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Climate adaptation and livelihoods: Measuring vulnerability and job creation in India

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Research Article

Keywords: climate adaptation, livelihoods vulnerability index, employment generation, input-output analysis, India, Global South

Posted Date: September 8th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-10034380/v1

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Abstract

Climatic changes interact with livelihoods insecurities, particularly in countries such as India, where a large proportion of the workforce is informally employed. India was among the ten countries most affected by extreme weather events during 1995–2024. A sharp increase in the frequency and intensity of such events is projected, with associated risks to millions of lives and livelihoods.

This paper develops two tools for tracking and prioritising climate adaptation in India. First, are livelihoods in certain regions more vulnerable to climatic changes? A livelihoods vulnerability index (LVI) is constructed by combining indicators of informality, landlessness, dependence on natural resources, gendered distribution of unpaid labour, and the proportions of socio-economically marginalised communities. The LVI identifies priority regions for adaptation intervention across diverse agro-climatic zones. Second, can institutional climate adaptation activities simultaneously address the climate and livelihoods crises in India? Job creation through five representative adaptation activities, addressing cyclones, extreme heat or cold, sea level rise, droughts, and flooding, is estimated using input-output analysis. Spending 1.5 percent of the GDP on climate adaptation can create jobs equivalent to 1.3 percent of the labour force as of 2017-18.

The vulnerability index and job creation metrics show how context-specific dimensions of climatic exposure and livelihoods can be systematically incorporated into adaptation tracking. This approach is particularly relevant for measuring the equity and livelihoods dimensions of adaptation interventions in Global South countries. This paper argues that investing in climate adaptation can secure livelihoods while building resilience to climate hazards.

Keywords: climate adaptation, livelihoods vulnerability index, employment generation, input-output analysis, India, Global South

JEL: Q54, J23, O13

1 Introduction

The existential threat of climate change interacts deeply with the vulnerabilities associated with insecure livelihoods. Climatic changes and variability are estimated to lead to the loss of millions of jobs over the next few decades. Conventional approaches to address either the ecological problem alone or the employment problem alone may not succeed and could even exacerbate the other problem. In this paper, I assess the potential of climate adaptation activities to simultaneously address the climate and livelihoods crises in India by developing two complementary tools for tracking and prioritising adaptation. The first is a livelihoods vulnerability index, a targeting metric that identifies priority regions for adaptation investment based on the intersection of climatic exposure and socio-economic vulnerability. The second is a set of job creation estimates, an outcome-oriented metric that quantifies the impact of adaptation interventions on employment. Together, the two measures integrate distributional and livelihood considerations with biophysical risks.

Across the world, climate change is being experienced through extreme weather events, rising sea levels, variability in monsoon rainfall, droughts, and their impacts on food and water security, health and nutrition, lives and livelihoods. Globally, a disaster related to a weather, climate, or water hazard occurred every day on average between 1970 and 2019 and caused damages worth USD 3.64 trillion . Some parts of the world will experience greater warming than others, and the worst affected by the effects of global warming are poor countries and poor people across countries. For instance, 91 percent of the deaths due to weather, climate, and water hazards occurred in developing economies. Although low-income countries tend to be most vulnerable, government-led adaptation interventions are predominantly in wealthy countries.

Understanding country-specific climate change trends is essential for effective adaptation planning as these may not align with global assessments, particularly for countries such as India with its diverse geography and reliance on monsoon precipitation . India was among the ten countries most affected by extreme weather events during 1995–2024 and has also been identified as a country exposed to recurring extreme events. Between 1970 and 2021, India experienced 434 recorded disasters that affected approximately 2.3 billion people and caused damages of around USD 140 billion. More intense, prolonged, and frequent heatwaves are projected over India, and extreme sea level events that have historically occurred once in a hundred years along the Arabian Sea coastline are projected to occur annually by mid-century

under SSP2-4.5 . The total average annual loss (AAL)[1] from cascading climate risks for India is estimated at 4.8 percent of GDP under the moderate climate change scenario (Representative Concentration Pathway or RCP 4.5) and 8.1 percent of GDP under the worst-case climate change scenario (RCP8.5) .

At the same time, despite relatively high rates of economic growth, a livelihoods crisis has been building in the Indian economy for several years and compounded during the Covid-19 pandemic . Cultivators and workers have had to contend with low rates of growth of agricultural output and inadequate generation of employment opportunities. Around 80 to 90 percent of the workforce is informally employed with insecure employment, low wages, and poor working conditions.

Multiple climate change hazards may overlap or follow in close succession, and each of them compound the impact on lives and livelihoods. Erratic rainfall in regions that earlier had steady rainfall patterns has resulted in severe losses for cultivators in different parts of India. The loss of income from the reduction in working hours due to extreme heat in India in 2021 was estimated at 5.4 percent of the GDP . Such effects are expected to compound in the future. For instance, the equivalent of 34 million full-time jobs could be lost in India by 2030 due to the increase in the frequency and intensity of heat stress.

I raise two key questions in this paper, and thereby develop two complementary tools for assessing adaptation strategies. First, are livelihoods in certain regions within India more vulnerable to changes in climate? Within countries, climate change impacts vary across space and time . The spatial variability in the vulnerability of livelihoods to climatic changes is assessed through a livelihoods vulnerability index (LVI). Second, can institutional climate adaptation activities simultaneously address the climate and livelihoods crises in the country? Forecasted climatic changes are used to identify potential adaptation activities, and the employment generated through five representative activities, addressing different climate hazards, is estimated using input-output analysis.

The key findings are as follows. By the LVI, the most vulnerable regions are in different states of the country and differ widely in agro-climatic characteristics (plains/ plateau/ hills, coastal/ dry/ Gangetic regions). As agro-climatic zones do not overlap with state boundaries, regions sharing common agro-climatic characteristics across states may face similar climate

[1] Average annual loss (AAL) refers to the expected value of loss every year during a long time period (UN ESCAP 2022). The calculation assumes that the occurrence of hazards is stationary and that the costs would be covered through annual payments of the amount (UN ESCAP 2022).

risks and vulnerabilities. Adaptation policies could therefore benefit from combined planning and interventions encompassing regions facing similar climate risks across administrative boundaries. By the job creation estimates, climate adaptation investments to the extent of 1.5 percent of the GDP of India can generate around 6.5 million jobs, accounting for 1.3 percent of the labour force as of 2017-18. Investing 3 percent of the GDP in a combined climate adaptation – mitigation programme could generate net gains of around 9.7 million jobs, relative to a fossil fuel-based programme.

Through this paper, I contribute to the work on assessing baselines and progress in climate adaptation as follows. First, the most vulnerable regions in the country in terms of livelihoods and climatic changes are identified for adaptation planning and intervention. Second, potential adaptation activities are listed and mapped to various climate hazards and associated risks. Third, job creation through representative adaptation activities is estimated, and the set of estimates provides an outcome-oriented metric for assessing adaptation interventions.

Section 2 of the paper covers a brief overview of forecasted climate changes in India and the relevant literature on climate adaptation and job creation. The data and methodology used are described in Section 3. In Section 4, the LVI is constructed to identify the priority regions for adaptation investment. Section 5 lists adaptation activities mapped to different climate hazards or risks and estimates job creation through investments in representative adaptation activities. Section 6 discusses the findings of the paper, and Section 7 concludes.

2 Background

2.1 Forecasted climatic changes over India

A review of forecasted climatic changes will be useful to identify key climate hazards for India, and to list and map potential adaptation activities to each hazard. Under the medium emission scenario of SSP2-4.5, climate models predict additional warming of 1.2-1.3°C for the Indian region by mid-century (2041–2060) relative to the recent past (1995–2014) . More frequent heatwaves of longer duration, higher intensity, and greater spatial coverage are also predicted. Higher warming is projected in the north and northwestern parts of the country .

Changes in rainfall patterns are a key area of concern in India, with livelihoods predominantly dependent on the agricultural sector. Extreme precipitation events have intensified, and climate models project an increase in mean southwest monsoon rainfall with

high spatial variability . Tropical cyclones pose a constant threat to states on the eastern coast such as Odisha, Andhra Pradesh, and Tamil Nadu .

Droughts and floods have increased in frequency since the middle of the twentieth century and are projected to increase further . In particular, the frequency of droughts is projected to increase in the central and northern parts of India, and the frequency of floods is projected to increase in southern peninsular India, and the Ganges and Brahmaputra basins .

Based on such forecasts and past climate-related hazards, a list of climate hazards and associated risks was compiled. The list includes the following broad heads: storms and flooding; extreme wind; heatwave; drought; soil erosion; sea level rise; land degradation; water degradation; groundwater depletion; shortage of essentials; livestock damage; financial loss or loss of property; biodiversity loss; and loss of livelihoods. Potential adaptation activities for each hazard or risk were then identified.

2.2 Climate adaptation and job creation

Current responses to climatic risks do not necessarily build adaptive capacity for the future and could even be maladaptive . The most common type of adaptation responses are behavioural or cultural in nature, and institutional responses are a minority . In India, institutional responses include heat action plans at sub-national levels. Of 37 heat action plans, only two conducted vulnerability assessments and the plans do not always consider vulnerable groups . Other institutional responses in India include the National Action Plan on Climate Change (NAPCC) 2008 and the National Adaptation Fund for Climate Change.

The NAPCC has been described as “simultaneously significant and hollow”, as it linked development and climate but without a long-term vision. With respect to mitigation, the targets for emissions reduction cannot be achieved if economies such as India continue on growth trajectories that are powered by fossil fuels consumption . At the same time, rich countries have greater responsibilities to reduce emissions and higher capabilities to finance mitigation investments . Countries across different levels of development would experience significant net gains in job creation with a transition from fossil fuel to clean energy investments. Such a transition in India is estimated to result in net gains in the range of 4.8 million–6.3 million jobs or 1–1.3 percent of the labour force in 2015. This paper assesses whether climate adaptation activities could also result in job creation in India.

The NAPCC emphasised a ‘development first’ approach with a focus on the climate co-benefits of developmental policies. Instead, a preferable strategy would be one that

157 simultaneously achieves multiple objectives. This paper puts forward a strategy to
158 simultaneously address the climate and livelihoods crises in India and develops tools to track
159 and prioritise adaptation progress.

160 ## 3 Data and methodology

161 The spatial variability in vulnerability was identified by constructing the LVI for regions in
162 India. The calculation of the index used the Periodic Labour Force Survey (PLFS) 2021-22,
163 All India Debt and Investment Survey (AIDIS) 2019, and Situation Assessment Survey and
164 Land and Livestock Holdings (SAS–LHS) of Agricultural Households 2019. As the PLFS is
165 representative only at the NSS region level (and not at the district level), the indicators were
166 estimated at the region level. Maps were plotted by assigning the LVI of a region to all the
167 districts in the region.

168 The index combines the following indicators: informal non-agricultural employment;
169 absence of owned land; sectors that are heavily reliant on natural resources; population share
170 of historically marginalised communities; gendered labour relations; irrigated agricultural land;
171 reliance on groundwater for irrigation; and loss of crop due to climate hazards. The last three
172 indicators are only included in the rural index. The rural LVI includes eight indicators and the
173 urban LVI includes five. The selection of indicators and associated variables are discussed in
174 section 4.

175 All indicators, except one, are assessed to be positively related to vulnerability of
176 livelihoods, that is, vulnerability increases with a rise in the value of each indicator. As such,
177 the value of each indicator was normalised by subtracting the minimum value[2] from it and
178 dividing by the range:

179 $$NI_{ir} = \frac{I_{ir} - Min_r\{I_{ir}\}}{Max_r\{I_{ir}\} - Min_r\{I_{ir}\}}$$

180 Here, NI_{ir} is the normalised value of indicator i in NSS region r,

181 I_{ir} is the actual value of indicator i in region r,

182 $Min_r\{I_{ir}\}$ is the minimum value of indicator i across all regions,

183 and $Max_r\{I_{ir}\}$ is the maximum value of indicator i across all regions.

[2] The maximum and minimum values were taken after excluding the union territories.

As the indicator on irrigated agricultural land is inversely related to livelihoods vulnerability, it was normalised as follows:

$$NI_{ir} = \frac{Max_r\{I_{ir}\} - I_{ir}}{Max_r\{I_{ir}\} - Min_r\{I_{ir}\}}$$

The indicator values were normalised separately for rural and urban areas. The rural/ urban LVI of a region was calculated by averaging the normalised values of all indicators. That is,

$$LVI_r = \frac{\sum_{i=1}^{n} NI_{ir}}{n}$$

LVI_r is the livelihoods vulnerability index of NSS region r,

and n is the number of indicators.

Following the regional vulnerability assessment, potential adaptation activities to address these vulnerabilities were listed and mapped to climate hazards and associated risks. Adaptation responses were identified using various sources – in particular, Ministry of Rural Development (2005); National Disaster Management Authority (NDMA), Government of India (2018); Pillai and Dalal (2023); Patra (2016); National Bank for Agriculture and Rural Development (NABARD), Government of India (2015); Scottish Natural Heritage (2000); Linham and Nicholls (2010); and Department of City Planning, City of New York (2013).

Five adaptation activities were selected from the list, each addressing different climate hazards. The selected activities are safe houses (cyclones); cooling centres or winter shelters[3] (heatwaves/ extreme cold); seawalls (sea level rise); water storage reservoirs (droughts); and constructed or restored wetlands and mangroves (flooding). For estimating the job creation through these adaptation activities, the 2018 input–output table (IOT) for India from the OECD database (2021 edition) was used along with the PLFS 2017-18.

A brief description of the methodology to estimate job creation through the input-output framework follows. The overview is based on Miller and Blair (2022) and earlier studies of climate mitigation activities. Input-output tables show the flows of products between industries during a given time period, where each industry is listed as both a seller and a buyer. Input-

[3] The government of Delhi operates 'rain basera' or night shelters during winters.

output coefficients a_{ij} represent the value of the inputs from industry i per unit value of output of industry j:

$$a_{ij} = \frac{z_{ij}}{x_j}$$

where x_j denotes the total output of industry j, and z_{ij} denotes the monetary values of inter-industry sales by industry i to all industries j, including itself. For the time period under consideration, the input-output coefficients are fixed – that is, the input-output framework assumes constant returns to scale.

$(\mathrm{I} - \mathrm{A})^{-1}$ is the Leontief inverse matrix, where A is the matrix of input-output coefficients. Multiplying the employment-output coefficients of industries (workers per unit of output in each industry) with the Leontief inverse matrix gives the simple employment multipliers. The direct jobs generated through stimulating economic activity in the same industry and the indirect jobs generated through stimulating demand in other industries supplying intermediate inputs can then be estimated.

To operationalise this methodology, the work participation rates, disaggregated by sector and sex and estimated using PLFS data, were multiplied with the population projections of the Technical Group on Population Projections (2020). The population was estimated for the mid-point of the reference period. That is, for the survey year 2017-18, the reference period for the usual status of employment was 1 July 2016 to 1 June 2018, and the population was estimated for June 2017. The PLFS data was also used to identify the distribution of the workforce across different industries. The shares of the workforce were multiplied by the projected population to reach the number of workers across industries. The employment-output ratios were then calculated using the estimated number of workers and the output of each industry in the IOT. The sectors in the IOT were matched to the industries in the PLFS survey as in Appendix Table A3.

After estimating the direct and indirect jobs corresponding to each industry, weights were assigned to industries supplying inputs according to their relative importance in costs for each activity. For climate mitigation activities, the weights were assigned to industries as in Azad and Chakraborty (2023). For climate adaptation activities, the weights used are listed in Appendix Table A4 and were based on the following sources: FEMA (2008); NABARD (2015); Hudson, Keating and Pettit (2015); Multi-Hazard Mitigation Council (2019); and the costing spreadsheet tool of the Environment Agency, UK Government. The number of jobs

created is estimated under the assumption that the total amount invested is equally divided between the five selected adaptation activities.

4 Identifying priority regions: Livelihoods vulnerability index

The first question relates to spatial variability in the vulnerability of livelihoods to climatic changes. Within countries, climate change impacts vary across space and time . Effectively addressing the climate and livelihoods crises calls for an assessment of regional and socio-economic variations in vulnerability. I construct a regional LVI using a set of socio-economic indicators that capture the intersections between livelihoods, climatic changes, and socio-economic characteristics. The LVI can function as a baseline metric which can be revised with subsequent rounds of the surveys to track progress in addressing livelihoods vulnerability with adaptation activities.

Vulnerability of livelihoods is represented through indicators of sensitivity or susceptibility to harm and capacity to adapt, in accordance with the IPCC (2022) definition of vulnerability. A contextual vulnerability approach is used, by which vulnerability is influenced not only by biophysical changes, but also by dynamic social, economic, political, institutional, and technological processes and structures . Adaptation can be transformative, and not merely technical, by changing underlying inequalities in socio-political relations that reproduce vulnerabilities .

As such, the formulation of the LVI is motivated by the sustainable livelihoods framework, as reformulated by Natarajan, et al. (2022). Indicator variables that represent certain dimensions of the framework have been used to calculate the rural and urban LVI of each region. Each of the selected dimensions is equally weighted in the index, as is each of the component indicators within each dimension. The selected dimensions of the framework (A–D) are listed below, with the indicators and corresponding variables listed below each dimension:

A. Livelihood characteristics, vulnerability, and opportunity

A.1. Informal non-agricultural employment: the proportion of workers in the non-agricultural sector that are informally employed. Informally employed workers include self-employed and casual workers, and regular workers without a written job contract or social security benefits.

A.2. Irrigated agricultural land: the proportion of plots of agricultural land that are irrigated. Only this indicator is inversely related to livelihoods vulnerability. Cultivators of rainfed

agricultural land are likely to be more vulnerable to climatic changes and variability. This indicator is only included in the rural index.

B. Physical assets

B.1. Absence of owned land: the proportion of households that do not own land. Household labour adaptation responses to drought in India vary by land ownership , and this indicator reflects the capacity to adapt of households through fall-back earning opportunities and livelihoods diversification.

C. Climate and environmental context and relations

C.1. Sectors that are heavily reliant on natural resources: the proportion of workers employed in agriculture, forestry, fishing, mining, or quarrying. This indicates susceptibility to harm in terms of exposure to outdoor conditions and the possible severity of damages to livelihoods due to extreme weather events. For instance, farmers adapt their irrigation investment and crop choices to decadal rainfall patterns .

C.2. Loss of crop due to climate-related hazards: the proportion of crop loss (without receipt of insurance claim) due to drought, flood, or natural disasters in the region. Non-receipt of insurance claim indicates differential experiences of crop loss. This indicator is only included in the rural index.

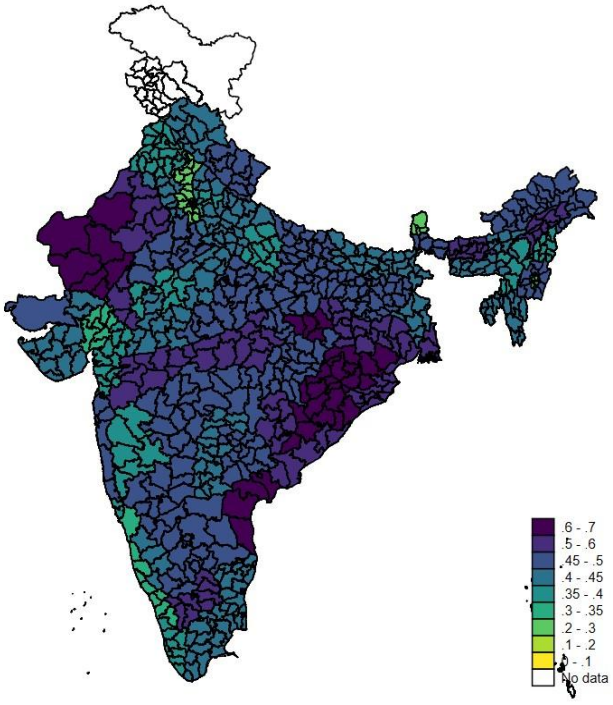
D. Relational power (human, social, political)

D.1. Marginalised communities in the population: population share of the Scheduled Castes (SC) and Scheduled Tribes (ST) in the region. These communities tend to be more vulnerable to climate variability due to their relative poverty and greater reliance on natural resources .

D.2. Gendered relations: the proportion of women that are primarily engaged in unpaid domestic work. Women are disproportionately affected by climatic changes, and the social organisation of reproductive and productive labour of women shapes their disproportionate vulnerability to climate risks . Environmental degradation and hazards could decrease access to resources such as water and increase the burden of unpaid household labour on women, particularly in households that rely on farming or agricultural labour. Increased burden of domestic labour could also constrain women's participation in paid work and reduce further their capacity to adapt to climatic changes.

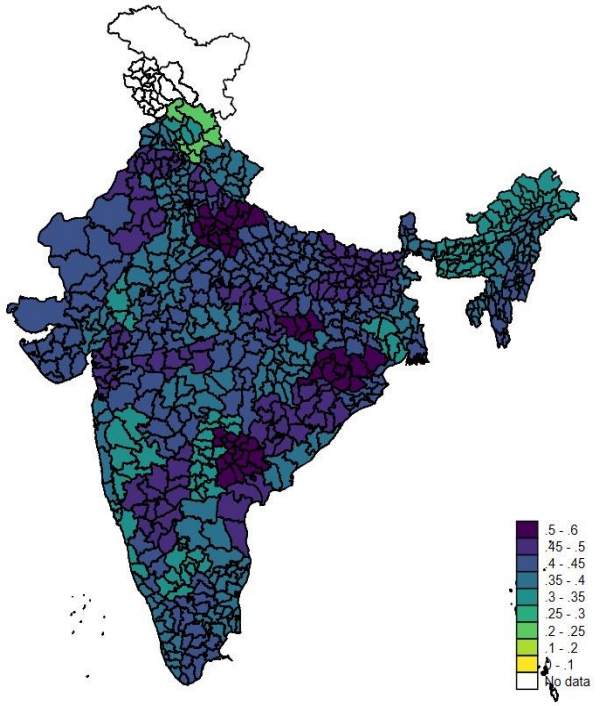
These indicators are computed and normalised for all regions (as per the National Sample Survey classification), separately for rural and urban regions.

Figure 1: Rural livelihoods vulnerability index



Source: Computed using PLFS 2021-22, AIDIS 2019, and SAS-LHS 2019
Union territories (except Delhi) have not been included in the calculation of the index.

Figure 2: Urban livelihoods vulnerability index



Source: Computed using PLFS 2021-22, AIDIS 2019, and SAS-LHS 2019
Union territories (except Delhi) have not been included in the calculation of the index.

The ranking by the LVI identifies the priority regions for policy action. Maps are plotted by assigning the LVI of a region to all districts in the region. The range of the rural LVI is 0.24–0.67 and the range of the urban LVI is 0.24–0.60. The index is a relative measure, and it cannot be inferred that regions with low indices have low vulnerability in absolute terms.

By the LVI, the rural regions that face the highest vulnerability of livelihoods with climatic changes include the following (Figure 1 and Appendix Table A1):

i. Northern Odisha (eastern plateau and hills)
ii. Northern Chhattisgarh (eastern plateau and hills)
iii. Coastal southern Andhra Pradesh (east coast plains and hills)
iv. Western Rajasthan (western dry region)
v. Southern Odisha (eastern plateau and hills)

The agro-climatic zone of each region is included in brackets. The zone reflects the biophysical environment, and the regions in an agro-climatic zone have relatively homogeneous agro-climatic conditions.

The most vulnerable urban regions (Figure 2 and Appendix Table A1) include:

i. Northern Chhattisgarh (eastern plateau and hills)
ii. Northern Odisha (eastern plateau and hills)
iii. Inland northeastern Telangana (southern plateau and hills)
iv. Southern upper Ganga plains, Uttar Pradesh (upper Gangetic plains)
v. Northern Rajasthan (Trans-Gangetic plains/ western dry region)

Thus, regions across different states and parts of the country and varying agro-climatic characteristics (plains/ plateau/ hills, coastal/ dry/ Gangetic regions) are highly vulnerable to the climate and livelihoods crises.

5 Assessing livelihoods outcomes: Job creation metrics

With vulnerable livelihoods across biophysical environments and geographical regions, the second question raised in the paper addresses whether institutional climate adaptation activities can contribute towards addressing these vulnerabilities. Various adaptation interventions were listed and mapped to climate hazards. Five representative activities that address different climate hazards were then selected, and the number of jobs created through investing in these activities was estimated as an outcome-oriented metric to evaluate adaptation strategies.

5.1 Listing and mapping adaptation activities

Climate hazards and associated risks were listed based on forecasted climatic changes over India (as reviewed in section 2.1). The list includes storms and flooding, extreme wind, heatwave, drought, soil erosion, sea level rise, land or water degradation, groundwater depletion, shortage of essentials, damages to livestock, financial loss or loss of property, harm to biodiversity, and loss of livelihoods. Appendix Table A2 lists the possible adaptation activities that can be used to address each climate hazard or risk. Just as climate change hazards overlap or follow each other and compound impacts, climate change solutions can also address multiple climate risks. The list in Appendix Table A2 reinforces this point – several activities are mapped to multiple hazards or risks. For instance, restoring wetlands can address storms and flooding, sea level rise, water degradation, groundwater depletion, and loss of biodiversity. Certain activities, such as sustainable agroforestry, can also perform the functions of both climate adaptation and mitigation.

5.2 Job creation through adaptation activities

To estimate the jobs generated through climate adaptation, five activities were selected from the list compiled in section 5.1. These activities are responses to different climate hazards and

include safe houses for cyclones, cooling centres or winter shelters for extreme heat or cold, seawalls for sea level rise, water storage reservoirs for droughts, and constructed or restored wetlands and mangroves for flooding. The selected activities also broadly align with the five priority adaptation measures highlighted by the Global Commission on Adaptation. For India, the order of priority based on estimated average annual losses is strengthening early warning systems, building new resilient infrastructure (score of 5 each), resilient water resources management, improving dryland agriculture crop production (score of 4 each), and protecting mangroves or nature-based solutions (score of 1) .

The jobs created through the five representative adaptation activities were estimated using input-output analysis. For instance, take the case of safe houses that can be used during cyclones or other disasters. The Multi-Hazard Mitigation Council estimated the job creation in different sectors through increase in demand for structural materials needed to exceed the design requirements for earthquake shelters in the United States. In the absence of similar data for India, the proportions estimated for different sectors were used as weights to estimate job creation through investments in safe houses. The industries identified were mining and quarrying, wood and wood products, metal products, construction, and repair and installation of machinery and equipment, and the respective weights assigned to these industries are listed in Appendix Table A4. Using these weights, the increase in output, and therefore employment, in different industries by building more safe houses was estimated. Investing USD 1 million in safe houses creates around 177 jobs, that is, 96 direct jobs and 81 indirect jobs (Table 1).

The exercise was similar for cooling centres or winter shelters, sea walls, water storage reservoirs, and constructed wetlands. Adaptation responses to the projected increase in the frequency and intensity of heatwaves could include constructing cooling centres, structures for water storage, and retrofitting buildings (Appendix Table A2). Spending USD 1 million on cooling centres is estimated to create around 157 jobs, of which 100 are direct and 57 are indirect jobs (Table 1). In response to the projected rise in sea level along the Indian coast, using the same amount to construct sea walls could generate 136 jobs. Restoring wetlands or mangroves for floods and constructing water storage reservoirs for droughts and other extreme weather events, with investments of USD 1 million each, are estimated to generate around 83 jobs and 99 jobs, respectively. Investing USD 1 million, equally divided between these five representative climate adaptation activities, is estimated to generate around 130 jobs, of which 70 are direct and 60 are indirect jobs.

Table 1: Job creation with investments of USD 1 million in climate adaptation

	Direct	Indirect	Total
A. Safe houses	96.3	80.5	176.9
B. Cooling centres/ winter shelters	100.4	56.6	157.0
C. Seawalls	73.0	62.8	135.8
D. Water storage reservoirs	43.2	55.6	98.7
E. Constructed/ restored wetlands or mangroves	36.3	46.9	83.2
Climate adaptation [0.20*(A+B+C+D+E)]	**69.8**	**60.5**	**130.3**

Note: The estimated jobs represent jobs per USD 1 million invested in climate adaptation activities.

Source: Calculated using 2018 OECD input-output table (2021 ed.), PLFS 2017-18, and Technical Group on Population Projections (2020)

5.3 Investing in climate adaptation

Under the worst-case climate change scenario (RCP8.5), the annual adaptation costs for South and South-West Asia have been estimated at USD 61.5 billion, of which around 93 percent is for climate-related hazards and the rest for biological hazards. Of the countries considered, India has the highest total adaptation costs at USD 45.3 billion . The methodology followed by ESCAP (2019) to calculate adaptation costs is as follows. Spatial datasets are used to estimate the population and infrastructure exposed to hazards in hotspots. The AAL is estimated using the extensive risks, indirect losses, and population exposure of each hazard. The economic impact of hazards is the estimated AAL for the current scenario, RCP4.5, or RCP8.5. The adaptation costs for climate-related hazards are the composite of the adaptation costs for droughts, floods, and tropical cyclones:

$$Climate\ related\ hazards\ AAL\ under\ RCP8.5\ (flood, tropical\ cyclone, drought) = (Extensive\ risk - multihazard\ AAL\ including\ indirect\ losses\ from\ tropical\ cyclone\ and\ floods + drought\ AAL\ \ under\ RCP8.5)$$

By this measure, the annual adaptation costs for climate-related hazards amounts to around 1.5 percent of the GDP for India . Assessing that at least this amount would need to be spent in adapting to climate change, I estimate the job creation effects of investing 1.5 percent of the GDP on adaptation activities. From section 5.2, investing USD 1 million, equally divided between the five representative climate adaptation activities, is estimated to generate around

130 jobs. Scaling up the amount to 1.5 percent of the GDP (approximately USD 50 billion)[4], around 6.5 million jobs could be created through investment in climate adaptation activities. This accounts for around 1.3 percent of the labour force as of 2017-18.

5.4 A combined climate adaptation-mitigation programme

Along with adaptation, mitigation activities are needed to slow the frequency and intensity of extreme weather events. Transitioning to clean renewable energy sources and increasing energy efficiency have been identified as feasible routes for economies to reduce carbon emissions while raising or maintaining their per capita energy consumption . Investing in a green energy programme over a fossil fuel programme has been estimated to increase net employment apart from its environmental benefits . The methodology was replicated, and the estimates were updated with recent data to determine the job creation estimates of a combined investment programme in climate mitigation and adaptation.

Investing USD 1 million in climate mitigation activities (renewable energy and energy efficiency) would generate around 158 jobs, of which 94 are direct jobs and 64 are indirect jobs (Table 2). Two-thirds of the investment in the climate mitigation programme is on expanding the use of renewable energy sources and one-third is on increasing energy efficiency. If USD 1 million had instead been invested in a fossil fuel-based programme (coal, oil, and gas), only 47 jobs would have been generated (Table 3).

Table 2: Job creation with investments of USD 1 million in climate mitigation

	Direct	**Indirect**	**Total**
A. Renewable energy [0.20*(i+ii+iii+iv+v)]	97.6	60.8	158.5
i. Bioenergy	196.9	44.1	241.0
ii. Wind energy	68.9	72.3	141.2
iii. Solar energy	50.2	66.9	117.1
iv. Geothermal	96.0	61.0	157.0
v. Small hydro	76.2	59.7	135.9
B. Energy efficiency [0.25*(i+ii+iii+iv)]	87.0	69.3	156.3
i. Retrofitting buildings	109.5	71.6	181.1
ii. Industrial efficiency	104.1	69.0	173.1
iii. Improved smart grids	67.0	76.1	143.1

[4] The GDP of India in 2022 was around USD 3.2 trillion. 1.5 percent of the GDP is around USD 48 billion. USD 50 billion is used as the amount invested in the exercises in sections 5.3 and 5.4.

iv. Public transport	67.5	60.4	127.9
Climate mitigation [(0.67*A) + (0.33*B)]	**94.1**	**63.6**	**157.7**

Note: The estimated jobs represent jobs per USD 1 million invested in climate mitigation activities.

Source: Calculated using 2018 OECD input-output table (2021 ed.), PLFS 2017-18, and Technical Group on Population Projections (2020)

Table 3: Job creation with investments of USD 1 million in climate adaptation/ climate mitigation/ fossil fuel programme

	Direct	**Indirect**	**Total**
Climate adaptation	69.8	60.5	130.3
Climate mitigation	94.1	63.6	157.7
Fossil fuel programme	5.4	41.7	47.1

Note: The estimated jobs represent jobs per USD 1 million invested in each of the three activity types.

Source: Calculated using 2018 OECD input-output table (2021 ed.), PLFS 2017-18, and Technical Group on Population Projections (2020)

From section 5.3, 1.5 percent of the GDP invested in a climate adaptation programme could generate around 6.5 million jobs. This accounts for around 1.3 percent of the labour force in 2017-18. An additional 1.5 percent of the GDP spent on climate mitigation activities would create around 7.9 million jobs (1.6 percent of the labour force in 2017-18). The net gains in employment from investing 3 percent of the GDP in a combined programme of climate adaptation and mitigation activities over the same amount spent instead on a fossil fuel-based programme would be 9.7 million jobs (around 2 percent of the labour force as of 2017-18). Thus, the job creation estimates of investing in a combined programme of climate adaptation and mitigation activities suggest its potential to simultaneously address the climate and livelihoods crises in India. The set of job creation estimates also provide an outcome-oriented metric to evaluate the employment impact of adaptation interventions.

6 Discussion

For the Indian region, climate models project serious implications of continued anthropogenic global warming and highlight spatially differentiated hotspots across the country . Past climate hazards have had immense economic costs, with a cyclone in 2020 causing over USD 13 billion of damages and a flood in 2014 causing USD 16.9 billion of losses. Developing countries, such as India, have lower capacities to adapt, and the livelihoods of people in these countries tend to be more dependent on natural resources. In the Indian economy, climate hazards affect

livelihoods in a context where relatively high rates of economic growth have not generated sustainable or secure jobs.

In this context, I raise and respond to two key questions and develop two complementary tools for tracking adaptation strategies. First, are livelihoods in certain regions within India more vulnerable to changes in climate? The LVI was constructed to integrate distributional and livelihoods considerations with biophysical risks and thereby identify priority regions for adaptation planning and intervention. It includes social, economic, and distributional dimensions of climate risk, such as the extent of informal employment, landlessness, reliance on natural resources, the gendered distribution of unpaid labour, and the population shares of historically marginalised communities. As such, the index integrates considerations of equity and inclusion into adaptation assessment and measurement.

In India, the most vulnerable regions by the LVI are located in different states and parts of the country and differ widely in agro-climatic characteristics. In the context of poverty alleviation, policies implemented within or across states may be more relevant than state-level policies as initial conditions and agro-climatic zones do not overlap with state boundaries . Likewise, regions sharing common agro-climatic characteristics across different states may face similar climate hazards, risks, and vulnerabilities. Policymaking on adapting to climate hazards could benefit from combined adaptation planning and interventions that encompass regions facing similar climate risks across states and administrative boundaries. Just as extreme weather events could be compounding, adaptation measures could address multiple climate risks. With loss of livelihoods among the climate risks, this paper assesses whether this risk could be addressed alongside biophysical risks through institutional responses and climate adaptation investments.

Second, can climate adaptation activities simultaneously address the climate and livelihoods crises in the country? Forecasted climatic changes were used to identify key climate hazards and associated risks for India, and potential adaptation activities were listed. Five representative adaptation activities addressing different climate hazards were selected, and the number of direct and indirect jobs generated through an expansion in these activities was estimated. The job creation estimates were derived as an outcome-oriented metric to quantify the impact of adaptation investments on livelihoods. This metric complements the LVI that identifies where such investments are most needed. This is particularly relevant in the Indian context, where economic growth has not resulted in formal employment creation.

The annual adaptation costs for climate-related hazards have been estimated at around 1.5 percent of the GDP of India. Investing this amount on adaptation activities would generate around 6.5 million jobs, and this accounts for around 1.3 percent of the labour force in 2017-18.[5] The exercises in this paper do not include estimates of the induced jobs generated through the multiplier effects of the programme. The job creation estimates are therefore likely to underestimate the effects of a climate adaptation programme.

Climate mitigation activities are also needed to slow the pace and intensity of climatic changes. The estimates in the paper suggest that the net gains in employment from investing 3 percent of the GDP in a combined climate adaptation and mitigation programme over a fossil fuel-based programme could generate around 9.7 million jobs, accounting for around 2 percent of the labour force as of 2017-18. The job creation estimates of investments in climate adaptation and mitigation activities suggest the strong potential for such a programme to simultaneously address the climate and livelihoods crises in India.

Concerns relating to livelihoods have been raised about the clean energy transition in India. The targeted addition to solar capacity with the clean energy transition in India is estimated to generate jobs primarily in the western and southern parts of the country while job losses would be concentrated in the coal-rich eastern states, and climate mitigation policies could exacerbate regional inequalities. On the other hand, the vulnerability assessment reveals that livelihoods in regions across different parts of the country are highly vulnerable to climatic hazards and risks, although the nature of the risk could differ. Adaptation activities are therefore needed across regions and could correct inequalities and any imbalances in job creation.

Certain limitations of the methodologies adopted in this paper are discussed here. First, the LVI is a relative, rather than an absolute, measure of vulnerability, and a low value of the index for a region does not imply low vulnerability in absolute terms. Second, the equal weighting of indicators and dimensions is one of the possible defensible choices, and the differences with alternate weighting schemes are an area for further work. Third, the LVI is constructed using survey data and represents the baseline, rather than a time series. Nevertheless, the same methodology can be applied to subsequent rounds of the surveys, and changes in livelihoods vulnerability can be tracked over time. The LVI can therefore function as a baseline against which future progress in adaptation and in addressing livelihoods

[5] The number and nature of the jobs generated could vary over time. Part of these activities, such as those in construction, may be one-time activities but could generate jobs for the maintenance of adaptation structures over time.

vulnerability can be assessed. Fourth, the employment estimates from the input-output analysis do not include the induced jobs generated through the multiplier effects of increased household spending from the additional incomes. The job creation estimates are therefore likely to underestimate the employment effects of a climate adaptation programme.

The vision for the combined adaptation-mitigation programme is that the new jobs directly created through the programme would be formal jobs with sustainable and secure earnings and working conditions. In a country where 80 to 90 percent of the workforce is informally employed, such a programme could transform their lives and livelihoods.

7 Conclusion

Adaptation actions that account for socio-economic vulnerabilities are urgently needed to avoid descending into 'adaptation apartheid' . In this paper, I develop two tools for tracking adaptation interventions in India: a livelihoods vulnerability index that identifies priority regions, and job creation estimates from adaptation activities using input-output analysis. The approach uses indicators that reflect the socio-economic context of the Indian economy, such as the extent of informality, land relations, reliance on natural resources, and socio-economic marginalisation. This work could inform comparable context-specific approaches for prioritising and assessing adaptation interventions in other Global South countries. Investing in climate adaptation can secure livelihoods while improving mechanisms to cope with climate hazards. Such activities, if planned and implemented carefully in accordance with the geographies, vulnerabilities, and socio-economic patterns of each region, could be transformational.

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