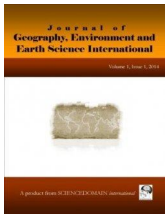

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A Study on the Productivity of Potato in Hugli District, West Bengal, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

In spite of its industrial importance, Hugli is one of the leading potato producing districts of West Bengal with momentous productivity. But the productivity has shown considerable variation in its quantity, yield per unit of land and area under the crop over the last few decades. The present study strives to assess the spatio-temporal dynamics, emphasizing on trend, growth and variability as well as inter-Block variations in potato productivity of Hugli District from 1990-91 to 2013-14. The study was primarily based on the secondary data obtained from various sources. Time series analysis (3 year moving average curve), Coppock's Instability Index and Sahu's Simple Achieved Variation have been used to analyze the trend, instability and sustainability of the productivity, whereas, Crop Yield and Concentration Indices Ranking Coefficient is employed to identify productivity regions of potato. The result has revealed a unique oscillating nature in area, yield and output over the study period. The area and the output of the crop have been increased almost 51.70% [Exponential R^2= 0.751] and 32.75% [Exponential R^2= 0.381] respectively, whereas the yield rate has shown an insignificant positive trend of growth [Exponential R^2= 0.014] during the same period. The Blocks have also revealed wide inter-disparity in productivity during the phase with considerable degree of instability and sustainability.

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Keywords: Crop yield and concentration indices ranking coefficient; Coppock's instability index; Sahu's simple achieved variation; productivity regions.

1. INTRODUCTION

Agricultural Productivity may be defined as 'the power of agriculture in particular locality to produce crops' regardless of the sources/causes of the power [1]. Simply, it is calculated as the ratio of total agricultural output to total input used and is often been considered as a measure of agricultural efficiency [2,3]. Various scholars have used multiple quantitative methods and techniques to assess crop productivity in global as well as in national and regional scale. Thomson (1926) has emphasized on gross output [4], whereas Kendall (1939) has proposed four coefficients such as 'Productivity Coefficient', 'Ranking Coefficient', 'Money Value Coefficient' and 'Starch or Energy Coefficient' for computation of agricultural productivity [1]. Khusro (1965) has explained the agricultural productivity as the output per unit of a single input and output per unit cost of all inputs used in the production system [5]. In 1965, Shafi has measured the agricultural productivity in terms of the labour efficiency by dividing the gross production in any unit of area by the number of labours employed in the cultivation process [6]. Yang has introduced a crop yield index in this context [7], which has further been exercised by Siddiqui and Usmani [8] and Aktar for the areas of Northern Bihar and West Bengal respectively [3]. Shafi has tried to assess the agricultural efficiency in India in 1967 and 1969 [9,10] by applying Stamp's Standard Nutrition Unit technique, proposed in 1958 [11]; whereas Mohammad and Singh (1981) have proposed to do the same by using net total productivity [12]. Dayal (1984) has computed the agricultural productivity in India in terms of 'land productivity', 'labour productivity' and 'aggregate productivity' [13], whereas Rosegrant and Evenson (1992) have used Tornquist-Theil total factor productivity index for the same purpose (for the period of 1956-87) [14]. Dharmasiri (2012) has employed 'Average Productivity Index' (API) to appraise the agricultural productivity in Sri Lanka [15]. On contrary, Singh (1976) has measured the regional disparity in agricultural productivity by delineating productivity regions with his technique called the 'crop yield and concentration indices ranking coefficient (*RCYiCi*)' [16]. In 2018, Saha and Mondal have applied the same technique in their study on the spatio-temporal variations of productivity of *boro* paddy in West Bengal for the period of 1994-95 to 2013-14 [17].

Since its introduction as an important cash crop during the last quarter of the last century, Hugli has attained a notable position in the production of potato (*Solanum tuberosum*) among the districts of West Bengal. More than 1/4th of the geographical area and almost 3/4th of the total farmers of the district have been familiar with potato cultivation since the 1970s [18]. In 2013-14, the district has possessed the second place (after Paschim Midnapore) by producing 2087514 metric tonnes of potato (comprising 27.93% of the state's total production) and nearly 33.25% (99.8 thousand hectares) agricultural land was used for the purpose. Concurrently, it has reported the highest average yield rate of 20811 kg/hectare among the districts of the state (District Statistical Handbook, Hugli, 2013-14). Potato ranked the highest produced crop of the district followed by *Aman* and *Boro* in 2013-14 and had achieved 2nd position in terms of area under the crop. Even in major Blocks of the District, potato has acquired the prime position instead of paddy and thus it has played a key role in the agrarian system of the area as well as in the life of the farmers.

Historically the district has experienced sequential alterations in cropping pattern from paddy and jute to potato during the last half of the 19th century [18]. Drastic fall in the demand of jute as fiber crop and increasing demand for potato in the regional and national market both as a food and cash crop have encouraged the farmers to switch over to potato cultivation. As a consequence, the district has witnessed a wider and significant spatio-temporal variation in area, output and yield rate of potato during the past few decades. One-sample t-test has demonstrated the significant variation in area, production and yield rate with the t-value of 35.90, 25.28 and 44.27 respectively over the study period of 24 years (1990-91 to 2013-14) (95% confidence level). Further, significant inter-Block disparity in the area, production and yield rate has also been observed during this phase with the F-value of 70.62, 47.67 and 1.74 respectively (One way ANOVA, Significance level 0.05%). Diverse agro-ecological situation along with some other factors like degree of urbanization, socio-economic status of farmers, cost of production, storage and marketing;

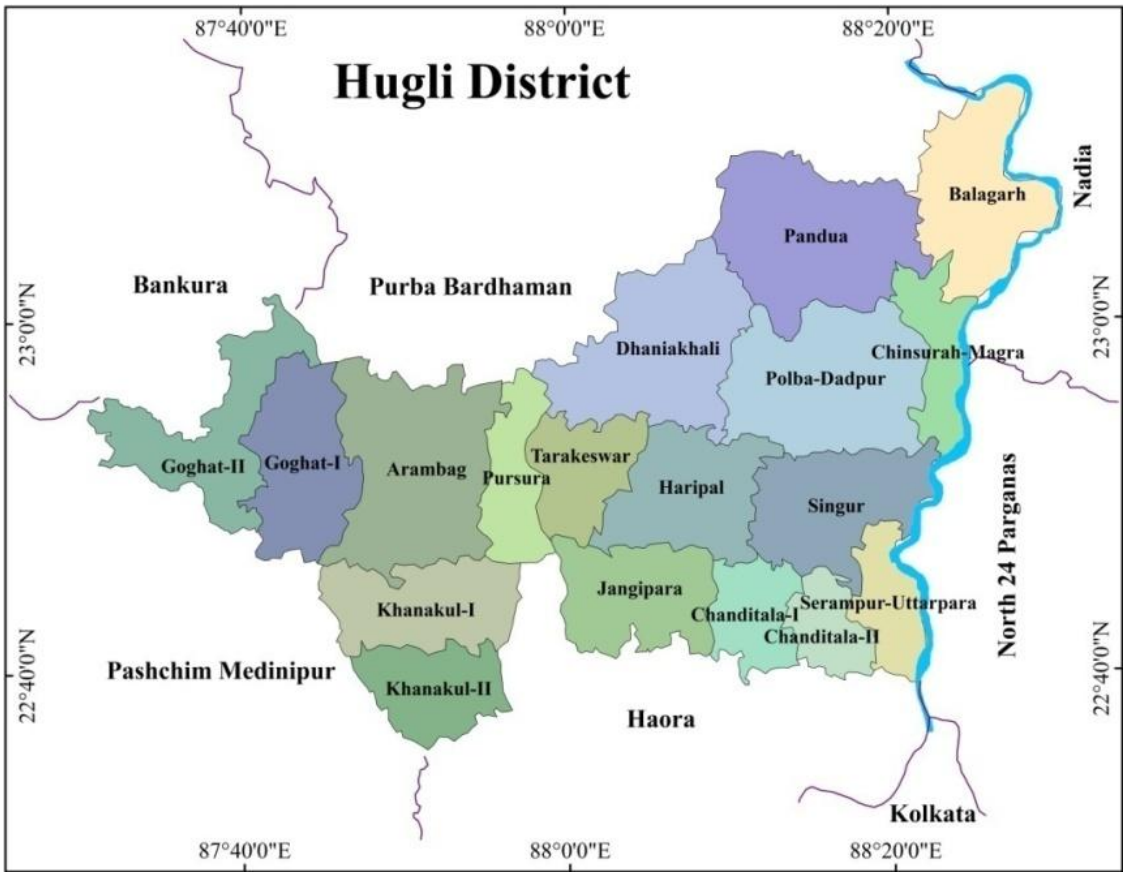

Fig. 1. The study area

infrastructural facilities including cold storages and transport routs, proximity of the market, recent changes in cropping pattern, emphasizing on *Boro* paddy cultivation (18). These have revealed farmers' attitude towards potato and are primarily responsible behind the inter-Block variability in potato productivity.

1.1 Objectives

The principal objectives of the study are:

- to analyze the spatio-temporal variations of potato in Hugli district for the period of 1990-91 to 2013-14; and
- to calculate the inter-Block variability of instability and sustainability of productivity of potato

1.2 The Study Area

Extending from 20°30'32"N to 23°01'20" North latitude and 87°30'20"E to 88°30'15"East longitude**,** the Hugli district is located in the western bank of Hooghly River. It is bounded by Purba Bardhaman and Bankura districts in the North, Haora district in the South, North 24 Parganas and Nadia districts in the East and Paschim Medinipur district in West (Fig. 1). Occupying 3149 $km^2$of geographical area, the district has accommodated nearly 5.52 million population with a population density of 1753/ km^2 (Census, 2011). Administratively it comprises 4 Sub-Divisions and 18 Community Development Blocks (Fig. 1).

2. MATERIALS AND METHODS

The study is principally based upon the secondary data that has been obtained from District Statistical Handbooks (1990-91 to 2013-14) and from the Directorate of Agriculture, Government of West Bengal, India. Block level data has been analyzed by using various simple statistical techniques for the stipulated period (1990-91 to 2013-14). 3-year moving average curve has been employed to assess the original trend by smoothing the fluctuations over the

period. Besides, compound annual growth rate of the variables is compute by fitting the exponential equation: $Y = ab^t$

Where, Y = area, production and yield; t = time period (in years); a = intercept; b = trend value; R^2= Coefficient of Determination (from 0 to 1)

Compound Annual Growth Rate (%) = (Antilog b – 1) × 100

Coppock's Instability Index (CII) has been computed for instability analysis of yield by using the formula [19]:

$$Vlog = \frac{\sum(log\frac{Xt+1}{Xt} - m)^2}{n}$$

$$CII\ (\%) = Antilog\left(\sqrt{Vlog} - 1\right)X\ 100$$

Where, X*t* = Area/ Production/ Yield, t = Year, n = Number of years, M= Mean of the difference between Logs of X_{t+1} and X*t* ; Log V = logarithmic variance of the series

A higher numerical value for the index signifies greater instability and vice-versa.

For sustainability analysis, Simple Achieved Variation (SAV) measure has been used interchangeably with Sustainability Index (SI) as proposed by Sahu et al. [20]. The formula is:

$$SI = \frac{Y_{max} - \bar{Y}}{\bar{Y}}$$

Where, $\bar{Y}$=Average Area/ Production/ Yield of the crop and Y_{max}= Maximum in this category over the period

In this measure, lower value denotes higher sustainability and vice versa.

Crop Yield and Concentration Indices Ranking Coefficient (*RCYiCi*) technique, as propounded by Singh in 1976 [16] has been applied in order to delineate productivity regions of potato of Hugli district for the years 1993-94, 2003-04 and 2013-14 at an interval of ten years. The method may be described as the average of the ranks of the Blocks, which have been obtained individually through the computation of crop yield index (*Yi*) and crop concentration index (*Ci*).

$$RCYiCi = \frac{Yi\ Ranking + Ci\ Ranking}{2}$$

Where,

$$Crop\ Yield\ Index\ (Yi) = \frac{Ya_e}{Ya_r}X100$$

Ya_e= Average yield (kg/ha) of potato of a particular Block and
Ya_r = Average yield (kg/ha) of potato

$$Crop\ Concentration\ Index\ (Ci) = \frac{Pa_e}{Pa_r}X100$$

Pa_e= Share of Potato area (%) to Gross Cropped Area (GCA) in a particular Block and
Pa_r = Share of Potato area (%) to GCA

A low value of *RCYiCi* denotes high productivity and vice versa. Three productivity regions i.e. High (<6), Moderate (6-12) and Low (> 12) have been delineated with the computed index value to show the variability as well as the disparity of productivity among the Blocks over the span.

3. RESULTS AND DISCUSSION

3.1 Growth Trends of Potato Productivity: Inter-Block Level Analysis

The area under potato in the district depicts an oscillating nature during the study periods designed with sequential rise and fall in every alternative year. . Almost all the Blocks show similar trend of swinging in area under the crop. This gradual expansion and reduction in area has been guided by the market price of potato and profit of the cultivators. Higher proportion of area under potato normally enhances the production, leading to decrease in the market price of potato. Naturally, the farmers, especially the small and the marginal ones, are failed to earn profit or even recover the capital invested. In this circumstance, the farmers who have experienced loss, reduce the area under the crop in next year. As a consequence, the agricultural output has reduced which leads to raise the price of the crop and has ensured increment of profit. The cultivators employ more agricultural land in potato cultivation that has repeated the previous situation. In spite of such oscillation, total land under potato of the district has been increased from 66082 ha. in 1990-91 to 99830 ha. in 2013-14 (Fig. 2). Hence, almost 51.07% (33748 ha) area has been increased during the overall stipulated period with the Compound Annual Growth Rate (CAGR) of 0.87%. The exponential model [R^2=0.751] indicates a strong positive

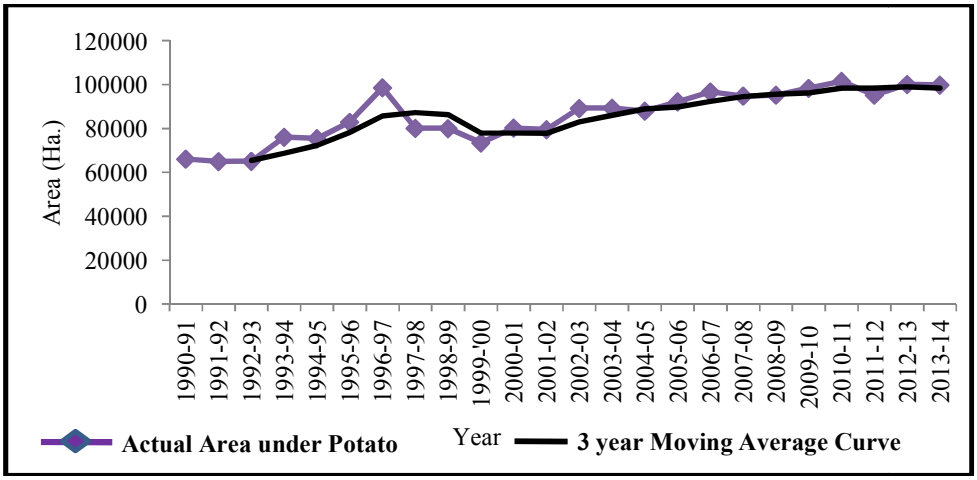

Fig. 2. Trend of area under potato, Hugli, 1990-91 to 2013-14

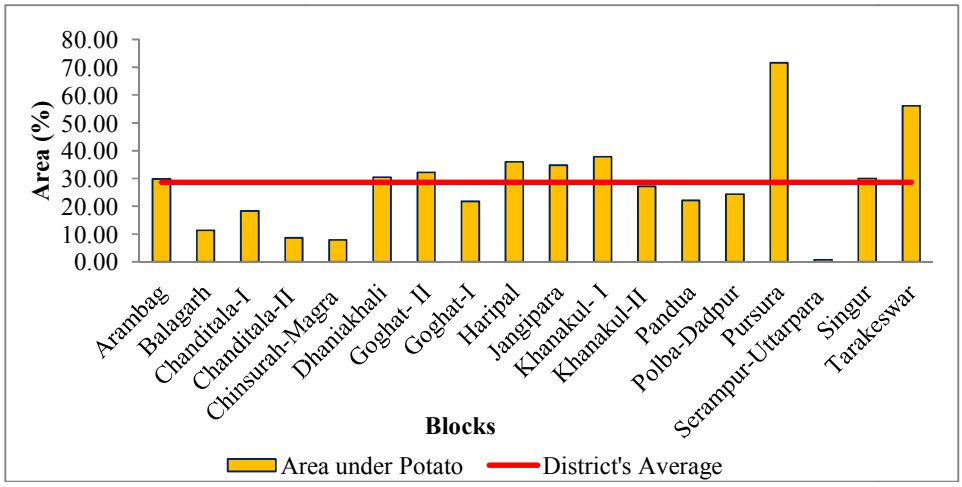

Fig. 3. Block wise distribution of area under potato, Hugli, 1990-91 2013-14

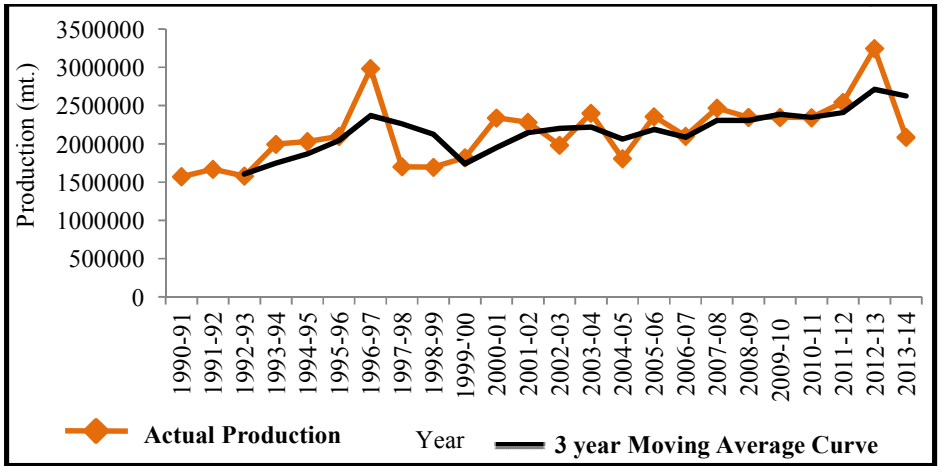

Fig. 4. Trend of potato production, Hugli, 1990-91 2013-14

trend in area under the crop. On an average, 28.63% of the geographical area of the district has been used for potato cultivation during the study periods. The Blocks have shown definite spatial variation in area under potato. Pursura Block has comprised the highest concentration of area under potato (71.62%), whereas, highly urbanized Serampur-Uttarpara Block has the lowest proportion of area under the crop (0.81%). Besides Pursura, another Eight Blocks namely, Tarakeswar (56.16%), Khanakul-I (37.82%), Haripal (36.02%), Jangipara (34.75%), Goghat-II (32.15%), Dhaniakhali (30.43%), Singur (29.98%) and Arambag (29.76%) have reported higher proportion of area than the district's average during the phase due to the agro-ecological suitability. Rest of the Blocks like Chinsurah-Magra (7.87%), Chanditala-I (18.37%) and II (8.64%), Goghat-I (21.75%), Khanakul-II (27.22%), Pandua (22.08), Polba-Dadpur (24.39%) and Balagarh (11.40%) show lesser percentage of area than the district's average (Fig. 3). The result reveals that for 3 Blocks, namely Chinsurah-Magra (R^2= 0.754), Haripal (R^2=0.547) and Pandua (R2=0.688) exponential model found to be the best fit for area under potato (Table 1 in annexure). Goghat-I and Khanakul-II have possed low concentration of area under potato due to its physical environmental adversities [18], whereas urbanization and associated infrastructural development are chiefly responsible factors for the other Blocks [21]. Rapid urban growth along with the flourishing Census Towns in those Blocks during the recent past years have shrank the net sown areas and increased the non-agricultural landuse. Likely, in Chinsura-Magra, the urban area has increased almost to 22.76%, which has reduced the net sown areas from 496 ha to 2861 ha during 2001-11. The urban area in Chanditala-II Block during the same period has been increased to 12 km^2 (66.57%), which has converted almost 2095 ha net sown area into non-agricultural land. Similarly, urban expansion in Chanditala-I (30.83 km^2), Pandua (4.75 km^2) and Balagarh (8.54 km^2) have reduced the net sown area to 242 ha, 571 ha and 611 ha respectively, that have influenced the area under potato (District Statistical Handbook, 2000-01 and 2010-11; Department of Agriculture, West Bengal). In spite of the fact, it may be noted that, surprisingly except Dhaniakhali, all other Blocks have shown positive trend of increase in area during the period as the farmers' have engaged more and more land in potato cultivation due to the growing demands of potato in the modern agro-industries as well as its economic profitability.

Generally, in normal circumstances, the production has shown a direct positive relationship with the area engaged in any crop cultivation. Naturally, the production of potato in the area has also shown annual variation with the sequential expansion and shrinkage of area under potato. Fig. 4 has depicted the annual changeable situation properly. Total agricultural output of potato has risen from 1572460 metric tonnes in 1990-91 to 2077514 metric tonnes in 2013-14, comprising 27.93% of the State's total agricultural production. Therefore, the production has raised almost 32.75% during the study period with 0.83% CAGR. The exponential model [R^2=0.381] signifies a moderate but positive trend. The average production of potato Blocks have shown a wider inter-Block disparity in during the study period. The Blocks, characterized with higher proportion of area under potato naturally show higher average production than the district's figure and vice-versa. The urbanized Blocks like Serampur-Uttarpara (853 mt.), Chinsurah-Magra (15663 mt.) and Chanditala-II (15110 mt.) located in the eastern margin of the District, have reported less average production during the period. On the other, Dhaniakhali has reported highest average production (212143mt.) followed by Arambag (202411mt.) and Tarakeswar (189608mt.) (Fig. 5).

Fluctuation in area and production naturally influence the average yield per unit of land during the period 1990-91 to 2013-14. It possesses a variable nature with sequential rise and fall in alternative manner. Besides the natural fertility of soil, some other factors like use of fertilizers, pesticides and HYV seeds, availability of irrigation facilities, degree of mechanization, capital investment etc. also influences the yield rate of potato in spatio-temporal context. It has shown insignificant, almost negligible but positive growth trend in yield of potato. Neither the linear (R^2= 0.035) nor the exponential curve (R^2=0.014) get fitted with the distributional pattern and fails to explain the nature of the data properly. 3 year moving average curve has revealed the oscillating nature of potato productivity (Fig. 6). Temporal variation in yield rate has been observed with the Compound Annual Growth Rate of 0.23% during the study period. On an average, the district's yield rate was 24830 kg/ha. The yield rate of the Blocks is not uniform,

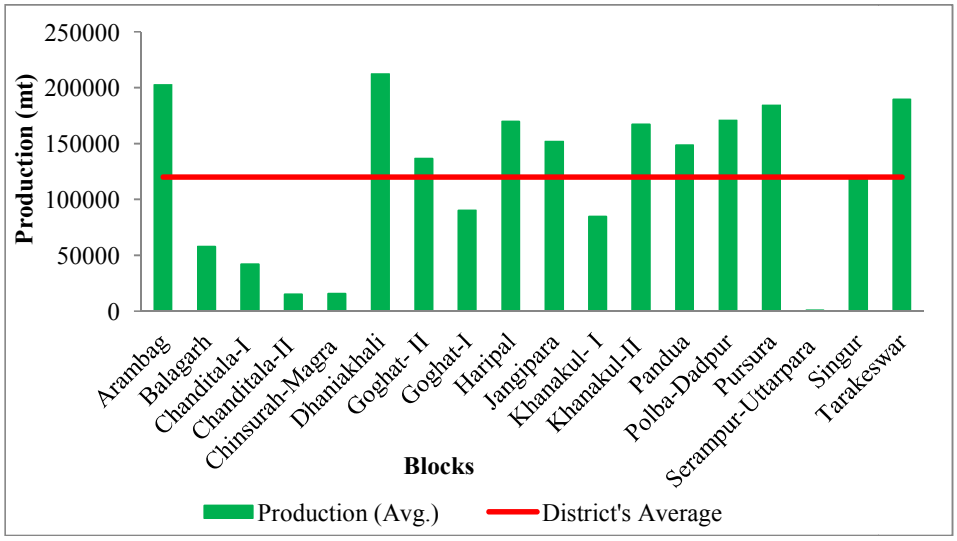

Fig. 5. Block wise potato production scenario, Hugli, 1991- 91 to 2013-14

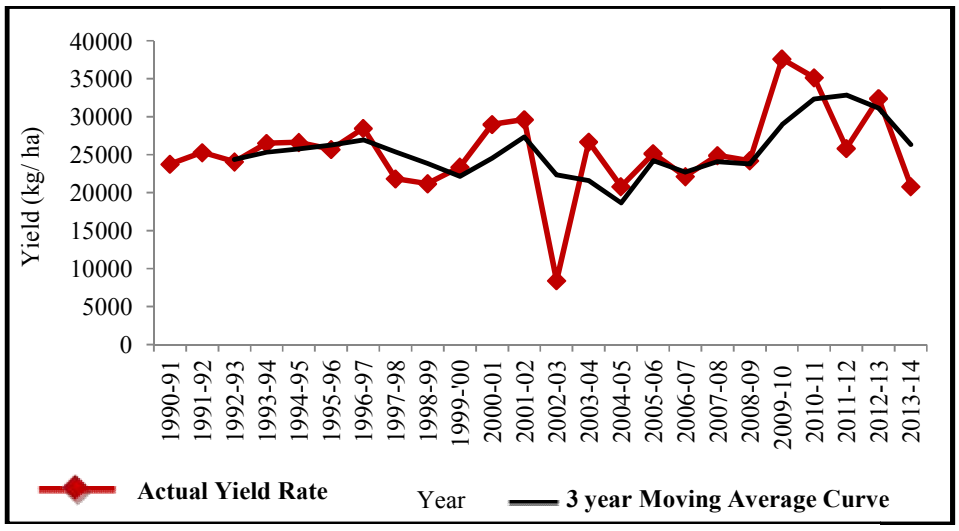

Fig. 6. Trend of yield of potato, Hugli, 1990-91 to 2013-14

rather varied insignificantly. Tarakeswar Block shows highest productivity per unit of land (27950 kg/ha), followed by Jangipara (26500 kg/ha) and Khanakul-I (25950 kg/ha), whereas, Goghat-I and II have reported lowest average productivity due to the inapt physico-ecological conditions.

3.2 Instability and Sustainability Analysis

Instability is one of the key parameters in the study of agricultural development. The nature of the growth-instability relation varies with the changing physical environmental circumstances (especially the weather condition) in spatio-temporal context [22]. Coppock's Instability Index (CII) has been computed for the entire period to examine the extent of variability of area, production and yield of potato. It has used logarthemetric values of the variable, instead of absolute values and gives a close approximation of the average year-to-year percentage variation in the value of the variable, adjusted for trend [23,24,25]. The magnitude of index exhibits the degree of instability [26]. On the other, Sahu's Simple Achieved Variation method has been employed to examine the sustainability of these three parameters [20], where lower value (closer to zero) of the index is the most desirable value as it posses greater sustainability status [27].

The CII value of the area and production for the entire district were 0.26 and 1.97 respectively, whereas the yield rate of the crop shows a significantly high instability of 7% for the period. On contrary, the sustainability index (SI) value of the entire district for area, production and yield of potato was found as 0.18, 0.50 and 0.68 respectively. Therefore, the district shows higher sustainability in area under potato and comparatively lesser sustainability in production and crop yield. The Blocks were classified into three categories, i.e. Low($< \bar{X} - ½\,\delta$), Moderate ($\bar{X} - ½\,\delta \; to \; \bar{X} + ½\,\delta$) and High ($\bar{X} + ½\,\delta$), separately for area, production and yield rate, considering the value for the period under study. Serampur-Uttarpara has shown the highest instability (17.68%) in the area under potato, followed by Chanditala-I (17.04%), Goghat-I (14.25%), Chanditala-II (10.31%) and Chinsurah-Magra (9.61%). Naturally, these Blocks have reported low sustainability in area under the crop (Table 2 in annexure). Chinsurah-Magra has reported the lowest sustainability in area (4.94) and production (5.79) of potato as a result of the establishment and expansion of urban centers. Some other urbanized Blocks like Serampur-Uttarpara (2.28), Chanditala-II (1.43) due to the gradual transformation of agricultural land into build-up areas [21]. On the other, Pursura Block has reported least instability (0.02%) and highest sustainability (0.11) in the area under potato for the entire period. Polba-Dadpur (0.18%), Jangipara (1.71%), Tarakeswar (2.21%), Dhaniakhali (2.34%), Haripal (2.60%) and Pandua (2.68%) Blocks have also accounted low instability (value: <3.94%) and higher sustainability for the area. Rest six Blocks namely Arambag, Balagarh, Goghat-II, Singur, Khanakul-I and II have shown moderate instability [value: 3.94 -9.39] in area. Regarding production, Pursura (0.34) has shown the highest sustainability by Tarakeswar (0.45) and Haripal (0.52). Other seven Blocks like Serampur-Uttarpara (17.63%), Goghat-I (17.97%), Arambag (12.99%), Singur (13.23%), Khanakul-II (13.25%), Chanditala-I (16.54%) and II (12.72%) have recorded high instability [value: >12.44%] and low sustainability, whereas, six Blocks namely, Goghat-II (0.40%), Pursura (2.25%), Jangipara (2.43%), Pandua (4.66%), Polba-Dadpur (5.38%) and Haripal (5.48%) have comprised low instability [value: <7%]. Rest five Blocks have shown moderate instability [value: 7% - 12.44%] in the production of potato over the study period. It has been observed that the Blocks have shown lesser variability regarding the sustainability in yield rate. Among the Blocks, Balagarh has shown the highest instability of 11.22% for the yield of potato, higher than the district's value. Another two Blocks i.e. Tarakeswar (6.19%) and Serampur-Uttarpara (5.49%) show high productivity [value: >4.92]. On contrary, Chanditala-II has reported lowest instability of 1.04%. Another four Blocks like Haripal (2.52%), Jangipara (1.23%), Pandua (1.95%) and Singur (1.34%) have comprised low instability [value: <2.58]. Rest 10 Blocks have comprised moderate [value: 2.58 - 4.92] instability in yield rate (Table: 2 in annexure). Khanakul-I (0.69) has reported the lowest sustainability (less than the district's figure), whereas Singur (0.22) has recorded the highest sustainability in crop yield. Another two Blocks, Serampur-Uttarpara (0.64) and Dhaniakhali (0.58) have also recorded comparatively lower sustainability regarding yield of potato (Table 2 in annexure).

3.3 Delineation of Productivity Regions of Potato: 1993-94, 2003-04 and 2013-14

In order to assess the Block level variations of productivity of potato in spatio-temporal context, high, moderate and low productivity regions have been recognized for the years of 1993-94, 2003-04 and 2013-14 respectively. It is found that many Blocks have shown rapid and significant changes in productivity during the specific time frame.

In 1993-94, Jangipara has shown the highest Yield (*Yi*) of potato, whereas, Haripal had recorded the lowest *Yi* value. Another five Blocks, like Chanditala-II, Khanakul-II, Pandua, Tarakeswar and Chinsurah-Magra have shown high Crop Yield index. On the contrary, five other Blocks had shown low crop yield index. In case of Crop Concentration Index (*Ci*), again Jangipara holds the highest position, followed by five other Blocks like Haripal, Tarakeswar, Dhaniakhali, Singur and Chanditala-II. On contrary, Balagarh has reported least *Ci* Index in that year. Another five Blocks namely, Chanditala-I, Chinsurah-Magra. Goghat-I, Pursura and Serampur-Uttarpara have also shown lower crop concentration index. As a whole, Jangipara Block recorded the highest productivity in that year. Besides, Pandua, Tarakeswar, Khanakul-II and Chanditala-II have comprised high productivity region of potato in the specified year. Another seven Blocks (38.89%) like Chinsurah-Magra, Serampur-Uttarpara, Singur, Haripal, Dhaniakhali, Pursura and Khanakul-I have occupied the moderate

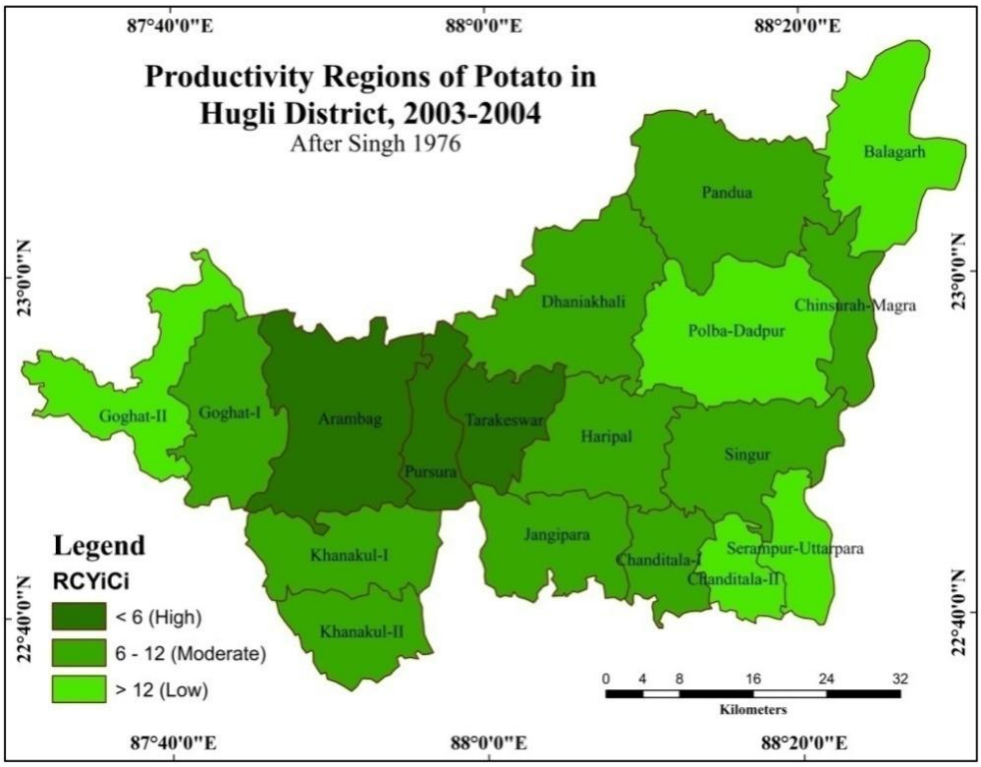

Fig. 7. Productivity regions of potato in Hugli district, 2003-2004

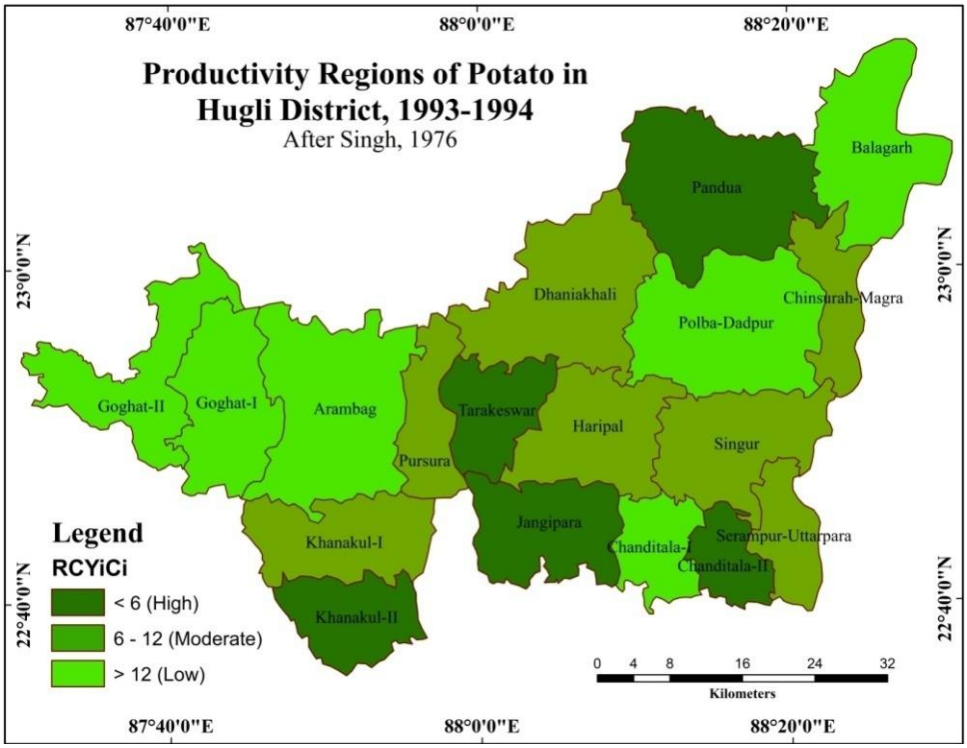

Fig. 8. Productivity regions of potato in Hugli district, 1993-1994

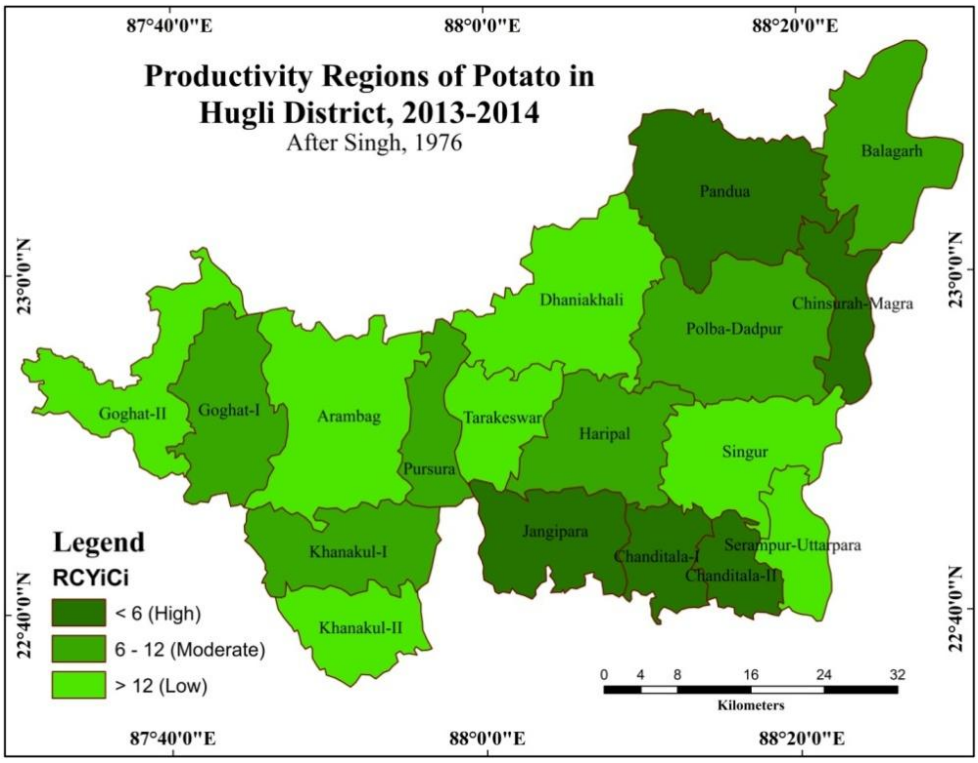

Fig. 9. Productivity regions of potato in Hugli district, 2013-14

Table 1. Productivity regions of potato in Hugli, 1993-94, 2003-04 and 2013-14

Year	Productivity regions	Number of blocks	Name of the blocks
1993-94	High (< 6)	5	Jangipara, Pandua, Tarakeswar, Chanditala-II, Khanakul-II
	Moderate (6 - 12)	7	Dhaniakhali, Pursura, Haripal, Singur, Serampur-Uttarpara, Khanakul-I, Chinsurah-Magra
	Low (> 12)	6	Goghat-I and II, Arambag, Polba-Dadpur, Balagarh, Chanditala-I
2003-04	High (< 6)	3	Tarakeswar, Arambag, Pursura
	Moderate (6 - 12)	10	Pandua, Dhaniakhali, Chinsurah-Magra, Singur, Haripal, Chanditala-I, Jangipara, Goghat-I, Khanakul-I and II
	Low (> 12)	5	Goghat-II, Polba-Dadpur, Balagarh, Chanditala-II, Serampur-Uttarpara
2013-14	High (< 6)	5	Pandua, Chinsurah-Magra, Jangipara, Chanditala-I and II
	Moderate (6 - 12)	6	Goghat-I, Khanakul-I, Pursura, Haripal, Polba-Dadpur, Balagarh
	Low (> 12)	7	Arambag, Goghat-II, Tarakeswar, Dhaniakhali, Singur, Serampur-Uttarpara, Khanakul-II

productivity region. Rest six Blocks have recorded lower productivity of potato during the period (Fig: 7; Table: 3 in annexure). Goghat-I and II have shown lower productivity owing to the geo-physical barriers for potato cultivation. In spite of the lowest yield rate, Haripal has placed itself in moderate productivity regions due to the higher proportion of area under potato to gross cropped area.

The productivity regions have been drastically rearranged in 2003-04. Tarakeswar Block has shown the highest crop yield index of 121.51%, followed by Arambag (113.59%) and Pursura (113.41%). On contrary, Goghat-II has shown the lowest yield (Yi value: 71.93%). Balagarh (85.81%), Haripal (86.57%), Chanditala-II (87.07%), Jangipara (93.71%) and Serampur-Uttarpara (94.41%) have also shown a lower

yield of potato. Rest of the Blocks have comprised moderate yield of potato. Pursura Block has revealed the highest percentage of area under potato to the gross cropped area (GCA) (34.13%) and has ranked first with the highest crop concentration index value of 173.23% by replacing Jangipara Block. Tarakeswar (154.94%), Haripal (138.34%), Singur (133.14%), Jangipara (118.08%) and Arambag (109.28%) have also recorded higher value in Crop Concentration (*Ci*). On the other, Serampur-Uttarpara has shown the lowest concentration of area under potato to GCA (*Ci* value 3.71, Rank: 18). Besides, lower concentration of area under potato is also found in Balagarh (40.07%), Chanditala-I (49.72%), Chinsurah-Magra (72.19%), Chanditala-II (72.64%) and Pandua (73.79%). Finally, three Blocks, namely, Tarakeswar, Arambag and Pursura have comprised the highly productive region, whereas Balagarh, Chanditala-II, Goghat-II, Polba-Dadpur and Serampur-Uttarpara have occupied low productive region. Rest of the Blocks (10 Blocks) have comprised moderate productivity region of potato (Fig. 8; Table 3 in annexure).

Jangipara again has ranked first in yield of potato with the highest value of 144.50% in 2013-14. Chanditala-I (139.74%), Chinsurah-Magra (138.42%), Pandua (137.83%) and Chanditala-II (131.68%) Blocks also have reported a considerable higher yield of potato compared to other Blocks. On the other hand, Khanakul-II has occupied the last position with the *Yi* value of 37.61%, followed by Arambag (59.96%) and Goghat-II (60.65%). It may be noted that Pursura Block has acquired the first position with highest *Ci* value of 258.79%, but has held the 15th rank in crop yield index (*Yi* :78.15%). In spite of decreasing trend in cropland, the Chinsurah-Magra Block has managed to hold the 2nd position with Yi value of 212.96%, by engaging nearly 46.97% of GCA in potato production. Blocks like Khanakul-I (193.18%), Pandua (185.25%), Chanditala-II (152.60%) and Chanditala-I (149.46%) have also accounted for the higher share of area under potato (%) in gross cropped area. Serampur-Uttarpara Block (*Ci*: 32.60) has shown the least share in area under potato due extension of urban sphere. Some other Blocks like Goghat-II (32.83%), Balagarh (43.02%), Singur (54.33%) and Tarakeswar (56.44%) have also comprised lower concentration in terms of area under potato. In totality, five Blocks, namely, Pandua, Chinsurah-Magra, Jangipara, Chanditala-I and II have comprised high productivity region (*RCYiCi* = <6) of potato in 2013-14. On the other, the low productivity region (*RCYiCi* = >12) contains seven Blocks of the district namely Arambag, Goghat-II, Tarakeswar, Dhaniakhali, Singur, Serampur-Uttarpara and Khanakul-II. The Moderate productivity region (*RCYiCi* = 6-12) consists of the rest six Blocks of the district (Fig. 9; Table 3 in annexure).

The following table (Table 1) represents the detailed zonation of Blocks according to the calculated productivity values that have depicted the temporal variability of the performance of the Blocks in potato cultivation.

4. CONCLUSION

The discussion has exhibited the unique oscillating nature of area under potato that has considerably influenced the output, but insignificantly manipulated the yield rate of potato over the study period. Significant inter-Block level disparity in productivity has been observed during the defined time span. Urbanization and associated changes in land use in the eastern Blocks notably affect the area and production of potato, whereas, the productivity of the crop in the western Blocks were governed by the physical conditions. The difficulties regarding the identification of any spatial pattern of yield rate of potato within this time span needs to be addressed. The district has revealed a unique spatio-temporal dynamism in totality as well as in inter-Block level.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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ANNEXURE

Table 1. Computation of block-wise exponential R^2, 1990-91 to 2013-14

Sl. No.	Name of the blocks	Area	Production	Yield rate
1	Arambag	0.247	0.120	0.001
2	Balagarh	0.065	0.116	0.019
3	Chanditala-I	0.150	0.184	0.044
4	Chanditala-II	0.053	0.103	0.085
5	Chinsurah-Magra	**0.754**	**0.707**	0.038
6	Dhaniakhali	0.002	0.047	0.067
7	Goghat- II	0.402	0.216	0.031
8	Goghat-I	0.089	0.065	0.021
9	Haripal	**0.547**	0.327	0.045
10	Jangipara	0.162	0.057	0.017
11	Khanakul- I	0.227	0.073	0.001
12	Khanakul-II	0.098	0.224	0.004
13	Pandua	**0.688**	**0.590**	0.034
14	Polba-Dadpur	0.225	0. 200	0.001
15	Pursura	0.098	0.046	0.014
16	Serampur Uttarpara	0.016	0.004	0.001
17	Singur	0.004	0.008	0.105
18	Tarakeswar	0.001	0.006	0.016

Table 2. Computation of instability and sustainability index, hugli, India, 1990-91 to 2013-14

Name of the block	Area		Production		Yield	
	CII (%)	SI	CII (%)	SI	CII (%)	SI
Arambag	5.75	0.67	12.99	0.74	3.71	0.27
Balagarh	8.7	0.86	11.09	1.16	11.22	0.25
Chinsurah-Magra	9.61	4.94	12.35	5.79	2.85	0.34
Chanditala-I	17.04	0.68	16.54	0.83	2.83	0.39
Chanditala-II	10.31	1.43	12.72	1.58	1.04	0.22
Dhaniakhali	2.34	0.40	7.72	1.20	4.64	0.58
Goghat-I	14.25	0.90	17.97	0.83	4.09	0.35
Goghat-II	5.23	0.60	0.40	0.73	3.35	0.39
Haripal	2.60	0.29	5.48	0.52	2.52	0.45
Jangipara	1.71	1.07	2.43	1.26	1.23	0.38
Khanakul-I	4.44	0.76	7.62	1.24	4.76	0.69
Khanakul-II	6.96	1.09	13.85	1.37	3.78	0.46
Pandua	2.68	0.71	4.66	1.03	1.95	0.38
Polba-Dadpur	0.18	0.49	5.38	0.59	3.59	0.38
Pursura	0.02	0.11	2.25	0.34	2.97	0.31
Serampur-Uttarpara	17.68	2.28	17.63	2.03	5.49	0.64
Singur	8.11	1.02	13.23	1.16	1.34	0.22
Tarakeswar	2.21	0.23	10.63	0.45	6.19	0.35

**CII= Coppock's Instability Index; SI= Sustainability Index*

Table 3. Computation of crop yield and concentration indices ranking coefficient, Hugli, 1993-94, 2003-04 and 2013-14

Sl No.	Name of the blocks	1993-94					2003-04					2013-14				
		Yi	R	*Ci*	R	*RCYiCi*	*Yi*	R	*Ci*	R	*RCYiCi*	*Yi*	R	*Ci*	R	*RCYiCi*
1	Arambag	86.02	15	79.54	10	**12.5**	113.59	2	109.28	6	**4**	59.96	17	96.00	10	**13.5**
2	Balagarh	99.75	8	8.28	18	**13**	85.81	17	40.07	17	**17**	104.08	8	43.02	16	**12**
3	Chanditala-I	80.51	17	36.37	15	**16**	102.96	8	49.72	16	**12**	139.74	2	149.46	6	**4**
4	Chanditala-II	106.55	6	110.89	6	**6**	87.07	15	72.64	14	**14.5**	131.68	5	152.60	5	**5**
5	Chinsurah-Magra	111.25	4	15.95	16	**10**	108.70	5	72.19	15	**10**	138.42	3	212.96	2	**2.5**
6	Dhaniakhali	92.94	11	155.07	4	**7.5**	101.60	10	95.23	11	**10.5**	81.88	12	72.09	13	**12.5**
7	Goghat-I	84.83	16	45.70	14	**15**	97.77	12	104.28	9	**10.5**	89.49	11	77.60	11	**11**
8	Goghat-II	92.02	14	73.70	11	**12.5**	71.93	18	98.28	10	**14**	60.65	16	32.83	17	**16.5**
9	Haripal	78.12	18	176.09	2	**10**	86.57	16	138.34	3	**9.5**	102.53	9	125.59	7	**8**
10	Jangipara	140.82	1	192.62	1	**1**	93.71	14	118.08	5	**9.5**	144.50	1	98.32	9	**5**
11	Khanakul-I	93.50	10	94.76	8	**9**	105.68	6	107.35	8	**7**	81.81	13	193.18	3	**8**
12	Khanakul-II	108.47	5	108.16	7	**6**	104.01	7	109.14	7	**7**	37.61	18	72.59	12	**15**
13	Pandua	120.53	2	80.03	9	**5.5**	98.16	11	73.79	13	**12**	137.83	4	185.25	4	**4**
14	Polba-Dadpur	92.03	13	73.40	12	**12.5**	86.57	16	74.36	12	**14**	126.15	6	125.09	8	**7**
15	Pursura	97.59	9	46.00	13	**11**	113.41	3	174.23	1	**2**	78.51	15	258.79	1	**8**
16	Serampur-Uttarpara	102.34	7	14.12	17	**12**	94.41	13	3.71	18	**15.5**	110.25	7	32.60	18	**12.5**
17	Singur	92.74	12	126.46	5	**8.5**	102.33	9	133.14	4	**6.5**	95.16	10	54.33	15	**12.5**
18	Tarakeswar	120.00	3	168.22	3	**3**	121.51	1	154.95	2	**1.5**	79.73	14	56.44	14	**14**

Yi = Crop Yield Index, Ci =Crop Concentration Index, $RCYiCi$ = Crop Yield and Concentration Indices Ranking Coefficient and R= Rank

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