



# Modeling the effect of agricultural inputs on the spatial variation of agricultural efficiency in West Bengal, India

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Received: 29 January 2019 / Accepted: 28 March 2019 / Published online: 6 April 2019  
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## Abstract

Scarcity of agricultural land is the single greatest constraint to the development of agro-based nations like India, and this problem has been augmented in present day due to the persistently growing pressure of population to the limited available land resource. Accordingly, improvement in agricultural efficiency seems to be the best alternative to meet the requirements of growing population along with the overall development. The central concern of this paper is to study the inter-district variations in agricultural efficiency in the state of West Bengal, one of the agro-based states in India during the period 2010–2011. The study also attempts to scrutinize the impact of agricultural inputs on agricultural efficiency. The level of agricultural efficiency was examined both in crops and aggregate levels based on the 22 major crops grown in the state. Besides, composite development index of agricultural inputs was computed based on optimum combinational composite index model (OCCIM). Wide inter-district variations have been witnessed in the magnitude of agricultural efficiency. The district of Malda was recorded as the maximum efficient district and Purulia was recognized as the least efficient district in terms of agriculture. In addition, inter-district variations in the development level of inputs were also observed in the state. The districts of Bankura and Cooch Behar were registered as maximum and minimum developed districts, respectively, in terms of agricultural inputs availability. The development level of inputs was affecting the agricultural efficiency in the positive orientation in the state. Finally, this paper computes a set of prospective targets of selected agricultural inputs for all districts along with the identification of model districts by using developmental distances between different combinations of districts, which would be in the direction of reducing the inter-district gap of agricultural efficiency.

**Keywords** Agricultural efficiency · Composite development index · Agricultural inputs · Optimum combinational composite index model (OCCIM) · Developmental distance · Model district · Prospective targets

## Introduction

Most of the agro-based nations like India suffer from the excessive pressure of growing population to their limited available land resources. Thus, agricultural land, one of the most fundamental bases of economy, is now gradually decreasing due to the conversion into area not available for cultivation. As a result, most of these countries are now facing by the problem of arable land scarcity. This problem has been reinforced in present day due to the displacement of arable land by riverbank erosion hazard in the floodplain areas of these countries (Haque and Zaman 1989; Islam and

Guchhait 2019). With the growth of 14% per decade of its population, West Bengal loses an area of about 8 km<sup>2</sup> of land annually by the alluvial channels from its deltaic plains (Bandyopadhyay et al. 2014). In the mean time, the state also suffers with the acute problems of flood, drought and water table lowering in its different parts. So the agrarian structure of the state witnesses with a distressed condition in recent years. In this regard, the augmentation of agricultural performance is the best alternative to meet the basic requirements of population and to continue the economic development of the state.

The dynamic nature of agricultural growth is a prominent characteristic in the state. In spite of several conducive conditions of agriculture, the growth rate of agricultural production in West Bengal was slow and lagged behind the national average for many years since independence (Saha and Swaminathan 1994). From the estimate of Boyce (1987),

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it was only 1.74% between 1949 and 1980, additionally the national growth rate was over 3%. Chattopadhyay (2005) noticed an unfavorable disseminative impact of agricultural growth on the rural population due to the impediment in agricultural production over the same period. The estimates of Rawal and Swaminathan (1998) on the growth rates of foodgrain production reveal that it was 0.79% annually during 1950s, the rate of growth increased to 3.3% in the 1960s but in the 1970s, it fell back to 0.96%. Boyce (1987), Ghosh (1998), Rawal and Swaminathan (1998) further observed that the factors behind the predicament in agricultural production in West Bengal were low level of irrigation development including poor water management and control and the semi feudal agrarian system. After a long stagnation, a significant increase in the production of agricultural output began in West Bengal from 1980s (Rawal and Swaminathan 1998; Nandy and Siddhanta 2000; Chattopadhyay 2005). This majestic increase has eventuated due to the emergence of modern technology, better management of high yielding variety seeds (HYVs) along with fertilizer technology and introduction of an another approach to rural advancement encompassing reforms in agrarian institutions, especially land reform and decentralized administration.

It is conspicuous that, in last two decades, there have been major institutional changes and agrarian development in rural areas and these are closely linked to the changes in agricultural productivity. But most of the land holders in West Bengal have been concentrated within the small and marginal groups of land holdings and thus the production on small and fragmented holdings is likely to have been a constraint on the adoption of technological changes involving with large capital investment and high risk. Although within West Bengal, the use of chemical fertilizers has increased in last three decades, the balanced ratio is to be adjusted on the basis of soil test. Besides, the use mechanized implements in agriculture differed significantly between size classes of holdings in West Bengal.

Most of the earlier studies emphasize mainly on the growth and stability in West Bengal agriculture. In addition, these studies have been conducted in terms of overall state instead of inter-district analysis. It is widely believed that the agricultural efficiency of a particular region is closely associated with the development level of agricultural inputs; thus, performance of a state should be judged not merely by the performance of the state as a whole but also in terms of how the performance level is affected by the development level of inputs spatially. It is in the perspective that a proper cognizance of the impact of agricultural inputs on the inter-district variation of agricultural efficiency presumes pragmatic significance. Against this research gap, the present study would concentrate on the following objectives: (1) to measure the spatial variation of agricultural efficiency both in crops and aggregate levels along with the discerning of

low efficient districts, (2) to explore the inter-district variations in the development level of inputs, (3) to examine the impact of agricultural inputs on agricultural efficiency and (4) to compute a set of prospective targets of agricultural inputs for all districts along with the identification of model districts.

## Study area

The state of West Bengal (88,752 Km<sup>2</sup>) is comprised of 23 administrative districts. It is bounded on north and south by 27°13'15" and 21°25'24" north latitudes, its northern most point being Darjeeling situated high up in the snowy peaks of the world's prodigious mountain, the Himalayas and the southernmost point extending in the great Bay of Bengal. East and west, it stretches by 89°53' 04" and 85°48' 20" east longitudes and is enclosed on the east by Bangladesh and Assam and on the west by Bihar, Orissa and Nepal (Fig. 1). The state, with the exception of mountainous terrain in north and the western plateau fringe, is characterized by the gigantic alluvial plains. Physiographically, the state may be divided into eight regions—(a) The Mountainous terrain of the north, (b) Sub-Himalayan alluvial fans, (c) The plains of North, (d) Degraded uplands in the south-west, (e) Lateritic Rarh tract, (f) Upper Ganga delta (UGD), (g) Lower Ganga delta (LGD), (h) Medinipur Coastal plain. The geological evolution coupled with the fluvial environments and their imprints on the landscape has sculpted distinct soil characteristics in the state. From the upper limit of Terai deposits in Darjeeling district to the lower limit of Barind tract in Malda, the soils are gradually changed from sandy and humus-enriched black soil to alluvial, controlled by sub-Himalayan fan deposits (De 1990; Bandyopadhyay et al. 2014). Similarly, the Archean fringe in the west is covered with the transported materials from Chotanagpur plateau by the east flowing tributaries of the river Bhagirathi-Hooghly and is dominated by red and lateritic soils which are atrocious in organic matter and nutrients. The deltaic part is dominated by two types of alluvial soils. The upper part is characterized by the alternative layers of silt and fine sand (Guchhait et al. 2016; Islam and Guchhait 2017), while the lower part is enriched with tidal silt, clay and sand (Bandyopadhyay et al. 2014). The coastal parts of the districts of Midnapore (E) and 24 Parganas (S) are dominated by recent alluvium, composed with the tidal and inter tidal silt and clay deposition. The soils of these coastal parts become salt infused due to the inundation by a large number of tidal creeks and bights.

The climate of West Bengal is tropical and humid with the exception of the northern hilly tract, the vicinity of the Himalayas. The temperature in the main land normally ranges between 24–40 °C during summer and 7–26 °C during the winter. The mean annual rainfall in the State is

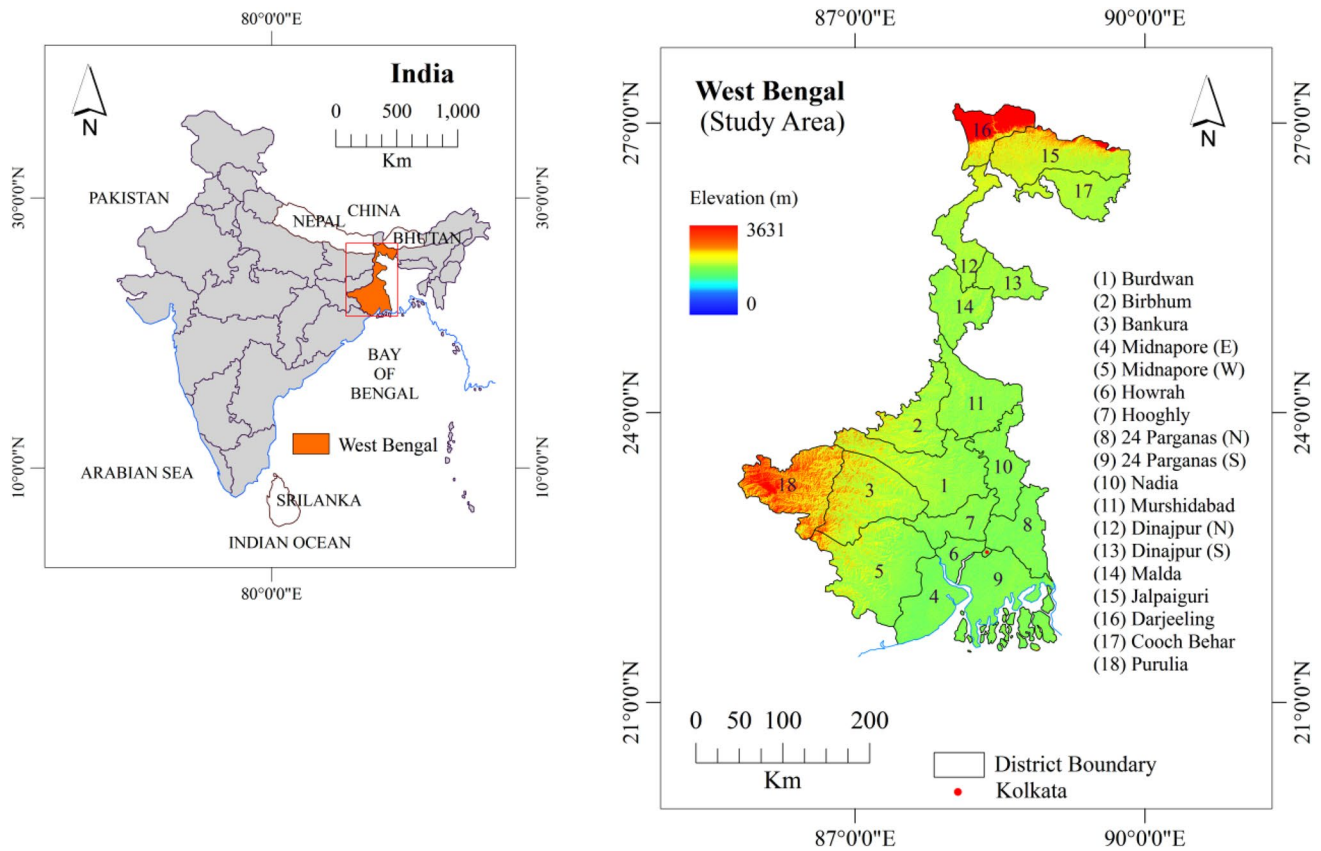


Fig. 1 Location of the study area, West Bengal

about 175 cm with substantial variations among the districts varying between 123.4 cm in Birbhum and 413.6 cm in Jalpaiguri. West Bengal’s population stands at 91.35 millions on 2011. Being the fourth largest states of the country in terms of population, it accounts for 7.55% of India’s population, as per 2011 census. West Bengal is predominantly an agrarian state. Sharing 2.7% land of the country, it produces nearly 8% of country’s food production and provides space 7.6% of the country’s population. The net cropped area is 5.45 million hectare which comprises 68% of the geographical area in which 2.33 million hectares area is irrigated (BAE&S 2012). The average size of land holding is only 0.64 hectare (GoWB 2012). At present, the agricultural and its allied sectors of the state contributes 16.96% to the Gross State Domestic Product (GSDP) with the growth rate of 3.33% annually (BAE&S 2016) and accords 7% to the economy of the country (CARE 2013). The present study has been conducted on 18 districts (the newly forged districts Jhargram, Alipurduar, Kalimpong and Paschim Bardhaman have been kept together with Midnapore (W), Jalpaiguri, Darjeeling and Burdwan, respectively, as they were in 2010–2011 to avoid

splitting of data in the period of study and the district of Kolkata is excluded for being an urban district).

## Materials and methods

### Database

The efficiency of agriculture depends on various input factors including physical, socio-economic and technological. The combined effects of these factors govern the agricultural performance of a particular region. In this present study, nine input factors (Table 1) are incorporated for quantifying the composite development score of agricultural inputs. Besides, agricultural efficiency is the aggregate performance of different crops in concern to their P/A ratio (Sinha 1968; Singh and Dhillon 2006). In order to compute agricultural efficiency index, 22 major crops grown in West Bengal have been taken into consideration. The area and production values of these crops along with the data on selected inputs have been collected from economic review (2011–2012) and statistical abstract (2013), published by Bureau of Applied Economics and Statistics

**Table 1** Selected agricultural inputs (factors) incorporated in this study

Agricultural inputs (notation)	Algorithm used	Data source
Intensity of irrigation ( $x_1$ )	Net irrigated area as percentage of net sown area [(NIA/NSA) × 100]	Chand et al. (2011) <a href="http://www.niap.res.in/upload_files/policy_paper/pp26.pdf">http://www.niap.res.in/upload_files/policy_paper/pp26.pdf</a>
Chemicalization level ( $x_2$ )	Use of chemical fertilizers in kilograms per hectare of total cropped area [Quantity of CFs/TCA]	Statistical abstract, West Bengal, 2013 <a href="http://www.wbpcsp.gov.in/SiteFiles/Publications/10_18052017120640.pdf">http://www.wbpcsp.gov.in/SiteFiles/Publications/10_18052017120640.pdf</a>
Intensity of labor ( $x_3$ )	Number of people actively employed in agriculture per 100 hectares of total cropped area [(TAL/TCA) × 100]	PCA, West Bengal, (2011) <a href="http://www.censusindia.gov.in/pca/pca.aspx">www.censusindia.gov.in/pca/pca.aspx</a>
Size of holdings ( $x_4$ )	Total amount in hectares of agricultural land per holding [TCA/Number of holdings]	Statistical abstract, West Bengal, (2013) <a href="http://www.wbpcsp.gov.in/SiteFiles/Publications/10_18052017120640.pdf">http://www.wbpcsp.gov.in/SiteFiles/Publications/10_18052017120640.pdf</a>
Intensity of cropland ( $x_5$ )	Percentage of net sown area to total cropped area [(NSA/TCA) × 100]	Statistical abstract, West Bengal, (2013) <a href="http://www.wbpcsp.gov.in/SiteFiles/Publications/10_18052017120640.pdf">http://www.wbpcsp.gov.in/SiteFiles/Publications/10_18052017120640.pdf</a>
Plowing level ( $x_6$ )	Density of plows per 1000 hectares of total cropped area [(Number of plow/TCA) × 1000]	Statistical abstract, West Bengal, (2013) <a href="http://www.wbpcsp.gov.in/SiteFiles/Publications/10_18052017120640.pdf">http://www.wbpcsp.gov.in/SiteFiles/Publications/10_18052017120640.pdf</a>
Levelerization level ( $x_7$ )	Density of levelers per 1000 hectares of total cropped area [(Number of levelers/TCA) × 1000]	Statistical abstract, West Bengal, (2013) <a href="http://www.wbpcsp.gov.in/SiteFiles/Publications/10_18052017120640.pdf">http://www.wbpcsp.gov.in/SiteFiles/Publications/10_18052017120640.pdf</a>
Puddlerization level ( $x_8$ )	Density of puddlers per 1000 hectares of total cropped area [(Number of puddlers/TCA) × 1000]	Statistical abstract, West Bengal, (2013) <a href="http://www.wbpcsp.gov.in/SiteFiles/Publications/10_18052017120640.pdf">http://www.wbpcsp.gov.in/SiteFiles/Publications/10_18052017120640.pdf</a>
Cropping intensity ( $x_9$ )	Total cropped area as percentage of net sown area [(TCA/NSA) × 100]	Statistical abstract, West Bengal, (2013) <a href="http://www.wbpcsp.gov.in/SiteFiles/Publications/10_18052017120640.pdf">http://www.wbpcsp.gov.in/SiteFiles/Publications/10_18052017120640.pdf</a>

NIA net irrigated area, NSA net sown area, HYV high yield variety, CFs chemical fertilizers, TCA total cropped area, TAL total number of agricultural laborers

(BAE&S 2012; 2013), Government of West Bengal and from Primary Census Abstract (PCA) of West Bengal (2011) and Policy paper-26, published by the Office of the Registrar & Census Commissioner, India and Indian Council of Agricultural Research (ICAR), respectively.

## Methods

In this study, five methodological phases have been undertaken: (1) computation of agricultural efficiency indices both in crops and aggregate levels, (2) estimation of composite development index of agricultural inputs by using optimum combinational composite index model (OCCIM) of Narain et al. (1991), (3) regionalization of the levels of agricultural efficiency and stages of development of agricultural inputs based on the properties of normal curve relating to the area lying at various units of standard deviation from mean of the efficiency scores/development indices, (4) measure the degree and direction of relationship between agricultural inputs and efficiency and (5) estimation of prospective targets of agricultural inputs for all districts along with the identification of model districts for them. The subsequent sections abridge the whole methodology arrogated in the present study.

## Computation of the agricultural efficiency index

The measurement of performances of different crops in respect to their outputs per unit area is known as agricultural efficiency. In other words, it refers to the yield efficiency (Singh and Dhillon 2006). With the help of quantitative measurement of agricultural efficiency, the poorly performed regions can be easily identified which will help the agricultural planners to implement of additional assistances. A few numbers of studies measured the agricultural efficiency at different regional scales have been conducted in last few decades by examining the input–output ratio (Sinha 1968). In this present study, the standard efficiency score of each crop has been extracted by computing the standard deviation of yield efficiency index of each crop. The yield efficiency index ( $C_{ij}$ ) for each crop can be measured by the following formula:

$$C_{ij} = Y_{ij}/Y_{ax} \quad (1)$$

where  $C_{ij}$  is the yield efficiency index of  $j$ th crop for  $i$ th region,  $Y_{ij}$  is the yield rate per unit area of the  $j$ th crop in  $i$ th district and  $Y_{ax}$  represents the yield rate of  $i$ th crop for the whole region. By using the yield efficiency index, standard

score ( $Z_{ij}$ ) of a particular crop may be computed by applying the following formula.

$$Z_{ij} = \frac{(Y_{ij} - \overline{C}_j)}{\sigma C_j} \tag{2}$$

where  $\overline{C}_j$  is the mean of yield efficiency index in the study area and  $\sigma C_j$  is the standard deviation of yield efficiency index of  $j$ th crop in the study area.

The standard score of  $j$ th crop for a particular district is then multiplied with area under  $j$ th crop to obtain the efficiency score of that crop.

The overall performance index also termed as aggregate efficiency index in agriculture is the weighted average of standard score of a particular district can be measured by:

$$Ei = \frac{(Z_{ij} \times A_j) + (Z_{ik} \times A_k) \dots + (Z_{in} \times A_n)}{A_j + A_k \dots + A_n} \tag{3}$$

where  $E^i$  is the aggregate agricultural efficiency of  $i$ th district,  $Z_{ij}, Z_{ik}, \dots, Z_{in}$  are the standard scores of crops  $j, k, \dots, n$  and  $A_j, A_k, \dots, A_n$  are the areas under the crops  $j, k, \dots, n$ .

### Estimation of the development level of agricultural inputs

As mentioned earlier, agricultural efficiency of a particular region depends upon a set of input ingredients. To analyze the combined impact of these ingredients, a single composite index value of inputs has been calculated by adopting the

optimum combinational composite index method (OCCIM) of Narain et al. (1991). In this study, the selected nine inputs are taken as input variables (Table 2) as a data matrix  $[X_{ij}]$ , where  $X$  represents the value of the  $j$ th variable for  $i$ th district. Different indicators used in this study have different units. Subsequently, the original values of the variables have been normalized in order to get unit free values. Thus, in order to obtain scaled values, they are normalized so that they all lie between 0 and 1. For this purpose, the method of UNDP’s Human Development Index (HDI) (UNDP 2006) is introduced here to normalize indicators on the basis of operational relationship between the indicators and input development. Two types of operational relationship are practicable. If the variables are positively associated with the development level of inputs, then normalization is achieved by using the following formula:

$$N_{ij} = \frac{X_{ij} - \text{Min}(X_{ij})}{\text{Max}(X_{ij}) - \text{Min}(X_{ij})} [\uparrow] \tag{4}$$

and if the variables are negatively associated with the development then normalization is done using the formula as below:

$$N_{ij} = \frac{\text{Max}(X_{ij}) - X_{ij}}{\text{Max}(X_{ij}) - \text{Min}(X_{ij})} [\downarrow] \tag{5}$$

where  $[N_{ij}]$  is the data matrix of normalized variables (Table 3),  $\text{Max}(X_{ij})$  and  $\text{Min}(X_{ij})$  show the maximum and minimum values of original variables and then the

**Table 2** Factors incorporated in measuring the development level of agricultural inputs

District	Agricultural inputs								
	$X_1$	$X_2$	$X_3$	$X_4$	$X_5$	$X_6$	$X_7$	$X_8$	$X_9$
Burdwan	42.52	219.95	134	1.53	64.75	438	332	31	165.30
Birbhum	69.32	218.03	110	1.35	70.93	900	577	58	131.56
Bankura	85.07	227.00	115	0.80	55.65	1382	852	25	121.77
Midnapore (E)	37.14	149.40	96	0.96	72.63	171	319	12	195.43
Midnapore (W)	34.61	144.45	101	1.20	52.36	793	517	47	180.69
Howrah	32.16	152.17	147	0.71	57.26	50	51	12	201.91
Hooghly	61.75	284.51	174	1.57	67.78	325	267	47	255.49
24 Parganas (N)	34.39	191.48	195	1.02	57.70	199	194	24	203.02
24 Parganas (S)	21.33	126.36	109	0.84	37.78	210	206	7	143.30
Nadia	31.68	150.04	159	1.59	74.35	174	165	4	231.53
Murshidabad	23.61	173.71	158	1.45	74.36	386	279	23	218.94
Dinajpur (N)	30.78	203.40	107	1.68	87.93	530	471	7	174.63
Dinajpur (S)	9.08	173.30	95	1.40	82.75	650	491	2	169.40
Malda	29.38	232.25	148	1.09	58.78	533	458	12	195.75
Jalpaiguri	17.01	200.52	64	1.87	53.66	519	473	8	164.62
Darjeeling	4.59	122.61	24	1.87	41.04	254	271	10	145.93
Cooch Behar	20.82	91.29	109	1.58	75.59	757	672	7	204.12
Purulia	33.15	82.18	59	0.68	36.14	1530	787	158	100.68

**Table 3** Normalized values of factors

District	Agricultural inputs								
	$X_1$	$X_2$	$X_3$	$X_4$	$X_5$	$X_6$	$X_7$	$X_8$	$X_9$
Burdwan	0.471	0.681	0.643	0.714	0.552	0.262	0.351	0.186	0.417
Birbhum	0.804	0.671	0.503	0.563	0.672	0.574	0.657	0.359	0.199
Bankura	<b>1.000</b>	0.716	0.532	0.101	0.377	0.900	<b>1.000</b>	0.147	0.136
Midnapore (E)	0.404	0.332	0.421	0.235	0.705	0.082	0.335	0.064	0.612
Midnapore (W)	0.373	0.308	0.450	0.437	0.313	0.502	0.582	0.288	0.517
Howrah	0.343	0.346	0.719	0.025	0.408	0.000	0.000	0.064	0.654
Hooghly	0.710	<b>1.000</b>	0.877	0.748	0.611	0.186	0.270	0.288	<b>1.000</b>
24 Parganas (N)	0.370	0.540	<b>1.000</b>	0.286	0.416	0.101	0.179	0.141	0.661
24 Parganas (S)	0.208	0.218	0.497	0.134	0.032	0.108	0.194	0.032	0.275
Nadia	0.337	0.335	0.789	0.765	0.738	0.084	0.142	0.013	0.845
Murshidabad	0.236	0.452	0.784	0.647	0.738	0.227	0.285	0.135	0.764
Dinajpur (N)	0.325	0.599	0.485	0.840	<b>1.000</b>	0.324	0.524	0.032	0.478
Dinajpur (S)	0.056	0.450	0.415	0.605	0.900	0.405	0.549	0.000	0.444
Malda	0.308	0.742	0.725	0.345	0.437	0.326	0.508	0.064	0.614
Jalpaiguri	0.154	0.585	0.234	<b>1.000</b>	0.338	0.317	0.527	0.038	0.413
Darjeeling	0.000	0.200	0.000	<b>1.000</b>	0.095	0.138	0.275	0.051	0.292
Cooch Behar	0.202	0.045	0.497	0.756	0.762	0.478	0.775	0.032	0.668
Purulia	0.355	0.000	0.205	0.000	0.000	<b>1.000</b>	0.919	<b>1.000</b>	0.000

Bold values display the  $N_{oj}$  values of factors

composite index value ( $D_i$ ) is calculated by employing the following for  $j$ th district.

Agricultural efficiency depends upon a large number of inputs. Therefore, to measure the development level of agricultural inputs for a particular district, nine inputs have been analyzed instead of any single input. Subsequently, with the help of optimum combination of these nine inputs, the composite index of input development ( $D_i$ ) has been allocated for each district. The  $D_i$  can be obtained as follows:

$$D_i = C_i / C \tag{6}$$

where,  $C = \bar{C}_i + 3\sigma C_i$  and  $C_i$  is the pattern of development, obtained as following matrix.

$$C_i = \left[ \sum_{j=1}^k \frac{P_j}{(CV)_j} \right]^{1/2} \tag{7}$$

where  $[P_{ij}] = [N_{ij} - N_{oj}]^2$  is the departure of standardized/normalized variables  $[N_{ij}]$  from the corresponding best values ( $N_{oj}$ ) and  $(CV)_j$  is the coefficient of variation in  $X_{ij}$  for  $j$ th indicator.  $N_{oj}$  symbolizes the best value of  $[N_{ij}]$  is the maximum or minimum value depending upon the operational relationship between the indicators and the development level of inputs. If the variables are positively related ( $\uparrow$ ) with the development then the maximum value will be chosen as  $N_{oj}$  whereas in negative relationship ( $\downarrow$ ), it will be the minimum value.

The value of Development index ( $D_i$ ) thus obtained is positive and lies between 0 and 1. The closer  $D_i$  is to 0 the more developed and the closer to unity, the less developed the inputs. The value of  $D_i$  is negatively associated with the development level. Therefore, during fractile classification, values of  $D_i$  for all districts are normalized by using the following UNDP's (2006) formula.

$$X_i = \frac{\text{Max}(D_i) - D_i}{\text{Max}(D_i) - \text{Min}(D_i)} [\downarrow] \tag{8}$$

where  $\text{Max}(D_i)$  and  $\text{Min}(D_i)$  are the maximum and minimum  $D_i$  values, respectively, and  $X_i$  is the normalized score of  $D_i$ .

### Regionalization of agricultural efficiency and development level of inputs

For classification purposes, a modest ranking of the districts based on efficiency indices/composite development indices of inputs availability is needed. Although, in order to classify districts according to the magnitude of spatial variations, a uniform method of regional demarcation was worked out which was based on the sequence of distribution of efficiency index/developmental index of inputs availability. Based on the properties of normal curve relating to the proportion of area lying at various units of standard deviation from the mean, uniform distribution classes of agricultural efficiency/inputs development were taken into account. On the basis of variation

**Table 4** Ranges of classes according to various units of standard deviation from mean

Class	Level of efficiency/development
Less than or equal to (Mean - $\sigma$ )	Low/poor
Mean to (Mean - $\sigma$ )	Moderate
Mean to (Mean + $\sigma$ )	High
Greater than or equal to (Mean + $\sigma$ )	Very high

of districts around and the mean value of the efficiency indices/composite indices, four levels/stages of efficiency/development were determined (Table 4).

**Measurement of the degree of relationship between agricultural inputs and agricultural efficiency**

Finally, the study explores the impact of agricultural inputs on agricultural efficiency by estimating the regression coefficient ( $b_{yx}$ ) that will come out once we become able to plot the best-fit regression line established between composite development index of inputs ( $x$ ) on aggregate agricultural efficiency ( $y$ ). The value of ( $b_{yx}$ ) is calculated as follows:

$$b_{yx} = r \frac{\sigma_y}{\sigma_x} \tag{9}$$

where,

$$r = \pm \frac{\sum xy - \frac{\sum x \sum y}{n}}{\sqrt{\sum x^2 - \frac{(\sum x)^2}{n}} \sqrt{\sum y^2 - \frac{(\sum y)^2}{n}}} = \pm \frac{\sum xy - \frac{\sum x \sum y}{n}}{\sigma_y \sigma_x} \tag{10}$$

The value of  $r$  ranges between +1 and -1, the extreme two values indicate perfect positive and perfect negative relationship, respectively.

**Determination of the prospective targets of selected agricultural inputs and identification of model districts**

For minimizing the regional incongruity in the efficiency of agriculture, reducing the regional disparity in the development of agricultural inputs is one of the cardinal facets of regional planning. By assigning the prospective targets of selected inputs for all districts can help to attain a balanced distribution of agricultural performances within the state of West Bengal.

In this present paper, a simple and objective approach is used to estimate the prospective targets of inputs for all districts and model districts for them which may be outlined as follows.

(a) Computation of composite indices of inputs development and ranking of districts correspondingly (Eq. 6).

(b) Computation of critical distance ( $D_c$ ) value by using the following formula:

$$D_c = \bar{d} + 2\sigma d_m \tag{11}$$

where  $\bar{d}$  = mean of  $d_m$ , and  $\sigma d_m$  = standard deviation of  $d_m$ . The  $d_m$  is the minimum non-zero value of each row, procured from proximity matrix (Eq. 12) between different combinations of districts.

$$d_{ip} = \left[ \sum_{j=1}^k (N_{ij} - Z_{pj})^2 \right]^{1/2} \tag{12}$$

Here  $D_{ii} = 0$  and  $D_{ip} = D_{pi}$  and the developmental distance ( $d_{ip}$ ) can be written as following matrix:

$$d_{ip} = \begin{bmatrix} 0 & d_{12} & \dots & d_{1n} \\ d_{21} & 0 & \dots & d_{2n} \\ \dots & d_{32} & \dots & d_{3n} \\ d_{n1} & d_{n2} & \dots & 0 \end{bmatrix} \tag{13}$$

(c) identification of model districts for a particular district ‘A’ by excluding of those district/districts which is/are less developed than ‘A’ and the developmental distance/distances of which is/are greater than  $D_c$  value concurrently and (d) estimation of prospective target of a particular indicator for ‘A’ can be estimated by obtaining the optimum value of actual figures of that indicator belonging to the model districts and the district of ‘A’ itself.

**Results and discussion**

**Agricultural efficiency in West Bengal during 2010–2011**

The present study explores the systematic assessment of agricultural efficiency for 18 districts of West Bengal. For this purpose, district wise agricultural efficiency index has been made both in crops and aggregate levels along with their ordinal rank (Table 5). Besides, spatial variations of agricultural efficiency (both in crops and aggregate levels) have been consummated by using the mean and standard deviation of normalized scores of extracted efficiency indices. Results of the present study are synopsisized into the following sections.

**Cereal efficiency**

The cereal efficiency index for each district of the state has been calculated based on the six cereal crops (rice, wheat, barley, maize, ragi and small millets). Results show that there exists a wide inter-district variation in the distribution

**Table 5** Agricultural efficiency in West Bengal (2010-11)

District	Cereal efficiency		Oilseeds efficiency		Pulses efficiency		Money crops efficiency		Aggregate efficiency	
	$Z_{ic} \times A_c$	Score	$Z_{io} \times A_o$	Score	$Z_{ip} \times A_p$	Score	$Z_{im} \times A_m$	Score	$E$	Score
Burdwan	4734.90	1.000 (1)	-89.43	0.442 (12)	29.06	0.400 (8)	163.39	0.295 (8)	0.718	0.919 (4)
Birbhum	2417.91	0.744 (5)	-122.10	0.423(16)	158.33	0.628 (3)	-185.61	0.171 (14)	0.637	0.897 (6)
Bankura	-611.10	0.410 (13)	-117.15	0.426 (15)	-2.15	0.344 (9)	-97.72	0.202 (13)	-0.320	0.632 (14)
Midnapore (E)	901.64	0.577 (9)	-849.47	0.000 (18)	153.91	0.621 (4)	-50.82	0.219 (11)	0.028	0.728 (11)
Midnapore (W)	2122.64	0.712 (7)	870.87	1.000 (1)	-8.67	0.333 (13)	-249.45	0.148 (15)	0.380	0.825 (8)
Howrah	-87.76	0.468 (12)	17.10	0.504 (4)	-2.82	0.343 (10)	51.87	0.255 (9)	-0.016	0.716 (12)
Hooghly	3572.56	0.872 (2)	-1.92	0.493 (5)	-4.3	0.341 (11)	315.58	0.349 (5)	0.820	0.947 (2)
24-Parganas(N)	309.00	0.512 (11)	146.57	0.579 (2)	43.05	0.424 (7)	1267.30	0.689 (3)	0.512	0.862 (7)
24-Parganas(S)	-3854.72	0.052 (17)	22.33	0.507 (3)	95.85	0.518 (6)	-77.21	0.209 (12)	-0.929	0.464 (16)
Nadia	493.59	0.532 (10)	-64.61	0.456 (11)	368.25	1.000 (1)	1230.27	0.676 (4)	0.371	0.823 (9)
Murshidabad	2509.65	0.754 (4)	-104.28	0.433 (14)	258.91	0.806 (2)	2138.75	1.000 (1)	0.651	0.900 (5)
Dinajpur (N)	2234.75	0.724 (6)	-175.75	0.392 (17)	-9.81	0.331 (15)	-501.50	0.058 (17)	0.370	0.823 (10)
Dinajpur (S)	1721.33	0.667 (8)	-35.10	0.473 (8)	-9.51	0.331 (16)	293.37	0.342 (6)	0.777	0.935 (3)
Malda	3082.38	0.818 (3)	-37.98	0.472 (9)	145.85	0.606 (5)	170.08	0.298 (7)	1.012	1.000 (1)
Jalpaiguri	-2947.64	0.152 (16)	-41.49	0.470 (10)	-24.44	0.305 (17)	1772.78	0.869 (2)	-0.261	0.648 (13)
Darjeeling	-831.77	0.386 (14)	-2.09	0.493 (6)	-5.88	0.338 (12)	-401.05	0.094 (16)	-1.349	0.348 (17)
Cooch Behar	-1625.91	0.298 (15)	-103.18	0.434 (13)	-8.67	0.333 (14)	-663.68	0.000 (18)	-0.553	0.568 (15)
Purulia	-4326.09	0.000 (18)	-16.28	0.484 (7)	-196.69	0.000 (18)	-22.10	0.229	-2.609	0.000 (18)
	$\bar{C} = 97.65$		$\bar{O} = 107.81$		$\bar{P} = 86.02$		$\bar{M} = 85.21$			
	$\sigma C = 12.84$		$\sigma O = 75.83$		$\sigma P = 28.11$		$\sigma M = 32.86$			

Scores indicate the normalized values of indices

Figures in parentheses indicate the ordinal ranks of the districts

of cereal efficiency along with a wide gap between maximum and minimum indices (Table 5). It is evident that the district of Burdwan was ranked by first position (4734.90) and the district of Purulia was ranked by last position (4326.09) in terms of cereal efficiency. There are 11 districts with positive efficiency scores where the cereal efficiency was above state’s average, while in remaining seven districts with negative scores, it was below state’s average. Based on the normal distribution of efficiency scores, 18 districts of West Bengal were categorized into four classes according to their levels of efficiencies (Table 6). According to fractile classification, three district (Burdwan, Hooghly and Malda) having about 16.67% to total efficiency were found to very high efficiency (> 0.820) category. High efficient (0.538–0.820) districts were Birbhum, Midnapore (E),

Midnapore (W), Murshidabad, Dinajpur (N) and Dinajpur (S) and these districts comprise about 33.33% to total cereal efficiency. Six districts (Bankura, Howrah, N. 24 Parganas, Nadia, Darjeeling and Cooch Behar) were experienced to be in moderately efficient (0.256–0.538) category and having about 33.33% to total cereal efficiency of the state while the low efficiencies (< 0.256) were documented in remaining three marginal districts (S. 24 Parganas, Jalpaiguri and Purulia) of the state which share 16.67% to total efficiency (Fig. 2).

**Oilseeds efficiency**

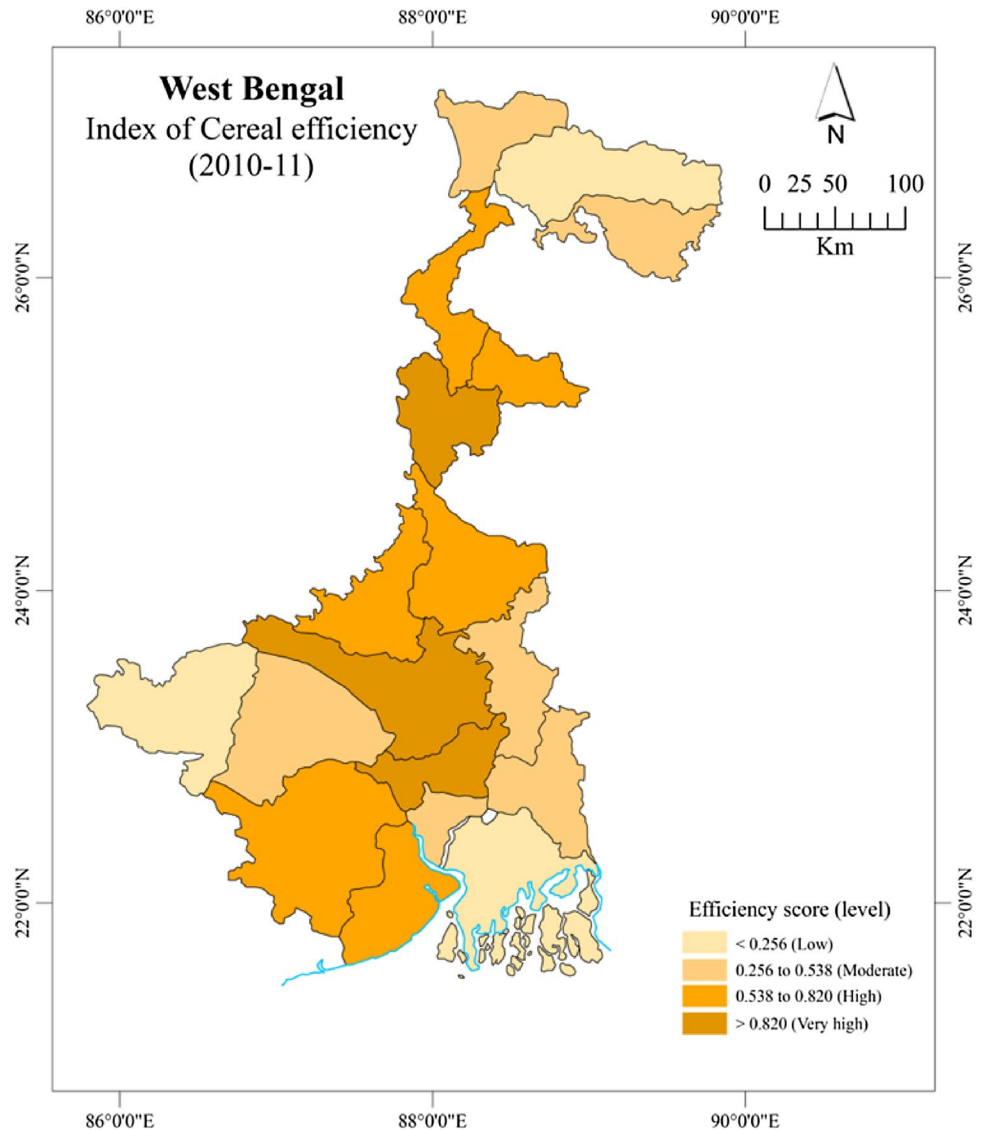
Oilseeds efficiency index has been computed for each district by taking into account of four crops (linseed, sesame,

**Table 6** Inter-district variation of cereal efficiency in West Bengal (2010–2011)

Level of efficiency	Number of districts	Name of the districts
Very high	3	Burdwan, Hooghly and Malda
High	6	Midnapore (W), Midnapore (E), Birbhum Murshidabad, Dinajpur (N) and Dinajpur (S)
Moderate	6	24 Parganas (N), Howrah, Bankura, Nadia, Cooch Behar and Darjeeling
Low	3	Purulia, 24 Parganas (S) and Jalpaiguri



**Fig. 2** Cereal efficiency regions (2010–2011)



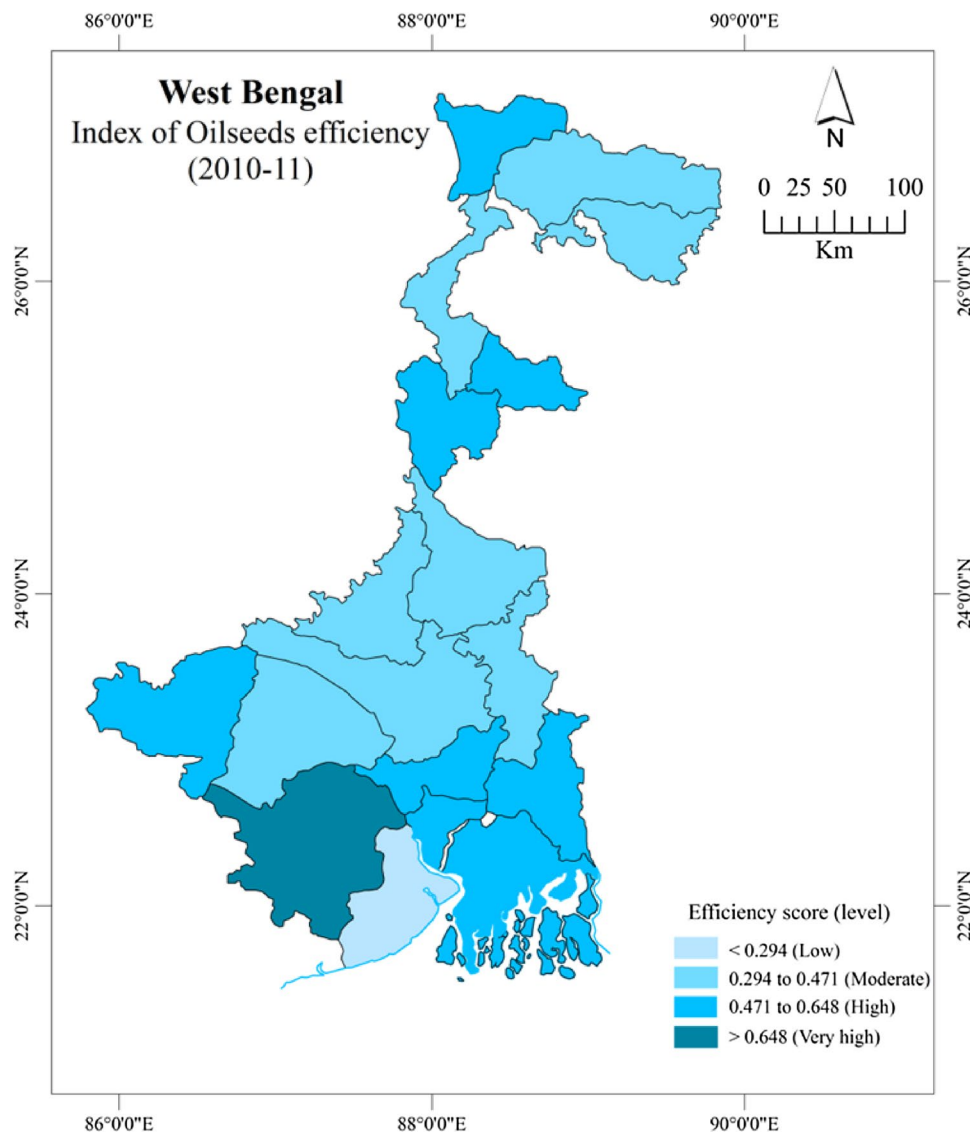
mustard seed and rapeseed). Table 5 reveals the district level distribution of oilseeds efficiency indices in West Bengal. As regards oilseeds efficiency, district of Midnapore (W) is the highest efficient (870.87) and the district of Midnapore (E) is the lowest efficient (− 849.47). There are 14 districts with positive efficiency scores where the oilseeds efficiency was above state’s average, while the remaining seven districts with negative scores hold oilseeds efficiency below the state’s average. Table 7 and Fig. 3 display the classification of districts of West Bengal lying in different stages of oilseeds efficiency. Regional variations based on normal distribution of efficiency indices show that only one district [Midnapore (W)] covering about 5.56% to total efficiency is very highly efficient (> 0.648) as compared to other districts of the state. Eight districts, namely Howrah, Hooghly, 24 Parganas (N), 24 Parganas (S), Dinajpur (N), Malda, Darjeeling and Purulia

**Table 7** Inter-district variation of oilseeds efficiency in West Bengal (2010–2011)

Level of efficiency	Number of districts	Name of the districts
Very high	1	Midnapore (W)
High	8	Howrah, Hooghly, 24 Parganas (N), 24 Parganas (S), Dinajpur (N), Malda, Darjeeling and Purulia
Moderate	8	Burdwan, Birbhum, Bankura, Nadia, Murshidabad, Dinajpur (N), Jalpaiguri and Cooch Behar
Low	1	Midnapore (E)

Malda, Darjeeling and Purulia are high level of efficiency (0.471–0.648). These districts together cover about 44.44% to total efficiency. The districts of Burdwan, Birbhum,

**Fig. 3** Oilseeds efficiency regions (2010–2011)



Bankura, Nadia, Murshidabad, Dinajpur (N), Jalpaiguri and Cooch Behar are moderately efficient (0.294–0.471) and share about 44.44% to total efficiency. The remaining one district (Midnapore (E)) covering about 5.56% efficiency is at the low efficiency level (<0.294).

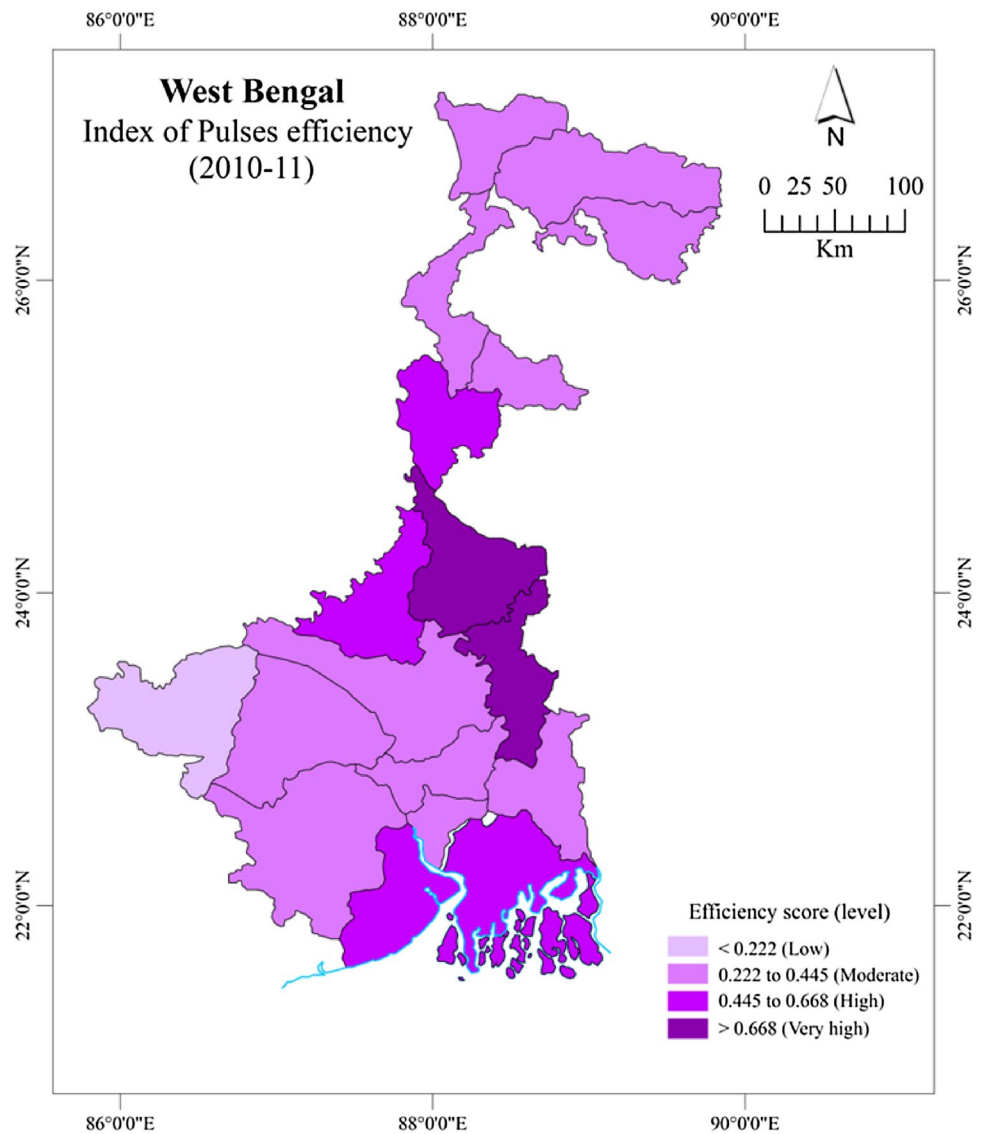
### Pulses efficiency

To measure the pulses efficiency, five crops (gram, arhar, mung, masur and maskalai) have been taken into consideration. Results presented in Table 5 depict that the efficiency indices range from a maximum of 368.25 in Nadia district to a minimum of –196.69 in Purulia. It is also observed that eight districts with positive efficiency scores were fallen above the state’s average efficiency of pulses, while

in remaining ten districts with negative scores, it was below state’s average.

The spatial variation of pulses efficiency, based on normal distribution of normalized efficiency scores is illustrated in Fig. 4. Results manifest that the very high efficiency scores of greater than 0.668 were confined in two districts (Nadia and Murshidabad) of south Bengal which constitute about 11.11% to total pulses efficiency of the state (Table 8). Highly efficient (0.445–0.668) districts were Birbhum, Midnapore (E), 24 Parganas (S) and Malda and these four districts cover about 22.22% of total pulses efficiency. The moderate efficiency scores (0.222–0.445) were spread over eleven districts (Burdwan, Bankura, Midnapore (W), Howrah, Hooghly, 24 Parganas (N), Dinajpur (N), Dinajpur (S), Jalpaiguri, Darjeeling and Cooch Behar) which comprise about 61.11% to total efficiency, while only one district (Purulia) was low efficient with

**Fig. 4** Pulses efficiency regions (2010–2011)



**Table 8** Inter-district variation of pulses efficiency in West Bengal (2010–2011)

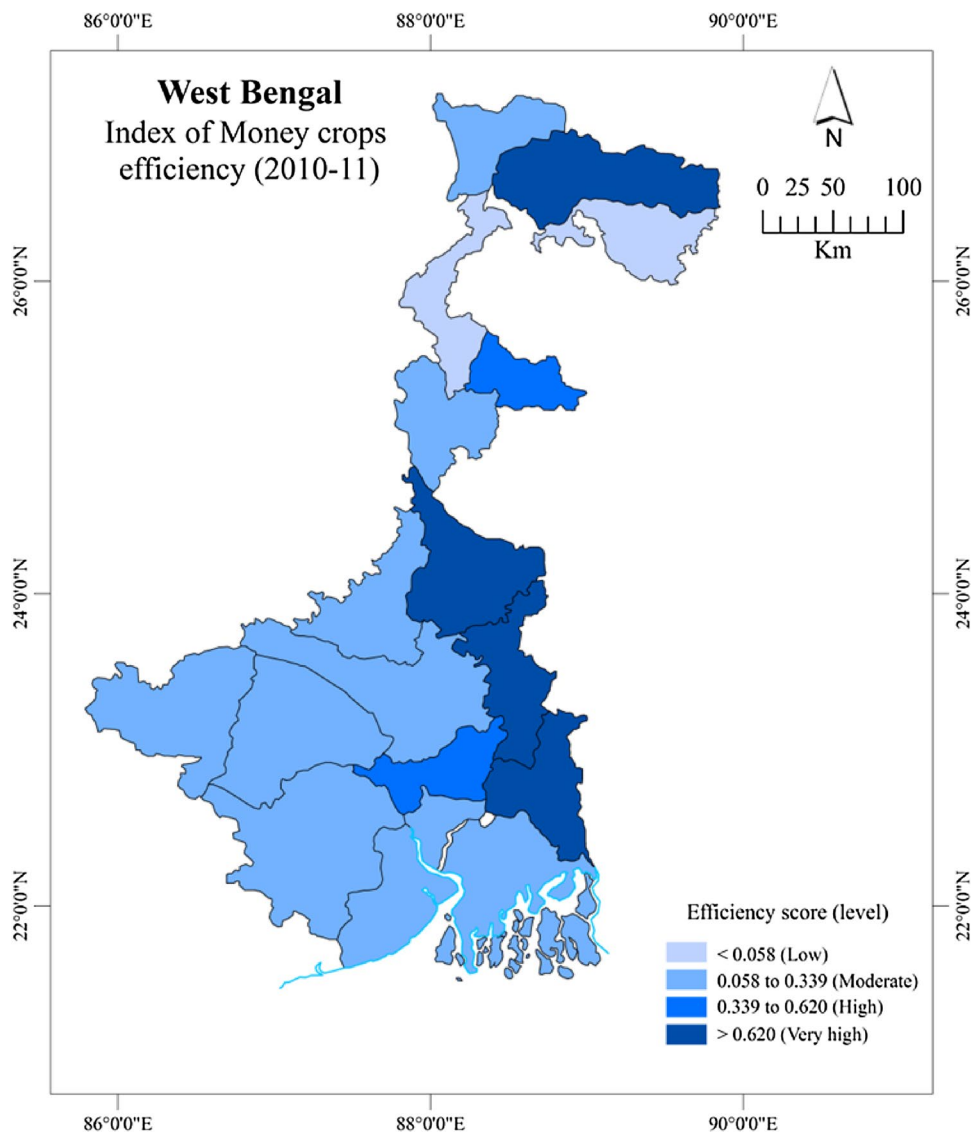
Level of efficiency	Number of districts	Name of the districts
Very high	2	Nadia and Murshidabad
High	4	Birbhum, Midnapore (E), 24 Parganas (S) and Malda
Moderate	11	Burdwan, Bankura, Midnapore (W), Howrah, Hooghly, 24 Parganas (N), Dinajpur (N), Dinajpur (S), Jalpaiguri, Darjeeling and Cooch Behar
Low	1	Purulia

the efficiency score of below 0.222 and constitute only 5.56% to the total pulses efficiency. The above distribution pattern clearly exhibits that more than 60% area of the state were distinguished as moderately efficient in terms of pulses production.

**Money crops efficiency**

In order to compute the money crops efficiency index, seven crops (jute, mesta, sunhemp, cotton, tea, sugarcane and tobacco) have been taken into account in this present study. Results show that the district of Murshidabad had the highest degree of efficiency (2138.75), while Cooch

**Fig. 5** Money crops efficiency regions (2010–2011)



**Table 9** Inter-district variation of money crops efficiency in West Bengal (2010–2011)

Level of efficiency	Number of districts	Name of the districts
Very high	4	24 Parganas (N), Nadia, Murshidabad and Jalpaiguri
High	2	Dinajpur (S) and Hooghly
Moderate	10	Burdwan, Birbhum, Bankura, Midnapore (E), Midnapore (W), Hooghly, 24 Parganas (S), Malda, Darjeeling and Purulia
Low	2	Dinajpur (S) Cooch Behar

Behar was the most inefficient district (− 663.68) in terms of money crops efficiency. It is clear from results that money crops efficiency in nine districts out of eighteen districts was above the state’s average while in remaining nine districts, it was below state’s average (Table 5). The spatial variation of money crops efficiency as illustrated in Fig. 5 and Table 9 depicts that, a very high efficiency index

of (> 0.620) was observed in four districts which cover about 22.22% to total money crops efficiency, out of which three districts (24 Parganas (N), Nadia and Murshidabad) are located in the fertile tract of upper Ganga delta region and the remaining one (Jalpaiguri) in the North Bengal. The high efficiency of money crops (0.339–0.620) was established in two districts [Dinajpur (S) and Hooghly]

which cover about 11.11% to total money crops efficiency in the state. Moderately efficient districts with efficiency scores ranging between 0.058 and 0.339) were Burdwan, Birbhum, Bankura, Midnapore (E), Midnapore (W), Hooghly, 24 Parganas (S), Malda, Darjeeling and Purulia and these districts comprise about 55.56% to total efficiency, while the remaining two districts (Dinajpur (S) Cooch Behar) sharing about 11.11% of total money crops efficiency fall under low efficiency level (<0.058).

**Aggregate agricultural efficiency**

The aggregate agricultural efficiency indices for all districts computed based on the weighted average of efficiency indices of four major crops are presented in Table 5. The results proffer that Malda was found to be the most efficient (1.01) district in the state, whereas the district of Purulia was the least efficient (-2.61). It is also beheld that, out of eighteen districts, eleven districts with positive efficiency indices have agricultural efficiency higher than state’s average, while in remaining seven districts with negative indices it was below state’s average. According to normal distribution of indices of aggregate efficiency, eighteen districts of West Bengal were assorted into four groups based on their level of efficiency (Table 10). Figure 6 evinces that a very high agricultural efficiency (> 0.977) is observed by only one district (Malda) which covers only 5.56% of total efficiency. Moreover, the efficiencies of selected crops range between high to very high in this district. The high agricultural efficiency (0.724–0.977) is being attended in ten districts and cover about 55.56% to the total agricultural. The spatial variation envisages that the high efficiency levels are concentrated in two areas, one of which is the vast tract of South Bengal comprising of eight districts [Burdwan, Birbhum, Midnapore (E), Midnapore (W), Hooghly, 24 Parganas (N), Nadia and Murshidabad] excluding the extreme western and southern parts, while the another area is the narrow belt of North Bengal plains, consisting of the districts of Dinajpur (N) and Dinajpur (S). Moderately efficient (0.471–0.724) districts were Bankura, Howrah, Jalpaiguri and Cooch Behar and they reckon 22.22% to total efficiency, while low efficiency (<0.471) is perceived in three isolated

patches, distributed in three marginal districts [Darjeeling, 24 Parganas (S) and Purulia] in the state.

**Impact of agricultural inputs on agricultural efficiency**

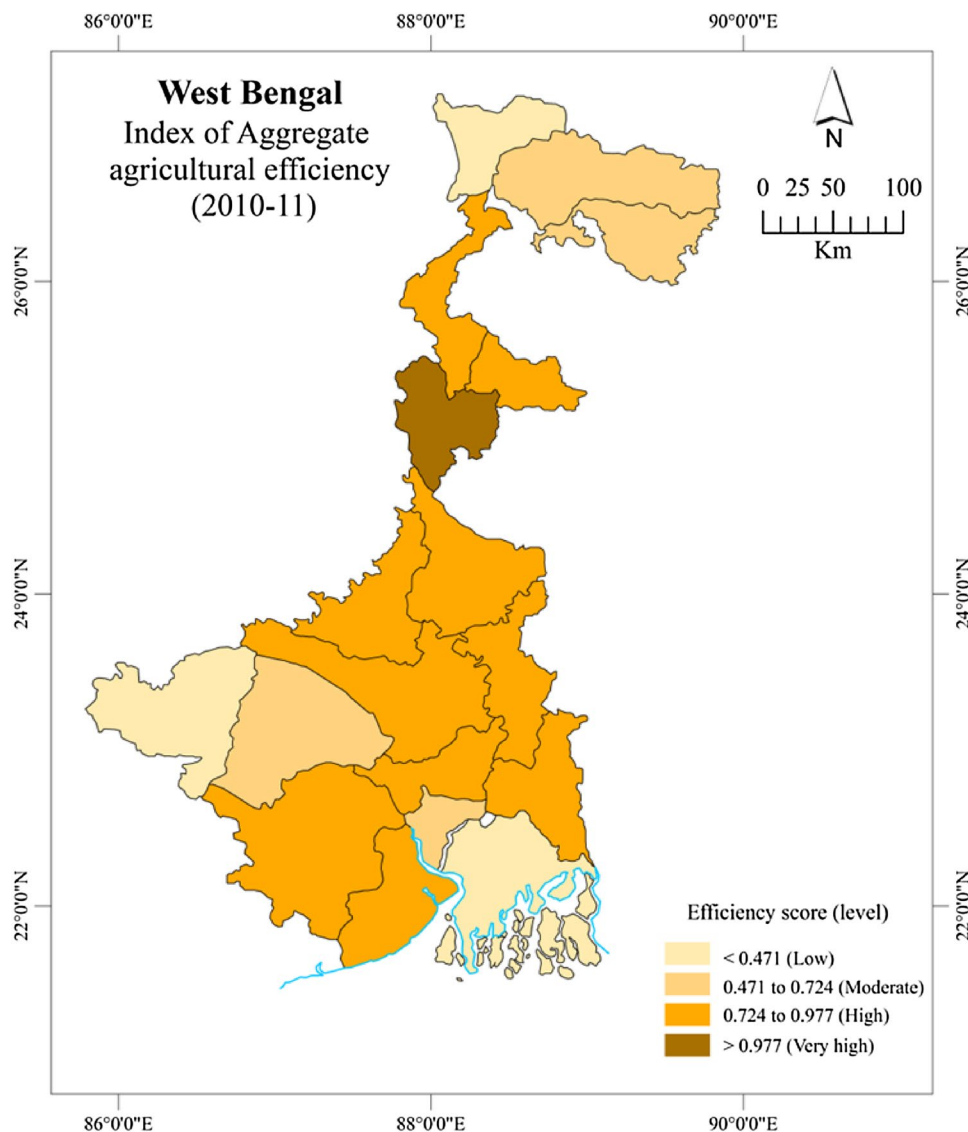
As introduced earlier, agricultural efficiency of a region is controlled by several factors which are simply called agricultural inputs. To measure the development level of inputs, a single composite development index has been computed for each district of West Bengal based on optimum combination of nine inputs (Table 11). The results show that the district of Birbhum was ranked first and the district of Darjeeling was ranked last in terms of development in agricultural inputs. On the basis of classification of development scores, districts are categorized into four stages of development (Fig. 7 and Table 12). According to inter-district variations, three districts viz. Birbhum, Bankura and Hooghly) having 16.67% to total development of inputs are registered as very highly developed (>0.721) districts. High development level of inputs (0.461–0.721) is observed in six districts [Burdwan, Midnapore (W), Murshidabad, Dinajpur (N), Malda and Purulia] which comprise for about 33.33% to total development of inputs in the state. Moderately developed districts (0.201–0.461) are 24 Parganas (N), Nadia, Dinajpur (S), Jalpaiguri and Cooch Behar which account for about 33.33% to total inputs development, while three districts [Howrah, 24 Parganas (S) and Darjeeling] with 16.67 of total development are registered as poorly developed (<0.201) districts in terms of agricultural inputs availability.

Since the agricultural production is an outcome of a multiple number of input ingredients, consequently, agricultural efficiency would also be higher among those districts where the development levels of inputs are also high. It is thus hypothesized in this present study that the development level of inputs is positively influencing agricultural efficiency. A cursory observation of Figs. 6 and 7 as well as the Scatter Plot that came out in Fig. 8 finds that twelve districts show the positive relationship between these two variables. In order to measure the extent to which the impact is occurring, I have fitted a regression equation ( $y = 0.268x + 0.600$ ) with composite

**Table 10** Inter-district variation of aggregate agricultural efficiency in West Bengal (2010–2011)

Level of efficiency	Number of districts	Name of the districts
Very high	1	Malda
High	10	Burdwan, Birbhum, Midnapore (E), Midnapore (W), Hooghly, 24 Parganas (N), Nadia, Murshidabad, Dinajpur (N) and Dinajpur (S)
Moderate	4	Bankura, Howrah, Jalpaiguri and Cooch Behar
Low	3	Purulia

**Fig. 6** Aggregate agricultural efficiency regions (2010–2011)



development index as independent variable and the aggregate agricultural efficiency scores as dependent variable. The correlation coefficient ( $r$ ) that came out from the slope coefficient of the fitted regression equation between these two variables has been found to be 0.275679. This justifies that there exists a positive relationship between development level of inputs and the level of agricultural efficiency in the state.

### Model districts and prospective targets of agricultural inputs

One of the pivotal aims of this study is to compute the prospective targets of different agricultural inputs for bringing a balanced distribution of agricultural efficiency in the state. Accordingly, the present study computes the prospective targets for the selected inputs for all districts

by identifying model districts, based on the critical distance value (0.39000987) and the developmental distances between different pairs of districts (Table 13). Results show that the maximum number of model districts is observed for two districts namely Midnapore (E) and Nadia while four districts (Birbhum, Bankura, Hooghly and Purulia) are experienced by only one model district for each of them. Being the most developed districts in terms of agricultural inputs availability, two districts (Birbhum and Hooghly) are witnessed as model districts for themselves (Table 14). By contrast, the district of Purulia is an outlier; therefore, the district of Birbhum has been selected as the model district of Purulia though the developmental distance (5.579) between these two districts is greater than the critical distance.

The present work also endorses prospective targets for all inputs and districts for curtailing the regional divergences in the development level of inputs, one of the important master

**Table 11** Composite development index of agricultural inputs

District	District code	Development matrix $[P_{ij}/(CV)_j]$									$C_i$	$D_i$	Score
		$X_1$	$X_2$	$X_3$	$X_4$	$X_5$	$X_6$	$X_7$	$X_8$	$X_9$			
Burdwan	$d_1$	0.076	0.019	0.021	0.008	0.025	0.124	0.076	0.354	0.006	0.842	0.615	0.639 (6)
Birbhum	$d_2$	0.010	0.020	0.041	0.018	0.013	0.041	0.021	0.220	0.028	0.643	0.470	1.000 (1)
Bankura	$d_3$	0.000	0.015	0.037	0.075	0.048	0.002	0.000	0.389	0.037	0.776	0.568	0.756 (3)
Midnapore (E)	$d_4$	0.096	0.082	0.056	0.054	0.011	0.192	0.079	0.468	-0.005	1.017	0.744	0.318 (14)
Midnapore (W)	$d_5$	0.107	0.088	0.050	0.029	0.059	0.057	0.031	0.271	-0.001	0.831	0.608	0.657 (5)
Howrah	$d_6$	0.117	0.079	0.013	0.088	0.044	0.228	0.180	0.468	-0.006	1.100	0.805	0.167(16)
Hooghly	$d_7$	0.023	0.000	0.003	0.006	0.019	0.151	0.096	0.271	0.000	0.753	0.551	0.799 (2)
24 Parganas (N)	$d_8$	0.108	0.039	0.000	0.047	0.042	0.185	0.121	0.395	-0.006	0.964	0.705	0.415 (10)
24 Parganas (S)	$d_9$	0.170	0.112	0.042	0.069	0.117	0.181	0.117	0.501	0.019	1.153	0.843	0.072 (17)
Nadia	$d_{10}$	0.119	0.081	0.007	0.005	0.009	0.192	0.132	0.521	-0.006	1.030	0.753	0.296 (15)
Murshidabad	$d_{11}$	0.158	0.055	0.008	0.012	0.009	0.136	0.092	0.400	-0.007	0.929	0.679	0.480 (9)
Dinajpur (N)	$d_{12}$	0.124	0.030	0.044	0.002	0.000	0.104	0.041	0.501	0.001	0.920	0.673	0.495 (8)
Dinajpur (S)	$d_{13}$	0.242	0.056	0.057	0.014	0.001	0.081	0.036	0.535	0.004	1.013	0.741	0.326 (13)
Malda	$d_{14}$	0.130	0.012	0.013	0.040	0.039	0.104	0.043	0.468	-0.005	0.919	0.672	0.498 (7)
Jalpaiguri	$d_{15}$	0.194	0.032	0.098	0.000	0.054	0.106	0.040	0.494	0.006	1.013	0.740	0.328 (12)
Darjeeling	$d_{16}$	0.271	0.118	0.167	0.000	0.102	0.170	0.094	0.481	0.017	1.192	0.872	0.000 (18)
Cooch Behar	$d_{17}$	0.173	0.168	0.042	0.005	0.007	0.062	0.009	0.501	-0.007	0.980	0.717	0.386 (11)
Purulia	$d_{18}$	0.113	0.184	0.106	0.092	0.124	0.000	0.001	0.000	0.059	0.824	0.603	0.669 (4)

Mean of  $C_i = 0.93883995$

$\sigma C_i = 0.14286001$

Figures in parentheses indicate the ordinal ranks of the districts

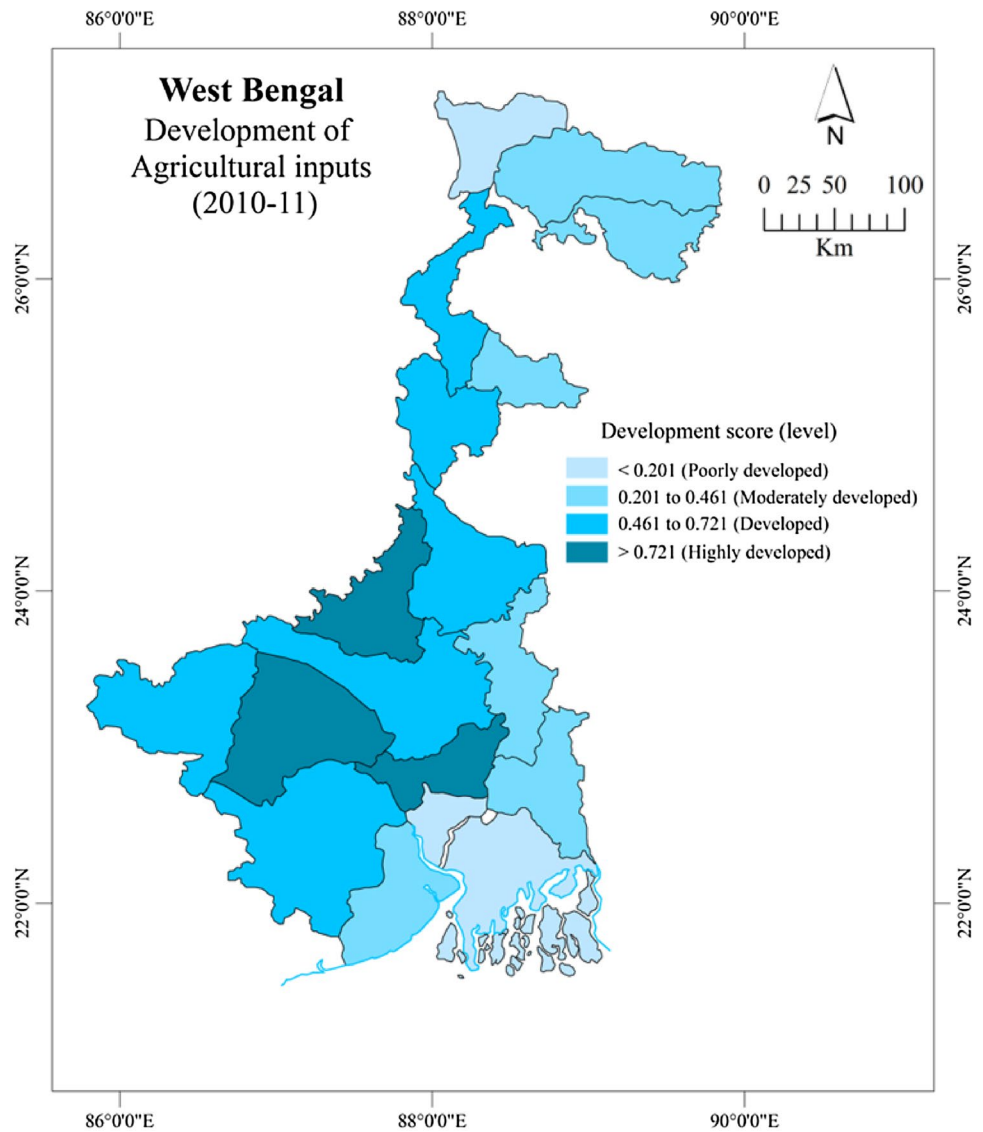
plans for bringing an impartial distribution of agricultural efficiency in the state. Results presented in Table 15 proclaim that prospective targets are exceedingly high for all inputs in almost all districts in West Bengal with the exception of Birbhum and Hooghly, two very highly developed districts in terms of agricultural inputs availability where these two figures are identical for all indicators. It is also evident that the actual achievements of intensity of irrigation, plowing level and puddlerization level are trailed behind that of prospective targets in three low developed districts (Darjeeling, 24 Parganas and Howrah). Decent efforts are requisite for executing these inherent targets.

### Conclusion

In this present study, I have measured the agricultural efficiency levels of 18 districts in West Bengal for the year 2010–2011, based on 22 major crops. Results, based on the normal distribution of efficiency indices, show that the state was experienced by a wide inter-district variation in the performance of agriculture both in crops and aggregate levels. The district of Malda was found to be more efficient in terms of overall agricultural performance, while three

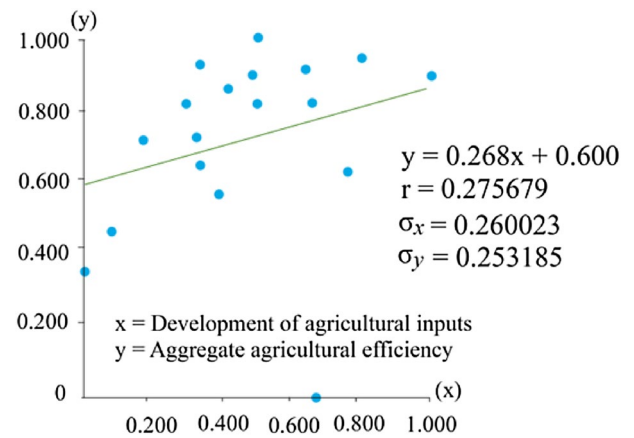
marginal districts [24 Pgs (S), Darjeeling and Purulia] of the state were found to be low efficient. As the agricultural efficiency is largely controlled and modified by a multiple number of inputs, thus to make a quite picture in the regional variation of inputs development, the composite indices in development of inputs have been computed by optimum combination of nine inputs those are closely related with the agricultural practices. It is evident that Birbhum, Bankura and Hooghly were very high developed and Howrah, 24 Parganas (S) and Darjeeling were poorly developed in terms of input level. The study has found that the agricultural efficiency level of the state is positively correlated ( $r=0.275679$ ) with the development level of inputs. The findings have also established that the result holds good for the 12 districts where the efficiency levels are positively associated with their development level of inputs, while in remaining six districts, this relationship operates in other way round. The other negative inputs such as low soil nutrients, rugged relief pattern, adverse climatic condition and natural hazards may be assumed to be the major hindrances in this aspect which are negatively impacting agricultural efficiencies in those six districts. Therefore, the above-mentioned physical, climatic and edaphic factors could be incorporated as inputs for further

**Fig. 7** Development level of agricultural inputs based on optimum combination of inputs



**Table 12** Inter-district variation in the development of agricultural inputs

Level of efficiency	Number of districts	Name of the districts
Very high	3	Birbhum, Bankura and Hooghly
High	6	Burdwan, Midnapore (W), Murshidabad, Dinajpur (N), Malda and Purulia
Moderate	6	Midnapore (E), 24 Parganas (N), Nadia, Dinajpur (S), Jalpaiguri and Cooch Behar
Low	3	Howrah, 24 Parganas (S) and Darjeeling



**Fig. 8** Relationship between development level of agricultural inputs and agricultural efficiency



**Table 13** Proximity matrix (Euclidean distances) between different pairs of districts based on nine input indicators

Districts	$d_1$	$d_2$	$d_3$	$d_4$	$d_5$	$d_6$	$d_7$	$d_8$	$d_9$	$d_{10}$	$d_{11}$	$d_{12}$	$d_{13}$	$d_{14}$	$d_{15}$	$d_{16}$	$d_{17}$	$d_{18}$	Nearest neighbor
$d_1$	0.000	2.501	4.558	2.524	2.457	3.226	2.968	2.471	3.525	2.673	2.086	2.085	2.712	<b>1.809</b>	2.563	4.204	3.526	6.697	$d_{14}$
$d_2$	<b>2.501</b>	0.000	2.751	3.754	2.898	4.907	4.253	4.334	4.808	4.698	4.044	3.148	3.760	3.340	3.840	5.449	4.192	5.579	$d_1$
$d_3$	4.558	<b>2.751</b>	0.000	5.266	4.108	6.142	5.874	5.672	5.706	6.514	5.866	5.164	5.369	4.463	5.427	6.933	5.488	5.609	$d_2$
$d_4$	2.524	3.754	5.266	0.000	2.543	<b>2.140</b>	4.166	2.739	2.910	2.500	2.261	2.696	2.524	2.503	3.384	4.160	3.048	6.800	$d_6$
$d_5$	2.457	2.898	4.108	2.543	0.000	3.458	4.463	3.312	2.924	3.600	2.916	3.198	2.842	<b>2.421</b>	2.725	3.736	2.640	4.838	$d_{14}$
$d_6$	3.226	4.907	6.142	2.140	3.458	0.000	4.294	<b>1.771</b>	2.444	2.740	2.722	4.229	3.998	2.864	4.483	4.877	4.482	7.412	$d_8$
$d_7$	<b>2.968</b>	4.253	5.874	4.166	4.463	4.294	0.000	3.162	5.675	3.341	3.117	3.939	4.870	3.162	4.793	6.491	5.251	8.513	$d_1$
$d_8$	2.471	4.334	5.672	2.739	3.312	<b>1.771</b>	3.162	0.000	3.232	2.364	2.036	3.782	3.881	2.043	4.284	5.311	4.302	7.437	$d_6$
$d_9$	3.525	4.808	5.706	2.910	2.924	<b>2.444</b>	5.675	3.232	0.000	4.067	3.837	4.592	3.972	3.339	3.698	3.440	4.382	6.194	$d_6$
$d_{10}$	2.673	4.698	6.514	2.500	3.600	2.740	3.341	2.364	4.067	0.000	<b>1.185</b>	2.856	3.201	2.950	3.787	4.735	3.288	8.180	$d_{11}$
$d_{11}$	2.086	4.044	5.866	2.261	2.916	2.722	3.117	2.036	3.837	<b>1.185</b>	0.000	2.317	2.499	2.135	3.347	4.623	2.880	7.406	$d_{10}$
$d_{12}$	2.085	3.148	5.164	2.696	3.198	4.229	3.939	3.782	4.592	2.856	2.317	0.000	<b>1.526</b>	2.769	2.659	4.444	2.691	7.345	$d_{13}$
$d_{13}$	2.712	3.760	5.369	2.524	2.842	3.998	4.870	3.881	3.972	3.201	2.499	<b>1.526</b>	0.000	2.763	2.525	3.921	2.203	6.788	$d_{12}$
$d_{14}$	<b>1.809</b>	3.340	4.463	2.503	2.421	2.864	3.162	2.043	3.339	2.950	2.135	2.769	2.763	0.000	3.061	4.738	3.519	6.770	$d_1$
$d_{15}$	2.563	3.840	5.427	3.384	2.725	4.483	4.793	4.284	3.698	3.787	3.347	2.659	2.525	3.061	0.000	<b>2.379</b>	3.214	6.645	$d_{16}$
$d_{16}$	4.204	5.449	6.933	4.160	3.736	4.877	6.491	5.311	3.440	4.735	4.623	4.444	3.921	4.738	<b>2.379</b>	0.000	4.230	6.770	$d_{15}$
$d_{17}$	3.526	4.192	5.488	3.048	<b>2.640</b>	4.482	5.251	4.302	4.382	3.288	2.880	2.691	2.203	3.519	3.214	4.230	0.000	6.470	$d_5$
$d_{18}$	6.697	5.579	5.609	6.800	<b>4.838</b>	7.412	8.513	7.437	6.194	8.180	7.406	7.345	6.788	6.770	6.645	6.770	6.470	0.000	$d_5$

Bold values specify the  $d_m$  values

Mean of  $d_m$  ( $\bar{d}$ ) = 2.226217

Standard deviation of  $d_m$  ( $\sigma(d_m)$ ) = 0.846941

**Critical distance ( $D_c$ ) = 3.92000987**

**Table 14** Model districts for the different districts in West Bengal

District	Model districts
Burdwan	Birbhum, Midnapore (W) and Hooghly
Birbhum <sup>a</sup>	Birbhum
Bankura	Birbhum
Midnapore (E)	Burdwan, Bankura, Midnapore (W), 24 Parganas (N), Murshidabad, Dinajpur (N), Dinajpur (S), Malda, Jalpaiguri and Cooch Behar
Midnapore (W)	Birbhum
Howrah	Burdwan, Midnapore (E), Midnapore (W), 24 Parganas (N), Murshidabad and Malda
Hooghly <sup>a</sup>	Hooghly
24 Parganas (N)	Burdwan, Midnapore (W), Hooghly, Murshidabad, Dinajpur (N) and Malda
24 Parganas (S)	Burdwan, Midnapore (E), Midnapore (W), Howrah, 24 Parganas (N), Murshidabad, Malda and Jalpaiguri
Nadia	Burdwan, Midnapore (E), Midnapore (W), Hooghly, 24 Parganas (N), Murshidabad, Dinajpur (N), Dinajpur (S), Malda, Jalpaiguri and Cooch Behar
Murshidabad	Burdwan, Midnapore (W), Hooghly, Dinajpur (N) and Malda
Dinajpur (N)	Burdwan, Birbhum, Midnapore (W) and Malda
Dinajpur (S)	Burdwan, Birbhum, Midnapore (W), 24 Parganas (N), Murshidabad, Dinajpur (N), Jalpaiguri and Cooch Behar
Malda	Burdwan, Birbhum, Midnapore (W) and Hooghly
Jalpaiguri	Burdwan, Birbhum, Midnapore (W), Murshidabad, Dinajpur (N), Malda and Cooch Behar
Darjeeling	Midnapore (W), 24 Parganas (S), Dinajpur (S) and Jalpaiguri
Cooch Behar	Burdwan, Midnapore (W), Murshidabad, Dinajpur (N) and Malda
Purulia <sup>b</sup>	Birbhum

<sup>a</sup>District is the model district for itself (Higher level of development in comparison with other districts)

<sup>b</sup>The district is an outlier (lowest level of development in comparison with remaining districts and the developmental distance from all districts is  $> D_c$ ), nevertheless the model district is identified from its nearest neighbor (20th column of Table 13)

**Table 15** Prospective targets of inputs for all districts

District	Inputs								
	X <sub>1</sub>	X <sub>2</sub>	X <sub>3</sub>	X <sub>4</sub>	X <sub>5</sub>	X <sub>6</sub>	X <sub>7</sub>	X <sub>8</sub>	X <sub>9</sub>
Burdwan	69.32 <sup>b</sup>	284.51 <sup>b</sup>	174 <sup>b</sup>	1.57 <sup>b</sup>	70.93 <sup>b</sup>	900 <sup>b</sup>	577 <sup>b</sup>	58 <sup>b</sup>	255.49 <sup>b</sup>
Birbhum	69.32 <sup>a</sup>	218.03 <sup>a</sup>	110 <sup>a</sup>	1.35 <sup>a</sup>	70.93 <sup>a</sup>	900 <sup>a</sup>	577 <sup>a</sup>	58 <sup>a</sup>	131.56 <sup>a</sup>
Bankura	85.07 <sup>a</sup>	227.00 <sup>a</sup>	115 <sup>a</sup>	1.35 <sup>b</sup>	70.93 <sup>b</sup>	1382 <sup>a</sup>	852 <sup>a</sup>	58 <sup>b</sup>	131.56 <sup>b</sup>
Midnapore (E)	85.07 <sup>b</sup>	232.25 <sup>b</sup>	195 <sup>b</sup>	1.87 <sup>b</sup>	87.93 <sup>b</sup>	1382 <sup>b</sup>	852 <sup>b</sup>	47 <sup>b</sup>	218.94 <sup>b</sup>
Midnapore (W)	69.32 <sup>b</sup>	218.03 <sup>b</sup>	110 <sup>b</sup>	1.35 <sup>b</sup>	70.93 <sup>b</sup>	900 <sup>b</sup>	577 <sup>b</sup>	58 <sup>b</sup>	180.69 <sup>a</sup>
Howrah	42.52 <sup>b</sup>	219.95 <sup>b</sup>	195 <sup>b</sup>	1.59 <sup>b</sup>	74.36 <sup>b</sup>	793 <sup>b</sup>	517 <sup>b</sup>	47 <sup>b</sup>	231.53 <sup>b</sup>
Hooghly	61.75 <sup>a</sup>	284.51 <sup>a</sup>	174 <sup>a</sup>	1.57 <sup>a</sup>	67.78 <sup>a</sup>	325 <sup>a</sup>	267 <sup>a</sup>	47 <sup>a</sup>	255.49 <sup>a</sup>
24 Parganas (N)	61.75 <sup>b</sup>	284.51 <sup>b</sup>	195 <sup>a</sup>	1.68 <sup>b</sup>	87.93 <sup>b</sup>	793 <sup>b</sup>	517 <sup>b</sup>	47 <sup>b</sup>	255.49 <sup>b</sup>
24 Parganas (S)	42.52 <sup>b</sup>	232.25 <sup>b</sup>	195 <sup>b</sup>	1.87 <sup>b</sup>	74.36 <sup>b</sup>	793 <sup>b</sup>	517 <sup>b</sup>	47 <sup>b</sup>	218.94 <sup>b</sup>
Nadia	61.75 <sup>b</sup>	284.51 <sup>b</sup>	195 <sup>b</sup>	1.87 <sup>b</sup>	87.93 <sup>b</sup>	793 <sup>b</sup>	672 <sup>b</sup>	47 <sup>b</sup>	255.49 <sup>b</sup>
Murshidabad	61.75 <sup>b</sup>	284.51 <sup>b</sup>	174 <sup>b</sup>	1.68 <sup>b</sup>	87.93 <sup>b</sup>	793 <sup>b</sup>	517 <sup>b</sup>	47 <sup>b</sup>	255.49 <sup>b</sup>
Dinajpur (N)	69.32 <sup>b</sup>	232.25 <sup>b</sup>	148 <sup>b</sup>	1.68 <sup>a</sup>	87.93 <sup>a</sup>	900 <sup>b</sup>	577 <sup>b</sup>	58 <sup>b</sup>	195.75 <sup>b</sup>
Dinajpur (S)	69.32 <sup>b</sup>	219.95 <sup>b</sup>	195 <sup>b</sup>	1.87 <sup>b</sup>	87.93 <sup>b</sup>	900 <sup>b</sup>	672 <sup>b</sup>	58 <sup>b</sup>	218.94 <sup>b</sup>
Malda	69.32 <sup>b</sup>	284.51 <sup>b</sup>	174 <sup>b</sup>	1.57 <sup>b</sup>	70.93 <sup>b</sup>	900 <sup>b</sup>	577 <sup>b</sup>	58 <sup>b</sup>	255.49 <sup>b</sup>
Jalpaiguri	69.32 <sup>b</sup>	232.25 <sup>b</sup>	158 <sup>b</sup>	1.87 <sup>a</sup>	87.93 <sup>b</sup>	900 <sup>b</sup>	672 <sup>b</sup>	58 <sup>b</sup>	218.94 <sup>b</sup>
Darjeeling	34.61 <sup>b</sup>	200.52 <sup>b</sup>	109 <sup>b</sup>	1.87 <sup>a</sup>	82.75 <sup>b</sup>	793 <sup>b</sup>	517 <sup>b</sup>	47 <sup>b</sup>	180.69 <sup>b</sup>
Cooch Behar	42.52 <sup>b</sup>	232.25 <sup>b</sup>	158 <sup>b</sup>	1.68 <sup>b</sup>	87.93 <sup>b</sup>	793	672 <sup>a</sup>	47 <sup>b</sup>	218.94 <sup>a</sup>
Purulia	69.32 <sup>b</sup>	218.03 <sup>b</sup>	110 <sup>b</sup>	1.35 <sup>b</sup>	70.93 <sup>b</sup>	1530 <sup>a</sup>	787 <sup>a</sup>	158 <sup>a</sup>	131.56 <sup>b</sup>

<sup>a</sup>The prospective target and actual achievement are equivalent

<sup>b</sup>The prospective targets is greater than actual achievement

explanation. The estimated prospective targets along with the model districts for all indicators and districts convey that the actual achievements of some inputs like intensity of irrigation, plowing level and puddlerization level are lingered behind that of prospective targets in poorly developed districts. So we can emphatically culminate that proper policy actions should be initiated for reducing the regional disparity in the development level of inputs availability which will help to enhance the performance level of the districts and corroborate a balanced distribution of agricultural efficiency in the state.

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