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Understanding Constraints and Enablers of Climate Risk Management Strategies: Evidence from Smallholder Dairy Farmers in Regional South India

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Abstract: The adoption of effective coping strategies is crucial for successful adaptation to the impacts of climate change in the dairy sector. However, little attention has been paid to understanding the perceived constraints and motivations toward such strategies. A survey was conducted among 104 dairy farmers from three semi-arid regions of South India. The aim of the survey was to explore the dairy farmers' perception of climate risk, how it impacts their dairy farming system, the coping strategies they employ, and the barriers they face when implementing these strategies. The survey also investigated the factors that facilitate the adoption of adaptation measures. The results indicate dairy farmers in the region perceive drought, pests and diseases, and high temperatures as the major risks associated with climate change, which has resulted in decreased dairy income, animal health problems, reduced fertility, and food intake problems for their cattle. In response to climate variability, dairy farmers have adopted various coping strategies. The most important strategies include buying livestock insurance, keeping low debt obligations, and growing drought-tolerant grass varieties. However, most farmers face significant constraints in adopting these and other strategies including a lack of climate forecast data, the high cost of adaptation activities, and weak institutional support. On the other hand, the key enabling factors that support the adoption of these strategies include milk production security, suitable feed growing conditions, and family interest. Most importantly, the study found that certain factors such as age, education, number of earning family members, annual milk production, monthly cattle expenses, and landholdings significantly influenced dairy farmers' strategies for adapting to climate change. The study recommends that providing timely climate forecasts, implementing improved policies such as vaccination and cattle health services, and establishing strong institutional support systems can help dairy farmers become more resilient to climate change and protect their livelihoods.

Keywords: risk perceptions; adaptation constraints; adaptation facilitation; institutional support; access climate forecast

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1. Introduction

India has been the largest milk-producing country in the world for nearly two-and-a-half decades. India contributes 23% to global milk production [1]. At present, global milk production is growing at a rate of two percent per annum, whereas in India, its growth rate

is over six percent per annum [1]. The per capita availability of milk in India is also much higher than the world average. In the last three decades, the daily milk consumption in the country rose from 107 g per person in 1970 to 427 g per person in 2020–2021, compared to a world average of 322 g per day during 2021 [1].

The dairy sector in India plays a crucial role in supporting livelihood opportunities for 81 million dairy farmers [2], who are predominantly smallholder dairy farmers (i.e., 2–5 cattle per farm family) and the landless, particularly in the rural areas of the country. These smallholder dairy farmers contribute 62% of milk production in the country [3]. In India, dairy farming systems are most often benevolent due to the complementary nature of crop and livestock production. Much of the feed to animals is derived from agricultural remains and by-products. Although dairy farming has been reported as an age-old and complementary agricultural practice, particularly for the marginal and landless farmers in India [4], it has gained much popularity and attracted attention of the large farming households in recent decades [5–7].

However, this vital dairy industry in India is facing tremendous pressure from climate change impacts, which ultimately threatens sustainable livelihoods in the rural areas of most of the regions of the country [8]. Dairy farmers are similarly exposed to uncertainty regarding changing climatic conditions that produce abrupt changes in environmental factors. For example, the southern semi-arid regions of the country have been hit hard by changes in rainfall patterns, and widespread drought for many years, which has greatly affected dairy farming operations in the last few decades [9].

Climate-change-induced abrupt precipitation patterns and rising temperatures have heightened risks to the health and welfare of livestock [8,10]. For instance, foot-and-mouth disease (FMD), which is a dominant livestock disease in India, has been reported to be more prevalent under extreme and abrupt changes in rainfall and temperature [11–13]. Moreover, health risks of livestock animals are predicted to be accelerated due to a likely increase in average temperature by 2 °C by 2050 in the coming decades [14], as heat stress can inhibit the immune system of livestock leading to an increase in the potential outbreak of infectious diseases [12,15–17].

The quality and quantity of milk, wool, and meat associated with climate variability and extreme weather have also led to a drop in the market prices of final products [8,10,18], resulting in variable production supply that threatens food security [19–23]. However, managing the multi-faceted risks associated with climate change impacts (e.g., health risks, feed availability, milk prices) in the dairy farming industry is becoming more challenging due to a lack of relevant climate information [24–27]. Thus, there is a need for a thoughtful understanding of the prospects of decision making that are site-specific to help smallholder dairy farmers battling the wave of climate risks [28–30].

Numerous studies have been conducted worldwide on farmers' perceptions of climate change and their adaptation strategies in the cropping sector. These studies highlight the significance of understanding farmers' perceptions of climate change and their coping mechanisms. However, most existing studies have focused on the impacts of climate change on the livelihoods of farming communities in the cropping sector and their locally preferred adaptation strategies [31–34]. Limited research has been conducted on farmers' perceptions of climate change and their adaptation strategies in the livestock sector.

For example, a study by Montcho et al. [35] found that farmers adopted local measures to adapt to perceived climate change, which had negative impacts on livestock productivity, such as reduced herd size, milk production, and fodder availability. However, existing studies have paid little attention to the autonomous adaptation choices of smallholder dairy farmers and the factors that motivate them to adopt these strategies [36,37].

A comprehensive investigation of farmers' autonomous adaptation choices is crucial for developing climate-responsive adaptation planning on a large scale. It is also important to document the susceptibility of dairy farmers and animal production to climate risks in the Indian context. Furthermore, limited research has been conducted to assess the knowledge and perceptions of dairy farmers in southern India, highlighting the need for additional research [28,30,38]. Therefore, it is imperative to understand smallholder dairy farmers' perceptions of climate change and their coping strategies while considering the factors that affect their adaptation choices.

This study aims to investigate how smallholder dairy farmers perceive climate risks and how these risks affect their dairy activities. The study will also examine the current risk management strategies used by farmers, as well as the obstacles and opportunities for adaptation. Furthermore, the study will identify the factors that influence dairy farmers' choice of coping strategies for climate-change-related risks in their dairy farming system.

2. Material and Methods

2.1. Selection and Description of the Study Area

Karnataka is the second most vulnerable state in India to be impacted by climate variability and change as it comprises the aridest and driest regions [39]. Karnataka's agriculture and socio-economic settings act as an appropriate representative unit for South India's semi-arid regions. Dairy farming is one of the major livelihood activities besides agriculture in most Indian states. The state has variable rainfall, diverse soil types, and cropping patterns, and the state is divided into 10 agro-climatic zones [40]. The climate-change-induced risks and impacted zones can cause distress to cattle health and other dairying activities. Hence, it is important to study the dairy farmers' perception of various climate risks and impacts, adaptation, and mitigation strategies in the semi-arid pastoral regions in southern India (Bengaluru Rural/Urban and Chikkaballapur).

The reason for choosing these regions is because of their vulnerability to drought, livestock feed constraints, and water availability issues [39]. Bengaluru and Kolar-Chikkaballapur milk unions are the top two in the state, contributing around 25% to total dairy cooperatives and milk producers in Karnataka while adding about 34% to average milk procurement [41]. The study area receives erratic rainfall averaging 661–1086 mm per annum and high temperatures of over 29–39 °C in summer. Figures S1 and S2 show average rainfall and temperature trends from 2000 to 2022. From the Karnataka state, the study regions (e.g., districts) were selected based on the secondary sources where climate change impacts on the dairy sectors were reported in the literature. Then, from the districts, eight villages were selected to administer the survey. The selected villages were Adde Vishwanathapura, Byatha, Chalahalli, Kadathanamalli, Marelenahalli, Neralaghatta, Tharabanahalli, and Bachuvarihalli (Figure 1).

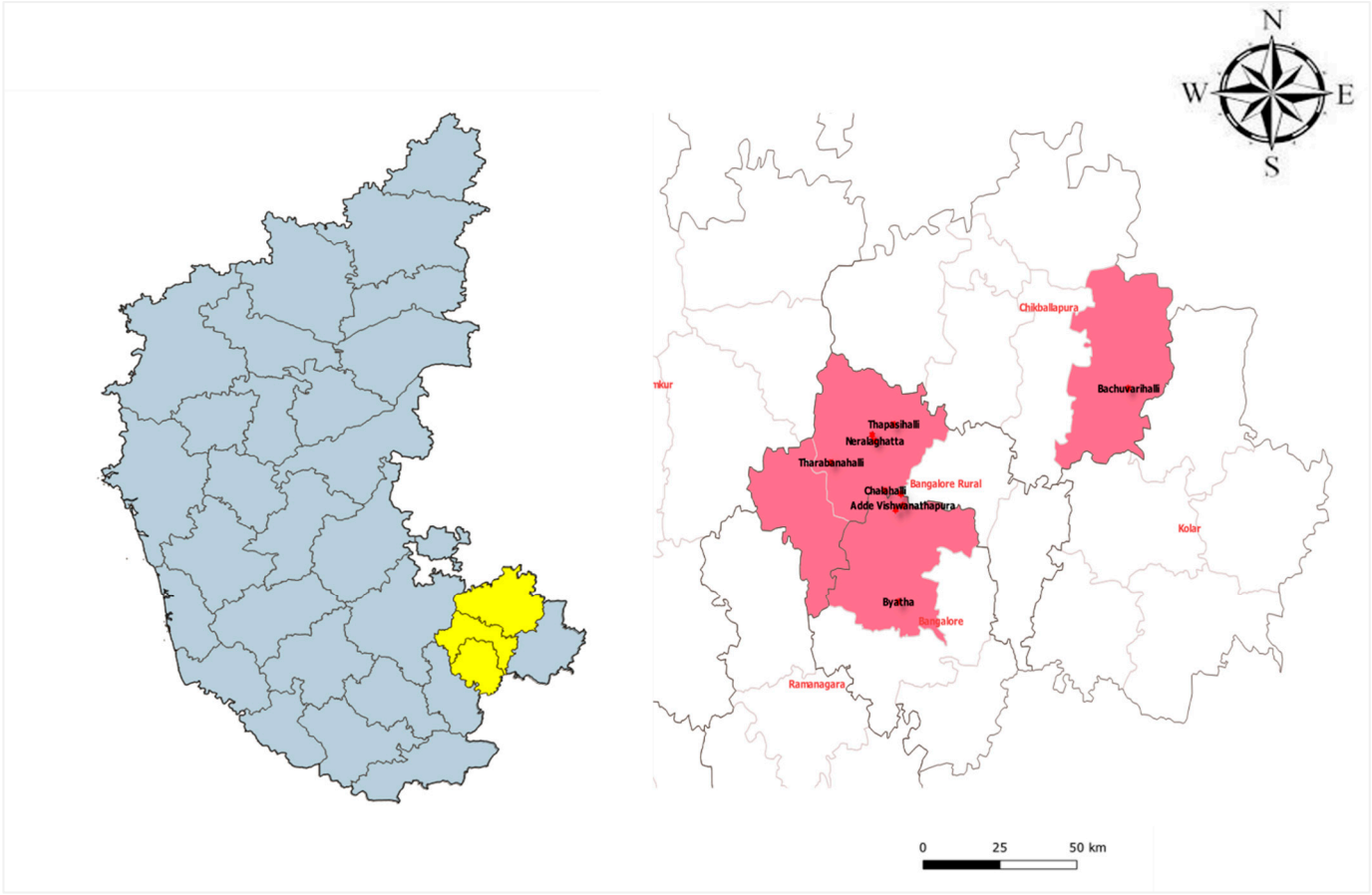

Figure 1. The location of the study areas (red polygons—**right** insert) on the regional map was selected in the state of Karnataka, covering the districts of Bengaluru (rural and urban) and Chikkaballapur (yellow polygons—**left** insert).

2.2. Survey and Data Collection

Primary data were collected through a survey using a pre-tested and structured multiple-choice questionnaire where respondents were able to select different answer options for each question. The initial questionnaire of the study was prepared following Phellas et al. [42]. Having preliminary contact with some of the key informants in the study area, the lead author organized several phone calls with several smallholder dairy farmers to pre-test the questionnaire. By addressing the comments returned during the pre-testing, the initial questionnaire was then restructured and finalized, and employed for data collection. A similar procedure of pre-testing a structured questionnaire was also used in several studies exploring farmers' perceptions of environmental changes [43,44].

The questionnaire was divided into sections to collect information on dairy farmers' socio-economic characteristics; cattle information and consumption patterns; climate risks and impacts (peril) that farmers experienced in the last decade in the region; the climate risks impact on dairy activities that farmers consider (relevant/nonrelevant); a list of barriers and enablers, that farmers need toward their adaption and mitigation measures; and the climate risk management strategies that are (important/not important) to dairy farmers.

Before administering the survey in the studied area, human resources ethics clearance was sought, and approval was gained from the University of Southern Queensland (H22REA088). Following ethics approval, a field trip was organized to administer the survey. The lead author carried out the surveys in a face-to-face interview with each of the 104 respondents.

To operationalize the survey, a stratified sampling procedure was followed to select the respondents, where the individual dairy farming household was considered a primary

sampling unit. Firstly, the study regions (e.g., districts) were selected based on a literature review of reported climate change impacts on the dairy sectors. Then, eight villages were selected from the districts to administer the survey. The selected villages were Adde Vishwanathapura, Byatha, Chalahalli, Kadathanamalli, Marelenahalli, Neralaghatta, Tharabanahalli, and Bachuvarihalli. From each village, the smallholder dairy farmers (i.e., respondents) were selected based on recommendations from dairy heads in each village and the availability of participants, to obtain a representative (in terms of gender, cattle ownership) sample of farmers. Thus, a total of 104 diverse socio-economic-centric rural dairy and agricultural farmers were selected from the study region. A similar stratified sampling procedure was also reported in a study that explored farmers' perceptions of climate change and adaptation strategies [45]. In addition to primary data collected from dairy farmers, this study also utilized secondary data (documents and reports) from public institutions such as the Department of Animal Husbandry and Dairying to support its findings.

Farmers' perceptions regarding the climate risks, impacts, coping strategies, barriers of adaptation, and enablers of adaptation were gathered on the predefined (structured) statements focusing on whether they agree with the statements (i.e., yes/no, important/not important). The details of various dimensions relevant to climate risk perception, adaptation, etc., elicited through farmer's survey are depicted in the flow chart (Figure 2) for a clear understanding.

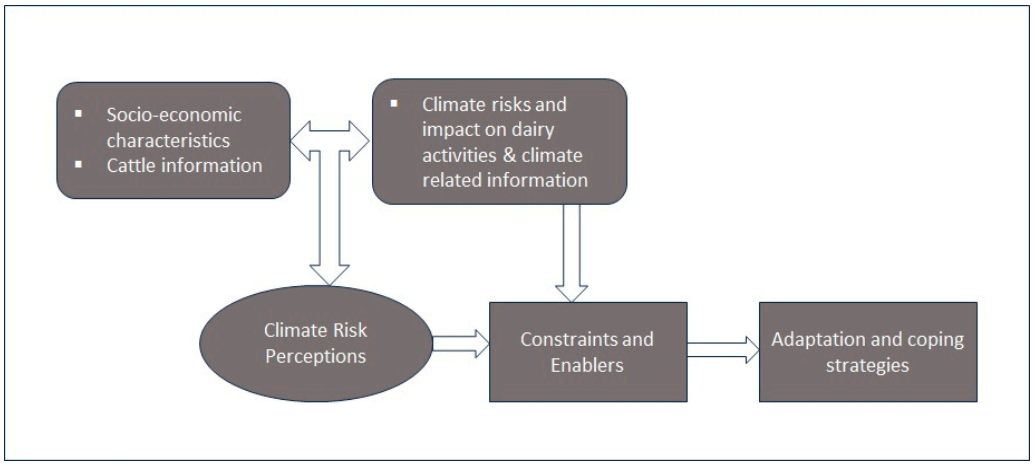

Figure 2. Conceptual framework of data collection process on various factors by dairy farmers.

2.3. Statistical Analysis

Farmers' perceived responses to different issues of climate risks affecting dairy farming, and adaptation choices were presented in terms of "yes" and "important" to demonstrate that the farmers agreed with the statement asked through a structured questionnaire. Similar analysis and results presentation were also reported in studies of farmers' perceptions of climate change in the agricultural sector [35,46].

Following gathering responses on the different variables, these "yes/important" were then coded with a number, and analyzed using SPSS statistical software (version 28.0.1.0 (142)) [47]. Non-parametric chi-square tests were conducted to show the relationship between some of the independent variables and farmers' knowledge of climate change. Furthermore, a chi-square test was carried out to demonstrate the differences among the farmers' perceptions in different dimensions of climate change and adaptation strategies, the constraints of adopting these strategies, as well as facilitating factors in their adoption of these coping strategies, and expressed in percentages.

Additionally, a logistic regression test was conducted to explore the factors affecting farmers' choices of coping strategies using whether each of the selected adaptation strategies (e.g., cash in hand, using drought tolerant grass varieties, buying livestock insurance)

was important or not important using the dependent variable with the socio-economic characteristics of the respondents (e.g., gender, age, education, family member, land holding) as independent variables. This analysis identified whether socio-economic, sociopsychological, and related variables contributed to the adaptation strategies chosen, leading to meaningful inferences from the study.

3. Results

3.1. Socio-Economic Characteristics of Respondents

The socio-economic characteristics of the smallholder dairy farmers surveyed are summarized in Table 1. The mean age of the respondents was 50.55 years, having 8.32 years of schooling. The average landholding capacity of the respondents was 3.26 acres across the eight surveyed villages in Karnataka. The average annual income was 108,928 INR and the annual milk production per cattle was 3499 L.

Table 1. Socio-economic characteristics of the respondents surveyed in this study. Number of surveyed farmers = 104.

Socio-Economic Characteristics (Unit of Measurement)	Mean	Std. Deviation	S.E
Age (Number)	50.55	13.55	1.32
Education (Schooling years)	8.32	4.19	0.41
Landholding capacity (Acres)	3.26	2.89	0.28
Annual Income (INR)	108,928	60,751	5957
Herd size (Number of animals)	2.21	1.19	0.11
Annual milk production per cattle (Liter)	3499	1319.07	129.34
Annual expenses per cattle (INR)	45,450	15,625.24	1532.18

3.2. Relationship of Socio-Economic Features of the Smallholder Dairy Farmers and Their Knowledge of Climate Change

The majority of the socio-economic characteristics of the respondents had a significant relationship with the dairy farmer's knowledge of climate change, except for the gender and age of the respondents. The results of these relationships among the socio-economic characteristics and knowledge of climate change in terms of "yes" responses are presented in Table 2. Among the respondents, 56% of males and 44% of females reported knowledge of climate change. In terms of age of the respondents, the vast majority (51.5%) of respondents who held knowledge of climate change were between "31 and 50" years of age, followed by the 51–70 years age group (35.4%). In connection to the educational qualifications, the vast majority (53.5%) of the respondents who mentioned "yes" have a high school level of education. Results also revealed that the highest "yes" responses (96%) indicating having knowledge of climate change were recorded from the respondents whose primary occupation was agriculture. Furthermore, in terms of landholding capacity, the highest "yes" responses (41.4%), indicating that they have knowledge of climate change, were reported from the marginal landholding group of farmers followed by small landholding farmers (34.3%), as presented in Table 2.

Table 2. Relationship among the socio-economic features of the respondents and their knowledge of climate change.

Socio-Economic Features		% of Respondents Mentioned "Yes"	Chi-Square
Gender	Male	55.6	2.42 ^{ns}
	Female	44.4	
Age	<30 years	5.1	4.13 ^{ns}
	31–50 years	51.5	
	51–70 years	35.4	
	>70 Years	8.1	
Education	Illiterate	11.1	8.75 **
	Primary	14.1	
	Middle school	11.1	
	High School	53.5	
	University	10.1	
Primary occupation	Agriculture (Dairy and crops)	96.0	14.23 **
	Other business	1.0	
	Dairy only	3.0	
Landholding	Marginal (<2.47 acre)	41.4	3.14 *
	Small (2.47–4.94 acre)	34.3	
	Medium (4.94–9.88 acre)	20.2	
	Large (>9.88 acre)	4.0	

^{ns} = not significant (i.e., $p > 0.05$); * $p < 0.10$ ** $p < 0.05$.

3.3. Farmers' Perception of the Risks of Climate Change on the Dairy Farming Systems

Smallholder dairy farmers' perceptions of climate change risks on their dairy farming system are presented in Figure 3. Risks related to drought and to pests and disease were the two most highly ranked risks. When asked about drought, 91% of the respondents mentioned "yes" as drought was a severe climate change risk. Similarly, 89% of the respondents reported an increase in pests and diseases as a result of climate change, and 81% of the farmers identified heat stress as a climate change risk. Regarding erratic rainfall, hailstorms, and floods, 78%, 68%, and 64% of the farmers recognized these as climate change risks, respectively.

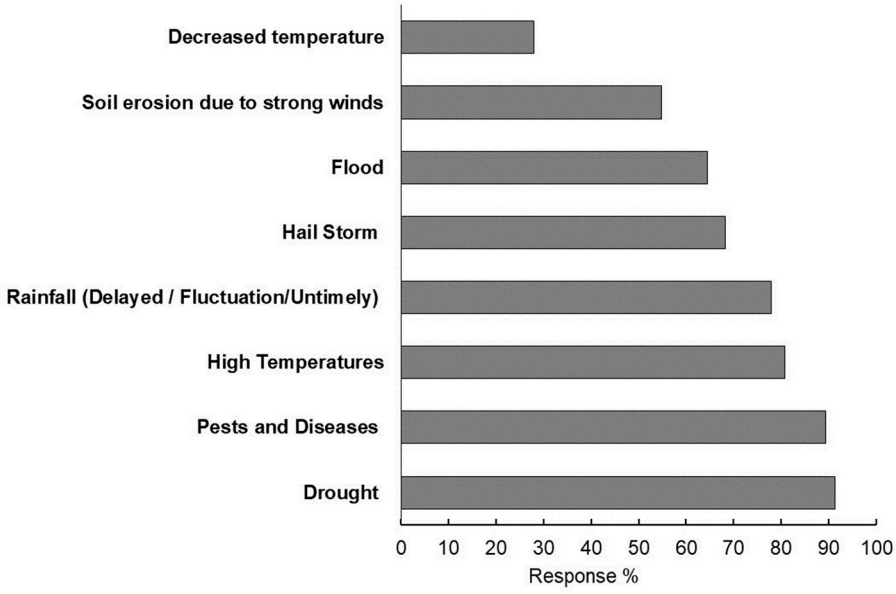

Figure 3. Main climate risks identified during the survey and corresponding farmers' responses (in percentage). Number of farmers surveyed = 104.

3.4. Farmers' Perceptions of the Impacts of Climate Risks on the Dairy Farming System

Smallholder dairy farmers were asked whether they agreed (yes) or not (no) with the impacts of each of the climate change risks on their dairy farming system, and their responses indicating "yes" they agreed are presented in Figure 4. Most farmers agreed that climate change has a negative impact on their dairy farming activities, especially in terms of labor and income. They attributed this to a decrease in milk production. Additionally, 99% of the farmers noted that animal health issues were a direct result of high temperatures, particularly during the summer months (March to May). The farmers also reported experiencing severe drought in the region, which has resulted in a decrease in food intake (98%) and feed issues (96%) due to the high temperatures (see Figure 4).

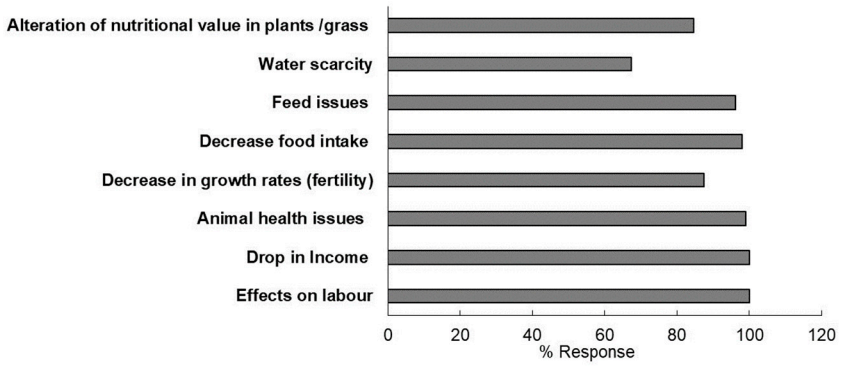

Figure 4. Farmers' perceptions of the impacts of climate risks on the dairy farming system. Number of farmers surveyed = 104.

3.5. Dairy Farmers Adaptation Strategies

Farmers were asked to share their thoughts on the impact of climate risks on dairy activities and which adaptation strategies they deemed important to mitigate these effects. These responses were expressed in percentages of farmers who mentioned that the specific adaptation strategy was important. The study revealed a range of adaptation strategies that are commonly used in the dairy industry to combat climate-change-induced risks. Results indicated that in terms of buying livestock insurance and low debt obligations, 100% of the respondents mentioned these coping strategies are important, followed by using drought-tolerant variety grass (99%), value addition of dairy products, and keeping cash in hand (98%), off-farm employment (88%), and selling livestock (80%) as the most important adaptation strategies to climate change impacts, However, regarding income diversification, crop insurance, and increasing herd size, farmers' responses were divided by both important and not important, which indicated by 61%, 60%, and 58% toward "yes" the adaptation strategies are important respectively (Figure 5).

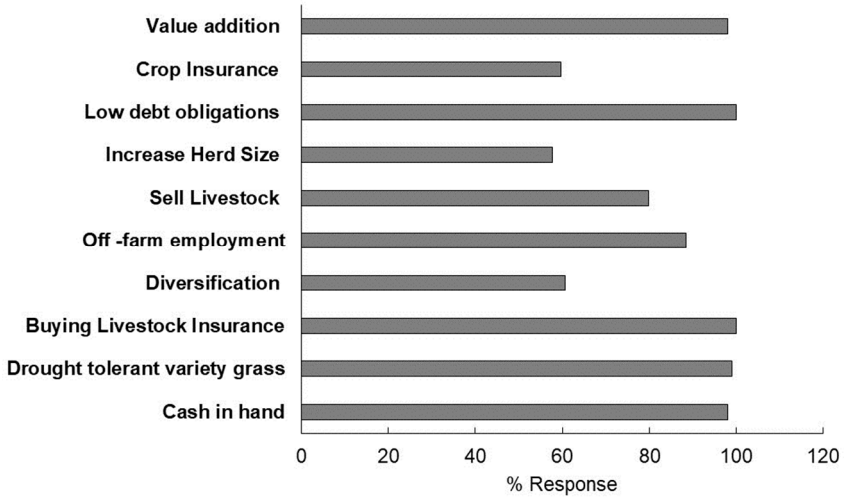

Figure 5. Coping/adaptation strategies adopted/practiced by the smallholder dairy farmers. Number of farmers surveyed = 104.

Following an understanding of the perceived coping strategies for dealing with climate change impacts, this study then investigated how these perceptions varied according to the salient socio-economic features of the respondents (Table 3). The study found that farmers were divided on the importance of adaptation strategies based on the gender of the respondents. However, in terms of the primary occupation of the respondents, more than 95% of those farmers whose occupation was agriculture (livestock and dairy) mentioned all the perceived adaptation strategies were important to them, while only 5% of them perceived coping strategies were not important. Similar trends were also observed in the case of the educational qualifications of the respondents. The findings demonstrated that many of the respondents who had high school-level educational qualifications (~50%) mentioned that adaptation strategies were important to them (Table 3).

Table 3. Farmers' perceived coping strategies for climate change impacts as influenced by different socio-economic features.

Adaptation Strategies	% of the Respondents Mentioned the Adaptation Strategies as Important										Chi-Square
	Gender		Occupation			Educational Qualification					
	Male	Female	Agriculture	Business	Dairy	Illiterate	Primary	Middle School	High School	University	
Value addition	53.8	46.2	95.7	1.1	3.2	14.0	16.1	9.7	50.5	9.7	64.65 **
Crop Insurance	54.8	45.2	93.5	1.6	4.8	14.5	11.3	9.7	58.1	6.5	3.84 *
Low debt obligation	53.8	46.2	94.5	1.1	4.4	11.0	16.5	13.2	49.5	9.9	58.50 **
Increase herd size	53.3	46.7	93.3	1.7	5.0	11.7	16.7	11.7	51.7	8.3	2.46 ^{ns}
Sell livestock	51.8	48.2	94.0	1.2	4.8	12.0	15.7	10.8	49.4	12.0	36.96 **
Off-farm employment	54.3	45.7	95.7	1.1	3.3	12.0	15.2	10.9	51.1	10.9	61.53 **
Diversification	46.0	54.0	93.7	1.6	4.8	15.9	12.7	9.5	52.4	9.5	4.6 **
Buying livestock insurance	54.0	46.0	94.0	1.0	5.0	13.0	16.0	12.0	50.0	9.0	88.61 **
Cash in hand	52.9	47.1	94.1	1.0	4.9	12.7	15.7	11.8	51.0	8.8	95.15 **
Drought-tolerant grass cultivation	47.1	52.9	94.1	1.0	4.9	12.7	14.7	11.8	51.0	9.8	96.15 **
Alternative income sources	55.1	44.9	94.9	0.0	5.1	12.2	16.3	12.2	50.0	9.2	81.38 **

^{ns} = not significant (i.e., $p > 0.05$); * $p < 0.10$, ** $p < 0.05$.

3.5.1. Barriers to Adaptation

Apart from perceived important adaptation strategies and factors influencing adaptation in this study, we further assessed the barriers to their adaptation by dairy farmers. Findings indicated that most of the farmers agreed with the perceived statements of the adaptation barriers, such as "lack of climate forecast", "adaptation strategies were expensive", and "weak institutional support". The "yes" responses toward these statements were 100%, 99%, and 84%, respectively, while the case of "policies of dairy co-operatives" yielded a similar proposition of the responses toward "yes" it is important, and "no" it is not as important (Figure 6).

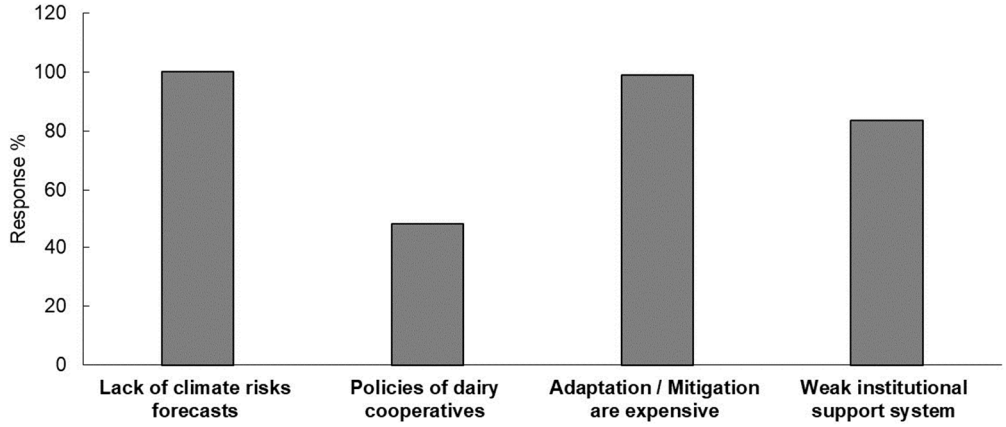

Figure 6. Barriers to adaptation reported by dairy farmers. Number of farmers surveyed = 104.

3.5.2. Motivating Factors for Adopting the Climate Impact Adaptation Strategies

Despite the barriers to adaptation, some factors drove the local farmers to act upon and adopt appropriate and timely measures. The findings of this study revealed that in cases of "family interests", "milk production security", and "economic interests", and "suitable growing feed condition" were reported as the most important motivating factors, as almost 99% of the respondents mentioned "yes" toward these statements. In comparison, 90% of the respondents mentioned "no" toward the statement of a motivating factor as "taking collective action for climate risks" (Figure 7).

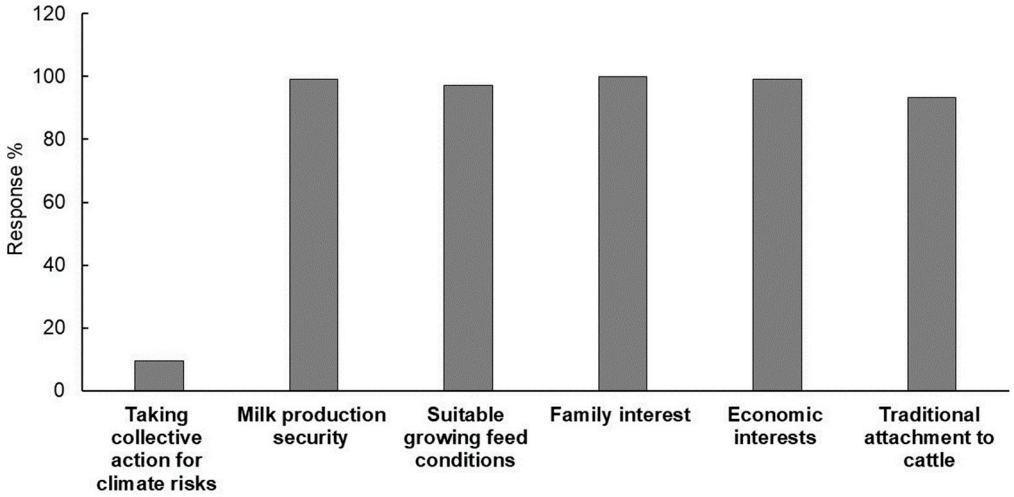

Figure 7. Motivating factors to adopt adaptation strategies. Number of farmers surveyed =104.

3.5.3. Determinants of Dairy Farmers' Coping Strategies to Climate Change Impacts

The results show that the eight variables are critical in one or multiple adaptation strategies adopted by smallholder dairy farmers (Table 4). Gender has a significant influence

($p < 0.05$) when considering diversification in dairy farming, and female farmers preferred this over male dairy farmers. Age affected the adoption of cash in hand, the decision to grow drought-resistant grass, increasing the herd size, and low debt obligation. Farmers with more experience in the dairy industry tend to prefer conservative adaptation strategies such as diversification and using drought-tolerant grass varieties as livestock feed. Education also had a positive effect on similar adaptation decisions. The more years spent in education, the more farmers chose diverse adaptation measures to counter the risks of climate change. Higher education positively affected the consideration of crop insurance as an adaptation strategy. More earning family members opted for off-farm employment and this positively affected crop insurance adaptation by 6%, which shows the additional income makes the farmer capable of buying risk-sharing strategies like insurance. Annual dairy income influenced the farmers to opt for growing drought-tolerant varieties of grasses, which makes sense in so far as additional investment is required for such an adaptation measure apart from regular dairy operations. The cattle expenses affected farmers' decisions on the amount to be held in the form of cash for unforeseen circumstances and affected the decisions to adapt diversification and consider off-farm employment significantly ($p < 0.05$). Land holdings of farmers impacted the decision to obtain off-farm employment. It positively influenced the growth of drought-tolerant grass varieties and value addition to dairy farming activities in terms of better hygiene conditions for cattle in place on the relevant farm. In this study context, value addition meant improved conditions for cattle in terms of hygiene and other actions taken for the protection and welfare of animals.

Table 4. Coefficient estimates from a logistic regression on the factors influencing/affecting different adaptation measures (coping strategies) adopted by dairy farmers.

Predictors Variables	Response Variables (i.e., Adaptation Measures)									
	Cash on Hand	Drought-Tolerant Variety Grass	Buying Livestock Insurance	Diversification	Off-farm Employment	Sell Livestock	Increase Herd Size	Low-Debt Obligation	Crop Insurance	Value Addition
Gender (0 for male, 1 for female)	NS	NS	NS	−0.63 **	NS	NS	NS	NS	NS	NS
Age	−0.86 *	0.951 *	NS	NS	NS	NS	0.007 *	0.029 **	NS	NS
Education (y)	NS	NS	NS	NS	NS	NS	0.01 *	0.11 *	0.007 *	NS
Earning family members	NS	NS	NS	NS	1.19 **	NS	NS	NS	0.06 **	NS
Annual income	NS	0.00 **	NS	NS	NS	NS	NS	NS	NS	NS
Annual milk production	−0.018 **	NS	−0.001*	NS	NS	NS	NS	−0.00 **	NS	NS
Expenses per cattle per month	0.016 *	NS	NS	0.00 *	−0.001 **	NS	NS	NS	NS	NS
Landholding	NS	NS	NS	NS	0.021 **	NS	NS	NS	NS	NS

Statistical significance; * indicates $p < 0.1$; ** indicates $p < 0.05$, NS = not significant (and so coefficient not shown). Dependent variable: Not important = 0, Important = 1.

4. Discussions

Exploring the perceived constraints and enabling factors of the coping strategies is imperative to successfully plan for climate change adaptation. However, the existing discourses of perceptions of climate change adaptation studies are overwhelmed by the crop sector studies, which are predominantly focused on risk and adaptation and pay little attention to perceived constraints and facilitating factors. To understand these issues, a structured questionnaire survey was adopted in this study to investigate the smallholder dairy farmers' perceptions of climate change and their coping strategies, as well as barriers and enabling factors to adopt these coping strategies, which could help to plan comprehen-

sive adaptation actions. This section discusses the findings of this study in the following subsections.

4.1. Smallholder Dairy Farmers' Knowledge of Climate Change and Their Perceptions of Climate Risk and Impacts

The socio-economic characteristics of dairy farmers are important because they influence their economic behavior and determine the ability of farmers to adequately adopt climate risk management strategies. The results of this study demonstrated a significant relationship between their knowledge of climate change and most of the socio-economic characteristics of the farmers (Table 2). These results were found to be consistent with previous studies, indicating that dairy farmers understanding and knowledge of climate change are key drivers to their adaptation approaches [46]. Further, socio-economic features play a vital role in farmers' perceptions of climate change issues, which, in this study, was a driving indicator of adopting coping strategies. For example, the existing literature has demonstrated that education levels play a key role in the enactment of climate adaptation measures based on perceptions of farmers and climate-related information [48]. In addition to local indigenous knowledge, climate science education would help farmers acquire further knowledge and skills to read and understand a wide range of climate-related information and determine how it impacts dairy. The level of a farmer's education also influences the quality of decisions made by dairy farmers whenever a climate risk triggers an adaptation response.

Results further indicated significant associations among the respondents in connection to the impacts of educational qualification on their knowledge of climate change. The results showed that the farmers who were more aware of climate change had completed high school education, followed by those who had completed primary education. On the contrary, most respondents who indicated that they did not know about climate change were illiterate or held primary levels of educational qualification. Results also revealed that land holdings of dairy farmers had a significant association with their knowledge of climate change; in particular, those farmers with marginal and small landholdings agreed they had knowledge of climate change, which dominated in this sample study. These findings are consistent with another study, which indicated that farmers' perceptions play a significant role in the adaptation process [49].

The study conducted in the region has shown that farmers consider drought as the most devastating climate risk, followed by increased pests and diseases, erratic rainfall, hailstorms, and floods. Moreover, the farmers' views on climate change have been verified by comparing them with the observed rainfall and temperature data obtained from the meteorological stations in the region between 2000 and 2022, as illustrated in Figure S1. The meteorological records reveal that the region has experienced 23 years of erratic annual average rainfall, with seven years (2011–2014, 2016, 2018, 2019) in the last decade having below-average rainfall, leading to droughts as shown in Figure S2. Additionally, drought periods were characterized by high mean temperatures ranging from 34 and 39 degrees, which were reported frequently. Therefore, the perceived climate risks by farmers in the region are consistent with the reported data in the existing literature.

In addition, farmers reported heat stress and increased pest and disease incidence in cattle could be a result of drought and high mean temperatures. Rainfall data show a fluctuation trend notably in the years (2020–2022) with heavy rainfall posing different challenges to dairy activities, particularly the landless and small land-holding farmers who depend on pasture grazing around water bodies. Thus, the findings of this study regarding farmers' perceptions of climate change issues were consistent with the meteorological records, signifying that farmers were closely connected to weather and climate cycles and were able to describe environmental factors affecting their dairy farming activities. As most farmers were involved in agriculture production, they were mainly concerned about drought and above-average rainfall years (2020–2022) in the region since they caused a series of crop failures. This experience created further worry for future cultivation and

cattle feed security. The foot and mouth disease (FMD) outbreak in the years 2013 and 2018 was confirmed [11] as an extreme challenge by dairy farmers in the study. Unfortunately, stress on cattle is just one way that extreme heat is challenging dairy farmers with small herd sizes.

The reported list of climate change impacts on dairy activities in this study was found to be consistent with previous studies that also indicated similar implications on dairy farming [46,50–52]. The findings of this study are consistent with [35,53–55], who reported that climate change impacted risks, particularly, heat stress affects milk production in cattle. Persistent dry spells and severe rain were also found to affect the availability of fodder [56] and, in turn, the cost of feed. Thus, the findings of this study were consistent with previous research on the pressures of soaring cattle feed costs and water scarcity issues that led to severe distress from season to season in terms of climate-associated risks [39,57,58], compelling farmers to review their decisions. Previous research has mainly concentrated on the environmental effects that affect livestock productivity, such as the availability of food, shelter, and milk production [59,60]. However, this study has taken into consideration animal welfare concerns, particularly, nutrition, which were previously overlooked.

4.2. Smallholder Dairy Farmers' Coping Strategies, Constraints, and Facilitating Factors in Adopting These Strategies

The findings of this study have shown that a vast majority of the smallholder dairy farmers opined that buying livestock insurance is the most important adaptation strategy to cope with the climate change impacts, followed by growing drought-tolerant variety grass and off-farm employment (Figure 4). Farmers' primary occupations and educational qualifications were found to be the major factors influencing their coping strategies for climate change impacts. In fact, a range of socio-economic, political, institutional, and region-specific environmental factors have a bearing on the adaptive capability of the livestock sector toward climate change. The findings also demonstrated that those farmers with marginal land holdings subject to droughts and unpredictable rainfall are often required to seek off-farm employment, which can involve migration to nearby towns to cope with the financial distress caused by climate change.

The study found that farmers agreed to keep cash in hand as an important adaptation measure to climate risk. Saving money has been a long-standing practice among farmers to tackle tough times by making lifestyle changes when required. Keeping low debt obligations and not depending on money lenders was preferred due to the exorbitant interest rates they charged, which has led fellow dairy farmers to fall into a debt trap. In small-scale mixed crop–livestock systems, farmers have limited economic opportunities compared to cropping systems [61]. Previous studies have shown that keeping cash on hand is the most important risk management strategy for dairy farmers [62,63].

Previous studies also indicated that frequent and persistent droughts lead to the drying of natural pastures, which causes feeding problems for animals and affects the availability of water and the quality of fodder resources in the region [35,64]. Thus, those farmers facing fodder deficiencies made sure to stock some seasonal-based crop residue, purchasing from nearby localities. In addition to diversified feedstock (e.g., drought-tolerant grass, drumstick tree leaves), farmers also introduced diversified livestock to keep their livelihood sustainable through alternative income generation activities and to enhance their livelihood resilience by spreading risk across a number of income channels. For example, farmers reared goats/sheep to gain extra income, particularly to support the period when milk production is usually reduced due to the gestation period. Some women farmers have started chicken farming and selling eggs to earn extra income when their land is not used for agriculture.

Many farmers chose to take advantage of cattle insurance offered by dairy co-operatives, who subsidized the insurance premium by 50%. Although insurance was purchased regularly over the years, some farmers reported losing their animals if they missed a year. A few well-educated farmers were aware that the insurance policy was put in place to deliver

protection mechanisms to the cattle rearers against any eventual loss of their animals due to death and to validate the benefit of cattle insurance. They also knew the scheme was designed to achieve improvements in the health of cattle and their products. However, the illiterate farmers were not aware of this scheme in place to support their business. According to [65,66], cattle holding size positively affected the adaptation decisions of dairy farmers. Those farmers in this study who had experienced a series of losses in agriculture operations preferred to increase their herd size to sustain their living standards.

Farmers may face crop failures, loss of income, and additional expenses during climate change. To offset these challenges, they may be forced to sell some of their livestock [49,64]. Additionally, farmers concerned about the potential impact of pest and disease outbreaks on their animals or reduced milk production due to diseases may prefer to sell some of their livestock. This situation is further exacerbated by the threat of increased livestock mortality due to extreme temperature events in the region.

Another strategy adopted by some farmers was to plant additional shade trees in the study regions, particularly for those farmers who lacked an animal shelter. This was considered an excellent adaptation strategy to prevent animals from the impacts of excessive heat stress. Planting trees also served as supplementary fodder sources. An example of a tree that is suitable for the region is *Moringa olifera*, also known as the 'drumstick tree' [67]. It is drought-resistant, can withstand varying temperature ranges, and grows rapidly and vigorously. Leaves of the tree have high protein content with other essential amino acids [67]. Thus, this kind of tree provides shade to the smallholder dairy farmers and provides nutritious feed to the livestock. This tells us how farmers keep indigenous practices in place and how these traditionally practiced mechanisms hold their importance even after multiple generations. Their perception of its effectiveness was based on the belief that it can lower the negative effects of rising temperatures on cattle health and quality milk production.

Moreover, various, green-dried fodder mixes offered to cattle are an experimental strategy to fight climate change, particularly during hot and rainy months, as reported by farmers in the study region. Besides averting the adverse impact of climate change on agricultural and cattle milk production in the future, planting fodder trees for cattle and ruminants is emerging in the region as a practical solution. This approach not only helps with sustainability but also generates income through growth and harvesting. While crop insurance was another potential strategy, some farmers deemed other strategies as important in the study region to their farming approach.

Findings of this study have shown that dairy farmers in the studied region perceived "lack of climate forecast", "high cost of adaptation strategies", and "weak institutional support" as the most important constraints of adopting the coping strategies. In addition to the lack of farmers' knowledge, easy accessibility to available climate forecasting is also a barrier to dairy operations mentioned by the respondents of this study. This was particularly relevant for the landless farmers who were entirely dependent on natural pastures for animal feed and were worried that along with cattle's health, the operator's health was at stake in extreme weather conditions. Therefore, it is of the utmost importance to establish institutions that will help coordinate and implement farmer-friendly measures and provide educational support to access and interpret climate-related information.

In addition, farmers who had experienced crop failures in agriculture operations were solely dependent on income from milk sales and the sale of manure from the cattle owned. This being the case with most farmers in the study region, adaptation activities became expensive, requiring farmers to make tough choices daily considering the best interest of their animals. Farmers in this study reported that feed costs had jumped 30-40%, while the milk price had not changed to keep pace with additional costs in dairy operations.

Farmers appreciated vaccination programs, but those who lost cattle did not receive support, except for insurance claims. Dairy-cooperative-associated doctors were unable to provide timely information. The required help did not reach farmers on time, resulting in conflicts with policies. Some suggested that more money was needed to buy healthy cattle

and that a lack of communication between policy changes and farmers resulted in a lack of support. Lack of support and relevant information affected farmers, particularly when rainfall fell short of expectations. The study found that fundamentally improving access to essential services can effectively protect farmers' livelihoods and enhance their resilience to climate-change-induced risks, but there were some challenges around communication and access to critical services remaining that needed to be addressed.

Despite these barriers to adaptation discussed above, there were some factors that motivated the local farmers to act upon and adopt timely coping strategies. This study found that in cases of "family interests", "milk production security", "economic interests", and "suitable feed growing condition" are reported as the most important motivating factors that could facilitate farmers' adoption of climate risk management. Since climate-change-induced risks gravely affect dairy farmers' operations, they adopt various measures to minimize the impact when encountered. Furthermore, this study found that many farmers had recently built cattle housing on their farms, which was influenced by their strong bond with the animals they raised. The idea of taking collective action at the village level did not seem to drive them to adaptation as only 10% of farmers agreed it may be workable because of income differences, but other aspects took precedence over this. Although a labor-intensive activity, many women preferred to utilize their time in other ways than to become involved in low-productive activities, especially for those who were solely managing every dairy activity. These findings provide an understanding of dairy farmers' requirements and priorities, which can help guide researchers and policymakers in their effort to develop and align comprehensive strategies to tackle the climate change impacting dairy in Karnataka, India, and other countries with a similar set of dairy systems.

4.3. Determinants of Dairy Farmers' Coping Strategies for Climate Change Adaptation

In this study, the factors influencing the adaptation strategies were examined by logistic regression analysis. Results revealed a significant positive relationship between most of the socio-economic variables and climate-induced adaptation measures of dairy farmers in the studied region (Table 4). The study results were consistent with previous findings indicating dairy farmers' socio-economic variables and other factors associated with dairy related to the location, which affected adaptation decisions and coping mechanisms. For instance, Abbas et al. [49] reported that farmers' education, farming experience, herd size, and access to extension services influenced adaptation strategies such as selling weak/deceased animals, migration, and off-farm income activities in their study of dairy farmers in Punjab, Pakistan.

Furthermore, the age of the farmer, tropical livestock unit, type of animal breed, perceived benefits of the technology, access to extension, and farmer group membership influenced the adoption of climate-smart Brachiaria grass among dairy farmers in Eastern and Western regions of Kenya [68]. Farming experience, cattle herd size, non-agricultural income, membership in an organization, number of farm assets, level of education, and climate zone were the major variables affecting farmers' adaptation strategies among cattle farmers in Benin and Turkey [34,69]. Thus, to make the policies effective aiming at climate change adaptation, it is, therefore, necessary to take into account the local farmers' understanding of how dairy farmers perceive climate change, the differences in perception, and what factors influence them to adopt various strategies and decision making in a regional setting.

5. Conclusions

India's smallholder dairy farmers are facing significant challenges from climate change, which not only threaten their dairy activities but also the well-being of their livestock, which are valuable possessions. Understanding smallholder farmers' perceptions of climate change and coping strategies could help better plan and ultimately protect their livelihood options. This study in regional South India investigated dairy farmers' perceptions of climate change risk impact on dairy, as well as adaptation strategies. First, dairy farmers

perceived significant changes in the local climate, and impacts such as drought, lengthy periods of high temperatures, pests, and diseases in cattle, and changing rainfall patterns affected dairy production in the study area. Second, farmers indicated how this has affected animal health, with exceptionally high temperatures followed by heavy rainfall for those who are dependent on natural pastures grazing their livestock, highlighted as being particularly important.

Third, in response to the changing local climate, dairy farming households are adopting multiple response measures to avoid hazards in milk production and cattle health. Among diverse adaptation strategies, buying livestock insurance, keeping low debt obligations, and growing drought-tolerant varieties of grass appeared to be the most adopted adaptation measures, while crop insurance, diversification, and increasing herd size were reported as moderately adopted strategies. Financial constraints and lack of information were regarded as the greatest barriers to dairy farm-level adaptation. Regression analysis further revealed that dairy farmers' age, education, land holdings, annual milk production, and cattle expenses influenced the types of adaptation strategies undertaken. The findings of this study also demonstrated that dairy farmers' adaptation to climate risks is largely associated with their access to essential institution-led services such as climate forecasts and extension services.

The use of a survey based on the recall method of eliciting information from farmers itself was a limitation. In addition, the study results may not generalize to other areas well as the data were confined to only two districts of southern India. Nonetheless, based on our study findings, we suggest that relevant institutions, policymakers, and stakeholders should improve farmers' access to essential services that could enhance their ability to prepare for and adapt to climate hazards in order to increase their climate resilience. Finally, the study findings highlight where future studies should focus to better understand dairy farmer perspectives, priorities, and needs, and importantly how to incorporate these into climate change adaptation.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su16052018/s1, Figure S1. Mean monthly rainfall and temperature in the study area (data presented is the average of 2000–2022). Figure S2. Annual total rainfall in the study area.

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References

1. DAHD. Basic Animal Husbandry Statistics, Department of Animal Husbandry and Dairying, Government of India. Available online: https://dahd.nic.in/schemes/programmes/animal-husbandry-statistics (accessed on 7 February 2024).
2. DAHD. Annual Report 2019–2020, Departmenrt of Animal Husbandry, Ministry of Fisheries (DAHD), Government of India. Available online: https://dahd.nic.in/sites/default/filess/Annual2019-20.pdf (accessed on 17 June 2021).
3. Jatwani, M.; Swain, S. Is small scale dairy farming dying out? An In-depth study. *Indian J. Community Med. Off. Publ. Indian Assoc. Prev. Soc. Med.* **2020**, *45*, S47.
4. Aubron, C.; Bainville, S.; Vignes, M.; Philippon, O.; Dervillé, M.; Daviron, B.; Dorin, B. Milk and dairy in India's development path: Lessons from a multi-location research. *VKCoE Dig.* **2020**, *1*, hal-03658334.
5. Kishore, A.; Birthal, P.S.; Joshi, P.K.; Shah, T.; Saini, A. Patterns and drivers of dairy development in India: Insights from analysis of household and district-level data. *Agric. Econ. Res. Rev.* **2016**, *29*, 1–14. [CrossRef]
6. Das, A.K.; Saha, C.K.; Alam, M.M. Greenhouse gas emissions from dairy farming in Bangladesh. *World* **2017**, *1*, 92–101.
7. Tiwari, S. Contribution of Dairy Farming on Livelihood: A Case Study of Madhyabindu Municipality, Nawalpur. Ph.D. Thesis, Department of Rural Development, Nagaland, India, 2023.
8. Pawar, S.S.; Sajjanar, B.; Lonkar, V.; Kurade, N.; Kadam, A.; Nirmal, A.; Brahmane, M.; Bal, S. Assessing and mitigating the impact of heat stress in poultry. *Adv. Anim. Vet. Sci* **2016**, *4*, 332–341. [CrossRef]
9. Muralikrishnan, L.; Padaria, R.N.; Choudhary, A.K.; Dass, A.; Shokralla, S.; El-Abedin, T.K.Z.; Abdelmohsen, S.A.M.; Mahmoud, E.A.; Elansary, H.O. Climate change-induced drought impacts, adaptation and mitigation measures in semi-arid pastoral and agricultural watersheds. *Sustainability* **2022**, *14*, 6. [CrossRef]
10. Ahmed, S.; Iqbal, Z.; Antahal, P.C. Impact of climate change on nomadic herders' livelihoods: Evidence from Bakarwal community in the Western Himalayas in India. *Environ. Dev.* **2023**, *48*, 100930. [CrossRef]
11. Subramaniam, S.; Mohapatra, J.K.; Sahoo, N.R.; Sahoo, A.P.; Dahiya, S.S.; Rout, M.; Biswal, J.K.; Ashok, K.S.; Mallick, S.; Ranjan, R. Foot-and-mouth disease status in India during the second decade of the twenty-first century (2011–2020). *Vet. Res. Commun.* **2022**, *46*, 1011–1022. [CrossRef]
12. Eskdale, A.; Tholth, M.; Paul, J.D.; Desphande, J.; Cole, J. Climate stress impacts on livestock health: Implications for farming livelihoods and animal disease in Karnataka, India. *CABI One Health* **2022**, *2022*. [CrossRef]
13. Nejash, A.; Kula, J. Impact of climate change on livestock health: A review. *Glob. Vet.* **2016**, *16*, 419–424.
14. World Bank Group. *Mean Projections—CMIP6, IPCC Sixth Assessment Report*; World Bank Group: Washington, DC, USA, 2022.
15. Lara, L.J.; Rostagno, M.H. Impact of heat stress on poultry production. *Animals* **2013**, *3*, 356–369. [CrossRef]
16. Cole, J.; Desphande, J. Poultry farming, climate change, and drivers of antimicrobial resistance in India. *Lancet Planet. Health* **2019**, *3*, e494–e495. [CrossRef]
17. Vinke, K.; Gabrysch, S.; Paoletti, E.; Rockström, J.; Schellnhuber, H.J. Corona and the climate: A comparison of two emergencies. *Glob. Sustain.* **2020**, *3*, e25. [CrossRef]
18. Cramer, W.; Guiot, J.; Fader, M.; Garrabou, J.; Gattuso, J.-P.; Iglesias, A.; Lange, M.A.; Lionello, P.; Llasat, M.C.; Paz, S. Climate change and interconnected risks to sustainable development in the Mediterranean. *Nat. Clim. Chang.* **2018**, *8*, 972–980. [CrossRef]
19. Barnes, A.P.; Toma, L. A typology of dairy farmer perceptions towards climate change. *Clim. Chang.* **2012**, *112*, 507–522. [CrossRef]
20. Thornton, P.; Nelson, G.; Mayberry, D.; Herrero, M. Impacts of heat stress on global cattle production during the 21st century: A modelling study. *Lancet Planet. Health* **2022**, *6*, e192–e201. [CrossRef] [PubMed]
21. Birthal, P. Climate Change and Risk Management in Indian Agriculture. *Environ. Chall.* **2022**, *8*, 100543.
22. Moran, J. *Business Management for Tropical Dairy Farmers*; CSIRO Publishing: Clayton, Australia; Landlinks Press: Collingwood, Australia, 2009.
23. Douphrate, D.I.; Hagevoort, G.R.; Nonnenmann, M.W.; Lunner Kolstrup, C.; Reynolds, S.J.; Jakob, M.; Kinsel, M. The dairy industry: A brief description of production practices, trends, and farm characteristics around the world. *J. Agromedicine* **2013**, *18*, 187–197. [CrossRef] [PubMed]
24. Patel, S.; Patel, M.; Patel, J.; Patel, A.; Gelani, R. Role of women gender in livestock sector: A review. *J. Livest. Sci.* **2016**, *7*, 92–96.
25. Birthal, P.; Taneja, V.; Thorpe, W. Smallholder livestock production in India-Opportunities and challenges. In Proceedings of the ICAR-ILRI International Workshop, New Delhi, India, 31 January–1 February 2006.
26. Sarkar, A.; Dutta, A. Challenges and opportunities of dairy sector in India vis-à-vis world: A critical review. *Explor. Anim. Med. Res.* **2020**, *10*, 9–17.
27. Rohith, G. Performance of Cattle Insurance in Select Districts of Karnataka. *J. Anim. Res.* **2019**, *9*, 431–438. [CrossRef]
28. Ahmed, M.; Suphachalasai, S. *Assessing the Costs of Climate Change and Adaptation in South Asia*; Asian Development Bank: Mandaluyong, Philippines, 2014.
29. Byrareddy, V.; Kouadio, L.; Mushtaq, S.; Kath, J.; Stone, R. Coping with drought: Lessons learned from robusta coffee growers in Vietnam. *Clim. Serv.* **2021**, *22*, 100229. [CrossRef]

30. Singh, S.; Kagweza, O.O. *The Impacts of Climate Change in Lwengo, Uganda*; Intechopen: London, UK, 2021.
31. Islam, M.A.; Warwick, N.; Koech, R.; Amin, M.N.; de Bruyn, L.L. The importance of farmers' perceptions of salinity and adaptation strategies for ensuring food security: Evidence from the coastal rice growing areas of Bangladesh. *Sci. Total Environ.* **2020**, *727*, 138674. [CrossRef]
32. Alam, G.M.; Alam, K.; Mushtaq, S. Climate change perceptions and local adaptation strategies of hazard-prone rural households in Bangladesh. *Clim. Risk Manag.* **2017**, *17*, 52–63. [CrossRef]
33. Below, T.B.; Schmid, J.C.; Sieber, S. Farmers' knowledge and perception of climatic risks and options for climate change adaptation: A case study from two Tanzanian villages. *Reg. Environ. Chang.* **2015**, *15*, 1169–1180. [CrossRef]
34. Koç, G.; Uzmay, A. Determinants of dairy farmers' likelihood of climate change adaptation in the Thrace Region of Turkey. *Environ. Dev. Sustain.* **2022**, *24*, 9907–9928. [CrossRef]
35. Montcho, M.; Padonou, E.A.; Montcho, M.; Mutua, M.N.; Sinsin, B. Perception and adaptation strategies of dairy farmers towards climate variability and change in West Africa. *Clim. Chang.* **2022**, *170*, 38. [CrossRef]
36. Sejian, V.; Bhatta, R.; Malik, K.; Madiajagan, B.; Ali, Y.; Al-Hosni, Y.; Sullivan, M.; Gaughan, J. Livestock as Sources of Greenhouse Gases and Its Significance to Climate Change. In *Greenhouse Gases*; Intechopen: London, UK, 2016; pp. 243–260.
37. Singhal, K.K.; Mohini, M.; Jha, A.K.; Gupta, P.K. Methane emission estimates from enteric fermentation in Indian livestock: Dry matter intake approach. *Curr. Sci.* **2005**, *88*, 119–127.
38. Lane, D.; Murdock, E.; Genskow, K.; Rumery Betz, C.; Chatrchyan, A. Climate change and dairy in New York and Wisconsin: Risk perceptions, vulnerability, and adaptation among farmers and advisors. *Sustainability* **2019**, *11*, 3599. [CrossRef]
39. DDMA. Chikkaballapur District Disaster Management Plan, District Disaster Management Authority (DDMA), Chikkaballapur. Available online: https://chikkaballapur.nic.in/en/departments/ddma_cbp_en/ (accessed on 29 March 2021).
40. Garg, K.K.; Anantha, K.; Nune, R.; Akuraju, V.R.; Singh, P.; Gumma, M.K.; Dixit, S.; Ragab, R. Impact of land use changes and management practices on groundwater resources in Kolar district, Southern India. *J. Hydrol. Reg. Stud.* **2020**, *31*, 100732. [CrossRef]
41. Geetha, R.S.; Murthy, P.S.S. Evolution of Dairy Cooperatives in Karnataka: A Special Focus on Women's Dairy Cooperatives. *Asian J. Agric. Ext. Econ. Sociol.* **2021**, *39*, 1–7. [CrossRef]
42. Phellas, C.N.; Bloch, A.; Seale, C. Structured methods: Interviews, questionnaires and observation. *Res. Soc. Cult.* **2011**, *3*, 23–32.
43. Islam, M.A.; de Bruyn, L.L.; Warwick, N.W.; Koech, R. Salinity-affected threshold yield loss: A signal of adaptation tipping points for salinity management of dry season rice cultivation in the coastal areas of Bangladesh. *J. Environ. Manag.* **2021**, *288*, 112413. [CrossRef] [PubMed]
44. Hasan, M.K.; Kumar, L. Perceived farm-level climatic impacts on coastal agricultural productivity in Bangladesh. *Clim. Chang.* **2020**, *161*, 617–636. [CrossRef]
45. Islam, M.A.; Lobry de Bruyn, L.; Koech, R.; Warwick, N. Contextualisation of salinisation and adaptation preferences in the coastal areas of Bangladesh: Bringing together farmers' salinity perspectives into place-based policy initiatives. *Land Degrad. Dev.* **2022**, *33*, 3882–3900. [CrossRef]
46. Wetende, E.; Olago, D.; Ogara, W. Perceptions of climate change variability and adaptation strategies on smallholder dairy farming systems: Insights from Siaya Sub-County of Western Kenya. *Environ. Dev.* **2018**, *27*, 14–25. [CrossRef]
47. Verma, J.P. *Data Analysis in Management with SPSS Software*; Springer Science & Business Media: Berlin, Germany, 2012.
48. Sertse, S.F.; Khan, N.A.; Shah, A.A.; Liu, Y.; Naqvi, S.A.A. Farm households' perceptions and adaptation strategies to climate change risks and their determinants: Evidence from Raya Azebo district, Ethiopia. *Int. J. Disaster Risk Reduct.* **2021**, *60*, 102255. [CrossRef]
49. Abbas, Q.; Han, J.; Adeel, A.; Ullah, R. Dairy Production under Climatic Risks: Perception, Perceived Impacts and Adaptations in Punjab, Pakistan. *Int. J. Environ. Res Public Health* **2019**, *16*, 4036. [CrossRef]
50. Asravor, R. Smallholder farmers' risk perceptions and risk management responses: Evidence from the semi-arid region of Ghana. *Afr. J. Econ. Manag. Stud.* **2018**, *9*, 367–387. [CrossRef]
51. Bishu, K.G.; O'Reilly, S.; Lahiff, E.; Steiner, B. Cattle farmers' perceptions of risk and risk management strategies: Evidence from Northern Ethiopia. *J. Risk Res.* **2018**, *21*, 579–598. [CrossRef]
52. Meraner, M.; Finger, R. Risk perceptions, preferences and management strategies: Evidence from a case study using German livestock farmers. *J. Risk Res.* **2019**, *22*, 110–135. [CrossRef]
53. Bett, B.; Kiunga, P.; Gachohi, J.; Sindato, C.; Mbotha, D.; Robinson, T.; Lindahl, J.; Grace, D. Effects of climate change on the occurrence and distribution of livestock diseases. *Prev. Vet. Med.* **2017**, *137*, 119–129. [CrossRef] [PubMed]
54. Diniso, Y.S.; Zhou, L.; Jaja, I.F. Dairy farmers' knowledge and perception of climate change in the Eastern Cape province, South Africa. *Int. J. Clim. Chang. Strateg. Manag.* **2022**, *14*, 168–179. [CrossRef]
55. Abdelatty, A.M.; Iwaniuk, M.E.; Potts, S.B.; Gad, A. Influence of maternal nutrition and heat stress on bovine oocyte and embryo development. *Int. J. Vet. Sci. Med.* **2018**, *6*, S1–S5. [CrossRef] [PubMed]
56. Radha, M.; Singh, D.S.K.; Beillard, M.J. *Dairy and Products Annual—2022*; USDA: Washington, DC, USA, 2022.
57. KSNDMC. Drought Management Strategies. In Proceedings of the National Conference, Melbourne, Australia, 8–9 March 2019.
58. Rawat, S.; Ganapathy, A.; Agarwal, A. Drought characterization over Indian sub-continent using GRACE-based indices. *Sci. Rep.* **2022**, *12*, 15432. [CrossRef] [PubMed]

59. Herrero, M.; Wirsenius, S.; Henderson, B.; Rigolot, C.; Thornton, P.; Havlík, P.; De Boer, I.; Gerber, P.J. Livestock and the environment: What have we learned in the past decade? *Annu. Rev. Environ. Resour.* **2015**, *40*, 177–202. [CrossRef]
60. Kumar, S.; Raju, B.; Ramarao, C.; Ramilan, T. Sensitivity of livestock production to climatic variability under Indian drylands and future perspective. *Curr. Agric. Res. J.* **2015**, *3*, 142–149. [CrossRef]
61. Rivera-Ferre, M.G.; López-i-Gelats, F.; Howden, M.; Smith, P.; Morton, J.F.; Herrero, M. Re-framing the climate change debate in the livestock sector: Mitigation and adaptation options. *WIREs Clim. Change* **2016**, *7*, 869–892. [CrossRef]
62. Lien, G.D.; Flaten, O.; Ebbesvik, M.; Koesling, M.; Valle, P.S. Risk and risk management in organic and conventional dairy farming: Empirical results from Norway. In Proceedings of the 14th Congress of the International Farm Management Association, Perth, Australia, 10–15 August 2003.
63. Akcaoz, H.; Kizilay, H.; Ozcatalbas, O. Risk management strategies in dairy farming: A case study in Turkey. *Int. J. Anim. Vet. Adv.* **2009**, *8*, 949–958.
64. Godde, C.M.; Mason-D'Croz, D.; Mayberry, D.E.; Thornton, P.K.; Herrero, M. Impacts of climate change on the livestock food supply chain; a review of the evidence. *Glob. Food Secur.* **2021**, *28*, 100488. [CrossRef]
65. Aryal, J.P.; Rahut, D.B.; Maharjan, S.; Erenstein, O. Factors Affecting the Adoption of Multiple Climate-Smart Agricultural Practices in the Indo-Gangetic Plains of India. In *Natural Resources Forum*; Blackwell Publishing Ltd.: Oxford, UK, 2018; pp. 141–158.
66. Maindi, N.; Osuga, I.; Gicheha, M. Advancing climate smart agriculture: Adoption potential of multiple on-farm dairy production strategies among farmers in Murang'a County, Kenya. *Livest. Res. Rural. Dev.* **2020**, *32*, 63.
67. Nouala, F.; Akinbamijo, O.; Adewumi, A.; Hoffman, E.; Muetzel, S.; Becker, K. The influence of Moringa oleifera leaves as substitute to conventional concentrate on the in vitro gas production and digestibility of groundnut hay. *Livest. Res. Rural Dev.* **2006**, *18*, 121.
68. Maina, K.W.; Ritho, C.; Lukuyu, B.A.; Rao, E. Socio-economic determinants and impact of adopting climate-smart Brachiaria grass among dairy farmers in Eastern and Western regions of Kenya. *Heliyon* **2020**, *6*, e04335. [CrossRef] [PubMed]
69. Idrissou, Y.; Assani, A.S.; Baco, M.N.; Yabi, A.J.; Traoré, I.A. Adaptation strategies of cattle farmers in the dry and sub-humid tropical zones of Benin in the context of climate change. *Heliyon* **2020**, *6*, e04373. [CrossRef]