Identification of potential areas for crops

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Identification and delineation of potential areas for different crops, both at country and state level by using available legacy data assumes importance, in order to preserve and conserve these areas to feed the increasing population and future generations. In this direction, a new integrated approach has been developed to identify potential areas for different crops and the same has been validated. Identifying and delineating commodity specific areas/zones, would help in enhancing the productivity and profitability and framing of land use policies.

Keywords: Potential areas, commodity specific zones/areas, relative spread index, relative yield index, land use policy.

IN India, agriculture plays an important role in providing rural livelihood, ensuring food self-sufficiency and inclusive economic development. India is one of the most land scarce countries in the world, with average per capita availability of arable land having reduced from 0.22 ha in 1991 to 0.15 ha in 2011 (ref. 1). India is already experiencing high pressure on its productive agricultural land resources. A decline in the availability of agricultural land could have serious implications for maintaining food self-sufficiency, as well as in ensuring household food security and rural livelihoods. Despite growing population and increased demand for agricultural products, the net sown area in the country has not increased during the last 3–4 decades. Scope for horizontal expansion under crops is limited; productivity enhancement is the only alternative to meet the increased demand.

Enhancing and maintaining sustainability in crop productivity is possible only when efficient locations are identified for crops[2]. The crop adaptability to a particular region determines the productivity of the concerned crop. Even though a particular crop is widespread in a region, the productivity might not be high due to many obvious reasons[3]. Therefore, growing efficient crops in an area will not only increase production but also save cost of production and cost involved in transporting both the inputs and outputs. Advances in agricultural sciences have helped in development of several techniques to find out suitable crops in specified areas[4–7]. Tools for identifying the efficient areas for crops are the relative yield index (RYI) and relative spread index (RSI)[8] which in turn identify efficient cropping zone of the crops.

At present, there are two approaches to identify suitable or efficient areas for crops. Numerous studies have been carried out at the state, region, district, block and watershed levels to identify suitable areas for different crops by matching crop requirements with bio-physical parameters like climate, soil depth and texture, etc. of an area[6,7]. In most cases more than one crop is suitable to a particular unit area and it is a qualitative assessment and one cannot say which crop is most suitable or productive.

Efficient zone is an area which has high spread and crop productivity. Several studies have used RSI and RYI to identify efficient crop zones/areas in India, viz. efficient rice cropping zones in Puducherry[9]; prospective cropping zones for rice, maize, sorghum, pearl millet, red gram, black gram, green gram, chick pea, horse gram, cotton, sunflower and groundnut in Tamil Nadu[10]; efficient cropping zones for groundnut in Tamil Nadu[11]; potential cropping zones for coconut, mango, banana, grapes, guava, lemon, jackfruit, tomato, brinjal, chillies, bhendi, onion, turmeric, garlic, coriander and ginger in Tamil Nadu[12], and efficient cropping zones for rice, groundnut and maize in Tamil Nadu[13]. To identify efficient crop zones different studies have used different criteria that have varied with crops. RSI and RYI are calculated based on temporal database related to area and productivity of crops in different years or mean of 5 or 10 years. Spread of a crop is directly related to market prices and availability of specific infrastructure facilities, but the spread may not be the same over a period of time in a particular area. Crop productivity depends on suitable bio-physical characteristics and management. Some crops may have high spread in the region, but productivity may not be high and hence uneconomical to farmers due to non-suitable bio-physical characteristics. Hence, a new approach has been developed by integrating bio-physical suitability of an area and RSI and RYI to identify potential areas for a particular crop, to conserve and maintain them to meet future demands of an increasing population on a sustainable basis.

Potential areas can support more specified land use objectives in terms of suitable soil and climatic features to obtain maximum productivity and profitability by conserving natural resources. This facilitates better identification of promising crops and cropping systems, implementation or introduction of new technologies or schemes for the specified crop, replacing the uneconomical crop in the identified areas and using natural resources to the maximum extent possible without any degradation. Potential areas identified for particular crops in a state could be named as Special Commodity Zones (SCZ). State governments can formulate integrated policies to develop advanced techno-infrastructure facilities to support the farming community.

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Table 1. Criteria for classification of efficient areas

National level				
RSI	RYI	Efficient areas	Suitability classes	Potential areas
>125 (high)	>125 (high)	Most efficient areas	S1 and S2	Potential
<125 (low)	>125 (high)	Efficient areas		Moderate potential
>125 (high)	<125 (low)	Moderately efficient areas		Marginally potential
<125; >100 (low)	<125; >100 (low)	Less efficient areas		Less potential

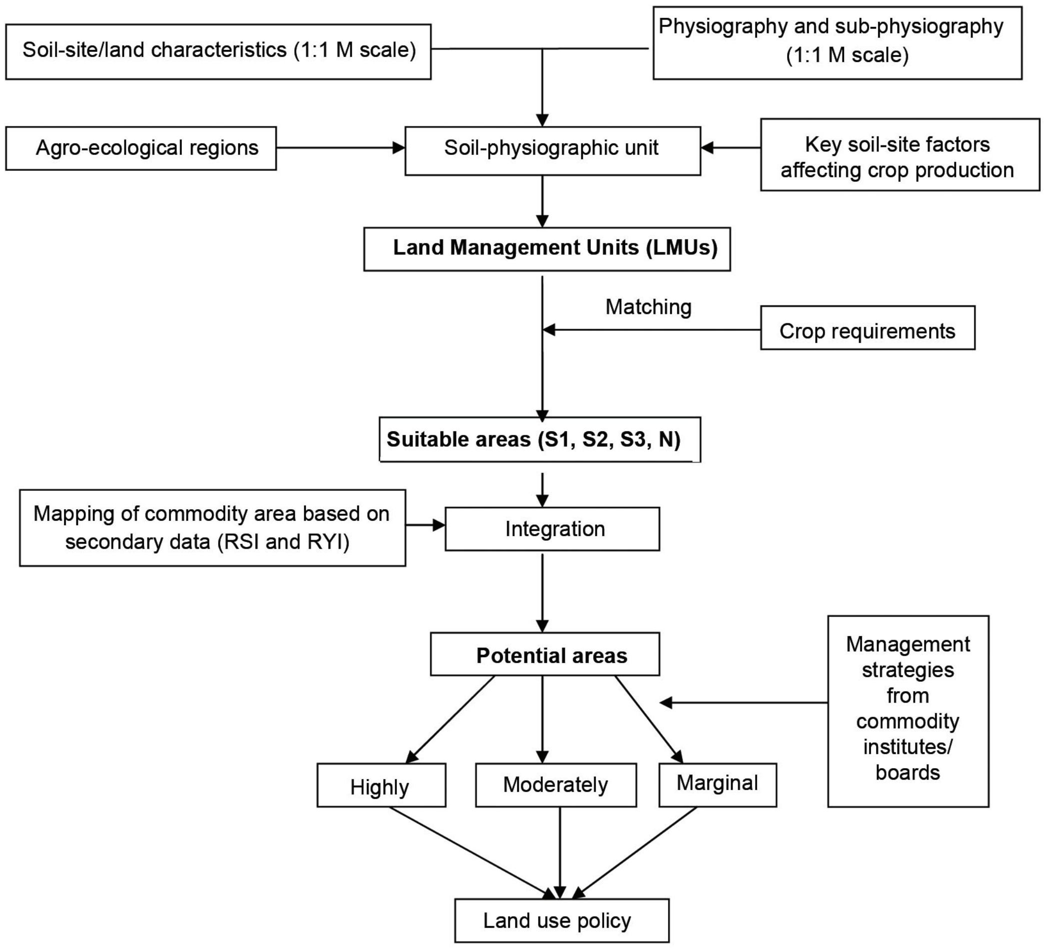

Figure 1. Methodology followed for identification of potential areas.

The present exercise was therefore carried out with the methodology depicted in flow diagram (Figure 1) to identify potential areas of crops. The data sets used and steps followed are described as follows – Data sets: (i) Soil resource information prepared at 1 : 1 m scale; (ii) soil morphological, physical, and chemical properties; (iii) climatic data from the India Meteorological Department.

Land management unit (LMU) is a homogenous land unit having similar soil parameters like soil depth, texture, gravelliness, soil reaction, inherent soil fertility, slope, erosion and climate under irrigated and rainfed condition. It is derived from the soil resource map of the country at 1 : 1 million scale by grouping similar mapping units. In this way, 668 LMUs were delineated and further evaluated for priority areas.

Identification of potential areas for particular crops followed a two-stage procedure. In the first stage, RSI and RYI were calculated and linked with the suitability class of the crop in different LMUs. A district was assigned a given suitability class if more than 60% of its area belonged to the particular class.

To determine RSI and RYI, data related to area, production and productivity of a particular crop and total cultivable area in different districts, states and the

Table 2. Important land qualities and related characteristics

Land quality	Land/soil characteristics
Temperature and light energy for plant growth	Temperature (max. and min.), sunshine hours and day length.
Moisture availability in crop growing season	Rainfall, LGP.
Root development and anchorage	Soil depth and texture.
Oxygen availability to roots	Soil depth, texture in root zone, structure and hard pans.
Nutrient availability in root zone	Drainage, depth of ground water table, frequency and period of flooding, moisture retention capacity of soils.
Sensitivity to soil toxicity	Organic matter, CEC, base saturation, NPK status and pH.
Workability and management	pH, salinity, sodicity, $CaCO_3$, Al and heavy metals, slope, surface stoniness/rockiness.

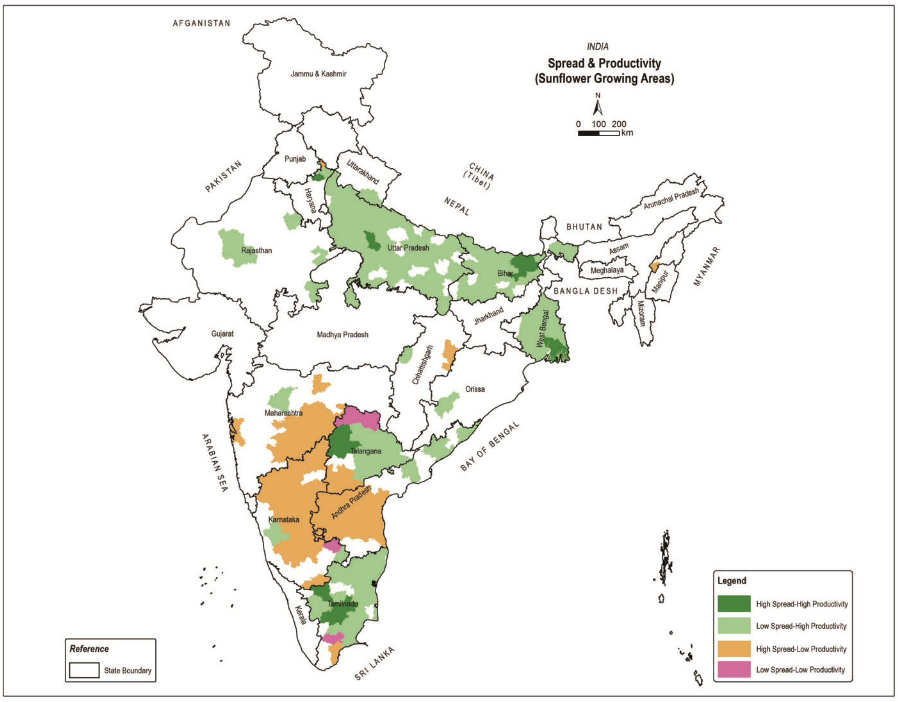

Figure 2. Efficient areas for sunflower in India.

country were collected from 2009 to 2014. From the data, RSI and RYI were computed using the formula: RSI = area of particular crop expressed as % of total cultivable area in the district/area of crop expressed as % of the total cultivable area of the country ×100, RYI = mean yield of a particular crop in a district (kg ha^{-1})/mean yield of the particular crop at the national level (kg ha^{-1}).

RSI and RYI limits that are used to classify efficient areas are presented in Table 1. Most efficient areas are those areas where RSI and RYI are >125. If RYI is >125 and RSI is <125 such areas are efficient in productivity but the spread is less. If spread is more (RSI > 125) and productivity is low (RSI < 125) the areas are moderately efficient; and all other areas of low spread and productivity are less efficient to a particular crop.

Each plant species requires specific soil-site conditions for its optimum growth. Plant growth requires reasonable moisture and nutrient supply, linked to a sufficient rooting depth, and a good energy regime for photosynthesis and biomass production. Crop growth requirements or qualities are plant-specific and may therefore differ from crop to crop, and even from cultivar to cultivar. These crop requirements or qualities are moreover not always directly measurable in the field and may need to be derived from other observations.

The matching process consists of comparing climatic, soil and physiographic requirements with individual crop growing conditions for each LMU. Results are expressed in a suitability classification, as a percentage of maximum potential yield within this LMU. The matching exercise includes two steps, dealing in turn with a climatic and a soil-physiographic evaluation. Initially, the climate of the concerned LMU is compared with that of the crop requirements. The specific soil and crop-linked growing

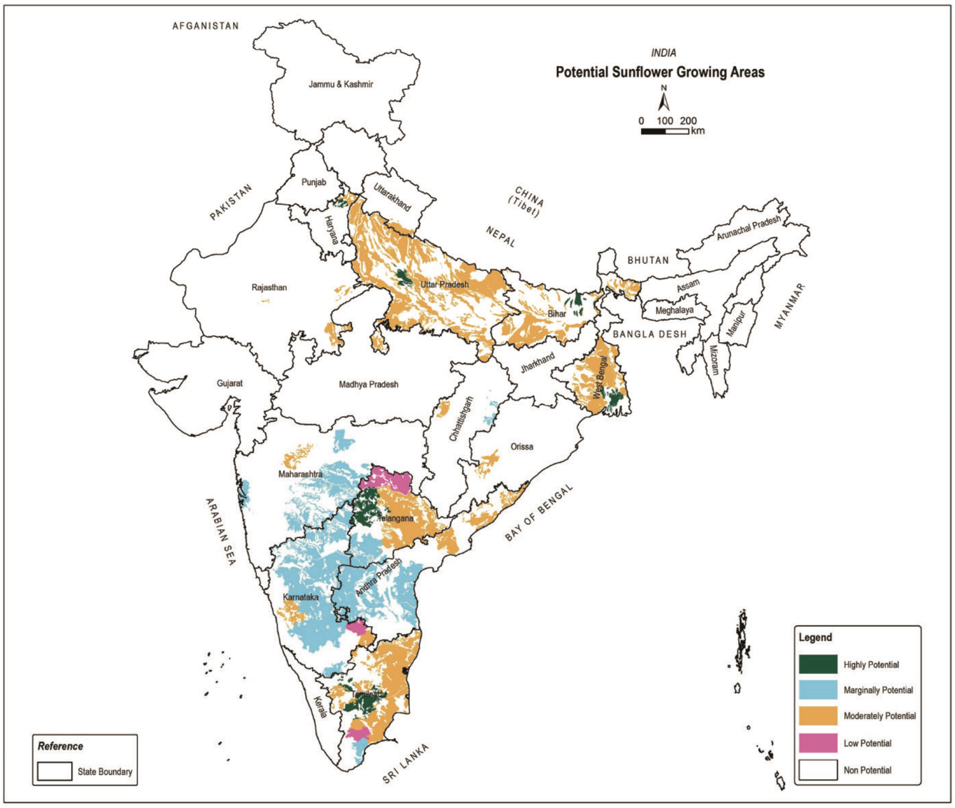

Figure 3. Potential areas for sunflower in India.

season is calculated, using rainfall data, in particular length of growing period (LGP).

The second step in the matching procedure refers to the comparison of individual soil and physiographic properties of soil units with the computed crop requirements in terms of nutrient supply, rooting depth, susceptibility to toxic elements and trafficability/workability. Soil-site suitability criteria of major crops have been published by NBSS&LUP[6]; these criteria have been used to assess soil-suitability of different crops in different LMUs to rate suitability class in geographic information system (GIS).

On the basis of the degree and number of constraints identified, a suitability classification may be established as: (i) highly suitable S1 (S1 – with no or slight limitations); (ii) moderately suitable S2 (S2 – moderate limitation); (iii) marginally suitable S3 (S3 – severe limitation) and; (iv) unsuitable (N) classes.

S1 classes correspond to areas, which have a yield potential above 80% of maximal attainable harvest within the climatic area. This figure drops to 50% and 20% for classes S2 and S3 respectively. Table 2 summarizes the list of important land qualities with relevant land characteristics and possible limitations that influence crop performance.

RSI and RYI data of a given crop were linked to suitability classes (Table 1) in GIS environment to identify potential areas for that crop using criteria to identify potential crops by integrating RSI, RYI and suitability classes[14].

Potential areas are areas where a particular crop has high spread and productivity and these areas are bio-physically suitable to the crop. Moderate potential areas have low spread but high productivity and are bio-physically suitable to a particular crop. Marginally potential areas have high spread but low productivity and are bio-physically suitable to a particular crop. Less potential areas are low spread with low productivity and may be bio-physically suitable, but the farmers' socio-economic conditions may hinder the growth of the less potential areas also require more investment and time to popularize the particular crop. Therefore, suggestions of alternate crops would be more acceptable than the particular crop.

To demonstrate the feasibility of the methodology, sunflower crop was selected for the case study and following the above mentioned methodology (Figure 1), efficient areas (Figure 2), potential areas for sunflower at the national level (Figure 3), efficient areas of Karnataka (Figure 4) and West Bengal (Figure 5), potential areas for sunflower in Karnataka (Figure 6) and West Bengal (Figure 7) were delineated. Efficient areas usually indicate district as a unit, but in practice the whole district may not be suitable for a particular crop. Integrating suitability with efficient

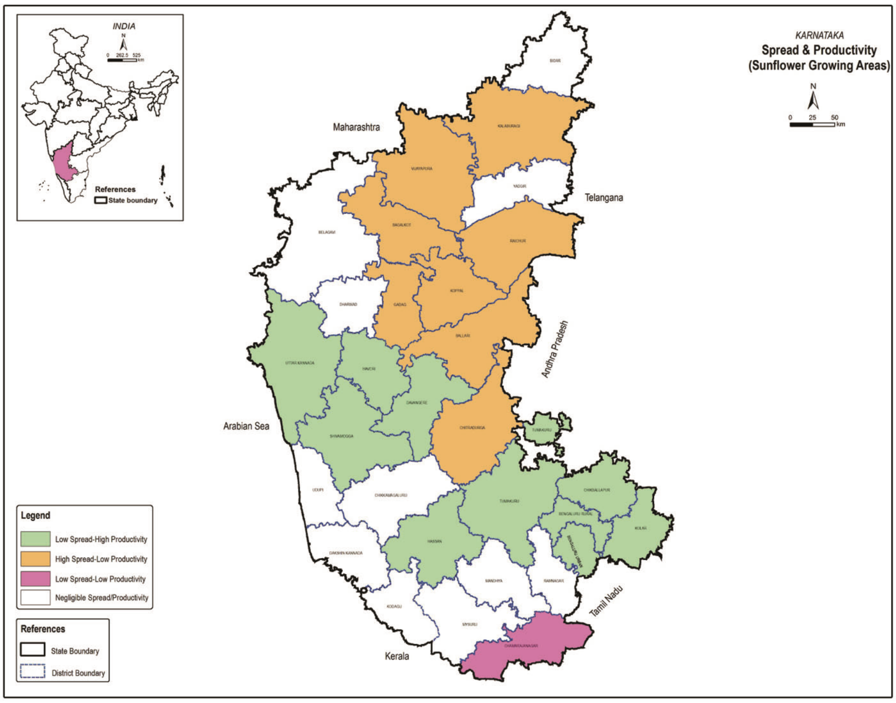

Figure 4. Efficient areas for sunflower in Karnataka.

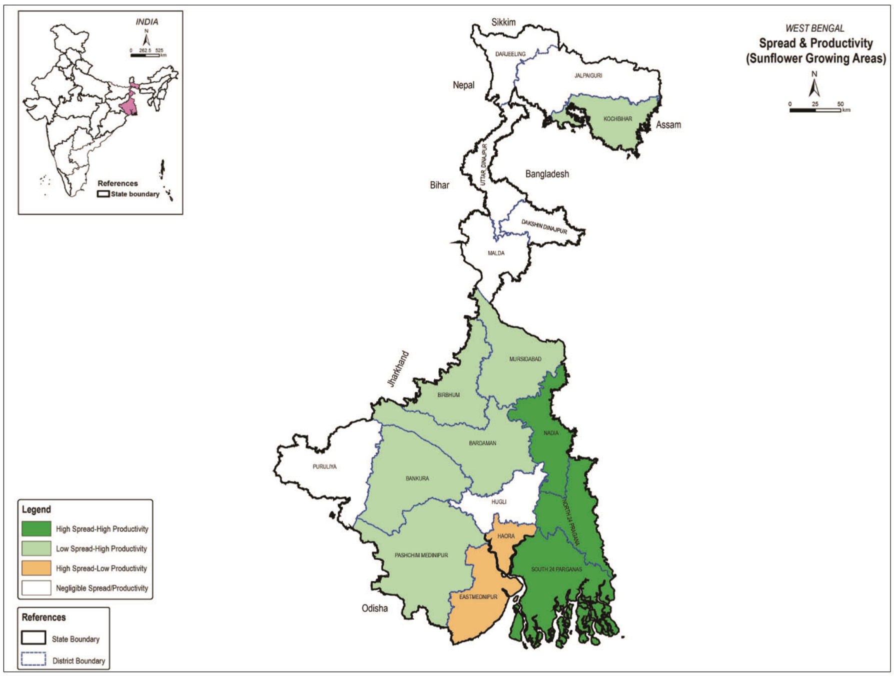

Figure 5. Efficient areas for sunflower in West Bengal.

areas, one can within the district easily identify areas that have potentiality for a particular crop.

Field verification of different categories of potential areas in Karnataka and West Bengal for sunflower was carried out. Two locations in each moderate and marginal potential area were selected for validation. Bagalkote and Koppal districts of Karnataka representing marginally potential, and Bankura and West Midnapur of West Bengal representing moderate potential for sunflower were selected for on-farm trials with two treatments, viz.

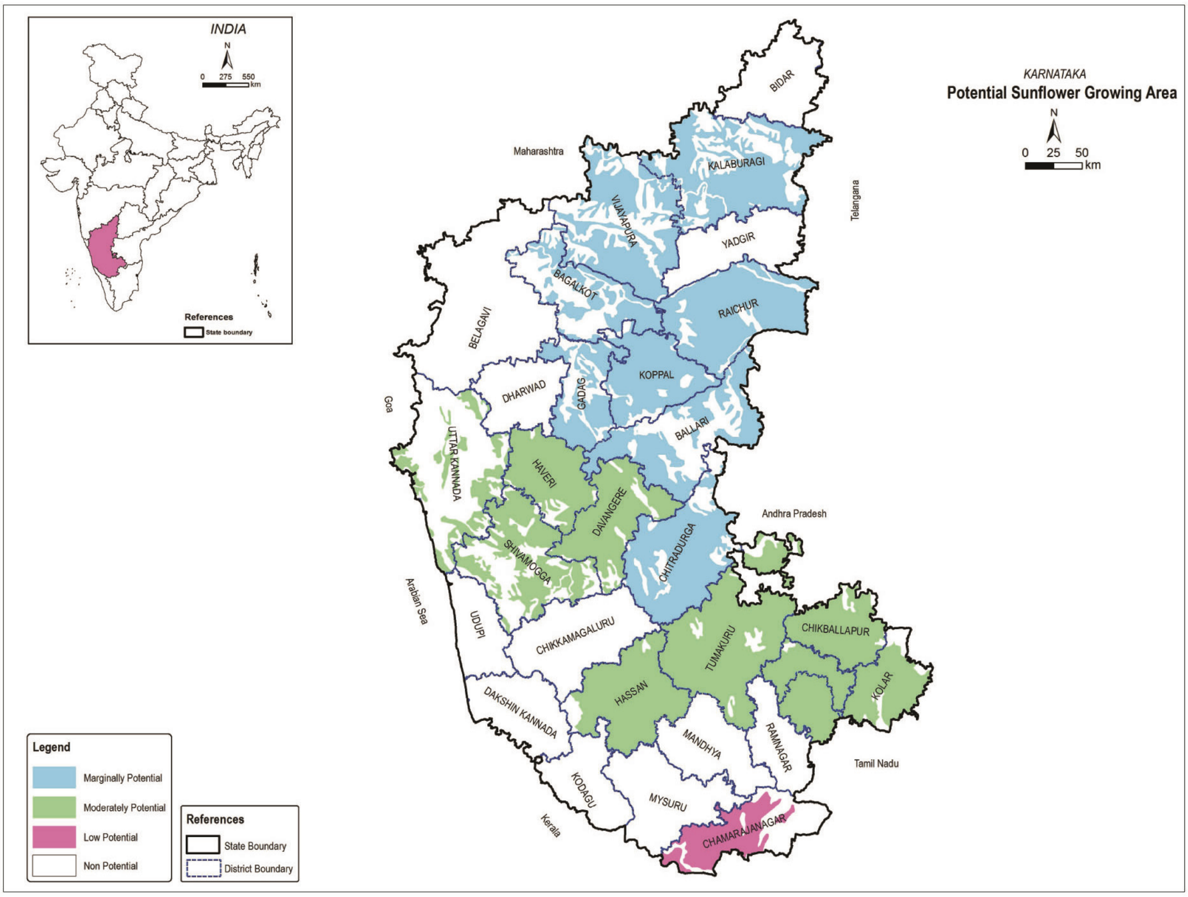

Figure 6. Potential areas for sunflower in Karnataka.

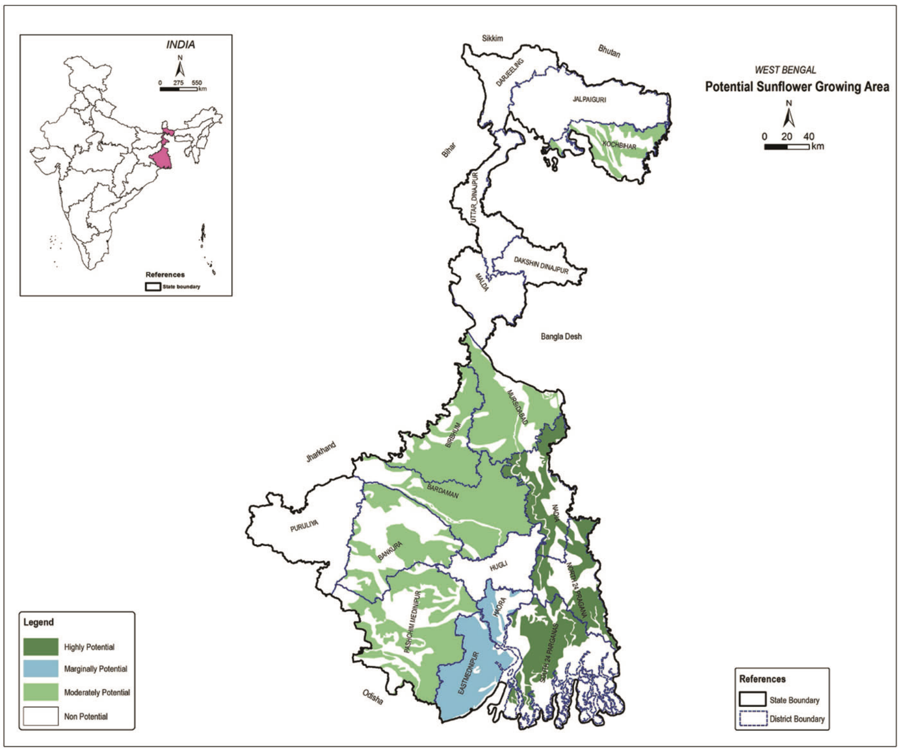

Figure 7. Potential areas for sunflower in West Bengal.

Table 3. On-farm trails on evaluation of performance of sunflower under best management practices over farmer's practice

	BMPs yield (kg/ha)	FP yield (kg/ha)	Increase over FP (%)	FLD yield (kg/ha)	Increase over FLD (%)	District yield (kg/ha)	Increase over district (%)	State yield (kg/ha)	Increase over state (%)
Marginally potential areas (Bagalkote and Koppal districts of Karnataka)	1116	899	24	930	20	586	90	548	103
Moderately potential areas (Bankura and West Midnapur district of West Bengal)	1850	1356	36	1470	26	1333	39	1293	43

farmers practice and best management practice (BMP). One hundred and sixty four farm trials in Karnataka and 226 farm trials in West Bengal were conducted for sunflower. The data presented in Table 3 indicates that BMP improved productivity of crop by 24% and 36% over farmers practice in marginally and moderate potential areas respectively. In marginally potential areas, productivity improvement due to BMP was 90% and 103% compared to district and state average. Similarly in moderate potential areas it was 39% and 43% (Table 3). This clearly suggests that there is greater scope to double the productivity of sunflower in marginally potential areas where the area under the crop is high but productivity is low.

The following are some inputs to policy decisions: (i) In potential areas the focus should be on soil and plant health management and transfer of new technologies related to a particular crop for sustainability. (ii) In moderate potential areas, focus is needed on area expansion of a particular crop by conducting front line demonstrations, farmer participatory research, incentives to farmers for growing a particular crop by way of higher minimum support price, timely availability of inputs and establishment of market and processing units. (iii) In marginally potential areas efforts are needed to enhance the productivity of a particular crop by effective transfer of technology through farmers participatory research, introduction of suitable hybrids/varieties, timely availability of inputs, capacity building of farming community and creation of market and processing units. (iv) In less potential areas, it is better to suggest alternate crop/cropping system, which is economically better than less potential crop(s).

A top-down approach is useful in framing potentially suitable locations, but a complementary bottom-up analysis is still required to ultimately identify areas for sustainable crop production.

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