



## Article

# Farmers' Perception and Efficacy of Adaptation Decisions to Climate Change

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**Abstract:** Climate change is viewed as the main obstacle to agricultural development in developing countries. The high dependence on agriculture and allied sectors makes many countries vulnerable to the climate change phenomenon. There is a gap in macro and micro-level understanding of climate change. Thoughtful farmers' perceptions and impacts of climate change on farming are fundamental for developing various mitigation and adaptation strategies. Therefore, the main aim of the present study was to understand the pattern of climate variability, farmers' perceptions about climate change, and farmers' adaptation strategies based on their socio-cultural background in the villages of Goa, on the west coast of India. The results reveal that about 62% of the sampled farmers have experienced climate change in terms of meteorological indicators such as increased average temperature, decreased total rainfall, delayed onset of monsoon, and an increase in the length of the summer season. The temperature trend analysis (0.009 °C/year) validated farmers' perceptions, while the perception of rainfall differed (−1.49 mm/year). Farmers are convinced that climate change has affected their farming (declining crop and livestock productivity, water depletion, and other related farm operations). They strive to adapt to climate change through crop diversification, an integrated crop-livestock system, contingency crop planning, and the adaptation of new crops and varieties. This study could be helpful for policymakers to establish a climate-resilient agriculture system by ensuring timely availability of farm inputs, accurate weather forecasting, and encouraging insurance products for crop and livestock enterprises, which will help farmers cope with the changing climate to enhance their income and economic wellbeing. Further, adaption of integrated farming, agroforestry, and indigenous technical knowledge is imperative to combat the ill effects of climate change.

**Keywords:** climate-resilient; climate change perception; climate adaptation; farmers' income; Mann–Kendall test

## 1. Introduction

Climate change can be defined as a global phenomenon of climate transformation mainly characterized by the changes in the usual climate of the planet Earth concerning temperature, precipitation, and wind that are primarily caused by human activities [1]. Further, these climatic aberrations are associated with various adverse impacts on agriculture, water resources, forests and biodiversity, coastal management, and human health [2–5]. As climate change is a long-term shift in global or regional climate patterns, from an agricultural perspective, recent-age farmers face the multifaceted challenges of providing food and nutritional security to protect environmental quality and agricultural sustainability [6]. The effect of climate change has added more woes to these challenges. Rising temperature and changing rainfall patterns, droughts, floods, and other weather aberrations affect crop growth, livestock performance, water availability, and ecosystem services [7,8].

Apart from temperature and rainfall variability in India, drought, flood, and soil degradation are among the significant climate change features responsible for lower agricultural productivity [4]. These, coupled with a traditional package of practices, using old varieties, mono-cropping, reliance on single agri-enterprises, and poor government policy, affect small and marginal farmers' ability to adapt to climate change, which in turn reduces the performance of already-weak agriculture [9]. Currently, there is a broad scientific consensus that climate aberrations are unavoidable [10]. The effects of climate change on society have become an international issue of common concern to governments, societies, and scientific communities [2,11,12]. Agricultural production is deceptively affected by climatic shock, which is usually demonstrated by the outbreak of pests and disease, and land degradation problems [5]. The supply of diverse crops and livestock products while protecting the environment is a significant challenge in the near future. Climate change may decrease world food production by 1.5% per decade [13]. Climatic factors such as temperature, solar radiation, relative humidity, and carbon dioxide (CO<sub>2</sub>) concentration have affected plant growth and yield [14]. However, climate change affects agroecosystem services by rising temperature and changing precipitation patterns [10].

The agroecosystem in India is very fragile due to its high level of vulnerability to climate change impacts such as rising sea level, delayed onset of monsoon, higher or lower rainfall, increase in the duration of hot days, etc. For example, differentially affected maize yield in different regions due to climatic aberrations [15]. Agarwal and Swaroop Rani [16] observed changing temperature and rainfall trends and analyzed their effect on different crops over different parts of India. In this regard, adaptation to changing climate with climate-resilient technologies and their precision appears to be an effective method for farmers to mitigate the adverse effects of climate change [17]. Climatic factors such as temperature, solar radiation, relative humidity, and atmospheric carbon dioxide (CO<sub>2</sub>) concentration have been shown to affect the processes of both photosynthesis and dry matter allocation in plants. Increasing the temperature by one °C and CO<sub>2</sub> concentration to 500 ppm will considerably decline wheat productivity and significantly affect wheat grain and biomass yield [14]. Hence, the results provided a base for preliminary coping and prioritizing adaptation options for future climate change scenarios [18].

Nizam [19] studied the rainfall and temperature variability in the Anuradhapura district from 1941 to 2010 and farmers' perception of climate change. They found that a majority of the farmers' perceptions were analogous to a statistical record of meteorological data. Sarkar and Padaria [20] observed that nearly 38% of the respondents had heard about climate change and most of them perceived climate change due to fast industrialization. People's awareness was more about the temperature change, reduction in agricultural and livestock production, increased diseases, sea-level rise, etc. than the phenomena such as frequent cyclones, cold wave occurrence, and heavy fog [21]. The average score on the awareness of perceived consequences due to climate change was very high for reducing agricultural production. Dhanya and Ramachandran [22] found a good similarity between farmers' perceptions with the statistical trends of meteorological variables, except for rainfall in the semiarid region of South India. Climate change poses

a threat to smallholder farmers on the west coast of India due to the lack of reliance and climate-sensitive small-scale production systems. Adaptation strategies are affected by several factors such as education level, size of the farm family, gender of head of the family, crop-livestock component, access to extension services and credit from different agencies, knowledge about an improved package of practices, etc. [23–25].

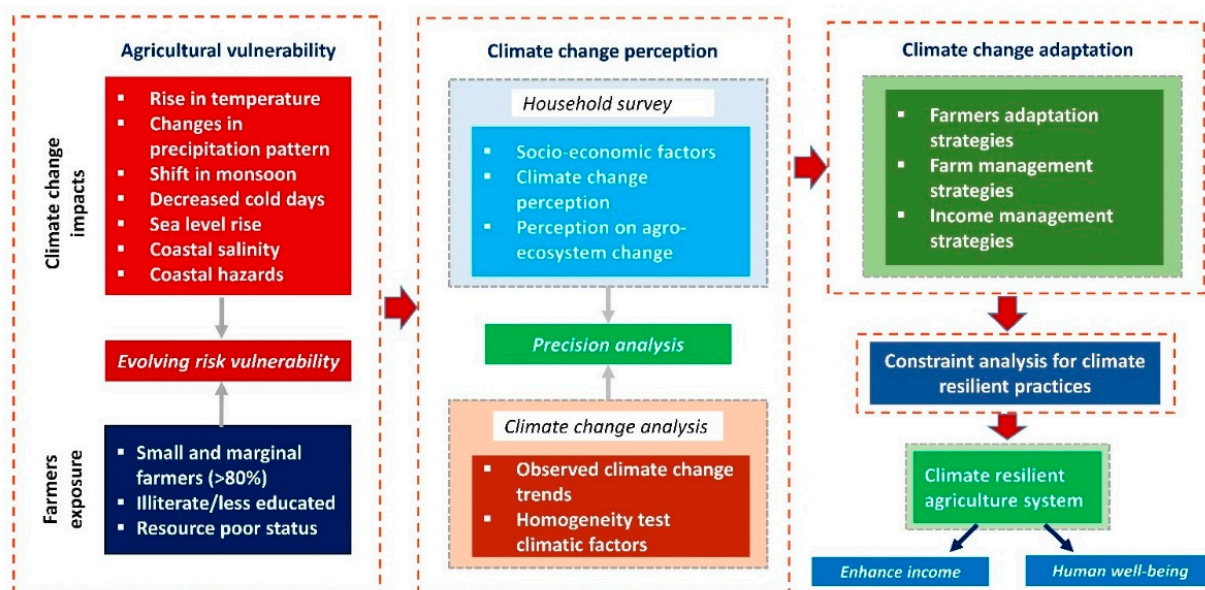
Goa is a coastal state facing significant problems due to climate change and associated impacts. The crop production in the region is influenced by a variety of factors, including climate, soil, topography, and institutional and socioeconomic condition of the farmers. With 80% of small and marginal farmers, regional agriculture is very sensitive to climate change [26]. The marginal and small landholders with less climate-resilient management and capital-intensive technologies are more sensitive to climate change [9,27]. Despite perceiving the climate change phenomenon, farmers and policymakers frequently fail to respond to its repercussions due to socioeconomic and institutional restrictions such as lack of willingness, insufficient capital/resources, misbelief, and lack of knowledge [28]. In most scenarios, farmers are aware of the adverse effects of overuse of natural resources; despite this, they continue to overuse. Farmers focus on sustaining their production and income rather than environmental protection. Hence, it is critical to understand farmers' perceptions of climate change, the precision with which they perceive climate change, and the efficacy of agricultural adaptation to climate change. Moreover, developing and adopting climate-resilient practices is a significant challenge, as the agriculture systems are operated mainly by small and marginal farmers. Many of these farmers are illiterate/less educated and resource-poor with a lower adaptive capacity [27,29].

As a result, large-scale adoption of resilient climate practices cannot be possible, as most practices are region-specific [30]. Studies by Shewamake [31], Slegers [32], Gandure et al. [33], and others focused on drought preparedness, impact on, and response by, the farming community, perceptions of climate change, the interrelationships between land degradation and drought and rainfall and drought, scarcity of water, and coping responses in the global context. Bahta et al. [34] investigated communal crop and livestock farmers' perceptions of agricultural drought, as well as the application of resilience theory to farming and an understanding of drought vulnerability in their operations. In the Eastern Cape province of South Africa, researchers discovered that communal farmers' perceptions indicate that they receive insufficient government support; they do not believe social networks are effective in reducing drought risk, gender stereotyping, and psychological stress; and their farming experiences high levels of stock theft and insecurity. Further, Bahta [35] advocates that all key stakeholders should work together to support techniques that will help smallholder livestock producers become more resilient against agricultural drought in the Northern Cape province of South Africa. Although few studies have been undertaken in India to ascertain farmers' perceptions of climate change, there is a need for location-specific studies as the implications of climate change, adaptation strategies, and farmers' knowledge are highly site-specific. Therefore, the present study attempts to identify farmers' perceptions in the North Goa district of Goa and assess the precision of perceptions by comparing the observed perceptions with meteorological data and their adoption strategies to overcome the effects of climate change. This evidence may lead to developing climate-resilient agriculture practices and policies, augmenting crop and livestock production for resource-poor farmers to cope with changing climatic impacts.

#### *Conceptual Framework of the Study*

We developed a conceptual framework based on the agricultural vulnerability imposed by climatic threats. The framework also focuses on analyzing climate change perception factors and existing adaptation strategies in the coastal districts of Goa, which can help develop climate-resilient practices and agricultural systems to enhance income and human well-being. Many studies showed that climate change had brought several atmospheric phenomena, such as a rise in temperature, changes in precipitation patterns, a shift in monsoon, and decreased cold days [36]. These phenomena collectively reduced

crop and livestock productivity over the decades [37]. In India, 55% of the population is dependent on agriculture for livelihood security, with the majority being small and marginal farmers [38]. Therefore, assessing farmers' perceptions of their ability to cope (temporary adjustments in response to change) or adapt (longer-term changes in livelihood strategies) to climate change is necessary for achieving sustainable livelihoods. Different climate change beliefs, their confirmation with meteorological data, and farmer adoption techniques were all addressed in past studies. Farmers in India's arid eastern state of Karnataka perceived a reduction in output and revenue due to climate change as a serious limitation [39]. Farmers in the majority of cases perceive changes in monsoon patterns, as well as the onset and termination of rainfall, as a result of climate change [40,41]. Changes in seasonal wind speed and direction are viewed as climate change stress by 44 percent of respondents in cyclone-prone locations in Madhya Pradesh, India [42]. Assessing resilience and the ability to adapt or successfully cope positively requires an analysis of various factors, including an evaluation of historical experiences of responses to various climatic aberrations. The effectiveness of the adaptation strategies to climate change depends mainly on community awareness measured by the farmer's perception of the threats [43]. The perception of risk, belief systems, psychological distance, and trust [44] and the willingness to contribute to social capital [45] are crucial in the adaptation process of agriculture to climate change. Though the farmers are aware of the changing climate, they need more awareness about adapting to climate change [28]. To develop adaptation and mitigation strategies, it is imperative to know the farmers' perceptions of climate change, their perception precision in relation to observed meteorological data, and their adoption strategies for overcoming climate change to develop a climate-resilient crop system in Goa (Figure 1).



**Figure 1.** Conceptual framework of the present study to develop climate-resilient agriculture systems in the North Goa district, coastal India.

## 2. Material and Methods

### 2.1. Description of Study Area

This study is a part of the collaborative research project entitled “Integrated Farming System for improving nutrition and livelihood of farm women under different agroecosystems”. The Goa state of India falls in the Western Plains and Western Ghat climatic zone under the hilly coastal sub-region. The geographical area of the North Goa district is 1736 km<sup>2</sup> and lies between 15°49′ N and 73°83′ E. It receives most of the rainfall from the southwest monsoon from June to September. The mean annual rainfall of the region is

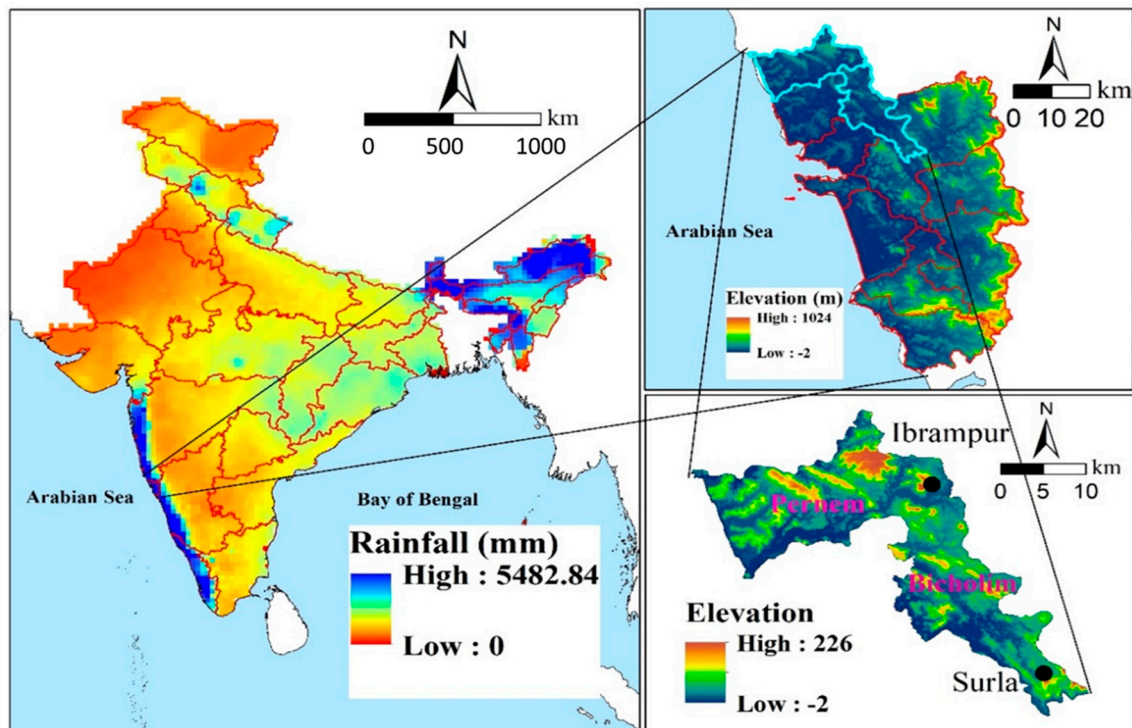


3328 mm. The average temperature ranges between 20–32 °C. The study area falls in the North Goa district and has a population of 0.82 million people, with 0.42 million males and 0.41 million females. In the North Goa district, almost 39.72 percent of the population lives in villages. The total number of people living in rural regions in North Goa is 0.324 million, with males and females being 0.1364 million and 0.061 million, respectively. The population density of the district is 471 persons per square kilometer. In North Goa, the male-to-female ratio is 963 for every 1000 males. North Goa has an average literacy rate of 89.57 percent. When looking at things from a gender perspective, male and female literacy rates were 93.40 percent and 85.60 percent, respectively. The total number of literates in the North Goa district is 663,060, with 351,738 males and 311,322 females. The region's climate is warm and humid with a mean annual temperature of 27.8 °C, a mean maximum temperature of 30.2 °C, generally achieved in May, and a mean minimum temperature of 26.4 °C, typically reached in January. The average yearly temperature difference between summer and winter is 4 degrees Celsius (Sehgal & Mandal, 1994). The annual mean precipitation is 2910.5 mm, which is completely due to the southwest monsoon. June has the most precipitation (828.8 mm), with some pre-monsoon showers in April and May. Along the coast, the study area includes both hills and plains. Shallow, slightly to moderately acidic, and gravelly soils characterize the hills. The coastal plains' soils are extremely deep, moderately acidic to severely acidic, and classified into Inceptisols, which are rich in phosphorus and aluminum, and Entisols, which have sandy loam to sandy textures. Farming is the main occupation of the people in the region, with 35% of the population engaged directly in agriculture and allied activities. Further, rice is the dominant field crop, followed by cashew, coconut, and areca nut cultivated in the district. Groundnut and cowpea are grown under rice fallows using residual soil moisture. However, some parts of the study area are emerging as among the most industrialized, mining, urbanization, and manufacturing hub. Farmers in Goa earn an average income of INR 91,098 a year, including INR 16,893 from farming, INR 15,097 from dairying, INR 12,243 from non-farm activities, and INR 46,865 from wage labor and salary.

## 2.2. Questionnaire, Sampling and Field Survey

The data were collected from the Ibrampur and Surla village of Pernem and Bicholim taluk, respectively, in the North Goa district of Goa state (Figure 2). The village's geographical location is on the foothills of Western Ghats and the topography of the land is undulating in the mid-remote area. The study's pertinent data were gathered from both primary and secondary sources. The primary source of data was a cross-sectional survey of 200 households conducted in 2017–2018. A sample of 200 farmers (representing 10% of the total farmers in each village) was selected from the two villages of the district through random sampling techniques in the agricultural year from July 2017 to June 2018. We designed a questionnaire based on the presurvey interviews with village cadres and farmers or herdsmen. Farming households were the unit of analysis, and the head of the family was interviewed. Further, the enumerators conversant in the local language and traditions were hired for carrying out the field survey. Agricultural households were asked about their primary adaptation strategies towards climate change impacts to finalize the adaptation options. Based on the respondents' interviews in the presurvey, it was found that many smallholder farmers in the coastal districts of Goa have applied different adaptation strategies for climate change. The primary data majorly include demographic, socioeconomic, institutional, and biophysical attributes. The data consist of information on farmers' perception of temperature and rainfall patterns over the past 36 years and farm strategies adopted by the farmers. Our primary assumption was that the farmers within each village might have significant variations in climate change perception and skills and knowledge, which may, in turn, differentiate their adaptive capacities and the choice of adaptation strategies. Since climate change can have different consequences in different villages, farmers can adopt different adaptation strategies in their respective villages. These

adaptation strategies are also characterized by the socioeconomic, household conditions of the villages.



**Figure 2.** Map of the study area ( $15.2993^{\circ}$  N,  $74.1240^{\circ}$  E).

The analytical study employed (i) detailed survey questionnaires, (ii) group discussions, and (iii) field observation methods as participatory rural appraisal (PRA) tools with the help of language interpreters during the survey with household heads or other senior members. Since climate change can have different consequences in different villages, farmers can adopt different adaptation strategies based on their villages' socioeconomic and household characteristics.

### 2.3. Collection of Climatic Data

Daily maximum and daily minimum temperatures were collected from India Meteorological Department (IMD), Pune for Pernem and Bicholim taluk. Monthly and yearly means of the temperatures, annual and seasonal precipitation, and linear trends in these parameters were investigated. The parametric linear and nonparametric Mann–Kendall trend tests of meteorological parameters were analyzed using Microsoft Excel, and graphs were plotted. The homogeneity tests such as Pettit's test (this test is also more sensitive to the breaks in the middle of the series), standard normal homogeneity test (SNHT; is more sensitive to the breaks near the beginning and the end of the series), and Buishand's test (this test is more sensitive to breaks in the middle of time series) were performed at a significance level of 0.05 using Microsoft Excel. The homogeneity test was performed to identify and adjust non-climatic variations caused by changes in observing practices, observing time, site relocation, etc. The inhomogeneities in the time series data can interfere with assessing any climate trends and extremes. On the basis of the computed mean value, the Garrett ranking technique was used to identify and rank various adoption strategies practiced by farmers. The main benefit of this technique is that the adoption strategies are arranged based on the farmer's perception. Hence, the same number of responses on two

or more strategies may obtain different ranks. The normal rank was converted into % using the following Garrett's formula (Equation (1)):

$$\% \text{ position} = 100 \times (r_{ij} - 0.5) / n_j \quad (1)$$

where  $r_{ij}$  = rank given for  $i$ th factor by  $j$ th individual;  $n_j$  = number of factors ranked by  $j$ th individual.

The scores are obtained by referring to the table given by Garrett and Woodsworth [46]. The essential strategies are identified by ranking the scores of individual adoption strategies.

### 3. Results and Discussion

#### 3.1. Socioeconomic Characteristics of Farm Households

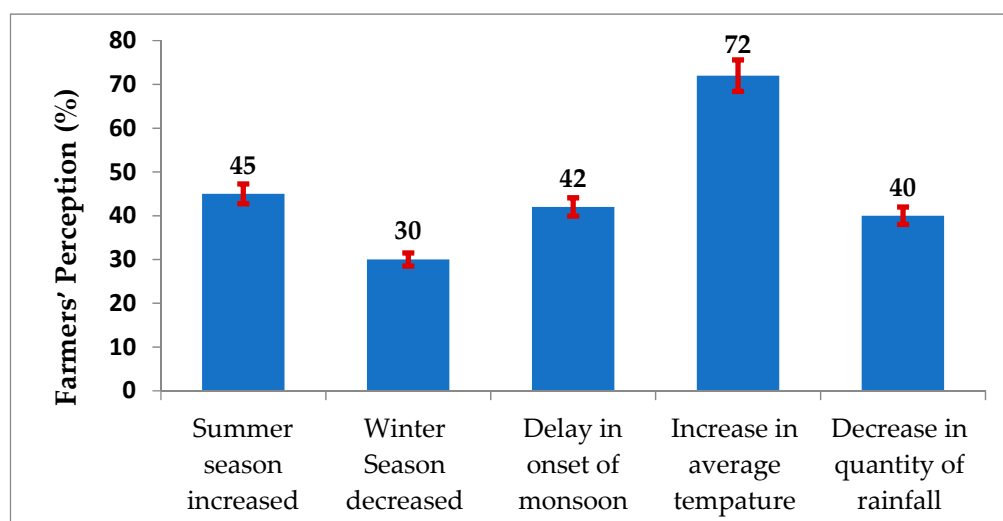
The socioeconomic characteristics of farm families are believed to have diverse impacts on farmers' perceptions about climate change and their capability to adapt. The age of the farmer represents their experience in farming. The majority of the farmers were from the middle age group (59%), followed by the age-old group (24%) (Table 1). The family structure of the farmers in the study region was mainly nuclear (68%) with fewer joint families (32%). Regarding farming types, 41% of the farmers were engaged in livestock farming and 51% practiced crop-based agriculture, while 8% were following crop and livestock integration. The majority of farmers were marginal and small, with less than one hectare of land due to subdivision and land fragmentation, which are more prevalent in the nuclear family system than in the traditional joint family system. Attaining higher education levels helps farmers access information on improved technology and resources. Most of the farmers studied at the high school level (61%), about only 4% had attained graduation, 15% studied until the primary, and 12% up to higher secondary, while 8% were uneducated among the respondents.

**Table 1.** Socioeconomic characteristics of sampled farm households in North Goa district.

Particulars	Pernem Block (%)	Bicholim Block (%)	All Farmers
<b>Sample Size</b>	<b>50</b>	<b>50</b>	<b>100</b>
Average age of the farmers (years)			
Young age (<35 years)	9	8	17
Middle age (35–55 years)	27	32	59
Old age (>55 years)	14	10	24
Family Size (no.)			
Up to 5	32	36	68
More than 5	18	14	32
Livestock (yes = 1; otherwise = 0)	41	0	41
Crop (yes = 1; otherwise = 0)	1	50	51
Crop & Livestock (yes = 1; otherwise = 0)	8	0	8
Landholding type (no.)			
Marginal (<1 ha)	19	23	42
Small (1–2 ha)	13	16	29
Semi-medium (2–4 ha)	10	8	18
Medium (4–10 ha)	6	2	8
Large (>10 ha)	2	1	3
Education (no.)			
Uneducated	4	4	8
Primary	8	7	15
High School	30	31	61
Higher secondary	6	6	12
Graduation	2	2	4

### 3.2. Perceptions about Climate Change

About 62% of the sampled farmers perceived climate change in various meteorological indicators (Figure 3). Approximately 40% had perceived that there was a decrease in the quantity of rainfall. However, 42% had perceived a delay in monsoon onset by one day than earlier. Even 72% of farmers perceived an increase in annual temperature, and few of them (30%) stated that there is an increase in the length of the summer season, and the span of the winter season was decreased. It was evident from the results that farmers were reluctant to take up the second crop, especially pulse, during the summer season due to an increase in hot days. Earlier studies in numerous parts of India found that the majority of farmers observed an increase in temperature and a decrease in rainfall over time [47–50]. Dhanya and Ramachandran [22] also observed delayed onset of monsoon and a decrease in rains under the semiarid region of Tamil Nadu, India. Likewise, Shashidhar and Reddy [48] reported an increased temperature rainfall variability over the year. According to studies on farmers' perceptions of climate change in coastal ecosystems, farmers in West Bengal, India's east coast, score the highest on farmers' awareness of the perceived effect of climate change on agricultural production [21].

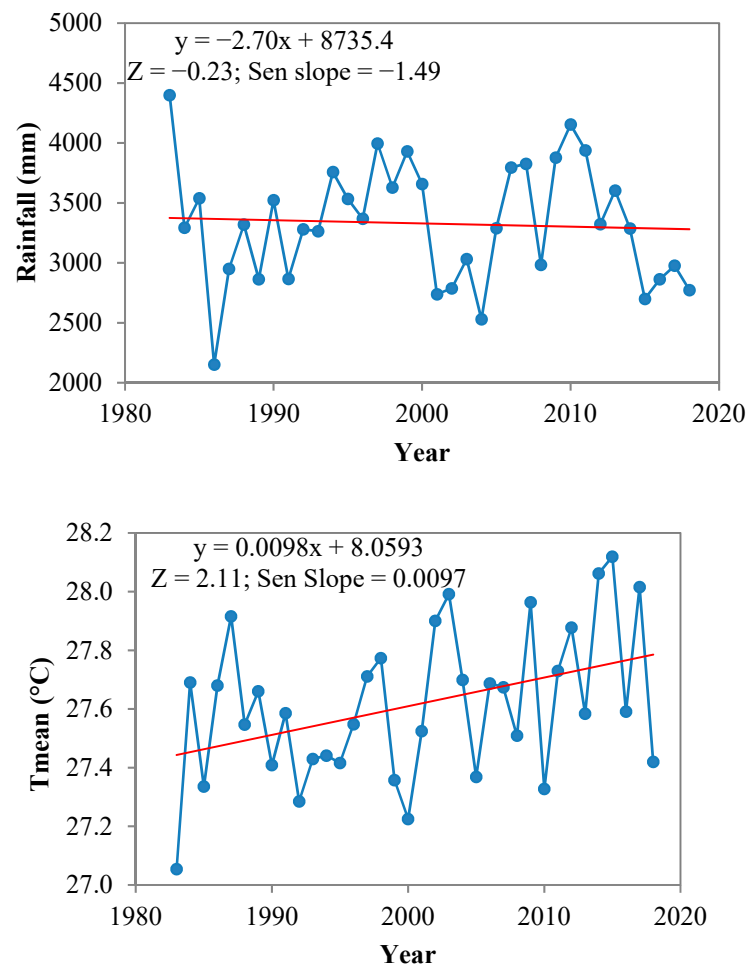


**Figure 3.** Farmers' perceptions (%) about climate change.

### 3.3. Actual Climate Trend of Goa

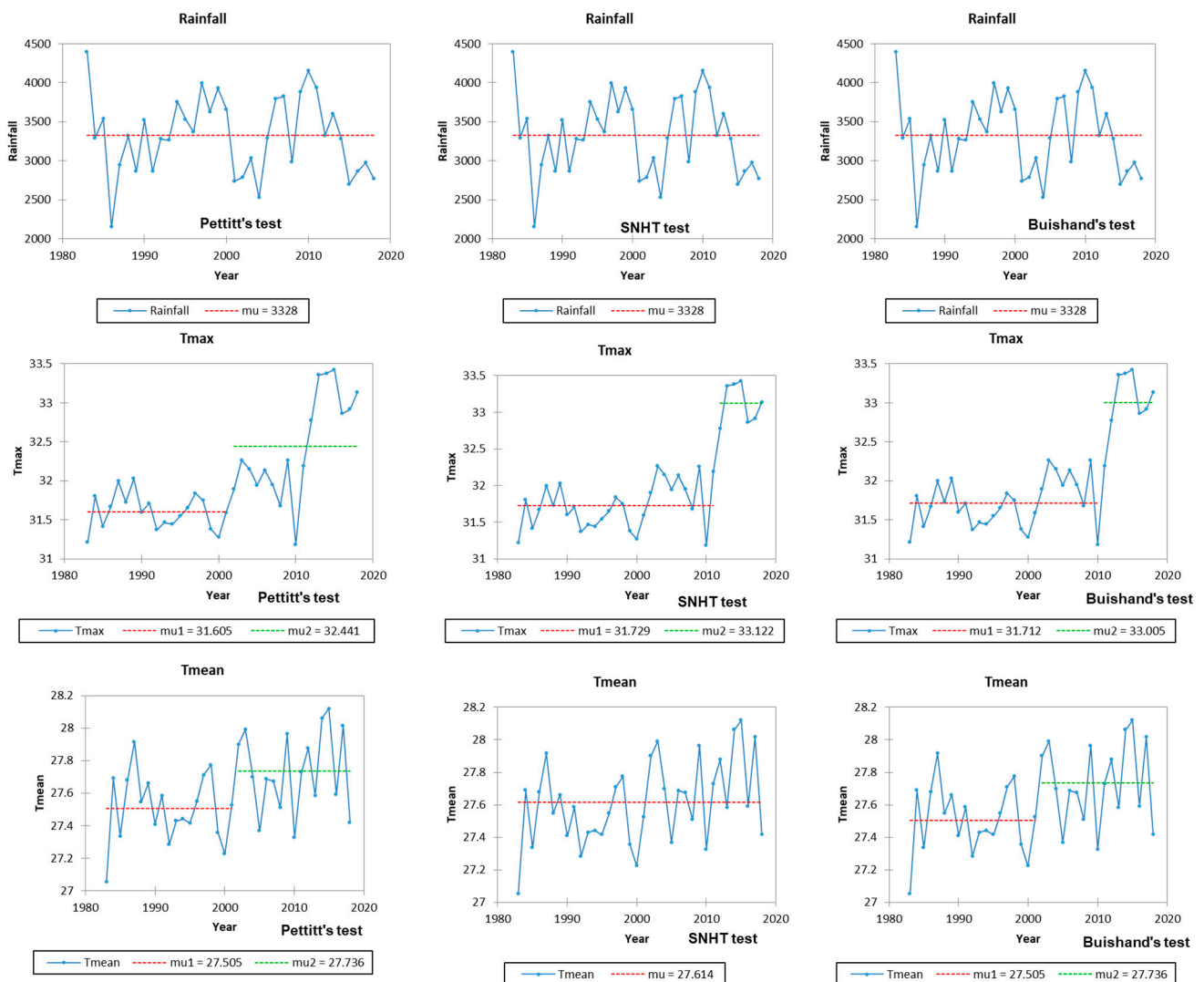
To validate the perceptions of the sampled farmers, the long-term data on temperature and rainfall pertaining to Goa state were analyzed. Figure 4 elucidates a highly erratic amount of rainfall during 1986, 2001–2005, and 2008. The overall linear trend for rainfall of the study period (1983–2018) was found to be non-significantly decreasing ( $-2.7031$  mm/year). Some of the farmers (42%) reported a delay in the onset, and 40% of the farmers reported a decrease in the quantity of rainfall. However, farmers' perceptions about the amount of rainfall trend differed. This could be due to farmers' concerns about the availability of rainfall during the main crop-growing season. They do not account for the total rainfall received in their area annually. Additionally, respondents noted that crop growth is harmed by the delayed commencement and periodic dry spells. Furthermore, the homogeneity tests (Pettitt, SNHT, and Buishand test, Figure 5) accepted the null hypothesis of data homogeneity, and no trend was found. On the basis of this analysis, it can be concluded that there has been no change in the total amount of rainfall over the year from 1983 to 2018.





**Figure 4.** Trends in annual rainfall and mean temperature of Goa (1983–2018).

Regarding the maximum temperature, there was a slight variation in temperature from 1983–2018, and an increasing trend was observed ( $0.0098\text{ }^{\circ}\text{C}/\text{year}$ ). The lower mean maximum temperature (Figure 5) was observed in the year 1983 ( $31.2\text{ }^{\circ}\text{C}$ ). The calculated average Sen's slope for maximum temperature indicated the increasing trend ( $+0.04\text{ }^{\circ}\text{C}/\text{year}$ ). Likewise, the result of the Pettitt test showed a rising shift in the temperature; the mean maximum temperature was  $31.605\text{ }^{\circ}\text{C}$  before 2001; however, it increased to  $31.899\text{ }^{\circ}\text{C}$  after 2002 (Figure 5). Most of the farmers (72%) perceived that there is a significant increase in temperature. Farmers also perceived higher temperatures even in January and February, which were very pleasant months before, that affected the flower production in cashew and cowpea. The calculated average Sen's slope for mean temperature also indicated the increasing trend ( $+0.0097\text{ }^{\circ}\text{C}/\text{year}$ ). The Buishand range test also showed an increasing trend and observed a shift in mean annual temperature from 2001 (Figure 5). The increasing temperature trend is in close agreement with the earlier studies [49,51,52]. Earlier studies also reported decreasing rainfall trends [53] but differed by a few [48,50,54]. Likewise, Shashidhar and Reddy [48] reported an increased temperature rainfall variability over the years. Further, the increasing temperature trend is in close agreement with the earlier studies [55–57]. Many constraints are affecting the adoption of climate-resilient technologies in the region.

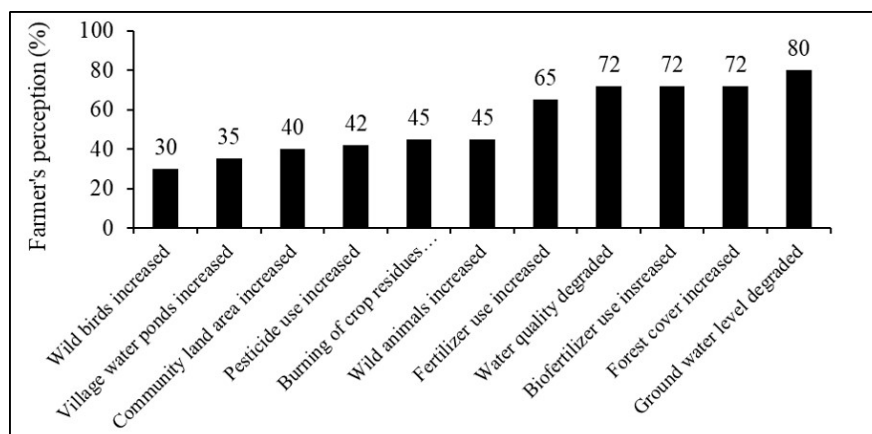


**Figure 5.** Homogeneity test of annual rainfall, maximum temperature, and mean temperature of Goa (1983–2018).

### 3.4. Farmers' Perceptions on Change in Agroecosystems over the Years

Approximately 80% of farmers have perceived that groundwater level has depleted, while 72% have stated that water quality has degraded over the years (Figure 6). In recent years, forest cover has increased, which 72% of farmers perceive it because of government policies regarding mangroves [58] that promoted forest area increase over the years. Hence, the 1997 government policy currently in place increased the planting of trees, reduced the cutting of trees, and increased forest cover over the years. As the forest area is increased, there was an increase in the tendency of wild animals (45%) and wild birds (30%) to damage the crops, as their forage areas came within the vicinity of the farms. Farmers also observed considerable pressure on agricultural land, as some of these have been converted into community land (40%). The rapid urbanization and industrialization led to a high price of farmland, causing a loss of farmland in recent times. Additionally, farmers noted a rise in the usage of agricultural inputs such as biofertilizers (72%), fertilizers (65%), and insecticides (42%), as well as crop residue burning (45%). Growing improved fertilizer-responsive varieties and increased pests and disease have forced farmers to use fertilizers and pesticides. In recent times, the combined harvesting of paddy has left a massive amount of crop residue in the field. It has become challenging to manage the paddy straw, so crop burning has increased significantly in Goa. Farmers have perceived an increase in

the number of farm ponds in the village (35%) for aquaculture production and irrigation purpose during the summer season. The state government of Goa is promoting soil and water conservation practices at the village level, especially water harvesting through farm ponds; thereby, the number of farm ponds has increased in the region. The farm pond is one of the best climate-resilient strategies to increase cropping intensity by growing short-duration crops in the summer.



**Figure 6.** Farmers' perceptions on different indicators of agroecosystem.

### 3.5. Adaptation Strategies to Climate Change

The adoption strategies are both climate-change- and economic-driven. For instance, increased saltwater ingress into the agricultural fields has led to the adoption of saline-tolerant rice varieties. In response to the increased incidence of pests and diseases, the adoption of pest- and disease-resistant vegetables and plantation crops has become more common. The farmers of the study region well perceived the changing climatic parameters, especially temperature, and made adaptive responses to curtail the adverse effects that conceded their farm output, income, and food security. The farmers of this region are practicing various adaptation strategies to secure their occupation and income during the adversities caused by climate change. Farm management strategies: A perusal of various farm management strategies practiced by farmers showed that crop diversification (vegetable, fruits, and plantation crops) is the foremost strategy adopted by Pernem farmers, followed by crop management practices (Table 2). Crop diversification is an emerging strategy for adapting to climate change in the study locations.

**Table 2.** Farm management strategies practiced by farmers.

Sl. No.	Strategies	Pernem		Bicholim	
		Garrett Score	Rank	Garrett Score	Rank
1	Crop diversification	92.5	1	92.5	1
2	Adaptation of POP of respective crops	77.5	2	57.5	6
3	Inter and mix cropping	72.5	3	82.5	2
4	Adoption of variety	67.5	4	67.5	4
5	Drought tolerant hardy varieties	62.5	5	62.5	5
6	Water conservation	57.5	6	47.5	8
7	Combining farm enterprise with livestock	52.5	7	-	
8	Alternate cropping	47.5	8	72.5	3
9	Adaptation of new crops	42.5	9	52.5	7
10	Manipulating sowing date	37.5	10	42.5	9

Note: POP: package of practices.

Moreover, diversifying the cropping system, especially into high-value crops such as spice and vegetable cultivation, is more remunerative and helps efficient water and

land utilization. The crop diversification is mainly driven by suitable climatic conditions, irrigation availability, and increased demand for vegetables by restaurants due to increased tourism activity. The earlier studies also reported crop diversification as a climate-resilient strategy to avert economic loss [59–61]. A study in Sub-Saharan Africa also reported that adaptation to climate change impacting agriculture was a major concern as many stakeholders felt that particular emphasis was needed on how to assist farmers in improving their adaptive capacity [62]. Goa's traditional areca nut farming system includes around 34 crops species to meet the food and nutritional requirement of the farm family [63]. Farmers usually practice inter/mixed cropping, e.g., chili, vegetable cowpea, and multistoried cropping in plantation crops. Farmers are intended to accept different varieties, and most preferences are given to drought-tolerant and hardy varieties (sugarcane: SNK-707, cowpea: Goa cowpea-3, and moong: TM 96-2).

Water availability can be exacerbated by differences in the beginning of rainfall, seasonal rainfall, and temperature variations. Farmers are conserving water by practicing farm ponds to avail of the same in the summer season. Soil conservation measures as adaptation strategies on their farmland are more susceptible to soil erosion climate change risks. Adopting compartmental bunding, contour bunds, and live bunds has effectively reduced soil and nutrient loss in the high-slope areas. The establishment of field bunds plays a critical role in choking floods and increasing water infiltration into the soil. This finding corroborates the findings of Kassie et al. [64] and Wossen et al. [65]. They emphasized the critical role of social capital in increasing adoption of improved farmland management practices in order to mitigate the adverse effects of climate change on land degradation. In addition, they found a significant effect of household endowments and access to information on selecting sustainable farming practices. Berry et al. [66] and Rey [67] indicate that irrigation as an important adaptation measure helps to buffer for moisture deficits induced by changes in climate.

Some farmers have combined their livestock with cropping to sustain their livelihood in the form of an integrated crop-livestock system (ICLS). The adoption of ICLS provides multiple ecosystem services such as provisioning services (food, feed, fuel, income, and fodder), regulatory services (soil fertility enhancement, soil carbon sequestration), and supporting services (biodiversity conservation, employment potential) [6,68,69]. ICLS also encourages residue recycling and nutrient recycling within the system. Therefore, ICLS is a prominent climate-resilient strategy to combat the adverse effects of climate change. Few farmers are following alternate cropping to tackle the problem of climate change. Some innovative and progressive farmers have also adopted market-oriented high-value crops in the region, such as sweet corn, baby corn, and watermelon. Farmers are extensively market-oriented, and hence to increase their production and profit, they adopt high-yielding new varieties (chili: hybrid Nisha, Bhagyalakshmi) and new vegetable crops (bottle gourd, bitter gourd) and following an improved package of practices. Crop diversification is ranked highest among the adaptation strategies to combat climate change impacts on agriculture in the current study. Crop diversification, especially introducing new crops for better income, is practiced to mitigate climate change impacts at Sahel [70].

Income management strategies: Farmers adopted various income management strategies to sustain their livelihood during climate adversities. Farmers of Pernem usually borrow money from self-help groups, followed by friends and relatives (77.5 and 72.2, Garrett score, respectively) (Table 3). The farmers sell their livestock during adverse conditions to sustain their livelihood. During adverse conditions, they hunt for non-farm employment in the vicinity. The farmers avail the benefits of the farmers' loans from nationalized and cooperative banks. Sometimes very small farmers migrate to surrounding cities in search of employment to sustain their livelihood. On the other hand, farmers of Bicholim are also giving their prior preference to self-help groups for borrowing money, followed by friends and relatives (72.5 and 57.5, Garrett score, respectively). They usually migrate to cities to earn their livelihood and those who cannot afford to leave their home seek employment in the vicinity area. They are less oriented towards farmer's loans, fearing that banks' interest

rates will be higher and there is a chance of their product being sold cheaper during the glut period in the market.

**Table 3.** Income management strategies practiced by farmers.

Sl. No.	Strategies	Pernem		Bicholim	
		Garrett Score	Rank	Garrett Score	Rank
1	Borrowing from self-help groups	77.5	1	72.5	1
2	Borrowing from friends and relatives	72.2	2	57.5	2
3	Sale of livestock	67.5	3	-	-
4	Non-farm employment	52.5	4	47.5	4
5	Farmers loan from bank	47.5	5	37.5	5
6	Migration	42.5	6	52.5	3

### 3.6. Constraints in Adopting Climate-Resilient Practices

Table 4 depicts the biophysical and socioeconomic constraints affecting the adoption of climate-resilient technologies. According to survey results, the majority of the farmers listed smaller and fragmented land holdings, inadequate/non-availability of farm credit, marketing of produce, and non-availability of quality seed/planting material as important detrimental factors hindering the adaptive capacity of the small and marginal farmers. The adaptation to climate change decreases with decreased landholding. The fragmented landholding impedes the adoption of improved practices and reduces capital investment from farmers [23,71,72]. This further implies that adaptation is a specific feature of a farm that depends on the socio-economic condition of the farmers. Micro-credit financing through cooperative banks and nationalized banks will help farmers buy critical inputs, establish irrigation facilities, and obtain small-scale farm mechanization to combat climate change effects [22]. Furthermore, inadequate market facilities for agricultural produce and a lack of price assurance will affect crop and varietal diversification. Non-availability of quality seed/planting material will further affect inter-and mixed cropping, which is essential to reduce crop failure risk and avoid reliance on mono-cropping. Likewise, the non-availability of laborers at the critical stage of crop growth or harvest will further reduce the production and profitability of the agricultural production system. In recent times, the rural youth are migrating towards cities searching for jobs due to less profitability from the agricultural production system.

**Table 4.** Biophysical and socioeconomic constraints affecting climate change adaptation.

Sl. No.	Constraints	Ranks
1	Non-availability of high yielding variety	9
2	Non-availability of quality seed/planting material	4
3	Fertilizers & pesticides quality	5
4	High incidence of insect-pests and diseases	6
5	Problem of infertility in buffaloes	11
6	Problem of infertility cattle (cows)	8
8	Lack of remunerative and assured prices of crops	12
9	Inadequate/non-availability of farm credit	2
10	Scarcity of farm labor	10
11	Smaller and fragmented land holdings	1
12	Marketing of produce	3
13	Value addition	7

South Asia and Southern Africa are two critical regions where crop-based agriculture is likely to suffer severely due to climate change if adaptation strategies are not taken up [13]. The adaptation level of people to the adverse impact of climate change depends upon their awareness level or farm experiences and their exposure to modern ICT. The farmers of the study region are well aware of the changing climatic parameters, especially temperature,



and have adopted several strategies to combat the ill effects of climate change. The present study finds no difference in rainfall pattern, but a slight delay in the onset and intermittent dry spells were observed. It can be concluded that there was no shift in the total amount of rainfall over the year from 1983–2018, and the main reason might be due to increased forest cover as per farmers' perception (Figure 5). According to Ellison et al. [73], increased forest cover and expansion increases evaporation and, consequently cloud formation, thereby leading to higher rainfall. Tropical forests have significant transpiration and cloud formation and they also absorb large amounts of carbon dioxide, resulting in higher rainfall [74,75].

Small or marginal-sized land holdings constitute a significant constraint in adopting climate change in the study. Climate change impacts are severe on smallholdings of apple farmers in Himachal, India [52]. Furthermore, agrochemicals and adopting an improved package of practices were found necessary as an adaptation strategy to combat the climate change effect. The use of pesticides and micronutrients is very much essential to rectify pest damage and micronutrient deficiency. Although the use of agrochemicals exacerbates climate change, it is imperative. A similar observation was made by Fagariba and Soule [76] in the Sissala West district of northern Ghana. Adopting improved crop varieties and crop diversification reduces farmers' vulnerability, hence they are less likely to be adversely affected by climate change than traditional varieties. Changing the type of crops grown is another adaptation strategy that subsistent farmers in Goa adopt to help them adapt to climate change and climate variability. The farmers are responding to perceived climate change, such as an increase in temperature and late-onset of monsoon. They are modifying agricultural and farming practices to deal with socio-economic changes, and some of these changes, such as changing sowing and harvesting timing, cultivation of short-duration cultivars, intercropping, crop diversification, investment in irrigation, integrated farming system, agroforestry, etc., are helping in adapting agriculture to climate change. Therefore, from this study, we may conclude that the farmers of this region are passively taking steps to adapt to climate change.

### *3.7. Implications and Limitations of the Study*

Finding that the region saw a rise in temperature and a decrease in rainfall has implications, and there is a need to create and promote climate-resilient strategies. As a result, to enhance resilience, all important stakeholders should work together to strengthen policies and initiatives that adapt climate-resilient practices in small and marginal landholders. The study has the advantages of elaborate micro-level analysis of climate change perception and adaption of agriculture in two villages, including socioeconomic and climatic datasets. The study is limited in scope only to cover tropical ecosystems and not the temperate, desert, and other agroecosystems. Though the design has some limitations, we could obtain more information about the farm households through participatory rural appraisal (PRA) tools. The data collection including the PRA method and the analysis can provide a better understanding of the regional differences in adaptation strategies dealing with climatic changes. Although the present study provides an understanding of the micro-level adaptation strategies adopted by sample farmers and their leanings from past experiences in dealing with climate uncertainties, risks, and hazards, the study has future scope to identify suitable climate change adaptation strategies in other agroecosystems and other abiotic stresses induced by the climate change phenomenon. Increased temperature and fluctuating rainfall are two major challenges in the region, and the small and marginal farms are especially highly vulnerable. Farm ponds, diversification of crops, and livestock integration are some of the best climate adaptation strategies used by the region's farmers. Policy interventions such as institutional support, credit facility, and subsidy mechanism to support good adaptation strategies would boost climate-resilient agriculture.

#### 4. Conclusions

In this study, the analysis of farmers' perceptions about climate change reported that climate change has affected their farming in one way or another. It is concluded that about 62% of the sampled farmers in the region have experienced climate change in terms of meteorological indicators such as the increase in average temperature, decrease in total rainfall, delay in onset of monsoon, and increase in the summer season. The parametric linear and nonparametric Mann–Kendall trend tests of meteorological parameters were analyzed using Microsoft Excel, and graphs were plotted. The temperature trend analysis ( $0.009\text{ }^{\circ}\text{C}/\text{year}$ ) validated farmers' perceptions, while the perception of rainfall differed ( $-1.49\text{ mm}/\text{year}$ ). In addition, farmers are convinced that climate change has affected their farming in terms of declining crop and livestock yield, rising input costs, enormous pressure on agricultural land, groundwater depletion, a wild animal menace on crops, etc. Hence, this study suggests that policymakers concerned with development and functionalities should ensure timely availability of agricultural inputs, accurate long-term weather forecasting, and encourage insurance products for crop and livestock enterprises, which will help resource-poor farmers cope with a changing climate. Furthermore, a strong institutional environment is needed to support adaptation, focusing on farmer-led participation and the security of farmers' livelihoods. It is imperative to implement and/or broaden policies that seek to directly or indirectly secure farmers' income, such as crop insurance, subsidies, access to credit, and other incentives that motivate farmers to adopt improved crop varieties. This may lead to crop and livestock production augmentation and enhance the farmers' income.

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