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India

Diagnostic Assessment of Select Environmental Challenges

An Analysis of Physical and Monetary Losses of Environmental Health and Natural Resources

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ABBREVIATIONS AND ACRONYMS

ACS	American Cancer Society
ACU	Adult Cattle Units
ADB	Asian Development Bank
AF	Attributable fraction
ARI	Acute respiratory illness
BAU	Business as usual
BLL	Blood Lead Concentration
BP	Blood pressure
C	Carbon
CB	Chronic Bronchitis
CEA	Country Environmental Analyses
CED	Cost of environmental degradation
CI	Confidence Interval
CO_2	Carbon Dioxide
CO_2-eq	Carbon Dioxide Equivalent
COI	Cost-Of-Illness
COPD	Chronic obstructive pulmonary disease
CPCB	Central Pollution Control Board
CVA	Cardiovascular disease
DALY	Disability Adjusted Life Years
DPL	Development Policy Lending
EC	Electrical conductivity
G	Gram
GBD	Global burden of disease
GDP	Gross Domestic Product
GHG	Greenhouse gases
Ha	Hectare
HCA	Human Capital Approach
HH	Household
IHD	Ischemic heart disease
IQ	Intelligence quotient
IUC	The International Union for Conservation of Nature
Kg	Kilogram
LRI	Lower Respiratory Illness
M	Meter
MMR	Mild Mental Retardation
NFHS-3	National Family Health Survey-3
NPV	Net present value
NSS	National Sample Survey Organization
OR	Odds ratio
ORT	Oral Rehydration Therapy
PM	Particulate Matters
PPP	Purchasing power parity
RAD	Restricted Activity Days
RICE	Regional integrated model of climate and the economy
Rs.	Indian Rupee
SBR	The Sundarbans Biosphere Reserve
SD	Standard Deviation
MT	Metric Tonne
TDM	Total Dry Matter
UNEP	The United Nations Environment Programme
USD	US dollars
VSL	Value of Statistical Life
WCMC	World Conservation Monitoring Centre
WDI	World development indicators
WHO	World Health Organization
WSH	Water supply, sanitation and hygiene
WTP	Willingness to pay

Vice President:	Isabel M. Guerrero
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Sector Director:	John Henry Stein
Sector Manager:	Bernice K.Van Bronkhorst
Task Manager:	Muthukumara S. Mani

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Executive Summary

Coverage

1. This report provides estimates of social and financial costs of environmental damage in India from three pollution damage categories:(i) urban air pollution, including particulate matter and lead, (ii) inadequate water supply, poor sanitation and hygiene, (iii) indoor air pollution; and four natural resource damage categories: (i) agricultural damage from soil salinity, water logging and soil erosion, (ii) rangeland degradation, (iii) deforestation and (iv) natural disasters. The estimates are based on a combination of Indian data from secondary sources and on the transfer of unit costs of pollution from a range of national and international studies (a process known as benefit transfer). Data limitations have prevented estimation of degradation costs at the national level for coastal zones, municipal waste disposal and inadequate industrial and hospital waste management. It is doubtful, however, that costs of degradation and health risks arising from these categories are anywhere close to the costs associated with the categories considered. Furthermore the estimates provided do not account for loss of non-use values (i.e., values people have for natural resources even when they do not use them). These could be important but there is considerable uncertainty about the values[1].

Methodology for Valuation of Environmental Damage

2. The quantification and monetary valuation of environmental damage involves many scientific disciplines including environmental, physical, biological and health sciences, epidemiology, and environmental economics. Environmental economics relies heavily on other fields within economics, such as econometrics, welfare economics, public economics, and project economics. New techniques and methodologies have been developed in recent decades to better understand and quantify preferences and values of individuals and communities in the context of environmental quality, conservation of natural resources, and environmental health risks. The results from these techniques and methodologies can then be, and often are, utilized by policy makers and stakeholders in the process of setting environmental objectives and priorities. And, because preferences and values are expressed in monetary terms, the results provide some guidance for the allocation of public and private resources across diverse sectors in the course of socio-economic development.

3. The terminology used in this report needs some qualification. Environmental damage means physical damages that have an origin in the physical environment. Thus, damages to health from air or water pollution are included as well as damages from deforestation. The term cost means the opportunity cost to society, i.e., what is given up or lost, by taking a course of action. When goods traded in markets are damaged, prices and knowledge of consumer preferences for the damaged goods (embodied in the demand function) and production information (embodied in the supply function) provide the necessary information for computing social costs. Estimating social costs from reduced productivity of agricultural land due to erosion, salinity or other forms of land degradation is a good example. However, many damages from environmental causes are to "goods," such as health, that are not traded in markets. In these cases, economists have devised a

[1] A companion study on the value of ecosystem services in India estimates non-use value of forests at about 5 percent of total ecosystem service values.

number of methods for estimating social costs based on derived preferences from observable or hypothetical behavior and choices.

4. One example is the value of time lost to illness or provision of care for ill family members. If the person who is ill or who is providing care for someone who is ill does not otherwise has a job the financial cost of time losses is zero. However, even in such a case the person is normally engaged in activities that are valuable for the family and time losses reduce the amount of time available for these activities. Thus, there is a social cost of time losses to the family. In an economic costing exercise this is normally valued at the opportunity cost of time, i.e. the salary, or a fraction of the salary that the individual could earn if he or she chose to work for income. In summary, social costs are preferred over financial costs because social costs capture the cost and reduced welfare to society as a whole. All cost are estimated as flow values (annual losses).

5. Unfortunately, information needed to estimate social costs for some categories is often lacking, particularly in developing countries, such as India. In such cases one has the option of relying on financial costs, which generally do not capture all the social costs. In this report, financial costs have been used for a significant part of the analysis, but with social costs being reported wherever these could be obtained or estimated. In general for a country like India these financial costs are likely to underestimate social costs.

Interpretation of Results

6. The methodology of CED estimations is close to the green accounting concept, yet it is not the same. While green accounting takes into account positive and negative changes, CED focuses on a negative side only. This methodology is widely used in the Bank and aims to communicate the current level of the negative impact on environment and natural resources. There is an ongoing effort to create an inclusive system of green accounting for India (Dasgupta, 2011) that is thus methodologically different from this study.

7. Estimates of the costs of degradation are generally reported as a percent of conventional GDP. This provides a useful estimate of the importance of environmental damages but it should not be interpreted as saying that GDP would increase by a given percent if the degradation were to be reduced to zero. Any measures to reduce environmental degradation would have a cost and the additional cost goes up the greater is the reduction that is made. Hence a program to remove all degradation could well result in a lower GDP. The analysis of the 'right' level of reduction is an additional exercise that is not part of this (or indeed any cost of degradation) study. What is provided here is a measure of the overall damage relative to a benchmark, in which all damages related to economic activity are eliminated.

8. The benchmark clearly has a major effect on the estimates produced. The aim in each case is the level of damage that can be attributed to economic activity but this is not always easy to establish and there is always an element of arbitrariness in the value chosen. In the report we give the benchmark value of each category of damages, with whatever justification is available. We also try to be consistent with benchmark values used in similar studies for other countries that have been conducted at the Bank. Table 1.1 summarizes the benchmark values used in the study.

Table 1.1 Benchmark Values Used in the Study

Source of Damage	Benchmark Value	Comment
Health		
Mortality from PM2.5	7.5 ug/m3	Assumed background level in many studies including WHO
Morbidity from PM10	Zero concentration	
Mortality and morbidity from waterborne diseases	Disease rates that prevail in developed countries	WHO methodology uses this benchmark (Fewtrell and Colford, 2004).
Averting expenditures against unsafe water	Zero	No expenditure is necessary if water supply is safe.
Mortality and morbidity from indoor air pollution	Odds Ratio of 1	Implies no additional risk of these impacts as a result of indoor air pollution
Natural resources other than forests		
Soil salinity and waterlogging	Zero salinity/waterlogging	No loss of productivity compared to unaffected areas
Soil erosion	Zero erosion	No soil loss
Rangeland	Zero loss	No loss of productivity compared to unaffected areas
Forest degradation		
Timber	Value of service in non-degraded forest	80-100% loss
Non-timber products		20-100% loss
Eco-tourism		100% loss

Uncertainty

9. The exercise conducted here has a great deal of uncertainty, including that arising from limitations of data on social costs, from methods used to estimate the effects of pollution and resource degradation on indicators of health or output (i.e. the concentration-response functions), and from the transfer of some unit values from studies outside of India. It would be a major task to handle all these uncertainties quantitatively and that has not been possible in this study. In particular, to keep the analysis simple, we do not report all the statistical uncertainties, such as those for concentration-response coefficients, and we rely on central estimates. While some components of the central estimates do use "mean" input parameters and estimates, some inputs into the damage calculations cannot be considered "means" in the statistical sense. For example they may be judgmental estimates based on a mixture of the expected mean or median value. Thus, the reader should interpret these estimates as "midpoint" or "middle" values. At the same time we have attempted to represent the uncertainty for each category of damage by providing a range based on a combination of factors, details of which can be found in the relevant sections.

10. Finally, in making the estimates, we have taken a conservative approach or, put another way, a "defensible borders" approach, where we choose models and data and make assumptions and interpretations that, at least partly, are justified by pointing out that other approaches would yield higher estimates of social costs.

Results

11. The report estimates the total cost of environmental degradation in India at about Rs. 3.75 trillion (US$80 billion) annually, equivalent to 5.7 percent of GDP in 2009, which is the reference year for most of the damage estimates. Of this total, outdoor air pollution accounts for Rs. 1.1 trillion followed by the cost of indoor air pollution at Rs. 0.9 trillion, croplands degradation cost at Rs. 0.7 trillion, inadequate water supply and sanitation cost at around at Rs. 0.5 trillion, pastures degradation cost at Rs. 0.4 trillion, and forest degradation cost at Rs. 0.1 trillion.

12. High and low estimates **for the selected degraded media are presented in table ES1 below.**

Table ES.1: Annual Cost of Environmental Damage – Low and High Estimates (Rs. Billion per year)

	"Low"	**Mid-point Estimate**	"High"	Midpoint Estimate as percent of Total Cost of Environmental Damage
Environmental Categories				
Outdoor air pollution	170	1,100	2,080	29%
Indoor air pollution	305	870	1,425	23%
Crop lands degradation	480	703	910	19%
Water supply, sanitation and hygiene	475	540	610	14%
Pastures degradation	210	405	600	11%
Forest degradation	70	133	196	4%
TOTAL ANNUAL COST (billion R's/yr.)	1,710	3,751	5,821	1
Total as percent of GDP in 2009	2.60%	5.70%	8.80%	

Note: Staff estimates are rounded to the nearest ten.

I. Cost of Environmental Degradation

1. This section provides a summary of estimated social and financial costs of environmental damage. A discussion of each environmental category is provided in the following sections.

2. Environmental pollution, degradation of natural resources, natural disasters and inadequate environmental services, such as improved water supply and sanitation, impose costs to society in the form of ill health, lost income, and increased poverty and vulnerability. This section provides overall estimates of social and economic costs of such damages, referring, as much as possible, to damages for 2009. In some cases, however, the figures may be based on damages in an earlier year if that was the latest information available (see later sections for details).

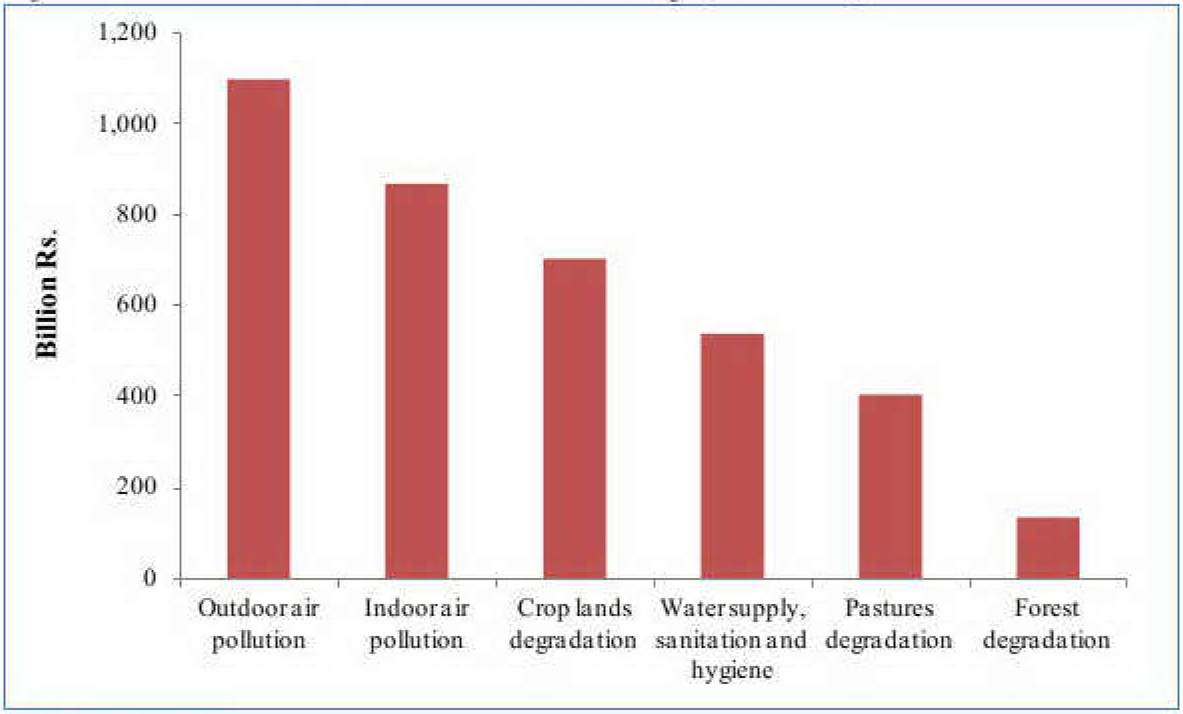
3. Of all the categories of degradation listed above, natural disasters are questionable because they are not the result of anthropogenic factors, although such factors can exacerbate the impacts of natural disaster. For this reason we do not include them in the main set of estimates. Since the damages arising from natural disasters are of interest to policy makers, and some CED studies do include them, we have reported these damages separately in Annex III.

4. The results are summarized in Figures 2.1 and 2.2 and in Table 2.1. Total damages amount to about Rs. 3.75 trillion (US$80 billion) equivalent to 5.7 percent of GDP. Of this total, outdoor air pollution accounts for the highest share at 1.7 percent (Figure 2.1) followed by cost of indoor air pollution at 1.3 percent, croplands degradation cost at just over one percent, inadequate water supply, sanitation and hygiene cost at around at 0.8 percent, pastures degradation cost at 0.6 percent, and forest degradation cost at 0.2 percent. The individual damages are shown as shares of the total in Figure 2.2. Outdoor air pollution accounts for 29 percent, followed by indoor air pollution (23 percent), cropland degradation (19 percent), water supply and sanitation (14%), pasture (11%), and forest degradation (about 4% each).

5. In addition India has experienced some damages from natural disasters (floods, landslides, tropical cyclones, and storms). These are not included in the above figures for the reasons given. Over the period 1953-2009 damages from natural disasters were estimated at Rs. 150 billion a year on average (in constant 2009 prices) and took the form of loss of life and injury, losses to livestock and crops and losses to property and infrastructure. Details are given in Annex III**2**.

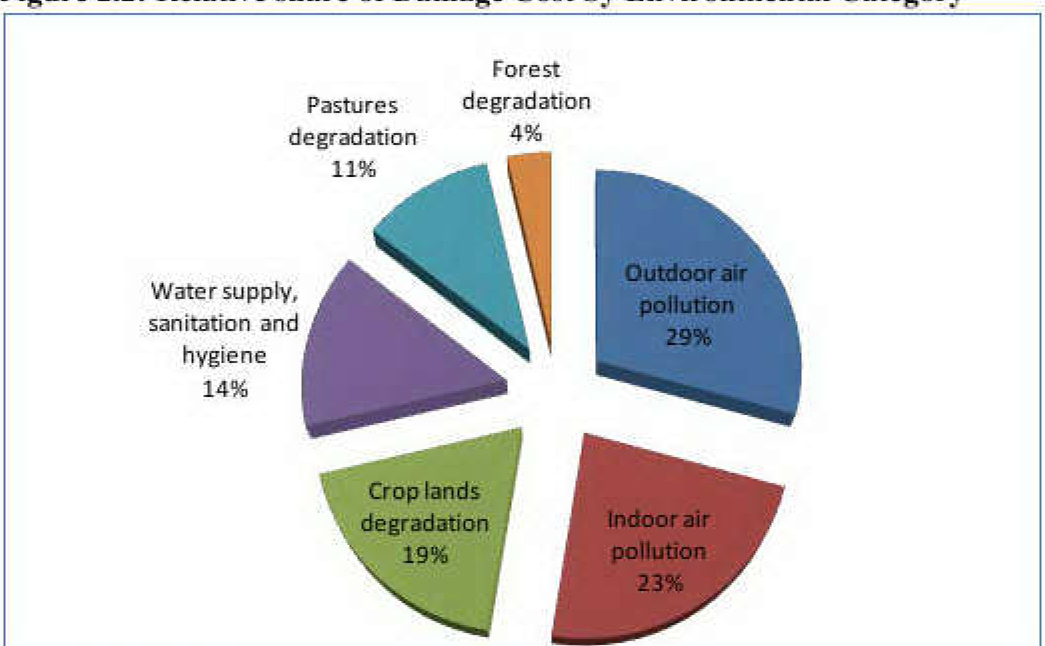
[2] We look at damages over a relatively long period because annual figures are highly variable.

Figure 2.1: Annual Cost of Environmental Damage (Billion Rs.)



Source: Staff estimates.

Figure 2.2: Relative share of Damage Cost by Environmental Category



Source: Staff estimates.

6. In addition to the mid-point values, "low" and "high" estimates of annual costs are presented in Table 2.1. The "low" and "high" range estimates differ considerably across the

categories because of the uncertainties related to economic valuation procedure or uncertainties about exposure to specific hazards. The urban air pollution estimate range is mainly affected by the social cost of mortality which is derived by applying two different valuation techniques (Section III.1). The range for indoor air pollution arises mainly from the uncertainty of exposure level to indoor smoke and from the use of fuel wood (Section V). In the case of agricultural soil degradation, the range is associated with uncertainty of yield losses from salinity (Section VI.1). The range for water supply, sanitation and hygiene is in large part associated with uncertainties regarding estimates of diarrheal child mortality and morbidity (Section IV). The range for deforestation is associated with the uncertainty of the use benefits of forest (Section VII.3) If we take the lower bound of the estimates, the figures are about 45 percent of the mean values (or 2.6 percent of GDP), while if we take the upper bound they are 64 percent higher than the mean (or about 8.9 percent of GDP)3.

Table 2.1: Annual Cost of Environmental Damage – Low and High Estimates (Rs. Billion per year)

	"Low"	**Mid-point Estimate**	"High"	Midpoint Estimate as percent of Total Cost of Environmental Damage
Environmental Categories				
Outdoor air pollution	170	**1,100**	2,080	29%
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Forest degradation	70	**133**	196	4%
TOTAL ANNUAL COST (billion R's/yr.)	1,710	**3,751**	5,821	1
Total as percent of GDP in 2009	2.60%	**5.70%**	8.84%	

Note: Staff estimates are rounded to the nearest ten.

Health Related Damages among selected populations in India

7. The damages associated with environmental health are estimated for different groups of the population. This mainly reflects differences in terms of who is affected by the

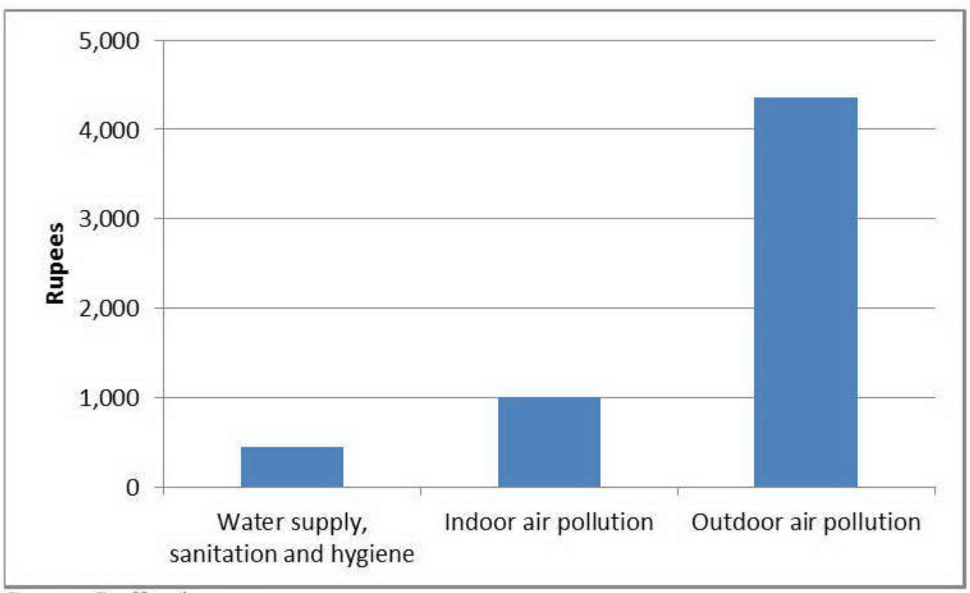
[3] Adding up of lower or higher bounds reflects only differences in calculation, and not actual changes in losses, associated with environmental degradation . A midpoint estimate presents an average of low and high estimates, the range is related to both uncertainties of valuation method and uncertainties of exposure to specific hazards.

different pollutants but also the availability of data. The outdoor air pollution losses were estimated for the inhabitants of cities with a population of over 100 thousand (due to data limitations); inadequate water supply, sanitation and hygiene costs were estimated for the whole population of India; and indoor air pollution costs were estimated for the households that use solid fuel for cooking (about 75 percent of all households). These differences in coverage should be borne in mind when comparing across the different environmental burdens. In particular coverage for outdoor air pollution is less complete than the others and thus the figures for that category are underestimated.

8. The higher costs for outdoor/indoor air pollution are primarily driven by an elevated exposure of the urban and rural population to particulate matter pollution that results in a substantial cardiopulmonary and COPD mortality load among adults. As noted the rural population has only been assessed for indoor air pollution.

9. Figure 2.3 gives estimates of damage per person within the different exposed populations used to construct the figures in Table 2.1. We note that a significant part of the health burden, especially from water supply, sanitation and hygiene is borne by children under 5 (Figure 2.4). These figures would suggest that about 23 percent of under-5 mortality can be associated with indoor air pollution and inadequate water supply, sanitation and hygiene, and 2 percent of adult mortality with outdoor air pollution.

Figure 2.3: Annual Environmental Health Losses per Person of the Exposed Population



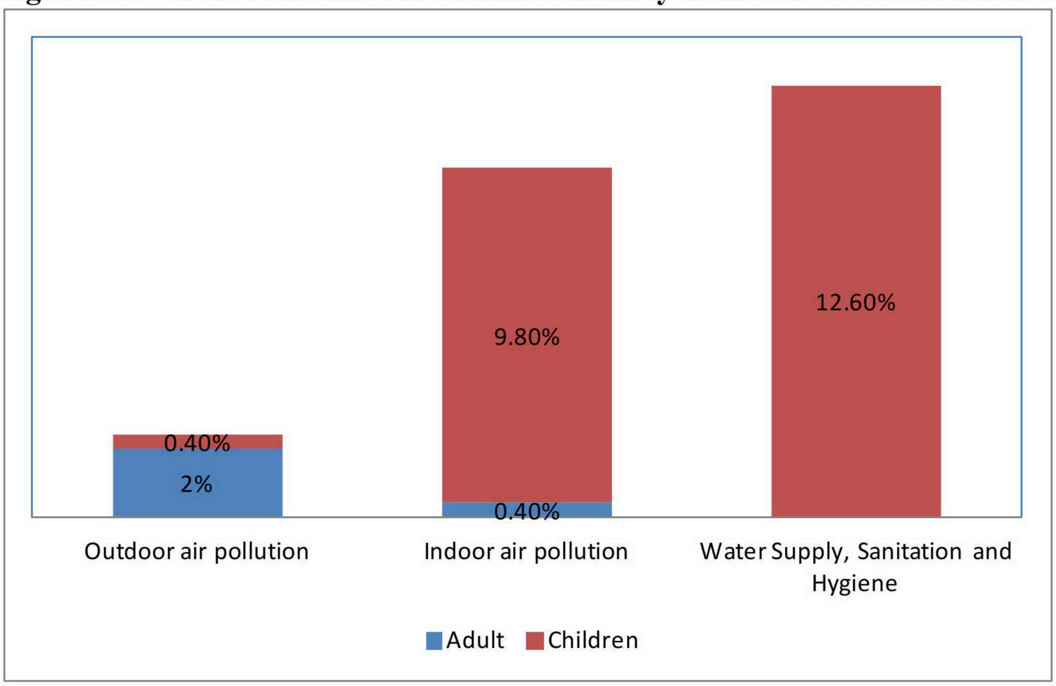
Source: Staff estimates.

Environmental Damages and the Poor

10. While this report does not address the impacts of the losses estimated above on poor households (that is something that should be undertaken as a separate study) one can comment on how the poor are affected by the environmental damages. First the losses related to water and sanitation and hygiene are likely to be concentrated among the poor

who most often do not have access to piped water or sanitation. Second the rural population is more affected by the water and indoor air pollution-related damages than the urban population. For the urban population the distribution of impacts by income class is less certain. Some studies indicate that urban ambient air quality does affect the poor more than the rich (Garg, 2011) but the present study has not been able to confirm this point. In overall terms, however, it is very likely the case that the poorer urban population suffers more both from urban air pollution and inadequate water supply, sanitation and hygiene and in general it is the poor who are included in all major cost categories (those who live in big cities and use solid fuel for cooking).

Figure 2.4: Estimated Share of Annual Mortality from Different Sources in India



Source: Staff estimates.

Other Categories of Damages

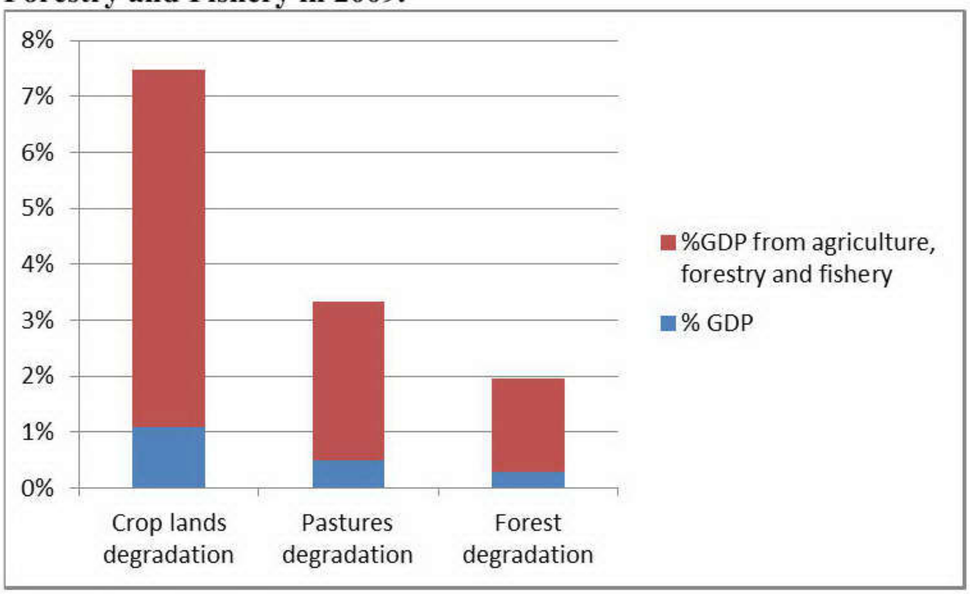
11. Cropland damages arise from the decline the value of crops due to soil erosion, water logging, salinity and overgrazing. We derive a range of estimates due to uncertainty of crop and pasture profitability as well as the uncertainty of the level of degradation.

12. Forest degradation has arisen in India from unsustainable logging practices in some regions, and general over-exploitation of forest resources. Although the country has gained about 7 percent in overall forest cover between 1990 and 2010 there has also been a notable degradation in some forests. It is this that results in losses of ecosystem services including carbon sequestration, provision of timber and non-timber forest products, recreational and cultural use of forests and prevention of soil erosion. The losses are valued using a range of techniques, which are subject to considerable uncertainty arising from the estimates of forest productivity and methods of obtaining values for the non-marketed services.

13. Finally impacts of changes in fisheries were examined but it was not possible to value these in monetary terms due to gaps in the data.

14. Another way of looking at the role of environmental resources is in terms of the "GDP of the poor"**4**. Natural resources degradation is more significant when compared with their income. One measure of the growth potential for the poor is in the share of GDP generated in agriculture, forestry and fishery, which made up about 17 percent of GDP in 2010. To be sure not all the GDP in these sectors goes to the poor but a more significant part of it does than for some other sectors. Figure 2.5 summarizes potential impact of natural resource degradation losses on the GDP and GDP of the poor (i.e. GDP in agriculture, forestry and fishery). In total these losses are amount to about 2 percent of GDP and 11 percent "GDP of the poor" (GDP in Agriculture, Fishery and Forestry) in India. It should be noted that while this being an interesting concept, this could also be underestimation of impact of environmental damage suffered by the poor as much of the health damage from pollution in urban areas is also predominantly borne by the urban poor.

Figure 2.5: Natural Resource Losses Compared to GDP and GDP in Agriculture, Forestry and Fishery in 2009.



Source: Staff estimates.

Comparison with other Countries

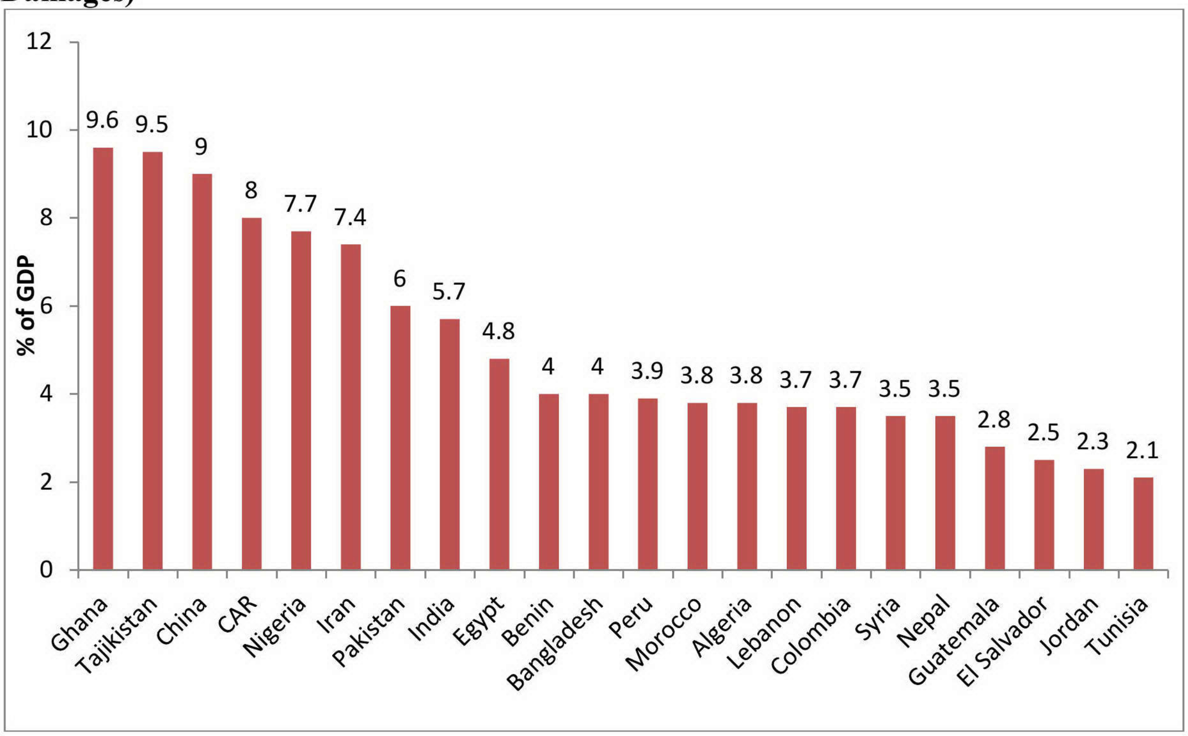
15. The cost of environmental degradation in India is roughly comparable with other countries with similar income level (Figure 2.6). Studies of the cost of environmental degradation were conducted using a similar methodology in Pakistan, a low income country, and several low and lower-middle income countries in Asia, Africa and Latin America. They show that monetary value of increased morbidity, mortality and natural

[4] Gundimeda & Sukhdev (2008) introduced a concept GDP of the poor that includes GDP only from agriculture, forestry and fishery, since these sectors reflect growth potential for most of the rural, predominantly poor Indian making up 72 percent of the total. The importance of these sectors for the poor is also discussed in World Bank (2006).

resources degradation typically amounts to 4 to 10 per cent of GDP, compared to 7 percent of GDP in India5.

16. The situation also looks consistent across different countries if one compares only the health cost of outdoor air pollution (Figure 2.7). In all the selected countries these vary between 1.1 to 2.5 percent of GDP. In India the health cost of outdoor air pollution is estimated at about 1.7 percent of GDP. The high cost of outdoor air pollution-related mortality in urban areas is the main driver of environmental health costs.

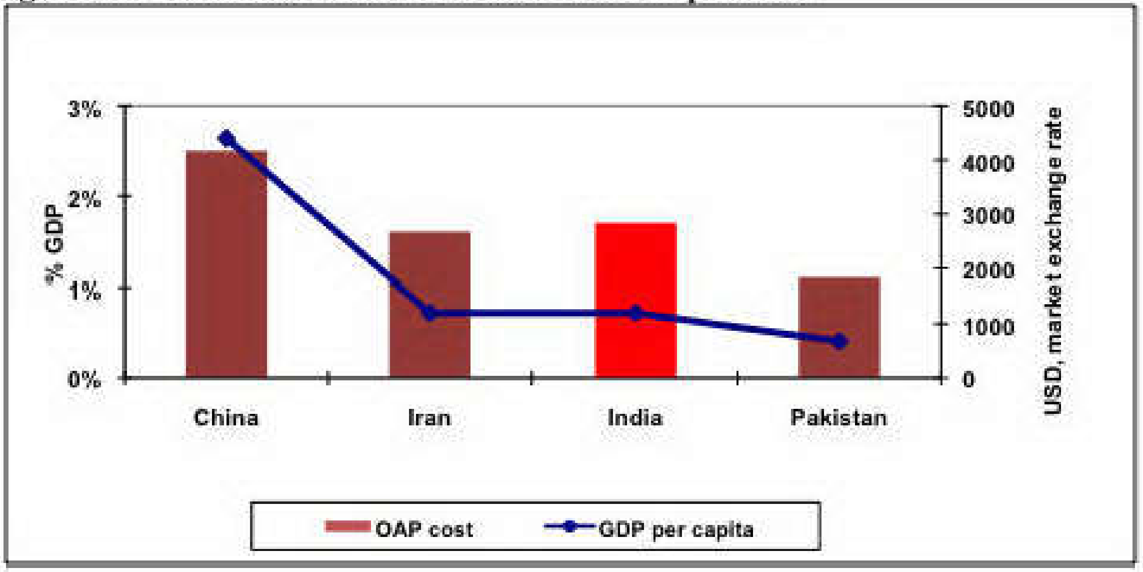
Figure 2.6: Cost of Environmental Degradation (Health and Natural Resources Damages)



Source: Bank (2012): Green Growth: Path to Sustainable Development.

[5] The environmental media included in the analysis include outdoor/indoor air pollution, inadequate water supply, sanitation and hygiene and natural resource degradation (soils salinity/erosion, pastures degradation, deforestation and forest degradation, fishery loss). Losses from natural disasters were included in CED study in Peru and in Iran.

Figure 2.7: Health Cost Attributed to Outdoor Air pollution



Source: Islamic Republic Of Iran: Cost Assessment Of Environmental Degradation, World Bank, 2005; Ghana Country Environmental Analysis, World Bank, 2006; Pakistan: Country Strategic Environmental Assessment, World Bank, Volume II, 2007; World Bank, 2007. Cost Of Pollution In China. Economic Estimates Of Physical Damages World Bank.

17. A World Bank study on China (2007), later cited in China 2030 (World Bank, 2012), applied a methodology for outdoor air pollution valuation similar to the one utilized in this report.

II. Urban Air Pollution

Particulate Matter

18. There is substantial research evidence from around the world that outdoor urban air pollution has significant negative impacts on public health and results in premature deaths, chronic bronchitis, and respiratory disorders. A comprehensive review of such studies is provided in Ostro (1994), Ostro et al. (2004). The air pollutant that has shown the strongest association with these health endpoints is particulate matter and other secondary particles with similar characteristics of less than 10 microns in diameter (PM10)6. Research in the United States in the 1990s and most recently by Pope et al (2002) provides strong evidence that it is particulates of less than 2.5 microns (PM2.5) that have the largest health effects. Other gaseous pollutants (SO2, NOx, CO, and ozone) are generally not thought to be as damaging as fine particulates. However, SO2 and NOx may have important health consequences because they can react with other substances in the atmosphere to form secondary particulates. In particular, the evidence implicates sulfates formed from SO2, but is much less certain about nitrates, formed from NOx.

19. The focus of this report therefore is the health effects of all fine particulates (PM10 and PM2.5) since they are regarded as criteria pollutants and include components of other pollutants. They are an important cause of cardiovascular and pulmonary disease, and lung cancer in the population. This requires data on who is exposed, the health impacts of that exposure and the value attached to those impacts.

20. Given data limitations we can only estimate impacts for the urban populations and in fact only for a part of that population. Only major cities have TSP and PM10 monitoring data. In this study we focus on cities with a population of 100,000 and above only. Since the baseline population is from the 2001 census there are many cities that have achieved a population of 100,000 since 2001 and have not been included in the study. This can be updated in the future. .

21. Pollution data for all cities, where available, was taken from the Central Pollution Control Board's (CPCB) Environmental Data Bank website for the year 2008. Health damage estimates for PM10 were calculated based on observations for the year 2008. The study included 96 cities with monitoring stations and 223 cities with no monitoring stations (254 million people in total). The population for 96 cities with monitoring stations amounts to 186 million, or about 16% of the country's population. These are given in Annex I (Table A1) which also provides details on estimation of exposed urban population and annual average PM10 levels used in the report. In addition there are about 225 cities with an average population of 69 million for which there are no data on PM concentrations. Since excluding them from the estimation of health impacts would be a serious omission, annual average PM10 levels were assigned to these cities based on scaling up of the World Bank modeling PM10 concentrations (taken from the World Bank Internal Research Database), using an average factor for the major cities. Annex I lists the additional cities included and the estimated concentrations.

[6] Also called total suspended particulates or TSP.

22. The age distribution of the urban population was estimated using urban population parameters from the 2001 India Census. PM10 were transformed into PM2.5 to obtain values for the latter using a ratio of 0.5 based on evidence from India (CPCB, 2011). This ratio reflects the mean of the PM2.5/PM10 ratio for large Indian cities reported in this paper

23. Based on the current status of worldwide research, the risk ratios, or concentration-response coefficients from Pope et al (2002) were considered likely to be the best available evidence of the mortality effects of ambient particulate pollution (PM 2.5).

24. Damages due to anthropogenic factors are measured from a ba**seline PM2.5** concentration, which we set equal to 7.5 ug/m3 (as in WHO (2002). This is considered to be the level one would find in the natural environment. A log-linear function for estimating cardiopulmonary mortality associated with outdoor air pollution was applied. The methodology is described in Annex I.

25. The morbidity effects assessed in most worldwide studies are based on PM10. Concentration-response coefficients from Ostro (1994, 1998) and Abbey et al (1995) have been applied to estimate these effects. Ostro (1994) reviews worldwide studies and based on that Ostro (1998) estimates concentration-response coefficient for restricted activity days, and Abbey et al (1995) provides estimates of chronic bronchitis associated with particulates (PM10). A linear function for estimating morbidity end-points associated with outdoor air pollution was applied. The methodology is described in Annex I.

26. The mortality and morbidity coefficients are presented in Table 3.1 based on these estimates. Further details on the application of the concentration-response coefficients are given in Annex I.

Table 3.1 Urban Air Pollution Concentration-Response Coefficients

Annual Health Effect	Concentration-response Coefficient	Per 1 ug/m^3 annual average ambient concentration of:
Long term mortality (% change in cardiopulmonary and lung cancer mortality)	0.8% *	PM 2.5
Acute mortality children under five (% change in ARI deaths)	0.166%	PM10
Chronic bronchitis (% change in annual incidence)	0.9%	PM10
Respiratory hospital admissions (per 100,000 population)	1.2	PM10
Emergency room visits (per 100,000 population)	24	PM10
Restricted activity days (% change in annual incidence)	0.475%	PM10
Lower respiratory illness in children (per 100,000 children)	169	PM10
Respiratory symptoms (per 100,000 adults)	18,300	PM10

*Mid-range coefficient from Pope et al (2002) reflecting a linear function of relative risk. In the analysis however, we used a log-linear

Source: Pope et al (2002), Ostro (2004) for the mortality coefficients. Ostro (1994, 1998) and Abbey et al (1995) for the morbidity coefficients.

27. The health effects of air pollution can be converted to disability adjusted life years (DALYs) to facilitate a comparison with health effects from other environmental risk

factors. DALYs per 10 thousand cases of various health end-points are presented in Table 3.1. Further details of how they were arrived at are given in Annex I.

Table 3.2: DALYs for Different Health Endpoints

Health Effect	DALYs lost per 10,000 cases
Mortality adults	75,000
Mortality children under 5	340,000
Chronic Bronchitis (adults)	22,000
Respiratory hospital admissions	160
Emergency Room visits	45
Restricted activity days (adults)	3
Lower respiratory illness in children	65
Respiratory symptoms (adults)	0.75

Note: DALYs are calculated using a discount rate of 3% and full age weighting based on WHO tables.

28. Urban air particulate pollution is estimated to cause around 109,000 premature deaths among adults and 7,500 deaths among children under 5 annually. Adult mortality estimated above is consistent with Cropper et al's (2012) estimate of the annual mortality associated with coal electricity generation in India (about 60,000 people calculated as about 650 deaths per year with 92 coal burning power plants in India). Electricity generation is responsible for a fraction of PM pollution analyzed in this report7. Estimated new cases of chronic bronchitis are about 48,000 per year. Annual hospitalizations due to pollution are estimated at close to 370 thousand and emergency room visits/outpatient hospitalizations at 7,300 thousand per year. Cases of less severe health impacts are also presented in the Table. In terms of annual DALYs lost mortality accounts for an estimated 60 percent, chronic bronchitis around 5 percent, restricted activity days (RADs) for 7 percent, and respiratory symptoms for 25 percent.

. **Table 3.3: Estimated Health Impact of Urban Air Pollution**

Health end-points	Total Cases	Total DALYs
Premature mortality adults	109,340	820,049
Mortality children under 5	7,513	255,431
Chronic bronchitis	48,483	106,663
Hospital admissions	372,331	5,957
Emergency room visits/Outpatient hospital visits	7,303,897	32,868
Restricted activity days	1,231,020,030	369,306
Lower respiratory illness in children	16,255,360	105,660
Respiratory symptoms	3,917,855,052	293,839
TOTAL		1,989,773

Source: Staff estimates.

29. The estimated annual cost of urban air pollution health effects is presented in Table 3.4. The cost of mortality is based on the human capital approach (HCA) as a lower bound and the value of statistical life (VSL) as an upper bound for adults and HCA for children.

[7] Cropper et al (2012) analyses direct emissions from coal burning power plants and applied annual average intake PM2.5 fractions. Ambient concentrations of PM2.5 are analyzed in this report.

Both methods are discussed further in Section VI. Details of the valuation of mortality and morbidity end points are given in Annex I.

30. The cost-of-illness (COI) approach (mainly medical cost and value of time losses) was applied to obtain an estimate of the morbidity cost (see cost of morbidity in Table 3.4).

31. To summarize, the mean estimated annual cost of PM urban air pollution totals 1,103 billion Rs. or 1.7 percent of GDP in 2009. About 93 percent of the cost is associated with mortality, and 7 percent with morbidity (Table 3.4). Measured in terms of Disability Adjusted Life Years (DALYs)1 about 54 percent of the cost is associated with mortality and 46 percent with morbidity (Table 3.3). All damages are measured from a baseline concentration of PM2.5 of 7.5 ug/m3 and zero threshold of PM10. More details of the methodology of the analysis are presented in Annex I.

Table 3.4: Estimated Annual Cost of Health Impacts (Billion Rs.)

Health categories	**Total Annual Cost***	**Percent of Total Cost* (Mean)**
Mortality		
Adults	1,018	92.2%
Children under 5	13	1.2%
Morbidity:		
Chronic bronchitis	1	0.1%
Hospital admissions	3	0.3%
Emergency room visits/Outpatient hospital visits	8	0.7%
Restricted activity days (adults)	46	4.2%
Lower respiratory illness in children	14	1.3%
Total cost of Morbidity	72	6.6%
TOTAL COST (Mortality and Morbidity)	1,103	100 %

* Percentages are rounded to nearest percent.
Source: Staff estimates.

[8] The sum of years of potential life lost due to premature mortality and the years of productive life lost due to disability (www.who.int).

III. Water Supply, Sanitation and Hygiene

32. The main health impacts of unclean water and poor hygiene are diarrheal diseases, typhoid and paratyphoid. In addition there are costs in the form of averting expenditures to reduce health risk. Diarrheal and related illness contributes the dominating share of the health cost. We consider these in turn.

Diarrheal Diseases, Typhoid and Paratyphoid

33. Based on an extended meta-analysis of peer reviewed publications, WHO has proposed a rigorous methodology9 that links the access to improved water supply, safe sanitation, and hygiene to diarrheal illnesses (mortality and morbidity of children under 5) and other population morbidity. About 88 % of diarrheal cases globally are attributed to water, sanitation and hygiene (Pruss-Ustun et al, 2004). This is a conservative approach where malnutrition impact on early childhood diseases is omitted. If considered, this additional indirect impact would approximately double the mortality attributed to water supply, sanitation and hygiene (WSH) (World Bank, 2010). However, a major part of these losses are in the form of acute respiratory mortality that was accounted for in the indoor air pollution section. To avoid double counting and be on a conservative side we considered only direct impact of inadequate water supply, sanitation and hygiene (WSH).

34. Mortality for children under 5 and diarrheal-based child mortality are high in India. Baseline health data for estimating the health impacts of inadequate water supply, sanitation and hygiene are presented in Table 4.1. The Office of the Registrar General (2004) indicates that 14 percent of child mortality was due to intestinal diseases. A baseline diarrheal mortality rate of 14 percent of under-5 child mortality is thus used for diarrheal mortality estimation.

35. For diarrheal morbidity, however, it is very difficult or practically impossible to identify all cases of diarrhea. The main reason is that substantial numbers of cases are not treated or do not require treatment at health facilities, and are therefore never recorded. A second reason is that cases treated by private doctors or clinics are often not reported to public health authorities. Household surveys therefore provide the most reliable indicator of total cases of diarrheal illness. Most household surveys, however, contain only information on diarrheal illness in children. Moreover, the surveys only reflect diarrheal prevalence at the time of the survey. As there is often high variation in diarrheal prevalence across seasons of the year, extrapolation to an annual average will result in either an over- or underestimate of total annual cases. Correcting this bias is often difficult without knowledge of seasonal variations.

36. In spite of all these difficulties a reasonable estimate has been made of the number of cases and prevalence of diarrhea in the population, along with the number of DALYs per 100,000 cases of diarrhea. Details are given in Annex I, with the figures summarized in Table 4.1.

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[9] Fewtrell, L. and J. Colford Jr. (2004).

Table 4.1: Baseline Data for Estimating Health Impacts

	Baseline	Source:
Under-5 child mortality rate in 2006	52-82	NFHS-3
Diarrheal mortality in children under 5 years (% of child mortality)	14 %	Office of Registrar General (2004)
Diarrheal 2-week Prevalence in Children under 5 years	8.9-9%	NFHS-3
Estimated annual diarrheal cases per child under 5 years	1.85-1.87	Estimated from NFHS-3
Estimated annual diarrheal cases per person (> 5 years)	0.37-0.56	International experience (Krupnick et al, 2006)
Hospitalization rate (% of all diarrheal cases) –children under 5 years	0.15%	NSS (2004)
Hospitalization rate (% of all diarrheal cases) –children under 5 years	0.3-0.6 %	
Percent of diarrheal cases attributable to inadequate water supply, sanitation and hygiene	90 %	WHO (2002b)
DALYs per 100 thousand cases of diarrhea in children under 5	70	Estimated from WHO tables
DALYs per 100 thousand cases of diarrhea in persons >5 years	100-130	
DALYs per 100 thousand cases of typhoid in persons under 5 and over 5	190-820	
DALYs per case of diarrheal and typhoid mortality in children over 5 and under 5	32-34	

37. Table 4.2 presents the estimated health impacts from inadequate water, sanitation and hygiene, based on the parameters given in Table 4.1, including the assumption (from WHO) that 88 percent of diarrheal illness is attributable to water, sanitation and hygiene. The table also provides estimates of DALYs lost to waterborne diseases. About 60 percent of the DALYs are from diarrheal child mortality. Typhoid/paratyphoid deaths add another 20 percent of DALY.

Table 4.2: Estimated Annual Health Impacts from Water, Sanitation, Hygiene

	Cases		Estimated Annual DALYS		% of Total DALYS
	Urban	Rural	Urban	Rural	
Children (under the age of 5 years) – increased mortality (Thousand)	41	198	1,384	6,714	87-93
Children (under the age of 5 years) – increased morbidity (Thousand)	57,831	178,898	20	63	1
Population over 5 years of age – increased morbidity (Thousand)	149,836	344,183	177	406	11-6
Typhoid/paratyphoid mortality (Thousand)	0.57		19		0
Typhoid/paratyphoid morbidity (Thousand)	1,150		8		0

Source: Staff estimates.

38. The estimated costs associated with the impacts identified above are given in Table 4.3. Details of the baseline cost data are given in Annex I. The hypothetical value from which the estimates are based relies on the WHO methodology which uses conditions in

developed countries as the benchmark. The incidence rates for these illnesses are close to zero in those countries (0.3 per person/year as in Fewtrell and Colford, 2004). Further details are given in Annex I.

39. The total cost is Rs. 490 billion. The cost of mortality is based on the human capital approach (HCA) for children under 5 see Annex I.5). The cost of morbidity includes the cost of illness (medical treatment, medicines, and value of lost time) and value of lost DALYs estimated at GDP per capita. We used GDP per capita as a proxy for WTP for one additional year of life, expressed in DALYs.

Table 4.3: Estimated Health Impacts from Inadequate Water, Sanitation, Hygiene

	Estimated Annual Cost Rs. Bn.		
	Urban	**Rural**	**Total**
Mortality			
Children under age 5 diarrheal mortality	50	227	277
Children under age 5 typhoid			0.3
Persons over 5 typhoid			0.5
Morbidity			
Diarrheal morbidity	105	103	208
Typhoid morbidity[10]			3.3
TOTAL ANNUAL COST	155	330	489.1

Source: Staff estimates.

Averting Expenditures

40. In the presence of perceived health risks, individuals often take measures to avoid these risks. These are usually considered as a cost of the health risks of environmental burdens. If consumers perceive that the municipal water supply or the other sources of water supply they rely on are unsafe, they are likely to purchase bottled water for drinking purposes, or boil their water, or install water purification filters. The estimated costs of these options are given in Table 4.4, with details on the estimated unit costs available in Annex I. The assumed hypothetical level of expenditure here is zero (i.e. no avertive expenses would be incurred if the water supplied was safe). The total amount of avertive expenditures for India amount to about Rs. 55 Bn. a year.

Table 4.4: Estimated Total Annual Household Cost of Averting Expenditures

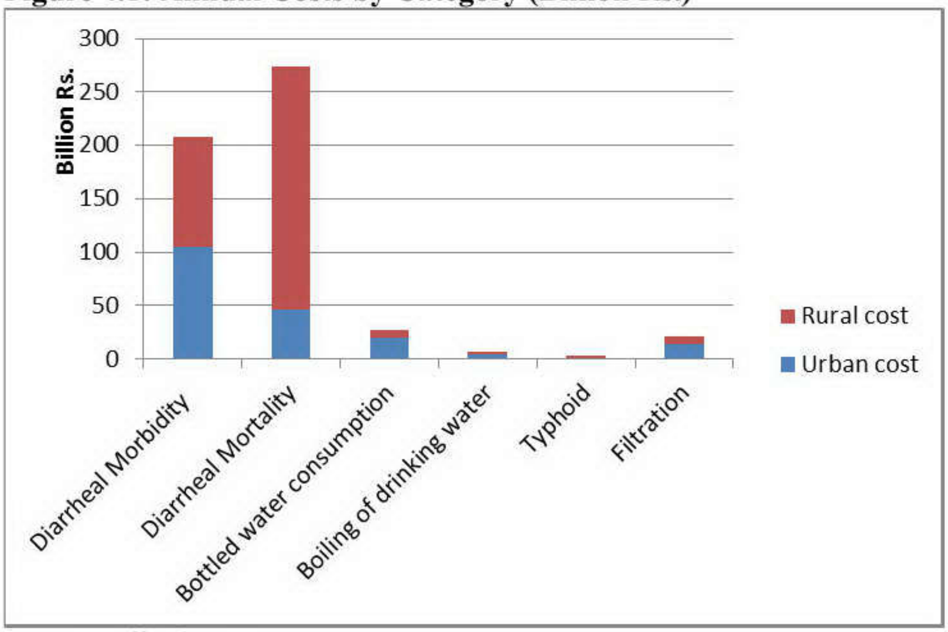
	Total Annual Cost (Billion Rs.)	
	Urban	**Rural**
Cost of bottled water consumption	20	7
Cost of household boiling drinking water	4	3
Cost of household filtering drinking water	14	7
Total annual cost	38	17

Source: Staff estimates.

[10] About 25 percent of estimated COI is from hospitalization and doctor visits, 70 percent is from time losses for the ill individuals and their caregivers during illness

41. In summary the estimated annual cost associated with inadequate water supply, sanitation and hygiene is presented in Figure 4.1, totaling 470-610 billion Rs. per year, with a mean of 540 billion Rs. The cost of health impacts represents an estimated 90 percent of total mean cost, with averting expenditures accounting for about 10 percent. Health impacts include both mortality and morbidity, and averting expenditures include bottled water consumption, and household boiling of drinking water. Annual costs by major category are presented on Figure 4.1.

Figure 4.1: Annual Costs by Category (Billion Rs.)



Source: Staff estimates.

IV. Indoor Air Pollution

42. WHO (2002b) estimates that 1.6 million people die each year globally due to indoor smoke from the use of traditional fuels in the home. The most common is incomplete combustion of fuels such as wood, agricultural residues, animal dung, charcoal, and, in some countries coal. The strongest links between indoor smoke and health are for lower respiratory infections, chronic obstructive pulmonary disease (COPD), and for cancer of the respiratory system. Indoor smoke is estimated to cause about 37.5 percent, 22 percent, and 1.5 percent of these illnesses globally (WHO 2002b).

43. According to FSI (2011), firewood constitutes the major source of cooking energy in India and more than 853 million people use firewood for cooking in India. As per the 2011 census, 49 per cent of the households in the country use firewood for cooking. In some states, it is as high as 80 per cent. The forest rich states have higher incidence of firewood use for cooking. Our study conforms to FSI findings.

44. There are two main steps in quantifying the health effects. First, the number of people or households exposed to pollution from solid fuels needs to be calculated, and the extent of pollution, or concentration, measured. Second, the health impacts from this exposure should be estimated based on epidemiological assessments. Once the health impacts are quantified, the value of this damage can be estimated.11

45. The odds ratios in Table 5.1 have been applied to young children under the age of five years (for ARI) and adult females (for ARI and COPD) to estimate the increase in mortality and morbidity associated with indoor air pollution.12 It is these population groups who suffer the most from indoor air pollution. This is because women spend much more of their time at home, and/or more time while cooking (with little children at their side), than in comparison with older children and adult males, who spend more time outdoors.

Table 5.1: Health Risks of Indoor Air Pollution

	Odds Ratios (OR)	
	"Low"	"High"
Acute Respiratory Illness (ARI)	1.9	2.7
Chronic obstructive pulmonary disease (COPD)	2.3	4.8

Source: Desai et al (2004).

[11] Currently, there is no standard technique/SOP available to measure indoor air pollution in India. The Central Pollution Control Board (CPCB) is association with Indian Institute of Technology; Delhi is developing SOP on indoor air pollution in India. Once the more rigorous and replicable methodology is available more certain estimates could be hopefully prepared in the future and used to inform decisions.

[12] Although Desai et al (2004) present odds ratios for lung cancer, this effect of pollution is not estimated in this report. This is because the incidence of lung cancer among rural women is generally very low. The number of cases in rural India associated with indoor air pollution is therefore likely to be minimal.

46. The NFHS-3 reports that 90 percent of rural and 32 percent of urban households use solid fuels for cooking in India. The national weighted average is about 71 percent.

47. To estimate the health effects of indoor air pollution from the odds ratios in Table 5.1, baseline data for ARI and COPD need to be established. These data are presented in Table 5.2, along with unit figures for disability adjusted life years (DALYs) lost to illness and mortality. The hypothetical level against which damages are calculates is a situation in which there is no exposure to indoor air pollution and the odds ratio is one. Some further details relating to the data are given in Annex I.

Table 5.2: Baseline Data for Estimating Health Impacts

	Baseline		**Source:**
	Urban	Rural	
Female COPD mortality rate (% of total female deaths)	9.5%		WHO estimate for India, Shibuya et al (2001)
Female COPD incidence rate (per 100 thousand)	79		
ARI 2-week Prevalence in Children under 5 years	22%	22%	NFHS-3, 2006
Estimated annual cases of ARI per child under 5 years	1.0	1.0	Estimated from NFHS-3, 2006
Estimated annual cases of ARI per adult female (> 30 years)	0.4	0.5	Estimated from a combination of NFHS-3, 2006 and Krupnick et al, 2006
ARI mortality in children under 5 years (% of child mortality)	22%		Office of Registrar General (2004)
DALYs per 100 thousand cases of ARI in children under 5	165	165	
DALYs per 100 thousand cases of ARI in female adults (>30)	700	700	Estimated from WHO tables
DALYs per case of ARI mortality in children under 5	34	34	
DALYs per case of COPD morbidity in adult females	2.25	2.25	
DALYs per case of COPD mortality in adult females	6	6	

For details see Annex I.

48. The results of the estimation of health losses associated with indoor air pollution are presented in Table 5.3. Estimated cases of ARI child mortality and ARI morbidity (children and female adults) from indoor air pollution represent about 38-53 percent of total ARI in India. Similarly, the estimated cases of COPD mortality and morbidity represent about 46-72 percent of total estimated female COPD from all causes.

49. Table 5.3 also gives the DALYs lost to indoor air pollution. An estimated 8 million DALYs are lost each year. About 70-80 percent are from mortality and 20-30 percent are from morbidity.

Table 5.3: Estimated Annual Health Impacts of Indoor Air Pollution (Thousands)

	Estimated Annual Cases (000)		Estimated Annual DALYs (000)	
	Urban	Rural	Urban	Rural
Acute Respiratory Illness (ARI):				
Children (under the age of 5 years) – increased mortality	19.5	166.4	662	5,660
Children (under the age of 5 years) – increased morbidity	7,570	47,925	12.5	79
Females (30 years and older) – increased morbidity	9,401	47,384	65.8	331.7
Chronic obstructive pulmonary disease (COPD):				
Adult females – increased mortality	7.5	53.4	74	363
Adult females – increased morbidity	39,000	202.5	127.7	455.6
Total Disability Adjusted Life Years (DALYs)-mortality and morbidity			942.4	6,889.3

Source: Staff estimates.

50. The central estimated costs associated with the impacts identified above are given in Table 5.4. The baseline cost data used in arriving at these estimates can be found in Annex I. Briefly, the cost of mortality is based on the value of statistical life (VSL) estimated for India as a higher bound and HCA as a lower bound for adults and on HCA for children under 5. The cost of morbidity includes the cost of illness (medical treatment, value of lost time, etc) and value of DALYs estimated in GDP per capita.

51. To summarize, the total annual cost of indoor air pollution is estimated at Rs. 305-1425 billion, with a mean estimate of about Rs.865 billion (Table 5.4) or 1.3 percent of GDP in 2009. About 68 percent of this cost is associated with COPD, and 32 percent with ARI.13 COPD and ARI mortality represents about 90 percent of the total cost, and morbidity about 10 percent. (Figure 5.1).

Table 5.4: Estimated Annual Cost of Indoor Air Pollution

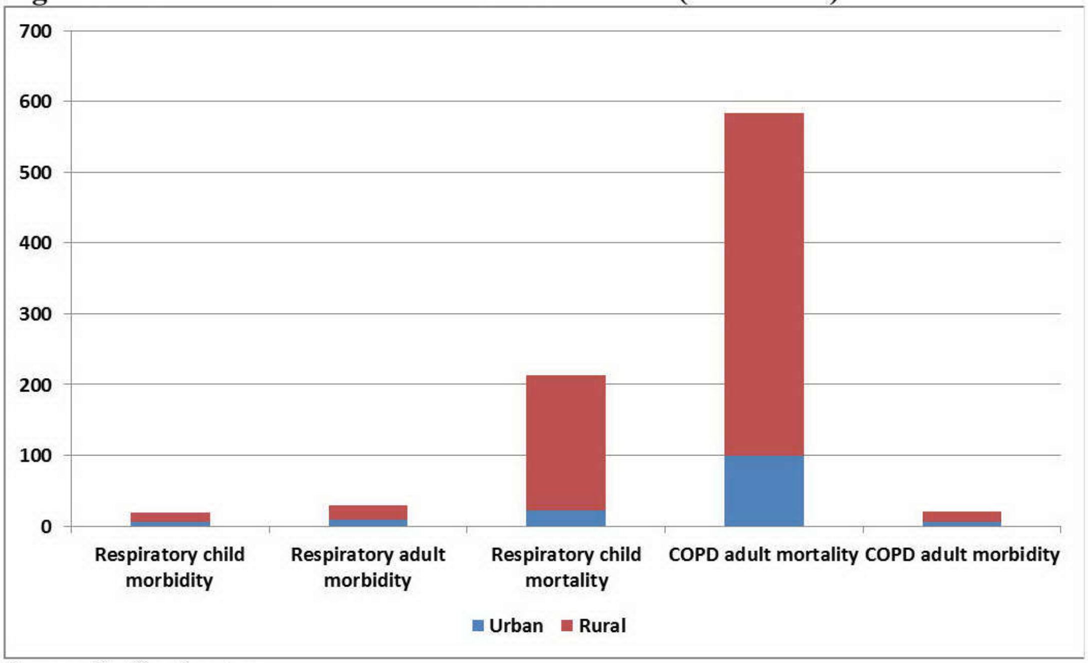
	Estimated Annual Cost (Billion Rs)	
	Urban	Rural
Acute Respiratory Illness (ARI):		
Children (under the age of 5 years) – increased mortality	20	190
Children (under the age of 5 years) – increased morbidity	5	15
Adult females – increased morbidity	10	20
Chronic obstructive pulmonary disease (COPD):		
Adult females – increased mortality	99	485
Adult females – increased morbidity	6	15
TOTAL	140	725

Source: Staff estimate.

52. Taking another classification, respiratory child mortality is 77 percent of the cost, and adult female chronic obstructive pulmonary disease (COPD) mortality is 21 percent of the cost (Figure 5.1). Acute respiratory illness (ARI) in adult females and in children represent 2 percent of cost.

[13] Based on the mean estimated annual cost.

Figure 5.1: Annual Costs of Indoor Air Pollution (Billion Rs.)



Source: Staff estimates.

V. Natural Resources: Land Degradation, Crop Production and Rangeland Degradation

53. As World Bank, 2007 indicates, “Difficult livelihood conditions and land management practices create high dependence and pressure on local natural resources”. Major categories of land degradation in India are similar to those in other Asian countries. They include: (1) water and wind soil erosion and in particular, irrigation-related land degradation, including secondary salinity, water logging and irrigation-related soil erosion, (2) pasture and range land degradation, (3) degradation of forests and bushes and related loss of biodiversity, and (4) other forms of land degradation as a result of natural disasters, soil contamination, etc. Land degradation eventually causes landslides and mudflows especially in the sensitive mountainous areas. Most affected by degradation is pasture land near villages as well as bush and tree vegetation. Common causes are ineffective land management and lack of alternate energy resources. Land degradation not only affects agricultural productivity, biodiversity and wildlife, but also increases the likelihood for natural hazards (World Bank, 2007).

54. Losses to croplands and rangelands include damages from soil salinity and water logging due to improper irrigation practices and human-induced soil erosion. In the absence of data on the annual increase in salinity and eroded croplands and rangelands, the annual loss of agricultural production (crop and rangeland fodder) is estimated based on accumulated degradation. This estimate may be more or less than the net present value (NPV) of annual production losses depending on the rate of annual increase in degradation. The losses are considered in this section and the next.

Soil Salinity and Water Logging

55. Soil salinity and water logging reduce the productivity of agricultural lands and, if a threshold salinity level is exceeded the land becomes unfit for cultivation. According to the conventional welfare economics, if agricultural markets are competitive, the economic costs of salinity would be measured as the losses in consumer surplus (consumer willingness to pay above market price) and producer surplus (profit) associated with the loss in productivity. These losses include direct losses through reduced yields as the land becomes saline or degraded. In practice, the calculations can be more complex as account needs to be taken of crop substitution to more saline-tolerant but less profitable crops and other indirect losses. Because of a lack of data, the losses here are approximated by the value of “lost” output related to the salinity, with some simple adjustment for changes in cropping patterns.

56. The estimated losses from saline soils were calculated under the assumption that such land is only used for wheat production (if it is used at all). This reflects the assumption that when soils are saline farmers will tend to plant crops that are more tolerant of this factor and wheat is such a crop, as opposed to pulses and rice. FAO estimates indicate a loss of yield of 5% for wheat per unit salinity (dS/m) for levels of salinity over 6 dS/m.

Taking these values and applying them to lands under wheat is the basis of the estimated loss of output14.

Table 6.1. Land degradation in India, million hectares (2002)

Degradation type	Degree of Degradation				
	Slight	Moderate	Strong	Extreme	Total
Water Erosion	27.3	111.6	5.4	4.6	148.9
a. Loss of topsoil	27.3	99.8	5.4	-	132.5
b. Terrain Deterioration	-	11.8	-	4.6	16.4
Wind Erosion	0.3	10.1	3.1	-	13.5
a. Loss of topsoil	0.3	5.5	0.4	-	6.2
b. Loss of topsoil/terrain deterioration	-	4.6	-	-	4.6
c. Terrain deformation/over blowing	-	-	2.7	-	2.7
Chemical Deterioration	6.5	7.3	-	-	13.8
a. Loss of nutrient	3.7	-	-	-	3.7
b. Salinization	2.8	7.3	-	-	10.1
Physical Deterioration	-	-	-	-	116.6
Waterlogging	6.4	5.2	-	-	11.6
Total (affected area)	36.8	137.9	8.5	4.6	187.8

Source: indiastat.com

57. The estimates indicate a net income from a hectare of land under wheat in 2009 as being in the range Rs 8,000-18,000 and total losses from salinity based on the above assumptions come out at between Rs. 0-10 billion in scenario 1 and between Rs. 3-13 billion in scenario 215.

58. In addition to the losses we also have to account for losses from strongly saline lands that could not be cultivated at all. There are estimated to be about 13 million hectares of agricultural land that cannot be cultivated, either because they are waterlogged or because they are highly saline. If we assume half of this area is saline then annual net losses from land wasted due to salinity are about Rs. 60-135 billion Rs.

59. In total therefore losses due to salinity amount to between Rs. 63 and Rs 148 billion. The middle of that range is 110 billion Rs. (0.17% of GDP in 2010).

[14] Cost of agricultural production in India is reported in indiastat.com. Indiastat is one of the most comprehensive sources of secondary level socio-economic India-centric statistical online database. The data sources include reports, statistical publications, policies, and other releases by various ministries/departments of the Government of India, and States including those sited here. It covers socio-economic data under more than 30 classifications, which are further divided into hundreds of sub-categories. It is extensively used by scholars all over India and world.

[15] Information of the salinity level (slight, moderate, strong) was not available at the time of the study. 2 scenarios were considered to address this issue. Scenarios are described in Annex II.

[15] Information of the salinity level (slight, moderate, strong) was not available at the time of the study. 2 scenarios were considered to address this issue. Scenarios are described in Annex II.

60. The losses due to water logging are estimated in a similar way. Then annual production losses are about 20 billion Rs. or 0.03% of GDP in 2010.

61. The remaining waterlogged wasteland is estimated to be 7.5 million. ha. None of this is deemed to be cultivatable. Given that the lost annual profit for paddy production on one hectare is in the range 15,000-24,000 Rs/ha. the annual net losses from land wasted due to water logging are about 83-143 billion Rs. or 113 billion Rs. on average (0.2% of GDP in 2010).

Soil Erosion

62. In addition to soil salinity land degradation caused by wind and water erosion is substantial in India (Table 6.1). Two major impacts of this erosion are sedimentation of dams and loss of nutrients in the soil.

63. Soil erosion contributes to sedimentation of dams in India. This in turn reduces the capacity of dams and thus irrigation capacity. We do not have reliable data on sedimentation of dams and reduction in the capacity of dams in India. Hence estimates of losses in crop production as a result of sedimentation could not be made.

64. As far as soil erosion and the loss of soil nutrients is concerned, this can be valued in terms of the costs of replacing the losses.

65. The estimated cost of soil nutrients (in terms of nitrogen, phosphorus and potassium) substitution is about 320-600 billion Rs. or 460 billion Rs. on average (0.7 % of GDP in 2010). Soil erosion is thus by far the most substantial problem of land degradation in India.

66. Methodology for the cost of soil salinity, waterlogging and nutrients loss is presented in Annex II.

67. Adding up the three categories of losses arising from land degradation in India we get a total of 715 billion Rs. or 1.1 % of GDP in 2010 (Table 6.2). Another way to express the loss is as a percentage of GDP from agriculture, forestry and fishery, which are sources of income predominantly for the poor. Gundimeda and Sukhdev (2008) refer to this as the "GDP of the poor" and as a percent of that the loss is about 6.4%.

Table 6.2. Estimated Annual Cost of Crop Losses Due to Land Degradation

	Total Loss (billion Rs)			% of GDP	% GDP of the poor
	Low	Mean	High	2010	
Salinity losses	63	110	148	0.2%	1.1%
Waterlogged land losses	103	133	163	0.2%	1.2%
Erosion losses	320	460	600	0.7%	4.1%
Total Crop Land Degradation Losses	480	703	910	1.1%	6.4%

Source: Staff estimates.

Rangeland Degradation

68. Land use reported in India suggests that the main causes of rangeland degradation in India are irrational land use management practices leading to denudation of vegetation from rangelands which, exacerbated by intermittent droughts, has resulted in many pockets of desertification.16 According to land use data about 10 million hectares are classified as permanent pastures. At the same time, about 1.5 times more land, including that under miscellaneous tree crops and groves and cultivable waste land, is also used as pastures. There is a substantial share of degraded lands within all these land categories. Forest lands that are used as pastures are estimated in the next section to avoid double-counting. An estimated 60 percent of livestock grazes in the forest area (Kapur et al., 2010).

69. The loss in yield is valued in two ways. In the first method the reduction in fodder production is valued at the price of fodder. In the second method the loss of fodder is converted into a loss of livestock based on livestock feed requirements and a value is attached to the loss of livestock. In both cases the hypothetical value against which losses are calculated is one in which original productivity prevails.

70. The estimated annual cost of rangeland degradation for the two methods is summarized in Table 6.3. The mean of two estimates is 405 billion Rs at 0.6% of GDP in 2010 or 3.6% GDP of the poor.

Table 6.3. Annual Cost of Rangelands Degradation in India

	Billion RS.	% of GDP	% of GDP of the poor
Market value of fodder losses	400-800	0.6-1.2%	3.6-7.2%
Foregone livestock income from fodder losses	170-256	0.3-0.4%	1.5-0.2.3%
Mean cost	405	0.6%	3.6%

Source: Staff estimates.

[16] Rangelands is a term commonly used in the WB studies. However, it could be substituted for grazing lands.

VI. Forest Degradation

71. The cost of deforestation and degradation of forests is the aggregate social loss associated with degraded or deforested lands. These losses include, in theory, a wide range of local, regional, national, and even global costs. Examples include direct losses of timber, fuel wood and non-timber products, recreation and tourism losses and indirect use losses (such as those associated with damages to ecosystem services, water supply and carbon sequestration), and non-use value loss associated with loss of forests. This section examines each of these categories of losses with the available data.

72. India's forest cover is about 21% of total land area (about 69 million hectares). Dense forest constitutes only 12% of total forest cover area. Although forest cover area increased by 0.1% in 2007, the north-eastern mountainous states with the most dense forest, like Nagaland, Arunachal Pradesh, Tripura and Assam, continued to experience deforestation due to the widespread practice of shifting cultivation. This loss is especially damaging for hilly areas where destructive agricultural practices can result in total ecosystem destruction. Total annual deforested land averaged from 2006-2009 is at about 0.6 million hectares annually.17

73. Many sources reflect a substantial level of land degradation in India. Overexploitation of forest resources has led to the opening up of the canopy and an increase of shrub-covered areas. The degraded area grew from 19.5 to 24.4 million hectares in 2003 (3rd National Report on Implementation of UN Convention to Combat Desertification, 2003). From the figure of 2.4 million hectares and with annual forest deforestation assumed to be at the same level as in 2006-2009, the total degraded forest area in 2009 would be estimated at 28 million hectares.18

74. The estimated losses from the degraded forests are based on the use values attached to the forest in their non-degraded state. Previous studies have estimated the use values for two categories: direct use value and indirect use value. Under direct use value they have included: (i) Timber, (ii) Non-timber forest products, (iii) Fodder, (iv) Eco-tourism and (v) Carbon sequestration. Under indirect use values they have covered (i) Soil erosion prevention and (ii) Water recharge. No estimate has been made of non-use values from forests, nor has any account been taken of biodiversity values (e.g. from bioprospecting) although these can be significant. Details of the valuation of each of these services are given in Annex II.

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[17] The study used data from various sources including FSI. We would like to note that a study recently conducted by a team of forestry researchers at the Indian Institute of Science (IISc) led by Prof. N H Ravindranath, Bangalore for " Current Science" journal says that massive deforestation in India has been masked by Forest Survey of India's data. The IISc study contradicts FSI's forest-cover figures and highlights a loss of 99,850 hectares of forests in two years. While acknowledging data limitations we therefor provide a range of estimates.

[18] The forest losses considered are consistent with a number of other studies including FSI. We agree that In total forest coverage in India increased at the time of a study but we looked at degradation aspects only. We have provided conservative estimates.

75. A summary of the values obtained, both in total and normalized in terms of Rs. per hectare are given in Table 7.1. The biggest source is carbon sequestration, followed by fodder and ecotourism.

76. In order to value the losses we assume that degraded forests provide between 20 and 80 percent for most of the direct use values but none of the indirect values since indirect values are only associated with dense forest functions. In the case of sequestered carbon a more precise figure is available: degraded forests are associated with 20% loss of total accumulated carbon (Gundimeda, 2001), reported in the range of 21-59 tC/hectare in India,19 valued at a social cost of carbon USD20 per ton of CO220 (see further explanation in Annex II). The losses are applied to 29 million hectares of degraded forest and about 0.6 million hectares of deforested lands.

Table 7.1. Estimated annual use values per hectare of forest in India (Billion Rs. except where indicated)

	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	617.7
Per hectare, Rs.	6,471.3	8,871.2
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	639.6
Total per hectare, Rs.	6,785.9	9,185.7

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.

77. Based on these figures total annual losses from degraded forest land and annual deforestation losses are presented in Table 7.2. The resulting losses are in the range of 0.1-0.3% of GDP. We should note that this is very likely an underestimate of total losses as it

[19] We assume that degraded land would continue to sequester carbon up to 80% of what it uptakes on non-degraded forest. Carbon issues are complicated and at the next stage they should be carefully studied in the context of geographical location and other specific factors. This study attempted to provide indicative country-wide estimates.

[20] The same CO_2 price is applied in China 2030 (World Bank, 2012).

excludes non-use values loss. Gundimeda (2005) estimates that the non-use and bioprospecting values of forests could be as much as 6-20 times greater than use values. Due to the high uncertain nature of this estimate we did not use it in this study.

Table 7.2. Estimation of annual forest value loss, Rs. per hectare, except where indicated

Losses	% loss	Low	High
		Direct values	
Timber	80-100%	198	248
Non timber values	20-100%	60	301
Fodder	0%	1,356	2,712
Ecotourism	100%	51	51
Carbon sequestration	20%	766	975
Total direct		2,432	4,287
Average % loss		42%	53%
Total direct , Rs Bn.		60.5	106.7
Indirect values			
Soil erosion	0-100%	0	1,783
Water recharge	0-100%	0	765
Total indirect		0	2,548
Average % loss		0	100
Total indirect , bil Rs		0.0	63.4
Total degradation losses, Bill Rs		60.5	170.2
Total deforestation losses (20% carbon losses only) Bill Rs		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).

78. If related to the GDP of the poor that was about 17% of the total GDP in India in 2010, then losses in forestry sector are at about 0.6-1.7%.

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Annex I: Methodology of Environmental Heath Losses Valuation

I. Outdoor air pollution

Mortality

79. Based on the current status of worldwide research, the risk ratios, or concentration-response coefficients from Pope et al (2002) were considered likely to be the best available evidence of the mortality effects of ambient particulate pollution (PM2.5). These coefficients were applied by the WHO in the World Health Report 2002, which provided a global estimate of the health effects of environmental risk factors. Pope et al (2002) provide the most comprehensive and detailed research study to date on the relationship between air pollution and mortality. The study confirms and strengthens the evidence of the long-term mortality effects of particulate pollution found by Pope et al (1995) and Dockery et al (1993). The study found a statistically significant relationship between levels of PM 2.5 and mortality rates, controlling for all the factors discussed above.

80. Damages due to anthropogenic factors are measured from a baseline PM2.5 concentration, which we set equal to 7.5 ug/m3 (as in WHO 2002). This is considered to be the level one would find in the natural environment.

Morbidity

81. While the mortality effects are based on PM2.5, the morbidity effects assessed in most worldwide studies are based on PM10. Concentration-response coefficients from Ostro (1994, 1998) and Abbey et al (1995) have been applied to estimate these effects. Ostro (1994) reviews worldwide studies and based on that Ostro (1998) estimates concentration-response coefficient for restricted activity days, and Abbey et al (1995) provides estimates of chronic bronchitis associated with particulates (PM10). The mortality and morbidity coefficients are presented in Table A1.0 based on these estimates.

Table A1.0 Urban Air Pollution Concentration-Response Coefficients

Annual Health Effect	Concentration-response Coefficient	Per 1 ug/m^3 annual average ambient concentration of:
Long term mortality (% change in cardiopulmonary and lung cancer mortality)	0.8% *	PM 2.5
Acute mortality children under five (% change in ARI deaths)	0.166%	PM10
Chronic bronchitis (% change in annual incidence)	0.9%	PM10
Respiratory hospital admissions (per 100,000 population)	1.2	PM10
Emergency room visits (per 100,000 population)	24	PM10
Restricted activity days (% change in annual incidence)	0.475%	PM10
Lower respiratory illness in children (per 100,000 children)	169	PM10
Respiratory symptoms (per 100,000 adults)	18,300	PM10

*Mid-range coefficient from Pope et al (2002) reflecting a linear function of relative risk. In the analysis however, we used a log-linear

Source: Pope et al (2002), Ostro (2004) for the mortality coefficients. Ostro (1994, 1998) and Abbey et al (1995) for the morbidity coefficients.

82. Baseline concentration for the application of the concentration response functions was set at 7.5 ug/m3 for PM2.5 (as for mortality). As in Ostro (1994) there is no threshold for morbidity, estimated utilizing PM10 concentrations.

Expressing Health Effects in DALYS

83. The health effects of air pollution can be converted to disability adjusted life years (DALYs) to facilitate a comparison with health effects from other environmental risk factors. DALYs per 10 thousand cases of various health end-points are presented in Table 3.2.

II. Estimation of urban population and of annual average PM10 concentrations

84. The last available census was in the year 2001, since it is conducted once every decade. The population figures for India are slightly outdated given the rapid growth in population and urban areas around the country. Consequently this study uses population figures from the 2001 census that have been projected to 2009 using UN Population Fund projections for urban areas in India. The UN database provides annual population growth rates for selected cities, which have been used for the population projections. For cities without these growth rates, we take the average annual growth rate and project the population to 2009.

85. In this study we focus on cities with a population of 100,000 and above only. Since the baseline population is from the 2001 census there are many cities that have achieved a population of 100,000 since 2001 and have not been included in the study. This can be updated once the figures for the latest census are released in 2011.

86. Pollution data for all cities, wherever available, was taken from the Central Pollution Control Board's (CPCB) Environmental Data Bank website for the year 2008. Health damage estimates for PM10 were calculated based on observations for the year 2008. The average concentration was calculated by taking the arithmetic average for all available observations in the year 2008. The local state pollution control board is in charge of measuring pollution levels in each city at each of the monitoring stations. There are supposed to be 104 observations for each monitoring station in each city annually, which is roughly two readings a week at each monitoring station. The frequency of observations depends on the pollution control board officials at the city level. Once the data has been collected, it is loaded on the CPCB Environment Data Bank website directly by the local officials.

87. The PM10 concentrations data from CPCB is best available source since this is the only monitoring agency with the most widespread network. The CPCB does not cover all cities in our list of cities with a population of 100,000 and above. For these cities, the PM10 concentrations have been projected to 2009.

88. The monitoring stations in cities are placed in three areas, residential, industrial and sensitive areas. Residential areas are areas with housing, industrial areas are locations with

mostly industries and sensitive areas are either locations with monuments or biodiversity and zoo parks. Depending on the city and the prominent activities, some have greater number of monitoring stations in residential areas and other have majority of the monitoring stations in industrial areas. Cities with monuments will have monitoring stations in these sensitive areas. Therefore, the distribution of these monitoring stations by type is not constant in each city.

Table A1.1: Average Annual Concentrations of PM10 (μg/m^3) and Population for Major Indian Cities

	2008 PM10 Concentration Projections (ug/m3)	2009 Population Projections (Thousands)
Meerut	313	1,413
Yamunanagar	301	340
Ludhiana	271	1,668
Ghaziabad	236	791
Firozabad	222	418
NEW DELHI	214	21,331
Delhi	214	13,010
Kanpur	210	3,195
Indore	196	2,093
Raipur	192	906
Lucknow	189	2,723
Amritsar	189	1,252
Satna	188	248
Agra	188	1,643
Allahabad	181	1,238
Ranchi	175	1,078
Jamshedpur	172	1,341
Chandrapur	170	349
Guwahati	164	1,015
Faridabad	163	955
Gwalior	162	1,008
Jalandhar	150	884
Jodhpur	148	1,026
Noida	148	226
Alwar	144	325
Jabalpur	136	1,324
Asansol	135	1,372
Durgapur	133	658
Dhanbad	131	1,285
Jhansi	130	569
Nagpur	128	2,526
Bombay/ Mumbai	127	19,460
Jaipur	126	3,012
Kota	125	837
Patna	120	2,231
Nellore	118	489
Sagar	115	397
Hisar	112	280
Bhilai Nagar	109	1,059

	2008 PM10 Concentration Projections (ug/m3)	2009 Population Projections (Thousands)
Dehradun	109	569
Korba	107	355
Varanasi	106	1,391
Rajkot	105	1,304
Hubli-Dharwad	103	918
Calcutta/ Kolkata	103	17,032
Bhopal	102	1,780
Raurkela	102	616
Ujjain	101	560
Bangalore	97	6,982
Vijayawada	96	1,171
Chandigarh	95	1,012
Jamnagar	95	590
Pune	94	3,854
Udaipur	91	477
Ahmedabad	88	5,531
Surat	88	3,982
Ramagundam	87	331
Bhubaneswar	86	875
Kolhapur	84	647
Imphal	84	313
Hyderabad	84	6,551
Dewas	84	254
Cuttack	81	680
Visakhapatnam	80	1,575
Nashik	79	1,524
Solapur	79	1,092
Salem	78	901
Vadodara	77	1,810
Shillong	72	345
Gulbarga	71	480
Kurnool	71	426
Coimbatore	71	1,748
Warangal	69	723
Amravati	66	651
Baleshwar	66	157
Thiruvananthapuram	64	981
Madras/ Chennai	63	7,347
Haldia	61	155
Mangalore	60	659
Thane	58	1,241
Dibrugarh	56	194
Sangli	55	562
Shimla	54	171
Pondicherry	50	620
Sambalpur	50	299
Hassan	50	168
Mysore	49	914
Kakinada	48	506
Kottayam	46	257
Kochi	43	1,538

Madurai	42	1,311
Aizawl	36	240
Tirupati	34	292
Kozhikode	34	966
Belgaum	33	622
Palakkad	30	278

Source: estimated by A. Sagar.
Population in each city was estimated from 2001 Census data.

Table A1.2 PM 10 Estimates and Population for Cities with no Monitoring Data

	2009 Population Projections (Thousands)	2008 PM10 Concentration Projections (ug/m3)
Cities with population above 1 million		
Kalyan	1,568	45
Haora	1,469	154
Srinagar	1,176	20
Aurangabad	1,152	118
Durg	1,132	122
Cities with population above 0.5-1 million		
Tiruchchirappalli	980	63
Bareilly	842	164
Aligarh	832	62
Bhiwandi	824	58
Moradabad	814	120
Gorakhpur	781	158
Tiruppur	759	59
Guntur	728	81
Kannur	717	55
Bikaner	643	149
Bhavnagar	626	105
Ajmer	622	142
Rajahmundry	620	53
Bokaro Steel City	616	102
Saharanpur	579	150
Ulhasnagar	570	70
Tirunelveli	567	58
Kollam	560	39
Erode	559	59
Malegaon	529	54
Akola	507	93
Cities with population 0.1-0.5 million		
Vellore	480	65

	2009 Population Projections (Thousands)	2008 PM10 Concentration Projections (ug/m3
Nanded	478	95
Bhatpara	471	99
Gaya	455	142
Davangere	444	50
Tuticorin	433	47
Dhule	430	63
Panihati	426	156
Thrissur	425	45
Kamarhati	412	155
Allappuzha	409	48
Kharagpur	409	93
Shahjahanpur	402	169
Bhagalpur	402	148
Patiala	392	154
Muzaffarnagar	383	156
Bellary	379	95
Barddhaman	379	74
Rampur	377	156
Jalgaon	374	63
Muzaffarpur	373	283
Nizamabad	372	95
Ichalakaranji	365	60
Mathura	365	110
South Dum Dum	360	147
Bilaspur	355	91
Baranagar	347	162
Ahmednagar	343	101
Darbhanga	337	217
Siliguri	335	127
Rohtak	334	79
Cuddapah	334	87
Eluru	329	56
Ondal	327	93
Brahmapur	325	97
Farrukhabad Cum Fategarh	323	80
Thanjavur	312	60
Bihar Sharif	311	84
Latur	305	66
Habra	304	64

	2009 Population Projections (Thousands)	2008 PM10 Concentration Projections (ug/m3)
Ratlam	303	91
Bijapur	298	50
Shimoga	298	46
Panipat	295	174
Navsari	295	44
Parbhani	294	79
Nagercoil	294	44
Hardwar	290	123
Bally	285	146
Bhilwara	284	129
Dindigul	282	50
Tumkur	278	58
English Bazar	274	115
Vizianagarm	274	51
Faizabad	273	145
Karnal	272	169
Jalna	270	78
Anantapur	270	44
Anand	270	117
Burhanpur	267	77
Kanchipuram	264	59
Raichur	264	76
Nadiad	263	113
Mirzapur-cum-Vindhyachal	262	99
Junagadh	258	53
Wadhwan	257	156
Murwara (Katni)	253	117
Ganganagar	250	141
Porbandar	248	95
Bhusawal	247	70
Raiganj	246	99
Machilipatnam	246	64
Bathinda	246	149
Agartala	243	95
Arrah	243	161
Bharatpur	242	142
Kolar Gold Fields	242	69
Nabadwip	241	84
Raniganj	241	91
Katihar	239	128

	2009 Population Projections (Thousands)	2008 PM10 Concentration Projections (ug/m3)
Hugli-Chinsura	235	151
Sambhal	233	102
Kumbakonam	233	57
Munger	232	80
Bhadravati	231	48
Khammam	230	67
Karimnagar	230	78
Sikar	229	133
Dabgram	227	112
Morena	227	127
Hapur	226	140
Khandwa	224	85
Cuddalore	223	55
Sonipat	222	141
Tenali	222	68
Chiral	221	66
Phusro	220	79
Malappuram	220	31
Ambala	216	145
Bharuch	215	115
Amroha	212	137
Serampore	212	145
Purnia	212	133
Chapra	212	125
Pali	211	106
Maunath Bhanjan	211	152
Adoni	210	86
Jaunpur	210	135
Gurgaon	210	144
Bahraich	209	151
Hospet	208	71
Gadag-Betgeri	207	36
Proddatur	207	92
Chittoor	206	58
Barrackpur	206	128
Cherthala	205	42
Naihati	205	151
Bidar	205	132
Rae Bareli	201	147
Rewa	199	106
Ongole	199	66

	2009 Population Projections (Thousands)	2008 PM10 Concentration Projections (ug/m3)
Pathankot	198	109
Bulandshahr	197	106
Kamptee	196	86
Pollachi	196	37
Ranaghat	196	86
Neyveli	196	57
Baharampur	195	144
Balurghat	195	91
Medinipur	194	81
Rajnandgaon	194	75
Puri	193	74
Etawah	192	137
Gandhinagar	191	94
Modinagar	191	139
Hoshiarpur	190	110
Sitapur	188	121
Yavatmal	188	118
Bhiwani	188	155
Bhimavaram	187	57
Krishnanagar	187	89
Bhuj	187	51
Chandan Nagar	186	146
Mandya	186	52
Patan	186	58
Morvi	186	58
Nandyal	185	78
Guruvayur	183	36
Kanhangad	183	33
Fatehpur	182	130
Udupi	182	38
Mahbubnagar	181	68
Budaun	180	145
Silchar	178	76
Bankura	178	66
Arcot	177	62
Rajapalaiyam	176	46
Titagarh	176	145
Karur	176	51
Hathras	175	126
Sirsa	174	156

	2009 Population Projections (Thousands)	2008 PM10 Concentration Projections (ug/m3)
Bid	174	98
Jorhat	173	88
Valsad	173	66
Moga	171	136
Karaikkudi	171	51
Santipur	170	94
Mahesana	170	117
Patratu	170	77
Bhind	170	110
Gondiya	169	96
Tiruvannamalai	169	66
Shivapuri	167	147
Guntakal	166	89
Unnao	166	151
Abohar	166	102
Beawar	165	131
Pilibhit	165	141
Valparai	165	16
Damoh	162	103
Hindupur	162	56
Gandhidham	162	50
Haldwani-cum-Kathgodam	161	101
Thalassery	160	60
Chitradurga	160	52
Batala	160	101
Wardha	159	104
Alipurduar	159	134
Vadakara	158	34
Sivakasi	158	45
Kothagudem	158	69
Gudivada	157	55
Basirhat	157	59
Godhra	156	85
Guna	155	137
Tonk	155	107
Kanchrapara	155	126

Source: PM estimated by Aarsi Sagar based on the WB model.II.

III. Estimating Mortality and Morbidity Effects of PM

Concentration Response Functions

89. As noted in the report PM is the main form of outdoor air pollution pollutant that has health impacts. The Pope et al. (2002) study found a statistically significant relationship between levels of PM 2.5 and mortality rates, controlling for all the factors discussed above. Pope (2002) estimated relative risk for the linear function for cardiopulmonary mortality. That is

$$RR = \exp(\beta(X - X_0)) \qquad (1)$$

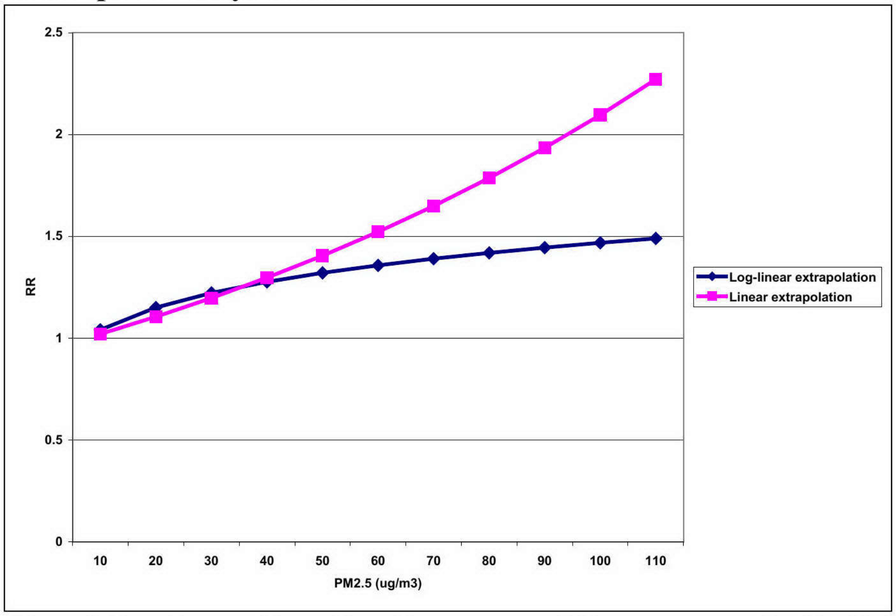
90. Where RR stands for relative risk for cardiopulmonary mortality, X is the observed PM2.5 concentration and X0 is a background PM2.5 concentration, which we set equal to 7.5 ug/m3 (as in WHO (2002)). Based on that, one finds the increase to be 6-9 percent in cardiopulmonary mortality, and 8-14 percent for lung cancer per 10 ug/m3 of PM2.5. The mortality coefficient in Table 3.1 is a combination of the cardiopulmonary and lung cancer mortality risk ratios.

91. However, for higher PM2.5 concentrations than Pope considered in his analysis and such as those found in India Ostro (2004) proposed to use log-linear relative risk function from cardiopulmonary mortality reflecting the uncertainty about the health impact with higher PM2.5 concentration. The log-linear relative risk function for cardiopulmonary mortality has the form:

$$RR = \left[(1 + X)/(1 + X_0)\right]^{\beta}, \qquad (2)$$

where β is equal to 0.15515 (Ostro, 2004). In order not to overestimate the impacts of higher concentrations we used the log-linear form. The difference between the two can be seen in Figure A1.1

Figure A1.1: Alternative Concentration-Response Curves For Mortality From Cardiopulmonary Diseases



92. The share of cardiopulmonary and lung cancer deaths in total mortality varies sometimes substantially across countries. It may therefore reasonably be expected that the risk ratios for cardiopulmonary and lung cancer mortality provide more reliable estimates of mortality from PM 2.5 than the risk ratio for all-cause mortality when the risk ratios are applied to countries other than the United States. The cardiopulmonary risk ratio is therefore used in this report.

93. In order to apply the mortality coefficients in Table 3.1 to estimate mortality from urban air pollution, baseline data on total annual cardiopulmonary and lung cancer deaths are required. For this purpose we applied the Office of Registrar General (2004) report on causes of death in India for this purpose. Urban crude mortality rate of 5.9 per 1,000 was applied, along with an average cardiopulmonary and lung cancer mortality rate of 35 percent of total deaths. Annual ARI deaths for children under 5 of 22 percent from the report of the Office of Registrar General (2004).

Estimating Morbidity Cases and Costs of PM10

94. A number of issues need to be addressed with respect to the morbidity costs.

a. Baseline Incidence. To apply the coefficients in Table 3.1 we need information in some cases on the baseline rates of the incidence of the health item (e.g. chronic bronchitis). This is not available for India so the rate was taken from from WHO (2001) and Shibuya et al (2001) for the Sear D regions of WHO[21]. Since this figure

[21] WHO Member States are grouped into 6 geographical regions: AFRO (Africa), AMRO (Americas), EMRO (Eastern Mediterranean), EURO (Europe), SEARO (South-East Asia) and WPRO (Western Pacific). The 6 WHO regions are further divided based on patterns of child and adult mortality in groups ranging from A (lowest) to E (highest): AFR (D,E); AMR (A,B,D); EMR (B,D); EUR (A,B,C); SEAR (B,D); WPR (A,B).(www.who.int).

is taken from outside India and applied nationally it has therefore not been possible to provide city specific CB incidence rates.

b. Restricted Activity Days. In the case of restricted activity days the background values were estimated from ARI prevalence in the adult population (see Section V on health loss from indoor air pollution). From international experience each illness was estimated to last 7 days of which 5 were counted as restricted activity days.

c. Other morbidity health endpoints. These are hospital admissions of patients with respiratory problems, emergency room visits (or hospital out-patient visits), lower respiratory infections in children, and respiratory symptoms. These are the most common health endpoints considered in most of the worldwide studies on air pollution. The coefficients are expressed as cases per 100,000 in the absence of incidence data for India. It should be noted that it would be preferable to have incidence data and use coefficients that reflect percentage change in incidence. Increases in asthma attacks among asthmatics have also been related to air pollution in many studies. This however requires data on the percentage of the population that are asthmatic and frequency of asthma attacks, which is not readily available for India.

d. Use of DALYS and calculation of DALYs per Health effect. The base case numbers of DALYs per endpoint given in Table 3.3 are based on the disability weights and average duration of each illness. The weights for lower respiratory illness (LRI) and chronic bronchitis (CB) are disability weights presented by the National Institute of Health, United States.[22] Disability weights for the other morbidity end-points are not readily available, and are estimates by Larsen (2004a) based on weights for other comparable illnesses.[23] Average duration of CB is estimated based on age distribution in India and age-specific CB incidence in Shibuya et al (2001). Years lost to premature mortality from air pollution is estimated from age-specific mortality data for cardiopulmonary and lung cancer deaths, and have been discounted at 3 percent per year. Average duration of illness for the other health end-points is from Larsen (2004a). The details are summarized in Table A1.3.

Table A1.3: Calculation of DALYs per Case of Health Effects

	Disability Weight	Average Duration of Illness
Mortality	1.0	(7.5 years lost) or 70 years lost for children under 5
Lower respiratory Illness – Children	0.28	10 days
Respiratory Symptoms – Adults	0.05	0.5 days
Restricted Activity Days – Adults	0.1	1 day
Emergency Room Visits	0.30	5 days
Hospital Admissions	0.40	14 days*
Chronic Bronchitis	0.2	20 years

* Includes days of hospitalization and recovery period after hospitalization.

[22] See: http://www.fic.nih.gov/dcpp/weights.xls

[23] The disability weight for mortality is 1.0.

e. Baseline data to value costs per case of illness. These are summarized in Table A1.4. Some of these data require explanation. The value of time for adults is based on urban wages. Economists commonly apply a range of 50-100 percent of wage rates to reflect the value of time. The rate of 200 Rs per day is an average urban wage in India. It was estimated using the India 2011 data on household monthly income from wages. 75 percent of this rate has been applied for both income earning and non-income earning individuals. There are two reasons for applying the rate to non-income earning individuals. First, most non-income earning adult individuals provide a household function that has a value. Second, there is an opportunity cost to the time of non-income earning individuals, because they could choose to join the paid labor force.[24]

Table A1.4: Baseline Data for Cost Estimation

	Baseline	**Source:**
Cost Data for All Health End-Points:		
Cost of hospitalization (Rs per day)	980	NSS, 2004, and per consultations with medical service providers, and health authorities
Cost of emergency visit (Rs) - urban	800	
Cost of doctor visit (Rs) (mainly private doctors) – urban	800	
Value of time lost to illness (Rs per day)	150	75% of urban wages in India
Chronic Bronchitis (CB):		
Average duration of Illness (years)	20	Based on Shibuya et al (2001)
Percent of CB patients being hospitalized per year	1.5 %	From Schulman et al (2001) and Niederman et al (1999)
Average length of hospitalization (days)	10	
Average number of doctor visits per CB patient per year	1	
Percent of CB patients with an emergency doctor/hospital outpatient visit per year	15 %	
Estimated lost work days (including household work days) per year per CB patient	2.6	Estimated based on frequency of doctor visits, emergency visits, and hospitalization
Annual real increases in economic cost of health services and value of time (real wages)	2 %	Estimate
Annual discount rate	3 %	Applied by WHO for health effects
Hospital Admissions:		
Average length of hospitalization (days)	6	Estimates
Average number of days lost to illness (after hospitalization)	4	
Emergency Room Visits:		
Average number of days lost to illness	2	
Restricted Activity Days:		
Average number of days of illness (per 10 cases)	2.5	
Lower Respiratory Illness in Children:		
Number of doctor visits	1	
Total time of care giving by adult (days)	1	Estimated at 1-2 hours per day

[24] Some may argue that the value of time based on wage rates should be adjusted by the unemployment rate to reflect the probability of obtaining paid work.

IV. Impacts from inadequate WSH

A. Background

95. Inadequate quantity and quality of potable water supply, sanitation facilities and practices, and hygiene conditions are associated with various illnesses both in adults and children. Esrey et al (1991) provides a comprehensive review of studies documenting this relationship for diseases such as schistosomiasis (bilharzia), intestinal worms, diarrhea etc. Fewtrell and Colford (2004) provide a meta-analysis of studies of water supply, sanitation and hygiene that updates the findings on diarrheal illness by Esrey et al. While diarrheal illness is generally not as serious as some other waterborne illnesses, it is more common and affects a larger number of people.

96. Water, sanitation and hygiene factors also influence child mortality. Esrey et al (1991) find in their review of studies that the median reduction in child mortality from improved water and sanitation was 55 percent. The term improved water and sanitation refers to a change from the status quo to a situation where the MDGs which define improved water and sanitation are being met. Shi (1999) provides econometric estimates of the impact of potable water and sewerage connection on child mortality using a data set for about 90 cities around the world. Literacy and education level are also found to be important for parental protection of child health against environmental risk factors. Esrey and Habicht (1988) reports from a study in Malaysia that maternal literacy reduces child mortality by about 50 percent in the absence of adequate sanitation, but only by 5 percent in the presence of good sanitation facilities. Literacy is also found to reduce child mortality by 40 percent if piped water is present, suggesting that literate mothers take better advantage of water availability for hygiene purposes to protect child health.

97. Findings from the Demographic and Health Surveys around the world further confirm the role of literacy in child mortality reduction. Rutstein (2000) provides a multivariate regression analysis of infant and child mortality in developing countries using Demographic and Health Survey data from 56 countries from 1986-98. The study finds a significant relationship between infant and child mortality rates and piped water supply, flush toilet, maternal education, access to electricity, medical services, oral rehydration therapy (ORT), vaccination, dirt floor in household dwelling, fertility rates, and malnutrition. Similarly, Larsen (2003) provides a regression analysis of child mortality using national data for the year 2000 from 84 developing countries representing 95 percent of the total population in the developing world.

B. Estimating Incidence

98. The estimation of the incidence of disease in India was based significantly on the NFHS-3 survey, which provides data on diarrheal prevalence in children under the age of five years. It reports a diarrheal prevalence (preceding 12 days) rate of 8.9 percent in urban areas and 9 percent in rural areas. This rate is used to estimate annual episodes per child under 5, and then total annual cases in all children under 5. The procedure applied is to multiply the two-week prevalence rate by 52/2.5 to arrive at an approximation of the number of annual cases of per child. The prevalence rate is not multiplied by 26 two-week

periods (i.e. 52/2), but multiplied by 52/2.5 for the following reason: The average duration of diarrheal illness is assumed to be 3-4 days. This implies that the two-week prevalence captures a quarter of the diarrheal prevalence in the week prior to and a quarter in the week after the two-week prevalence period.

99. The NFHS-3 household survey does not (nor does any other household survey in India) provide information on diarrheal illness in the population above 5 years of age. International experience provides an indication of the annual incidence of diarrhea per child relative to annual incidence for the rest of the population. International experience suggests that diarrheal incidence in the population above 5 years of age is 20 percent of incidence in children under 5 years. It should be noted however that usually the databases are for cases of diarrhea treated at health facilities. In general, the percentage of cases of diarrhea that are treated at health facilities is higher among young children than older children and adults. 20 percent is likely an underestimate of diarrheal cases in the population above 5 years of age. The annual cases of diarrhea per person among the population above 5 years of age, presented in Table 4.1, is therefore estimated in the range of 0.2 to 0.3 of the annual cases per child under 5 (see Krupnick et al, 2006).

100. Sometimes diarrheal illness requires hospitalization. NSS (2004) provides some information on diarrheal hospitalization in urban and rural areas. A hospitalization rate of 0.15 percent for children and 0.3-0.6 percent for population over 5 was applied to all cases of diarrhoea estimated above.

101. In addition to the number of cases we also need the DALYS associated with the cases. In order to calculate these we require the disability weight for diarrheal morbidity, which is taken as 0.119 for children under 5 and 0.086 for the rest of the population, and the duration of illness is assumed to be 7 days for children (as in Krupnick, 2006) and 3-4 days for adults.

102. For typhoid, the disability weight is estimated at 0.2. Duration of illness is estimated from the study in India (Sinha et al, 1999). Average duration is about 11 days for children under 5 and 13 for people above 5 (average age is 10 years old). Typhoid annual incidence of typhoid in 2009 is reported in (http://www.indiastat.com).

103. However, the DALYs per 100 thousand cases of diarrheal illness are much higher for the population over 5 years of age. This is because DALY calculations involve age weighting that attaches a low weight to young children and a higher weight to adults that corresponds to physical and mental development stages.25 For diarrheal and typhoid child mortality the number of DALYs lost is 34 for those under 5, and 32 for those above 5 (they are mostly under 14 years old on average for typhoid). This reflects an annual discount rate of 3 percent of life years lost.

[25] It should be noted that some researchers elect not to use age weighting, or reports DALYs with and without age weighting.

C. Baseline Cost Data

104. The baseline cost data are given in Table A1.12, with the source of the estimate in each case. Two points to note are the following:

a. Percent of diarrheal cases in the age group older than 5 years treated at medical facilities is estimated from percent of treated cases among children using international experience.
b. The value of time for adults is based on national average wages. Economists commonly apply a range of 50-100 percent of average urban and rural wage rates to reflect the value of time. The daily rate of 150 Rs. in urban areas and 60-75 Rs. in rural areas, reflects around 75 percent of average weighted wage in India.[26] These rates for value of time are applied to both income earning and non-income earning adults. There are two reasons for applying the rates to non-income earning adults. First, most non-income earning adults provide a household function that has a value. Second, there is an opportunity cost to the time of non-working individuals, because they could choose to join the paid labor force.[27]

Table A1.12: Baseline Data for Cost Estimation

	Baseline	**Source:**
Percent of diarrheal cases treated at medical facilities (children < 5 years) and with medicines	58-65%	NFHS-3
Percent of diarrheal cases treated with ORS (children < 5 years)	37-44%	NFHS-3
Percent of diarrheal cases treated at medical facilities (population > 5 years) and with medicines	40-50%	Estimated from a combination of international experience and Krupnick et al (2006).
Average Cost of doctor visits (urban and rural) – Rs.	100-500	Estimated from a combination of international experience (WHO) and per consultations with pharmacies, medical service providers, and health authorities
Average Cost of medicines for treatment of diarrhea – Rs.	100	
Average cost of ORS per diarrheal case in children (Rs.)	15-30	
Average duration of diarrheal illness in days (adults and children)	3-7	Krupnick et al (2006)
Hours per day of care giving per case of diarrhea in children	2	Assumption
Hours per day lost to illness per case of diarrhea in adults	2	Assumption
Value of time for adults (care giving and ill adults) – Rs/hour	9-19	Based on urban and rural wages in India (see Outdoor air pollution section)
Hospitalization rate (% of all diarrheal cases) –children under 5 years	0.75 %	NSS (2004)
Hospitalization rate (% of all diarrheal cases) –population over 5	0.5 %	
Average length of hospitalization (days)	2	Adjusted from (Larsen 2004)
Time spent on visitation (hours per day)	4	Assumption
Average cost of hospitalization (Rs. per day)	600-980	NSS, 2004
Percent of diarrheal cases attributable to water, sanitation and hygiene	90 %	WHO 2002b

[26] This corresponds to a daily urban average wage rate of about 200 Rs. and rural wage rate of 80-100 Rs.

[27] Some may argue that the value of time based on wage rates should be adjusted by the unemployment rate to reflect the probability of obtaining paid work.

D. Averting Expenditures

105. The elements in the calculation of averting expenditures are the following:

106. Bottled Water. From a combination of Jethoo and Poonia (2011) and NFHS-3 it was estimated that about 1.5 Billion liters of bottled water are sold in urban areas and 0.5 billion liters in rural areas of India annually. It is used as a lower bound of bottled water consumption in India. Worlds Water Institute (see 'http://www.worldwater.org/data20062007/Table13.pdf) provides much higher estimate at about 40 Billion liters in total. We consider it as a higher bound of bottled water consumption in India. Total annual cost of bottled water consumption is estimated at about 20 Billion Rs. in urban areas and 7 Billion Rs in rural areas. http://www.gits4u.com/water/water16.htm supplies information about price and cost of bottled water production on India.

107. It should be noted that a portion of bottled water consumption is not only associated with perceptions of health risk of water supply, but rather also a matter of choice of life-style and convenience. In the absence of data, no adjustment has been made to account for this. The estimated cost of bottled water consumption associated with health risk perceptions is therefore an unknown overestimate of health risk costs.

108. Boiling of Water. According to NFHS-3, 16 percent of households boil their drinking water in urban areas and 8% boil drinking water for cooking in rural areas, either all the time or sometimes. Table 4.9 presents the estimated annual cost of boiling water for those households, totalling 4.5-9.5 billion Rs. per year.

109. Table A1.13 presents the data used to estimate the annual cost of boiling drinking water and A1.14 gives some of the baseline information that goes into making the calculations. It is assumed that the average daily consumption of drinking water per person is 0.5-1.0 liters among households boiling water. Residential cost of energy is estimated based on data from local experts. The average stove efficiency is for electric, natural gas and kerosene. Lower efficiency was applied for wood stove.

110. Water Filtering. According to NFHS-3, 13 percent of households filter their drinking water in urban areas and 3 % filter drinking water for cooking in rural areas. Then in total, there are about 10 million households filter water in urban areas and 5 million in rural areas. With average filter price at about 4000 Rs. and 1000 Rs. price of candle filter (per consultations with local experts) total annual filtering cost are at about 14 Billion Rs. in urban and 7 Billion Rs. in rural areas.

Table A1.13: Estimated Annual Cost of Boiling Drinking Water

	Estimated Annual Cost (Billion Rs.)	
	"Low"	**"High"**
Annual cost--using fuel wood for water boiling	1.5	3
Annual cost--using kerosene for water boiling	0.5	1
Annual cost--using natural gas for water boiling	2.5	5
Annual cost--using other types of energy for water boiling	0.0	0.5
Total Annual Cost	4.5	9.5

Table A1.14: Baseline Data for Cost Estimation

	Data:	
Percentage of households that boil their drinking water	8-16%	NFHS-3
Average daily consumption of drinking water	0.5-1.0	Liters per person per day
Percent of households using fuel wood for cooking	32-90%	NFHS-3
Percent of households using kerosene for cooking	1-8%	
Percent of households using natural gas for cooking	9-59%	
Percent of households using other types of energy for cooking	0-1%	
Energy requirement of heating of water (100% efficiency)	4200	Joules/ltr/1 degree C
Average Stove efficiency for heating of water	50 %	Varies by type of stove
Average wood Stove efficiency for heating of water	20 %	
Average time of boiling water (after bringing water to boiling point)	10	Minutes
Cost of LPG	310	Rs/ per 14.2 kg
Cost of kerosene	12	Rs/liter
Average cost of fuel wood	1 Rs per kg	http://infochangeindia.org/index2.php?option=com_content&do_pdf=1&id=5739

V. Indoor Air Pollution

111. Desai et al (2004) provides a review of research studies around the world that have assessed the magnitude of health effects from indoor air pollution from solid fuels. The odds ratios for acute respiratory illness (ARI) and chronic obstructive pulmonary disease (COPD) are presented in Desai et at (2004). The odds ratios represent the risk of illness for those who are exposed to indoor air pollution compared to the risk for those who are not exposed. The exact odds ratio depends on several factors such as concentration level of pollution in the indoor environment and the amount of time individuals are exposed to the pollution. A range of "low" to "high" ratios is therefore presented in Table 5.1 that reflects the review by Desai et al (2004).

112. Studies around the world have also found linkages between indoor air pollution from traditional fuels and increased prevalence of tuberculosis and asthma. It is also likely that indoor air pollution from such fuels can cause an increase in ischemic heart disease and other cardiopulmonary disorders. As discussed in the section on urban air pollution, Pope et al (2002) and others have found that the largest effect of urban fine particulate pollution on mortality is for the cardiopulmonary disease group. As indoor smoke from traditional fuels is high in fine particulates, the effect on these diseases might be substantial. More research, however, is required in order to draw a definite conclusion about the linkage and magnitude of effect.

A. Details of Estimation of parameters

113. Annual new cases of ARI and COPD morbidity and mortality (Di) from fuel wood smoke were estimated from the following equation:

Di = PAR *DiB (1)

where DiB is baseline cases of illness or mortality, i (estimated from the baseline data in Table 5.2), and PAR is given by:

PAR = PP*(OR-1)/(PP*(OR-1)+1) (2)

Where PP is the percentage of population exposed to fuel wood smoke (32 percent of the urban and 86 percent of rural population according to India Census 1998), and OR is the odds ratios (or relative risk ratios) presented in Table 5.1.

WHO (Desai, et al, 2004) suggests to use ventilation coefficient 0.25 for households that use improved stove or have kitchen outside. National survey of solid fuel use in NFHS-3 estimated that in 22% of rural households and in 9% of urban households kitchens are located outside of the houses. So the solid fuel use exposure formula was corrected accordingly.

114. The following details relate to table 5.2 in the main report:

a. WHO estimates on COPD mortality for India are utilized in the analysis. COPD morbidity incidence, according to international disease classifications, are not

readily available for India. Regional estimates from WHO and Shibuya et al (2001) for the Sear D-WHO subregions are therefore applied.

b. The national average two-week prevalence rate of ARI in children under 5 years as in NFHS-3 is used to estimate total annual cases of ARI in children under 5. The procedure applied is to multiply the two-week prevalence rate (24 percent) by 52/3 to arrive at an approximation of the annual cases of ARI per child. A factor of 52/3 is applied for the following reason: The average duration of ARI is assumed to be about 7 days. This implies that the two-week prevalence captures half of the ARI prevalence in the week prior to and the week after the two-week prevalence period.

c. There is no information on ARI prevalence in adults. Krupnick et al (2006) provides an indication of the annual incidence of ARI per child relative to annual incidence for the rest of the population. An analysis of the database suggests that ARI incidence in the population above 5 years of age is 0.36 of the incidence in children under 5 years. In general, the percentage of cases of ARI that are treated at health facilities is higher among young children than older children and adults. For instance, in Krupnick (2006), the percentage of treated cases of ARI among 0-4 year olds is 1.15 times higher than among 4-year old children. Thus the incidence ratio of 0.36 is likely an underestimate of ARI cases in the population above 5 years of age. The annual cases of ARI per person among the population above 5 years of age, presented in Table 5.3, is therefore estimated in the range of 0.36 to 0.42 [(1/(0.85))*0.36] of the annual cases per child under-5.

d. ARI mortality in children under 5 years is presented in Table 5.2. 22 percent of children under 5 mortality due to respiratory infections reported in Office of Registrar General (2004). It suggests high mortality load among the corresponding category of population in India.

e. Table 5.2 also presents DALY per cases of ARI and COPD, which are used to estimate the number of DALYs lost because of indoor air pollution. The disability weight for ARI morbidity is the same for children and adults (i.e., 0.28), and the duration of illness is assumed to be the same (i.e., 7 days). The DALYs per 100 thousand cases of ARI is however much higher for adults. This is because DALY calculations involve age weighting that attaches a low weight to young children, and a higher weight to adults, that corresponds to physical and mental development stages.[28] For ARI child mortality the number of DALYs lost is 34. This reflects an annual discount rate of 3 percent of life years lost.

f. DALYs lost per case of COPD morbidity and mortality is based on life tables and age-specific incidence of onset of COPD reported by Shibuya et al (2001) for the Sear D region. A disability weight of 0.2 has been applied to COPD morbidity. A discount rate of 3 percent is applied to both COPD morbidity and mortality.

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[28] It should be noted that some researchers elect not to use age weighting, or reports DALYs with and without age weighting.

B. Baseline Data for Costs

115. Baseline data for the cost estimates of morbidity are given in Table A1.15. The percentage of ARI cases in the age group older than 5 years treated at medical facilities is estimated from percent of treated cases among children (NFHS-3) and the ratio of treated cases among children under 5 to treated cases among the population above 5 years of age (Krupnick, 2006).

116. The value of time for adults is 75 percent of urban and rural average daily wages, which are 150 Rs. and 60-75 Rs. respectively. The rationale for valuation of time was discussed in the section on water, sanitation and hygiene, and in the urban air pollution section.

117. There is very little information about the frequency of doctor visits, emergency visits and hospitalization for COPD patients in any country in the world. Schulman et al (2001) and Niederman et al (1999) provide some information on this from the United States and Europe. Figures derived from these studies are applied to India in this report. Estimated lost work-days per year is based on frequency of estimated medical treatment plus an additional 7 days for each hospitalization and one extra day for each doctor and emergency visit. These days are added to reflect time needed for recovery from illness.

118. To estimate the cost of a new case of COPD, the medical cost and value of time losses have been discounted over an assumed 20-year duration of illness. An annual real increase of 2 percent in medical cost and value of time has been applied to reflect an average expected increase in annual labor productivity and real wages. The costs are discounted at 3 percent per year, a rate commonly applied by WHO for health effects.

Table A1.15: Baseline Data for Cost Estimation

	Urban	Rural	Source:
Percent of ARI cases treated at medical facilities (children < 5 years)	78.1%	66.3%	NFHS-3
Cost of medicines for treatment of acute respiratory illness	240	240	Per consultations with pharmacies
Percent of ARI cases treated at medical facilities (females > 30 years)	35%	29%	International experience
Percent of COPD patients being hospitalized per year	1.5		Assumption based on Schulman et al (2001) and Niederman et al (1999)
Percent of COPD patients with an emergency doctor/hospital outpatient visits per year	15		
Average number of doctor visits per COPD patient per year	1		
Estimated lost workdays (including household work days) per year per COPD patient	2.6		Estimated based on frequency of doctor visits, emergency visits, and hospitalization
Cost of doctor visit Rs. per visit	700	100	NSS, 2004 and per consultations with pharmacies, medical service providers
Cost of hospitalization (Rs. per day)	980	600	
Cost of emergency visit (Rs.)	800	300	

Average duration of ARI in days (children and adults)	7		Assumption
Hours per day of care giving per case of ARI in children	2		Assumption
Hours per day lost to illness per case of ARI in adults	3		Assumption
Value of time for adults (care giving and ill adults) – Rs/hour	19	7.5-9.5	75% of rural wages in India
Average days hospitalization for COPD	10		Larsen (2004b)

VI. Valuation of Premature Mortality

119. Two distinct methods of valuation of premature mortality are commonly used to estimate the social cost of premature death, i.e., the human capital approach (HCA) and the value of statistical life (VSL). The first method involves estimating income losses from premature death and was dominant in the past. But because this measure is not based on individual preferences and for other conceptual problems, it has been overtaken by both stated and revealed preference approaches to estimating preferences for reducing mortality risks. The monetary value of these preferences, or willingness to pay, when divided by the relevant risk reduction yields the value of statistical life (VSL). Because HCA almost always underestimates the VSL, the HCA has been applied as a low estimate and VSL as a high estimate in estimating the cost of premature mortality.

A. Human Capital Approach.

120. The HCA is based on the economic contribution of an individual to society over the lifetime of the individual. Death involves an economic loss that is approximated by the loss of all future income of the individual. Future income is discounted to reflect its value at the time of death. The discount rate commonly applied is the rate of time preference. Thus the social cost of mortality, according to the HCA, is the discounted future income of an individual at the time of death. If the risk of death, or mortality risk, is evenly distributed across income groups, average expected future income is applied to calculate the social cost of death. Mathematically, the present value of future income is expressed as follows:

$$PV_0(I) = \sum_{i=k}^{i=n} I_0(1+g)^i / (1+r)^i \qquad (1)$$

where PV_0 (I) is present value of income (I) in year 0 (year of death), g is annual growth in real income, and r is the Ramsey discount rate. As can be seen from (1), the equation allows for income to start from year k, and ending in year n. In the case of children, we may have $i \in \{16,\ldots,65\}$, assuming the lifetime income on average starts at age 16 and ends at retirement at age 65. The annual growth of real income is variable, and set at about 5 percent for the first 30 years and reducing to 2 percent over the next 35 years. The GDP per capita growth rate was computed in the CGE model for India (see World Bank forthcoming report "Economic Growth and Environmental Sustainability"). Since the real

growth of GDP per capita is quite high, it should be accounted for in determining the social discount rate. We apply the Ramsey discount rate to real GDP per capita assuming an intertemporal coefficient of consumption equal to 1, as in Summers and Zeckhauser (2008). Then the average effective discount rate is set at about 1percent.

121. The most important practical issue raised regarding the HCA is the application of this valuation approach to individuals that do not participate in the economy, i.e., to individuals not having an income, such as the elderly, family members taking care of the home, and children. One may think of an extension of the HCA that recognizes the value of non-paid household work at the same rate as the average income earner, or at a rate equal to the cost of hiring a household helper. In this case, the HCA can be applied to non-income earners and children (whether or not children will become income earners or take care of the home during their adult life). In the case of the elderly, the HCA would not assign an economic value to old individuals that have either retired from the workforce or do not make significant contributions to household work. This obviously is a serious shortcoming of the HCA approach.

122. The estimated cost of mortality in India based on HCA is presented in Table A1.16. Average annual income is approximated by GDP per capita, corresponding to around 57 thousand Rs. per year. The estimates are from equation (1).

Table A1.16: Cost of Mortality (per Death) using HCA

	Average Number of Years Lost	Thousand Rs
Adults:		
Mortality from Urban Air Pollution	8	430
Mortality from Indoor Air Pollution	7	390
Children:		
Mortality from Urban Air Pollution	65	1,148
Mortality from Indoor Air Pollution	65	1,148
Mortality from Diarrheal Illness, Typhoid , children under 5	65	1,148
Mortality from Diarrheal Illness, Typhoid , children under 19	55	1,863

B. Value of Statistical Life.

123. While the HCA involves valuation of the death of an individual, VSL is based on preferences for reducing mortality risk by a small amount. Everyone in society is constantly facing a certain risk of dying. Examples of such risks are occupational fatality risks, risks of traffic accident fatality, and environmental mortality risks. It has been observed that individuals adjust their behavior and decisions in relation to such risks. For instance, individuals demand a higher wage (a wage premium) for a job that involves a higher than average occupational risk of fatal accident, individuals may purchase safety equipment to reduce the risk of death, and/or individuals and families may be willing to pay a premium or higher rent for properties (land and buildings) in a cleaner and less polluted neighborhood or city.

124. Through the observation of individuals' choices and willingness to pay for reducing mortality risk, it is possible to measure or estimate the value to society of reducing mortality risk, or, equivalently, measure the social cost of a particular mortality risk. For instance, it may be observed that a certain health hazard has a mortality risk of 1/10,000. This means that one individual dies every year (on average) for every 10,000 individuals. If each individual on average is willing to pay 10 Rupees per year for eliminating this mortality risk, then every 10,000 individuals are collectively willing to pay 100 thousand Rupees per year. This amount is the VSL. Mathematically it can be expressed as follows:

$$VSL = WTP_{Ave} * 1/ R \qquad (2)$$

where WTP_{Ave} is the average willingness-to-pay (Rupees per year) per individual for a mortality risk reduction of magnitude R. In the illustration above, R=1/10,000 (or R=0.0001) and WTP_{Ave}= 10 Rupees. Thus, if 10 individuals die each year from the health risk illustrated above, the cost to society is 10* VSL = 10*100 thousand Rupees = 1 million Rupees.

125. A number of VSL studies have been conducted in India. Table A1.17 presents a summary.

Table A1.17: Value of Statistical Life in India

Name of Study	Method of Estimation	Value	Adjusted Value (2010)	Adjusted Value in $ (2010) using ` 47.5 = $1 exchange rate
Shanmugam K.R. (1997	Compensating-wage differentials	` 12,084,000	` 18,932,020	$398,569
Simon et al (1999)	Compensating-wage differentials	` 6,417,341 - ` 15,040642	` 16,197,563	$341,001
Bussolo and O'Connor (2001).	PPP and income elasticity Brandon (1995) estimate	$ 202,000 - $343,860, use the central value of $273,000	` 19,109,280	$402,301
Madheswaran (2007)	Compensating wage differentials	` 15,000,000	` 16,939,353	$356,618

Source: prepared by A. Sagar.

126. The average VSL from these comes out at about $375,000 (Rs. 17.8 million) and this figure was applied in the report. From Table 6.2 it can be seen that the ratio of VSL/HCA is about 16 times for children and 44 times for adults.

127. In this report we used the average of the VSL and HCA values for adults (i.e. $192,000 or Rs. 9.1 million). For children we do not use the VSL value at all as none of the VSL studies are for children. Hence we take only the HCA value of $24,168 or Rs. 1.148 million (Table 6.1). This conservative approach is also consistent with other costs of degradation studies that have been conducted.

Annex II: Methodology of Natural Resource Degradation Valuation.

I. Soil Degradation

128. There is a lot of evidence that India has a substantial land degradation problem. Official data on land degradation are summarized in the table below. Total degraded area is 188 mn ha. (Table AII.1), which amounts to about 60 percent of total reporting land for land utilization statistics in the country29.

Salinity losses

129. The estimated losses from saline soils were calculated under the assumption that such land is only used for wheat production (if it is used at all). This reflects the assumption that when soils are saline farmers will tend to plant crops that are more tolerant of this factor and wheat is such a crop, as opposed to pulses and rice. FAO estimates indicate a loss of yield of 5% for wheat per unit salinity (dS/m) for levels of salinity over 6 dS/m. Taking these values and applying them to lands under wheat is the basis of the estimated loss of output30. Research by the Central Soil Salinity Research Institute (CSSRI) (2010) estimates about 3 million hectares of agricultural land as saline.

Table AII.1. Land degradation in India, million hectares (2002)

Degradation type	Degree of Degradation				
	Slight	Moderate	Strong	Extreme	Total
Water Erosion	27.3	111.6	5.4	4.6	148.9
a. Loss of topsoil	27.3	99.8	5.4	-	132.5
b. Terrain Deterioration	-	11.8	-	4.6	16.4
Wind Erosion	0.3	10.1	3.1	-	13.5
a. Loss of topsoil	0.3	5.5	0.4	-	6.2
b. Loss of topsoil/terrain deterioration	-	4.6	-	-	4.6
c. Terrain deformation/over blowing	-	-	2.7	-	2.7
Chemical Deterioration	6.5	7.3	-	-	13.8
a. Loss of nutrient	3.7	-	-	-	3.7
b. Salinization	2.8	7.3	-	-	10.1
Physical Deterioration	-	-	-	-	116.6
Waterlogging	6.4	5.2	-	-	11.6
Total (affected area)	36.8	137.9	8.5	4.6	187.8

Source: indiastat.com

130. Two scenarios are considered both of which assume that the total land cultivated for wheat in saline conditions is 2.9 mn ha. In scenario 1 it is assumed that these lands are only slightly saline (EC=4-8 dS/m). In scenario 2 some of this land is assumed to be slightly saline (2 million hectares) but some wheat is also cultivated on a moderately saline lands (0.9 million hectares). The estimated losses are then multiplied by the wheat farmgate

[29] 305.67 million hectares in 2008.
[31] The cost of wheat production are taken from indiastat.com.

prices in 2009 (12,000 Rs./Tonne (FAOSTAT)) and costs of production deducted to arrive at a net loss figure31.

Waterlogging losses

131. We assume that rice is mostly cultivated on waterlogged lands. Average rice yield losses on a waterlogged land are assumed to be 40% of the observed yield (as in Gundimeda, 2005). Based on available data it is estimated that rice is cultivated on 1.7 million hectares of waterlogged lands. Furthermore the annual farmgate price of paddy is 18,000 Rs. (FAOSTAT).

Soil erosion losses

132. State of Environment, India, 2001 and Gundimeda et al., 2005 report that annually about 29-55 tonnes of major nutrients is leached out from the land in India. Table AII.2 presents an estimate of the amount of fertilizers required to substitute annual humus loss of nutrients through leaching.

Table AII.2. Fertilizers for Nutrient Loss Substitution

	Required to replace the leached out major nutrients, in tonnes		Price in 2009, Rs./t
	Gundimeda, 2005	State of Environment, 2001	
Nitrogen	1.4	0.8	22,000
Phosphorus	3.3	1.8	15,000
Potassium	50.2	26.3	10,375

Source: State of Environment, India, 2001 and Gundimeda et al., 2005; indiastat.com; Nitrogen recalculated from price of Urea (46% N), Phosphorus is recalculated from price of Diammonium Phosphate@ (18-46-0), potassium is recalculated from price Muriate of Potash (60% K2O) presented in indiastat.com.

II. Pastures degradation

133. Data on the extent of degraded grazing lands were not readily available. In the last 60 years lands available for grazing have remained relatively stable, but livestock measured in Adult Cattle Units (ACU) have increased by about 50 percent. The impact of this increase in pressure has been a decline in the fodder available on rangelands. Based on interviews with rangeland experts in India and data in Roy and Roy (1996),32 the current average yield is estimated at 1.1 tons of dry matter (DM) per hectare on degraded rangelands. In the absence of degraded grazing land productivity data, we assume that productivity on the degraded lands is at 0.55 TDM/ha. Original productivity is assumed at the 3.5 TDM/hectare. This is at the lower level of different grazing lands productivities presented in Roy and Roy, 1996.

134. For the first method we use a fodder price of 4000-8000 Rs. per ton of DM (price of grains residuals and grass fodder from http://www.downtoearth.org.in/node/802). Based on that the loss the reduced fodder production amounts to 400-800 billion Rs. per year average

[31] The cost of wheat production are taken from indiastat.com.

[32] TDM/ha estimated from Adult Cattle Unit (ACU) consumption of 2% of body weight per day.

for a sustainable rangeland fodder utilization rate of 40 or 60% (see Hocking and Mattick,1994). On average this is at about 0.91% of GDP in 2010.

135. Additional losses could be attributed to complete loss of pasture lands and their transfer to barren lands. However, there is no reliable data that would allow estimation of this loss.

136. The second method takes the loss in fodder and calculates the number of animals it would support and the net income from these animals. The steps in the calculations are as follows:

1. Due to degradation the fodder from the rangelands in India has declined by between 89 and 134 million tons (TDM). This is based on a rangeland area of 79.8 mn ha, with a sustainable consumable yield of between 1.4 and 2.1 tons per ha. Due to degradation this yield has fallen by 80%.

2. The decline in yield could have supported 50 and 75 million ACUs, given that each ACU requires 1.8 tons of TDM per annum.

3. Each ACU has a contribution to GDP of Rs. 3,410. This is based on the fact that there are 499 million ACUs in India and their total contribution to GDP is Rs. 1,702 billion.

4. Hence the total loss in income from the degradation is between Rs.170 billion and Rs. 256 billion or between 0.3 and 0.4 percent of GDP.

III. Forest Degradation

137. Loss of forest value by the degraded forest is in the core of forest degradation methodology. The methodology for forests valuation is presented below. Only forest use values are estimated in the report.

138. The use values used in the study are taken from the extended study Green Accounting for Indian States and Union Territories Project (GAISP) (2005-2006) that was designed to build a system of adjusted national accounts for India to estimate genuine national wealth as a comprehensive measure of growth instead of GDP. We applied some of the estimates developed in this study to estimate CED of forests in India.

139. Forests yield a wide variety of plants and animals used in the traditional life and farming system: (a) foodstuffs (including mushrooms, fruits, nuts, roots, game, and leaves) to complement diets or generate small amounts of cash; (b) medicinal plants and seasonings, either used domestically or sold in local markets; (c) construction materials and materials for household utensils, including furniture wood, roofing materials, mats, trays, storage containers, and house timber; (d) fuel wood for cooking and small-scale enterprises; and (e) commercial extraction of chicle and resins. Forests are also supplementary areas for grazing, and in the tropical zones are used in rotation in the traditional slash and burn agricultural systems. Direct use values for forest lands could be estimated based on direct

market values of goods produced there. Values of major forest goods, like roundwood (including timber and fuel wood), non-timber values and fodder were estimated using market prices. World Bank (2006) reports that 5%-42% of rural household income is generated by forest products.

Logging

140. FAO (2009) Forest products reported annual roundwood production in India. It includes all wood removed with or without bark, including wood removed in its round form, or split, roughly squared or in other form (e.g. branches, roots, stumps and burls (where these are harvested). Fuelwood is included in this aggregate. FAO (2009) estimates that annual roundwood production is at about 3.3 million m3. If as in Gundimeda (2005) about 10% of forest is destroyed at the time of logging, then total roundwood removed is at about 3.7 million m3 annually. Brandon (1995) suggests an average stumpage price for $100 per m3 of roundwood. It approximately corresponds to the roundwood profit margin reported in World Bank (2006). Then estimated value of annual timber extraction in India is at about 17 billion Rs. As in Gundimeda (2005) we apply a conservative estimate of non-timber values at 301 Rs./ha. timber.

Non-Timber Value

141. Non-timber value is estimated at about 21 Billion Rs. Annually.

Fodder

142. Fodder is estimated in Gundimeda (2005) at about 23.6 million tonnes annually (4.9 tonnes of dry matter and 2% of 3 tonnes of leaf biomass per hectare). With current fodder prices at 8000 Rs./t and relatively cheap substitution of straw at 4000 Rs./t total value of fodder generated in forest cover land is in the range 94-189 billion Rs.

Recreations Use (Eco-Tourism)

143. Gundimeda (2005) applies travel cost method to estimate ecotousrism value per hectare of Indian forests. Only national parks are assumed to attract tourists. He estimates that 15.7 million hectares of natural parks in India bring 14,165 million Rs. annually. Then assuming growth of tourist industry up to 2020, annualized NPV of tourist industry (4% discount) per hectare would be about 3260 Rs. or about 51 billion Rs. for all natural parks. This estimate reflect potential benefits from forests in India, so this benefit is quite uncertain.

Carbon Sequestration

144. Carbon storage is another important function of forests that adds to its value. There are a lot of studies that estimate carbon potential of Indian forests. We apply estimated average net carbon accumulation by hectare of forest reported in Gundimeda1 (2001) 1.1-1.4 t/hectare annually. The carbon price is assumed at 20USD/tCO2, which corresponds to the recent estimate of the social price of carbon. Other alternatives for carbon price (i.e. CDM price) do not provide a viable alternative. For instance, CDM price is mainly driven by EU ETS limits on international offsets. The EU regulated entities have nearly filled in their limits (including phase 3 EU ETS) and, therefore, over the last several months the spread between EUA and CER continues to grow. US$20 of social cost of carbon in this

case appears as today's equivalent of future proxy of global carbon price. It is a good reasonable estimate for shadow benefits of carbon sequestration.

145. Then annual benefits from net carbon accumulation by forests are in the range 270-340 Billion Rs.

Indirect Use Values

146. Indirect use values of forest include watershed protection, nutritional and erosion/flood prevention, and water/nutrient recycling. Although there is no definite agreement in the literature about the magnitude of this forest value, Pearce et al (1999) presents a higher end estimation of US $30 per hectare of forest generalized from the literature review. In this study erosion prevention value was estimated using data on nutrients loss prevention per hectare of dense forest reported in Gundimeda (2005). Total soil loss prevented by dense forest is estimated using fertilizers' prices from indiastat.org and www.indg.in, recalculated per tonne of N, P, and K. The resulting figure of total soil loss prevented by forests comes out at 15.5 billion Rs. Details are given in the table below.

Table AII.3. Estimation of erosion loss prevention function in India.

	N (urea)	P (Diammonium Phosphate)	K (Muriate of Potash)	Organic carbon
Loss prevented, t	232,492	4,409	826,749	2,254,770
Effective price, Rs./t	25,000	6,880	10,375	500
Loss prevented, Billion Rs.	5.8	0.03	8.6	1.1

147. Water recharge value was estimated from opportunity price of water adjusted to 2009 with WPI (7.9 Rs./m3). Water recharge value per hectare of dense forest was estimated in Gundimeda (2005) at 106 m3. Then total water recharge value of forest is at 6.4 billion Rs. Flood prevention damage was excluded from consideration since flood losses were estimated in a separate chapter. Gundimeda (2005) suggested that presence of dense forest will reduce flood damage by one third. However separate analysis is required to associate flood damage function with dense forest in each state where dense forest is present.

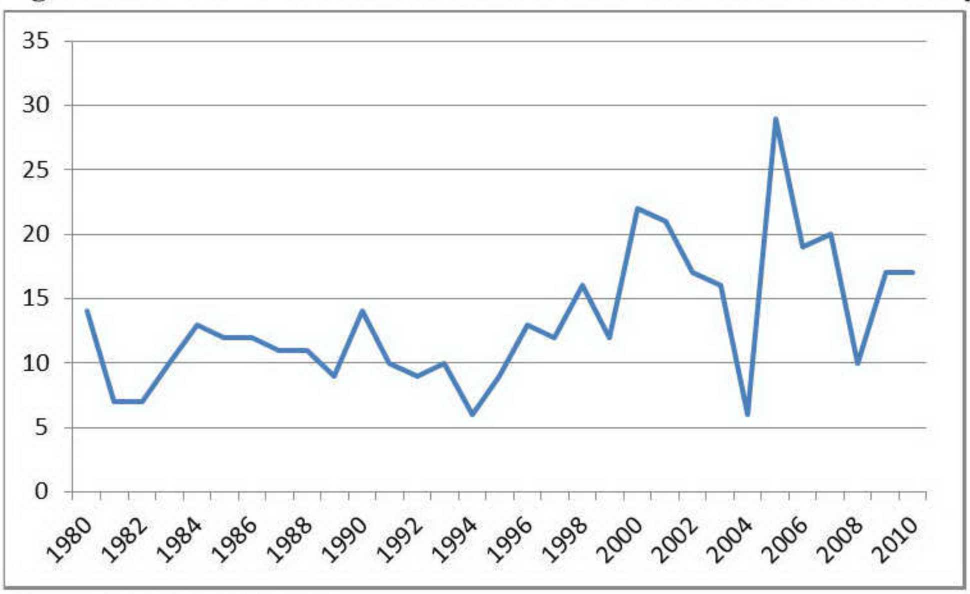
Annex III: Natural Disaster Costs

Background

149. India is annually afflicted by natural disasters such as floods, landslides, tropical cyclones, and storms occur periodically. The total mean annual cost of natural disasters was estimated at 150 billion Rs. or 0.23 percent of GDP in 2009.

150. In the literature floods and storms, including tropical cyclones are indicated as a significant source of natural hazard and damage for human health, agriculture, real estate, infrastructure and personal property. Natural disasters occurrence is highly uncertain. Although published data are incomplete and very often not comparable, based on available sources it is possible to analyze implied damage from natural disasters in India. Figure AIII.1 presents occurrence of natural disasters, including floods, heat and cold waves, storms, tropical cyclones, droughts, mudslides and landslides, epidemics, etc. registered by EM-DAT starting 1980 in India.

Figure AIII.1. Annual occurrence of natural disasters in India: last 30 years.



Source: EM-DAT, 2011.

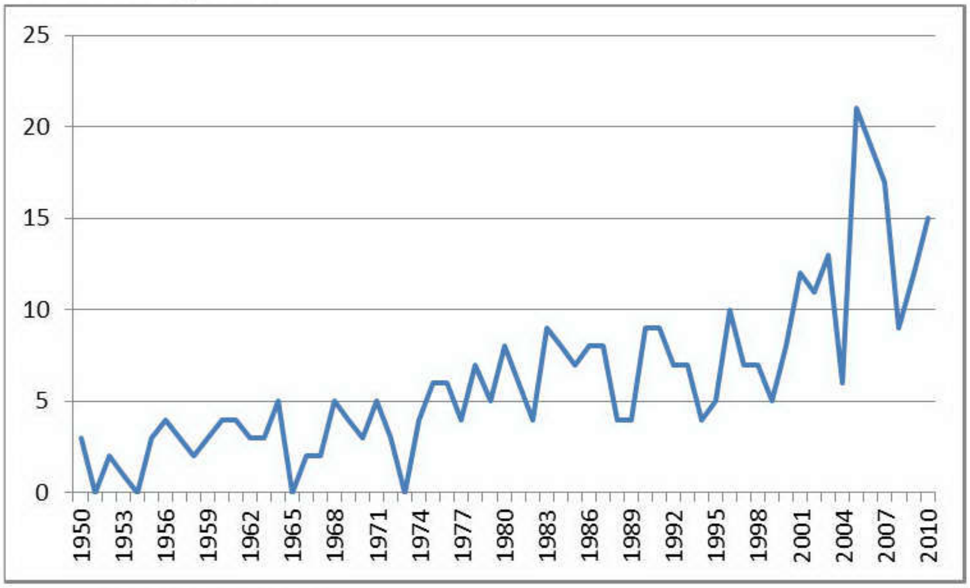
151. During the last decade natural disasters' frequency has significantly increased. Climate change could be accountable for some of this increase but anthropogenic activity was an important confounding factor that exacerbated the negative impact of natural causes. The main types of natural disasters were tropical cyclones, floods and severe storms and their frequency increased over the last decade, see figure AIII.2.

Impacts of Natural Disasters

152. Economic losses from natural disasters include direct and indirect costs. Direct costs include human health losses in terms of mortality and morbidity, property damage, crop and livestock damage in agriculture and public infrastructure losses. Due to the lack of data we were not able to estimate indirect losses, reflected in contraction of economic activity,

property value losses, etc. associated with short term and long term shocks of economy induced by natural disasters. Figure A3.3 presents estimated direct losses from floods and storms in India starting 1993.

Figure A3.2. Floods, tropical cyclones & storms: annual occurrence in India in the last 60 years.



Source: EM-DAT, 2011.

153. The direct economic losses from natural disasters were estimated using physical indicators of losses due to floods and heavy rains. Details are given in Table AIII.1.

Table AIII.1: Methods of Valuation for Natural Disasters

Category of Damage	Method of Valuation	Comments
Loss of life	Average of HC and VSL approaches for adults, HC approach for children	Rs. 9 million per adult Rs. 1.4 million. per child
Injury	Based on loss of earnings. 0.5 months of wage loss per event at 75% of wages	Rs. 1,100 per person per event
Crops	Loss of net revenue per hectare under wheat and paddy with cropping intensity of 1.39	Average net revenue for wheat and paddy was taken as Rs. 13,000/ha.
Livestock	Market price of and indigenous cow	Priced at 20,000 Rs. [33]
Property Damage	Adjusted for inflation information	Adjustment based on WPI
Public Infrastructure	Adjusted for inflation information	Adjustment based on WPI from

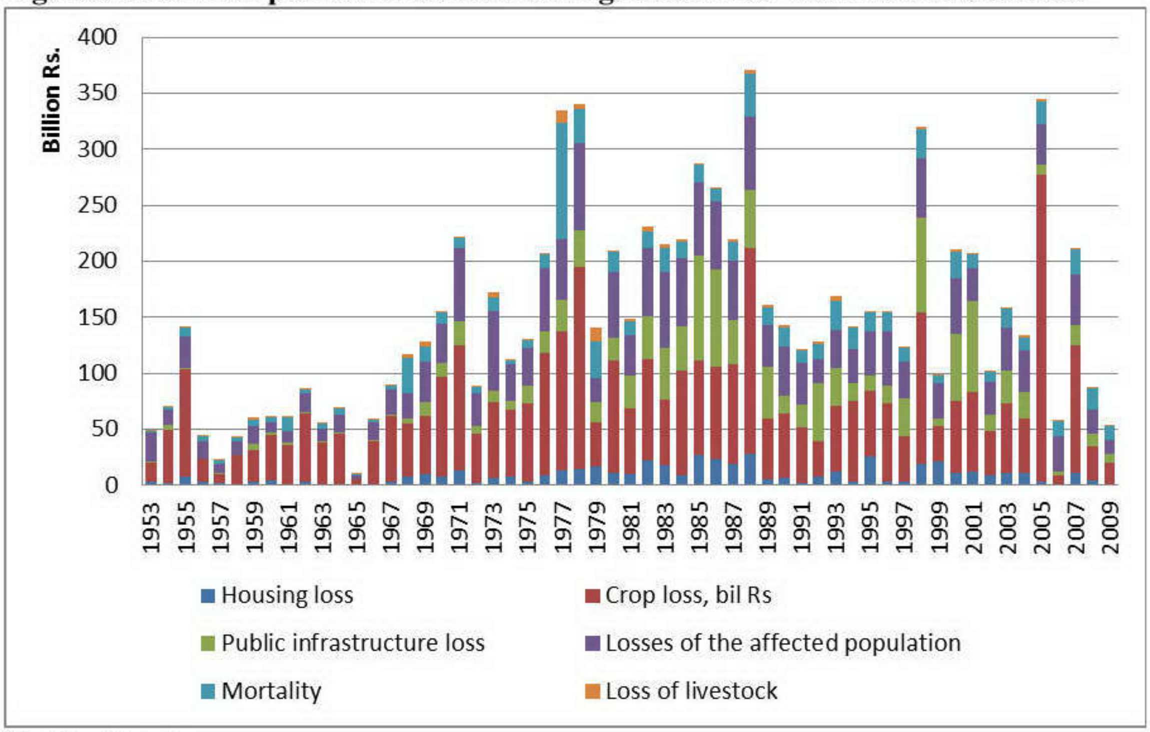
Source: Staff estimates

154. Figure AIII.3 presents estimated composition of annual damage associated with natural disasters that were estimated at 150 Billion Rs. on average over the period 1953-

[33] Expert estimates.

2009 (in constant 2009 prices)34. As a percentage of GDP, we look at damages over the relatively recent past, as the level of damages is a function of the level of development. At the same time figures for one year can be misleading as disasters have a high degree of volatility. Hence we consider the average damages from 2000 to 2009, which turn out to be 0.37% of 2009 GDP. Crop losses dominate the total damage (about 45% of average losses) and losses of the affected people are second at about 24% of damage.

Figure AIII.3. Composition of annual damage associated with natural disasters.

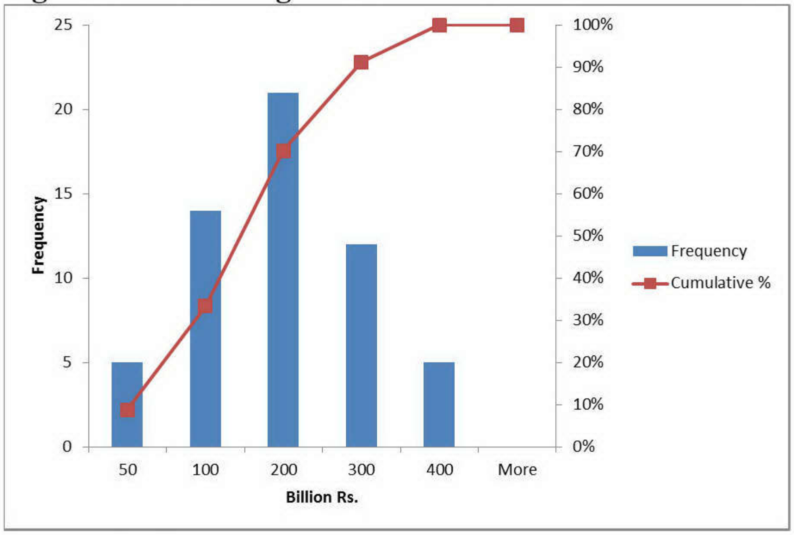


Staff estimates

155. Estimated annual damage exhibits substantial variability and slight tail risk of occurrence of rare events with high negative outcome. Figure AIII.4 below presents histogram of annual losses distribution over the same period of time starting in 1953. The most likely magnitude of annual damage is in the range 100-300 billion Rs. with a mean at 150 Billion Rs. and standard deviation (SD) at 87 Billion Rs. Damage distribution has a slight positive skewness and kurtosis. It confirms a conclusion about right tail: low frequency of events with high anticipated losses from natural disasters. In the future frequency and value of these events may increase.

[34] Losses starting from 1953 are valued at 2009 prices since some components of the losses were not valued (loss of life, losses of affected people, livestock loss). Crop losses were estimated in the same way to maintain comparability of the cost components. Other losses (housing losses and public infrastructure losses) were adjusted for inflation since there is no data on the level of assets loss.

Figure AIII.4. Histogram of annual losses distribution.



Source: Staff estimates

156. The natural disaster analysis aims to demonstrate a magnitude of economic losses related to natural disasters. These losses are not entirely attributable to environmental degradation, but attribution of this damage to different anthropogenic and non-anthropogenic causes was not in the scope of this study. Yet the costs related to natural disasters are seen as environment-related and are generally higher where protection measures are limited – typically in developing countries. Moreover there has been an increase in damages arising from such disasters over the past decades. Hence information on trends on damages from natural disasters could be of interest.

157. The estimate was based on information available and performed in a conservative way. Results of the analysis for each type of disaster are aggregated and averaged. Although a distinction between flow and stock is important, for housing and infrastructure losses we included the full recovery cost. If houses are destroyed regularly, then the recovery cost appears as a flow. For more detailed analysis the methodology developed under the auspice of the GFDRR could be applied. This analysis could be performed in the future.