Measurement of productivity and liability level of crops

Soham Biswas*

Department of Geography, Berhampore College, Berhampore, Murshidabad 742 101, India

Crop productivity is the capacity of an area to produce crops; a manifestation of complex interaction of various factors of production that together determine the existing condition of the farm environment. Without proper idea of the present productivity level, effective measures for further improvement cannot be initiated. Geographers and agricultural economists have long been engrossed in measuring agricultural productivity. Here I discuss a new method of measuring crop productivity, i.e. determining crop productivity level of an area with respect to the maximum achievable productivity limit under existing conditions of the farm environment. The method also measures the productivity deficiency level of various crops which makes the selection of liable crops much more sound and logical, and is helpful to formulate both the overall and crop-specific developmental strategies. Standard classes of crop productivity, yield achievement, yield deficit and crop liability levels have been prepared separately based on their index values.

Keywords: Crop productivity and liability, developmental strategies, farm environment, yield achievement and deficit.

MAJORITY of the people in the underdeveloped and developing countries live in rural areas and earn their livelihood through agriculture. So any small change in the agricultural sector would affect the economy of these countries. Though it has been found that in many cases, agriculture does not contribute much to the economic growth of a country because of low productivity and low contribution to GDP compared to other sectors of economy, many economists, agricultural geographers and policy makers have long argued for increasing crop productivity in a sustainable manner[1]. Increased crop productivity would not only be beneficial to the farmers, but also would strengthen the economy of the nation.

Crop productivity of any region may be seen as the overall capacity of the present farming system. It is the manifestation of complex inter-play of various factors of the farm environment[1,2]. Physical factors (such as climate, soil, etc.) and human-induced factors (viz. level of farm mechanization and use of various inputs like skill and knowledge of the farmers, institutional assistance, etc.), as well as market factors like demand and crop selection, together constitute the farm environment of any region[1–3]. Crop productivity reflects the overall performance of an area in terms of crop production, which is the blending effect of all the factors of the farm environment[4–7]. It is difficult to determine the influence of any one factor on crop productivity; but some factors play a dominant role over others which remain passive. Crop productivity is also highly variable; some crops have low productivity by inheritance, but still may be largely cultivated by the farmers because of market demand or specific food habit of the inhabitants, or specific and unique prerequisite physical conditions for the crop. Internal factors may also govern the productivity. For example, some crops are more resistant to pests while some are vulnerable. Some crops require specific climate or soil condition (e.g. cotton requires regur soil, high humidity adds flavour to coffee, tea, etc.) that cannot be created artificially.

Traditional farming is not adequate to meet the needs of growing population and it has become necessary to raise the productivity level. Crop productivity has been increased through additional application of inputs and improved technologies and machinery all over the world. However, there exists a certain limit beyond which productivity cannot be increased. It is the complex interplay of these factors that influences productivity differences in various parts. Agriculture is becoming more mechanized and technology-based. This has increased productivity, but has interfered with nature and has been slowly but continuously deteriorating the agro-ecosystem. It was necessary to increase crop productivity in the agricultural societies of under-developed and developing countries to feed the huge population, and not for commercial purposes. Besides achieving food security it brings higher income, employment opportunity and savings, and ensures a better standard of living. It is also beneficial for any region and country through export of surplus products, development of agri-allied sector; it also checks the inflation. Thus, higher agricultural productivity strengthens the existing agro-economic structure and brings overall socio-economic development of the concerned area. Thus it is essential to measure the agricultural productivity of an area, as it gives a clear picture of the overall achievement of the area in terms of crop production. Agricultural geographers and economists have devised various methods to measure agricultural productivity all

*e-mail: bsoham99@gmail.com

over the world[1,3]. It is the objective of the present study to devise a new measure of crop productivity. It estimates the present status of crop productivity of an area in regard to achievable maximum productivity under current condition of the farm environment. The method also provides a useful tool to estimate yield deficiency (i.e. deviation from achieving maximum production) of each crop grown in an area and its degree of liability. This method has been illustrated for Murshidabad district, West Bengal, India.

Crop productivity measurement

Agricultural productivity as mentioned earlier, is a tangle concept. It can be treated as the capacity of the farming system to produce crops at varied levels. It is the manifestation of complex interplay of various components of the farm environment which incorporates both the environmental and human-related factors of crop production[1,3–6]. Every crop has a different yield rate and shares different amounts of cropland and therefore makes a definite contribution to overall productivity of any region. These two actually reflect the combined effect of all concerned physical and human factors of production.

In this study, composite crop productivity has been considered as the combined effect of all the factors of production which exist in the region. This method is only aimed at estimating the crop productivity level. Variation in crop productivity does not give any information about the degree of influence of specific factors; rather this would require more detailed study regarding the inputs, technologies, soil, climate, etc. at sub-regional level. In order to measure crop productivity, an index of hectare-yield (kg/ha) of various crops grown in the sub-area unit has been pre-meditated by dividing the hectare-yield of various crops by maximum hectare-yield of the respective crops in the entire region. This simple ratio provides the index of yield achievement of each crop in the sub-area units. In this method, the highest hectare-yield of a crop throughout all the sub-area units of the region has been considered as the maximum achievable yield limit of each crop. Thus, the ratio of actual hectare-yield of each crop to its maximum hectare-yield reflects the yield achievement (efficiency) level with respect to the highest hectare-yield of each crop in the region. This may be expressed as

$$I_{\mathrm{Y\ av}.a} = Y_a / Y_{a.max}, \tag{1}$$

where $I_{\mathrm{Y\ av}.a}$ is the yield achievement index of crop a in a sub-area unit, Y_a the hectare-yield of crop a in the sub-area unit and $Y_{a.max}$ is the highest hectare yield of crop a in the entire region.

As this is a simple ratio, the maximum value of yield achievement index ($I_{\mathrm{Y\ av}}$) would be equal to 1, where the actual hectare-yield of a crop in a sub-area unit is equal to the highest hectare-yield of the respective crop in the entire region. On the other hand, theoretically, the yield achievement index may attain the minimum value of 0. Thus this index ranges between 0 and 1 ($0 \leq I_{\mathrm{Y\ av}} \leq 1$).

Then, weighted yield indices of various crops have been calculated by multiplying the yield achievement index with the ratio of cropland under a particular crop and the total cropland under all the selected crops in a sub-area unit. Cross-section area (a simple ratio of cropland under specific crop to total cropland) was used to give weightage. Then all the weighted yield achievement indices were added to obtain the composite crop productivity index (CCPI) of a sub-area unit. Thus, the weighted yield achievement index indicates the contribution of various crops to CCPI. This is expressed as

$$I_{\mathrm{WY\ av}.a} = I_{\mathrm{Y\ av}.a} \times \frac{C_a}{C}, \tag{2}$$

where $I_{\mathrm{WY\ av}.a}$ is the weighted yield achievement index of crop a in a sub-area unit, $I_{\mathrm{Y\ av}.a}$ the yield achievement index of crop a in a sub-areal unit, C_a is the area under crop a in the sub-area unit and C is the total cropland under all the selected crops in a sub-area unit.

$$\mathrm{CCPI} = I_{\mathrm{WY\ av}.a} + I_{\mathrm{WY\ av}.b} + I_{\mathrm{WY\ av}.c} + \ldots + I_{\mathrm{WY\ av}.n}$$

$$= I_{\mathrm{Y\ av}.a} \times \frac{C_a}{C} + I_{\mathrm{Y\ av}.b} \times \frac{C_b}{C} + I_{\mathrm{Y\ av}.c} \times \frac{C_c}{C} + \ldots + I_{\mathrm{Y\ av}.n} \times \frac{C_n}{C}$$

$$= \frac{1}{C}(I_{\mathrm{Y\ av}.a} \times C_a + I_{\mathrm{Y\ av}.b} \times C_b + I_{\mathrm{Y\ av}.c}$$

$$\times C_c + \ldots + I_{\mathrm{Y\ av}.n} \times C_n). \tag{3}$$

Now, different types of crops may be grown in a region. Some crops may be of long duration and some of short duration. Long-duration crops may be grown fewer times, whereas short-duration crops may be grown multiple times in an agricultural year. If the environmental conditions, inputs and farming techniques remain the same, a particular crop grown in a definite area is expected to yield the same production each time. This only contributes to the gross cropped area and gross production in a region, but would not affect the yield or productivity. This is because yield or productivity implies production per unit of land cultivated. Hence it is assumed that the crop duration has no influence over the productivity of a region. Here a simple ratio of gross crop area under a specific crop (irrespective of duration) and total cropland was used to give weightage in the estimation of crop productivity. If a short-duration crop is grown multiple times, then it would affect the productivity according to the changed weightage value. If the crop is cultivated fewer times (short- or long-duration crop), the weights would be in accordance. Thus, the method includes both the long- and short-duration crops at the same time. Whatever be the frequency of cultivation, the production and area under specific crop are incorporated in the estimation as weightage to the yield.

CCPI may attain the maximum value of 1, where the actual hectare-yield of various crops in a sub-area unit is equal to the highest hectare-yield of the respective crops in the entire region. Hence, the yield achievement index attains the maximum value of 1 and CCPI of the sub-area unit thus becomes

$$CCPI = \frac{1}{c}(I_{\mathrm{Y\ av}.a} \times C_a + I_{\mathrm{Y\ av}.b} \times C_b$$

$$+ I_{\mathrm{Y\ av}.c} \times C_c + \ldots + I_{\mathrm{Y\ av}.n} \times C_n)$$

$$= \frac{1}{c}(1 \times C_a + 1 \times C_b + 1 \times C_c + \ldots + 1 \times C_n)$$

$$[I_{\mathrm{Y\ av}.a} = Y_a / Y_{a.max} \text{ or } I_{\mathrm{Y\ av}.a} = Y_{a.max} / Y_{a.max} = 1].$$

$$= \frac{1}{c}(C_a + C_b + C_c + \ldots + C_n)$$

$$= \frac{1}{c} \times C\ [(C_a + C_b + C_c + \ldots + C_n) = C] = 1.$$

Theoretically, CCPI may attain the minimum value of 0, but practically it would always be greater than zero, unless there is total crop failure due to some unprecedented causes like inundation, invasion of sea water, etc. However, hectare-yield of various crops below half of the maximum hectare-yield indicates very low crop productivity and very poor agricultural scenario in a region, although low productivity may be due to regional variation in soil fertility or agro-ecosystem. This technique only estimates the productivity level in a region, but the attributes of low productivity are subject to in-depth study, which may be carried out separately based on the findings of the present study. Hence, taking hectare-yield of each crop of a sub-area unit to be half of the maximum hectare-yield of the respective crop, we get

$$CCPI = \frac{1}{c}(I_{\mathrm{Yav}.a} \times C_a + I_{\mathrm{Yav}.b} \times C_b$$

$$+ I_{\mathrm{Yav}.c} \times C_c + \ldots + I_{\mathrm{Yav}.n} \times C_n)$$

$$= \frac{1}{c}\left(\frac{Y_a}{Y_{a.max}} \times C_a + \frac{Y_b}{Y_{b.max}} \times C_b\right.$$

$$\left. + \frac{Y_c}{Y_{c.max}} \times C_c + \ldots + \frac{Y_n}{Y_{n.max}} \times C_n\right)$$

$$= \frac{1}{c}\left\{\left(\frac{\frac{1}{2} \times Y_{a.max}}{Y_{a.max}}\right) \times C_a + \left(\frac{\frac{1}{2} \times Y_{b.max}}{Y_{b.max}}\right) \times C_b\right.$$

$$\left. + \left(\frac{\frac{1}{2} \times Y_{c.max}}{Y_{c.max}}\right) \times C_c + \ldots + \left(\frac{\frac{1}{2} \times Y_{n.max}}{Y_{n.max}}\right) \times C_n\right\}$$

$$= \frac{1}{c}\{1/2(C_a + C_b + C_c + \ldots + C_n)\}$$

$$= \frac{1}{c}\left\{\frac{1}{2} \times C\right\} = \frac{1}{2} = 0.5.$$

In this method, CCPI value of 0.5 has been taken as the limit below which agricultural productivity is considered very poor and above which the productivity varies between moderate low to very high up to the value of 1. Productivity index value ranging between 0.5 and 1 has been divided into five distinct categories of equal interval. For a region where all the crops (or majority of them) have almost equal yield rates with respect to the maximum rate of yield of the respective crops in the entire region, the composite productivity would be very high. Thus, a region where all the crops have more than 80% yield rate relative to their respective maximum yield rate should be considered as high or very high crop productivity region ranging between 0.8 and 1. Therefore, index values between 0.8 and 0.9 as well as 0.9 and 1, are considered as high and very high crop productivity classes (or regions) respectively. Composite index values between 0.5 and 0.8 have been considered to indicate medium level of performance in terms of productivity in the region and yield rate of crops in such regions would be 50–80% of maximum yield rate of the respective crops in the entire region. This range has been grouped into three productivity classes, viz. moderate low (0.50–0.60) – marginally better productivity than poor category; moderate (0.60–0.70) – absolute medium productivity level where yield of all crops (or majority) is 60–70% of maximum yield; and moderate high category (0.70–0.80).

The range of classes has been assigned (Table 1) based on a simple hypothetical assumption that all the crops in

Table 1. Standardized classes of composite crop productivity index (CCPI)

Crop productivity class	CCPI value
Very poor	<0.25
Poor	0.25–0.50
Moderate low	0.50–0.60
Moderate	0.60–0.70
Moderate high	0.70–0.80
High	0.80–0.90
Very high	0.90–1.00

a region have equal of yield rates in their own category; but this may not be time in reality. However, it would not affect the productivity ranges, because in this method, combined yield rates of all the crops have been considered while evaluating productivity indices, where low yield of some crops may be compensated by those with high yield rates. Therefore, it would give almost accurate information of the overall productivity level of any region.

In this method, the contribution of various crops to the overall productivity of a sub-area unit does not solely depend on their share of cropland; rather it is the combined effect of yield achievement index and ratio of area under various crops (i.e. product of these two). Thus it leads to better identification of major crops on the basis of weighted yield achievement indices, e.g. in a sub-area unit X, the hectare-yield of crops a and b is 1000 and 1760 kg/ha respectively; whereas the highest hectare-yield of crops a and b in the entire region (R) is 2000 and 2200 kg/ha respectively. Crop a is cultivated in 50 ha and crop b has a cropland of 40 ha, and the total cropland under all the selected crops in unit X is 150 ha. Now, applying the above method we get:

Yield achievement index of crop a, $I_{\mathrm{Y\,av}.a}$

= 1000/2000, i.e. 0.50.

Weighted yield achievement index of crop a, $I_{\mathrm{WY\,av}.a} = 0.50 \times 50/150 = 0.167$; it is the contribution of crop a to the total productivity of X.

Similarly, yield achievement index of crop b, $I_{\mathrm{Y\,av}.b} =$ 1760/2200, i.e. 0.80.

Weighted yield achievement index of crop b, $I_{\mathrm{WY\,av}.b} = 0.80 \times 40/150 = 0.213$.

Thus it is clear from the above that crop b contributes more to the overall productivity of X, though it shares less cropland than that of crop a. This is because crop b has higher yield achievement level compared to crop a. Thus, on the basis of simple yield achievement index, it appears to be much easier to determine the yield level and contribution of individual crops to total productivity. In this study, standard classes of these two indices have been assigned for this purpose.

Yield achievement categories (Table 2) were assigned based on index values, i.e. ratio of yield of a crop to its highest yield rate in the entire region. Thus, a crop with less than 50% yield rate of its highest yield has been considered as one with very poor yield. The yield index value ranging between 0.50 and 1, has been grouped into five categories with equal intervals, where yield achievement level increases with ascending index value, i.e. towards achieving maximum yield with respect to the highest yield of the respective crop.

Weighted crop yield index represents the contribution of each crop to the composite productivity of a region. Various classes (i.e. level of contribution, Table 3) have been assigned by taking 0.5 as a limit, above which the level of contribution of a crop to the productivity of a region is considered as very high, i.e. a crop contributes more than half of the composite productivity of the region. Index values ranging between 0.25 and 0.50 indicate high contribution of the crop under consideration. In both cases, these are dominant crops with a large share of cropland or with remarkable high yield rate or both. Below the index value of 0.25 up to 0, there are five different categories with regard to level of contribution. The level of contribution gradually declines with decreasing index value. Crop with index value below 0.1 shows low and very low level of contribution to the overall productivity of a region. Such crops are either cultivated in less area or have very low yield rates. Weighted yield index value ranging between 0.25 and 0.10 has been grouped into three categories of moderate level of contribution, viz. moderate high, moderate and moderate low.

Identification of liable crops

The above crop productivity measure also offers provision to estimate deficiency in output per hectare of cropland of various crops, which is complementary to their yield achievement level. It is expressed as

$$
\begin{aligned}
I_{\mathrm{YD}a} &= (Y_{a.max} - Y_a)/Y_{a.max}, \\
&= 1 - (Y_a/Y_{a.max}) \\
&= 1 - I_{\mathrm{Y\,av}.a} \qquad (4)
\end{aligned}
$$

where Y_a is the hectare-yield of crop a in the sub-area unit, $Y_{a.max}$ the highest hectare-yield of crop a in the entire

Table 2. Standardized classes of yield achievement index

Degree of yield achievement	Index value
Very poor	<0.50
Poor/low	0.50–0.60
Moderate	0.60–0.70
Moderate high	0.70–0.80
High	0.80–0.90
Very high	0.90–1.00

Table 3. Standardized classes of weighted yield achievement index

Level of contribution	Index value
Very high	≥0.50
High	0.25–0.50
Moderate high	0.20–0.25
Moderate	0.15–0.20
Moderate low	0.10–0.15
Low	0.05–0.10
Very low	<0.05

region and $I_{\mathrm{Y\,av.}a}$ is the yield achievement index of crop a in the sub-area unit.

Thus, the crop with higher yield achievement index would have low yield deficiency index and vice versa. Then the weighted yield deficit indices of various crops have been estimated by multiplying the yield deficit index with the ratio of cropland under each crop and total cropland under selected crops of the sub-area unit. This weighted value helps identify the 'liable' crop which needs more attention to minimize the gap between yield achievement and maximum achievable limit of the crop. It is expressed as

$$\text{Weighted yield deficit index } (I_{\mathrm{WYD}a}) = I_{\mathrm{YD}a} \times \frac{C_a}{C}, \quad (5)$$

where $I_{\mathrm{YD}a}$ is the yield deficit index of crop a, C_a the area under crop a in the sub-area unit and C is the total cropland under selected crops in the sub-area unit.

This can be explained with the previous example; just adding a new crop c which has an yield rate of 900 kg/ha and shares an area of 30 ha. The maximum hectare-yield of crop c in the region R is 1500 kg/ha. Now, applying the above equation, we get

$$I_{\mathrm{YD}a} = 1 - 0.50 = 0.50,$$

$$I_{\mathrm{WYD}a} = I_{\mathrm{YD}a} \times C_a/C = 0.50 \times 50/150 = 0.167.$$

Similarly, $I_{\mathrm{YD}b} = 1 - 0.80 = 0.20$,

$$I_{\mathrm{WYD}b} = I_{\mathrm{YD}b} \times C_b/C = 0.20 \times 40/150 = 0.053.$$

Also,

$$I_{\mathrm{YD}c} = (1 - 900/1500) = 1 - 0.60 = 0.40,$$

$$I_{\mathrm{WYD}c} = I_{\mathrm{YD}c} \times C_c/C = 0.40 \times 30/150 = 0.08.$$

Thus, it is clear from the above result that, crop a (0.167) is the most liable with maximum yield deficit. Crop c follows with index value of 0.08, though it shares less area than crop b (lowest liability), but has higher yield deficiency than the latter. Thus it seems to be much easier to identify the liable crops (i.e. crops with higher yield deficiency) among various crops in any region or sub-region. Further, it makes selection of target crops easier and meaningful, as it considers both the yield deficit and share of cropland. In the present article, liability level of various crops has been grouped into six distinctive standardized classes based on the index value of weighted yield deficiency. Table 4 shows the standard groups of crop liability levels.

Table 4. Standardized classes of crop liability level

Degree of crop liability	Index value
Very severe	≥0.25
Severe	0.20–0.25
High	0.15–0.20
Moderate high	0.10–0.15
Moderate	0.05–0.10
Low	0.01–0.05
Very low	<0.01

A case study – Murshidabad district, West Bengal, India

In the present study, the crop productivity of Murshidabad district, West Bengal, India has been measured using the method discussed above. Murshidabad has been selected arbitrarily, only to illustrate the uses and applicability of the method.

There are 26 blocks in the district and it stretches between 24°50′20″–23°43′30″N and 88°46′00″–87°49′17″E. Murshidabad district is regarded as a 'crop museum' and one of the food granaries of West Bengal, because almost every type of crop is grown here more or less abundantly. The district has an agrarian economy, as more than 85% of the population directly or indirectly depends upon agriculture and agri-allied sector. The district has a net cropped area of 365,000 ha (64% of the total geographical area) and a gross cropped area of 892,451 ha; thus cropping intensity is 244.5%. The district has a diversified cropping pattern. For the present study, eight major crops have been selected, with two crops each from four major crop groups – (i) cereals – rice and wheat; (ii) pulses – gram and masur; (iii) oilseed – mustard and till and (iv) cash crops – jute and potato. The present study is based on secondary data, collected from various State Government offices for the year 2011–12 (ref. 8). The yield achievement indices and contribution of various crops have been found and their spatial distribution (block level) has been discussed with suitable maps and charts. Then the composite crop productivity index of the district has been estimated, followed by a detailed discussion. Finally, the yield deficit indices have been measured to identify the liable crops at the block-level.

The method has been elaborated for the Berhampore block (Table 5).

CCPI of Berhampore block is

$$\begin{aligned} &0.36023 + 0.17323 + 0.00249 + 0.00415 \\ &\quad + 0.09116 + 0.01336 + 0.23555 + 0.00051 \\ &= 0.88151 = 0.882. \end{aligned}$$

The contribution of rice to total productivity is 0.36023 for the Berhampore block. Similarly, the contribution of various crops has been measured (Table 6), followed by a detailed discussion.

Table 5. Composite crop productivity index of Berhampore block, Murshidabad district, West Bengal

Crop	Yield rate (kg/ha)	Area under crop ('000 ha)	Yield achievement index ($I_{Y\ av}$) (column 2/column 8)	Weighted yield achievement index ($I_{WY\ av}$)[column 4 × column 3/49.615]	Yield deficit index (I_{YD}) (1 – column 4)	Weighted yield deficit index (I_{WYD})[column 6 × column 3/49.615]	Maximum yield (kg/ha)
Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8
Rice	3069	19.470	0.918	0.36023	0.082	0.03218	3344
Wheat	3296	8.602	0.999	0.17323	0.001	0.00017	3299
Masur	405	0.346	0.362	0.00249	0.638	0.00440	1120
Gram	904	0.305	0.669	0.00415	0.331	0.00205	1350
Mustard	929	6.582	0.687	0.09116	0.313	0.04154	1353
Til	1107	0.696	0.954	0.01336	0.046	0.00064	1160
Jute	13.58*	13.559	0.862	0.23558	0.138	0.03772	13.75
Potato	29,790	0.055	0.739	0.00081	0.261	0.00021	40,315
Total		49.615					

Source: Ref. 8. *Yield of jute in bales/ha.

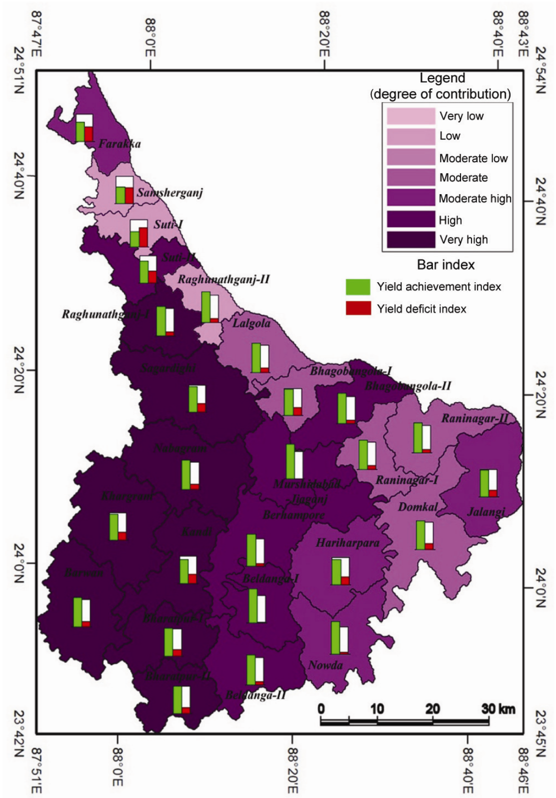

Figure 1. Spatial distribution (block level) of weighted yield index of rice, Murshidabad district, 2011–12; Source: Table 6.

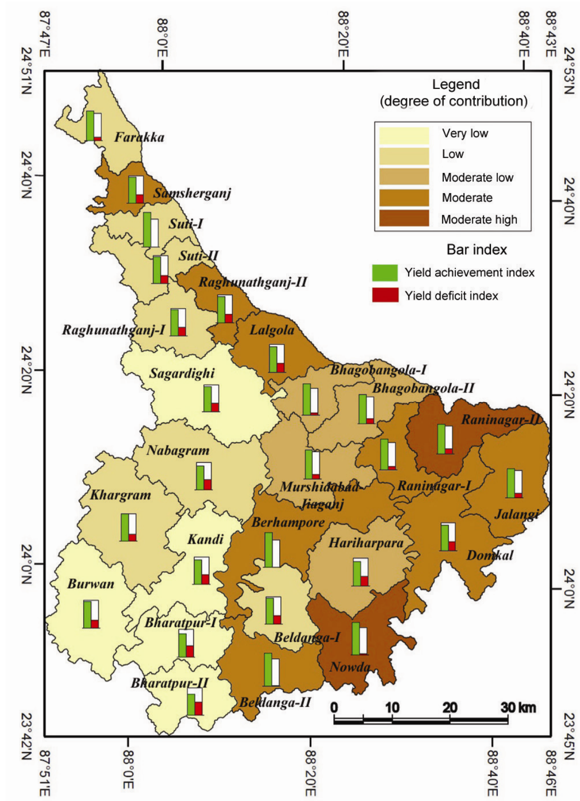

Figure 2. Spatial distribution (block level) of weighted yield index of wheat in Murshidabad district, 2011–12; Source: Table 6.

Spatial distribution of crop-wise yield achievement, contribution to CCPI and deficit level

Crop-specific block-wise yield achievement index, yield deficit index and weighted yield achievement index have been calculated using the CCPI formula (Table 6), followed by discussion (Figures 1–5; figures for crops like gram, til and potato have not been given, because they do not show much regional variation).

Regional variation of crop productivity

CCPI was estimated for each of the sub-area units (here blocks, Table 7) using the method explained earlier. The obtained index values of all the blocks were then grouped into three distinct categories following the standard classes of CCPI mentioned earlier in the text. These three categories formed on the basis of CCPI values represent three distinct degrees of crop productivity, viz. very high, high and moderate high.

Table 6. Yield achievement, weighted yield achievement (contribution level to CCPI), yield deficit, weighted yield deficit indices of eight selected crops in Murshidabad district, 2011–12

	Rice				Wheat			
Block	YAI	WYAI (contribution level to CCPI)	YDI	WYDI (liability index and liability level)	YAI	WYAI (contribution level to CCPI)	YDI	WYDI (liability index and liability level)
Berhampore	0.91800	H (0.36022)	0.08200	0.03218 (L)	0.99900	M (0.17323)	0.00100	0.00017 (VL)
Beldanga-I	0.97500	H (0.35801)	0.02500	0.00918 (VL)	0.74600	L (0.09607)	0.25200	0.03235 (L)
Beldanga-II	0.88800	H (0.39968)	0.11200	0.05042 (M)	0.96400	M (0.17593)	0.03600	0.00657 (VL)
Nowda	0.93500	MH (0.22829)	0.06500	0.01484 (L)	0.94400	MH (0.22829)	0.05600	0.00966 (VL)
Hariharpara	0.75700	MH (0.21471)	0.24900	0.07117 (M)	0.71900	ML (0.14198)	0.28100	0.05544 (M)
Lalgola	0.85900	M (0.16479)	0.14100	0.00421 (VL)	0.74000	M (0.17032)	0.26000	0.00443 (VL)
Bhagobangola-I	0.76500	M (0.16947)	0.23500	0.05208 (M)	0.92300	ML (0.11012)	0.07700	0.00919 (VL)
Bhagobangola-II	0.89900	H (0.29829)	0.10100	0.03351 (L)	0.85300	ML (0.12101)	0.14700	0.02086 (L)
Mur-Jiaganj	1.00000	H (0.38872)	0.00000	0.00000 (VL)	0.85300	ML (0.12025)	0.14700	0.02073 (L)
Nabagram	0.83300	VH (0.68574)	0.16700	0.13745 (MH)	0.69500	L (0.05273)	0.30500	0.02314 (L)
Domkal	0.82100	M (0.19456)	0.17900	0.04243 (L)	0.73600	M (0.16308)	0.26400	0.05847 (M)
Jalangi	0.78900	MH (0.21066)	0.21100	0.05630 (M)	0.85400	M (0.19269)	0.14600	0.03294 (L)
Raninagar-I	0.86300	M (0.18356)	0.13700	0.02915 (L)	0.89500	M (0.17799)	0.10500	0.02088 (L)
Raninagar-II	0.88300	M (0.19939)	0.11700	0.02643 (L)	0.84900	MH (0.20236)	0.15100	0.03600 (L)
Kandi	0.71900	VH (0.57426)	0.28100	0.22427 (S)	0.71500	VL (0.02741)	0.28500	0.01092 (L)
Khargram	0.74900	VH (0.66248)	0.25100	0.21687 (S)	0.80100	L (0.05186)	0.19900	0.01288 (L)
Burwan	0.84900	VH (0.70437)	0.15100	0.12528 (MH)	0.76400	VL (0.01263)	0.23600	0.00389 (VL)
Bharatpur-I	0.81400	VH (0.71554)	0.18600	0.16350 (H)	0.67200	VL (0.01064)	0.32800	0.00519 (VL)
Bharatpur-II	0.81200	VH (0.74149)	0.18800	0.17169 (H)	0.60900	VL (0.00036)	0.39100	0.00023 (VL)
Farakka	0.57100	MH (0.23947)	0.42900	0.17986 (H)	0.87500	L (0.07641)	0.12500	0.01092 (VL)
Suti-I	0.64500	H (0.28498)	0.35500	0.15684 (H)	0.77200	L (0.07992)	0.22800	0.02359 (L)
Suti-II	0.44300	L (0.07528)	0.55700	0.09468 (M)	1.00000	L (0.05345)	0.00000	0.00000 (VL)
Raghunathganj-I	0.72000	VH (0.52067)	0.28000	0.20237 (S)	0.75000	L (0.05721)	0.25000	0.01907 (L)
Raghunathganj-II	0.72000	L (0.07834)	0.28000	0.03045 (L)	0.75000	M (0.15714)	0.25000	0.05391 (M)
Samsherganj	0.50700	L (0.05781)	0.49300	0.05623 (M)	0.75000	M (0.16314)	0.25000	0.05437 (M)
Sagardighi	0.74500	VH (0.57497)	0.24600	0.18769 (H)	0.74900	VL (0.04517)	0.26000	0.01587 (L)
	Masur				Gram			
Berhampore	0.36200	VL (0.00249)	0.63800	0.00440 (VL)	0.66900	VL (0.00415)	0.33100	0.00205 (VL)
Beldanga-I	0.53800	VL (0.00253)	0.46200	0.00217 (VL)	0.60100	VL (0.00117)	0.39900	0.00078 (VL)
Beldanga-II	0.29600	VL (0.00095)	0.70400	0.00226 (VL)	0.63200	VL (0.00143)	0.36800	0.00084 (VL)
Nowda	0.43700	VL (0.01520)	0.56300	0.01960 (L)	0.59800	VL (0.01853)	0.40200	0.01246 (L)
Hariharpara	0.60100	VL (0.01796)	0.39900	0.01193 (L)	0.59700	VL (0.00516)	0.40300	0.00348 (VL)
Lalgola	0.43600	VL (0.00239)	0.56400	0.00309 (VL)	0.74500	VL (0.00268)	0.25500	0.00092 (VL)
Bhagobangola-I	0.36700	VL (0.00375)	0.63300	0.00646 (VL)	0.63200	VL (0.00750)	0.36800	0.00437 (VL)
Bhagobangola-II	0.43600	VL (0.00315)	0.56400	0.00407 (VL)	0.74500	VL (0.00603)	0.25500	0.00206 (VL)
Mur-Jiaganj	0.43800	VL (0.00596)	0.56200	0.00769 (VL)	0.74500	VL (0.00777)	0.25500	0.00266 (VL)
Nabagram	0.68800	VL (0.00026)	0.31200	0.00012 (VL)	0.79300	VL (0.00228)	0.20700	0.00059 (VL)
Domkal	0.90300	VL (0.02819)	0.09700	0.00303 (VL)	NA	NA	NA	NA
Jalangi	0.91100	VL (0.03499)	0.08900	0.00342 (VL)	0.74100	VL (0.00378)	0.25900	0.00132 (VL)
Raninagar-I	0.88100	VL (0.03013)	0.11900	0.00407 (VL)	0.74700	VL (0.00513)	0.25300	0.00174 (VL)
Raninagar-II	0.92600	VL (0.06719)	0.07400	0.00537 (VL)	0.74100	VL (0.00856)	0.25900	0.00299 (VL)
Kandi	1.00000	VL (0.00579)	0.00000	0.00000 (VL)	1.00000	VL (0.00579)	0.00000	0.00000 (VL)
Khargram	0.35500	VL (0.00007)	0.64500	0.00014 (VL)	0.92700	VL (0.00123)	0.07300	0.00009 (VL)
Burwan	0.85000	VL (0.00305)	0.15000	0.00054 (VL)	0.88700	VL (0.00132)	0.11300	0.00017 (VL)
Bharatpur-I	0.67400	VL (0.00613)	0.32600	0.00296 (VL)	0.64600	VL (0.00355)	0.35400	0.00194 (VL)
Bharatpur-II	0.59800	VL (0.00292)	0.40200	0.00197 (VL)	0.88400	VL (0.00156)	0.11600	0.00020 (VL)
Farakka	0.95700	L (0.05924)	0.04300	0.00266 (VL)	0.70100	VL (0.04169)	0.29900	0.01777 (L)
Suti-I	0.81200	ML (0.11396)	0.18800	0.02639 (L)	0.70100	VL (0.00015)	0.29900	0.00006 (VL)
Suti-II	0.81900	VL (0.04240)	0.18100	0.00937 (VL)	0.70100	VL (0.02461)	0.29900	0.01049 (L)
Raghunathganj-I	0.81900	VL (0.01699)	0.18100	0.00376 (VL)	0.70100	VL (0.00772)	0.29900	0.00329 (VL)
Raghunathganj-II	0.81900	L (0.00389)	0.18100	0.00086 (VL)	0.70100	VL (0.00507)	0.29900	0.00216 (VL)
Samsherganj	0.81900	VL (0.01976)	0.18100	0.00437 (VL)	0.70100	VL (0.00247)	0.29900	0.00106 (VL)
Sagardighi	0.50400	VL (0.00411)	0.49600	0.00405 (VL)	0.71300	VL (0.00188)	0.28700	0.00075 (VL)

(*Contd*)

Table 6. (*Contd*)

	Mustard				Til			
Block	YAI	WYAI (contribution level to CCPI)	YDI	WYDI (liability index and liability level)	YAI	WYAI (contribution level to CCPI)	YDI	WYDI (liability index and liability level)
Berhampore	0.68700	L (0.09116)	0.01300	0.04154 (L)	0.95400	VL (0.01336)	0.04600	0.00064 (VL)
Beldanga-I	0.58600	ML (0.12845)	0.41400	0.09073 (M)	0.82700	VL (0.01856)	0.17300	0.00388 (VL)
Beldanga-II	0.69000	L (0.07361)	0.31000	0.03306 (L)	0.68300	VL (0.00475)	0.31700	0.00220 (VL)
Nowda	0.82900	L (0.08842)	0.17100	0.01823 (L)	0.88200	VL (0.01863)	0.11800	0.00249 (VL)
Hariharpara	0.81500	L (0.09283)	0.18500	0.02107 (L)	0.97100	VL (0.03341)	0.02900	0.00099 (VL)
Lalgola	0.80700	M (0.16309)	0.19300	0.03899 (L)	0.86100	VL (0.00821)	0.13900	0.00132 (VL)
Bhagobangola-I	0.84000	VL (0.00750)	0.16000	0.03298 (L)	0.93400	L (0.05724)	0.06600	0.00405 (VL)
Bhagobangola-II	0.80700	M (0.15091)	0.19300	0.03609 (L)	0.86100	VL (0.01427)	0.13900	0.00230 (VL)
Mur-Jiaganj	0.80700	ML (0.10453)	0.19300	0.02499 (L)	0.86100	VL (0.01651)	0.13900	0.00266 (VL)
Nabagram	0.73600	L (0.05297)	0.26400	0.01899 (L)	0.61500	VL (0.00242)	0.38500	0.00152 (VL)
Domkal	0.59800	L (0.05786)	0.40200	0.03904 (L)	0.78400	VL (0.02787)	0.21600	0.00768 (VL)
Jalangi	0.75000	L (0.05314)	0.25000	0.01771 (L)	0.77800	VL (0.02879)	0.22200	0.00821 (VL)
Raninagar-I	0.87400	ML (0.14149)	0.12600	0.02039 (L)	1.00000	VL (0.02203)	0.00000	0.00000 (VL)
Raninagar-II	0.88400	L (0.09951)	0.11600	0.01306 (L)	0.79400	VL (0.04476)	0.20600	0.01161 (L)
Kandi	0.73100	L (0.06161)	0.26900	0.02267 (L)	0.48700	VL (0.00852)	0.52200	0.00929 (VL)
Khargram	0.76900	H (0.03022)	0.23100	0.00908 (VL)	0.49400	VL (0.00272)	0.50600	0.00278 (VL)
Burwan	0.74400	VL (0.02438)	0.25400	0.00839 (VL)	0.65600	VL (0.01047)	0.34400	0.00549 (VL)
Bharatpur-I	0.68100	VL (0.02229)	0.31900	0.01043 (L)	0.57100	VL (0.02214)	0.42900	0.01596 (L)
Bharatpur-II	0.48600	VL (0.01112)	0.51400	0.01177 (L)	0.73800	VL (0.03599)	0.26200	0.01277 (L)
Farakka	0.81000	L (0.09900)	0.19000	0.02322 (L)	0.59600	VL (0.00073)	0.40400	0.00049 (VL)
Suti-I	0.74400	ML (0.10730)	0.25600	0.03691 (L)	NA	NA	NA	NA
Suti-II	1.00000	ML (0.10915)	0.00000	0.00000 (VL)	NA	NA	NA	NA
Raghunathganj-I	0.63800	L (0.05836)	0.36200	0.03312 (L)	0.59800	VL (0.00051)	0.40200	0.00345 (VL)
Raghunathganj-II	0.63800	ML (0.11533)	0.36200	0.06546 (M)	NA	NA	NA	NA
Samsherganj	0.63800	ML (0.11350)	0.36200	0.064429M)	NA	NA	NA	NA
Sagardighi	0.59700	L (0.07807)	0.40300	0.05268 (M)	0.57200	VL (0.00322)	0.42800	0.00241 (VL)
	Jute				Potato			
Berhampore	0.86200	MH (0.23558)	0.13800	0.03772 (L)	0.73900	VL (0.00081)	0.26100	0.00021 (VL)
Beldanga-I	0.89600	MH (0.21703)	0.10400	0.02519 (L)	0.56500	VL (0.00796)	0.43500	0.00613 (VL)
Beldanga-II	0.67600	M (0.16251)	0.32400	0.07787 (M)	0.74400	VL (0.00594)	0.25600	0.00205 (VL)
Nowda	0.84600	H (0.32363)	0.15400	0.05889 (M)	0.50100	VL (0.00373)	0.49900	0.00371 (VL)
Hariharpara	0.88100	H (0.28623)	0.11900	0.03865 (L)	0.66800	VL (0.00352)	0.33200	0.00175 (VL)
Lalgola	0.91900	H (0.37922)	0.08100	0.03343 (L)	0.62600	VL (0.00268)	0.37400	0.00160 (VL)
Bhagobangola-I	0.91200	H (0.33167)	0.08800	0.03199 (L)	0.53900	VL (0.00322)	0.46100	0.00276 (VL)
Bhagobangola-II	0.91900	H (0.27197)	0.08100	0.02398 (L)	0.63500	VL (0.00722)	0.36500	0.00415 (VL)
Mur-Jiaganj	0.91900	H (0.26704)	0.08100	0.02354 (L)	0.44900	VL (0.00305)	0.55100	0.00375 (VL)
Nabagram	0.98000	VL (0.01570)	0.02000	0.00320 (VL)	0.63500	VL (0.00373)	0.36500	0.00215 (VL)
Domkal	0.85400	H (0.30539)	0.14600	0.05221 (M)	0.57400	VL (0.01450)	0.42600	0.00849 (VL)
Jalangi	0.88100	H (0.29815)	0.11900	0.04029 (L)	0.63100	VL (0.01115)	0.36900	0.00652 (VL)
Raninagar-I	0.91100	H (0.32522)	0.08900	0.03177 (L)	0.45100	VL (0.00242)	0.54900	0.00356 (VL)
Raninagar-II	0.92200	MH (0.22451)	0.07800	0.01899 (L)	0.62700	VL (0.02453)	0.37300	0.01459 (L)
Kandi	0.97400	VL (0.02821)	0.02600	0.00075 (VL)	0.52400	VL (0.01279)	0.47600	0.01161 (L)
Khargram	0.94300	VL (0.00004)	0.05700	0.000003 (VL)	0.66100	VL (0.00321)	0.33900	0.00164 (VL)
Burwan	0.95100	VL (0.00051)	0.04900	0.00003 (VL)	0.78900	L (0.07859)	0.21100	0.02099 (L)
Bharatpur-I	0.93800	VL (0.00373)	0.06200	0.00025 (VL)	0.68700	VL (0.01143)	0.31300	0.00521 (VL)
Bharatpur-II	0.95100	VL (0.00389)	0.04900	0.00020 (VL)	0.56200	VL (0.00209)	0.43800	0.00163 (VL)
Farakka	0.91400	M (0.17233)	0.08600	0.01621 (L)	0.32200	VL (0.01934)	0.67800	0.04077 (L)
Suti-I	1.00000	M (0.16644)	0.00000	0.00000 (VL)	0.68900	VL (0.00241)	0.31100	0.00109 (VL)
Suti-II	0.97500	VH (0.56639)	0.02500	0.01426 (L)	1.00000	VL (0.01003)	0.00000	0.00000 (VL)
Raghunathganj-I	0.97500	L (0.06157)	0.02500	0.00158 (VL)	0.39300	VL (0.00236)	0.60700	0.00365 (L)
Raghunathganj-II	0.97500	H (0.47025)	0.02500	0.01205 (L)	0.48400	VL (0.00146)	0.51600	0.00155 (VL)
Samsherganj	0.97500	H (0.43499)	0.02500	0.01115 (L)	0.55400	VL (0.00931)	0.44600	0.00749 (VL)
Sagardighi	0.99800	VL (0.00116)	0.00200	0.00005 (VL)	0.52200	VL (0.00116)	0.47800	0.00107 (VL)

Source: Computed by author from ref. 8. YAI, Yield achievement index; WYAI, Weighted yield achievement index; YDI, Yield deficit index; WYDI, Weighted yield deficit index. For weighted crop yield (contribution level) classes refer to Table 3; VH, Very high; h, High; MH, Moderate high; M, Moderate; L, low and VL, Very low. For crop liability classes refer to Table 4. VS, Very severe; S, Severe; MH, Moderate high; M, Moderate; L, low and VL, Very low.

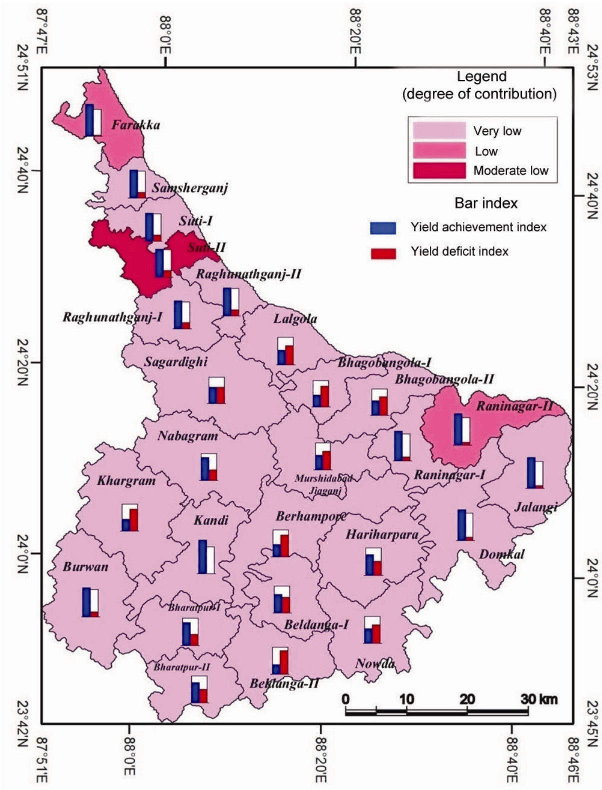

Figure 3. Spatial distribution (block level) of weighted yield index of masur, Murshidabad district, 2011–12; Source: Table 6.

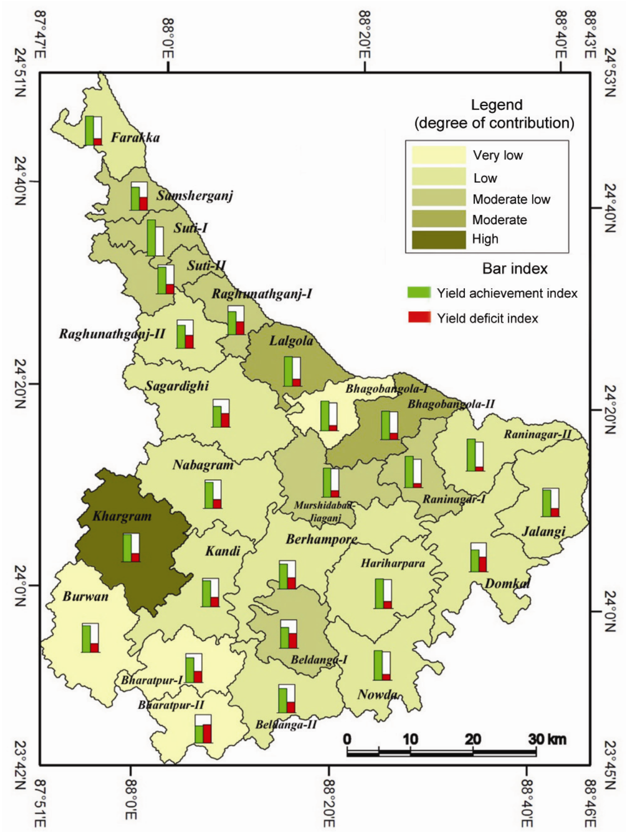

Figure 4. Spatial distribution (block level) of weighted yield index of mustard, Murshidabad district, 2011–12; Source: Table 6.

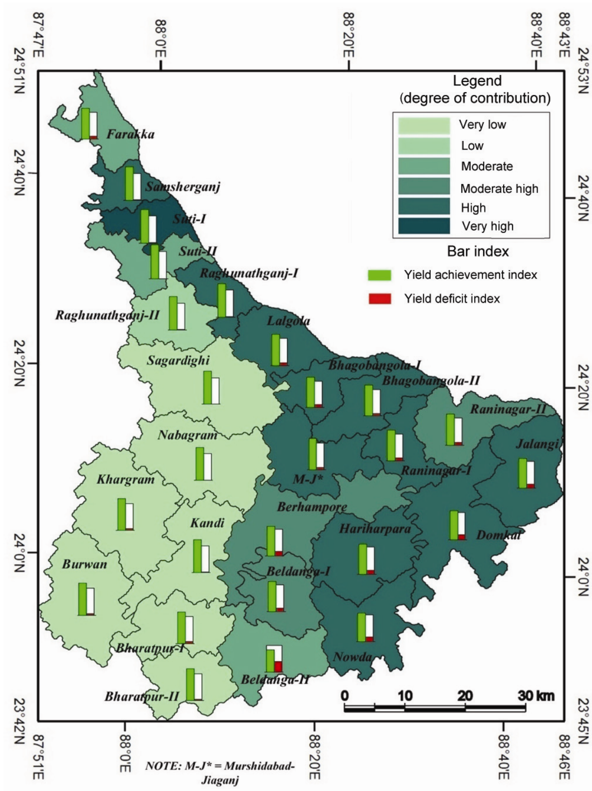

Figure 5. Spatial distribution (block level) of weighted yield index of jute, Murshidabad district, 2011–12; Source: Table 6.

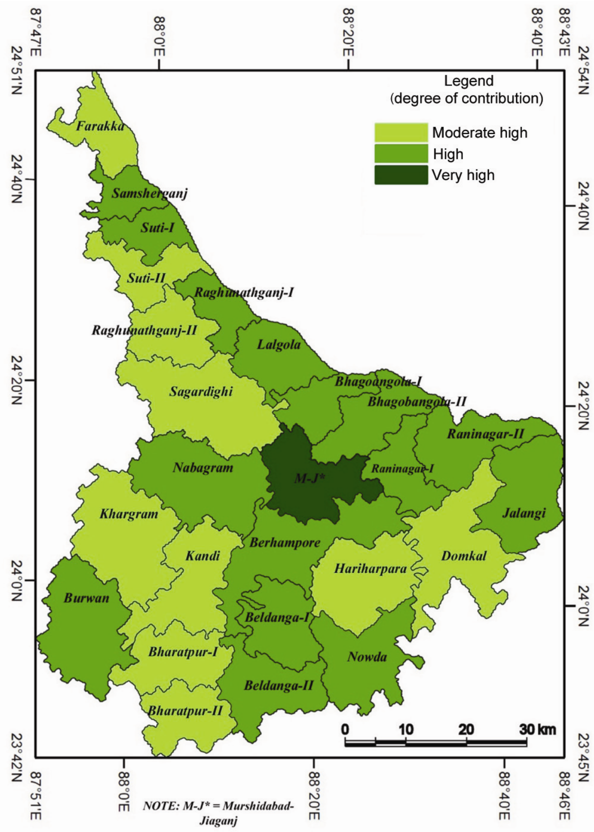

Figure 6. Spatial distribution (block level) of composite crop productivity index (CCPI), in Murshidabad district, 2011–12; Source: Table 7.

Figure 6 shows the spatial distribution of CCPI in various blocks of Murshidabad district. Very high crop productivity is observed only in Murshidabad–Jiaganj block in the central-east portion of the district. Most of the areas of the district (15 blocks, 57.67% of total blocks) show high crop productivity. They occur in a narrow belt of seven blocks running along the eastern edge of the district extending from Lalgola to Jalangi. Another belt of high crop productivity is found in the middle and southern parts, comprising four blocks, namely Berhampore, Beldanga I and II and Nowda. Other areas of high productivity are found to be scattered in the western and northern parts of the district. The areas of moderate high crop productivity seem to occur in clusters; one is confined to the western and southwestern part, the second lies in the northwest and the third patch is found in the southeastern part of the district. Thus, the regional distribution of crop productivity shows distinctive contrasting areas. Productivity is highest in the central part and higher in the eastern part of the study area, which more or less coincides with the new alluvium zone of Bagri region. In general, productivity is observed slightly low in the west and towards north and southeastern parts, and it seems to coincide with the older alluvium zones of Rarh.

Identification of liable crops

Crop liability index for various crops for each sub-area unit (here blocks) was calculated. It is the weighted crop yield deficit index that depends upon the yield deficit level and share of cropland under various crops. The degree of liability of various crops has been fixed based on this index following the standard crop liability groups given in Table 5. For the blocks, some crops have been identified as liable crops (Table 6).

In most of the blocks in the eastern part of the district, the liability level of most crops was found to be 'low', e.g. Berhampore, Murshidabad–Jiaganj, Jalangi, Lalgola, Raninagar-I and II, Bhagoangola-II, etc. Some blocks have few crops (like mustard, rice, jute and wheat) with moderate low to moderate high liability level, viz. mustard (moderate, 0.09073) in Beldanga-I, jute (moderate, 0.07737) and rice (moderate, 0.05042) in Beldanga-II, rice (moderately high, 0.13745) in Nabagram, etc. In the blocks in the western part of Murshidabad district, liability level of various crops (rice, wheat, potato, til, mustard, etc.) was found to range between low and severe. In many blocks, rice was the most frequent liable crop with high to severe liability level. Severe liability of rice was observed in Kandi and Khargram with liability index of 0.22427 and 0.21687 respectively. High liability level of rice was found in the blocks of Bharatpur I and II, Farakka, Suti-I and Sagardighi.

Thus it is evident that productivity blocks in the western part lag far behind those in the eastern part of the district. Moreover, based on these results, it would be more fruitful to initiate region-wise crop selection rather than implementing any single blind policy for the whole region and for all crops.

Conclusion

In this article, a technique has been presented which estimates crop productivity. It measures productivity of an area which provide its achievement towards attaining maximum productivity at a particular point of time. It is the estimation of the simplified relationship between the actual hectare-yield, maximum hectare-yield and area under a particular crop and the total cropland of any region under all the selected crops. The above technique also estimates yield achievement level and contribution of various crops to total productivity. The yield achievement index gives a clear picture of the present hectare-yield level with regard to achieving maximum yield output. The index values have been grouped into different standard categories ranging between '0' and '1', and each group corresponds to various degrees of crop yield achievement. Thus it provides better understanding of the present yield situation of the study area. Hence, a region with high crop productivity index indicates high efficiency of all the factors of production put together than in

Table 7. Composite crop productivity index and productivity levels of blocks in Murshidabad district, 2011–12

Block	CCPI	Crop productivity class
Berhampore	0.881	H
Beldanga-I	0.829	H
Beldanga-II	0.849	H
Nowda	0.859	H
Hariharpara	0.795	MH
Kandi	0.721	MH
Khargram	0.759	MH
Burwan	0.836	H
Bharatpur-I	0.791	MH
Bharatpur-II	0.799	MH
Farakka	0.709	MH
Samsherganj	0.801	H
Suti-I	0.755	MH
Suti-II	0.872	H
Raghunathganj-I	0.73	MH
Raghunathganj-II	0.824	H
Sagardighi	0.756	MH
Lalgola	0.808	H
Bhagobangola-I	0.856	H
Bhagobangola-II	0.873	H
Msd–Jiaganj	0.914	VH
Nabagram	0.816	H
Domkal	0.788	MH
Jalangi	0.833	H
Raninagar-I	0.889	H
Raninagar-II	0.87	H

Source: Computed by author from Table 6. For productivity classes refer to Table 1 (H, High; MH, Moderate high; VH, Very high).

a region with low crop productivity. However, the result does not identify the influences of individual factors upon crop productivity of any region.

The weighted crop yield index estimates the contribution of various crops to overall productivity. Besides, it helps identify the major crops of any region. A scale of crop productivity has also been prepared with six standard groups based on composite index values and each group represents a different degree of productivity. This also makes comparison between several area units and change detection in an area between two periods much easier. The technique can also be employed to analyse the trend in crop productivity of an area for a given period of time using linear regression for year-wise data of that period. The above method also provides a useful tool to calculate yield deficit index and liability level of various crops, which is actually the weighted yield deficit index. Yield deficit index is complementary to yield achievement index. Standardized groups of crop deficit and liability level have also been provided. This is useful to identify the liable crops of an area more accurately, as it considers both the yield deficit level and share of cropland under individual crops.

Variation in crop productivity as estimated in this method, however, does not give any information regarding the influences of individual factors for such variation. Rather it would require more detailed study about region-based crop inputs and level of technology. Also, the method is applicable to those regions where only crops are grown and animal husbandry is not considered as an integral part of the farming system. Data regarding various inputs, outputs and prices are not always available.

1. Bhatia, S. S., A new approach to measure agricultural efficiency in Uttar Pradesh. *Econ. Geogr.*, 1967, **43**, 224–260.
2. Singh, J. and Dhillion, S. S., *An Agricultural Geography*, Tata-McGraw Hill Publishing Company Limited, New Delhi, 1984.
3. Bhatia, S. S., Spatial variation, changes and trends in agricultural efficiency in Uttar Pradesh 1953–1963. *Indian J. Agric. Econ.*, 1967, **22**(1), 52.
4. Singh, J., A new technique for measurement of agricultural productivity. In *A Perspective in Agricultural Geography* (ed. Mohammed Noor), 1981, vol. 4, pp. 169–182.
5. Shafi, M., Measurement of agricultural productivity of the great Indian Plains. *The Geographer*, 1972, **19**, 296–305.
6. Darku, A. B., Malla, S. and Tram, K. C., Historical Review of Agricultural Efficiency Studies, Department of Economics, University of Lethbrige, Alberta, Canada, 2013.
7. Ogle, S. and Nagarale, V., Agricultural productivity of Baramati-tahasil, Pune district (Maharastra). *J. Agricul. Vet. Sci.*, 2014, **7**(5), 25–30.
8. *District Statistical Handbook – 2012 Murshidabad*, Bureau of Applied Economics and Statistics, Government of West Bengal, Kolkata, 2014.

ACKNOWLEDGEMENT. I thank the reviewers for their constructive comments that helped improve the manuscript.

Received 24 December 2015; revised accepted 25 August 2016

doi: 10.18520/cs/v112/i02/311-321