Climate Change and Rural Poverty Levels in India

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Although there is wide recognition of the adverse impacts of climate change and extreme weather events on poverty, there is hardly any empirical evidence to substantiate this. The trends and the role of agricultural growth and other factors on rural poverty in India—which has the largest concentration of the poor in the world—have been analysed, and the likely changes in rural poverty levels in India under alternative climate scenarios have been assessed. Evidence presented here suggests that rural poverty trends in India, which witnessed a significant decline during the post-reform period beginning from 1991, may get reversed and may increase due to the likely adverse impacts of climate change on Indian agriculture, and other drivers of poverty. Not only will the proportion of poor population likely rise, but also the depth and severity of rural poverty measured through the poverty gap index and squared poverty gap index may aggravate sharply in response to warming temperatures and other climatic changes.

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Poor and marginalised people will be affected the most by the risks posed by climate change and extreme weather events such as droughts, floods, cyclones and other natural calamities. This has an impact on their lives and livelihoods through loss of crop yields, incomes, assets, employment, etc. Added to this, a rise in food prices following crop loss hurts the poor who are net buyers of food. The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) notes that climate change and climate variability will "worsen existing poverty, exacerbate inequalities and trigger both new vulnerabilities and some opportunities for individuals and communities … it will create new poor between now and 2100 in developed and developing countries, and jeopardize sustainable development" (IPCC 2014a). "Climate change driven impacts … act as a threat multiplier meaning that the impacts of climate change compound other drivers of poverty … Climate change intersects with many causes and aspects of poverty to worsen not only income poverty but also undermine well-being, agency, and a sense of belonging" (IPCC 2014a). It will impede economic growth and efforts to achieve the United Nations' (UN) Sustainable Development Goal 1 that seeks to reduce the number of poor people by half and eradicate extreme poverty in all its forms everywhere by 2030. Funds that can otherwise be used for development purposes have to be diverted to invest in climate infrastructure and build climate resilience as well as provide safety nets for the poor (Ninan and Inoue 2017). The Stern Review (2007) observes that climate change is a grave threat to the developing world and a major obstacle to continued poverty reduction across its many dimensions.

Although there is recognition about the harmful effects of climate change and extreme weather events on poverty and poverty reduction, there are hardly any studies which have tried to assess the impact of climate change on poverty levels. The IPCC Assessment Report cited earlier acknowledges the lack of evidence or empirical studies that can shed light on the likely climate change impact on poverty levels, except for two studies from Zambia and Tanzania which suggest an increase in the numbers of the poor in response to warming temperatures (IPCC 2014a). This study seeks to address this research gap and assess the likely impact of climate change on rural poverty levels in India.

India is well suited for conducting the above study. It has the largest concentration of the world's poor, accounting for almost 30% of the total global poor of 767 million in 2013 living below the international poverty line of $1.9 per person per day (World Bank 2016). Besides, it is well endowed in terms of the availability of time series data on poverty spanning almost six decades from 1951 to 2012. Although the share of agriculture in gross value added in India has fallen to around 16% in 2015–16, India is still primarily an agrarian society with close to 50% of the labour force dependent on agriculture for their livelihood. Hence the agricultural sector, which is most climate sensitive, will continue to influence the fortunes of the poor in India, apart from other factors. The availability of a fairly good number of studies that have tried to assess the impact of climate change on Indian agriculture under alternative climate scenarios is another advantage. These studies suggest that agricultural output in India will decline sharply by 10% to 40% or more in response to rising temperatures and other climatic changes that will have serious implications for India's poor (Cline 2008; Dinar et al 1998; Kavi Kumar and Parikh 1998; Sanghi et al 1998; Sanghi and Mendelsohn 2008). Our focus is on rural poverty which accounts for major share of the total poor population in India. Although there is a trend towards urbanisation in Asia and other regions of the world, a recent UN report indicates that this pace in India is slower and even by 2050 almost 50% of the population will continue to reside in rural areas (UN 2014).

After discussing about the data and methodology used for the study, we analyse the trends and determinants of rural poverty in India. Thereafter, we rely on existing literature that has assessed the climate change impacts on Indian agriculture, and analyse the likely impacts of climate change on rural poverty levels in India under alternative climate scenarios.

Materials and Methods

To analyse the above issues the poverty data set compiled by G Datt, M Ravallion and R Murgai (2016) for a recent study has been used. These poverty estimates are computed based on the household consumer expenditure surveys collected by the National Sample Survey Office (NSSO). The poverty line used for computing the poverty indicators is determined by the Planning Commission as recommended by the Expert Group on Estimation of the Proportion and Number of Poor, 1993 (Planning Commission 1993). As per this, the poverty line corresponds to a per capita monthly expenditure of ₹49 for rural areas and ₹57 for urban areas at 1973–74 all India prices (Planning Commission 1993: 13). In terms of 2011–12 prices this was estimated at ₹617 and ₹922 in rural and urban areas (Datt et al 2016). These poverty lines correspond to a total household expenditure sufficient to provide, in addition to basic non-food items such as clothing and transport, a daily nutritional intake of 2,400 calories per person in rural areas and 2,100 calories in urban areas. Using the NSSO consumer expenditure survey results and this poverty line, Datt et al (2016) have computed three poverty indicators or measures, head count ratio (HCR), poverty gap index (PGI) and squared poverty gap index (SPGI), for rural and urban areas at all-India level. These indicators measure three dimensions of poverty, namely, the extent, depth and severity of poverty and belong to the general class of poverty measures proposed by Foster, Greer and Thorbecke in 1984 (World Bank 1997). The HCR measures the proportion of the population with per capita consumption or income levels below the defined poverty line whose real value is fixed over time; the PGI measures the average distance below the poverty line in the population (counting the non-poor as having zero poverty gap) expressed as a percentage of the poverty line; whereas the SPGI is based on the individual poverty gaps raised to a power of two, that is, it is the mean of the squared proportionate poverty gaps (World Bank 2007). Datt et al (2016) have also calculated the Gini ratios to measure the inequality in rural consumption (a proxy for income inequality). These poverty data along with the Gini ratios have been computed for the period 1951 to 2012, the latest year for which such data are available.

The data, however, suffer from a few limitations. The data are available almost uninterrupted from the 1950s to 1973–74. Thereafter, until 1986–87, they are available at greater point intervals due to a decision taken by the NSSO to collect such data on quinquennium basis (Ninan 2000). However, with a view to build a time series of poverty data, a decision was taken again to collect such data on an annual basis from 1986–97 based on a smaller sample to supplement those collected during the quinquennium surveys. Apart from this uneven spacing, the length of the NSSO consumer expenditure surveys has varied from six months to one year, and some based on calendar years and others corresponding to or nearabout the agricultural year (Ninan 2000). Notwithstanding these limitations, these are the only data on poverty available for a long time period for any developing country. A considerable amount of research analysing the poverty trends and its determinants in India (see for example, Ahluwalia 1978; Rath and Dandekar 1971; Datt and Ravallion 1998; Deaton and Drèze 2002; Ninan 1994, 2000; Ravallion and Datt 1996) have been based on the NSSO data. Time series data on other variables used for the study such as net gross domestic product (GDP) from agriculture, foodgrain production, Consumer Price Index for Agricultural Labourers (CPIAL) (for food and general items), gross cropped area, offtake of subsidised food through the public distribution system (PDS), net availability of foodgrain in India and estimated rural population have been collected from the Handbook of Statistics of the Indian Economy, 2014–15 published by the Reserve Bank of India (RBI), official publications of the Government of India such as the *Economic Survey 2012–13*, Agricultural Statistics at a Glance 2016, and Rural Development Statistics 2015–16.

Before estimating trends, we may take note of a few other factors. There are valid theoretical and empirical grounds to believe that the period to which these observations belong are not structurally homogeneous in terms of the factors influencing India's economic growth and the agricultural sector as well as the policy environment facing the poor. A visual examination of the poverty data indicates that poverty levels rose steadily up to 1968–69 and thereafter started falling though this trend was not smooth. The green revolution that facilitated the adoption of high-yielding crop varieties, especially rice and wheat, and other modern inputs, such as chemical fertilisers and pesticides marked an important phase in India's agricultural development when there was a structural break in the trend rate of agricultural growth in India from 1967 onwards that had an impact on the poor and poverty reduction. Besides this, the post-1969–70 phase also witnessed a spurt in pro-poor welfare programmes due to economic and political compulsions faced by the then Indian government. Thereafter, 1991 marked a watershed moment in India's growth story when the central government decided to usher in economic reforms and Structural Adjustment Programme (SAP) which again had an impact on the Indian economy and social sectors. For these reasons, to fit trends we have limited our analysis to the period from 1969 to 2012, the latest year for which poverty data are available, as noted earlier. Further, for fitting trends we have considered the period from 1969 to 1990 as the pre-reform period and from 1991 to 2012 as the post-reform period. For analysing determinants of rural poverty in India we have restricted our analysis to the post-reform period from 1991 to 2012.

To analyse the trends in rural poverty we have used the following model:

$g_t = a_0 + a_1 t + a_2 d + a_3 (d.t) + u$

where

g = Head Count Ratio or Poverty Gap Index or Squared Poverty Gap Index

d = Dummy variable where d = 0 for the pre-reform period and d = 1 for the post-reform period

t = Time variable

d.t = Product of dummy and time variables

u = Error term

From the estimated equation we can derive the equations for the pre- and post-reform periods (Periods I and II) as follows:

Period I: $g_t = a_0 + a_1 t$

Period II: $g_t = (a_0 + a_2 d) + (a_1 t + a_3 (d.t))$

The above model provides greater degrees of freedom for econometric analysis as inferences about the poverty trends during the pre- and post-reform periods can be made based on a single sample rather than two, that is, fitting two separate trends for Periods I and II (Ninan 2000). It also enables us to see whether the slope has changed over Periods I and II. Ordinary least squares (OLS) method has been used to estimate the linear trends in rural poverty at all-India level. The trends for Periods I and II for the three alternate poverty indicators, that is, HCR, PGI and SPGI, are derived from the estimated linear equation discussed earlier.

From the theoretical and empirical literature, it is seen that a number of factors influence rural poverty. Of them agricultural performance or output is seen to be a major factor influencing rural poverty. In a seminal paper Ahluwalia (1978) observed a strong negative association between agricultural performance and rural poverty in India. Later, other studies too confirmed this negative relationship between agricultural performance and rural poverty trends in India (Datt and Ravallion 1998; Ravallion and Datt 1995, 1996; Ninan 2000). A good agricultural performance is advantageous to the poor in many respects. A higher agricultural output helps reduce prices as well as improve food availability both of which are beneficial to the poor (Ninan 2000). Besides, it will not only augment employment opportunities in the agricultural sector but also spur growth in the non-agricultural sector, thereby creating income earning opportunities (Ninan 2000). Agricultural growth helps in raising agricultural incomes which benefits the poor. The World Development Report 2008 notes that growth in agriculture is two to three times more effective in reducing poverty than the same quantum of growth in the non-agricultural sectors (World Bank 2007). For our analysis two alternative specifications of the agricultural performance variable are used, that is, real net domestic product (NDP) from agriculture per capita (rural), and in the alternate case, foodgrain production per rural inhabitant.

Another factor that influences rural poverty is food prices. Food constitutes a major share of the consumption basket of the poor and hence a rise in food prices acts as a regressive tax and hurts the poor the most since they are net buyers of food, as noted earlier. The price index relevant for rural areas in India is the CPIAL compiled by the Labour Bureau. In recent years, the Labour Bureau furnishes such index separately for agricultural labourers and rural labourers. But the price index for rural labourers is available from 2011–12 onwards only. Hence, CPIAL, which is available for the entire period of our analysis, is used for our regression analysis. Two alternative specifications of this variable are used, namely, the food price index and alternatively the relative food to general CPIAL.

Numerous pro-poor welfare programmes ushered in after 1969–70, such as distribution of subsidised food through the PDS and under other schemes, as well as rural employment guarantee schemes, such as the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA), 2005, have helped reduce hunger by putting affordable food within the reach of economically and socially disadvantaged people as well as improving nutrition and the entitlements of the poor. To take note of the role of such pro-poor welfare programmes on rural poverty in India we have considered the offtake of PDS foodgrains to total net availability of foodgrains in India. A limitation, however, is that this data is not available separately for rural and urban areas and hence we must rely on the combined figures for rural and urban areas for specifying this variable.

It is well known that poverty, environment and population growth are closely linked. Population pressure on scarce environmental resources such as land can result in overexploitation of fragile resources which will impact the poor and poverty levels. Another variable considered for our regression analysis is rural population pressure on agricultural lands. To take note of land augmenting technologies this variable is expressed in terms of rural population on agricultural land, that is, per hectare (ha) of gross cropped area.

Growing rural inequalities in terms of income, consumption and access to resources too can impact adversely on rural poverty trends, apart from other factors. The Gini ratio that measures the inequality in rural consumption has been also considered in our analysis.

Keeping in view the above discussion, the following variables are used to analyse the determinants of rural poverty in India:

Dependent variables: HCR or alternatively PGI or SPGI.

Independent variables: To analyse the role of agricultural performance/output, food prices, rural population pressure on environmental resources, inequality in rural consumption (a proxy for inequality in rural incomes) and access to subsidised food distributed through the PDS on rural poverty in India, the following variables are used.

Agricultural performance/output variable (Two alternate specifications of the variable are used):
NDPAGRI = Real Net Domestic Product from agriculture in million rupees at 2004–05 prices per rural inhabitant
FDPROD = Foodgrains production per rural inhabitant

Price variable (Two alternate specifications are used):
FDPR = Consumer Price Index for Agricultural Labourers for food items with base 1986–87 = 100
RELFP = Relative Food to General Consumer Price Index for Agricultural Labourers with base 1986–87 = 100

Population pressure on environmental resources: RPPAL = Rural Population Pressure on Agricultural Land expressed in persons per ha of gross cropped area to take note of land augmenting technologies

Institutional intervention variable: PDS = Proportion of PDS Offtake of foodgrains to total net availability of foodgrains.

Inequality in consumption: RGINI = Inequality in rural consumption measured by Gini ratios

Table 1: Trends in Rural Poverty and Inequality in Rural Consumption in India, 1969 to 2012

Poverty Indicator	Pre-reform Period		Post-reform Period		Adj R^2	DW
	Constant	Time	Constant	Time		Statistic
Head count ratio	73.63*	–0.89*	72.80*	–1.71*	0.93	2.04
Poverty gap index	27.22*	-1.11*	27.46^{ns}	-1.19^{ns}	0.95	2.02
Squared poverty gap index	12.84*	-1.23*	12.74^{ns}	–0.86***	0.96	1.92
Gini ratio of inequality in consumption	30.44*	-0.24^{ns}	29.78^{ns}	-0.24^{ns}	0.08	1.90

1 These equations for the pre- and post-reform periods are derived from the estimated equations using the model discussed in the text. Trends computed are linear trends.
2 *, **, ***, indicates estimated coefficients to be statistically significant at 1%, 5%, and 10% levels of significance; ns- estimated coefficients not statistically significant at the above levels of significance. In the equations for the post-reform period derived from the estimated equations, the significance of the constant term is inferred based on the statistical significance of the dummy variable in the estimated equation, while that of the time trend variable is inferred based on the statistical significance of the (d.t) variable. Pre-reform period, 1969 to 1990; post-reform period, 1991 to 2012.
Source: The basic data on poverty indicators and inequality in consumption for rural India were computed by Gaurav Datt et al (2016) for a recent study. The latest year for which poverty data are available is 2012.

Table 2: Determinants of Rural Poverty in India, 1991 to 2012

Equation No	Estimated Linear Equations	Adj R^2	DW Statistic
	Dependent variable: Head count ratio		
1	-17.64^{ns} - 0.50 NDPAGRI* + 0.11 RELFP ^{ns} + 0.26 RGINI** - 0.49 PDS**	0.84	1.9
2	-26.02^{ns} - 0.20 FDPROD ^{ns} + 0.08 RELFP ^{ns} + 0.28 RGINI** - 0.85 PDS*	0.75	1.6
	Dependent variable: Poverty gap index		
3	-22.68^{ns} - 0.48 NDPAGRI* + 0.13 RELFP ^{ns} + 0.32 RGINI*** - 0.50 PDS*	0.86	1.9
4	-25.35^{ns} - 0.17 FDPROD ^{ns} + 0.10 RELFP ^{ns} + 0.34 RGINI* - 0.85 PDS*	0.78	1.5
	Dependent variable: Squared poverty gap index		
5	-13.59^{ns} - 0.47 NDPAGRI* + 0.14 RELFP ^{ns} + 0.36 RGINI* - 0.50 PDS*	0.86	1.8
6	-14.65^{ns} - 0.16 FDPROD ^{ns} + 0.12 RELFP ^{ns} + 0.38 RGINI* - 0.84 PDS*	0.78	1.4

1 For a description of the independent variables refer text.
2 *, **, *** denotes that estimated coefficients are statistically significant at 1%, 5% and 10% levels of significance; ns -not statistically significant at the above levels of significance.

Details regarding how we assess the likely changes in rural poverty levels in India under alternative climate scenarios are elaborated in the last section.

Results and Discussion

Rural poverty trends: Information about the trends in rural poverty in India for the three poverty indicators discussed earlier and trends in the inequality of rural consumption are presented in Table 1. The table reveals that during both the pre- and post-reform periods rural poverty trends in India measured by the three poverty indicators not only registered a decline, but this decline was faster during the post-reform period except for the SPGI. This declining trend was statistically significant in most cases except for the PGI during the post-reform period. Inequality in rural consumption in India measured in terms of Gini ratios also registered negative trends in both the periods though the coefficients were not statistically significant.

Determinants of rural poverty: Multiple linear regressions have been estimated to assess the role of the selected variables on rural poverty in India. Prior to undertaking the regression analysis, we checked whether the time series data of the variables under review are stationary or non-stationary. The Augmented Dickey–Fulton (ADF) test using the R software package was used which confirmed that the time series data of all the variables was stationary. A zero-order correlation matrix revealed high collinearity between some of our independent variables, that is, NDPAGRIC and FDPR (0.94), FDPR and RPPAL (0.85), FDPR with PDS (0.86), and RPPAL and PDS (0.87). Hence, this aspect was considered while estimating the regression equations. Of the estimated equations those that gave meaningful results with the estimated coefficients having expected signs and statistically significant (in most cases) are presented in Table 2.

As evident, the agricultural performance variable (NDPAGRI) has a significant and negative relationship with rural poverty trends in India during the post-reform period from 1991 to 2012. This is true for all three rural poverty indicators, HCR, PGI and SPGI. This is in conformity with findings of previous researchers who confirmed the poverty alleviating role of agricultural growth or performance (Ahluwalia 1978; Datt and Ravallion 1998; Ninan 2000; Ravallion and Datt 1995, 1996). However, most previous studies covered the pre-reform period prior to 1991 only or the initial years of the post-reform period. It is thus obvious that in the post-reform period too agricultural performance has continued to play a significant role in reducing rural poverty levels in India. A recent study notes that rural economic growth and the tertiary sectors too have also contributed to a decline in rural poverty in India in the post-reform period (Datt et al 2016). If we use the food production variable (FDPROD) in place of NDPAGRI it is seen that although this variable has the expected negative sign this coefficient was not statistically significant in the estimated equations for the three rural poverty indicators. The results also confirm that a rise in food prices tends to push up rural poverty levels in India though this coefficient was not statistically significant. Access to subsidised food through the PDS is seen to exercise a significant negative relationship with rural poverty levels for all three rural poverty indicators which attests to the poverty alleviating role of pro-poor welfare programmes in India. The study also confirms that a rise in rural inequality tends to aggravate rural poverty levels. In the estimated equations it is seen that these four variables together explain 75% to 86% of the variations in rural poverty trends in India for the three poverty indicators.

The elasticities of rural poverty in India to these, variables are presented in Table 3. As seen in the table, a 1% increase in real NDP from agriculture per capita (rural) will reduce rural HCR by 1.2%, rural PGI by 4.65% and rural SPGI by 12.93%. A 1% rise in the relative price of food (RELFP) will push up rural poverty levels by between 0.25% to 3.85% for the three poverty indicators. A 1% rise in rural inequality in consumption (RGINI) will result in between 0.62% to 9.9% rise in rural poverty levels. As regards the offtake of subsidised food through the PDS it is seen that a one percent rise in the offtake of the PDS foodgrains will reduce rural poverty levels by 1.17%, 4.84% and 13.7% corresponding to HCR, PGI and SPGI respectively.

Climate change and rural poverty levels: A few studies have tried to assess the likely impact of climate change on agriculture at the global level and across regions, countries and crops (Cline 2008; IPCC 2014b). Using alternate climate scenarios, models and varying assumptions regarding the likely trajectory of carbon emissions, temperature and precipitation, etc, in the future, the studies suggest different trends in agricultural yields across countries, regions and crops. At the global level the overall impact of baseline global warming with unabated rise in carbon emissions and likely rise of 4.4°C–5°C in land and farm area temperatures by the 2080s will result in a -16% reduction in agricultural productivity without carbon fertilisation benefits and a reduction of -3% only with carbon fertilisation benefits when results are weighted by agricultural output potential; the losses are greater when results are weighted by population or country (Cline 2008). The declines are sharper in developing countries as compared to industrial countries. While agricultural productivity in developing countries is estimated to decline at -21% without carbon fertilisation benefits and -9% with carbon fertilisation benefits, the decline is lower for industrial countries being -6% without carbon fertilisation benefits; however, when carbon fertilisation benefits on crop yields are considered, industrial countries report an increase of 8% in agricultural yields (Cline 2008). While regions or countries in the northern hemisphere report an increase in agricultural yields, those located close to the equator such as sub-Saharan Africa and South Asia will witness sharp declines (Cline 2008). For instance, using a Ricardian model, the United States (US), Canada, China, Germany and Russia report an increase in agricultural yields or no change (0% to 14% increase), whereas India, Ethiopia and South Africa report sharp reductions between -31% and -49% (Cline 2008). Alternatively using an agronomic model most countries report a decline in agricultural yields of between -4% and -35%. But if crop yields benefit from enhanced carbon concentration in the atmosphere, yields will rise by 5%–12% in the US, Canada, China, Germany and Spain.

Table 3: Elasticities of Rural Poverty in India with Respect to Selected Variables during the Period 1991 to 2012

Poverty Indicator	Independent Variables			
	NDPAGRI	RELFP	RGINI	PDS
Head count ratio	-1.20	+0.25	+0.62	-1.17
Poverty gap index	-4.65	+1.21	+3.13	-4.84
Squared poverty gap index	-12.93	+3.85	+9.90	-13.70

1 For a description of the independent variables refer text.
2 The elasticities presented here are computed from equations 1, 3 and 5 in Table 2.

The Fifth Assessment Report of the IPCC has collated evidences from several studies and notes that at the overall global level under A1B emission scenario and using alternate climate models (that is, CSIRO, MIROC) while yield of irrigated maize is likely to decline by -4% to -7% by 2050, for rain-fed maize this decline is likely to range between -2% and -12%; for irrigated rice the decline is estimated to range between -9.5% and -12% and rained rice between -1% and +0.07%; and for irrigated wheat between -10% and -13% and for rain-fed wheat -4% to -10% (IPCC 2014b). However, these trends mask wide variations across regions and subregions of the world. While many regions/subregions in North America and Europe are projected to register increases in yield depending upon the climate scenarios and models used, crop yields in sub-Saharan Africa and South Asia are projected to decline. For instance, in north-western US using A1B scenario, winter wheat is likely to increase by +19.5% by 2040 and +29.5% by 2080 with CO_2 benefits; spring wheat is, however, projected to decline by between -2-2% and -5.6% (IPCC 2014b). In the Boreal region of Europe yields of wheat, maize and soybean using A2 and B2 emission scenarios and alternate climate models such as HadCM3, HIRHAM, ECHAM4 are projected to rise by between 34% and 54% by 2080. Similar increases in crop yields are projected in other regions of Europe as well. In Africa, yields of wheat, maize, soybean and millets are expected to decline by -5% to -17% by 2050 whereas in South Asia sorghum and maize yields are expected to decline by -11% to -16% by 2050 (IPCC 2014b).

The impact of climate change on Indian agriculture has been analysed by many researchers using alternative climate change scenarios. A review of these studies covering rain-fed and irrigated crops by seasons, states and regions of India is available in a recent study by Ninan and Bedamatta (2012). The review indicates a decrease in production of crops in different states and regions of India with increases in temperature between 1°C to 5°C, change in rainfall patterns and intensity, and enhanced carbon concentration between 350 and 700 particles per million (ppm). A few studies indicate a probability of 10%–40% loss in crop production in India with increases in temperature and changes in other climate variables by 2080–2100. In areas located above 27° North latitude yields of rain-fed and irrigated wheat are likely to rise in response to climate change, whereas in all other locations wheat yields are expected to decline by 2.3%–23.9%. Rice production in some regions will fall by 3%–20% with a rise in temperatures, whereas in other regions with carbon fertilisation benefits and adaptation, rice yields may rise by 12%–35%. Yields of other crops such as maize, sorghum, soybean too indicate that while yields may fall with a rise in temperature and increased variability of rainfall, enhanced carbon concentration and adaptation efforts would lead to higher yields.

According to the Fifth Assessment Report of the IPCC, overall for India, using alternate emission scenarios and models, yields of irrigated rice are expected to decline by -4% to -10% and of rainfed rice by -2.5% to -6% with CO_2 benefits by 2020, 2050 and 2080 (IPCC 2014b). The declines for monsoon maize are projected to be in the range of 0% to -35% and for winter maize from +5% to -60% for the same time periods. In the Western Ghats region of India, yields of irrigated rice are projected to decline by -10% to +5% and of rained rice by -35% to +35%; for maize and sorghum yield declines are estimated to be as high as up to -50% (IPCC 2014b). The *Economic Survey 2017–18* suggests that climate change can reduce annual agricultural income by -15% to -18% on the average and up to 20%–25% for unirrigated areas (GoI 2018). The study further shows that average yields of kharif (autumn) season crops are likely to decline by -4% to -12.8% and for rabi (winter) season crops by 4.7% to 6.7%.

Impact of Climate Change on Indian Agriculture

To assess the likely impact of climate change on rural poverty trends in India, we need estimates of the overall impact of climate change on Indian agriculture. There are very few studies which have tried to analyse these impacts overall for the Indian agricultural sector. Notable among these are Cline (2008), Dinar et al (1998), Guiteras (2009), Kavi Kumar and Parikh (1998), Sanghi et al (1998) and Sanghi and Mendelsohn (2008). Using the Ricardian approach and alternate climate change scenarios with rise in mean temperatures varying between +1°C and +3.5°C and an increase in mean precipitation of between 1% and 15%, Kavi Kumar and Parikh (1998) and Sanghi et al (1998) examine the likely climate change impacts on net farm revenues or agricultural GDP for India. Using the IPCC's benchmark warming scenario of +2°C rise in mean temperature and a +7% rise in mean precipitation levels the two studies indicate that net farm revenues would decline by -8.69% to -12.3% (Table 4, p 42). The differences in the estimates between these two studies is due to the different data sets used for analysis. While Kavi Kumar and Parikh (1998) used meteorological data from the Indian Meteorological Department (IMD) for their analysis, Sanghi et al (1998) relied on a Food and Agriculture Organization (FAO) data set. The FAO data set differed from the IMD data set in terms of the period covered and larger coverage of geographical locations for recording meteorological data. If mean temperature were to rise to +3.5°C and mean precipitation to +7%, Sanghi et al's (1998) analysis shows that the decline in net farm revenues will rise further to -15.78%. If mean precipitation level were to rise to 15%, with mean temperature at +3.5°C, Kavi Kumar and Parikh's estimates indicate that net farm revenues in India will decline sharply by almost -25%. If mean precipitation levels were to decline by -8% and temperatures rise to +2°Cand 3.5°C, net farm revenues are estimated to fall by -20% and -26%, respectively (Sanghi and Mendelsohn 2008). In terms of agricultural GDP, the decline is estimated at between -2.04% and -5.87% for mean temperature rises of +2°C to +3.5°C and mean precipitation of +7% to + 15%.

In his study, Cline (2008) estimates the long-term effects of climate change on global agriculture in the 2080s as compared to baseline or business as usual (BAU) scenario. Using six climatic models, Cline's analysis indicates that a doubling of atmospheric carbon concentration above pre-industrial levels will lead to an eventual warming of 3.3°C. The corresponding atmospheric carbon concentration would reach 735 ppm by 2085 compared to the pre-industrial level of 280 ppm and 406 ppm in 2017 as per the Mauna Loa Atmospheric Observatory of the National Oceanic and Atmospheric Administration (NOAA). By the 2080s the six climate models predict an average surface temperature increase of nearly 5°C weighted by land area and about 4.4°C weighted by farm area. With rises in land and farm area mean temperatures of +4.4°C to +5°C and mean precipitation of +3%, Cline's analysis shows that India is likely to witness a sharp reduction in agricultural productivity of between -27% and -49% (based on agronomic and Ricardian models used for the analysis) by the 2080s.

Guiteras (2009) uses panel data for the period 1960 to 1999 covering 200 districts of India to assess the random year to year weather impacts on crop yields in India in the medium and long terms. He uses three alternate climate scenarios for his analysis, that is, BAU scenario (using the South Asia scenario of IPCC's climate scenario of A1F1 with a + 0.5°C increase in mean temperature and +4% increase in precipitation for the growing season months of June to September); Hadley 2010–39 A1F1 temperature prediction with a +4% increase in precipitation; and Hadley 2070–99 A1F1 temperature prediction with +10% increase in precipitation. His results indicate negative crop yield impacts for all three climate scenarios. While projected climate change impacts over the period 2010–39 reduce yields of major crops by 4.5% to 9%, the long-run impacts (Hadley 2070–99) are more damaging with crop yields projected to decline by 25% or more in the absence of long-run adaptation.

Using the above information and the elasticities of the three rural poverty indicators with respect to the agricultural performance variable (NDPAGRI) presented in Table 3 we assess the likely changes in rural poverty levels in India under alternative climate change scenarios as compared to 2012 rural poverty levels. The results presented in Tables 4a and 4b (p 42) show that under the different climate change scenarios considered with likely changes in net farm revenue/agricultural productivity, rural poverty levels in India will aggravate. For instance, the rural HCR will rise from 21.29% to between 24% and 31%. The depth and severity of poverty as measured by the rural PGI and SPGI respectively shows that rural poverty levels will aggravate sharply under the different climate change scenarios, almost doubling or trebling as compared to 2012 poverty levels. While rural PGI may rise from 4 to range between 6.9 and 11, the rural SPGI will likely rise from 1.2 to range between 1.6 and 7. In terms of the likely change in agricultural GDP too, the results indicate that rural poverty levels will aggravate under different climate change scenarios for all three rural poverty indicators with a sharp rise likely for the indicators depicting the depth and severity of poverty. The long run climate impacts using HadCM3 model and A1F1 scenario for the period 2070–99 show that the extent, depth and severity of rural poverty levels in India will aggravate sharply (Table 4b). A study by Jacoby et al (2010) also supports the finding that climate change will aggravate poverty levels in India. Although one may raise the issue of attribution, as stated earlier, climate change-driven impacts may act as a threat multiplier and compounds other (non-climatic) drivers of poverty, as is acknowledged by the Fifth Assessment Report of the IPCC (2014a).

We may, however, note a few limitations of our analysis. Both the Ricardian approach and the crop models used to assess the impact of climate change on Indian agriculture in the studies cited above have their merits and demerits. Although the Ricardian approach can examine how climate in different places affects the net revenue or value of farmland and account for the net benefits of adaptation to climate change, it is unable to account for the beneficial effects of carbon fertilisation (Mendelsohn et al 1994). Further, although the Ricardian approach measures the long-run adaptation costs of farming under new climate conditions, it does not measure the transition (dynamic) costs (Mendelsohn and Dinar 2009). Crop models which relate farm output to land quality, climate, fertiliser inputs, etc, assume little adaptation to changing economic and environmental conditions and tend to overestimate the damage costs of global warming (Mendelsohn et al 1994). Both, crop or Ricardian models cannot account for the influence of what are likely to be increases in extreme weather events,

Table 4b: Impact of Climate Change on Agriculture and Rural Poverty Levels in India under Alternative Climate Change Scenarios

Change in Crop Yields and Poverty Indicators	Study Source	Climate Change Scenarios		
		Business as Usual A1F1 +0.5°C Increase in Mean Temperature and + 4% Increase in Precipitation (2010–39)	HadCM3 A1F1 Temperature Prediction and + 4% Increase in Precipitation (2010–39)	HadCM3 A1F1 Temperature Prediction and + 10% Increase in Precipitation (2070–99)
Percent change in crop yields	Guiteras (2009)	-4.5%	-9%	-25%
Poverty indicators	Poverty Level in 2012	Change in Rural Poverty Level Based on Change in Crop Yields		
Head count ratio	21.29	22.44	23.59	27.68
Poverty gap index	4.01	4.85	5.69	8.69
Squared poverty gap index	1.19	1.88	2.57	5.04

1 Rural poverty levels for 2012 are taken from the poverty data set computed by Datt et al (2016); other poverty estimates corresponding to alternative climate change scenarios are author estimates.
2 Business as Usual (BAU) Scenario refers to South Asia scenario of IPCC or highest emission trajectory denoted by A1F1 scenario with +0.5°C increase in mean temperature and + 4% increase in precipitation for the growing season months (Guiteras 2009).
3 HadCM3 – Hadley Centre for Climate Prediction and Research Model produced by the British Atmospheric Data Centre. HadCM3-A1F1 assume high emission path scenario (Guiteras 2009).

Table 4a: Impact of Climate Change on Agriculture and Rural Poverty Levels in India under Alternative Climate Change Scenarios

Change in Net Farm Revenues or Agricultural Productivity/ GDP and Poverty Indicators	Study Source	Climate Change Scenarios					
		+2°C rise in Mean Temperature and 7% Rise in Mean Precipitation Levels	+2°C rise in Mean Temperature and -8% Decline in Mean Precipitation Levels	+3.5°C Rise in Mean Temperature and 7% Rise in Mean Precipitation Levels	+3.5°C Rise in Mean Temperature and -8% Decline in Mean Precipitation Levels	3.5°C rise in Mean Temperature and 14% (or 15%) Rise in Mean Precipitation Levels	Overall Warming of 3.3°C; 4.4°C–5°C Rise in Land/Farm Area Temperature; Carbon Concentration 735 ppm in the 2080s as Compared to Baseline/ BAU Scenario
Percent change in net farm revenue	Kavi Kumar and Parikh (1998)	-8.69%	–	–	–	-24.99%	–
Percent change in net farm revenue	Sanghi, Mendelsohn and Dinar (1998)	-12.3%	–	-15.78%	–	-10.33%	–
Percent change in net farm revenue	Sanghi and Mendelsohn (2008)	–	-20%	–	-26%	–	–
Percent change in agricultural GDP (1990s)	Kavi Kumar and Parikh (1998)	-2.04%	–	–	–	-5.87%	–
Percent change in agricultural productivity	Cline (2008)	–	–	–	–	–	
	1 Ricardian Model						-49%
	2 Crop Model						-27%
Poverty indicators	Poverty level in 2012	Change in poverty level based on change in net farm revenue					Change in poverty level based on change in agricultural productivity
Head count ratio	21.29	24.00	26.4	25.32	27.93	27.68	31
Poverty gap index	4.01	6.92	4.97	8.06	5.26	10.05	11.1
Squared poverty gap index	1.19	1.55	1.48	2.43	1.56	3.85	7.04
		Change in poverty level based on change in agricultural GDP					
Head count ratio	21.29	21.81	–	–	–	22.79	–
Poverty gap index	4.01	5.09	–	–	–	5.92	–
Squared poverty gap index	1.19	1.50	–	–	–	2.01	–

1 Rural poverty levels for 2012 are taken from the poverty data set computed by Datt et al (2016); other poverty estimates corresponding to alternative climate change scenarios are author estimates.
2 Ricardian model seeks to predict the agricultural consequences of global climate change. It fits an empirical relationship between land values and climatic, biophysical and socio-economic variables. Land values are assumed to reflect changes in agricultural productivity (Dinar et al 1998). Whereas crop models relate farm output to land quality, climate, fertiliser inputs and so on (Cline 2008).

such as droughts and floods, and insect pests (Mendelsohn et al 1994; Cline 2008). The estimates also do not take account of agricultural losses associated with rising sea levels, a major consideration in countries such as Bangladesh and Egypt (Cline 2008). Notwithstanding these limitations, our above analysis gives a broad idea of the likely outcomes of climate change on agriculture and poverty levels in India.

In Conclusion

Evidence presented here suggests that rural poverty trends in India which witnessed a significant decline during the post-reform period beginning from 1991 may get reversed and increase due to the likely adverse impacts of climate change on Indian agriculture, and other drivers of poverty. Not only will the proportion of poor population rise, but also the depth and severity of rural poverty measured through the rural PGI and SPGI may aggravate sharply in response to warming temperature and other climatic changes. If this happens it will not only impede economic growth in India but also jeopardise efforts to achieve the UN's Sustainable Development Goal that endeavours to halve the number of the global poor and eradicate extreme poverty in all its dimensions everywhere by 2030. This calls for strengthening safety nets, social networks and enhancing the adaptive capacity of the poor to face the risks posed by climate change and extreme weather events to Indian agriculture and economy. Popularising crop varieties, farm technologies and practices, and farming systems that can adapt to different biophysical and climatic environments may enable the agricultural sector to become climate smart and help mitigate the climate threats faced by the poor.

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