Vulnerability of dairy-based livelihoods to climate variability and change: a study of Western Ghats region in Wayanad, Kerala

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The study assesses the livelihood vulnerability of dairy farmers to climate variability and change (CVC) in Wayanad district of the Western Ghats region in Kerala. For this purpose, a Livelihood Vulnerability Index (LVI) was developed underlying the definition of Intergovernmental Panel on Climate Change consisting of 28 indicators and 7 LVI components. A fussel framework was used for conceptualizing the vulnerable situation. Participatory rural appraisal and personal interviews were used to collect household data of 180 dairy farmers of three taluks complemented by thirty years of gridded weather data. The normalized data were then combined into three indices, i.e. sensitivity, exposure and adaptive capacity, which were then averaged with weights given using principal component analysis, to obtain the overall index. LVI indicated that the dairy farmers of all the taluks of Wayanad are vulnerable to CVC with Pulpally taluka being the most vulnerable with 48.33% farmers under the high level vulnerability category with wide variation in LVI components across the taluks. For the sustenance of dairy farming of small and marginal farmers of the region and for mitigating risks, policies are required for incentivizing the livelihood infrastructure and promotion of grass root level innovations.

Keywords: Climate change, livelihoods, livelihood vulnerability, participatory rural appraisal, milk.

REDUCING rural poverty, achieving global food and nutritional security and mitigating climate change, are the three most critical and interrelated problems encountered by the global community[1]. Economically poor farmers are the most vulnerable group to the long-term impacts of climate change[2–5] and the impact is detrimental to a developing country like India where the main source of the livelihood population is agriculture and allied sectors[6–8]. The farmers often have limited capacity to adapt[9]. In India climate change significantly impacts agriculture as the west coast and southern India are projected to shift to a new high temperature climatic regime under 4°C warming[10]. In India, the livelihood of small farm holders (those owning less than 2.0 ha of farmland) that comprise 78% of the country's farmer population, is mostly affected by climate change[11]. Climate variability is the way the climate fluctuates yearly above or below a long-term average value. It is not as noticeable as weather variability because it happens over seasons and years. Climate change is a long-term continuous change (increase or decrease) to average weather conditions or the range of weather and climatological normal is 30-years average of weather variables[10].

Climate change impact differs from region to region, country to country, sector to sector and community to community[12,13]. Its vulnerability is dynamic and depends on both biophysical and social processes[14,15]. The Intergovernmental Panel on Climate Change (IPCC) defines vulnerability to climate change as 'the degree to which a system is susceptible, or unable to cope with adverse effect of climate change, including climate variability and extremes. Vulnerability to climate change depends on the rate of change of the climate and the extent to which a system is exposed, its sensitivity, and adaptation capacity'[10]. 'Sensitivity is the degree to which a system is affected, either adversely or beneficially by climate-related stimuli'. 'Adaptive capacity is the ability of a system to adjust to climate change including climate variability and extremes, to moderate the potential damage from it to take advantage of its opportunities or to cope with its consequences[2]'. Observed positive effects for poor and marginalized people, which are restricted, include examples such as diversification of social networks and of agricultural practices[11]. In India, the resilience of agricultural system is closely linked to the livestock system and the livestock's contribution towards risk reduction and adaptation to climate variability is significantly higher than their negative impacts[16]. The estimated annual loss at present due to heat stress among cattle and buffaloes at the all-India level is 1.8 million tonnes of milk, about 2% of the total milk production in the country, amounting to a whopping Rs 2661 crore[17]. This communication briefly assesses the overall household level livelihood vulnerability to climate change of the dairy farmers of Wayanad region, Kerala.

The present study is based on contextual vulnerability approach that usually centres on the present socio-economic factors or determinants of vulnerability, i.e. economic, social and institutional conditions. Fussel framework defines four fundamental dimensions to describe a vulnerable situation[18], concepts describing the vulnerability concepts and nomenclature of vulnerable conditions. Fussel describes climate-related vulnerability assessments based on 'characteristics of the vulnerable system, the type and number of stressors and their root causes, their effects on the system, and the time horizon of the assessment'[18]. The system of analysis is the first fundamental dimension that combines natural or human systems[18]. For the present study, the major component of the dairy farming system comprises the sample dairy farmers and the dairy animals of Wayanad, Western Ghats region. The second dimension is the attribute of concern: the valued

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attribute(s) of the vulnerable system that is/are threatened by its exposure to a hazard[18]. The present study finds out how the livelihood of dairy farmers is affected by CVC. The study is based on LVI by Hahn *et al.*[19], that includes seven major components (Table 1). The analysis of LVI components and their progress further permits discussing the livelihood vulnerability of farmers. Fussel defines the third dimension – the hazard as 'a potentially damaging influence on the system of analysis', 'some influence that may adversely affect a valued attribute of a system'. The present study considers the dynamic perspective of the system, while studying the effects of the multiple factors of CVC on changes in average milk production. The fourth dimension of vulnerable situations is the temporal reference. For the present study, the different dynamics of CVC is considered for the period 1994 to 2014 in addition to the current vulnerability assessment.

Participatory rural appraisal (PRA) techniques like transect walk, focus group discussions, time lines, seasonal calendar, actor system mapping, key informant interview, Venn diagram, problem tree analysis and semi-structured personal interview schedule were used to collect primary data of dairy farmers. Three PRA were conducted at taluk level, comprising of progressive farmers, dairy development officers and officers of milk cooperative societies. The primary data collected from farmers were validated with the members of respective milk cooperative societies. Secondary data sources were National Centers for Environmental Prediction (NCEP)/National Center for Atmospheric Research (NCAR) Reanalysis meteorological data, from National Oceanic and Atmospheric Administration (NOAA)[20] Physical Sciences Division (PSD) data sources, India Meteorological Department (IMD) data[21,22] and CRU 3.23 (Climate Research Unit, UK)[23] was taken and climatic indicators were calculated from the high resolution daily gridded temperature and rainfall data for the Indian region during a 30-year-period (1973–2013). Other secondary data sources like the Census of India data, 2011 and livestock census data, 2012 were used to validate the household level data.

The study was conducted during the year 2014–15. The Western Ghats, primarily the most deciduous and evergreen forests, and at greatest risk to climate change[24], was selected on purpose for being the biodiversity hotspot of India. Wayanad district of Kerala was selected since this district is fully covered under the Western Ghats. Wayanad can be considered as the 'milk feeder' district of the state. The average per day milk production of the district is about 3.2 lakh litres, out of which 1.6 lakh litres is being procured by 55 dairy co-operative societies. The average milk procurement of dairy co-operatives in the district is 2950 litres per day whereas the state average is below 400 litres[25]. Milk procurement during 1997–98 was 226 lakh litres and increased to 580 lakh litres during 2013–14. It was expected that milk procurement through dairy co-operatives in 2014–15 would be 650 lakh litres[25]. From Wayanad district, three taluks were randomly selected namely Sulthan Bathery, Mananthavady and Pulpally. Sixty dairy farmers were randomly selected from each taluk from the dairy farmer population in the taluk, and thus constituting a total of 180 respondents that owned a minimum of two dairy animals and a maximum of ten and who were dairy farmers since 1994.

Econometric and indicator approaches are two techniques commonly employed to measure vulnerability to CVC[19,26]. This study adopts the indicator approach in measuring the vulnerability of dairy farmers of the Western Ghat region to climate change and involves selection of indicators that largely account for vulnerability[27]. Statistical Package for the Social Sciences (SPSS 20)[28], R Core Team (2012)[29], Microsoft Excel 2007 are the major software packages used for analysis.

The indicators are selected to provide animal husbandry department, development organizations and policy makers a practical tool to assess the contributions of livestock, social and climatic factors that suits the need of each geographical location. Mathematical approach to LVI comprises of seven major components[26]: socio-demographic profile, livelihood strategies, social networks, health, food, livestock, natural disasters and climate variability. Each component comprises several indicators or sub-components. These were developed based on a review of the literature on each major component, as well as the practicality of collecting the needed data through household surveys (Tables 1 and 2). After normalization, the testing of suitability of indicators and elimination of non-significant indicators and assigning weightage were carried out using principal component analysis (PCA) following similar studies[30–32]. For the present study the cut-off value of the communality values was decided as 0.60. After selecting suitable indicators, PCA was run separately for major components of LVI and weights obtained for all major components for 1994, 2004 and 2014 to show the temporal reference.

The vulnerability indices of farmers varied from 0.2064 to 3.0114 (Table 3). The vulnerability index values for livestock component of LVI show that farmers of Mananthavady are most vulnerable while those from Sulthan Bathery are least vulnerable. In Mananthavady, the

Table 1. Categorization of major components into contributing factors from the IPCC vulnerability definition for calculation of the LVI

IPCC contributing factors to vulnerability	Major components
Exposure	Natural disasters and climate variability
Sensitivity	Health, food
Adaptive capacity	Livestock, livelihood strategies, social networks

Table 2. Indicators of livestock, livelihood strategies, social networks, health, and food component with operational definition standardized by expert opinion and by review of literature, collected by household survey and PRA techniques

Variables	Operationalization
Labour use for livestock	Male/female/child labour usage according to hours per day.
Average number of animals/household	It refers to the different categories and average number of dairy animals possessed by the household such as cross bred cows, buffaloes and local cows.
Livestock health services, usage and cost	Livestock diseases, services available, usage and the cost per year.
Livestock inventory	A complete list of items such as property, goods in stock related to livestock.
Education	Systematic instruction received especially at a school or university.
Experience in dairying	It is operationalized as the actual completed years of experience in dairy farming by the respondent.
Annual income	Total income from all sources.
Milk productivity	Average milk production per household.
Percentage of females engaged in dairying	Number of female respondents per household.
Capacity building for planning and improved risk management	Social or personal development that focusses on understanding the planning and improved risk management.
Agricultural intensification/extensification	Agricultural intensification can be defined as an increase in agricultural production per unit of inputs (which may be labour, land, time, fertilizer, seed, feed or cash)
Livelihood diversification	Livelihood diversification is defined as the process by which rural families construct a diverse portfolio of activities and social support capabilities in order to survive and to improve their standards of living.
Migration	Total movement by people from one place to another with the intention of settling permanently in the new location.
Mass media exposure	Mass media exposure is operationalized as the degree to which respondents were exposed to mass media communication, which included television, radio, tape recorded messages, newspaper, agricultural bulletins/magazines, etc.
Extension contact	Extension contact is operationally defined as the degree to which a respondent participates in various activities and maintains contact with extension personnel of the various agencies for obtaining information.
Social participation	Social participation refers to one's degree of participation in a community or society.
Direct effects of hazards such as heat waves, floods and storms	Extent to which directly affected by heat waves, floods and storms.
Infectious disease patterns occurrence	Number and frequency of infectious diseases.
Injury/death from hunger	Number of injury/death from hunger.
Number of malnourished children in family	Number of malnourished children in per family.
Struggle for food	Number of families that face scarcity of food.

majority of farmers are small, marginal or landless. Livestock inventory health services and reach of the Veterinary University and veterinary doctors were more in Sulthan Bathery when compared to other taluks. Mananthavady and Pulpally are tribal-dominated taluks and therefore livestock is reared for sustenance whereas a large number of progressive farmers were found in Sulthan Bathery region. In Pulpally region, due to higher mean standard deviation of monthly average precipitation and temperature since 1972 and thereby drying of Kabani river, there is less fodder production for the animals.

In case of socio economic and demographic profile, Pulpally and Mananthavady were found to be more vulnerable than Sulthan Bathery. The education level of tribal groups of Mananthavady was very low, among the least in the country and hence brought under a special scheme of District Primary Education Programme funded by World Bank. The tribal dropout was 61.11% in 2007–08. Five years later in 2011–12 it rose to 77.23% when compared to the total dropout in the district. There was an increase in trend of 16.12% of drop outs in the district's tribal sector alone[33]. The average milk productivity of animals is less than 5 litres for Mananthavady and Pulpally regions, and for Sulthan Bathery, it is more than 10 litres per animal with Holstein Friesian, non-descript and Jersey breeds. As milk productivity and livestock inventory were high, the annual income was also high for Sulthan Bathery farmers. As the crop patterns/crop combinations prevalent are based on unscientific norms, the degrading soil quality reduces the income from agriculture and dairying from Pulpally region.

The livelihood strategy component was also found to be low for Pulpally and Mananthavady. Cultivation of pepper, cardamom, coffee, tea, spices and other condiments and cattle rearing was the major source of livelihood, but due to erratic rainfall and drought the trend had changed. Income from forest resources like honey for the tribes of Mananthavady drastically reduced due to climate change. From Pulpally region, most family members were found migrating to other states such as Karnataka. This phenomenon increases the vulnerability as the family members who migrated could come back with some social vices or health issues, thus reducing the family labour available for farm operations. It is possible that

Table 3. INDEXED sub-components, major components for overall LVI to climate change of Wayanad, Kerala

Sub-component	Region			Major components	Region		
	Sulthan Bathery	Mananthawady	Pulpally		Sulthan Bathery	Mananthawady	Pulpally
Labour use for livestock	3.0574	2.9137	2.8561	Livestock	2.5699	2.3929	2.4486
Average number of animals/household	2.6236	2.4131	2.5036				
Livestock health services, usage and cost	2.0749	2.1231	2.0238				
Livestock inventory	2.5236	2.1216	2.4111				
Education	2.8050	0.3130	0.5236	Socio economic and demographic profile	2.5923	2.3959	2.3121
Experience in dairying	1.8609	1.7703	1.8509				
Annual income	1.9870	1.7530	1.0063				
Milk productivity	1.6969	1.5131	1.1210				
Percentage of females engaged in dairying	1.8726	1.8020	1.7805				
Capacity building for planning and improved risk management	1.8505	1.2514	1.2253	Livelihood strategies	1.8554	1.7002	1.7612
Agricultural intensification/extensification	1.2210	1.1206	1.0236				
Livelihood diversification	2.7020	2.5890	2.5061				
Migration	2.0115	2.0084	2.0412				
Mass media exposure	0.2643	0.2195	0.2064	Social networks	1.5328	1.3913	1.1619
Extension contact	1.6515	1.4514	1.1256				
Social participation	2.6826	2.5031	2.1536				
Direct effects of hazards such as heat waves, floods and storms	1.0215	1.0984	1.4225	Health	1.1778	1.4557	1.5965
Infectious disease patterns occurrence	2.4287	2.6540	2.7345				
Injury/death from hunger	0.6287	0.6148	0.6325				
Number of malnourished children in family	1.0941	1.2376	1.6906	Food	1.1181	1.5668	1.7873
Struggle for food	1.1422	1.8961	1.8841				
Average number of floods, drought and landslides since 1972	2.2981	2.3005	2.3107	Natural disasters and climate variability	1.8003	2.0797	2.1888
Percentage of households that did not receive a warning about the pending natural disasters	1.1887	1.9841	2.2812				
Percentage of households with an injury or death as a result of flood or drought since 1972	2.7132	2.7361	2.8050				
Mean standard deviation of monthly average of average maximum daily temperature since 1972	2.2281	2.4127	2.5236				
Mean standard deviation of monthly average of average minimum daily temperature since 1972	1.1892	1.9671	2.0794				
Mean standard deviation of monthly average precipitation since 1972	2.7034	2.8612	3.0114				
Mean standard deviation of mean air temperature since 1972	0.2814	0.2961	0.3107				

climate change may force the pace of rural-urban migration (rurbanization) over the next few decades[33].

The social network component of Mananthavady and Sulthan Bathery was similar while Pulpally is more vulnerable. Even though education, mass media participation, social participation and achievement motivation of Wayanad tribes are poor, due to the influence of NGOs like Wayanad social service society, milk cooperative societies, self-help groups (SHGs) like Kudumbasree, NABARD and other nationalized banks, the overall social network component of Mananthavady region is found to have improved in the present years. Pulpally is 24 km from Sulthan Bathery, surrounded by forest and hence there is little reach to universities, SHGs, NGOs owing to which awareness creation and training programmes on climate literacy are non-existent.

The accessibility to health facility centre is lowest in Mananthavady and Pulpally regions. As far as health and food were concerned, the number of malnourished children and infectious diseases in Pulpally and Mananthavady were more than those in other taluks.

From the same table, it was found that natural disasters and climate variability were more in Pulpally taluk of Wayanad and comparately lower in Mananthavady, Sulthan Bathery taluk. Pulpally taluk had comparatively higher variation in rainfall including less and excess number of rainy days and drastic variation in maximum and minimum temperatures. The annual southwest

monsoon rainfall is observed to be declining while the post-monsoon rainfall is increasing. Even the soil quality of Pulpally region is degrading and losing its gravelly quality due to unsustainable cultivation and climate change. As a result, the overall exposure index of Pulpally taluk is higher when compared to other sample taluks. All the taluks of Wayanad had higher landslide incidences from 1973 to 2013 (ref. 34). There was less variation in change of mean minimum and maximum temperature trend from 1973 to 2013 across Mananthavady region.

With a standard heptagon as background, a radar diagram was constructed for Wayanad by scoring the LVI components and indicators for the respondents of the taluks. The shape of the heptagon was used to show schematically the variation in vulnerability. Figure 1 shows a skewed heptagon indicating that dairy based livelihoods of the districts are vulnerable to climate change. In Pulpally region, livelihood strategies were found to be less diverse indicating more agrarian distress and migration. Accessibility to food is less in Pulpally compared to other taluks and greater malnourishment greater in this region. The figure shows that Pulpally and Mananthavady are the most exposed regions to CVC with Pulpally being the most sensitive region. The differential vulnerability of dairy farmers to climate variability exhibited among the taluks of Western Ghats region reflects different spatial combinations of climate exposure, sensitivity and adaptive capacity indices. The landslide risk made the taluks of Wayanad vulnerable because the economy of the people is significantly dependent on agriculture and dairying. Prolonged and heavy precipitation or a combination of the two and the resultant pore pressure differences are important causes of landslides. There were more than 29 cases of landslides reported in Wayanad[29] that completely blocked the transport and communication facilities. The relative high adaptive capacity component scores in these taluks moderated their livelihood vulnerability.

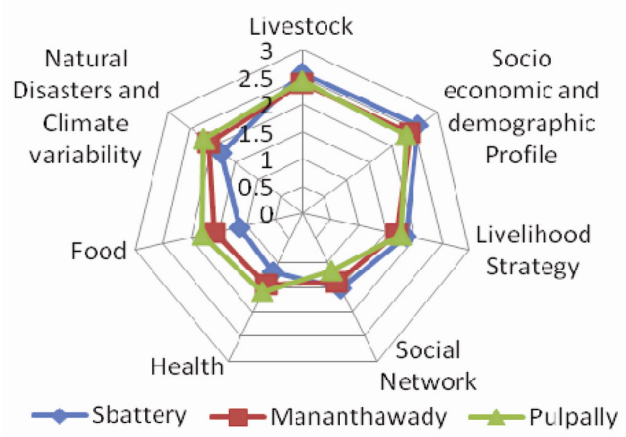

Figure 1. Major components of the livelihood vulnerability index (LVI) for Wayanad district. The radar diagram of different colours shows the LVI values for the major components, with the standard heptagon in the background.

Duncan's multiple range test was applied for a comparative evaluation of different components (Table 3) and the mean index value of components of vulnerability index at household level in Wayanad region is given in Table 4. Dairy farmers from Sulthan Bathery had the highest adaptive capacity (2.1376 ± 0.087) and dairy farmers of Pulpally had the lowest adaptive capacity (1.9209 ± 0.078). It was also found that there was no differentiation of adaptive capacity among dairy farmers of Mananthavady and Pulpally taluks. But, the adaptive capacity of dairy farmers of these taluks differed significantly ($P < 0.05$) from the dairy farmers of Sulthan Bathery. Dairy farmers of Pulpally taluk had the highest exposure (1.6919 ± 0.078) when compared to other taluks. Exposure of dairy farmers of Mananthavady and Pulpally taluks differed significantly ($P < 0.05$). Dairy farmers of Pulpally taluk were most sensitive (2.1888 ± 0.108), whereas those in Sulthan Bathery were least sensitive (1.8003 ± 0.118) to climate change.

Temporal analysis of LVI over the years (Figure 2) shows that in case of socioeconomic and demographic profile, there was an increasing trend from 1992 to 2013. Average literacy rate of the district and decision making capacity of the female population shows an increasing trend. When we consider the average milk productivity of the animals of the regions, it was less than 5 litres before 2000, but due to cross-breeding and artificial insemination, it is now more than or equal to 10 litres per animal. As milk productivity and livestock inventory increased, annual income should have also increased by 2014, but the sudden spread of diseases, combined with search for alternate occupations and migration reduced the net income from dairying.

Hence, it is clear from Table 5 that among the dairy farmers of Wayanad district, livelihood of farmers of Pulpally taluk was highly vulnerable. Dairy farmers of Sulthan Bathery taluk had the highest adaptive capacity and were least exposed. This may be the reason for least vulnerability of dairy farmers of Sulthan Bathery. Vulnerability, exposure and sensitivity of the livestock rearers of Pulpally was significantly different from their counterparts of Wayanad. The natural disasters and climatic variability also showed an increasing trend.

Moderate natural disasters and climate variability of Sulthan Bathery, households with good livestock potential and farmers with livelihood strategies and food and health facilities contributed to the social and ecological resilience of the system. Disruptive weather events had affected the milk-market chain and also other physical infrastructure facilities in Wayanad. PRA results revealed many new innovative practices like hydroponic fodder cultivation, farm fresh milk with more chilling units, low cost automatic water supply system for animals, climate friendly cattle sheds with cooling mechanisms, introduction of more resistant breeds like gir, tharparkar along with sahiwal, promoting indigenous breeds like kasargodan

Table 4. IPCC vulnerability index and its different components (mean ± SE) in the three taluks

$N = 180$	Adaptive capacity	Exposure	Sensitivity	IPCC vulnerability
Sulthan Bathery	2.1376 ± 0.087^{a}	1.1479 ± 0.092	1.8003 ± 0.118	1.55 ± 0.101
Mananthavady	1.9701 ± 0.012^{ab}	1.5112 ± 0.112^{ab}	2.0797 ± 0.122^{ac}	2.22 ± 0.106
Pulpally	1.9209 ± 0.078^{ab}	1.6919 ± 0.078^{b}	2.1888 ± 0.108^{c}	2.73 ± 0.117^{ac}

abc means dissimilar superscript which indicate significant difference of mean ($P < 0.05$).

Table 5. Distribution of households according to differential levels of vulnerability using cumulative square root frequency technique

$N = 120$	Low (0.66 to –1.07)	Medium (–1.08 to –2.75)	High (–2.75 to –3.2)
Sulthan Bathery (%)	49	35	16
Mananthavady (%)	13	55	32
Pulpally (%)	10	42	48
Overall (%)	24	44	32

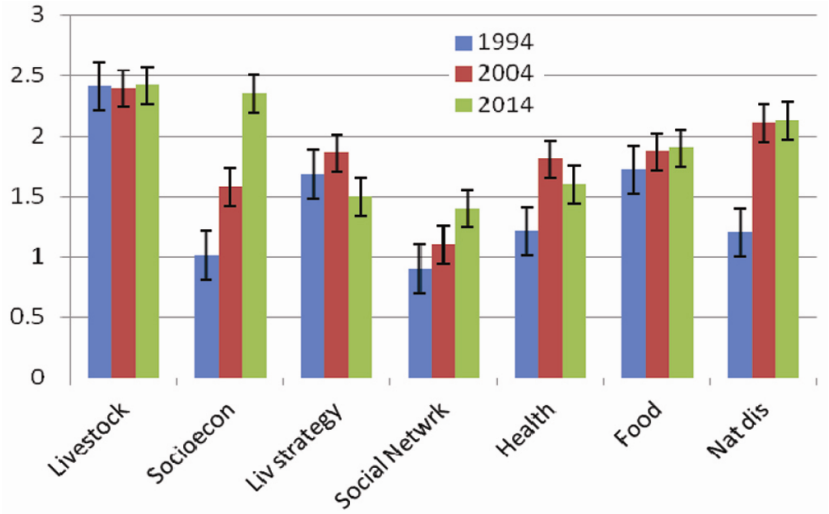

Figure 2. Aggregated values of LVI components over the years 1994, 2004 and 2014.

kullan, vechur and malanad gidda increased the overall adaptive capacity of the region.

This study clearly indicates that the positive effect of adaptive capacity was nullified by the combined effect of exposure and sensitivity among dairy farmers of Wayanad and this situation is alarming. Reducing vulnerability of dairy farmers of Wayanad by adaptation and mitigation process requires identification of different potential options depending on local contexts at grass root level. Adaptation policies and research in Wayanad should focus on improving the adaptive capacity component and preparing the extensionists of Wayanad region, Krishi Vigyan Kendras (KVKs) and universities to deal with the risks of CVC through extensive training programmes, workshops on climate science and communication on innovative climate information to clients, and promoting farmer to farmer extension system. However, biophysical exposure elements like temperature, rainfall and natural disasters control policy making. Hence an integrative coupled socioecological system analysis is needed for implementing and developing ecosystem-based strategies. Sustainable diversification of agriculture is needed for improving the adaptive capacity and livelihood security. The LVI-based ranking of taluks would aid development agencies, decision-makers and planners to map the most vulnerable regions for adaptation and mitigation interventions.

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