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Footprint of agricultural inputs on trend of productivity in West Bengal

ANWESHA BANERJEE[1*], SUMAN BERA[2] AND RAMKRISHNA MAITI[3]

Department of Geography and Environment Management
Vidyasagar University, Midnapore- 721102, West Bengal, India

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ABSTRACT

Agricultural productivity is the synthetic reflection of agricultural efficiency in which different inputs are being used and it helps to recognize the regional inequalities in agriculture. The main focus of the present study is on the district wise variation of trends in agricultural productivity in West Bengal from 1991 to 2011 as well as its relation to agricultural inputs like rainfall, percentage of cropped area, irrigation and fertilizer consumption. Therefore, trend analysis has been done by *Mann-Kendall test*together with the Sen's Slope Estimator for the determination of trend and slope magnitude.Alsoa regression analysis is done in between productivity and various inputs for answering the causes behind positive and negative trends. Most of the districts have facing negative trend in productivity since 1990. In Hooghly, Burdwan and Nadia districts,agricultural productivity is well enough in comparison to Purulia, Bankura, Darjeeling districts.

Key words: Agricultural productivity, Agricultural inputs, Productivity Trend, Mann-Kendall test

Agriculture is the foremost economic activity in West Bengal which is one of the most fertile regions in India. Over 58 per cent of the rural households depend on agriculture as their principal means of livelihood (Indian Brand Equity Foundation, 2016). It contributes around 18.7% to 18.8% of the state's gross domestic product (GSDP) from 2009-2010 to 2015 (India Brand Equity Foundation, West Bengal, November 2011 & 2015).Also west Bengal took an important position in terms of the average annual growth rate of the gross state domestic product from agriculture over the ten year from 1994 to 2004 at 3.64 % which is much higher than the national average (1.53%) and highest among all other states (Government of West Bengal 2009; Planning Commission and Central Statistical organization 2008).So, agriculture is most important sector because it helps to achieve required self-sufficiency in food production at the macro level, though this state has facing food deficit in rural region till today due to low productivity. Agricultural productivity means the degree to which the agricultural inputs are able to produce resources of a area for agricultural production (Singh, 1979).It tries to assessthe relative effectiveness of an area in utilizing various inputs and comparing the output of that area to the neighbouring area. Itis closely controlled by some physical factors i.e. topography,climate, soils, surface drainage and ground water potentiality etc but Enhanced agricultural productivity usually comes as a outcome of the effective apaptation of improved

[1&2]Research Scholar, [3]Professor and Head, Vidyasagar University, Midnapore- 721102 West Bengal

*Email Id: anweshabanerjee2011@gmail.com

technologies (FAO, 1981). Among the all factorsas well as technologies, rainfall, percentage of cropped area, irrigation and fertilizer consumption is most relevant to agricultural productivity. By demarcating the high, medium and low productivity region, the causative factors behind agricultural retardation may be found out and evenagricultural planning may be formulated to minimise the regional inequalities (Kothari and Kohli, 1997).

Study Area:

West Bengal is an eastern state of India and is lying between 21°25□24□□and 27°13□15□□ north latitudes and 85°48□20□□ and 89°53□04□□ east longitudes.The state has essentially a flat, featurelessalluvial plain, a large portion of it being a part of the delta of river Ganga. Two-third of the total geographical area of the state consists of flat alluvial plains with an elevation below 30 metres. The climate is generally tropical, hot and humid, monsoon type except in the northern mountains, where the altitude is the controlling factor. Agriculture dominates both the landscape and the economy of West Bengal and it is the major economic activity of West Bengal. Its proportion of agricultural land is highest amongthe all other Indian states. As per 2002 estimates West Bengal accounts for approximately 18 per cent of total rice production, 1.2 per cent of total wheat production, 4.5 per cent of total rapeseed-mustard production, 30 per cent of total potato production, and 77 per cent of total jute production in India (Ghose& Bhattacharya, 2011).

MATERIALS AND METHODS

The present study is entirely based on secondary data sources which are collected from Bureau of Applied Economics and Statistics, Govt. of West Bengal, Kolkata. In the present work, Enyedi's (1964) formula of agricultural productivity has considered. The crops areselected according to their percentage share in area in each and every districts of West Bengal. Enyedi while describing geographical types of agriculture in Hungery refers to a formula for determining agricultural productivity. This technique is admirable in the sense that it determines the productivity index of an area with reference to national level.This formula for assessing productivity coefficient would be read thus:

Productivity Index = $Y/Y_n \div T/T_n$

Where, Y is the total production of selected crop in unit area; Y_n is the total production of the same crop on national scale; T is the total cropped area of the unit area, and T_n is the total cropped area at national scale.

Trend of agricultural productivity from 1990 to2000 and 2000 to 2010 has been measured by using Mann- Kendall test for each crop.In the study non-parametric methods, Mann-Kendall (MK) test (Mann, 1945; Kendall, 1955) and Sen's estimator (P. K.Sen,1968) are used to detect the nature of trends in the time series. Mann-Kendall's method is applied to test the presence of a monotonic trend and the statistical significance of the trend and Sen's slope estimator for estimating true change per year in the time series. No pre-whitening of the data series is carried out. MK test is not only used for rainfall trends, but also widely used for analysing different climatic variables (Hirsch *et al.*1982 &1984; Douglas *et al.* 2006; Chen *et al.* 2007) and analysis of various environmental data (Hipel *et al.* 1994).

The Mann-Kendall test is appropriate in cases when the data values x_i of a time series can be assumed to follow the model

$$X_i = f(t_i) + \varepsilon_i \qquad (1)$$

Where $f(t_i)$ is a continuous monotonic increasing or decreasing function of time and the residuals ε_i

can suppose to be from the same distribution with zero mean. It is therefore assumes that the variance of the distribution is constant in time.

The null hypothesis of no trend, H_0, assumes that the observations x_i are independently distributed in time and the alternative hypothesis, H_1, denoted an increasing or decreasing monotonic trend. The number of annual values in the considered data series is designated by n. Missing values are allowed and n can thus be smaller than the number of years in the time series.

The Mann-Kendall test statistic S is established using the following formula

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sgn\,(x_j - x_k) \qquad (2)$$

Where, x_j and x_k are the annual values in years j and k, j> k, respectively, and

$$sgn\,(x_j - x_k) \equiv \begin{cases} 1 & if\, x_j - x_k > 0 \\ 0 & if\, x_j - x_k = 0 \\ -1 & if\, x_j - x_k < 0 \end{cases} \quad (3)$$

The variance of S is computed by the following equation which takes into account that ties may be present

$$VAR(s) = 1\left[\frac{n(n-1)}{18}(2n+5) - \sum_{p=1}^{a} t_p(t_p-1)(2t_p+5)\right] \quad (4)$$

Where, n is the number of data points, q is the number of tied groups and t_p is the number of data values in the $_p^{th}$ group. Z statistics or Normal Approximation test generally used when the sample size is greater than 10. The Normal approximation test (Z test) is developed by both the values of S and VAR(S) (Equation 5).

$$Z = \begin{cases} \dfrac{S-1}{\sqrt{VAR\,(S)}} & if\, S > 0 \\ 0 & if\, S = 0 \\ \dfrac{S+1}{\sqrt{VAR\,(S)}} & if\, S < 0 \end{cases} \quad (5)$$

The statistically significant trend is assessed by this Z value. The positive and negative values of Z denotes increasing and decreasing trend respectively. The statistic Z has a normal distribution. To test for either an increasing or decreasing monotone trend (a two-tailed test) at α level of significance, H_0 is rejected if the absolute value of Z is greater than $Z_{1-\alpha/2}$, where $Z_{1-\alpha/2}$ is acquired from the standard normal cumulative distribution tables(Tabari and Talaee, 2011).

Sen's slope estimator

To estimate the true slope of an existing trend (as change per year) the Sen's nonparametric method is used. It can be in cases where the trend can be assumed to be linear. This means that f (t)in equation (1) is equal to

$$f(t) = Q_t + B \qquad (6)$$

Where, Q is the slope and B is a constant.

To get the slope estimate Q in equation (6) we first calculate the slopes of all data value pairs

$$Q_t = \frac{X_j - X_k}{j - k} \qquad (7)$$

Where, x_j and x_k are the data scores at times *j* and *k* (*j*>*k*) respectively. If there are n values x_j in the time series we get as many as N = $n_{(n-1)/2}$ slope estimates of Q_i. The Sen's estimator of slope is the median of these N values of Q_i. The N values of Q_i are ranked from the smallest to the largest and the Sen's estimator is

$$Q = Q_{(N+1)/2} \qquad \text{if N is odd}$$

Or (8)

$$Q = \frac{1}{2}(Q_{[N/2]} + (Q_{[(N+2)/2]}) \qquad \text{if N is even}$$

Q is tested with a two-sided confidence interval at 100(1-α) % and the slope estimate is obtained by the nonparametric method.

The confidence interval at two different confidence levels; α= 0.01 and α= 0.05 as follows

$$C_\alpha = Z_{1-\alpha/2}\sqrt{VAR(S)} \quad (9)$$

Where, VAR(S) has been defined in equation (4), and $Z_{1-\alpha/2}$ is obtained from the standard normal distribution.

After that, $M_1 = (N - C_\alpha)/2$ and $M_2 = (N + C_\alpha)/2$ are computed. The lower and upper limits of the confidence interval, Q_{min} and Q_{max}, are the M_1^{th} largest and the $(M_2+1)^{th}$ largest of the N ordered slope estimates Q_i. If M_1 is not a whole number the lower limit is interpolated. Correspondingly, if M_2 is not a whole number the upper limit is interpolated.

Then to show the relationship between Agricultural Productivity and agricultural inputs, a set of threeinputs have been taken into account to determine the degree of relationship. This inputs are cropped area, Irrigated area, fertilizer consumption,In order to achieve the degree of relationship Karl Pearson product movement correlation coefficient technique is used.The technique is as under:

$$\text{Correlation Coefficient(r)} = \frac{\sum XY\text{-} (\sum X)(\sum Y)}{\sqrt{[n\sum X2\text{-}(\sum X)2] \times [n\sum Y2\text{-}(\sum Y)2}}$$

Where,r is the co-efficient of correlation;X is Independent variable;Y is Dependent variable;n is the number of observation

RESULTS AND DISCUSSION

Spatial variation of Agricultural productivity:

Spatial variation means variationin a particular areal unitand which is so much important for making out the regional inequality.So, districtspecific change in some crop productivity has compared between two decades (1990-91 to 2000-01 and 2000-01 to 2010-10). Though this state is well known for rice cultivation, in the present study nine crops are selected according to their percentage share in cropped area. On the basis of crop productivity, a district wise sequential arrangement of five crops (out of nine crops) in 1990-91 and 2010-11 period has presented in table-1& table-2 respectively. In 1990-91 periods, Aus paddy wasthe 1st crop inBurdwan, Birbhum, Howrah, Hooghly, N 24 Paragana district but in allsaid districts except Birbhum, 1st crop has been changed from auspaddy to potato in 2010-11 perioddue to decrease of average aus cropped area from 4.95 to 2.83 %as well as increase of average potato cropped area from 5.76 to 10.74%. In Nine districts of this state (Bankura, Midnapore, Nadia, Murshidabad, Uttar Dinajpur, Malda, Jalpaigri, Coochbehar, Purulia), maize was the 1st crop in 1990-91 and it is changed in 2010-11. It may be due to increase of fertilizer consumption (45.58 to 105.31 thousand tonne). Highest productivity of aus paddy has shifted from N 24 Paragana to Burdwanin those two decades due to two fold increase (85.80 to 164.5 thousand tonne)of fertilizer consumption.On the other, Bardwan was highest in Amanpaddy productivity in 1990-91 but Hooghly isexceeded Bardwan in 2010-11 because of enhancement of irrigated area and fertilizer consumption. In case of boro productivity, Malda is in 1stposition since 1990-91 because of holding more or less same cropped area, increament ofboth irrigated area and fertilizer consumption. DakhshinDinajpur is advanced from Uttar Dinajpur in wheat productivity in between aforesaid two periods. Maize productivity has been excessively diminishingin Bankura (highest) since 1990-91. The causes behind this diminution is mainly increase of cropped area, and fertilizer consumption. But Bankura has surpassed Howrah in jute productivity because of increasing cropped area from 4% to 12.63% and fertilizer consumption from 34 to 73 thousand tonne in between those two periods. From 1990-91, S 24 paragana is occupied its same highest position in Repseed-Mustard productivity.

On an average, the crop productivity of West Bengal have been facing changing pattern.Aus

Paddy (1.07 to 1.01), Aman Paddy (1.02 to 0.99), Wheat Paddy (0.94 to 0.92), Maize (1.76 to 0.98) and Jute (1.01 to 0.94) have experienced decreasing tendency from 1990-91 to 2010-11 periods and potato (0.74 to 1.14), rapeseed-mustard (0.94 to 0.96), Boro paddy (0.91 – 0.93) have experienced increasing tendency in same time period.

Relationship between Agricultural productivity (AP) & Agricultural Inputs (AI):

Agricultural production and efficiency are largely depends upon the agricultural inputs. Agricultural input means those technologies which have received increasing emphasis and breakthrough in agriculture.In this study four basic inputs have been chosen i.e. cropped area irrigated area, fertilizer consumption, and average rainfall in crop period.

Cropped area:

Cropped area means the total area sown once as a specific crop in a particular year. Agricultural productivity and the cropped area have a reciprocal relationship. Over the previous century, area occupied by agricultural landis nearly doubled globally (Houghton, 1994). The pace of cropland expansion has just increased by 10 % (Etter *et al.*, 2005). Here district wise change of cropped area has compared between two decades (1990-91 to 2000-01 and 2000-01 to 2010-11). Total cropped area of each crop (nine crops) has changed through time. The eleven districts of this state have been facing contraction of total cropped area and Bankura and Birbum has experiencedmaximum contraction. Alternatively Cropped area hasexpanded in Midnapore, Murshidabad, Hooghly, Uttar Dinajpur, Dakshin Dinajpur and Darjeeling districts and Midnapore is heighest among those. In crop specific analysis, cropped area of Aus Paddy and Aman paddy have decreased in most of the districts but the scenario has been changed in Boro paddy and Potato. Also the condition of Wheat, Jute and Sugarcane is not so well.

Irrigated area:

Irrigation connotes maintaining the water in the soil required for plant growth at particular time and place of deficient water supply. The agricultural aspect of irrigation denotes to use irrigation water for various cropping pattern and agricultural practices. Irrigation brings fourth 30 to 40% of World's food crops on only 17 % of all arable land (Seckler *et al.*, 1998). In water scarcity region,irrigation is deemed necessary for the extreme production of crops. So, if the percentage of irrigated area to the total cropped area has to be increased then the productivity of crops also enhance. In West Bengal, average irrigated area has reduced from 145.07 to 131.11 thousand hectares and in most of the districts, percentage of irrigated area to the total cropped area has reduced from 1990-91 to 2010-11. Only Burdwan, Birbhum, Bankura and Purulia have near about 50% irrigated area to the total cropped area and all other districts have no sufficient irrigated area to enhance the productivity.

Fertilizer Consumption:

Fertilizer,amaterial of natural and chemical origin is applied to soil to enhance the production ofagricultural crops. It provides three main macronutrient to the soil i.e. Nitrogen (N) for leaf growth, Phosphorus (P) for development of roots, flowers, seed and fruit and Potassium (K) for stem growth, movement of water in plants. These nutrients are needed for boosting plant growth as well as efficient crop production. In West Bengal, use of fertilizer has increased (752.90 to 1031.53 '000 tonnes) from 1990-91 to 2010-11 t. Also average fertilizer consumption per hectare cropped area also has raised from 120.48 kg to 242.70 kg in between these two decades. In spite of increasing the usage of fertilizer, the condition is turned around in the districts of Midnapore, Howrah and Darjeeling.

Cropped area, Fertilizer consumption, irrigated area and also rainfall is most important inputs in crop productivity. From table-3, it has been shown that in between two decades the relationship of agricultural inputs is varying with crop productivity. Irrigated area and fertilizer have strong influence on Aus Paddy, Aman Paddy, Potato and Sugarcane productivity. On the other hand, cropped area and irrigated area has influencing moderately on Boro Paddy, Wheat, Sugarcane productivity. But Rainfall has also strong positive relationship with Aus Paddy, Aman Paddy, jute, sugarcane productivity.

Trend of agricultural productivity:

Trend of agricultural productivity depicts the temporal changes in productivity which has computed between two decades (1990-91 to 2000-01 and 2000-01 to 2010-11). Also magnitude of productivitytrendsis obtained by the Mann–Kendall test, the Sen's slope estimator. Here both the positive and negative trend has recognized. Table 4 showing the crop wise significant positive and negative trend. Most of the districts has significant negative trends at the 95%, 99% and 99.9% confidence levels regarding various crop productivity.In the entire crop wise trend map, blue colour and green colour indicate the positive and negative trend respectively.

The average productivity of Aus paddy has been decrease by 6% since 1990-91.Out of eighteen districts(fig-5 & 6) only 4 districts i.e.Purulia, Malda, Murshidabad and Coochbehar have positive trend in aus paddy productivity (1990-91 to 2000-01) but except Murshidabad other aforesaid three districts has facednegative trend in in next decades because of so much decrease of crop area (Fig-2.a).

In 2010-2011 period,the scenario regarding productivity is well enough because there are about ten districts which have positive trend in Aus paddy prodctivity and especially Hooghly and Birbhum have gained positive trend for its strong relationship between Irrigation and fertilizer consumption (shown in table-3).Comperatively, Darjeeling, Jalpaiguri, S 24 Paragana, Midnapore district are in bad condition in Aus paddy productivity since 1990-91.

On the basis of cropped area and production, Aman paddy is the main crop in West Bengal. Like Aus Paddy the average productivity of Aman paddy also has declined 3% and most of the districts have facing despairing condition. In 1990-91 period eleven districts namely Medinipur, N & S 24 Paragana, Howrah, Hooghly, Burdwan, Murshidabad, Nadia, Darjeeling, Jalpaiguri and Coohbehar, have negative trend in Aman paddy productivity (Fig-7) because of decreasing cropped area but among those districts some districts has changed into positive trend in 2010-11 period due to increase of irrigation, fertilizer consumption and rainfall. Alongside, out of other six districts which have positive trend (1990-91), three districts (Purulia, Bankura, Birbhum) have changed their trend to negative for decreasing crop area in 2010-11 (Fig-2.b).

In case of Boro paddy productivity,the condition of West Bengal is not so well enough since 1990-91. The average productivity is declined by 3% because the increasing tendency of agricultural inputs (Cropped area, Irrigated area and Fertilizer consumption) is not sufficient to enhance the productivity. But if we go to district wise analysis, then it has been seen that Out of seventeen districts of this state,six districts (Midnapore, Howrah, Hooghly, S 24 Paragana, Malda and Jalpaiguri) have changed its productivity from negative to positive trend from 1990-91 to 2010-11 (Fig-9) and the causes behind this is increasing cropped area, irrigated area and Rainfall. Midnpur is one such district which was in negative trend in past decade,isin positive trendin recent decade due to enhancing irrigated areato the total cropped area (33.1 to 40.13 %) and fertilizer consumption (81.48 to 183.83 kg/hectare). In Malda irrigated area to the total cropped area is increased which in turn enhance productivity. But overall, Boro paddy productivity in this state is better than the aus paddy and aman paddy because of Irrigation facilities and fertilizer consumption.

This state is stand in a receding status comparatively to the other states of India in regarding Wheat productivity since 1990-91 because of the average total cropped area under wheat cultivation (293.55 thousand hectare) is much more less than the other crops (Aman Paddy- 3853.55 and Boro paddy- 1164.15 thousandhactare). The average wheat productivity in this state is declined by 5 % since 1990-91. But in district wise scenario it has seen that (Fig-11) fourdistricts(Bankura, Murshidabad, Birbhum and Burdwan) have positive trend due to increasing cropped area, irrigation and fertilizer and rest of the districts have negative trend in 1990-91 to 2000-01 period due to less sharing of total cropped area (3.71% in 1990-91) than the other crops (59.54% in Aman paddy, 12.40 % in Boro Paddy and 8.44 % in Aus Paddy). In 2000-01 to 2010-11 most of the south Bengal districts namely paschim and PurbaMedinipur, Howrah, Hooghly, N & S 24 Paragan and northernmost districts i.e. Jalpaiguri, Coochbehar, Uttar &DakshinDinajpur, Malda get positive trend in wheat productivity for raisingthe use of fertilizer and irrigated area. Only two districts (Bankura and Murshidabad) have been kept its same productivity since 1990-91 to 2010-11 due to more fertilizer consumption, increasing cropped area and also irrigation facility.Purulia and Darjeeling districts have stood themselves in negative trend since 1990-91 for their very low sharing of cropped area.

In 1990-91 Maize was an important crop in West Bengal with respect to productivity but in 2010-11, the condition has been changed vastly because of cropped area contraction. The average productivity of maize has been decreased by 78 % because the percentage share of total cropped area is very low than the other crops.In this state among the 17 districts only 7 districts have positive trend of productivity in 1990-91 to 2000-01 periods and Malda, Murshidabad and Jalpaiguri have high positive trend of productivity among them due to increasing share of cropped area but in next decade due to both increase of fertilizer consumption and irrigated area, fourteen districts (fig-14) have positive trend of productivity. In time, only Hooghly, N 24 Paragana, Murshidabad and Uttar Dinajpur have been proceeding with its same productivity. Since 1990-91 period, maize productivityhas faced negative trend in Purulia, Birbhum and Darjeeling districts due to less cropped area (Fig- 2.e), poor irrigation facility and rugged terrain.

In West Bengal, potato is most important crop after rice and jute and the productivity of this crop is tremendously raised by 40% due to increasing percentage of cropped area since 1990-91 (2.71 % to 7.63 %). Also, it is seen from the fig-15 & 16 that, out of seventeen districts only five districts (Birbhum, Burdwan, Bankura, Howrah and hooghly) has positive trend and rest of the districts have negative trend (1990-91 to 2000-01) in potato productivity but that scenario has been change surprisingly in next decade. Except Darjeeling, all of sixteen districts have positive trend of productivity for their strong relation to cropped area and large scale use of irrigation and fertilizer (table-3). In all of the districts of this state, cropped area has been increased during 1990-91 to 2010-11 period. The area of potato cultivation has been increased tremendously in Darjeeling but the trend of productivity is till negative.

Though in India, West Bengal is the undisputed king of jute production, the productivity is continuously decreasing from 1990-91 to 2010-11. In fig-17 only two districts i.e. Murshidabad and Nadia have been recognized as negative trend and in spite of increasing cultivated area till those two districts have been facing negative trend in productivity in 2000-01 to 2010-11. Purulia is not being able to agricultural practice of jute because of its rain fed character. Fourteen districts of this state have been facing positive trend and out of them only seven has kept its same trend because of its strong relation with Fertilizer consumption, irrigated area and rainfall (Table-3). Murshidabad has highest cultivated area of jute among all other but has been facing negative trend in jute productivity since 1990-91 due to decrease of demand.

In Comparison to other sate of India, West Bengal is in a backward position in sugarcane productivity because of over emphasizing on rice, potato and jute cultivation and cropped area contraction. In 1990-91 to 2000-01 period, Midnapur was in first position of sugarcane productivity (table-1)but it has been faced negative trend due to decreasing cropped area. But this district have been replaced by Malda districts as a first position (table-2) and it has continued its positive trend since 1990-91 to 2010-11 because of increasing cropped area, irrigation facility. Out of seventeen districts, only five districts of this state have negative trend of productivity and the main cause behind this negative trend is loss of cropped area (Fig- 2.h) in 1990-91 to 2000-01 period but and in 2000-01 to 2010-11 period, negative trend has shown in ten districts due to cropped area contraction mainly. So, the sugarcane productivity in this state has been worsening on account of losing cropped area in all districts (except Murshidabad). Coochbehar, Malda, Birbhum, Burdwan has retained their positive trend due to large scale utilization of irrigation and fertilizer consumption.

Rapeseed-Mustard is an important crop in west Bengal. Since 1990-91. The productivity is raised by 2%. From the fig-21 & 22, it has been realized that in rapeseed-mustard productivity, six districts (Purulia, Burdwan, Birbhum, Murshidabad, Malda and Darjeeling) of this state have positive trend in 1990-91 to 2000-01 for their cropped area enhancement. But in 2000-01 to 2010-11among those six districts, Purulia, Bankura, Burdwan and Darjeeling has been experienced negative trend due to loss of cropped area. Since 1990-91, S 24 Paragana is in a top position but has been faced negative trend in 1990-91 to 2000-01 period. In Bankura, Howrah, S 24 Paragana, Uttar &DakshinDinajpur, jalpaiguri and Coochbehar, due to decreasing cropped area the productivity trend is negative since 1990-91. Nadia, Hooghly and PaschimMedinipur have experienced positive trend due to more irrigation facility, fertilizer consumption.

CONCLUSION

The entire studyinfers that most of the agricultural crops have been facing decrement of cropped area and average productivity except potato. Maximum cropped area is decreased in respect to Aus Paddy cultivation.AmanPaddy is considered as major crop of West Bengal on the basis of sharing cropped area and productivity. Average potato productivity has been spectacularly increased and fifteen districts are in a positive trend. Though there have an increase of cropped area in between recent two decades, the average productivity of Boro Paddy and Rapeseed-mustard also isexperienced decreasing trend. Maize crop is diminished subsequently over two decades in term of productivity but the trend is slowly positive. In case of wheat, also productivity is decreased and nine district districts have negative trend. Overall, crop productivity scenario has characterised that northernmost hilly districts i.e. Darjeeling, Coochbehar, Jalpaiguri and westernmost undulating red-lateritic district i.e. Purulia and coastal saline zone i.e. S 24 Paragana has been experienced low productivity with reference to state level.Remaining districts have shown High productivity in agriculture.

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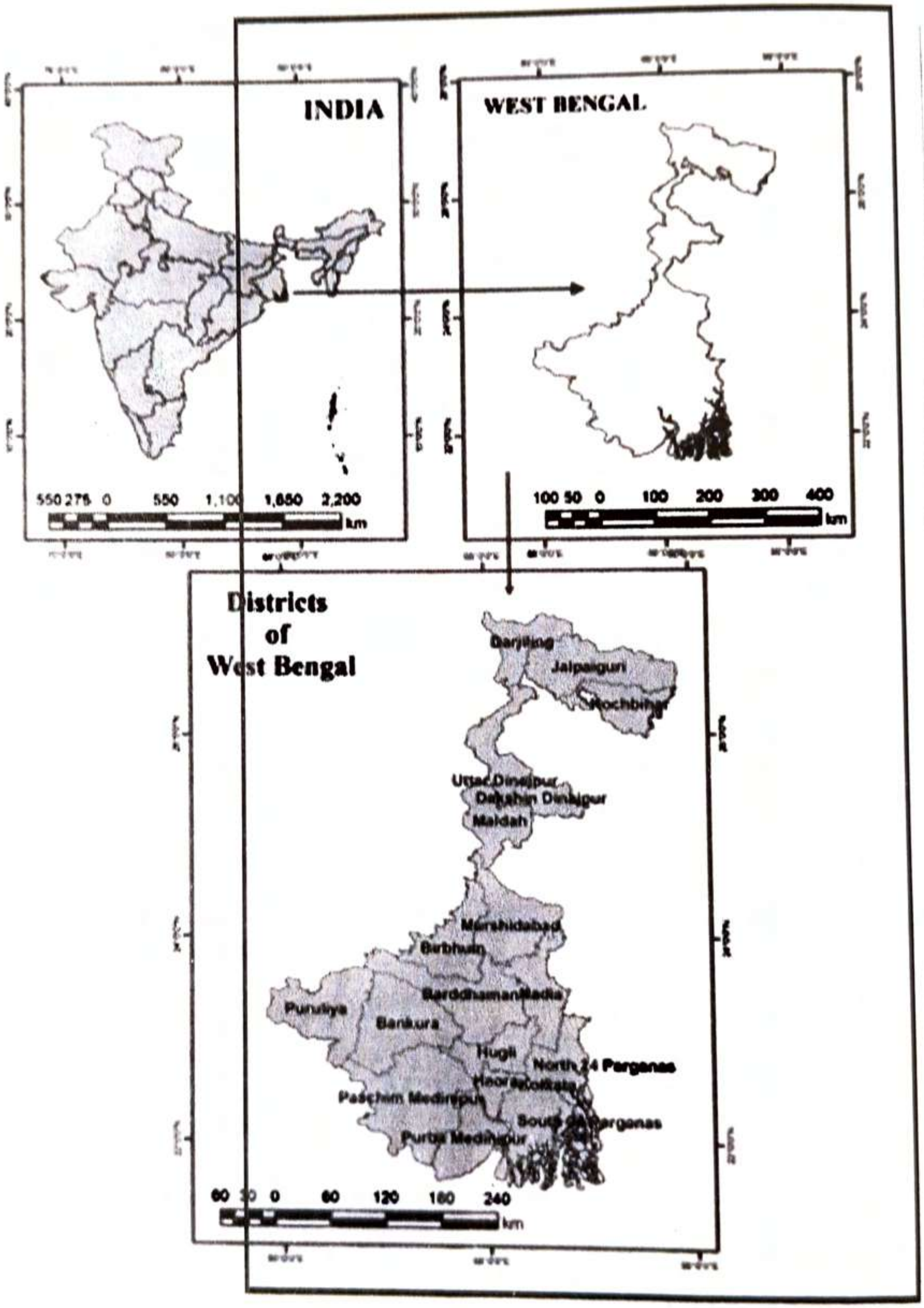


Fig 1 Study area

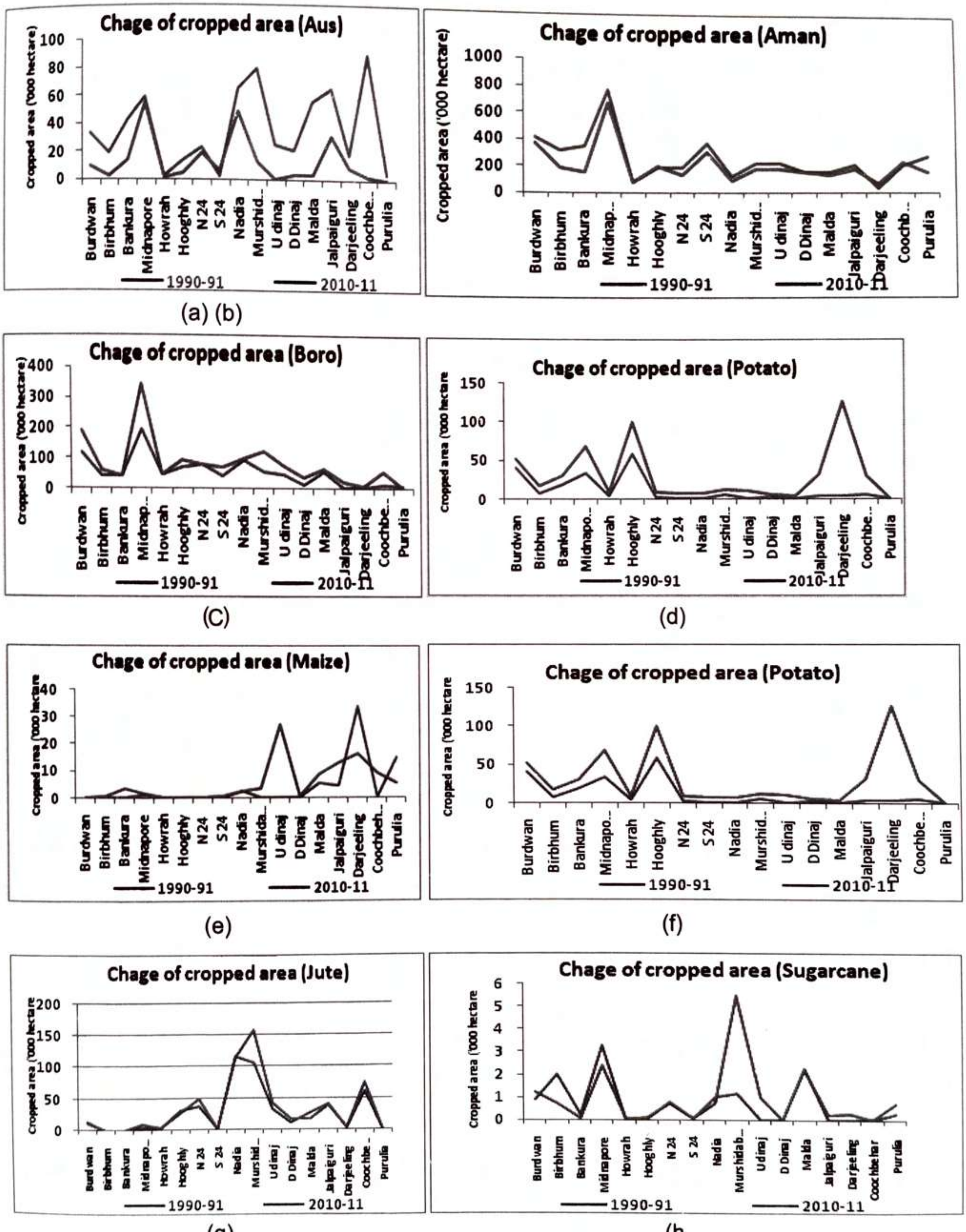


Fig 2 Districts wise changes of cropped area of some selected crops

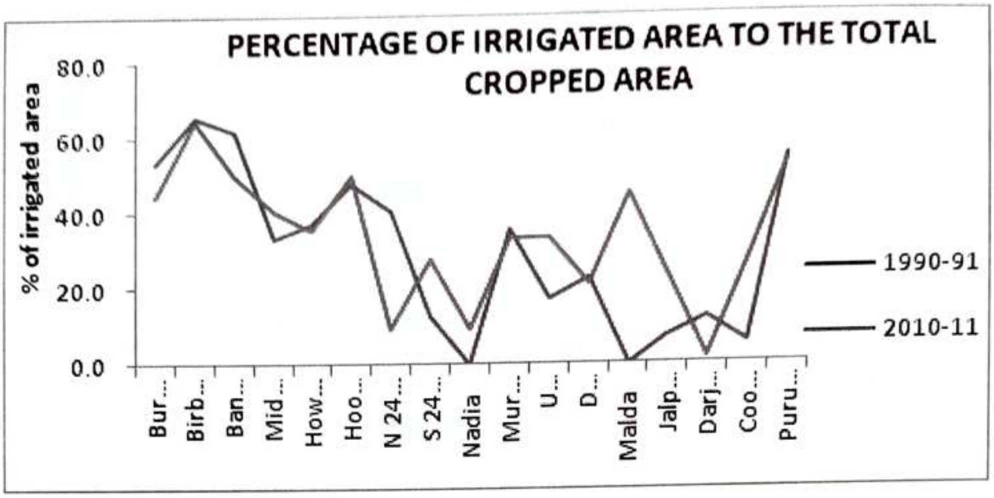


Fig 3 District wise change of irrigated area

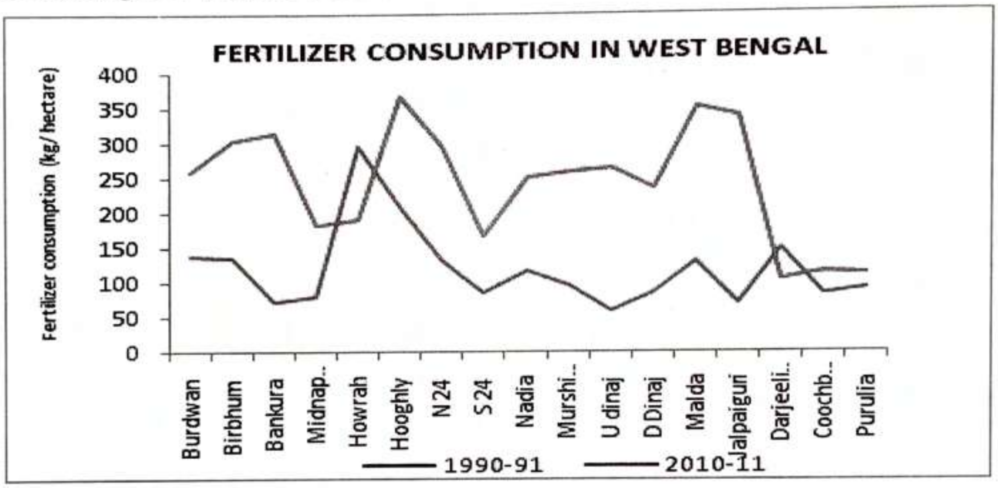
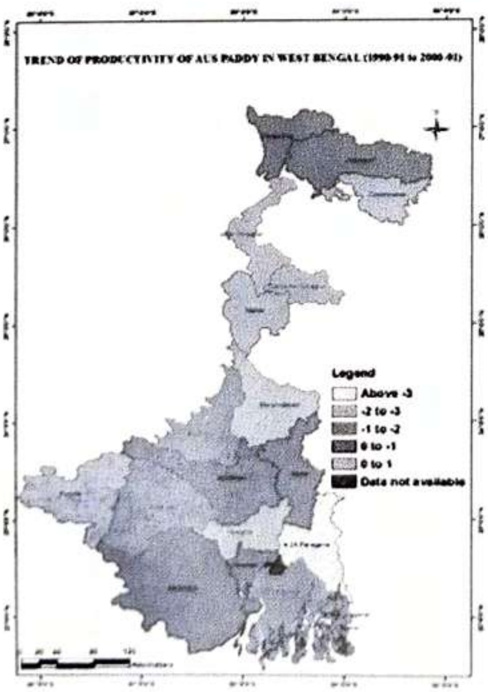


Fig 4 Fertilizer consumption per hectare cropped area



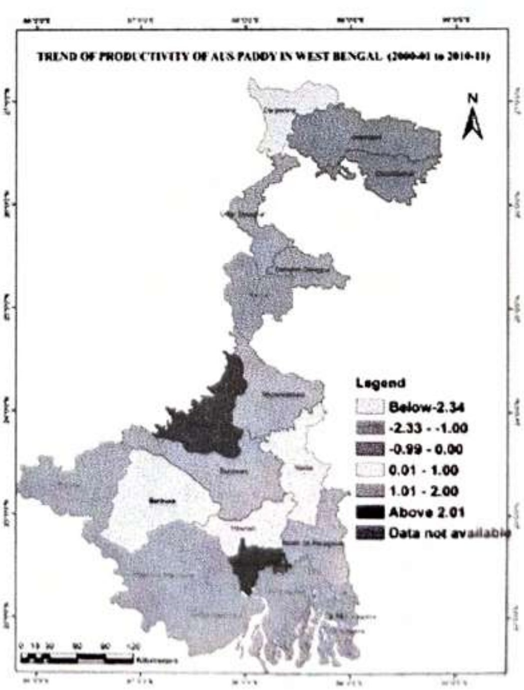


Fig 5 Trend of Aus productivity (1990-91 to 2000-01) Fig 6 Trend of Aus productivity (2000-01 to 2010-11)

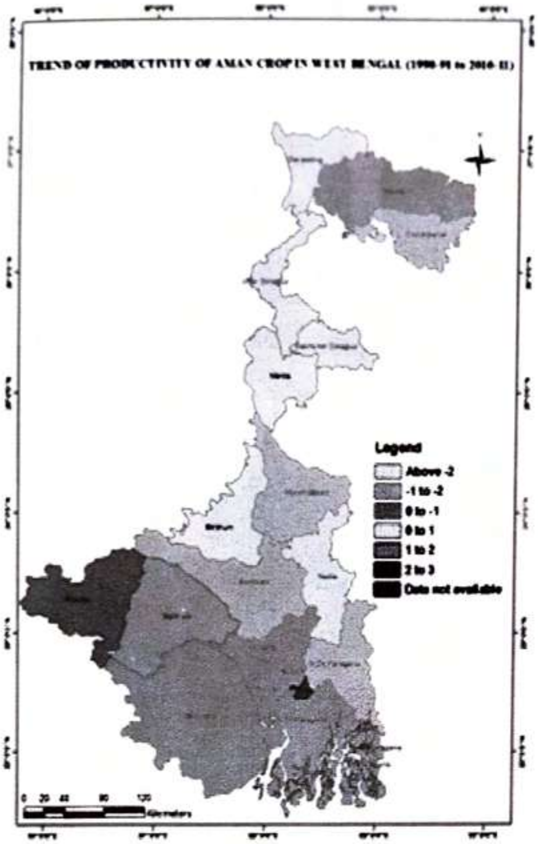


Fig 7 Trend of Aman productivity (1990-91 to 2000-01)

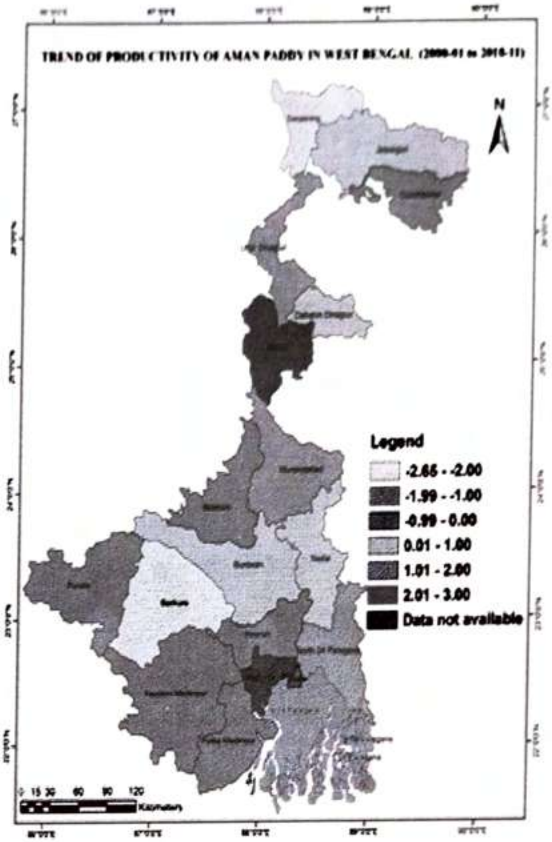


Fig 8 Trend of Aman productivity (2000-01 to 2010-11)

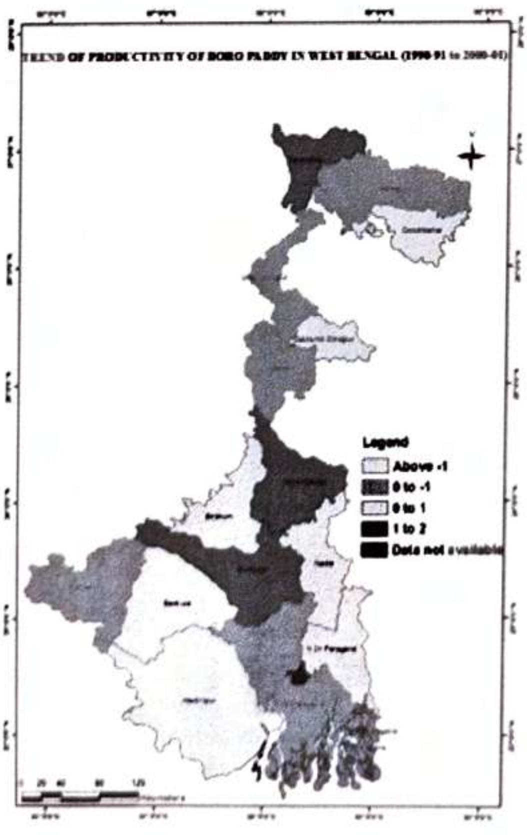


Fig 9 Trend of Boro productivity(1990-91 to 2000-01)

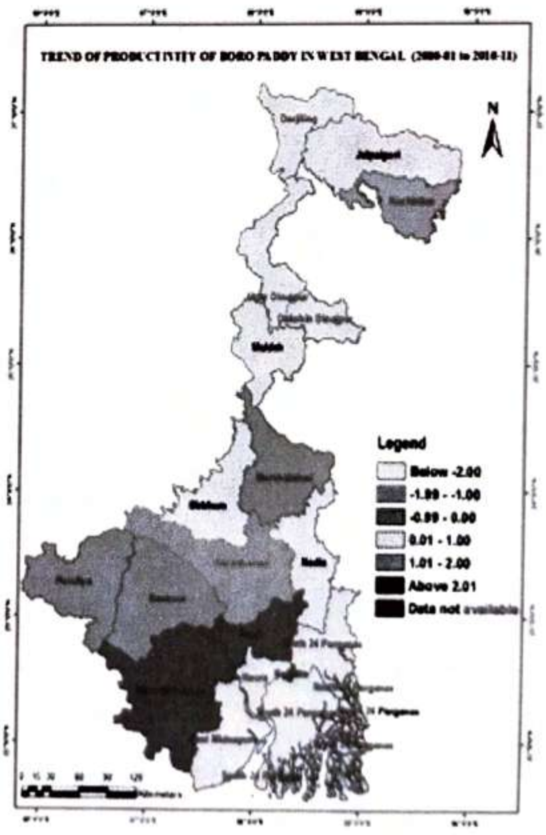


Fig 10 Trend of Boro productivity(2000-01 to 2010-11)

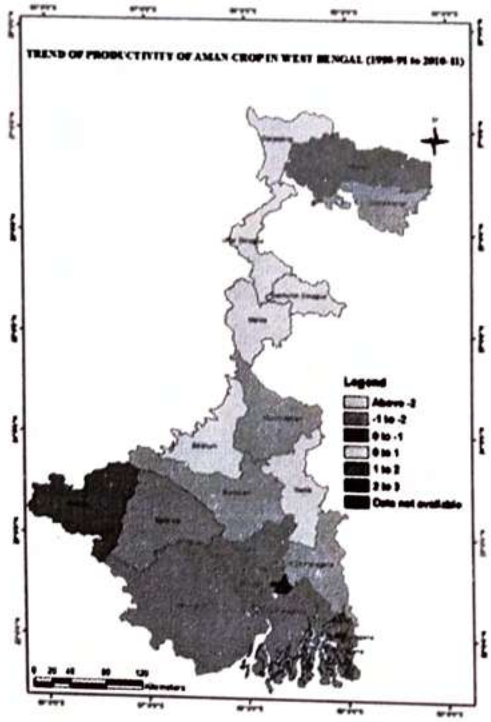


Fig 11 Trend of Wheat productivity(1990-91 to 2000-01)

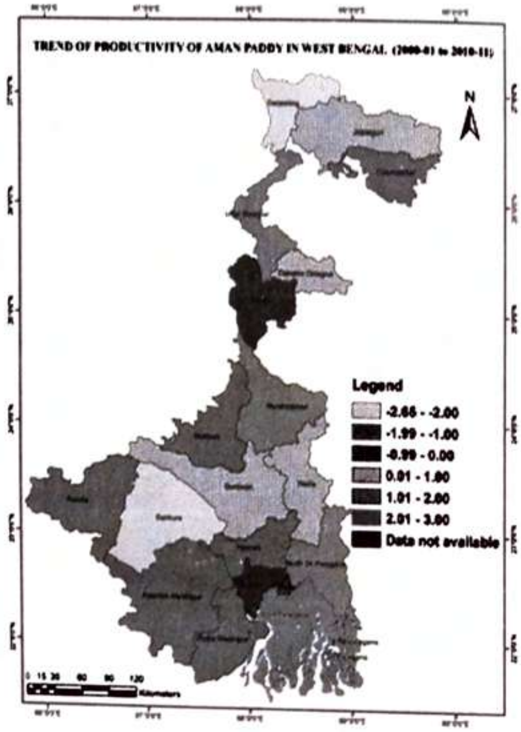


Fig 12 Trend of Wheat productivity(2000-01 to 2010-11)

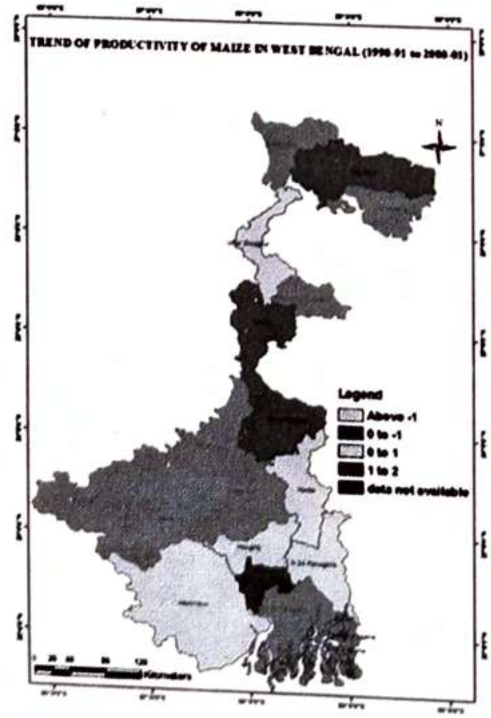


Fig 13 Trend of Maize productivity(1990-91 to 2000-01)

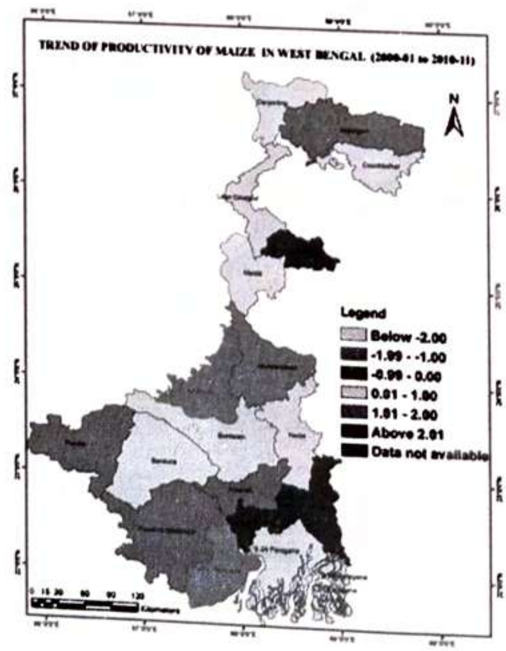


Fig 14 Trend of Maize productivity(2000-01 to 2010-11)

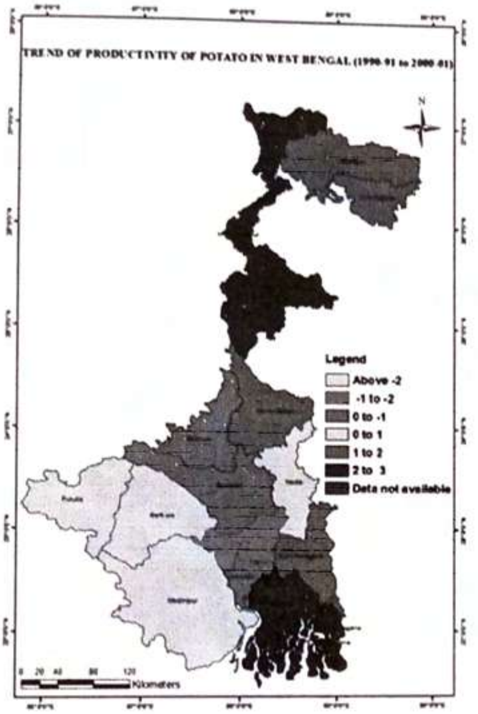


Fig 15 Trend of Potato productivity(1990-91 to 2000-01)

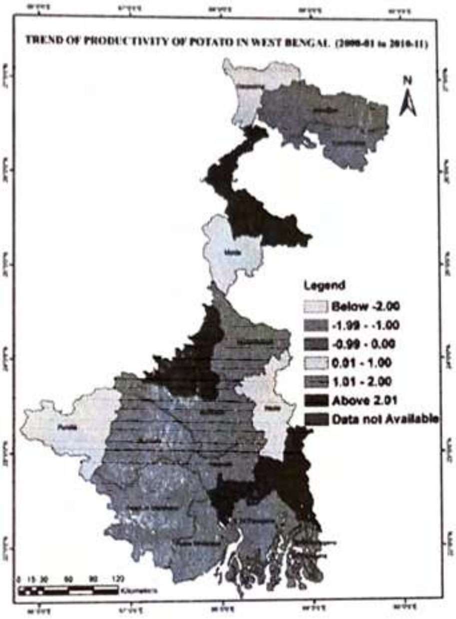


Fig 16 Trend of Potatoproductivity(2000-01 to 2010-11)

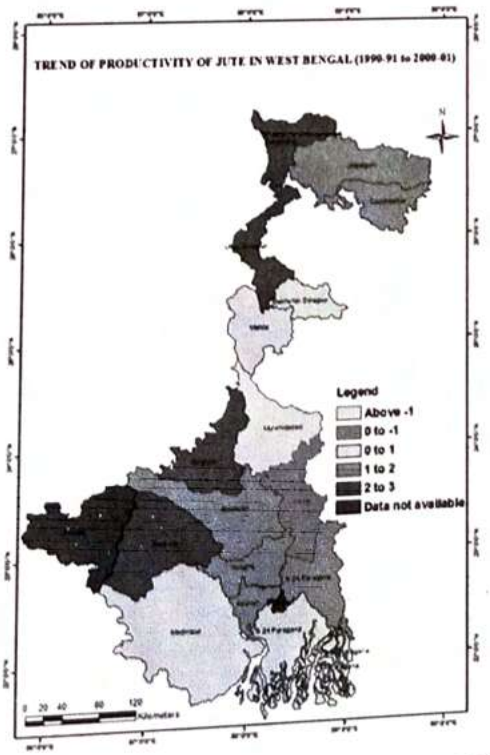


Fig 17 Trend of Jute productivity(1990-91 to 2000-01)

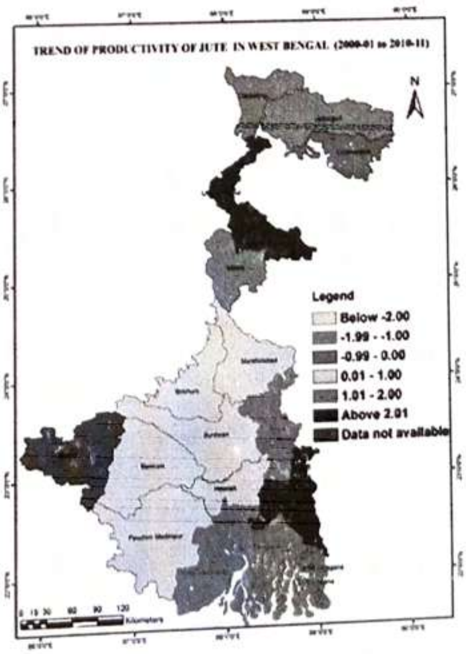


Fig 18 Trend of Jute productivity(2000-01 to 2010-11)

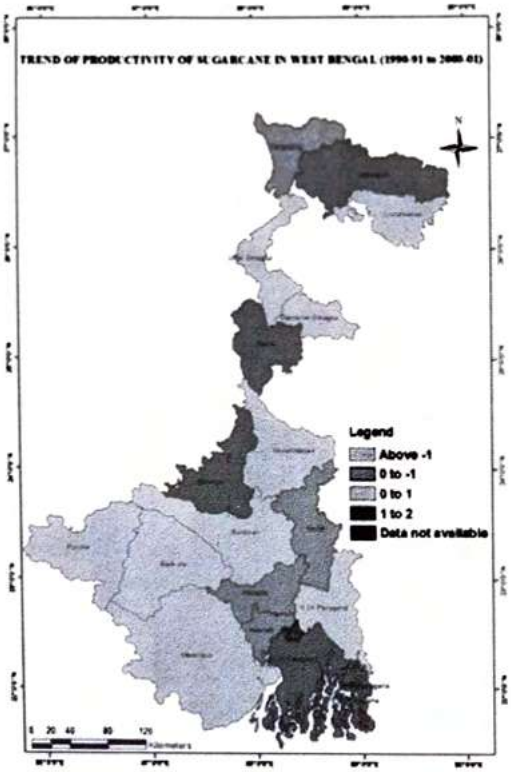


Fig 19 Trend of Sugarcane productivity (1990-91 to 2000-01)

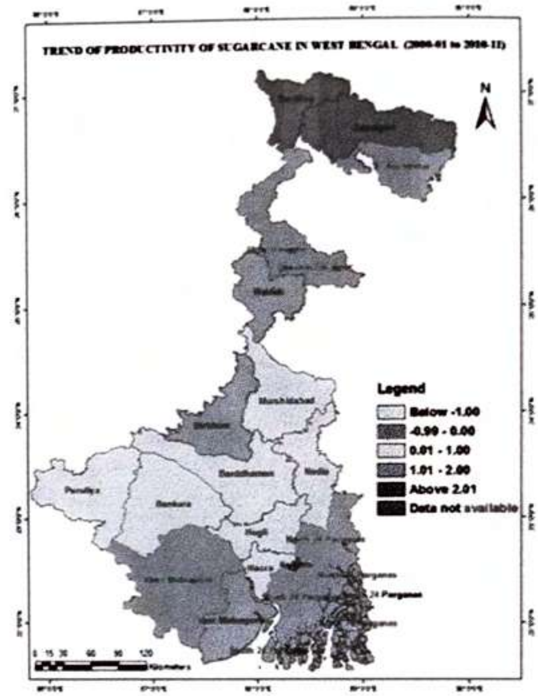


Fig 20 Trend of Sugarcane productivity (2000-01 to 2010-11)

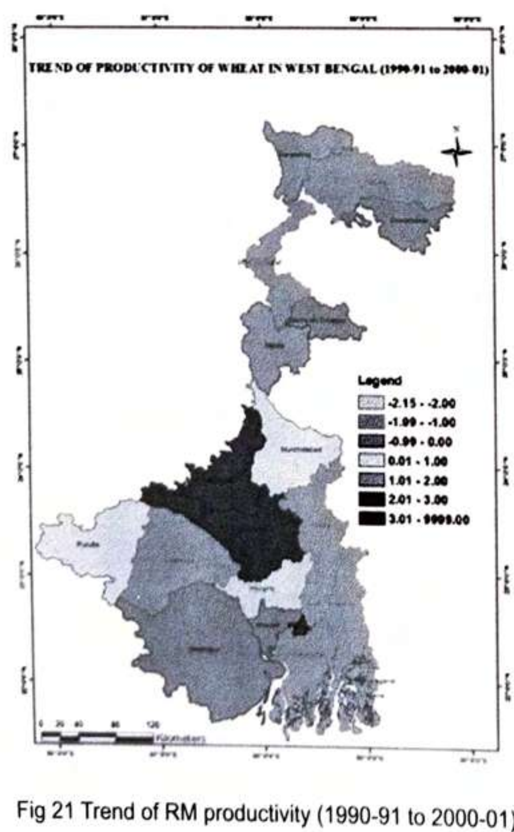


Fig 21 Trend of RM productivity (1990-91 to 2000-01)

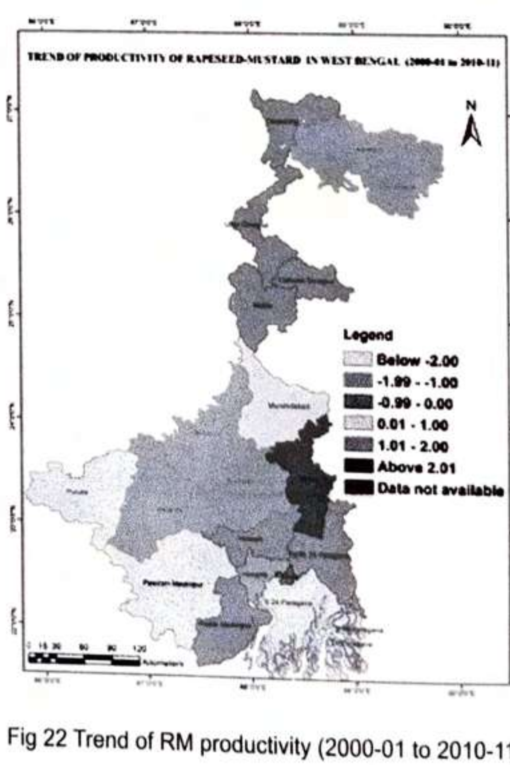


Fig 22 Trend of RM productivity (2000-01 to 2010-11)

Table 1 District wise sequential arrangement of crop in respect of productivity (1990-91)

Districts	DISTRICT WISE SEQUENTIAL ARRENGEMENT OF CROP(1990 1991)									
	1ST	Productivity	2ND	Productivity	3RD	Productivity	4TH	Productivity	5TH	Productivity
Burdwan	Aus	1.64	Aman*	1.57	Maize	1.57	Jute	1.25	Potato	1.12
Birbhum	Aus	1.72	Aman	1.30	Jute	1.23	Boro	0.96	Potato	0.93
Bankura	Maize*	4.62	Aus	1.60	Jute	1.29	Potato	1.15	Aman	1.14
Midnapur	Maize	2.30	Jute*	1.43	Sugarcane*	1.41	Aus	1.12	Boro	1.03
Howrah	Aus	1.65	Potato*	1.23	Jute	1.21	Wheat	1.01	Boro	0.97
Hooghly	Aus	1.42	Jute	1.30	Aman	1.29	Potato	1.12	RM	1.06
N 24 Paragana	Aus *	1.78	Aman	1.17	RM	1.12	Wheat	1.07	Jute	1.06
S 24 Paragana	RM*	1.41	Jute	1.12	boro	0.97	Aus	0.85	Wheat	0.85
Nadia	Maize	1.83	Aman	1.42	Jute	1.20	RM	1.20	Aus	1.11
Murshidabad	Maize	1.57	Aman	1.46	Jute	1.18	Boro	1.07	RM	1.04
U dinaj	Maize	3.15	Wheat *	1.24	boro	0.98	RM	0.89	Aman	0.81
D Dinaj	RM	1.28	Aus	1.16	Aman	1.11	Wheat	1.03	Boro	0.84
Malda	Maize	1.96	Wheat	1.20	Boro*	1.10	Aman	1.07	Sugarcane	0.99
Jalpaiguri	Maize	2.32	Boro	1.01	RM	0.81	Wheat	0.78	Aus	0.60
Darjeeling	RM	0.95	Aman	0.80	Jute	0.55	Wheat	0.52	Potato	0.41
Coochbehar	Maize	1.57	Aman	0.84	Wheat	0.84	Aus	0.81	Boro	0.81
Purulia	Maize	1.55	Sugarcane	1.10	Wheat	0.89	Boro	0.84	RM	0.79

Source: Prepared by the Author *Highest Productivity RM-Rapeseed-Mustard

Table 2 District wise sequential arrangement of crop in respect of productivity (2010-11)

Districts	DISTRICT WISE SEQUENTIAL ARRENGEMENT OF CROP(2010 2011)									
	1st crop	Productivity	2nd crop	Productivity	3rd crop	Productivity	4th crop	Productivity	5th crop	Productivity
Burdwan	Potato	1.48	Jute	1.47	Aus*	1.36	Sugarcane	1.29	Aman	1.17
Birbhum	Aus	1.31	Aman	1.16	Sugarcane	1.13	Potato	1.11	Boro	1.03
Bankura	Potato*	1.51	maize	1.51	Aus	1.10	Aman	1.00	Boro	0.91
E Midnapur	Jute	1.17	Wheat	1.10	RM	1.09	Boro	1.07	Potato	1.04
W Midnapur	Potato	1.51	Boro	1.10	Jute	1.08	Aus	1.05	Aman	1.00
Howrah	Potato	1.43	Jute	1.41	Aus	1.26	Boro	1.00	Aman	0.92
Hooghly	Jute*	1.49	Potato	1.38	Aman*	1.23	Aus	1.23	Maize	1.13
N 24 Paragana	Potato	1.42	RM	1.38	Jute	1.33	Sugarcane	1.14	Aus	1.09
S 24 Paragana	RM*	2.06	Potato	1.00	Boro	0.96	Wheat	0.95	Aman	0.85
Nadia	Sugarcane	1.12	Aman	1.08	Potato	1.07	Potato	1.07	RM	1.01
Murshidabad	Potato	1.19	Wheat	1.09	RM	1.08	Jute	1.04	Aman	1.04
U dinaj	Sugarcane	1.31	Potato	1.18	Aman	1.06	Maize	1.01	Wheat	1.00
D Dinaj	Maize*	1.58	Aman	1.19	Wheat*	1.11	Potato	1.06	Aus	1.05
Malda	Sugarcane*	1.37	Potato	1.16	Boro*	1.16	Aman	1.15	Wheat	1.11
Jalpaiguri	Sugarcane	1.09	Aman	0.91	Potato	0.91	Aus	0.89	Jute	0.84
Darjeeling	RM	0.98	maize	0.87	Jute	0.70	Aus	0.48	Aman	0.40
Coochbehar	Maize	0.95	Aman	0.92	Boro	0.88	Potato	0.85	Aus	0.79
Purulia	Maize	1.56	Boro	0.95	Aman	0.69	Potato	0.63	RM	0.54

Source: Prepared by the Author *Highest Productivity RM-Rapeseed-Mustard

Table 3 Relationship between productivity and agricultural inputs

AI →	Irrigated area (thousand hectare)		Fertilizer consumption (thousand tonne)		Cropped area (thousand hectare)		Rainfall (average in crop period in cm)	
Crops	1991	2011	1991	2011	1991	2011	1991	2011
Aus	0.57	0.43	0.54	0.54	0.19	0.10	0.52	0.11
Aman	0.55	0.54	0.49	0.64	0.02	0.30	0.44	0.51
Boro	0.36	0.41	0.40	0.32	0.40	0.50	0.34	0.57
Wheat	0.09	0.26	0.17	0.52	0.27	0.35	0.11	0.30
Maize	0.30	0.05	0.09	0.23	0.09	0.14	0.12	0.34
Jute	0.74	0.16	0.79	0.35	0.34	0.02	0.65	0.09
Sugarcane	0.73	0.17	0.51	0.45	0.58	0.34	0.65	0.76
Potato	0.67	0.49	0.72	0.55	0.63	0.42	0.02	0.14
Mustard	0.038	0.011	0.042	0.15	0.12	0.18	0.11	0.63

Source: Prepared by the author

Table-4 : values of statistics Z of the Mann–Kendall test and values of statistics Qmed of the Sen's slope estimator

1990-2001	Districts	Z	Signific.	Q	Signific.
Aman	N 24 Paragana	-1.97		-0.027	*
	Nadia	-2.50		-0.038	*
	Darjeeling	-2.33	*	-0.026	
	Purulia	2.15	*	0.020	
Aus	Hooghly	-2.15		-0.026	*
	N 24 Paragana	-3.58		-0.042	***
	U dinajpur	-2.15	*	-0.047	
	D dinajpur	-2.33	*	-0.026	
Jute	Birbhum	2.86		0.087	**
	Bankura	2.15		0.109	*
	U dinajpur	2.68	**	0.023	
	Darjeeling	2.50	*	0.032	
Mustard	Burdwan	2.33		0.016	*
	Birbhum	2.86		0.082	**
	Hooghly	-2.15		-0.052	*
	Nadia	-1.97		-0.020	*
	Malda	1.97	*	0.029	
Potato	Bankura	-2.33		-0.028	*
	S 24 Paragana	2.50		0.065	*
	U dinajpur	2.86	**	0.102	
	D Dinajpur	2.86	**	0.066	
	Malda	2.50	*	0.044	
	Jalpaiguri	1.97	*	0.049	
	Darjeeling	2.15	*	0.053	

2001-2011	Districts	Z	Signific.	Q	Signific.
Aman	Bankura	-2.65		-0.018	**
	Hooghly	2.65		0.012	**
	Malda	2.18	*	0.028	
	Darjeeling	-2.49	*	-0.038	
Aus	Birbhum	2.34		0.021	*
	E mid	-2.18		-0.039	*
	Hooghly	2.02		0.009	*
	Darjeeling	-2.34	*	-0.031	
Boro	W mid	2.49		0.016	*
	Hooghly	2.02		0.013	*
	U dinaj	-2.18	*	-0.011	
	Darjeeling	-2.96	**	-0.045	
Jute	Birbhum	-2.80		-0.070	**
	W mid	-2.49		-0.066	*
	N 24	2.65		0.020	**
	U dinaj	2.96	**	0.027	
Maize	Howrah	-1.97		-0.030	*
	Nadia	-2.49	*	-0.028	
	Malda	-3.27	**	-0.076	
	Darjeeling	-2.34	*	-0.062	
Potato	N 24	2.65		0.069	**
	U dinaj	2.49	*	0.059	
	Darjeeling	-2.02	*	-0.057	

* Trends statistically significant at the 95% confidence level.

**Trends statistically significant at the 99% confidence level.

*** Trends statistically significant at the 99% confidence level.