Climate Change and Cropping Pattern: An Analysis of the Dima Hasao (North Cachar Hills) District of Assam

Paramita Saha, Mashud Ahmed and Manuj Baruah

Research Journal of Agricultural Sciences
An International Journal

P- ISSN: 0976-1675
E- ISSN: 2249-4538

Volume: 13
Issue: 01

Res. Jr. of Agril. Sci. (2022) 13: 187–191

CARAS

Res. Jr. of Agril. Sci. (Jan-Feb 2022)
13(1): 187–191

ISSN: 0976-1675 (P)
ISSN: 2249-4538 (E)

www.rjas.org

Full Length Research Article

Climate Change and Cropping Pattern: An Analysis of the Dima Hasao (North Cachar Hills) District of Assam

Paramita Saha[1], Mashud Ahmed*[2] and Manuj Baruah[3]

Received: 06 Dec 2021 | Revised accepted: 12 Jan 2022 | Published online: 02 Feb 2022

ABSTRACT

A change in climate can have effects on crop yields and crop production areas across agro-ecological regions both due to temperature rise and changes in water availability. The primary objective of this study is to analyze the impact of climate change on cropping pattern in the Dima Hasao (North Cachar Hills) district of Assam. The study examines the trends of both climatic variables and key crops production area in the district for the period of 1981-2017. Non-parametric Mann-Kendall test has been employed to detect statistically significant trends and Sen's Slope test to find magnitudes of trends. The fully modified ordinary least squares (FMOLS) regression technique is applied to detect the impact of climatic variables on cropping pattern in the district. It has been observed that among climate variables temperature maximum (°C) is showing a negative trend whereas temperature minimum (°C) and rainfall (mm) are showing a positive trend. But rainfall has only significant trend at 5% level of significance. Area under production of rice, maize, rapeseed and mustard and potato are showing a significant positive trend. The study finds that area under different crops have different association with climate variables. However, only rainfall has shown a significant positive impact on the area of cultivation under maize, rapeseed and mustard and potato over the period of time whereas temperature maximum and minimum does not show any significant impact.

***Key words*:** Climate change, Cropping pattern, Rainfall, Temperature

Climate change is defined by the Inter-Governmental Panel on Climate Change as a long-term change in climate that may be recognized by changes in the mean and/or variability of its features [7]. The proportion of land under cultivation of different crops at different times is referred to as the cropping pattern. This indicates the planting season and crop arrangement in a certain geographical region. The relationships of climate change and cropping pattern are important as agriculture sector is most vulnerable to climate change [15-17]. As all agriculture relies on appropriate temperature ranges and rainfall patterns to raise crops and livestock, it is vulnerable to climate change. Climate change reduces agricultural production, both directly by causing harm to standing crops and indirectly by influencing cropping decisions [21]. Climate change has an influence on all aspects of the biosphere, from land to ocean to air. Climate change is being felt across the Indian subcontinent, but especially in high places like the Himalayas, where glaciers are retreating and rainfall is inconsistent [2]. India is an agrarian country with almost 65% of its population associated with agricultural activities. North-East India is relatively more vulnerable to climate change impacts due to its location in the Eastern Himalayan periphery, fragile geo-environmental, and economic under- development [16]. Impacts of climate variability on agriculture in Assam are already noticeable in terms of erratic monsoon, frequent floods, drought like situation and warming winter [3]. According to the recent report of the department of science and technology (Government of India), Assam is one of the relatively highly vulnerable states of India with vulnerability indices 0.620 [4].

The impact of changing climatic factors like change in the temperature and rainfall has affected the agricultural productivity and forced people to change agriculture pattern [2]. Any significant change in climatic conditions (Rainfall and temperature) will not only challenge the food production of North West India but also challenge the country's food security situation [1]. Crop diversification has an important role in enhancing farms income in the flood affected plains of Assam [13; 12]. It has been observed that along with other driving forces, climate variability and change are important causes of changing agriculture and cropping pattern in Mizoram [19]. It was also identified that the cropping patterns are modified by local farmers due to climate change impacts [8]. The two most important and prominent variables in climate and hydrological studies are rainfall and temperature. Any change in these two components will have a significant impact on the hydrological cycle, streamflow, and the corresponding water demand by various sectors [9]. Thus,

* **Mashud Ahmed**
✉ hmashud786@gmail.com

[1-3] Department of Economics, Tripura University, Suryamaninagar, Agartala - 799 022, Tripura, India

trend analysis of the time series behaviour of rainfall and temperature and their impact on crop production is important to understand the climate dynamics and cropping pattern. The objectives of this study are (i) To look at the trends in meteorological variables (Rainfall and temperature) and key crop production area in Assam's Dima Hasao (North Cachar Hills) district and (ii) To examine the impact of climate variables on cropping pattern in the district.

MATERIALS AND METHODS

Climate data: Data on annual maximum temperatures (°C), annual minimum temperatures (°C) and annual total rainfall (mm) for period 1981-2017 for Dima Hasao (North Cachar Hills) district has been collected from https://power.larc.nasa.gov/data-access-viewer/ which is free to access (Retrieved on 28 July 2021).

Agricultural data: Rice, maize, rapeseed and mustard and potato cultivation area were chosen for this study as per availability of secondary data for the period. Area under these crops (in 1000 ha) for the years 1981 to 2017 were collected from http://data.icrisat.org/dld/ (Retrieved on 3rd September 2021).

Trend analysis: Mann-Kendall (MK) approach [11], [14] was used to determine a statistically significant trend in the series through Eviews12. It's a rank-based non-parametric approach that works well with skewed variables and is resistant to extremes [5]. When dealing with non-normally distributed data, outliers, and non-linear trends, this technique can be used [6]. The MK test compares the null hypothesis of no trend against the alternative hypothesis of a rising or falling trend. Equation (1) calculates the MK test statistic (S).

$$= \sum_{k-1}^{n-1} \sum_{j=k+1}^{n} sign\,(x_j - x_{k)} \qquad \text{.......... (1)}$$

Where n is the time series length, x denotes the data point at times j and k (k>j), and equation denotes the sign function (2).

$$\text{sign}\,(x_j - x_k) = \begin{cases} +1, if\ (x_j - x_k)>0 \\ 0, \text{if}\ (x_j - x_{k)} = 0 \\ -1, if\ (x_j - x_{k)} <0 \end{cases} \qquad \text{.......... (2)}$$

If n is less than 10, the value of [S] is directly compared to Mann Kendall's theoretical distribution of S. The statistic S is considered to be asymptotically normal for n=10 or greater, with a mean E(S)= 0 and variance as follows:

Variance: Var(s) = 1/18[n(n-1)(2n+5)-Σt(t-1)(2t+50] …. (3)

Where t is the size of a specific tie, and $\sum_t$ denotes the total number of ties. A tie occurs when two samples of data have the same value, and the summation is applied to all ties. Equation (4) calculates the standard normal deviation Z.

$$Z = \begin{cases} \dfrac{s-1}{\sqrt{var(s)}}, & if\ S > 0 \\ 0, & if\ S = 0 \\ \dfrac{s+1}{\sqrt{var\ (s)}}, & if\ S < 0 \end{cases} \qquad \text{.......... (4)}$$

Positive Z (c) and negative Z (c) represent an upward and decreasing trend during the time, respectively, where Z (c) follows a normal distribution. If [Z]> $Z_{\alpha/2}$, at a level of significance, the null hypothesis Ho should be accepted in a two-sided trend test. The null hypothesis is tested at a 95% confidence level in this study.

A simple non-parametric approach proposed by Sen was also used to assess the magnitude of a time series trend [20]. Equation (5) is used to calculate the trend.

$$\beta = median\left(\frac{x_{j-}\ x_k}{j-i}\right), j > i \qquad \text{.......... (5)}$$

Where β is Sen's estimate of the slope. A time series with β >0 shows an upward trend. The data series, on the other hand, shows a declining tendency with time.

Time series and regression analysis: The collected time series data are analyzed using the fully modified ordinary least squares (FMOLS) method. This approach was chosen based on the amount of observations, which ranged from 1981 to 2017, and it may be used to estimate simply I(0), I(1), or a combination of I(0) and I(1) variables. More significantly, FMOLS is more successful for estimating data with a small sample size. Philips and Hansen first introduced and developed the FMOLS approach for estimating a single co-integrating relationship that has a combination of I(1) [18]. The Augmented Dickey-Fuller (ADF) test was used to determine if the time series data in this study was non-stationary. The Johansen Co-integration test was used to determine the validity of long-run correlations between variables, given that all variables are non-stationary at the level. If there is co-integration, it means that even if the variables are non-stationary at level, there is a long-run relationship between them [10]. All exercises have been done through EViews12.

RESULTS AND DISCUSSION

The trends of annual temperature maximum (T_{max}), temperature minimum (T_{min}) and average rainfall for the Dima Hasao district of Assam during the period 1981-2017 have been obtained by Mann Kendall (MK) test. In addition, Sen's slope of the regression line has been used to detect the magnitudes. Trends in crop production area under different crops are also obtained by MK test and displayed graphically through trend line. Impact assessments were done using fully modified ordinary least square (FMOLS) technique.

Trends in climatic variables

Annual temperature maximum (T_{max}) is showing a decreasing trend whereas annual temperature minimum (T_{min}) is showing a positive trend for the period 1981-2017 but these results are statistically insignificant. However, rainfall is showing a significant positive trend over the period (Table 1). The magnitudes of the trends are -0.015, -0.015 and 0.049 respectively for the T_{max}, T_{min} and rainfall respectively. The observed time series graph along with linear trend line is represented by (Fig 1).

Table 1 Result of the statistical test for climate variables

Climate variables	Mann Kendall Test			Sen's slope
	S	Z	P value	
T_{max}	-40	-0.510	0.609	-0.0157
T_{min}	122	1.582	0.113	
Rainfall	287	3.741*	0.0001	0.049

*Indicates values are statistically significant at 95% confidence level (α= 0.5)

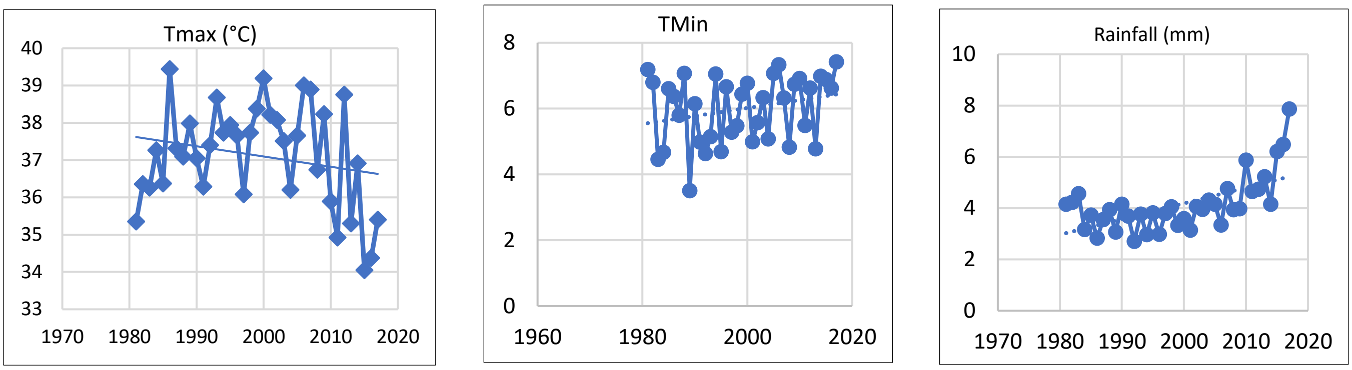

Fig 1 Observed trend line and time series graph for climatic variables

Trends in crop production area

The area of production under rice, maize, rapeseed and mustard and potato are showing a significant positive trend (Table 2). The magnitudes of trends are 0.496, 0.040, 0.038 and 0.012 for rice, maize, rapeseed and mustard and potato respectively. The observed time series graph along with linear trend line is represented by (Fig 2).

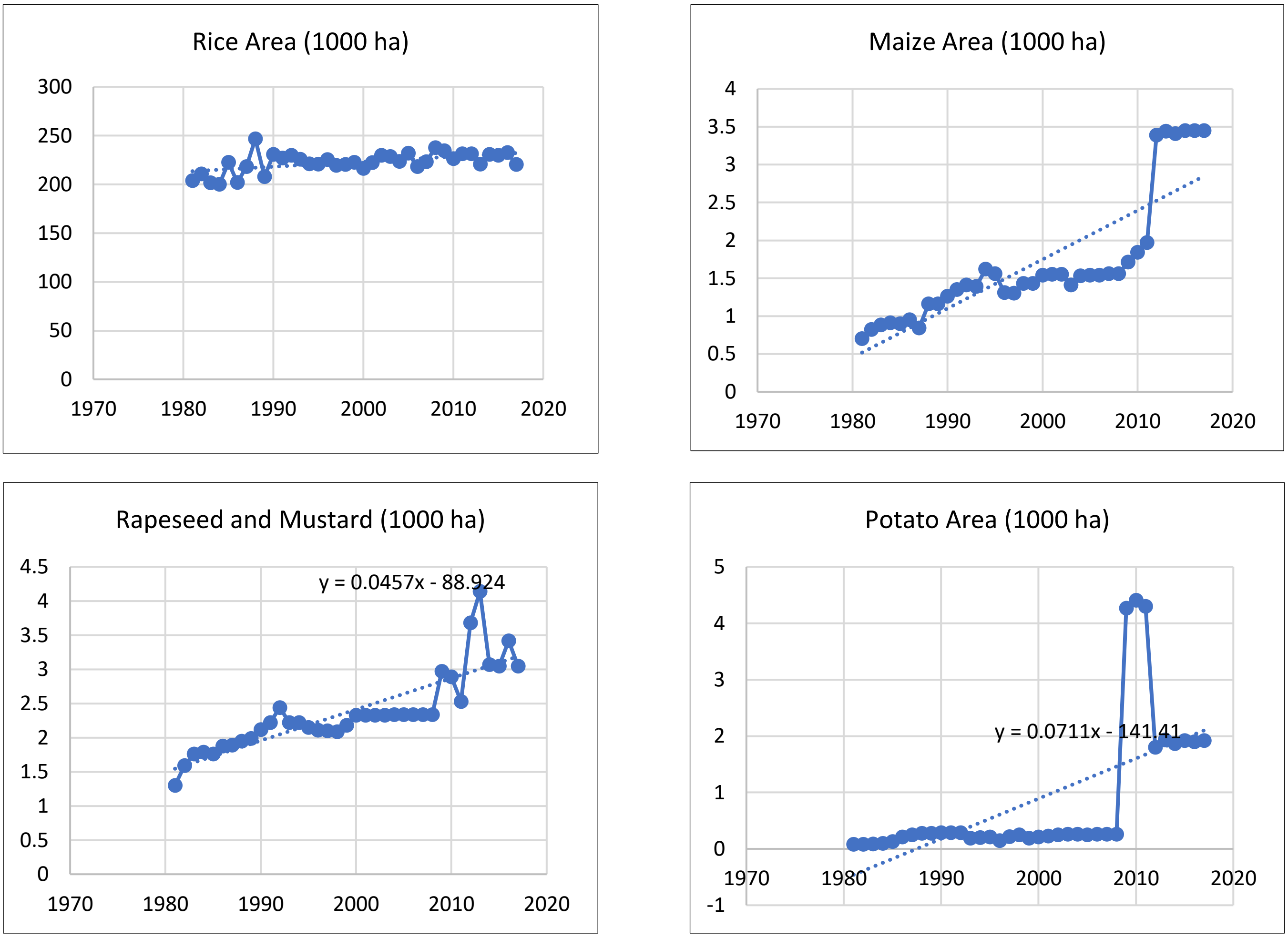

Fig 2 The observed time series graph along with linear trend line for crop variables

Table 2 Result of the statistical test for crop variables

Crop variables	Mann Kendall Test			Sen's
	S	Z	P value	slope
Rice area	234	3.047*	0.0023	0.496
Maize area	551	7.202*	<0.0001	0.040
Rapeseed and mustard area	535	7.002*	<0.0001	0.038
Potato area	384	5.025*	<0.0001	0.012

*Indicates values are statistically significant at 95% confidence level (α= 0.5)

Test for unit roots

To avoid spurious regression findings, the stationarity of the data is confirmed before proceeding with further analysis of the time series data. As a result, for each variable for which we had time series data, we ran an ADF unit root test. Some variables have been discovered to be non-stationary at levels, as shown in Table 3. Later, when unit root was tested on differentiated data, it was shown that all variables are stationary at the first difference at the usual level of significance. Furthermore, the initial difference stationarity of time series data implies that the data is integrated of order one, I (1).

Table 3 Augmented dicky fuller tests for unit roots

Variables	Levels			First difference		
	Test statistic	Critical value at 5%	P value	Test statistic	Critical value**	P value
T_{max}	-4.2458*	-2.9458	0.0020	-6.2262*	-2.9511	0.0000
T_{min}	-6.4578*	-2.9458	0.0000	-7.9557*	-2.9511	0.0000
Precipitation	3.6472*	-2.9639	1.0000	-10.3050*	-2.9484	0.0000
Rice area (in 1000 ha)	-4.7791*	-2.9458	0.0004	-9.4520*	-2.9511	0.0000
Maize area (in 1000 ha)	0.0032	-2.9458	0.9527	-5.6189*	-2.9484	0.0000
Rapeseed and mustard area (in 1000 ha)	-1.0698	-2.9540	0.7158	-3.1289*	-2.9540	0.0340
Potato area (in 1000 ha)	-1.9346	-2.9458	0.3184	-5.63.453*	-2.9484	0.0000

*Indicates significance at 5 percent level and ** Indicates critical value at 5 percent level

Johansen co-integration test

Given that all variables are non-stationary at level, co-integration testing verifies the validity of long-run correlations between variables. If the variables are co-integrated, it suggests that there is a long-run link between them, even if they are non-stationary at the level [10]. The goal of discovering the co-integrating vectors is to determine if the variables in the models have a long-term relationship. The Johansen co-integration test for climatic and agricultural variables is shown in (Table 4). As a result, at a 5% level of significance, both the Trace and Maximum-Eigen value tests confirm the rejection of the null hypothesis "there are no co-integrated vectors," indicating the presence of a long-term link between the variables. Furthermore, the existence of at least four co-integrating equations is proved by both Trace and Maximum-Eigen value tests (Table 4). As a result, the impact evaluations were conducted using the Fully Modified Ordinary Least Squares (FMOLS) approach.

Table 4 Johansen co-integration test

Co-integrating rank (r)	Trace test			
	Eigen value	Trace statistic	Critical value**	Prob.
r = 0*	0.8615	204.3409	125.6154	0.0000
r ≤ 1*	0.6989	135.1259	95.7536	0.0000
r ≤ 2*	0.6245	93.1045	69.8188	0.0002
r ≤ 3*	0.5663	58.8209	47.8561	0.0034
r ≤ 4	0.4153	29.5779	29.7970	0.0530
r ≤ 5	0.2547	10.7948	15.4947	0.2244
r ≤ 6	0.0142	0.5036	3.8414	0.4779
Co-integrating rank (r)	**Maximum Eigen (λ-max) value test**			
	Eigen value	λ-max statistics	Critical value**	Prob.
r = 0*	0.8615	69.2150	46.2314	0.0000
r ≤ 1*	0.6989	42.0213	40.0775	0.0298
r ≤ 2*	0.6245	34.2836	33.8768	0.0447
r ≤ 3*	0.5663	29.2429	27.5843	0.0304
r ≤ 4	0.4153	18.7831	21.1316	0.1033
r ≤ 5	0.2447	10.2911	14.2646	0.1935
r ≤ 6	0.0142	0.5036	3.8414	0.4779

Both Trace test and Max-eigen value test indicate 4 co-integrating equations at 0.05 level

*Indicates significance at 5 percent level and ** Indicates critical value at 5 percent level

Results of fully modified ordinary least squares (FMOLS)

The result of the long run model is presented in (Table 5). The coefficients of rainfall, temperature maximum and temperature minimum have positive association with rice cultivation area but they are statistically insignificant. In case of maize, the coefficient of rainfall is positive and significant in explaining changes in maize production area and the significant level is at 1 percent as shown by the probability value. This means if there is increase in 1 percent of rainfall, maize area will increase by 0.7044 percent. Temperature maximum and temperature minimum have positive and negative association respectively with Maize area but they are statistically insignificant. The long-run coefficient of rainfall has a positive and significant association with rapeseed and mustard as well as potato production area at 1 percent and 10 percent level of significance respectively. This indicates if rainfall level increases, the area under production of rapeseed and mustard and potato will also increase. Again, temperature maximum and temperature minimum have no significant association with Rapeseed and mustard production area in the long run.

CONCLUSION

In this study, the variability and long-term trends of annual temperature maximum, temperature minimum, and average rainfall for the Dima Hasao (North Cacher Hills) district of Assam are examined. The area of production for four major agricultural crops i.e., rice, maize, rapeseed and mustard and potato were selected on the basis of the availability of secondary data for the period 1981-2017. It has been observed that among climate variables, only rainfall (mm) is showing a significant positive trend over the period. Annual temperature maximum (T_{max}) and annual temperature minimum (T_{min}) are showing a negative and positive trend respectively but these results are statistically insignificant. Area under production of rice, maize, rapeseed and mustard and potato have a significant positive trend for the period. The study finds that area under different crops have different association with climate variables. However, only rainfall has shown a significant positive impact on the area of cultivation under maize, rapeseed and mustard and potato over the period of time whereas temperature maximum and minimum does not show any significant impact. This study depicts that rainfall is an important climatic variable for the Dima Hasao district which have significant association with area of cultivation under different crops.

Table 5 Results fully modified ordinary least squares (FMOLS)

Explanatory variable	Dependent variable: Rice area			
	Coefficient	Std. Error	t- statistic	Prob.
Rainfall	2.2177	2.4364	0.9102	0.3695
T_{max}	1.2018	1.8666	0.6438	0.5243
T_{min}	0.8516	1.9936	0.4272	0.6721
Constant	164.5405**	73.4798	2.2392	0.0322
R-squared	0.0474			
Adjusted R-squared	-0.0418			
	Dependent variable: Maize area			
Rainfall	0.7044***	0.1915	3.6776	0.0009
T_{max}	0.0527	0.1467	0.3591	0.7218
T_{min}	-0.0252	0.1567	-0.1610	0.8730
Constant	-3.0135	5.776	-0.5216	0.6055
R-squared	0.4794			
Adjusted R-squared	0.4306			
	Dependent variable: Rapeseed and mustard area			
Rainfall	0.5040****	0.1387	3.6314	0.0010
T_{max}	0.1194	0.1063	1.1231	0.2697
T_{min}	-0.0834	0.1135	-0.7348	0.4678
Constant	-3.6207	4.1856	-08650	0.3935
R-squared	0.3320			
Adjusted R-squared	0.2693			
	Dependent variable: Potato area			
Rainfall	0.7051*	0.3517	2.0048	0.0535
T_{max}	0.0007	0.2694	0.0027	0.9978
T_{min}	0.0608	0.2878	0.2113	0.8339
Constant	-2.4276	10.6084	-0.2288	0.8204
R-squared	0.2867			
Adjusted R-squared	0.2198			

*, **, *** shows significance at 10%, 5%, and 1* level, respectively

LITERATURE CITED

1. Ahlawat S, Kaur D. 2015. Climate change and food production in North West India. *Indian Journal of Agricultural Research* 49(6): 544-548.
2. Batool N, Shah SA, Dar SN, Skinder S. 2019. Rainfall variability and dynamics of cropping pattern in Kashmir Himalayas: a case study of climate change and agriculture. *SN Applied Sciences* 1(6): 1-9.
3. Deka RL. 2013. Climate change in the Brahmaputra valley and impact on rice yield and tea production. *Doctoral Thesis*, Centre for Environment, Indian Institute of Technology Guwahati, Assam.
4. DST. 2020. Climate Vulnerability Assessment for Adaptation Planning in India Using a Common Framework. Report of the Department of Science and technology, Government of India.
5. Hamed KH. 2008. Trend detection in hydrologic data: the Mann–Kendall trend test under the scaling hypothesis. *Journal of Hydrology* 349(3/4): 350-363.
6. Helsel DR, Hirsch RM. 1992. Statistical Methods in Water Resources. Vol. 49. Elsevier.
7. IPCC. 2012. Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the *Intergovernmental Panel on Climate Change.* Cambridge University Press, Cambridge, UK, and New York, NY.
8. Islam MS, Roy S, Afrin R, Mia MY. 2020. Influence of climate-induced disasters and climatic variability on cropping pattern and crop production in Bangladesh. *Environment, Development and Sustainability* 22(7): 6709-6726.
9. Jain SK, Kumar V. 2012. Trend analysis of rainfall and temperature data for India. *Current Science* 102(01): 37-49.
10. Johansen S. 1988. Statistical analysis of co-integration vectors. *Journal of Economic Dynamics and Control* 12 (2/3): 231-254.
11. Kendall MG. 1975. *Rank Correlation Methods*. Oxford University Press, New York, NY.
12. Mandal R. 2014. Cropping pattern choice and risk mitigation in flood affected agriculture: A study of Assam plains, India. SHSU Economics and Intl. Business Working Paper No. 14, 3.
13. Mandal R, Bezbaruah MP. 2013. Diversification of cropping pattern: its determinants and role in flood affected agriculture of Assam Plains. *Indian Journal of Agricultural Economics* 68: 169-181.
14. Mann HB. 1945. Nonparametric tests against trend. *Econometrica: Journal of the Econometric Society* 13(3): 245-259.
15. Mendelsohn RO, Dinar A. 2009. Climate change and agriculture: an economic analysis of global impacts, adaptation and distributional effects. Edward Elgar Publishing.
16. MoEF. 2010. One year on: A summary of the Ministry's Major Initiatives on Environment, Forest and wildlife in 2009-2010. GoI.
17. Nastis SA, Michailidis A, Chatzitheodoridis F. 2012. Climate change and agricultural productivity. *African Journal of Agricultural Research* 7(35): 4885-4893.
18. Phillips PCB, Hansen B. 1990. Statistical Inference in Instrumental Variables Regression with I(1) Processes. *The Review of Economic Studies* 57: 99-125.
19. Sati VP. 2017. Changing Agriculture and Cropping Pattern in Mizoram, Northeast India. Working Pape: December 2017. https://www.researchgate.net/publication/322100703 (Accessed on 10/12/2020).
20. Sen PK. 1968. Estimates of the regression coefficient based on Kendall's tau. *Jr. of the Am. Statistical Association*. 63(324): 1379-1389.
21. Trinh TA, Feeny S, and Posso A. 2021. The impact of natural disasters and climate change on agriculture: Findings from Vietnam. *Economic Effects of Natural Disasters*. Academic Press. pp 261-280.