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Climate change impacts on livestock for sustainable production: A Ricardian approach

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Abstract

The present study examined the impact of changing climate on livestock production and adaptation strategies to climate change focusing the South of the state 'Gujarat'. The samples of over 1200 livestock farmers from South Gujarat region were considered for the study and the farm-level data on net-revenue and its determinants were collected. The economic impact of changing climate on livestock was determined using the Ricardian approach. This approach regresses net farm revenue over a variety of climate, socioeconomic, and adaptive variables in order to identify the factors that drive variability in net farm revenue. The study found that a marginal increase in rainfall boosted net revenue per farm in South Gujarat by ₹142.75 significantly, but a marginal increase in temperature lowered net revenue by ₹9254.29 significantly. The households' adaptation methods to climate change, such as changes in animal breed, fodder and feed management, handling diseases, supplement feed, crop and livestock interactions, and animal shed alteration, were positively related to net revenue. A 2.5°C increase in temperature led to a ₹292.95 crore drop in net farm revenues across all farms, according to the uniform climate scenario. These findings demonstrated the urgent necessity for technological development of adaption packages for dairy production in the coming years. As a result, there is a need for investment in R&D so that researchers can create a farming package for cattle farmers that will allow them to remain in dairy by 2050 and 2100.

Keywords: Adaptation, determinants, climate change, Ricardian, socio economic

Introduction

The Indian livestock sector plays a major role in the economy of India, which is currently being impacted by the negative effects of climate change. Houghton *et al*. in 2001 [4] revealed how air temperature, humidity, wind speed, and various other climate variables influence the performance of animals, particularly growth, milk production, wool production and reproduction. As stated by Nidhishree *et al*., 2024 [19], the impact of the changing climate on animal productivity has been classified into four as follows: a) readily accessible feed, b) pasture and forage production. c) Health and reproduction, and d) Disease and its transmission. Climate change has four potential effects on animal health namely, heat-related diseases and stress, extreme weather occurrences, adapting animal production systems to new circumstances and emergence or re-emergence of diseases, especially diseases that are vector borne which relies heavily on environmental and climatic conditions. In India, livestock production is a key aspect of mixed farming systems. In addition, while sensitivity to climate change has received less attention in India, experimental research has been undertaken on the impact of season and climate on livestock output, performance, and other physiological characteristics. Some researchers found that the milk output of crossbred cows in India (such as Karan Fries, Karan Swiss, and various Holstein and Jersey crosses) is inversely associated with the temperature-humidity index. The projected annual loss due to heat stress among various animals in India was 1.8 million tons, accounting for approximately 2% of the country's total milk supply accounting more than Rs 2,661 crore. In India, According to Tailor and Nagda (2005) [28], heat stress has a negative impact on buffalo reproduction, despite the fact that buffaloes are morphologically and anatomically well adapted to hot and humid climates. Upadhya *et al.* (2007) [29] reported heat stress on Indian livestock. According to Maurya (2010) [10], the length of service period and dry period of all livestock animals increased during the drought. The disease outbreak was found to be associated with massive animal movement, which is influenced by climatic conditions (Sharma *et al*. 1991) [26]. Singh *et al*. (1996) [27] found that higher frequency of clinical mastitis in farm animals during hot and humid weather due to increased heat stress and greater fly population linked with hot-humid conditions. In addition, the hot-humid weather conditions were found to aggravate the infestation of cattle ticks like: *Rhipicephalus microplus*, *Haemaphysalis bispinosa* and *Hyalomma anatolicum* (Basu and Bandhyopadhyay, 2004;

Kumar *et al*., 2004) [1, 7]. Keeping these trends in mind, a study on climate change impacts on livestock as perceived by farmers and adaptation strategies to sustain livestock production was conducted for South Gujarat region.

Materials and Methods

Farm-level data on net-revenue and its determinants were collected from 1200 randomly selected livestock farmers spread all over the South Gujarat region comprising seven districts namely, Navsari, Valsad, Surat, Tapi, Narmada, Bharuch and The Dangs. From the districts Navsari and Valsad, 6 talukas, 12 villages and 180 farmers have been selected, individually. From Surat, 9 talukas, 18 villages and 270 farmers has been selected. From Tapi and Narmada districts, 5 talukas, 10 villages and 150 farmers have been selected, respectively. From the district Bharuch, 8 talukas, 16 villages and 240 households have been selected. From the hilly district 'The Dangs' 1 talukas, 2 villages and 30 households have been selected for the study. Out of seven districts, 40 taluka sand 80 villages have been selected. The data were collected with the use of a structured questionnaire administered to the livestock farmers. In respect of climate variables, January to December monthly means for precipitation and average temperature from year1980 to 2020 was obtained from, Agricultural Meteorology Department, NAU, Navsari.

Ricardian Model Specification for South Gujarat

This study applied the Ricardian approach to measure the effect of climate variables in South Gujarat agriculture. Specifically, by regressing land value (rents) on climate, household covariates and other climatic control variables, it was possible to measure the marginal contribution of each variable to land rents as capitalized in land value. A number of variables namely, climatic, soil, socio-economic and weather were examined to determine the intrinsic effect of climate on farmland, as in other Ricardian studies applied elsewhere (Mendelsohn and Dinar, 2003; Polsky, 2004) [11, 20].

However, in some specific areas, such as mainly developing countries, where land prices (rents) are difficult to calculate due to the lack of a well-functioning land market, Dinar *et al*. (1998) [2] and Mendelssohn (2009) [15] recommend using net income per farm (NRf). Therefore, this policy is often expressed by the livestock income equation (Mendelsohn, 2009) [15]:

$$LV = \sum P_i\, Q_i\,(X, F, H, Z, G) - \sum P_x\, X \qquad (1)$$

Where, *LV* is the value of land, *Pi* is the market price of crop/milk *i*, *X* is a vector of purchased inputs (except land), *F* is a vector of climate variables, *H* is rainy days, *Z* is a vector of socio economic variables, *G* is a vector of adaptation variables and *Px* is a vector of input prices (Mendelsohn *et al*., 1994) [17]. It is assumed that the farmer chose *X* so as to maximize net revenue per farm given the characteristics of farm and market prices. Depending on availability of data, the dependent variable can either be the annual net revenues. The former definition was employed for this study, as data on land value (rent) are not available due to the absence of the functioning land market in India.

The Ricardian model was developed to explain the variation in land value per hectare of crop-land/ livestock over climate zones (Mendelsohn *et al*., 1994) [17]. In several studies, the land value per hectare of crop-land/livestock has been found to be sensitive to seasonal precipitation and temperature (Seo*et al*., 2008) [24]. Similar results have also been found for livestock net revenue (Kurukulasuirya *et al.*, 2006 [8]; Seo and Mendelsohn, 2008a; 2008b) [23,25]. Following preceding research works done by Molua (2006) [18] and Mendelsohn *et al*. (2007) [12], the following Ricardian model relies on a quadratic formulation of climate:

$$NR / ha = \beta_0 + \beta_1 F + \beta_2 F^2 + \beta_3 Z + \beta_4 G + \mu \ \ldots\ldots(2)$$

Where, *NR* /*farm* represents net revenue per farm, *F* is avector of climate variables, *Z* is a set of socio-economic characteristics, *G* is a set of adaptation variables and is the error-term. Both linear and quadratic terms for temperature and precipitation have been introduced. The expected marginal impact of a single climate variable on the farm net revenue evaluated at the mean is given by Equation (3):

$$E\,[dNR/ha\,/df_i] = b_{1,i} + 2 * b_{2,i} * E[f_i] \ldots\ldots\ldots(3)$$

The signs of linear terms indicate the uni-directional impact of independent variables on dependent variable, the quadratic term reflects the non-linear shape of livestock net revenue of the climate response function. When the quadratic term is positive, the net revenue function of livestock is U-shaped and when the quadratic term is negative, the function is hill-shaped. The climate change studies revealed that livestock consistently exhibit a hill-shaped relationship with annual temperature, although the maximum of that hill varies with the breed. The marginal impact of different variables was estimated for the model. The advantage of this experiential approach is that the method includes both direct effect of climate change on animal productivity and the adaptation response by livestock farmers to local climate.

Results and Discussions

The study looked at climate scenarios existing in south Gujarat region to see how cattle output adapt to climate change. In the study, we employed the Ricardian approach to evaluate the economic impact of climate change on livestock in South Gujarat. The Ricardian technique regresses net farm revenue against numerous climate, socioeconomic, and adaptation variables to identify the drivers causing inconsistency in net farm revenue. Three models were constructed for the regression analysis. We used the first model to estimate the response of net farm revenue to only climate factors. In the second model, socioeconomic variables were integrated into the first model, and in the third model, household adaptation measures were added to the second model.

The Ricardian model specification for the region of South Gujarat assumes a quadratic relationship between net farm revenues and climatic variables in order to reflect the nonlinear interaction between net farm revenues and climatic variables, which is consistent with Ricardian studies applied elsewhere (Mendelsohn *et al*., 1994, 1996; Kavikumar and Parikh, 1998; Sanghi, 1998; Sanghi *et al*., 1998; Mendelsohn and Dinar, 1999, 2003; Mano and Nhemachena, 2007) [17, 16, 6, 22, 21, 13, 11, 9]. The quadratic term represents the response function of net revenue to climate variables.

A positive quadratic term suggests that the net farm revenue function is U-shaped, whereas a negative quadratic term indicates that it is hill-shaped (Mendelsohn and Dinar, 2003) [11]. The anticipated association between net revenue and temperature is hill-shaped, according to previous agronomic research and cross-sectional analysis (Mendelsohn and Dinar, 2003) [11]. This expectation indicates a negative association, meaning that any further increase in temperature would have a negative impact on net farm revenues and thus on agriculture. Moreover, the computation assumes a linear relationship between net farm revenues and other variables notably, socioeconomic and adaptations, which are consistent with the other Ricardian research stated earlier.

Relationship between Net Revenue and Climate Variables (Model 1)

Table 1 illustrates the Model 1 results, which show how net farm revenues respond to climatic variables. The co-efficient of determination (R^2) of 0.019 suggests that climate variables can explain only 1.9% of the fluctuations in net revenue. The adjusted R^2 value (0.08180) was less than the R-squared value, but not by much, indicating that the model does not have a major overfitting problem. The F-statistic (F = 2/17***) confirmed that the whole model is significant at 1%. The linear terms for winter temperature, summer precipitation, and winter precipitation variables were all positive and significant. The data underline the fact that bulk of South Gujarat's livestock production happens during the winter season. The findings also revealed that during the wet season, rainfall had a negative connection with net revenue. The linear term for rainy and summer mean temperatures was also negative, indicating a negative impact on net farm revenue. The quadratic factors for rainy and summer season rainfall show a U-shaped connection with farm net revenue, showing that more rainfall during rainy and summer seasons may be related with higher animal productivity.

The squared mean temperature for summer and winter, as well as the squared mean precipitation for summer, revealed an inverse quadratic association between net revenues and climate factors. The results obtained suggest that increasing summer temperature and rainfall would enhance farm net revenue, with diminishing marginal benefits until reaching a certain turning point, after which additional increases in these climate variables begin to have a negative impact on farm net revenue. Negative quadratic coefficients reflect a hill-shaped relationship between net revenue and climate variables.

Table 1: Model 1- Response of Farm Net Revenue to Climate Variables only

Variable	Model 1			
	Coefficient	**Std. Error**	**t**	**P>t**
Constant	9398769	6465069	1.45	0.146
Rainy temperature	-4199628.00	2060938.00	-2.04	0.042
Winter temperature	4331353.00	2148762.00	2.02	0.044
Summer temperature	-136380.20	114755.90	-1.19	0.235
Rainy precipitation	-753.92	1259.00	-0.6	0.549
Winter precipitation	16744.70	22799.05	0.73	0.463
Summer precipitation	14333.62	23625.70	0.61	0.544
Rainy temperature squired	63222.91	27736.82	2.28	0.023
Winter temperature squired	-74334.78	32816.40	-2.27	0.024
Summer temperature squired	1572.27	1330.90	1.18	0.238
Rainy precipitation squired	0.28	0.52	0.53	0.594
Winter precipitation squired	-204.39	320.74	-0.64	0.524
Summer precipitation squired	156.47	550.18	0.28	0.776
Rainy days	-215.99	312.41	-0.69	0.489
R-squared	0.019			
Adj R-squared	0.018			
F	2.17***			

Note: ***significant at 1%

Relationship between Net Revenue, Climate and Socio-economic Variables (Model 2)

Table 2 exhibits Model 2, which considers the response of net farm revenue to climate and socioeconomic variables. The inclusion of socioeconomic characteristics helps to capture spatial heterogeneity among the sampled households. These variables had a positive effect on net farm revenues, demonstrating the significance of regional diversity across the research region.

The socioeconomic variables included in model 2 were highly significant in explaining variation, particularly in net revenues among households. This highlights the relevance of controlling the socioeconomic variables: it emphasizes the regional differences in impacts on net livestock revenues across different study districts.

The socio-economic variables introduced could improve the model as the value of R^2 (0.188) and F- statistics (F = 2.36***), compared to first model, were improved and age of household and herd size variables were significant at $p < 0.05$ probability level.

Relationship between Farm Net Revenue, Climate Variables, socio-economic and adaptation Variables (Model 3)

Model 3 (Table 3) displays the standard Ricardian model's results for farm net revenue regression with adaption factors, which are coupled with the first two models. The insertion of these variables increased the co-efficient of determination (R^2) from 18.8 percent to 30.5 percent. The corrected R^2 value of 0.284 indicated that the model was not overfitted. The F-statistics (13.10; $p < 0.01$) suggested a substantial and well-behaved model. The findings also supported a quadratic link between net farm revenue and climatic variables.

The study found a significant nonlinear association between rainy season temperature and net revenue ($p < 0.05$). This means that lower temperatures during the wet season affect farmers' net revenue. Summer rainfall intensity has the potential to boost milk production, implying that more rainfall during the summer season has a positive relationship with increased net revenue since farmers will benefit from lower heat stress and increased milk production. The linear relationship discovered during the winter rainfall signifies that the winter season rainfall are beneficial to farm net revenue, with diminishing marginal benefits up to a maximum turning point, shortly after which further rise in these climate variables begin to have a negative impact on farm net revenue. The quadratic term for winter season rainfall had a hill-shaped association with net revenue and was not statistically significant. This means that additional increases in rainfall throughout the rainy season will reduce productivity. The winter temperature correlates positively with net revenue. The U-shaped association between winter season temperature and net revenue was statistically significant ($p < 0.05$), suggesting that it may benefit milk production. Rainy days have a beneficial relationship, but it is not significant. The temperature throughout the wet and summer seasons was negatively associated with net revenue, although this relationship was not statistically significant.

The squared term for winter season temperature showed a hill-shaped connection, indicating that increasing rainfall in these seasons reduces milk output and was statistically insignificant. The quadratic summer rainfall had a positive link with net revenue that was not statistically significant.

Most of the household variables had a significant effect on net revenue per animal. Among the socioeconomic variables, the age of the household head had a significant negative association with net farm revenue. This suggested that younger farmers may use better adaption strategies than older farmers. This conclusion is consistent with the findings of Seo and Mendelsohn (2007) [25],Mendelsohn (2009) [15], and Hassan and Nhemachena (2008_a, 2008_b) [3, 4].

Larger herds resulted in higher net farm revenue ($p < 0.05$). This shows that the herds in this study were primarily dependent and productive. The education level of the household head had a positive relationship with net revenue however was not statistically significant ($p < 0.05$). This means that higher levels of education typically result in higher net revenue. As a result, an educated household head is capable of adopting new and improved technologies, as well as better optimizing farming techniques. The land holding and veterinary costs were favorably associated with greater net revenue, although the relationship was not statistically significant. Farmers that were knowledgeable about climate and weather change had a higher net farm revenue.

Households' adaptation to climate change, including changes in animal bread, feed and fodder management, disease management, supplementary feed, crop and livestock interactions, and shed modification, had a positive and statistically significant impact on net revenue ($p < 0.05$). This means that these adaption methods have a considerable effect on raising net revenue. The size of the stake exhibited a linear connection with net revenue, which was not statistically significant. This suggests that large farms produce more per farm than small farms. One possible explanation for this observation is that large farms require more fixed resources than small ones.

The outcomes revealed that the seasonal climatic factors had distinct effects on the three models. In some seasons, both linear and squared terms were significant, showing that climate influenced the agricultural net profits in a nonlinear way. The influence of quadratic seasonal climate variables on net farm profits was clearly not identified by examining the coefficients, as both the linear and squared terms play a role (Kurukulasuriya *et al*., 2006) [8]. The sign of the quadratic term determines whether the relationship with net farm revenue is hill-shaped or U-shaped, depending on whether it is positive or negative. To quantify the influence of seasonal climatic variables on net revenue, we would need to calculate the marginal impact of each climate.

Marginal Impacts of Climate Variables on Net Revenue

To better explain the climate coefficients, the study evaluated the marginal impacts of a change in each climate variable (temperature and precipitation) using Standard Ricardian model results (Table 4). These values were greatly dependent on the regression equation employed and the climate being analyzed.

The marginal impact study was carried out to determine the effect of small temperature and rainfall fluctuations on farmers' net revenue. The study found that a marginal increase in rainfall boosted net revenue per farm in South Gujarat by ₹142.75, but a marginal increase in temperature lowered net revenue by ₹9254.29.

This conclusion was consistent with the findings of several research in the literature (Mendelsohn *et al*., 1994 [17]; Kurukulasuriya *et al*., 2006 [8]; Kabubo and Karanja, 2007 [5]; Mano and Nhemachena, 2007) [9], which indicated that rising temperatures were deleterious to crop and livestock output. The rainy season rainfall had a beneficial impact on net revenue in the research area. Higher rainfall during the wet season improved net revenue for farms. During the rainy season, a 1mm increase in rainfall increased net revenue by ₹142.75 for all farms.

Table 2: Model 2 - Response of Farm Net Revenue to Climate and socio-economic Variables

Variable	Model 2			
	Coefficient	**Std. Error**	**T**	**P>t**
Constant	8602461.00	8279587.00	1.04	0.30
Rainy temperature	-4235208.00	1889283.00	-2.24	0.03
Winter temperature	4422463.00	1980726.00	2.23	0.03
Summer temperature	-128931.30	108136.60	-1.19	0.23
Rainy precipitation	-807.13	1189.21	-0.68	0.50
Winter precipitation	17280.94	21359.20	0.81	0.42
Summer precipitation	10079.47	21101.13	0.48	0.63
Rainy temperature squared	64333.62	25887.20	2.49	0.01
Winter temperature squared	-76765.46	30786.04	-2.49	0.01
Summer temperature squared	1478.01	1280.83	1.15	0.25
Rainy precipitation squared	0.31	0.49	0.65	0.52
Winter precipitation squared	-221.26	299.62	-0.74	0.46
Summer precipitation squared	255.99	522.59	0.49	0.62
Rainy days	73.811	269.585	0.270	0.784
Age of Household-head	-737.47	261.83	-2.82	0.01
Education status of household-head	589.16	600.57	0.98	0.33
Herd size	8747.59	2795.19	3.13	0.00
Land holding	160.92	2721.11	0.06	0.95
Area under green fodder	-5.43	45.00	-0.12	0.90
Vetnary cost	4.06	5.21	0.78	0.44
R-squared	0.18			
Adj R-squared	0.17			
F	14.47***			

Note: ***significant at 1%.

Table 3: Model 3 - Response of Farm Net Revenue to Climate, Socio-economic and adaptationVariables

Variable	Model 3			
	Coefficient	**Std. Error**	T	P>t
Constant	5319164.00	5426392.00	0.98	0.33
Rainy temperature	-3596971.00	1787502.00	-2.01	0.04
Winter temperature	3965987.00	1897557.00	2.09	0.04
Summer temperature	-117979.20	105813.30	-1.11	0.27
Rainy precipitation	-1238.20	1199.18	-1.03	0.30
Winter precipitation	23679.25	21446.59	1.10	0.27
Summer precipitation	8309.62	19196.40	0.43	0.67
Rainy temperature squared	52528.65	24535.66	2.14	0.03
Winter temperature squared	-67093.14	29585.10	-2.27	0.02
Summer temperature squared	1305.77	1261.00	1.04	0.30
Rainy precipitation squared	0.49	0.49	0.99	0.32
Winter precipitation squared	-314.69	301.39	-1.04	0.30
Summer precipitation squared	457.38	522.64	0.88	0.38
Rainy days	96.60	251.36	0.38	0.70
Age of Household-head	-653.30	247.00	-2.64	0.01
Education status of household-head	428.27	610.44	0.70	0.48
Herd size	7718.91	2969.62	2.60	0.01
Land holding	598.42	2716.60	0.22	0.83
Area under green fodder	-8.73	55.45	-0.16	0.88
Vetnary cost	3.96	5.34	0.74	0.46
Access to weather information	2549.17	2524.71	1.01	0.31
Change in herd size	1963.21	3547.17	0.55	0.58
Change in bread	19421.76	9459.05	2.05	0.04
Feed and fodder management	14061.44	2612.06	5.38	0.00
Disease management	2353.90	985.51	2.39	0.02
Supplementary feed	25487.29	10535.05	2.42	0.02
Crop and livestock interaction	32808.74	13691.52	2.40	0.02
Change in animal shed structure	19986.39	8310.65	2.40	0.02
Heat stress management	5241.46	4861.32	1.08	0.28
R-squared	0.305			
Adj R-squared	0.2849			
F	12.60***			

Note: ***significant at 1%.

Table 4: Marginal impact of climate on farmers' net revenues in South Gujarat

Variable	Net Revenue (₹ per ha)
Mean annual temperature	-9254.29
Mean annual rainfall	142.75

Source: Computed from field data

Uniform Climate Scenarios

The study additionally assessed the effects of future climate change scenarios on milk production in the study region. It investigated the sensitivity of net farm revenues to adverse temperature and rainfall fluctuations. The estimated models were used to simulate variations in net farm revenues caused by climate variables. The scenarios evaluated included temperature increases of 2.5 °C to 5 °C, as well as rainfall decreases of 7 percent to 14 percent. The scenarios were based on those developed by Kurukulasuriya *et al*. (2006) [8], who calculated the effects of climate change on African agriculture. Mano and Nhemachena (2007) [9] estimated this influence on Zimbabwean agriculture. Citing Kurukulasuriya *et al.* (2006) [8], we used the predicted regression coefficients (Table 5) to determine how climate change affects net revenue in each study district across the State. We then multiplied the change in net revenue per farm by the number of animals in each research district to calculate the overall impact for each district. This figure was then added together across all of the districts to calculate the total impact for South Gujarat.

Table 5: Projected impacts on Net Farm Revenue from Uniform Climate Scenarios

Climate change scenarios	All farms	% change
+2.5 °C increase in temperature		
Δ Net revenue (₹ per farm)	-2113.15	22.83
Δ Total net revenue (₹ crore)	-292.95	
+5 °C increase in temperature		
Δ Net revenue (₹ per farm)	-3330.01	35.98
Δ Total net revenue ((₹ crore)	-461.64	
7% reduction in rainfall		
Δ Net revenue (₹ per farm)	-46.55	32.61
Δ Total net revenue ((₹ crore)	-6.45	
14% reduction in rainfall		
Δ Net revenue (₹ per farm)	-72.93	51.09
Δ Total net revenue (₹ crore)	10.11	

Note: Using coefficients in Table 3 and uniform climate changes

These 'uniform' scenarios presume that there is only one facet of climate change, namely that the shift is uniform throughout the region. A 2.5 °C increase in temperature would reduce net farm revenues by ₹ 292.95 crore across all farms. The analysis found that a 5 °C increase in temperature would result in a net revenue drop of ₹ 461.64 crore for all farms. A 7% and 14% decrease in precipitation would reduce net farm revenue by ₹ 6.45 crore and ₹ 10.11 crore, respectively, across the region.

The study also looked at a collection of climate change scenarios from the Special Report on Emissions Scenarios (SRES). We selected the A2 scenarios from the Third Assessment Report. The SRES scenarios were designed to investigate future global environmental trends, with a focus on greenhouse gas production and aerosol precursor emissions. After testing a variety of scenarios, the study employed the models CGM2, HadCM3, and PCM.

The forecasted climate variables (temperature and precipitation) were utilised to evaluate the expected marginal effects of climate change on net farm profits, using Ricardian model estimations. Tables 6 and 7 indicate the average temperature and rainfall expected by the three models for 2050 and 2100. The CGM2 and HadCM3 models expected a 4°C rise in temperature by 2100, whereas the PCM predicted a 2°C increase. In terms of rainfall, the CGM2 model anticipated an average decrease of 10%, the HadCM3 model indicated an average loss of 17%, and the PCM model predicted an average decrease of 21% by 2100.But, despite predictions made on mean rainfall (either increase or decrease), depending on the situation, it actually varied significantly.

Table 7 shows the projected impacts from the SRES scenarios. The scenarios suggest that future temperature increase will have a detrimental impact on farm net profits, particularly for farms in the region. Further temperature increase would be damaging to the region's agricultural and livestock production by 2050 and 2100, correspondingly. According to the CGM2, Had CM3, and PCM scenarios, net farm revenues will decline by ₹410.23 crore, ₹403.60 crore, and ₹152.33 crore across all farms by 2100.

Table 6: Climate Predictions of SRES Models by 2050 and 2100

Model		Current	2050	2100
CGM2	Temperature	26.13	29.60	30.13
HadCM3		26.13	30.01	30.13
PCM		26.13	28.67	28.13
CGM2	Precipitation	133.86	132.76	123.86
HadCM3		133.86	123.64	116.86
PCM		133.86	123.08	112.86

Temperature in ^{0}C and precipitation (mean) in mm

Table 7: Projected Impacts on Net Farm Revenue from SRES Climate Scenarios

Scenario	CGM2	CGM2	HadCM3	HadCM3	PCM	PCM
	2050	2100	2050	2100	2050	2100
All farms						
ΔNet revenue (₹ per farm)	2562.80	2959.18	2186.03	2911.34	3187.82	1098.84
ΔTotal net revenue (₹ crore)	355.28	410.23	303.05	403.60	441.93	152.33

Note: Using coefficients in Table 5 and SRES climate scenarios

Further decline in precipitation and a rise in temperature in the region expected that dairy farming would become unviable, and if dairy farmers are to continue farming, the government and private institutions must desperately develop ways to assist farmers in adapting to these future unfavorable climatic conditions.

These findings also demonstrated an urgent need for technological development of adaption packages that are not required under current farming settings but will be beneficial to dairy output in the future. As a result, more research and development funding is required. The researchers can also contribute by developing a farming package for farmers that will allow them to stay in dairy by the years 2050 and 2100, such as one that includes technologies and extension services.

Conclusion
In accordance with the findings of the study, climatic changes (in the form of severe droughts, floods, extreme rainfall, and landslides) pose a substantial threat to development initiatives and Millennium Development Goals which aimed at reducing poverty. Climate-induced disasters have a direct impact on farmers' livelihoods since they rely on agriculture and animal husbandry, all of the respondents agreed that a drop in animal-agricultural production weakened the local economy. Because livestock is and will continue to play a significant part in the rural economy, it is critical to find appropriate solutions to mitigate the negative effects of climate change on livestock output.

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