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Integrated Farming Systems as an Adaptation Strategy to Climate Change: Case Studies from Diverse Agro-Climatic Zones of India

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Abstract: Climate change impacts agricultural productivity and farmers' income, integrated farming systems (IFS) provide a mechanism to cope with such impacts. The nature and extent of climatic aberrations, perceived impact, and adaptation strategies by the farmers reduce the adverse effects of climate change on agriculture. Therefore, a study was conducted to investigate 2160 IFS farmers about their perceptions of climate change, barriers, and the likelihood of adapting to the negative impacts of climate change. The study observed an increasing rainfall trend for humid (4.18 mm/year) and semi-arid (0.35 mm/year) regions, while a decreasing trend was observed in sub-humid (−2.02 mm/year) and arid (−0.20 mm/year) regions over the last 38 years. The annual rise in temperature trends observed in different ACZs varied between 0.011–0.014 °C. Nearly 79% of IFS farmers perceived an increase in temperature, decreasing rainfall, variability in the onset of monsoon, heavy terminal rains, mid-season dry spells, and frequent floods due to climate change. The arid, semi-arid, sub-humid, and humid farmers' adapted several measures in different components with an adaption index of 50.2%, 66.6%, 83.3%, and 91.6%, respectively. The majority of the IFS farmers perceived constraints in adopting measures to climate change, such as meta barriers, capacity barriers, and water barriers. Therefore, we infer that educated farmers involved in diversified and profitable farms with small to medium landholdings are concerned more about climate change in undertaking adaptive strategies to reduce the environmental impact of climate change.

Keywords: climate change; climate adaption; rainfall anomaly; Mann-Kendal test; integrated farming system; agro-climatic zone

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1. Introduction

The effect of climate change is evident in agriculture and allied activities [1], affecting food and livelihood security [2–5]. Extreme weather events such as drought, flood, and cyclones are likely to become more frequent in changing climates [6]. However, climate change is expected to affect agriculture differently (negatively or positively) in different parts of the world [1,7–9]. Crops, fish, and livestock productivity may increase or decrease based on agro-climatic zones (ACZ) and the severity of impacts [10–13]. For instance, increasing soil salinity is evidenced in arid regions [14], whereas dry zones are vulnerable to drought with increased temperature [15,16], and wet regions are expected to receive excess and erratic rains, causing floods [17,18]. Moreover, the farmer's vulnerability to climate change impacts and their level of adoption varied significantly based on their level of education, farming experience, farm size, and annual income. Awareness and perception of natural disasters and their impact are the first step in planning and implementing mitigation strategies [19,20].

Climate change and natural hazards will affect India badly due to reducing arable land, burgeoning population, over-dependence on agriculture, dwindling soil fertility, rainfed farming, low technical and financial development, and adaptation to climate change [4,21–23]. Climate change forecasts for India up to 2100 suggest a 2–4 °C increase in temperature, with a significant change in rainfall [24]. Another report suggests that average temperatures would rise by 3–6 °C, and precipitation would increase by 15–40% in India [25]. Specifically, the crop and livestock component suffers significant yield losses due to climatic variabilities and extreme weather events such as droughts, cyclones, and floods [26]. Climate change impacts are pronounced on crop yields, severely affecting the farmers' income. Several earlier workers forecasted crop yield loss owing to increased temperature and rainfall to the tune of 3–17% [27], 10–40% [28], and 10% [29] by the end of the century. Livestock farmers suffer severely due to drought to provide water and fodder to animals [20]. Therefore, adaptation to climate change is critical to maintaining agricultural and livestock production.

Risk perception is critical in the decision-making process for adaptation to cope with climate change and mitigation measures [18,30]. A complex interaction of social, cultural, psychological, and economic factors operates on perception and coping mechanisms. Farmers' knowledge also influences risk perception, length of farming experience [18,31], and social and economic factors [32]. Farmers' decisions on climate change adaptation are influenced mainly by socioeconomic and marketing considerations, available knowledge and technology [33], and governmental policy support. Farmers expect benefits from adoption in terms of increased productivity, profitability, resource conservation (water and soil, etc.), and other services in exchange. Farmers' adaptation strategies to climate change mainly depend on income, education, age [20,34–36] and access to credit [37], and policy support. Earlier studies highlighted different climate change perceptions, their validation with meteorological data, and adoption strategies by farmers. Reduction in yield and income due to climate change is perceived as a significant constraint by farmers in the dry eastern region of Karnataka, India [15]. Change in the monsoon pattern or initiation and termination of rainfall due to climate change is perceived in most cases by farmers [20,38]. Changes in seasonal wind speed and direction are perceived in cyclone-prone areas as climate change stress by 44% of the respondents in Madhya Pradesh, India [39]. About 88% of the respondents reported a reduction in rainfall in Himachal Pradesh, India [16]. Adaptations to climate change include changing planting times [15,40] to cope with the changes in the onset of the monsoon. About 19% of Bolivia farmers reported adopting either new crops or new crops with drought/disease tolerance or early maturity as the mitigation option [41]. Adaptation of drought-tolerant varieties as the chief means to cope with climate change has been reported in South Africa [42] and Southwest Nigeria [20].

To deaccelerate the anthropogenic climate change phenomenon, emphasis has been primarily focused on climate change modeling, climate change impacts, lowering emission rate, increasing carbon sequestration rate, risk assessment, and adaptation. An integrated approach to farming systems could be an ideal solution to ensure the food security of the ever-increasing global population at a time when there are twin problems of land degradation and carbon emissions [4]. However, little has been studied to understand field-level approaches like IFS as a measure to adapt and mitigate climate change. Additionally, despite significant progress in climate change studies in understanding and dealing with climate change and its implications on agricultural production globally, local knowledge and concern, particularly among India's rural farmers, is critical. Studies around the world show farmers' adaptation to climate change depend on their perceptions of changing climate [8,20]. Small landholders (SLHs) constitute 85% of the total landholdings in India, often face complex biophysical and socioeconomic conditions, and are the principal managers of agricultural produce in India [4]. Farming is becoming increasingly risky due to climatic uncertainty, especially among the small and marginal farmers, due to a lack of resources and their inability to adopt new, improved technologies. Indian agriculture is mainly rainfed, thus rainfall and temperature are the most crucial climatic factors. Even a minimal change significantly affects India's crop and livestock farming [21,25,43,44]. These studies further reported that farmers are likely to be more severely affected by their lack of adaptive capacity to climatic variability [45]. Therefore, the objectives of the current study were to (i) analyze the perception of farmers over diverse ACZs on climate change and its impact on agriculture, livestock, and fishery production, and (ii) validate the farmers' perception with the metrological data; and (iii) understand the adaptation barriers among farmers in mitigating climate change impacts. We believe the output of this research article will enhance our understanding of improved adaptation strategic planning for advancing farmers' climate change adaptation and mitigation strategies.

2. Material and Methods

2.1. Study Area

The study was carried out in locations representing arid, semi-arid, sub-humid, and humid zones of India. The details of study locations (districts) under each agro-climatic zones (ACZ), along with geographical coordinates (latitude, longitude, and altitude), were listed in Table 1. There are three different seasons in the four regions: the rainy (monsoon) season (June–September), the winter season (October–February), and the summer season (March–May). The four areas reflect a wide range of farming systems and occupations, with evident ecological variations across the communities. The selected households maintain crops and livestock, comprising integration of field crops, horticultural crops, livestock (dairy, poultry, goatery, duckery, etc.), fisheries, etc. Three climatic parameters, the maximum temperature, minimum temperature, and rainfall, were chosen due to the country's data availability across temporal and spatial scales. Rainfall is the most important climatic factor critical to survival, particularly concerning crop growth among small-scale farmers. The analytical procedure of the study were shown in Figure 1.

Table 1. Districts under different Agro-Climatic Zones (ACZ).

Sl No.	District	Longitude	Latitude	Altitude (m)	Climate
1	Sirsa	75.037765	29.537285	204	Arid
2	Krishnagiri	78.007621	12.51506	719	Arid
3	Mehsana	75.8497	25.24656	258	Arid
4	Ahmednagar	78.20408	17.82172	551	Arid
5	Udaipur	73.68626	24.57872	597	Arid
6	Dharmapuri	78.67291	10.56209	125	Arid
7	Amravati	77.75885	20.93162	342	Semiarid
8	Amritsar	74.87368	31.63431	231	Semiarid
9	Sivagangai	78.77676	10.16096	112	Semiarid
10	Gadag	75.68075	15.41634	659	Semiarid
11	Kanpur Dehat	80.32176	26.46091	131	Semiarid
12	Panchmahal	77.31016	28.6271	205	Semiarid
13	Pudukottai	78.72043	9.96506	63	Semiarid
14	Kolar	78.26806	13.17942	799	Semiarid
15	Aurangabad	84.37467	24.75367	116	Semiarid
16	Meerut	77.7061915	28.99633	227	Semiarid
17	Pune	73.85445	18.52143	550	Semiarid
18	Akola	77.002632	20.71166	289	Semiarid
19	Warangal	79.59821	17.98061	273	Semiarid
20	Angul	82.72345	21.09749	298	Subhumid
21	Dindori	73.83259	20.20373	624	Subhumid
22	Kabirdham	81.25158	22.11429	363	Subhumid

Table 1. *Cont.*

Sl No.	District	Longitude	Latitude	Altitude (m)	Climate
23	South 24 Paragnas	88.1913	21.87914	6	Subhumid
24	Kendrapara	86.4159937	20.50421	10	Subhumid
25	Pakur	87.8472316	24.63775	42	Subhumid
26	Dharwad	75.00665	15.45405	738	Subhumid
27	Thiruvananthapuram	76.99311	8.428108	8	Subhumid
28	Purnea	87.47312	25.77736	42	Subhumid
29	Nainital	79.45557	29.39178	1956	Subhumid
30	Samba	75.11656	32.56224	384	Subhumid
31	Amroha	78.47073	28.90662	217	Humid
32	Kangra	76.27236	32.10316	710	Humid
33	Pathinamthitta	76.57627	9.386745	27	Humid
34	Palghar	73.18871	17.75805	164	Humid
35	Nadia	23.48023	88.51757	12	Humid
36	Bhubaneswar	80.22195	12.96991	1	Humid

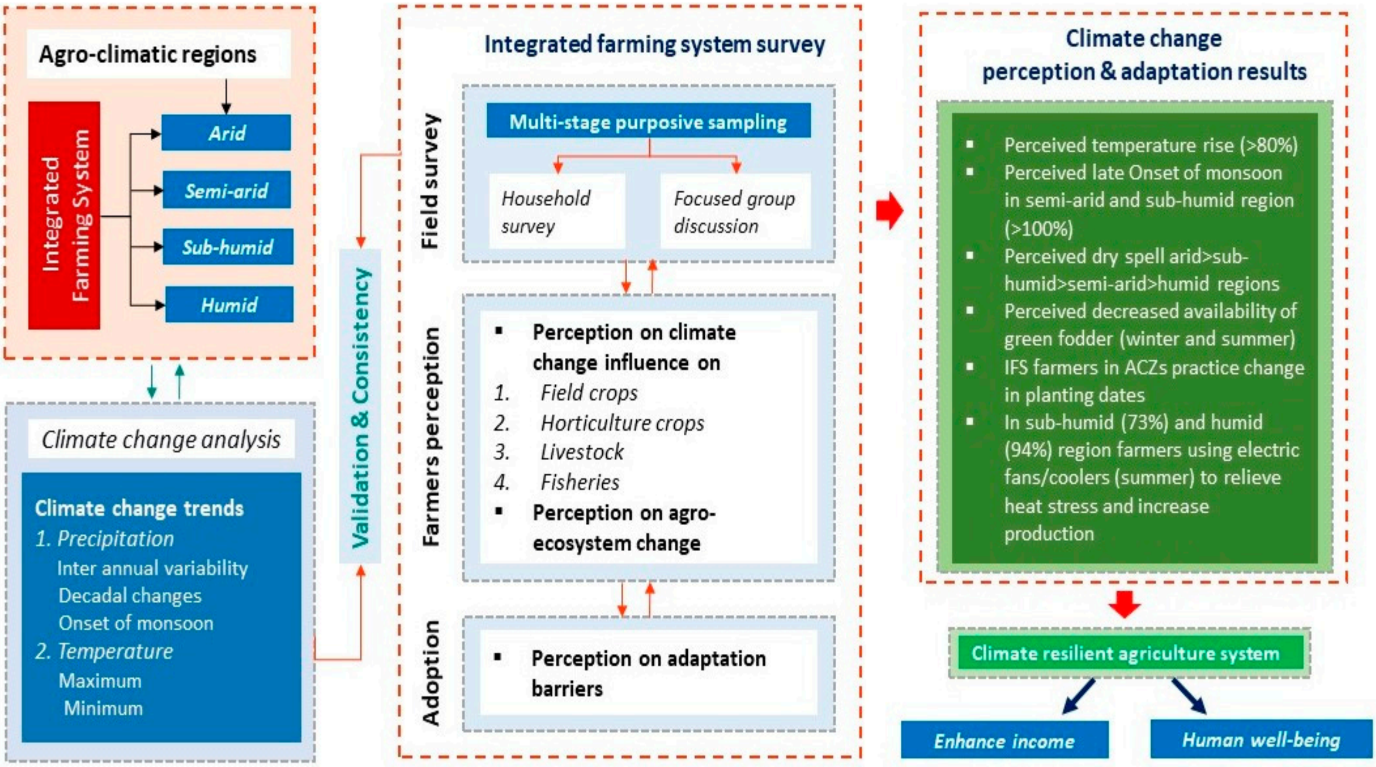

Figure 1. The analytical framework of the study.

2.2. Data Collection

We used crop-livestock data from integrated farming systems (IFS) farmers and climate data to analyze smallholder farmers' perceptions of climatic variability and compare historical trends based on meteorological data. We also collected data on mitigation strategies adopted by farmers to counter the ill effects of climate change. Historical meteorological and household data were utilized [46–48] in descriptive statistics to learn about IFS farmers' perceptions and adaptive capacity. Climatic data collected from the Indian Meteorological Department is more reliable than reanalysis data [22]. Daily rainfall, maximum and lowest temperatures were recorded over the last 38 years, from 1980 to 2018. The historical precipitation datasets were used to analyze intra-annual variability and decadal changes in precipitation.

2.3. Data Sampling

The respondents for the study were chosen using the multi-stage purposive sampling method. The districts (the smallest administrative unit) with varied ACZs, such as arid, semi-arid, sub-humid, and humid, were chosen in the initial stage to reflect the wide range of climates across the nation (Table 2). We selected farmers practicing IFS in each climatic zone using a purposive sample technique in the second stage. Next, the farm household was established, involving both men and women in maintaining the IFS farm. Farmers' perspectives of climate change, the influence of climate on field crops, horticultural crops, livestock and fisheries components, and climate change adoption barriers were all discussed in focus group discussions (FGD). Each FGD lasted for 2 to 3 h. In the final step, 2160 interviews with smallholder IFS farmers from the four ACZs were performed using the snowball sampling approach. In arid, semi-arid, sub-humid, and humid ACZs, interviews with 360, 780, 660, and 360 IFS farmers, respectively. Farmers' perceptions of the changing climate were elicited through conversations with them. We also gathered data on how climate change affects IFS production, such as field crops, horticultural crops, livestock, and fisheries.

Table 2. Summary of demographic and farming characteristics (in %).

Characteristic	Category	Arid	Semi-Arid	Sub-Humid	Humid
Educational level	None	22.5	12.4	7.2	6.5
	Primary	24.3	24.2	35.8	27.2
	Secondary	39.3	48.3	43.6	51.2
	College & University	13.8	15.2	13.5	14.7
Farm size (ha)	<1.0	72.8	60.6	63.4	76.0
	1–2.5	27.0	36.8	34.5	24.0
	>2.5	0.3	2.5	2.3	0.0
Farming Experience (year)	<10	17.5	12.1	4.1	10.8
	11 to 20	31.8	22.9	26.8	21.2
	21–30	20.7	27.1	25.1	23.8
	>30	29.8	33.2	44.2	44.3
Annual Income (Rs. Lakh)	<1.0	79.5	73.5	76.4	63.7
	1 to 2	15.0	17.0	16.5	22.7
	2 to 5	5.0	8.7	6.2	12.7
	>5	0.5	0.8	0.9	1.2
N				2160	

2.4. Barriers to Adoption

We identified different adoption barriers perceived by IFS farmers in different ACZs. Through FGDs, we collected information on common barriers to adoption in different ACZs, and they were included in the personal interviews of IFS farmers. We classified various adoption barriers into three categories: meta, capacity, and water. Uncertainty about the farm's ability to adapt to financial constraints, economic losses or cost savings due to changing practices, economic losses due to fewer or smaller subsidies, uncertainty about the magnitude of climatic changes, and environmental and climate regulations were considered meta barriers. Water barriers include water limitations and lack of irrigation potential. In contrast, capacity barriers include lack of land, non-availability of new technology, inadequate extension service, lack of agro-advisory services, and labor constraints.

The adaption index for the individual zone was developed considering the adopted adaptation measures. As per estimation using the following method, more than 50 percent of farmers adopted such measures to cope with climate change's ill effects.

$$Adaption\ index = \frac{Number\ of\ adopted\ adaptation\ measures\ by > 50\%\ farmers}{Total\ number\ of\ adaptation\ measures} \times 100$$

2.5. Data Analysis

2.5.1. Rainfall Indices

The Rainfall Anomaly Index (RAI) and the Cumulative Departure Index (CDI) were used to analyze the overall intensity and within-season variability of rainfall and the patterns of start and duration of the rainy season. The CDI and RAI were estimated using the following equations as mentioned by Ayanlade et al. [20].

$$\mathrm{CDI} = \frac{\mathrm{R_a} - \mathrm{R_m}}{\mathrm{SD}} \tag{1}$$

where CDI stands for cumulative departure index, Ra is for actual rainfall in the crop growing season, Rm stands for mean rainfall, and SD stands for standard deviation across the whole study period.

$$\mathrm{RAI} = +3\frac{\mathrm{R_F} - \mathrm{M_{RF}}}{\mathrm{MH_{10}} - \mathrm{M_{RF}}} \tag{2}$$

$$\mathrm{RAI} = -3\frac{\mathrm{R_F} - \mathrm{M_{RF}}}{\mathrm{ML_{10}} - \mathrm{M_{RF}}} \tag{3}$$

where RAI-rainfall anomaly index; $\mathrm{R_F}$-rainfall for the given year; $\mathrm{M_{RF}}$-mean annual rainfall; $\mathrm{MH_{10}}$, and $\mathrm{ML_{10}}$ are the mean of the period's ten greatest and lowest (respectively) rainfall (RF) values. The questionnaire and interview data classified farmers' views of rainfall beginning, volume, frequency, duration, intensity, variability/change, and cessation in the study region.

2.5.2. Mann–Kendall Test and Linear Regression Analysis

The Mann–Kendall test is a non-parametric tool for assessing climate data trends. A trend analysis of long-term climate data was undertaken to determine changes in climate patterns and analyze the link between farmers' perceptions and climatic realities. In this investigation, the statistical Mann–Kendall test was performed using Addinsoft's XLSTAT software. For both temperature and rainfall data for the four ACZs, the null hypothesis was evaluated at the 95% confidence interval. The null hypothesis in this test posits that there is no trend, and it is compared to the alternative hypothesis, which assumes that there is a trend. To assess temporal patterns in rainfall records, linear regressions were utilized [49].

2.5.3. Ordered Probit Analysis

An ordered probit model was utilized to investigate the influence of our explanatory model on the reported likelihood to participate in adaptive behavior in agricultural climate adaptation. An ordered probit model investigates the marginal effects of each variable on the many options within the ordered categories, or if each unit increase in the independent variable increases or reduces the likelihood of choosing each alternative dependent variable. Parameters were estimated using the XLSTAT using the means of 2160 observations for each variable. Three perception variables are independent in our analytical approach. Namely, (1) Farmers' reported beliefs in global climate change and (2) their influence on crops, livestock, and fisheries were among the perception factors, and (3) three different types of adaptation barriers. In addition, the model includes (4) four demographic factors (farm experience, yearly farm income, farm acreage, and education) that might influence whether or not a farmer makes modifications were considered.

3. Results and Discussion

3.1. Farmer's Perception of Climate Change and Its Impact

It was found that 50% of surveyed IFS farmers had an education level of secondary school ranging from 39.3% in arid to 51.2% in humid regions. The majority of the surveyed IFS farmers had less than one hectare of farmland (%), consistent with Nath et al. [4], this suggests that 85% of the farmers in India are smallholders with less than 1 ha of agricultural land. The length of farming experience varied, and the majority of the farmers had >30 years of experience across the climate zones. The majority of the IFS farmers had an annual income of <US$1300 (0.1 million Indian rupees), which again varied from 63.7% in humid to 79.5% in arid regions. The results revealed that most IFS farmers were small and marginal landholdings with an annual income of less than US$1300 (0.1 million Indian rupees).

The four ACZs differ in environmental and climatic characteristics and climate change scenarios. Most respondents perceived an increase in temperatures and the late onset of rainfall in all the surveyed locations. In the semi-arid zone, all the farmers perceived a temperature rise. Likewise, most of the IFS farmers in arid, sub-humid, and humid also perceived an increase in temperature over recent years. In addition, the farmers in arid, semi-arid, and sub-humid regions perceived the late onset of monsoon. The decrease in rainfall amount was perceived as higher by IFS farmers of the semi-arid region followed by arid, sub-humid, and humid zone (Table 3). In the humid region, farmers perceived that the rains that used to come evenly during the planting season in previous years have become more unpredictable, erratic, terminal heavy rains and also causing flood situations. In the arid, semi-arid, and sub-humid zone, the majority of the farmers' noted that the rain mainly started late and caused mid-season dry spells affecting crop growth and productivity. Farmers of all four ACZ's perceived an increased incidence of the dry spell. However, the higher dry spell perceived by IFS farmers were in the order of arid > sub-humid > semi-arid > humid regions. The earlier studies across the world also confirm that farmers perceived less rain [50–53], a decreased rainfall duration [54,55], and unpredictable and irregular rainfall patterns [10]. The interviewed farmers also confirmed that hailstorms were common in the humid zone. According to the farmers, the number of storms had increased over time, resulting in flash floods that wash away their crops. Likewise, Shashidhar and Reddy [56] reported an increased temperature and rainfall variability over the year. Studies on the perception of climate change by farmers of coastal ecosystems indicate the maximum score on the farmers' understanding of the perceived consequence of climate change on the reduction of agricultural production in West Bengal, east coast India [57].

Table 3. Major perceptions from the interviews and focus group discussions.

Components	Characteristic/Parameter	Arid	Semiarid	Sub-Humid	Humid
Weather	Temperature increased	83	100	91	83
	late onset of monsoon	83	100	100	50
	Decrease in rainfall amount	83	91	77	65
	Terminal heavy rains	67	77	85	90
	Frequency of dry spells increased	83	72	81	55
	Frequency of floods increased	49	54	76	100
	Climate change is happening	74.7	82.3	85.0	73.8
Crops	Cropping pattern changed	100	100	100	100
	Incidence of pests and diseases increased	100	100	91	83
	Productivity of crops increased	39	42	63	83
	Availability of irrigation water decreased	100	100	100	100
Horticulture	Changes observed in the growing of crops	83	100	91	100
	Productivity of crops increased	67	100	91	100
	Early flowering in fruits/plantation crops	67	62	91	83
	Insects pest infestation increased	83	77	91	83
	Water requirement of crops increased	100	77	100	83
Livestock	Number of livestock per household decreased	100	92	100	100
	Milk productivity increased	100	92	91	100
	Green fodder availability decreased	100	100	91	100

Table 3. *Cont.*

Components	Characteristic/Parameter	Arid	Semiarid	Sub-Humid	Humid
Fish	Number of ponds decreased	83	38	82	83
	Water requirement of pond is increased	83	38	73	83
	Fish mortality in pond increased	83	31	73	83
	Disease infestation increased	83	31	73	83

Farmer's perception of climate change impacts on field crops, horticulture crops, livestock, and the fishery was shown in Table 3. Most IFS farmers noticed changes in cropping patterns, increased pests, and diseases, and decreased availability of irrigation water, especially during winter and monsoon. However, some farmers also perceived increased crop productivity, which may be due to increased crop productivity by crop improvement and the adoption of better crop management practices [58,59]. Likewise, in the horticulture sector, several changes have been perceived by IFS farmers over the years. The farmers perceived changes in the growing of crops like the cultivation of new crops, broccoli, leafy vegetables, spices, fruits, and plantation crops. Like in field crops, insect pest infestation increased severely, causing heavy use of pesticides. Based on a Ricardian model involving 5000 farmers of 11 African countries, Kurukulasuriya and Mendelsohn [60] found the farmers switch their crops to fit the perceived change in the climate. The introduction of hybrid crops and the growing of high water-requiring crops created water scarcity in crop field management. The farmers also perceived early flowering in fruits/plantation crops, especially cashew, mango, areca nut, and coconut. The fishery and livestock sectors were also affected due to changing climate, mainly by an increase in temperature and a dry spell, and a decrease in total rainfall. The IFS farmers in all the ACZs perceived decreased availability of green fodder, especially in the winter and summer seasons. Further, most IFS farmers also perceived a decrease in the number of fish ponds, increased water requirement, and fish mortality due to increased temperature and disease outbreaks, bird damage, etc.

3.2. Comparing Farmer's Perceptions with the Meteorological Data

Using RAI and the Mann-Kendall test, farmers' perceptions were compared to historical trends from meteorological data.

3.2.1. Rainfall Anomaly Index (RAI) and Cumulative Departure Index (CDI)

Figure 2 shows the RAI results with 5- a year moving average for arid (Figure 2a), semi-arid (Figure 2b), sub-humid (Figure 2c), and humid (Figure 2d) ACZs. The analysis was performed using daily rainfall data from 1980 to 2018. With a 5-year moving average, RAI was compared with farmers' perceptions of dry spells, seasonal variability, and the onset of monsoon. Figure 2a–d reveals a persistent high variability in annual rainfall based on a 5-year moving average. The 5-year moving average trend lines were not consistent throughout the 38 years. Within the 38 years study period, annual rainfall was below average in all study sites by 21, 19, 20, and 23 years in arid, semi-arid, sub-humid, and humid zones, respectively. These findings suggest that these years had lower-than-normal rainfall and were also characterized by late-onset and early cessation of rains. The deficit rainfall over mean annual rainfall under different ACZs were shown in Table 4. The data supports farmers' perceptions of rainfall variation within the season, and recently, rainy days have been fluctuating. Several dry spells throughout the rainy seasons and a distinct small dry season [61,62] were the causes of the considerable fluctuation in rainfall in recent years, which are indications of climate change. The same trend in seasonal variability, late onset of monsoon, and increased dry spells have been perceived by farmers of arid, semi-arid, sub-humid, and humid ACZs.

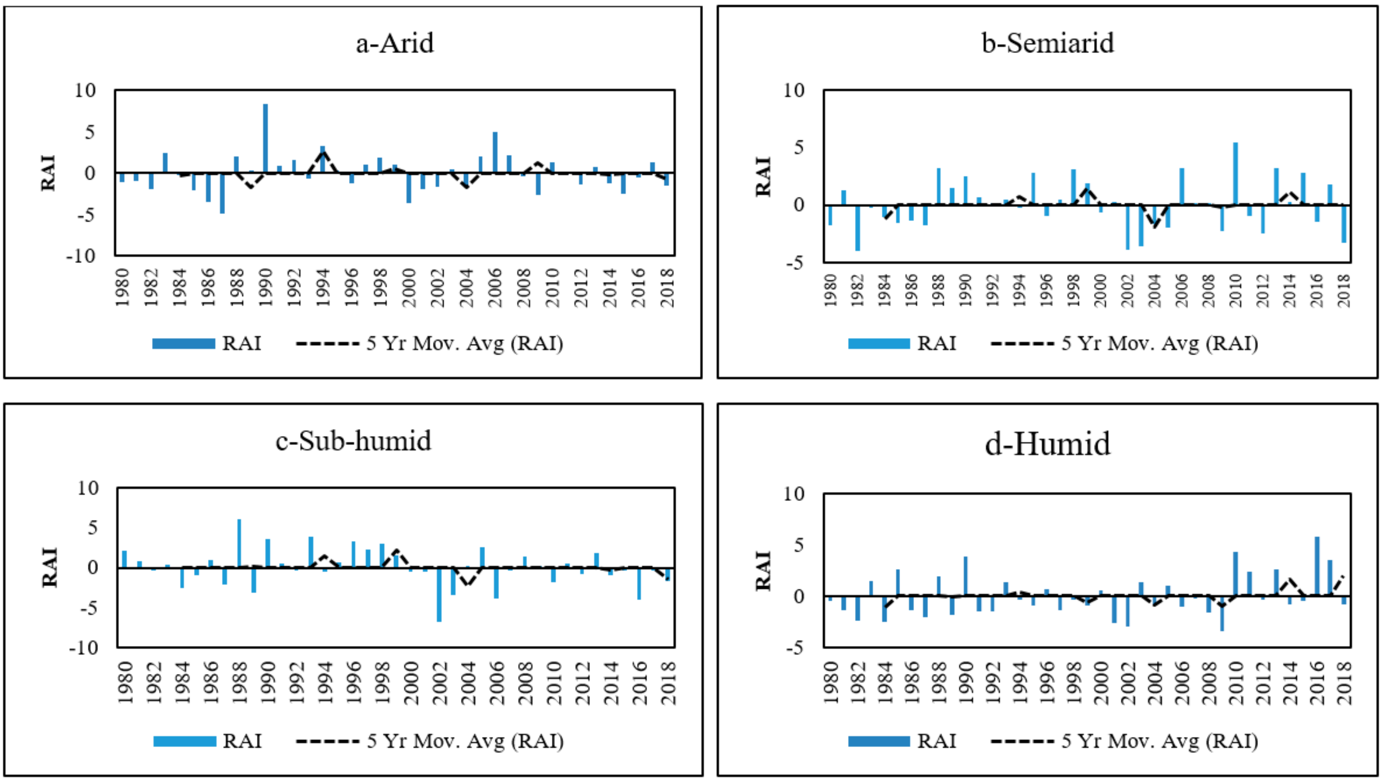

Figure 2. Rainfall Anomaly Index (RAI) and 5-year moving average analysis for Arid (**a**), Semiarid (**b**), Sub-humid (**c**) and Humid (**d**) regions from 1980 and 2018.

Table 4. Seasonal Rainfall (mm) variation over mean rainfall in different ACZ's.

Year	Arid	Semiarid	Sub-Humid	Humid
1980	−67.4	−92.5	88.9	−46.3
1981	−63.3	66.0	35.4	−136.1
1982	−123.2	−212.2	−16.0	−244.5
1983	152.0	−15.1	14.6	152.1
1984	−13.3	−57.5	−112.2	−260.1
1985	−130.0	−82.2	−42.3	264.0
1986	−225.3	−71.4	38.4	−135.7
1987	−310.5	−93.6	−90.0	−203.8
1988	128.2	169.7	265.3	200.6
1989	5.9	78.7	−136.2	−182.0
1990	528.6	129.2	154.6	388.9
1991	59.1	34.0	24.5	−146.3
1992	99.9	2.5	−12.9	−149.5
1993	−39.9	27.3	165.9	139.4
1994	209.6	−8.0	−24.8	−31.9
1995	10.3	146.3	31.5	−98.1
1996	−82.1	−51.0	140.7	68.9
1997	64.7	22.4	95.4	−144.3
1998	121.8	162.1	132.3	−39.8
1999	65.5	100.5	63.4	−91.4
2000	−232.5	−34.6	−23.9	54.3
2001	−125.4	16.6	−23.8	−269.9
2002	−105.2	−205.3	−296.6	−299.3
2003	28.8	−188.6	−148.5	139.6
2004	−101.0	−87.7	4.2	−76.4
2005	124.8	−102.8	110.3	102.8
2006	317.4	168.6	−168.7	−99.3
2007	138.2	2.7	−17.8	−2.9

Table 4. *Cont.*

Year	Arid	Semiarid	Sub-Humid	Humid
2008	−26.2	1.4	60.6	−168.0
2009	−165.3	−116.8	3.5	−345.5
2010	79.0	287.1	−81.3	439.8
2011	−8.8	−50.9	25.3	246.4
2012	−88.6	−128.0	−36.3	−32.7
2013	51.1	167.4	78.4	265.2
2014	−81.3	16.7	−40.3	−83.5
2015	−154.6	147.8	−10.8	−43.9
2016	−34.6	−74.1	−173.1	591.9
2017	85.3	95.6	−3.2	354.2
2018	−92.0	−170.2	−74.6	−76.9

Note: Negative sign indicates deficit rainfall.

We further verified farmers' perception of growing season rainfall and the onset of rainfall, which farmers perceived as reducing total growing season rainfall in recent years. Figure 3a–d depicts the CDI of rainfall in arid, semi-arid, sub-humid, and humid ACZs. The results in Figure 3a–d show significant fluctuations in rainfall during the growing season in all the ACZs. The CDI reveals a regular rainfall pattern during the growing season; however, it shows a general below-normal rainfall pattern in all the ACZs for the majority of the year (Table 4). These results show a general and consistent negative value for seasonal rainfall in all the ACZs, which implies that the rainfall during the seasonal rainfall has reduced. This might confirm the farmers' perception of change in the onset of rainfall and increased incidence of dry spells in all the ACZs.

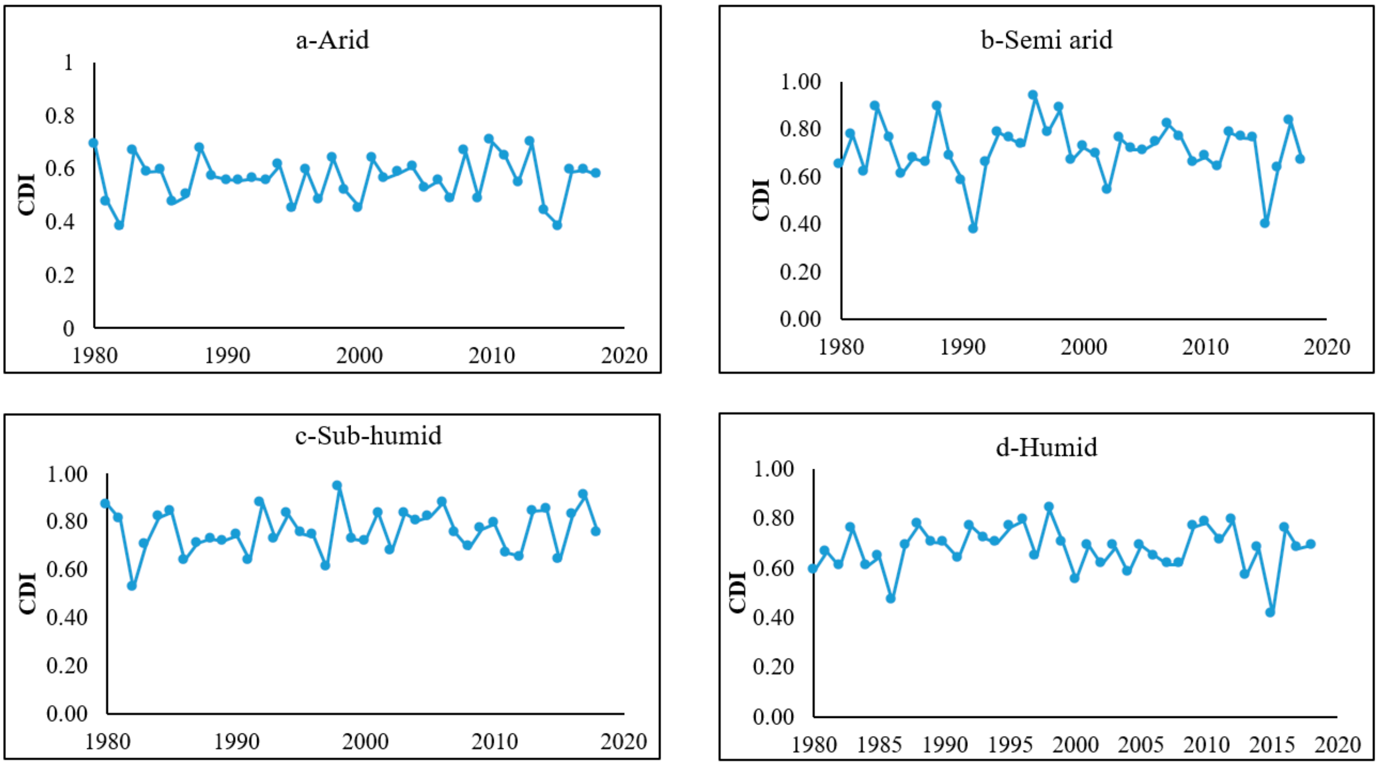

Figure 3. Growing season fluctuation analysis based on Cumulative Departure Index (CDI) between 1980 and 2018 of Arid (**a**), Semiarid (**b**), Sub-humid (**c**) and Humid (**d**) regions.

3.2.2. Mann-Kendall Test Results of Rainfall Trends in the Varied Agro-Climatic Zones of India

Table 5 shows 12-month precipitation accumulation observations for each of the four ACZs. The results showed increasing rainfall for semi-arid (0.35 mm/year) and humid (4.18 mm/year) ACZs. The trend line slope was not very large in magnitude, but it was positive. In contrast, the trend line showed negative rainfall values for arid (−0.20 mm/year) and sub-humid (−2.02 mm/year) zones in small quantities over 38 years. Overall, there was no significant trend in the mean annual rainfall between the climatic zones in India and we accepted the null hypothesis. The farmers' perceptions about the quantity of rainfall trend differed. It is due to the concern of the farmers about moisture availability during the primary crop growing season. Farmers were not concerned about the total annual rainfall received at their location. Although we have seen variation in the rainfall during the growing season confirmed by RAI and CDI analysis, the Mann-Kendall test showed homogeneity of data that resulted in non-significant variation in mean annual precipitation. Based on the findings, it is critical to address that the possible impact on agricultural productivity is rising, and falling rainfall trends in these ACZs continue in the future. Excess rainfall, for example, has been proven to cause soil saturation, landslides, runoff, and soil erosion in humid regions of the world [63]. However, a decrease in rainfall in the future might impact the long-term viability of surface water supplies and groundwater recharge [64], especially in arid and sub-humid regions of the country.

Table 5. Mann-Kendall and Regression Statistics Results of mean annual rainfall, maximum temperature, and minimum temperature for the different ACZs.

	Mean	Kendall's Tau	*p*-Value	Test Interpretation	Equation	R^2	*p*-Value (Slope)
Rainfall							
Arid	831	−0.004	0.981	No trend	$y = -0.1338x + 1098.1$	$R^2 = 0.0004$	−0.20
Semiarid	1165	0.026	0.828	No trend	$y = 0.871x - 576.3$	$R^2 = 0.0071$	0.35
Sub-humid	1053	−0.171	0.127	No trend	$y = -2.2273x + 5505.6$	$R^2 = 0.0564$	−2.02
Humid	1486	0.174	0.122	No trend	$y = 5.1548x - 8818.3$	$R^2 = 0.0725$	4.18
Maximum Temperature							
Arid	31.5	0.26	0.02	Trend	$y = 0.0145x + 2.5549$	$R^2 = 0.1584$	0.014 **
Semiarid	32.2	0.31	0.01	Trend	$y = 0.0112x + 9.6817$	$R^2 = 0.2552$	0.011 **
Sub-humid	31.6	0.46	<0.0001	Trend	$y = 0.0148x + 1.9643$	$R^2 = 0.363$	0.014 ***
Humid	29.8	0.22	0.0046	Trend	$y = 0.0135x + 2.8601$	$R^2 = 0.1341$	0.013 **
Minimum Temperature							
Arid	18.1	0.40	0.0003	Trend	$y = 0.0173x - 16.612$	$R^2 = 0.3141$	0.018 **
Semiarid	20.9	0.21	0.06	No Trend	$y = 0.008x + 4.8346$	$R^2 = 0.1109$	0.006 **
Sub-humid	20.0	0.00	0.01	Trend	$y = 0.0121x - 4.2732$	$R^2 = 0.2831$	0.012 **
Humid	17.4	0.42	0.00	Trend	$y = 0.017x - 16.533$	$R^2 = 0.3402$	0.017 **

Note: ** Shows statistical significance at $p \leq 0.05$. *** 0.1%.

3.2.3. Mann-Kendall Test Results of Temperature Trends in the Varied Agro-Climatic Zones of India

The mean maximum and minimum temperature readings for each of the four ACZs were shown in Table 5. The Mann–Kendall test was statistically significant for all four ACZs for maximum and minimum temperature data. H_0 was rejected in this case, suggesting a trend in the data for all four ACZs. The results showed an increase in temperature in arid (0.014 °C/year), semi-arid (0.011 °C/year), sub-humid (0.014 °C/year), and humid (0.013 °C/year) ACZs. Similarly, results showed an increase in mean minimum temperature in arid (0.018 °C/year), semi-arid (0.006 °C/year), sub-humid (0.012 °C/year), and humid (0.017 °C/year) ACZs. In all four ACZs, the climatic data corroborated farmers' perceptions. The growing temperature trend is consistent with previous investigations [16,65,66]. Increasing rainfall trends were also reported in earlier studies [67] but differed by a few [56,68,69]. With the four ACZs exhibiting an increasing upward trend in temperature over the last 38 years, it's critical to understand how this may impact IFS output if the trend continues.

3.3. Adaptation Strategies to Changing Climate

3.3.1. Field and Horticulture Crops

The IFS farmers of the four ACZs adopted several measures to counter the changing climate in different components of the IFS. Various climate change adaptive strategies are listed in Table 6. Only 17% of the IFS farmers in the arid region adopted insurance to reduce crop failure and livestock health risks. While the IFS farmers of semi-arid, sub-humid, and humid regions were found to be more aware of crop insurance to reduce the associated risk of crop failure. Almost all the IFS farmers in all the ACZs practice change in planting dates, majorly to avoid terminal drought/rainfall, pest and disease incidence, and a contingency plan to prevent short/extended mid-season dry spells. Intercropping is one of the best low-cost climate-resilient practices, adopted majorly to reduce soil erosion, improve soil fertility (by including legumes as a cover crop), and as a trap crop to break the pest and disease cycle. The adoption of intercropping was found higher in arid and semi-arid zones. Higher adoption under arid and semi-arid zones is mainly due to higher water constraints and shorter growing periods because of poor rainfall distribution. The earlier studies also reported that intercropping as a climate-resilient strategy is more in arid and semi-arid zones to avert economic loss [70–72]. Adopting a mixed cropping/intercropping system also provides food and nutritional security to the farm household and exploits the interspace between the main crop and extra moisture. Likewise, most IFS farmers across the ACZs have changed to short and drought-resistant varieties as a contingency plan for terminal drought/dry spells. These varieties were high-yielding and completed their lifecycle 30–40 days earlier than the traditional varieties and provided a scope for the sequential crop after the main crop. The farmers of semi-arid, sub-humid, and humid zones were essentially adopting soil and moisture conservation techniques to control runoff and water erosion. The rainwater harvest mechanism is used at Gladstone village in Central South Africa to mitigate drought stress [67]. Farmers were conserving water by practicing farm ponds to avail of the same in the summer season. The adoption of compartmental bunding, contour bunds, and live bunds was most effective in reducing soil and nutrient loss under slopy areas. The establishment of field bunds plays a critical role in choking floods and increasing water infiltration into the soil. Similar findings were also reported by Kassie et al. [73] and Wossen et al. [74] elsewhere.

Table 6. Farmers' adaptive strategies in response to changing climate.

Components	Adoption Strategies	Percentage of Adoption			
		Arid	Semiarid	Sub-Humid	Humid
Crops & Horticulture	Having farm insurance	17	26	42	45
	Change in planting dates of major crops	75	92	91	83
	Intercropping/mixed cropping adopted	91	92	73	78
	Changed to short, drought-resistant varieties	83	62	55	67
	Soil moisture conservation techniques adopted	33	54	55	67
Livestock	Rear cross breeds	83	91	91	90
	Raising green fodder in the offseason	69	72	73	83
	Use of electric fans/coolers during summer	33	38	73	94
	Prophylactic measures taken against disease infestation	80	77	82	89
Fisheries	Rear improved fingerlings	17	8	55	83
	Introduction of new species	23	23	45	63
	Use of pucca ponds to avoid the seepage loss of water	32	15	18	67
Adoption Index		**50.2**	**66.6**	**83.3**	**91.6**

3.3.2. Livestock and Fisheries

The farmers of all the ACZs adopted the rearing of crossbreds (a cross between indigenous and exotic breeds of livestock). The main advantage of rearing crossbreeds is adaptability to local climatic conditions, disease resistance, higher milk yield, and ease of management. Another climate-resilient practice adopted by IFS farmers in the four ACZs was growing green fodder in the offseason mainly to ensure year-round availability of energy and fiber sources to meet the nutritional requirement of the livestock. The efficient extension activity and incentives by respective state animal husbandry departments, universities, and the Indian Council of Agricultural Research (ICAR) for popularising improved fodder cultivars lead to higher adoption of fodder cultivation and conservation through silage. The farmers in sub-humid and humid ACZs were found using electric fans/coolers during summer to relieve heat stress to the animals resulting in the boosting of milk production. The major economically significant diseases affecting the livestock sector in India are foot and mouth disease, Hemmorroghic Septicaemia, and PPR in ruminants. India's central and state governments initiated the prevailing mass animal vaccination program, which has increased the animals' mass immunity. The recently formed FMD and Brucella eradication program has further boosted the vaccination program in the country. These contributed to higher prophylactic measures against disease infestation in all the ACZs. The adoption of rearing of improved fingerling was restricted to humid ACZs due to better extension activity by concerned field workers of the fisheries department of respective states. This, in turn, led to the introduction of new species and higher adoption of managed ponds to reduce seepage loss.

3.4. Perceived Barriers to Adoption

The majority of the IFS farmers perceived constraints in adopting measures to climate change. Among meta barriers, the farmers of the arid and semi-arid zones perceived financial conditions at the farm and uncertainty regarding the magnitude of climate changes as significant constraints in affecting the adaptive capacity of the IFS farmers (Table 7). While in humid zones, less than 50% of the IFS farmers perceived Meta barriers as the constraint in adopting climate change practices. Farmer's capital determines the ability to mitigate water poverty [75]. Due to the collective decision-making process, shared resources, and sensible agroecology practices, institutional mechanisms such as cooperative organizations effectively adapt to climate change [76]. Among capacity barriers, the IFS farmers of all four ACZs perceived shortage of labor and land as significant constraints reducing the adaptive capacity of the farmers.

Table 7. Potential barriers to implementing adaptation measures.

Potential Barriers		Arid	Semi-Arid	Sub-Humid	Humid
Meta-Barriers	Government policy	73.4	69.0	57.8	32.0
	Farming policy regulations	77.8	73.0	67.9	42.4
	Uncertainty regarding the magnitude of climate changes	92.0	83.0	61.9	49.5
	Financial constraints at the farm	91.0	79.0	63.8	37.9
Capacity Barriers	Shortage of land	78.0	63.5	72.1	67.0
	Non-Availability of new technologies	69.0	72.7	43.9	35.0
	Poor Extension Service	72.5	58.2	48.9	38.8
	Lack of agro-advisory services	82.9	72.0	62.5	41.9
	Shortage of labor	84.0	67.0	95.0	92.0
Water Barriers	Water scarcity constraints	92.2	92.2	42.0	39.0
	Poor potential for irrigation	94.3	94.3	34.5	29.0

Further, the farmers in arid, semi-arid, and sub-humid ACZs perceived problems such as lack of agro-advisory services, poor extension service, and non-availability of new technologies as potential capacity barriers. A study in sub-Saharan Africa also reported that adaptation to climate change impacts depends on assisting farmers in improving their adaptive capacity through extension activities and agro advisories [77]. Inappropriate adaptation strategies to reduce climate change are lack of access to early warning, high cost, and lack of labor, governance, and policy issues of local administration [78]. The water barriers like water scarcity constraints and poor potential for irrigation were found higher in arid and semi-arid regions. The higher water constraints were due to lower total rainfall and less water conservation for the summer season. Less than 50% of the farmers in sub-humid and humid perceived water constraints. The long-term solution to mitigate climate change would require infrastructures such as irrigation in dry areas, windbreaks in hurricane-prone regions, check dams in flood-prone areas, and the promotion of traditional water harvesting systems. Social capital formed by cooperation, trust, and reputation with both public and private institutions [79] plays a crucial role in climate resilience at the macro level. About 70% of the respondents in Yogyakarta, Indonesia have expressed a willingness to contribute to social capital to mitigate climate change impacts [80]. The humid and sub-humid IFS farmers perceived lower adoption barriers but had problems with labor and land. The arid and semi-arid IFS farmers perceived higher constraints which significantly reduced the farmers' adaptive capacity, especially water barriers, financial constraints, inadequate knowledge, and technical support.

3.5. Adaption Index

The higher adaption index was observed in humid ACZ followed by sub-humid, semi-arid, and arid zones (Table 6). The result implies that the humid and sub-humid zone farmers are more innovative in adapting measures against climate change due to reduced levels of barriers, especially water. The water was a significant constraint affecting adaption measures in arid and semi-arid regions. Moreover, the low level of income and education also affect the adaption capacity of IFS farmers in the arid and semi-arid zones.

3.6. Effect of Perceived Climate Change and Its Impact, Perceived Barriers, and Adaptive Capacity on Farmers' Likelihood to Adapt to Climate Change

Table 8 shows the findings of the ordered probit analysis of anticipated future modifications. By displaying the importance of all parameter estimations, we make it easier to compare the results. As expected, climate change impacts significantly influence the likelihood of future adaptation in all four ACZs. However, perceived climate change and its effects were negatively correlated with ventilated shelters, rearing improved fingerlings, and introducing new species in Arid ACZ. This indicated that farmers were more unwilling to spend money on high-cost practices and quickly adopt low-cost technologies. Further, perceived climate change and its impacts were more strongly correlated with changes in planting dates, growing short-duration varieties, rearing of crossbreds, and prophylactic measures against pests and diseases in all four ACZs.

The likelihood of future adaptation was substantially linked with all three types of perceived barriers to adaptation. Contrary to our predictions, the correlations were positive; the more significant the perceived barriers to adaptation, the more farmers, said they were likely to adapt. In both arid and semi-arid ACZs, meta-barriers were more strongly correlated with the likelihood of adapting to potential climate change impacts. Still, they were negatively associated with the adoption of improved fingerling rearing, the introduction of new fish species, and the use of managed ponds. In all four ACZs, capacity barriers significantly influenced the likelihood of adapting to future negative climate change consequences. The Farmer's likelihood to adopt was found more in the sub-humid and humid region in response to capacity barriers. At the same time, the water barriers were positively influenced by the water conservation measures, intercropping, and growing of short-duration varieties in all the ACZs. The water constraints negatively affected the adoption of rearing of improved fingerlings, the introduction of new fish species, and the use of managed ponds in arid, semi-arid, and sub-humid ACZs.

The results revealed that with the increase in education, farm experience, farm size, and farm income, the Farmer's likelihood of adapting to the negative impacts of climate change is increasing. With the increased education level of farmers in the arid zone, they are likely to adapt to changes in planting dates, intercropping/mixed cropping adopted, short and drought-resistant varieties, and soil moisture conservation techniques. While the education greatly influenced the adoption of almost all the climate-resilient practices except the adaption of rearing of improved fingerlings, the introduction of new fish species, and the use of managed ponds in arid, semi-arid, and sub-humid ACZs. However, education positively correlated with climate-resilient practices in the humid zone. The Farmer's education level [81] decides to change of planting date to adapt agriculture to climate change. Likewise, farm experience, farm size, and farm income also influenced Farmer' likelihood to adapt to adverse impacts of climate change. Therefore, we infer that educated farmers who run diversified and profitable farms with small to medium landholdings are concerned more about climate change in undertaking adaptive strategies to reduce the environmental impact of climate change.

Overall, the findings show that Indian farmers perceive climate change risks to be very high and have high adaptation barriers. Nevertheless, Indian farmers indicate a moderate to a high likelihood that they will undertake adaptive behavior in the future subject to various obstacles and socio-demographic issues (Table 8). The farmers of sub-humid and humid regions are more likely to undertake adaptive behaviors that protect against the dangers of climate change. At the same time, the ability of IFS farmers in arid and semi-arid zones to adapt to climate change is greatly affected due to meta, capacity, and water barriers and their sociodemographic factors. The responses of IFS farmers indicate that they would change their farming practices wherever possible to optimize in response to adverse impacts of climate change, whether by changing planting dates, adoption of intercropping/mixed, short, drought-resistant varieties, soil moisture conservation techniques under annual and perennial cropping systems. In addition, rearing of crossbreeds under livestock and fishery components, growing green fodder in the ventilated shelter, and prophylactic measures against pests and diseases were adopted. But farmers are reluctant to take farm insurance in all the ACZs and not adopt rearing of improved fingerlings, introduce new fish species, and use good ponds in arid, semi-arid, and sub-humid zones (Table 8). This implies that farmers are more likely to adjust to allow for gradual and flexible responses, which is consistent with prior research on decision-making in uncertain situations [82–85]. Our results show that most interviewed IFS farmers agree (79%) that climate change affects cropping and livestock activity. Similar studies [86,87] on farmers' perceptions have shown that 35–68% of farmers believe climate change occurs.

Table 8. Ordered Probit Analysis Results: analysis of the effect of perception of climate change, barriers of adoption, and sociodemographic factors on adoption practices.

	Have Insurance	Change in Planting Dates	Intercropping/Mixed Cropping Adopted	Short, Drought-Resistant Varieties	Soil Moisture Conservation Techniques	Rear Crossbreeds	Raise Green Fodder in the off Season	Use of Ventilated Shelter	Prophylactic Measures	Rear, Improved Fingerlings	Introduction of New Fish Species	Use of Good Ponds
						Arid						
Perceived climate change and its impact		0.0345 ***	0.128 *	0.057 ***		0.038 **	0.028 **	−0.187 **	0.234 **	−0.072	−0.328 *	
Meta-Barriers	0.153 *	0.0257 **	0.5100 (*)	0.0090	0.0070 ***	0.2760 *	0.0250 **	0.1987 *	0.068 **	−0.0051 **		−0.0021 **
Capacity Barriers	0.0112 ***	0.0019 **		0.0020 *	0.0174 (*)	0.0132	0.0017		0.0190	−0.0003	−0.0050	−0.0025
Water Barriers	0.0009 ***	0.0023 **	0.0095 *	0.0512 (*)	0.2370 *	0.0780 **	0.2380 *			−0.2010 *		−0.052 **
Education		0.036 **	0.421 *	0.082 **	0.009 ***							
Farm experience		0.035 **	0.002 ***	0.009 ***	0.021 **	0.321 *	0.071 **	0.421 *	0.72 **			
Annual Income	0.0181 *	0.02625	0.0018	0.0081	0.0189	0.2889	0.0639	0.3789	0.648 *			
Farm Size			0.006 *	0.001 ***	0.009 ***	0.007 ***	0.0009 ***					
						Semi-arid						
Perceived climate change and its impact		0.095 ***	0.028 ***	0.182 ***	0.022 *	0.008 **	0.0002 ***	0.012 **	0.445 *			
Meta-Barriers	0.138 *	0.023 **	0.007 ***	0.025 **	0.215 *	0.24 (*)	0.022 **	0.093 **	0.235 *	−0.004 **	−0.0001 ***	−0.0005 ***
Capacity Barriers	0.012 **	0.002 **	0.0006 ***	0.002 **	0.019 **	0.022 **	0.0024 **	0.008 ***	0.02 **	0.0004 ***	0.012 **	0.004 ***
Water Barriers	0.002 **	0.005 **	0.022 **	0.120 *	0.556 *	0.1833 *	0.5593 (*)			−0.472 (*)		−0.122 *
Education	0.283 (*)	0.031 **	0.366 *	0.071 *	0.008 **	0.014 **	0.054 **	0.312 **				
Farm experience	0.158 **	0.017 **	0.205 *	0.039 **	0.004 ***	0.007 ***	0.03 **	0.174 **	0.0025 **			
Annual Income	0.142 *	0.015 **	0.1846 *	0.03 **	0.0039 ***	0.007 ***	0.027 **	0.157 *	0.0032 **			
Farm Size	0.158 *	0.017 **	0.205 *	0.039 **	0.004 **	0.007 ***	0.030 **	0.174 **				
						Sub-humid						
Perceived climate change and its impact	0.142 **	0.038 ***	0.108 *	0.039 ***		0.038 **	0.028 **	0.187 *	0.234 **	0.072 **	0.328	
Meta-Barriers	0.167 **	0.027 **	0.008 ***	0.032 **	0.2601 *	0.3005 *	0.027 **	0.112 *	0.2843 (*)	0.005 **	0.0001 **	0.0006 **
Capacity Barriers	0.297 **	0.002 ***	0.0007 ***	0.002 ***	0.023 **	0.027 **	0.002 ***	0.010 **	0.025 **	0.0005 ***	0.0153 **	0.004 **
Water Barriers	0.211 **	0.006 **	0.027 **	0.1455 *	0.673 (*)	0.221 *	0.676 **	0.481 *		−0.571 **		−0.147 *
Education	0.323 *	0.037 **	0.443 *	0.0863 **	0.009 ***	0.016 **	0.065 **	0.377 *				
Farm experience	0.181 *	0.021 **	0.2481 *	0.04834 **	0.005 ***	0.009 ***	0.036 **	0.211 *	0.083 **			
Annual Income	0.163 **	0.0191 **	0.223 (*)	0.043 **	0.004 ***	0.008 ***	0.032 **	0.1902 *	0.029 **			
Farm Size	0.166 **	0.021 **	0.248 **	0.048 ***	0.005 ***	0.009 ***	0.036 **	0.211 *				

Table 8. *Cont.*

	Have Insurance	Change in Planting Dates	Intercropping/Mixed Cropping Adopted	Short, Drought-Resistant Varieties	Soil Moisture Conservation Techniques	Rear Crossbreeds	Raise Green Fodder in the off Season	Use of Ventilated Shelter	Prophylactic Measures	Rear, Improved Fingerlings	Introduction of New Fish Species	Use of Good Ponds
						Humid						
Perceived climate change and its impact	0.0008 ***	0.025 ***	0.128 *	0.057 ***		0.038 **	0.028 **	0.187 *	0.234 **	0.072 **	0.328 $^{(*)}$	
Meta-Barriers												
Capacity Barriers	0.425 $^{(*)}$	0.001 *	0.0003 ***	0.001 **	0.012 *	0.014 *	0.001 ***	0.005 ***	0.013 **	0.0002 **	0.008 ***	0.002 ***
Water Barriers												
Education	0.22 $^{(*)}$	0.023 **	0.272 *	0.053 **	0.005 **	0.01 *	0.04 **	0.232 *	0.005 **	0.005 **	0.0021 **	0.002 **
Farm experience	0.125 *	0.013 **	0.152 *	0.029 **	0.0032 **	0.005 ***	0.022 **	0.1299 *	0.025 **	0.0029 **		0.054 *
Annual Income	0.112 *	0.011 **	0.1373 *	0.0267 **	0.0029 **	0.005 ***	0.020 **	0.116 *	0.008 **	0.0006 **		0.321 *
Farm Size	0.238 *	0.013 **	0.152584 *	0.0297 **	0.003 **	0.005 **	0.022 **	0.129 *				

Note: * denotes the statistical significance (5% *, 1% ** and 0.1% ***) of estimated parameters.

4. Conclusions

The present study's findings reveal a persistent high variability in annual rainfall based on a 5-year moving average. The RAI suggests that those years with lower-than-normal rainfall were characterized by late-onset and early cessation of rains. The CDI reveals a regular rainfall pattern during the growing season, with seasonal variations such as fluctuation in the onset of monsoon, increased dry spells, and heavy terminal rains. The farmers of arid and semi-arid zones perceived a higher rate of barriers than in sub-humid and humid zones. The farmers of sub-humid and moist regions are more likely to undertake adaptive behaviors that protect against the potential negative impact of climate change. Our findings indicate that farmers are more likely to protect against its ill effects when farmers believe in climate change. The study suggests climate change adaptation needs to be prepared based on farmer perception and historical weather records suitable for a given agro-climatic zone. We also suggest education and skills training related to climate change adaptation and mitigation may be initiated to improve farming practices and sustainable land management. One of the critical features of IFS is the continuous integration of site-specific knowledge and practical experiences into future management planning and practices. Therefore, site-specific studies and practical experiences must be integrated into future policy formulation and implementation.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and the Code of Ethics of the International Sociological Association (ISA) for the formulation and execution of the questionnaire. The protocol including survey and agricultural intervention was approved vide F. No. A. Ext. 20-3/2014-AE-I dated 28-10-2017 under AICRP IFS by Indian Council of Agricultural Research, New Delhi. We adhered to the Code of Practice for the housing, nutrition, husbandry, and care of animals used for the recording of productivity data. Further, the results are reviewed by the Institute Research Council of ICAR- Indian Institute of Farming Systems Research, Modipuram as well as the Project Monitoring Committee (PMC) of the funding agency on annual basis.

Informed Consent Statement: Since the study required information recording based on an interview with humans, before conducting the survey, we informed the participant about the purpose and the utilization of the survey, and informed consent was obtained from each of the participants.

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