essential to list out and develop the database on land ecosystem service monetary value. This section describes the data collection procedure adopted for systematic documentation of land ecosystem service valuation in India.

An extensive literature survey has been undertaken to identify various services such as provision, supportive, regulating, and cultural services by the terrestrial land ecosystem. The survey covered peer-reviewed scientific journals databases as well as the gray literature such as Government Reports, unpublished papers/reports, Ph.D. thesis etc. The search protocol included a combination of keywords: "Land degradation + Economic Loss", "Ecosystem Service + Economic Cost" and "Land Ecosystem Services + Economic Valuation". Subsequently, the articles including all the terms in the text and published and unpublished between 1960 and 2016 have been selected. In all, 97 articles/studies have been identified and finalized as relevant studies pertaining to the economic cost of land degradation in India. These studies are listed in the appendix tables.

While collecting data and selection of publications and value estimates for land ecosystem, following specific criteria were taken into account: 1) Refer to original case studies and within the political boundary of India; 2) Directly provided monetary value to ecosystem/biome (\$ or Rs/ha/year) would be considered for constructing dataset; 3) Wherever direct monetary values are not reported physical values (t/ha/year) also considered; 4) The physical values (i.e. t/ha/year) are converted into monetary values using benefit transfer approach. All monetary values are expressed in standardized monetary units specific to a year. Many studies provided Soil Organic Carbon stock per hectare per year. The SOC value is converted into monetary values using social cost of carbon proposed by Nordhaus (2011). The social cost of carbon is taken as 7.98 US dollars for India for the year 2015.

Values Standardization

The selected estimates are standardized using the following procedure; Land ecosystem service values have been reported in the literature in many different metrics and referring to different years (e.g., WTP per household per year, capitalized values, marginal value per hectare, and

the average value per hectare per year etc.). In order to facilitate comparison between these values, they were standardized to 2012 international US dollars per hectare per year using a general standardization technique (TEEB, 2007; Braat and Ten Brink, 2008; Elsasser et. al., 2009). Following this approach, all estimates were converted into the official Indian currency when needed, then these values were adjusted to 2012 values and finally, they were converted into international dollars by using the purchase power parity (PPP) conversion factor (local currency per international \$ series) (TEEB, 2007). Official exchange rates, WPI Index and PPP conversion factors are taken from the World Bank World Development Indicators.

The standardized monetary values show national average values. All standardized values are segregated into four categories of values - provisioning, regulating, supporting and cultural - for each type of biome (namely, forest, grassland, and cropland). The aggregate value of all the four sub-categories of ecosystem services is taken as Total Economic Value (TEV) for each biome. The total economic values are expressed finally in \$/ha/y for cropland, grassland, and forest land.

THE COST OF LAND DEGRADATION IN INDIA

The main objective of this paper is to analyze the extent and economic cost of land degradation through the TEV approach. The main findings are reported in this section.

Extent of Land Degradation in India

The analysis based on the land degradation data reported in the Desertification and Land Degradation Atlas of India (ISRO, 2016) reveals that 96.40 Mha. area of the country is undergoing a process of land degradation (29.32 percent of the total geographic area of the country) during 2011-13, while during 2003-05 the area undergoing process of land degradation was 94.53 Mha (28.76 percent of the total geographic area of the country). Thus there is an increase of 1.87 Mha areas

undergoing a process of land degradation (constituting 0.57 percent of the total geographic area of the country) during the time frame 2003-05 and 2011-13. Forest land recorded more degradation than any other land ecosystems in all regions of the country. On the other hand, cropland has shown improvement in north, south and northeast regions of the country over the two periods.

In the case of high-level degradation forest, vegetation and cropland biomes 7,333,276 ha during the 2003-05 time frame and 7,303,470 degraded in the 2011-13 period out of 327,525,500 ha in India. During 2003-05 to 2011-13 time frames the total land degradation in main three categories is 29,806 ha.

ISRO (2016) reports land use change during 2003-2005 and 2011-2013 time periods. Status of land is reported under the categories, forest, agriculture, grassland, Grassland / Grazing land, Land with scrub, Barren, Rocky area, Dune / Sandy area, Glacial, Periglacial and other land use. The data also documents different processes, such as vegetation degradation, salinity, water logging, mass movement, frost heaving, manmade and many other ways, leading to land degradation. Vegetation and grassland degradation are documented across the country. Bihar, Gujarat, Odisha, Telangana, Karnataka and Maharashtra are affected more by water erosion. The problem of wind erosion is widely affecting Rajasthan. The process of Salinity/alkalinity problem is seen across the country mostly in agricultural dominated states. Water logging problem is mostly affecting states with major irrigation projects. During eight years period (i.e., 2003-05 to 2011-13) forest land has been changed/degraded across the country except in Odisha. The bulk of forest land conversion into agricultural land is the main reason for forest land degradation. The agricultural land cover is increased in many states from 2003-05 to 2011-2013 period. States like Uttar Pradesh, Odisha, Madhya Pradesh, Telangana, Assam, and Meghalaya`s agricultural land has been improved the land fertility due to land use change.

As a country in India 797,576 ha of forest, 248,330 ha of grassland, and 64,431ha of cropland has been degraded over 8 years period (see Table 1 for details). To calculate the annual degradation from 2003-05 to 2011-13 is divided by 8 years.

Table 1: Annual Land Use Cover Change: 2003-05 to 2011-13
(in ha)

State	Forest	Grassland	Cropland
Andhra Pradesh	258	-2797	11245
Arunachal Pradesh	11759	895	0
Assam	127625	21793	-7001
Bihar	-13565	1018	44989
Chhattisgarh	2188	-5141	16179
Goa	5870	0	-1
Gujarat	69175	-13495	81221
Haryana	897	2227	5127
Himachal Pradesh	94872	113477	33787
Jammu and Kashmir	10179	62891	31468
Jharkhand	71876	-2920	-476
Karnataka	10341	-3008	-15946
Kerala	8879	97	-917
Madhya Pradesh	2175	12099	-259
Maharashtra	840	-8796	438172
Manipur	3205	-2309	0
Meghalaya	20963	-96	-5230
Mizoram	84731	464	675
Nagaland	129036	11428	0
Odisha	-7576	-26	-33143
Punjab	8027	8944	9102
Rajasthan	10039	-2404	-123036
Sikkim	2963	-2849	0
Tamil Nadu	16960	189	0
Telangana	2481	131	-92989
Tripura	106495	4822	-2633
Uttar Pradesh	8642	-2020	-360266
Uttarakhand	7290	53716	0
West Bengal	951	0	34363
Total	797576	248330	64431

Source: Extracted and compiled from India Space Research Organization (ISRO), 2016.

Value of Ecosystem Services

Total economic values of cropland, grassland, and forest ecosystem biomes estimated through the meta-analysis of various India specific studies are given in Table no.1. Forest land ecosystem provides a large variety of services compared to the other two biomes and accordingly has higher TEV. The average TEV values are (\$/ha/year-2012) 7057, 4726 and 6344, respectively for forestland, grassland and cropland. These estimated values fall within the range of global ecosystem service values reported by TEEB (2010) and De Groot (2014). The average global TEV values (\$/ha/year-2012) are 7187, 5564, and 7435 forestlands, grassland, and cropland, respectively.

In the case of forestland, the literature search yielded a significant number of studies that cover provisioning, regulating, supporting and cultural services provided by the forest ecosystem. However, there is a paucity of studies pertaining to provisioning, regulating and cultural services provided by the grasslands in India and also the regulatory services provided by the croplands. The database of ecosystem service values developed by the present study through the exhaustive literature review includes 54 percent more number of studies in the case of forestland and almost double that in the case of grassland and cropland, compared to India specific studies of the TEEB (2010) and De Groot (2014) global databases. Further, the Indian studies on an average report lower value for different ecosystem services compared to those reported in other country studies. Independent of the reasons behind such undervaluation, this could lead to overall lower estimates for the cost of land degradation in an analysis based exclusively on the Indian Total Economic Values of ecosystem services.

Table 2: Monetary Value of Services Provided by Forestland, Grassland, Cropland

(in Int. \$/ha/year-2012 values)

Ecosystem	Service	Sub service	No. of Estimates	Sub service mean value	Sub service maximum value	Sub service minimum value
Forest land	Provision	Raw material	7	419	1373	0.1
		Food	2	513	952	72
		Medical	4	890	1211	611
	Regulative	Climate regulation	14	4873	10218	252
		Erosion prevention	2	1150	2152	147
		Soil fertility maintain	3	1330	3635	138
		Water flow regulation	1	98	98	98
	Supportive	Genepool Protection	1	347	347	347
	Cultural	Recreation	3	367	834	25
		TEV All services	47	7057 ¹	13184	1650
Grassland	Provision	Raw material	2	781	1228	333
		Food	1	143	143	143
	Regulative	Climate regulation	19	3727	8219	750
		-	0	0	0.00	0.00
	Cultural	-	1	75	75	75
		TEV All services	23	4726	9665	1302
Cropland	Provision	Food	13	2872	6638	194
		Regulative	Climate regulation	6	2015	2915
	Supportive	Erosion prevention	8	1457	2581	547
		-	0	0	0	0
	Cultural	-	0	0	0	0
		TEV All services	27	6344	8368	4303

Source: Own estimates based on meta-analysis of different studies.

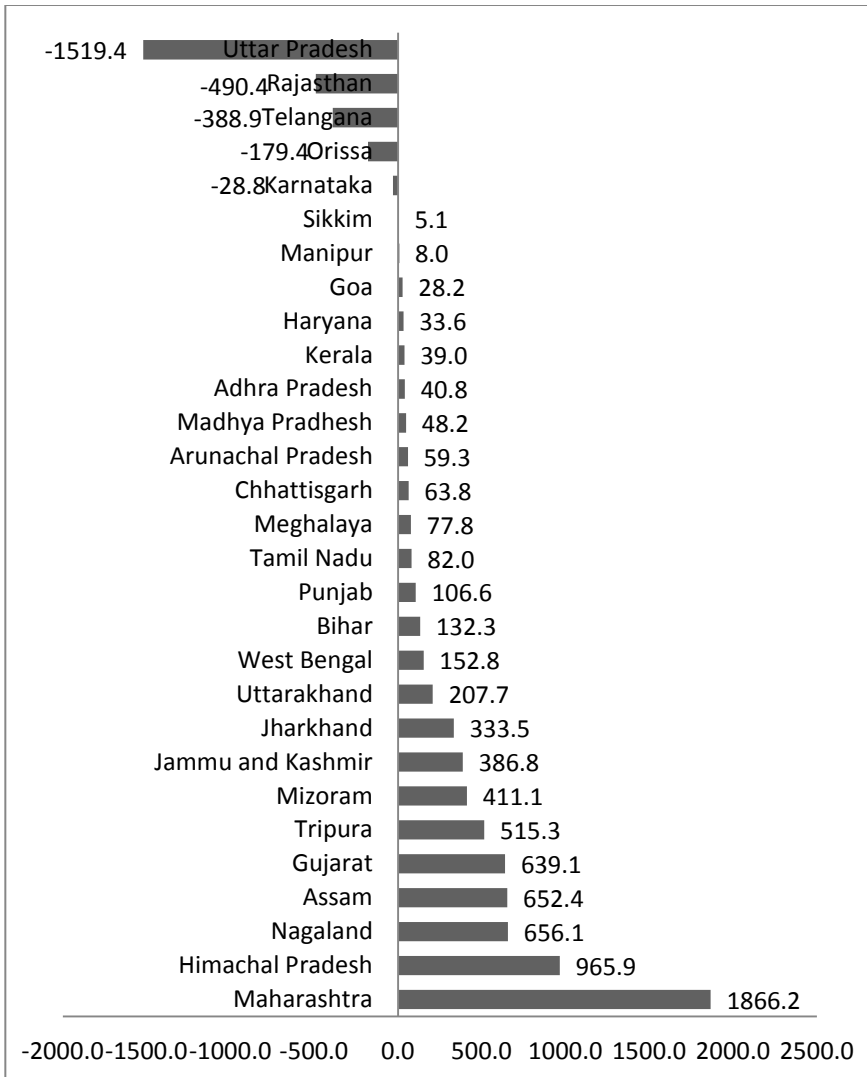
¹ The TEV value here is the average of Meta estimation TEV and Verma (2014) TEV values.

Cost of Land Degradation

The primary purpose of this study is to estimate the economic cost of land degradation in India. To achieve this goal the average TEV value of ecosystem services from cropland, grassland, and forestland biomes are multiplied with the extent of state wise land degradation. This will provide first order approximation of cost of degradation in cropland, forestland, and grassland biomes.

Values were converted into year wise based on biophysical land degradation data period (i.e. during 2003-05 and 2011-13 years) to understand the yearly trend of economic cost of land degradation in different parts of the country. The processes of land degradation/desertification will lead to reduction in the provision of ecosystem services to human beings. Land degradation not only reduces the welfare of human beings, but will also affect other ecosystem functions with a different scale. The present analysis does not account for such feedback effects.

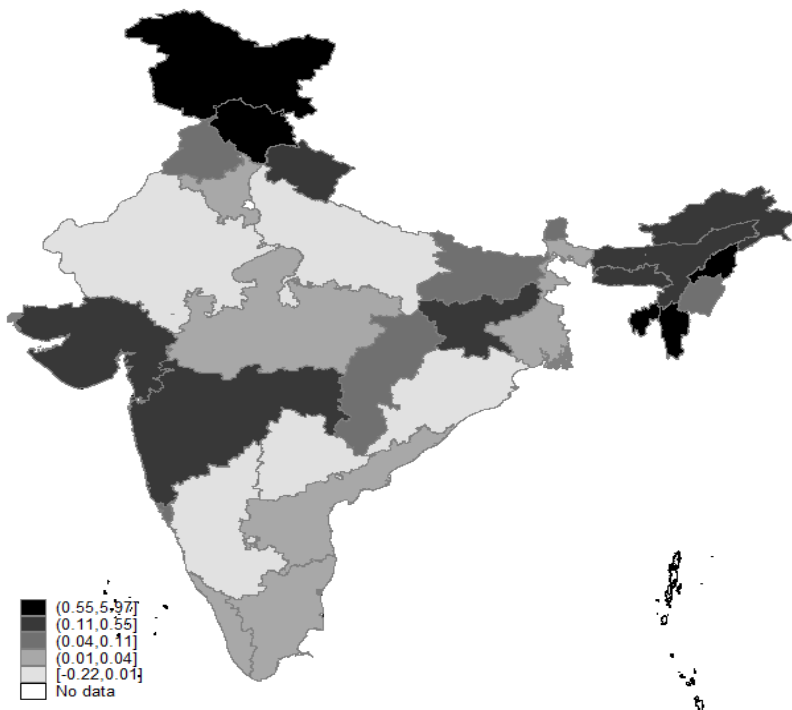
Figure 3: Annual Cost of Land Degradation from 2003-05 to 2011-13
(Values are in Rs. Crore and 2012 prices)



Source: Own estimates.

Figure 3 shows the annual total economic cost of land degradation across different states of India. It can be seen from the figure that relatively higher costs of land degradation are borne by the states like Maharashtra, Himachal Pradesh, Nagaland, Assam, Gujarat, Tripura and Mizoram. Forest land biome degradation is a key variable for high-level land degradation cost (see Table1 for more details).

Figure 4: Total Annual Cost of LD as a Percentage to GSDP in 2012 Prices



Source: Own estimates.

Sikkim, Manipur, Goa, Haryana, Kerala, Andhra Pradesh, Madhya Pradesh, Arunachal Pradesh and Tamilnadu states have relatively less annual economic cost of land degradation. Interestingly, Uttar Pradesh, Rajasthan, Telangana, Odisha and Karnataka states accounted negative

values of total economic cost of land degradation. In other words, the total economic value of land fertility improved in these states. Agricultural or cropland land fertility improvement could be the main reason for the negative value of the economic cost of land degradation in these states. The sustainable land management practices adopted by farmers and effective government policies could be the main factors for improvement of agricultural land biome in these five states.

Figure 4 shows the annual total cost of land degradation expressed as a percentage to GSDP in 2012 prices. Jammu and Kashmir, Himachal Pradesh and all north-east states except Manipur and Sikkim show a higher range of annual land degradation values to Gross State Domestic Product (GSDP). The range falls between 0.45 to 5.97 percentage points in these states. Total land use change and lower GSDP values are responsible for higher percentage values. In states like Rajasthan, Uttar Pradesh, Telangana, Karnataka, and Orissa, the negative percentages are reported due to land fertility improvements described above. The range of annual economic cost due to land degradation as a percentage of GSDP ranges between 0.01 to 0.44 percent in other states in the country.

DISCUSSION AND CONCLUSIONS

The assessment of the economic cost of land degradation is carried out in the earlier literature mainly through the production loss and replacement cost analysis. These analyses basically take into account only onsite physical loss due to land degradation in croplands. Most of the earlier studies have assessed the cost of land degradation using such partial framework in India. The majority of the studies did not consider the losses in ecosystem services from the forest and other terrestrial biomes. Waterlogging, salinity, erosion are the main processes leading to land degradation. The estimates of land degradation costs have varied significantly in India due to methodological and data constraints. As

discussed in the introduction section, more recent studies including the present study have used TEV framework for assessing the cost of land degradation in India. Table 3 provides a comparative overview of estimates made by different studies on the cost of land degradation in India. Based on the methodology adopted, the estimates reported in this study are comparable with those given in Mythili and Goedecke (2016). Relatively higher estimates given by Mythili and Goedecke (2016) are due to high cultural and recreation values adopted in that study based on the global studies.

Table 3: Annual Impact of Land Degradation in India

S. no	Area of the country	Valuation method	Annual ELD	Select ed units	Data period	Study	Remarks
1	All India	Production loss	75183	INR Million/year	1989	NRSA (1989)	Water logging and salinity
2	All India	Production loss	124000	INR Million/year	1990	ARPU (1990)	Water logging and salinity
3	All India	Production loss	448640	INR Million/year	1994	Sehgal and Abrol (1994)	Water logging and salinity
4	All India	Replacement method	9130	INR Million/year	1989	Reddy (2003)	Based on NRSA of area affected
5	All India	Replacement method	28661	INR Million/year	1994	Reddy (2003)	Sehgal and Abrol (1994)
6	All India	Replacement method	11413	INR Million/year	1989	Reddy (2003)	Based on NRSA of area
7	All India	Replacement method and production function	76430	INR Million/year	1994	Reddy (2003)	Degradation area data(1994)
8	All India	TEV approach	245785	INR Million/year	2001 to 2009	Mythili and Goedecke (2016)	Land degradation, NRSA
9	All India	TEV approach	49045	INR Million/year	2003-05 to 2011-13	Present Study	ISRO, 2016

Source: Estimated and compiled by author, data extracted from Reddy (2003) and Mythili (2016).

Limitations

A piece of land degradation may not lose all its ecosystem values, whereas the present analysis assumes so. Ideally, one may want to know the transmission of land from one biome to another so that the loss of service under one biome is compensated by the gain in service under different biome. While another study (Mythily and Goedecke, 2016) using different physical data explicitly accounts for this, the physical data on land degradation used in this study does not facilitate such explicit accounting of land movement across different biomes. However, the degraded land stock estimates across different biomes over two time periods – namely, 2003-05 and 2011-13, enable accounting of land transition across biomes.

Economic valuation cannot value everything in ecosystem services; not all benefits provided by ecosystems are fully translatable into economic terms. The damage suffered by ecosystems can be non-linear, and the impact of changes in ecosystems can be much higher or irreversible above certain thresholds. Methodological limitations constrain the extent to which economic valuation methods can capture the ecological interdependencies of different ecosystem entities. As a result, valuation analysis often ignores or does not adequately account for, the internal structure of ecosystems, and the interdependencies and inter-linkages of different ecosystem entities.

In this study, the TEV value of different ecosystem services for various biomes taken from the literature. Different methods followed for various biomes and regions. Since the meta-analysis approach adopted here does not correct for these differences across studies, the cost estimates are likely to be biased. Future research may build upon the database used in this study to further improve the estimates of land degradation costs.

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APPENDIX

Appendix 1: Monetary Value of Services Provided by Forests

S. No	Sub Service	Valuation method	Reported value	Selected units	Data period	(\$/ha/year-2012 values)	Study
1	Raw materials	market price	589.64	Rs/ha/y	2005	310.78	Jyoti Parikh et. al. (2008)
2	Raw materials	market price	239.04	Rs/ha/y	2005	125.99	Jyoti Parikh et. al. (2008)
3	Raw materials	market price	2605.57	Rs/ha/y	2005	1373.33	Jyoti Parikh et. al. (2008)
4	Raw materials	market price	717.13	Rs/ha/y	2005	377.98	Jyoti Parikh et. al. (2008)
5	Medical	direct production	1211	Rs/ha/y	2005	638.29	Murthy, I. K., et. al. (2005)
6	Medical	direct production	2090	Rs/ha/y	2005	1101.58	Murthy, I. K., et. al. (2005)
7	Food	market price	50.7	\$/ha/y	2007	952.16	Singh, SP (2007)
8	Medical	direct production	2299	Rs/ha/y	2005	1211.74	Murthy, I. K., et. al. (2005)
9	Medical	direct production	1159	Rs/ha/y	2005	610.88	Murthy, I. K., et. al. (2005)
10	Food	unspecified	3.67	\$/ha/y	2008	72.20	Gubbi et. al. (2008)
11	Raw material	direct production	5676	Rs/pers on/year	2011	0.0006	Joshi et. al. (2011)
12	Raw material	direct production	4640	Rs/pers on/year	2011	0.0004	Joshi et. al. (2011)
13	Raw material	production	1211	Rs/ha/y	2001	746.31	Narendran et. al. (2001)
14	Climate regulation	Unspecified	17928.28	Rs/ha/y	2005	9449.53	Jyoti Parikh et. al. 2008

(Contd ...Table)

S. No	Sub Service	Valuation method	Reported value	Select ed units	Data period	(\$/ha/yea r-2012 values	Study
15	Climate regulation	Unspecified	167.6	\$/ha/y	2007	3147.56	Singh, SP (2007)
16	Water flow regulation	Unspecified	5.2	\$/ha/y	2007	97.66	Singh, SP (2007)
17	Erosion prevention	Unspecified	114.6	\$/ha/y	2007	2152.21	Singh, SP (2007)
18	Soil fertility mainten	Unspecified	11.6	\$/ha/y	2007	217.85	Singh, SP (2007)
19	Soil fertility mainten	Unspecified	429.6	Rs/ha/y	2011	138.35	Joshi et. al. (2011)
20	Soil fertility mainten	Unspecified	133.5	\$/ha/y	1992	3634.91	Chopra et. al. (1993)
21	Erosion prevention	cost-benefit analysis	388.13	Rs/ha/y	2009	147.14	
22	Climate regulation	NPV	4486.33	\$/ha/y	2012	4486.33	Verma et. al. (2014)
23	Climate regulation	NPV	5997.66	\$/ha/y	2012	5997.66	Verma et. al. (2014)
24	Climate regulation	NPV	8230	\$/ha/y	2012	8230	Verma et. al. (2014)
25	Climate regulation	NPV	3657	\$/ha/y	2012	3657	Verma et. al. (2014)
26	Climate regulation	Walkley-Black method	87.29	Mg/ha/y	2014	10218.56	Venkanna, K., et. al. (2014)
27	Climate regulation	Unspecified	4.23	kg/m ²	2014	5254.56	Fiener, Peter, et. al. (2014)
28	Climate regulation	NPV	5320	\$/ha/y		5320	Verma et. al. (2014)
29	Climate regulation	NPV	4348	\$/ha/y		4348	Verma et. al. (2014)

(Contd ...Table)

S. No	Sub Service	Valuation method	Reported value	Select ed units	Data period	(\$/ha/yea r-2012 values	Study
30	Climate regulation	NPV	3921	\$/ha/y		3921	Verma et. al. (2014)
31	Climate regulation	NPV	3385	\$/ha/y		3385	Verma et. al. (2014)
32	Climate regulation	Contingent Valuation	3.7	t C/h/y	2007	554.51	Singh, SP (2007)
33	Climate regulation	Benefit Transfer	8.5	\$/ha/y	2000	251.57	Verma, Madhu (2000)
34	Genepool Protection	unspecified	18.5	\$/ha/y	2007	347.43	Singh, SP (2007)
35	Tourism	Recreation exchange value	6.9	\$/ha/y	1993	240.81	Chopra, Kanchan (1993)
36	Tourism	Direct market pricing	1354	INR/ha /y	2001	834.44	Gundimeda et. al.(2006)
37	Tourism	secondary data approximation	0.765	\$/ha/y	1994	24.36	Chopra, Kanchan (1993)
38	Total services	TEV	4428.98201	\$/ha/y		4428.98201	Verma et. al. (2014)
39	Total services	TEV	4954.139242	\$/ha/y		4954.139242	Verma et. al. (2014)
40	Total services	TEV	2776.663741	\$/ha/y		2776.663741	Verma et. al. (2014)
41	Total services	TEV	5544.771098	\$/ha/y		5544.771098	Verma et. al. (2014)
42	Total services	TEV	3964.882258	\$/ha/y		3964.882258	Verma et. al. (2014)
43	Total services	TEV	3664.216762	\$/ha/y		3664.216762	Verma et. al. (2014)
44	Total services	TEV	5640.609917	\$/ha/y		5640.609917	Verma et. al. (2014)
45	Total services	TEV	1610.040954	\$/ha/y		1610.040954	Verma et. al. (2014)
46	Total services	TEV	3279.552435	\$/ha/y		3279.552435	Verma et. al. (2014)
47	Total services	TEV	3042.803861	\$/ha/y		3042.803861	Verma et. al. (2014)

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Appendix 2: Monetary Values of Services Provided by Grasslands

S. n.	Sub Service	Valuation method	Reported value	selected units	Data period	(\$/ha/year-2012 values)	Study
1	Raw material	Market price	280.27	Rs/h/y	1992	333.47	IGFRI, ICAR annual report 1992-93
2	Raw material	Market price	823	Rs/h/y	1990	1227.86	IGFRI, ICAR annual report 1990-91
3	Food	Market price	34	Rs/h/y	1977	142.82	Geevan, et. al. (2003)
4	Climate Regulation	Walkley-Black method	60.03	Mg C/ha/y	2014	7457.00	Venkanna, K., et. al. (2014)
5	Climate Regulation	Walkley-Black method	36.86	Mg C/ha/y	2015	4342.99	Venkanna, K., et. al. (2014)
6	Climate Regulation	Replacement cost method	27.06	Mg C/ha/y	2013	3483.41	Sundarapandian et. al. (2016)
7	Climate Regulation	Unspecified	6.8	Mg C/ha/y	2008	1067.48	Gupta et. al. (2016)
8	Climate Regulation	Unspecified	5.85	T C /ha/y	2008	918.34	Mangalassery et. al. (2014)
9	Climate Regulation	Unspecified	57.32	T C /ha/y	2010	7349.96	Pandya et. al. (2015)
10	Climate Regulation	Unspecified	2.45	kg/m ² /sqr	2014	3043.42	Fiener et. al. (2014)
11	Climate Regulation	Unspecified	1420	g/m ² /sqr/year	1972	5822.65	Ambasht et. al. (1972)
12	Climate Regulation	Unspecified	1330	g/m ² /sqr/year	1972	5453.61	KAR et. al. (2013)
13	Climate Regulation	Replacement cost method	1,131	g/m ² /sqr/year	1974	3411.76	Singh et. al. (1974)
14	Climate Regulation	Replacement cost method	1,377	g/m ² /sqr/year	1972	4904.91	Ramakrishnan et. al.(1988)

(Contd ...Table)

S. n.	Sub Service	Valuation method	Reported value	selected units	Data period	(\$/ha/year-2012 values	Study
15	Climate Regulation	Replacement cost method	497	g/m sqr/year	1973	1797.43	Ramakrishnan et. al.(1988)
16	Climate Regulation	Unspecified	989	g/m sqr/year	1973	3576.78	Jain et. al. (1972)
17	Climate Regulation	Unspecified	1447	g/m sqr/year	1978	3990.36	KAR et. al. (2013)
18	Climate Regulation	Unspecified	809	g/m sqr/year	1994	2055.66	Behera, et. al.(1994)
19	Climate Regulation	Unspecified	929	g/m sqr/year	2006	1660.25	Barik et. al. (2006)
20	Climate Regulation	Production	182.95	g/m sqr/year	1972	750.17	Shrimal et. al. (1975)
21	Climate Regulation	Replacement cost method	65	\$/ha/y	2005	1516.80	Badola et. al. (2010)
22	Climate Regulation	Unspecified	57.3	C t/ha/year	2009	8219.35	Nath et. al. (2009)
23	Tourism	Travel cost method	3.22	\$/ha/y	2005	75.13	Badola et. al. (2010)

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Appendix 3: Monetary Value of Services Provided by Croplands

S. No	Sub-service	valuation method	Reported values	selected units	Data period	(\$/ha/year-2012 values)	Study
1	Food	Direct production	1.36	tons/ha/y (rice)	2007	3051.107771	Ritzema et. al. (2008)
2	Food	Direct production	35.3+1.2	tons/ha/y (sugarcane +rice)	2007	6638.72187	Ritzema et. al. (2008)
3	Food	Direct production	1.4	tons/ha/y(wheat)	2007	4159.689076	Ritzema et. al. (2008)
4	Food	Direct production	2.03+0.4	tons/ha/y (rice+cotton)	2007	4066.758079	Ritzema et. al. (2008)
5	Food	Benefit Transfer	3.53	USD/ha/yr	1969	194.4586806	Chopra, K. (1993)
6	Food	Direct production	1.42	tons/ha/y (rice)	2011	3533.252492	CSSRIA
7	Food	Direct production	1.85	tons/ha/y (wheat)	2011	5449.433522	CSSRIA
8	Food	Direct production	0.78	tons/ha/y (cotton)	2011	5189.072168	CSSRIA
9	Food	Direct production	6.36	tons/ha (Sugar cane)	2009	1642.409581	Tripathi et. al. (2009)
10	Food	Direct production	3107.00	Rs/ha/yr	2013	828.4134529	Qadir et. al. (2014)
11	Food	Direct production	2366.00	Rs/ha/yr	2013	630.9804281	Qadir et. al. (2014)
12	Food	Direct production	4335.00	Rs/ha/yr	2013	1156.086287	Qadir et. al. (2014)
13	Food	Direct production	2982.00	Rs/ha/yr	2013	795.2593561	Qadir et. al. (2014)
14	Climate Regulation	Walkley-Black method	13.17	Mg C/ ha/y	2013	1498.216335	Venkanna et. al. (2014)
15	Climate Regulation	Walkley-Black method	20.51	Mg C/ ha/y	2013	2333.213138	Venkanna et. al. (2014)
16	Climate Regulation	Walkley-Black method	21.69	Mg C/ ha/y	2013	2467.449682	Venkanna et. al. (2014)
17	Climate Regulation	Walkley-Black method	25.62	Mg C/ ha/y	2013	2914.525627	Venkanna et. al. (2014)
18	Climate Regulation	Walkley-Black method	17.49	Mg C/ ha/y	2013	1989.658595	Venkanna et. al. (2014)
19	Climate Regulation	Unspecified	7.77	Mg C/ ha/y	2013	883.9135097	ICAR - IISS, (2015-2016)

(Contd ...Table)

S. No	Sub-service	valuation method	Reported values	selected units	Data period	(\$/ha/year-2012 values)	Study
20	Erosion prevention	replacement cost	50.17	USD/ha/y	1976	2089.226248	Narayana et. al. (1983)
21	Erosion prevention	replacement cost	46.50	USD/ha/r	1970	2581.056726	Singh et. al. (1990)
22	Erosion prevention	replacement cost	26.31	USD/ha/y	2001	773.2979358	Lal, Re (2001)
23	Erosion prevention	Benefit Transfer	19.15	USD/ha/y	1969	1054.92457	Chopra, K. (1993)
24	Erosion prevention	replacement cost	38.24	USD/ha/y	2005	892.2621633	Reddy et. al. (2005)
25	Erosion prevention	replacement cost	21.41	USD/ha/y	1985	547.5312731	Abrol, I. P., et. al. (2012)
26	Erosion prevention	replacement cost	82.59	USD/ha/y	1985	2111.906339	Abrol, I. P., et. al. (2012)
27	Erosion prevention	replacement cost	59.95	USD/ha/y	1990	1607.067389	Reddy (2003)

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