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Climate change effect on dairy in north eastern hills of India

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ABSTRACT

The experimental evidences on the effect of climate change on dairy animals are sufficient but primarily restricted to developed production system of plain land. Hence, this paper assessed the effect of climate change on dairy in the north eastern Himalayan states of India. A random sample of 240 farm households from Asom and Nagaland were interviewed and a case study was conducted in Mizoram. It was found that the livestock compositions have changed and the number of animal per household decreased during drought. The availability of fodder and pasture dwindled which increased the time spent on collection of fodder; and the milk yield of the dairy cows declined. Just & Pope stochastic production function revealed that the increase in maximum temperature is expected to increase the variability in milk yield in the north eastern hill states as the heat stress reduces the milk yield of dairy animals. Hence, location specific scientific housing and feed management may be adopted to reduce the negative effect of climate change on dairy animals.

Key words: Climate, Just & Pope Model, Milk, Perception

Climate change is likely to have impact on agriculture all over the world and the effect may become substantial in the hills due to their fragile ecosystems and poor adaptation capacity which makes the region comparatively more vulnerable. It has also the potential to affect the livestock and the poor livestock keepers as well as the ecosystem goods and services they depend upon. Livestock yield is a function of heat stress and fodder. Experiments have proved that beyond the thermo-neutral zone, the milk yield of dairy animals is negatively affected (Zeng and Chen 1980, Calil 2012). Low rainfall and higher temperature during drought affects the forage production and deteriorates the quality of pasture which ultimately influence the yield of animals (Li *et al.* 2010, Sejian *et al.* 2013). Any kind of environmental stress along with fodder shortage reduces the body weight, average daily gain and body condition of livestock (Upadhyay 2008, Misra and Mandal 2010). Increase in the temperature above 25°C and increase in average thermal humidity index (THI) result into heat stress, and change in feed intake and other physiological parameters. All these lead to reduced milk production (Lal *et al.* 1987, Mandal *et al.* 2002, Tailor and Nagda 2005). Upadhyay (2008) predicted loss of 1.6 mt by 2020 and 15 mt by 2050 in India due to increase in temperature. Sirohi and Sirohi (2010) reported 9.65 mt losses in milk production in India in case of increase in mean THI by 2 units. The effect will be higher for crossbred (CB) and exotic cows than local cows as they are more heat tolerant. The reproduction especially conception rates of dairy cows may drop in summer as heat stressed cows often express oestrus poorly due to reduced oestradiol secretion. The impacts also include change in the mix of livestock, and increased disease occurrences. During droughts, lack of water increases their vulnerability to diseases. The loss in milk and meat production due to Foot and Mouth (FMD) disease was around 40–45 billion per annum during 1990–2001 (GoI 2002). The production loss from clinical and sub-clinical mastitis was calculated to be ₹ 28 million at 1994 prices (Sirohi and Sirohi 2001). The souring or curdling of milk will be higher if the temperature continues to increase. The migration time, duration and distance travelled are also changing due to increase in temperature in the Himalayan region in case of transhumance pastoralism (Maiti *et al.* 2014, Feroze *et al.* 2015). Most of the experimental studies estimate the effect of climatic factors on yield of livestock but the interactive effects may be more extensive.

Livestock are considered to be important component in mix farming for increasing the resilience of vulnerable poor farmers who are subject to climatic shocks. The sector has the potential to have a role in both mitigation and adaptation through diversification. But the question is how the dairy sector will perform with changing climate. Hence, the

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present paper assessed the effect of climate change on dairy in the north eastern (NE) Himalayan states of India through farmers' perception and estimation of empirical econometric model.

MATERIALS AND METHODS

The study was conducted in NE Himalayan region of India which comprised seven hill states i.e. Arunachal Pradesh, Meghalaya, Mizoram, Manipur, Nagaland, Sikkim, Tripura and two districts i.e., NC Hills and Karbi Anglong of Asom. The region is dominated by hilly terrain and valley in between. Agriculture is the primary occupation of the people and livestock is an integral part of the farming system.

Household survey was conducted at Karbi-Anglong district (5°33'N to 26°35'N latitude and 92°10'E to 93°50'E longitude) of Asom and Dimapur district (25°60'N to 27°40'N latitude and 93°20'E to 95°15'E longitude) of Nagaland. Primary data were collected from a sample of 240 farmers from two selected states during 2014 using structured pre-tested schedule. To complement the survey a case study was conducted through focus group discussion (FGD) at Siphir village of Mizoram. The village (Latitude 23°48'28''N and Longitude 92°44'35''E) is situated in Tlangnuam block of Aizawl district. In-depth discussion was held with 20 dairy farmers (13 male and 7 female) of the village. Ethnographic mode of interviewing was adopted in which open ended questions were asked and emphasis was given to learn from their experiences.

Gridded rainfall (0.5° × 0.5°) and temperature (1° × 1°) data were retrieved from India Meteorological Department (IMD) data for the period of 1988–2007. Secondary data for milk yield of seven NE states were collected from Department of Animal Husbandry and Dairying website (www.dahd.nic.in).

Empirical Model (*Just and Pope Model*): The stochastic production function as suggested by Just and Pope (1978) is as below:

$$y = f(X; \beta) + \omega h\ (X; \delta)^{0.5}$$

where y is the milk yield and X is a vector of explanatory variables; ω is the stochastic term with mean zero and variance 1; β and δ are the production function parameters to be estimated using historical data.

The error term $\omega h\ (X; \delta)^{0.5}$ in equation (i) shows that Just-Pope model has hetroskedastic error terms. From equation (i), the expected yield of milk is given by $E(y) = f(X; \beta)$ and variability is given by $V(y) = h(X; \beta)$. The derivatives of the variance function $h(X; \beta)$ w.r.t. the input variables, viz. precipitation and temperature can be used to identify whether a climate variable increases or decreases crop variability. So if, $h_x = \delta h/\delta x>0$, it indicates that the corresponding input variable x is risk increasing, if $h_x< 0$ it implies risk decreasing. Maximum likelihood estimation (MLE) technique has been applied to estimate the mean and variance functions of the Just-Pope production function using GRETL 1.10.1.

RESULTS AND DISCUSSION

Basic information about the respondents: The respondents, on an average, were in their 40s in Asom and Nagaland whereas; in Mizoram the average age was 61 years (Table 1). A family comprised five to six members. Most of the respondents belonged to the unreserved category (70%) and other backward caste (OBC) category (21%) in Nagaland while, in Asom most of the respondents belonged to the OBC category (48%) and ST category (38%). All the respondents in Mizoram were ST. Among the respondents the literacy rate was 76% and 88% in Nagaland and Asom, respectively. Majority of the literate respondents were educated up to middle level, followed by primary and secondary education level. They mainly resided in semi-*pucca* or *pucca* type of houses in the study area. The operational landholding was 3.48 ha in Nagaland and 1.91 ha in Karbi Anglong but only 9.95 and 6.59% of the land was under irrigation, respectively (Table 1).

Table 1. Socio-economic information of sample farmers in Asom and Nagaland

Particular		Unit	Asom	Nagaland
Average age		years	44.39	42.28
Family size		no.	5.89	5.87
Social Group	Schedule Tribe	%	38.33	5.00
	Schedule Caste		0.83	1.67
	Other Backward Caste		48.33	20.83
	Others		12.51	70.00
Housing structure	Kaccha	%	2.50	13.33
	Semi-pucca		51.67	47.50
	Pucca		45.83	39.17
Operational land holding		ha	1.91	3.48
Irrigated land		%	6.59	9.95

Perception about climate change: All the respondents in Asom and Nagaland perceived that the summer temperature has increased in last 10 years. In case of winter temperature, the opinions were divided as about 60% in Asom and 23% in Nagaland felt that winter temperature has increased and 40% and 67% of them respectively felt it has decreased. Similarly, the respondents at Shiphir village in Mizoram reported about increase in temperature especially in the summer months. They informed that tropical tree like tamarind (*Tamarindus indica*) can grow now which was not possible ten years back. The incidence of frost has been lesser in recent times in the village which indicates that the temperature during winter is also rising.

Nearly all of the respondents reported that the amount of rainfall has declined in monsoon as well as post monsoon seasons and the onset of monsoon has been delayed in recent years in the study area. The respondents in Mizoram opined that rainfall pattern has become erratic in nature. The arrival of rainfall has been unpredictable and October to May experience long dry spells in the state.

The low rainfall has led to decreased water table and also the small streams and springs which are important sources of water dried up during the winter season. They relied mainly on water storage structures during the lean seasons. Water scarcity for domestic use some times, resulted into minor conflicts in the village. They also reported about increase in frequency and intensity of winds during the winter seasons and decrease in incidence of hailstorms in recent periods in Mizoram.

Effect on livestock composition: Local cattle were common in Asom and Nagaland; only a few households reported possession of CB cows. The number of households that possessed local cattle was comparatively higher in Asom than in Nagaland and the trend was opposite in case of CB cows (Table 2). Most of the respondents were small dairy farmers with an average of two local cows or one CB cow. Next to cattle were poultry and goat which were also found to be owned by higher number of households in Karbi-Anglong than in Dimapur. On an average a household owned 3–4 goats and 10–15 poultry birds in the study area.

The composition of different types of livestock possessed by a household changed during the drought periods in the study area (Table 3). Majority of the households reported that the number of poultry, dairy cows, pig, goat and sheep decreased due to the water stress and high temperature; interestingly the number of households reported no change in number was significantly large in case of cattle for meat purpose which is obvious as beef finds an important place in regular diet of the people of the region (Table 3). Greater reliance, as per the laws of ecosystems, on vegetarian food may not be the option to relieve the hill ecosystems of some pressure of climate change as it's the type of animals which are lesser sensitive or relatively resistant to the effect of climate change mainly constitute the source of animal protein for the people of the region. Moreover, consumer studies reveal that meat is integral part of the daily diet of the different tribes and considered to be kind of un-substitutable due to its custom and traditions. Shadap and Pala (2017) reported that tribes of Meghalaya spent 18.97% of their yearly food expenditure on meat which was higher than all other food items and only lower to cereals (22.84%). Vegetables for example accounted for only 10.77%. The per capita availability of meat in Meghalaya is around 48 g/person/day (GoM 2017).

Table 3. Effect of drought on livestock composition (in number) in Asom and Nagaland

Response	Dairy	Meat animal	Poultry	Pig	Goat/ sheep
Asom					
Decrease	78.13	0.00	80.00	58.82	79.17
Increase	0.00	0.00	0.00	0.00	0.00
No change	21.88	100.00	20.00	41.18	20.83
Nagaland					
Decrease	70.69	13.33	81.40	62.50	84.62
Increase	1.72	6.67	2.33	12.50	2.56
No change	27.59	80.00	16.28	25.00	12.82

At Sihphir village livestock is reared since time immemorial. Cattle, pig and poultry were the major livestock and some of them reared goat and sheep too. They reared CB cows mainly for milk purpose. During the times of climatic variability they preferred to keep pigs instead of cattle because the feed, fodder and water requirements are higher for cattle as compared to pigs. Availability of fodder and water were the considerations for the households while deciding the compositions of animals in herd. Increase in temperature can increase lignin and cell wall components in plants (Sanz-Saez *et al.* 2012, Polley *et al.* 2013) which reduces digestibility (IFAD 2010, Polley *et al.* 2013), leading to a decrease in nutrient availability for livestock (Thornton *et al.* 2009). The increased temperature also reduces the availability and deteriorates the quality of pasture available in the hills. Moreover the productivity and mortality of animals is influenced by Thermal Humidity Index (THI) and the threshold levels of THI vary for different animals. Farmers prefer to keep animals such as local cattle or pigs which can sustain the increased heat stress and feed on low quality fodder.

Effect on grazing land, fodder availability, milk and meat

Table 2. Livestock composition and investment on animals in Asom and Nagaland

Type	% of household possessing		Number		Investment (₹)	
	Asom	Nagaland	Asom	Nagaland	Asom	Nagaland
Dairy cattle						
Local male	51.67	42.50	1.81	2.31	26121	26912
Local female	63.33	58.33	2.22	2.17	12329	12393
Crossbred male	0.00	1.67	0.00	1.00	0.00	20000
Crossbred female	0.83	1.67	1.00	1.50	35000	24000
Small animals						
Sheep	0.83	6.00	2.00	4.33	8000	7000
Goat	34.17	25.00	2.66	3.73	4317	5257
Pig	12.50	6.67	2.33	2.88	9267	9313
Poultry	45.00	22.50	9.72	14.63	337	355
Duck	14.17	4.17	6.24	3.00	418	380

production: Reduction and deterioration in grazing land was common during drought due to heating and water stress. The availability of fodder also reduced in the region (Table 4) which forced the farmers to put extra effort to collect fodder but no gender discrimination was reported as both male and female shared the additional burden of fodder collection in the study area (Annexure I).

Majority of the respondents expressed that the milk yield declined during the drought period due to heat stress, less availability of green fodder and determination of grazing land in Asom and Nagaland. Most of them reported that the growth in body weight of milk animals was lesser during low rainfall or drought than the normal periods due to scarcity of green fodder. The percentage of the farmers who reported decline in milk yield was higher in Nagaland in comparison to Asom and it was opposite in case of meat production (Table 5).

The livestock rearers in Mizoram reported that the milk yield also reduced in those years when the winter temperature was relatively lower than the normal years. They explained that the cold weather makes the animal reluctant to drink water, which is necessary for milk production. Apart from this, scarcity of quality green fodder due to nearly no rainfall during winter season adds to the problem. During this season, they buy readymade feeds from the market.

The incidences of FMD and milk fever have risen during the period of January to June at Siphir village. The population of fly has increased which cause restlessness to cows especially during milking. It also acts as a vector for other diseases causing organism which affects the animal's health and lowers the quality of milk.

Adaptation strategy: Virtually no adaptation strategy was identified in the study area. Moreover, hardly any respondents (90%) knew about the livestock insurance programme. The role of government agency specific to climate change was not visible (Annexure II). About 15% respondents expressed their preference for scientific animal health management as mitigating option in the area.

Effect of climatic variability on milk productivity (*Just and Pope model*): Just and Pope Model was applied on panel data constructed from time series (1988–2007) of seven states (as district level data for Karbi-Anglong was not available) to assess the impact of climatic variable on mean yield and variability in yield of milk in North Eastern (NE) hill states. Milk yield was used as dependent variable in the model. Annual rainfall, annual minimum and maximum temperature, time as trend and state dummy were included as explanatory variables in the model. The coefficients were estimated using Maximum Likelihood (ML) technique. Various functional forms of mean function and variance function were used and the best fit is selected based upon the logical (sign and magnitude of coefficients) and econometric criteria *i.e.,* least Akaike criterion (AIC).

The average milk yield in the NE hill states was 47.1 thousand MT per year during the period of 1988–2007, with highest milk yield of 72.6 thousand MT per year in Manipur, followed by Meghalaya and Tripura. The inter year variability in milk yield was maximum in Tripura and minimum in Manipur. The mean rainfall was highest in Sikkim and lowest in Manipur. The mean maximum and minimum temperature was highest in Nagaland and AR, respectively whereas both were lowest in Sikkim (Table 6).

The double log linear model with the variance function in logarithmic form was found to be the best model. The trend variable is significant ($P<0.01$) in the mean function which implies that technological progress in the form of introduction of CB cows, artificial insemination programme *etc.* has positive influence on milk yield which is evident from increased milk yield over the study period. The yield of milk in different NE hill states is statistically different ($P<0.01$) from milk yield registered in Mizoram (Table 7).

In variance function, time is risk decreasing factor

Table 4. Farmers' perception (%) about effect of drought on grazing land and fodder availability in Asom and Nagaland

Response	Grazing land		Fodder availability: Green fodder		Fodder availability: Dry fodder	
	Asom	Nagaland	Asom	Nagaland	Asom	Nagaland
Decrease	87.67	71.83	92.42	75.00	72.83	67.80
Increase	0.00	0.00	0.00	0.00	13.58	5.08
No change	2.73	22.53	4.54	25.00	11.11	25.42
Not sure	8.22	4.23	1.51	0.00	1.23	0.00

Table 5. Farmers' perception (%) about effect of drought on livestock production in Asom and Nagaland

Response	Milking per day (No.)		Milk production		Meat	
	Asom	Nagaland	Asom	Nagaland	Asom	Nagaland
Decrease	60.00	86.36	64.29	92.00	100.00	75.00
Increase	8.00	4.55	7.14	4.00	0.00	25.00
No change	16.00	9.09	14.29	4.00	0.00	0.00
Not sure	16.00	0.00	14.29	0.00	0.00	0.00

Table 6. Mean and CV values for the explanatory variables used in Just & Pope model (1988–2007)

Indicator	Sikkim	AR	Megh	Man	Nag	Tripura	Miz	NEH
Milk yield ('000MT/year)	36.48 (22.01)	37.4 (36.64)	60.6 (15.83)	72.6 (11.77)	50.2 (21.86)	59.9 (42.26)	12.8 (31.57)	47.1 (25.99)
Rainfall	2671.9 (26.79)	2178.7 (11.60)	2441.6 (27.84)	1586.8 (12.01)	2078.9 (20.22)	2130.3 (24.47)	2556.2 (32.73)	2234.9 (22.24)
Min Temp	17.0 (7.03)	18.9 (3.74)	18.3 (2.42)	18.1 (2.51)	18.8 (2.05)	18.0 (2.09)	18.1 (1.92)	18.2 (3.11)
Max. Temp	26.7 (1.48)	28.5 (1.72)	28.0 (1.57)	28.2 (1.94)	29.1 (1.89)	28.2 (1.36)	28.0 (1.31)	28.1 (1.61)

AR, Arunachal Pradesh; Megh, Meghalaya; Man, Manipur; Nag, Nagaland; Miz, Mizoram. The figures in parenthesis indicate CV in %.

Table 7. Estimated Just and Pope Model for milk in NEH

Dependent variable:		Ln (Yield)	
Variables	b	SE	P
Mean function/Model		LnY-LnX	
Const	6.704	2.881	0.020***
Time	0.034	0.004	0.000***
MaxT	Š1.488	0.696	0.033
MinT	0.114	0.531	0.830
RainT	–0.019	0.071	0.790
Sikkim	0.997	0.071	0.000***
Arunachal	1.117	0.086	0.000***
Meghalaya	1.524	0.091	0.000***
Manipur	1.582	0.062	0.000***
Nagaland	1.379	0.053	0.000***
Tripura	1.685	0.056	0.000***
Variance function	Ln		
Const	–75.170	16.376	0.000***
Time	–0.276	0.018	0.000***
MaxT	26.937	5.742	0.000***
MinT	–4.445	4.507	0.324
RainT	–0.063	0.687	0.927
Akaike criterion	–65.826		

***indicates $P<0.01$

($P<0.01$) which implies that over the year the variability is declining which is as per our expectation. The maximum temperature is strongly ($P<0.01$) risk increasing factor. Increase in maximum temperature is expected to increase the variability in milk yield as the heat stress reduces the milk yield of dairy animals (Table 7) directly and through reduced fodder availability.

This study attempted to find out the effect of climate change on dairy in the NE Himalayan states of India. The survey and FGD revealed that the farmers perceived increase in temperature and decline in rainfall during the monsoon season. The number of different types of animals declined during the drought period, except the animals for meat purpose. The respondents reported that the milk yield declined and the body weight gain was lower in case of increase in temperature and during the drought period due to less availability of fodder. The time spent on fodder collection increased but no gender bias was observed for shouldering additional burden. The occurrence of FMD and fly population has increased in Mizoram. The Just & Pope model revealed that maximum temperature is a risk increasing factor for milk yield in the NE states but the technological factors played positive role in improving and stabilizing the milk yield over the years in the region. The dairy sector may become more vulnerable with further change in climatic factors. Location specific scientific housing, feed and health management may help to reduce the impact of climate change on the livestock sector.

Farmers in the study area hardly adopted, except changing the composition of livestock, any adaptation or mitigation strategy which is a matter of concern. Modification of production and management systems in terms of diversification of livestock, integration of livestock systems with forestry and crop production can be good adaptation measure (IFAD 2010). Improving feeding practices is another important aspect to indirectly improve the efficiency of livestock production (Havlík *et al.* 2013). Modification of diet composition, changing feeding time and/or frequency (Renaudeau *et al.* 2012), incorporating agro-forestry species in the animal diet (Thornton and Herrero 2010a,b) etc. can help to cope up with changing climate. Improving local genetics through cross-breeding with heat and disease tolerant breeds can be the breeding strategy. If climate change is faster than natural selection, the risk to the survival and adaptation of the new breed is greater. Strengthening of disease forecasting and surveillance system is a way to avoid disease outbreaks in changed climatic scenario.

Policy measures suitable for improving the adaptive capacity of the system is also crucial. Developing the capacity of livestock producers and herders to understand and deal with climate change by providing training in agro-ecological technologies and practices for the production and conservation of fodder will reduce malnutrition and mortality in herds. Promotion of livestock insurance can also act as cushion against mortality due to extreme climatic vulnerability.

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Annexure I

Gender wise sharing of extra burden during drought (in %)

State	Male	Female	Both
Nagaland	4.00	2.00	94.00
Asom	1.14	3.41	95.45

Annexure II

Agencies that supported the farmers

Government Department	Nagaland	Asom
Fisheries	0.00	0.83
Animal Husbandry	0.00	0.83