

Soybean Agriculture in India - A Spatial Analysis

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Abstract

An attempt has been made to characterize the soybean growing regions of India, at the district level on the basis of productivity, rainfall, soil type and concentration. The study has helped to devise 12 typologies based on the above four parameters and also provides an insight into the spatial distribution and variability of soybean yield, identification of priority areas where extension and research should be focused for vertical (yield) as well as horizontal expansion (area).

Introduction

During the Green Revolution, the major thrust was placed on increasing productivity of food grains, oilseeds and pulses. The main source of protein in a vegetarian diet remained outside the main stream of development. In view of this Bhalla and Singh (1997) pointed out that Indian agriculture during the last decade marked a distinct change in cropping pattern, away from the coarse cereals and toward oilseeds. This shift was particularly strong in the central region lending the country a status of the third largest producer of oilseeds in the world. But ironically, the per capita consumption per annum of 8 kg is just one third of the world average.

Oilseed crops occupy about 10% of the total cultivated area and contribute approximately 10% to the production of food crops. It has been reiterated that both conventional and nonconventional sources of oil must be tapped to meet the challenge. The potential of soybean in this context is far above the other oilseeds. Due to the

combined efforts of agricultural scientists and the ingenuity of Indian farmers, significant strides have been made in increasing the area under soybeans and productivity over the period 1983 to 2004 by 490% and 715% respectively. The world scenario indicates that the average productivity of Indian soybean of 1.074 t/ha is very low as compared to the world average of 1.8 t/ha and the Asian average of 1.3 t/ha. In this context the present paper attempts to analyze the agro-environmental characterization of soybean growing regions in India.

Data and Methodology

It is important to note that only 14 districts of M. P. claimed 61% of soybean area and produced 75% of the total soybean production of the country. It is necessary to identify characteristics, which discriminate the high production districts from the low production districts. The purpose of the analysis in the present study is to identify geo-environmental discriminators such as soil and rainfall, to assess regional disparities

in proportion of soybean area in gross cropped area (GCA) and productivity in 88 districts of M.P., Maharashtra, Rajasthan, Gujarat, Karnataka and UP. The selection criterion of soybean district is more than 100 ha of area under soybean crop. A rational scheme of soybean cropping typology is devised (Figure 1). Physical attributes like soil type and rainfall and physico-anthropogenic characteristics such as yield and crop concentration involving judgement and decision of a farmer are used. The soybean typologies would be obtained by following a four-step methodology with the incorporation of classificatory variables at each step like productivity, rainfall amount, soil type and crop concentration.

1. The analysis of productivity using the published yield (kg/ha) data for 88 soybean growing districts for 2002-03 has been carried out. The technique of Yield Index (Shafi, 1972) is adopted and two clusters of soybean districts obtained are A - High productivity and B - Low Productivity.

$$\text{Yield Index (YI)} = \frac{\text{Average soybean yield in the district 'a'}}{\text{Average soybean yield in the country}}$$

Yield index > 1.0 indicates higher productivity of the crop vis-a-vis the national figures.

- Soybean is cultivated in India mainly as a kharif crop, therefore, the influence of rainfall on yield has been assessed. Soybean growing districts are grouped according to Yield Index and June to September rainfall (1 - High RF > 800 mm, 2 - Low RF < 800 mm). Four clusters of soybean growing districts are identified.
- The role of soils in addition to YI and RF in soybean development is incorporated. Soils of soybean growing region are classified into two broad groups a - vertic and b - non-vertic soils. Thus 8 clusters of districts are obtained from YI-RF-SOIL analysis.

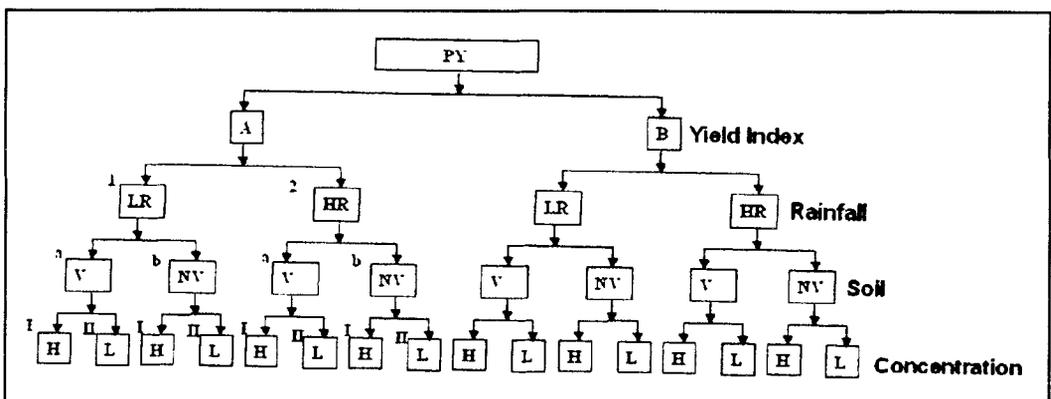


Fig. 1

Scheme adopted for framing soybean typologies

4. The proportion of soybean area in gross cropped area is widely varying from less than 1% to some 50%. It will be worthwhile to consider only those typologies for further intensive study which have high concentration of soybean area. The concentration of soybean area as proportion in GCA is studied by applying Bhatia's (1965) method for assessment of concentration of crop area in GCA.

$$\text{Crop Concentration (C)} = \frac{\text{Proportion of soybean area in GCA in district 'a'}}{\text{Proportion of soybean area in GCA in the country}}$$

Three schemes described above are combined with concentration (C) of soybean crop in the district (YI - RF - Soil - C) as I - High C > 1.0 and II - Low C < 1.0. The typology A2b1, as an example, can be interpreted as high productivity-low rainfall nonvertisols-high concentration soybean agro-ecosystem. The clusters devised at each step are distinguished from each other through their mean values while homogeneity within each of them is indicated by the coefficient of variation; CV(%) greater than 20% is considered to indicate heterogeneity within the cluster with respect to the mean soybean yield of the member districts. Among the different factors of production, water management plays the most important role. Hargreaves (1977) forwarded a simple but effective measure as 'Moisture Availability Index' (MAI) which is a moisture adequacy index at the 75% probability level of precipitation occurrence. It is the ratio of dependable rainfall and potential evapotranspiration. An MAI value of 1.00 means that

dependable precipitation equals potential evapotranspiration. A value of MAI of 0.33 or less for one month during the crop growing season is considered to be a danger signal of water deficit, causing the production to fall below an economic level. Whenever a monthly MAI value exceeds 1.2, according to Hargreaves then there is a need, except for rice, of good natural or artificial drainage. Against this, MAI is worked out as a criterion for determining beneficial/detrimental effects of rainfall on yield under rainfed agriculture and as an effective means of comparing areas of similar soybean agro-climates.

Results and Discussion

Soybean (*Glycine max(l) Merrill*) is a short season leguminous crop that grows well in a warm climate with intermediate to heavy rainfall. It is a highly nutritive crop which contains approximately 43% protein and 20% oil. It has been recognized as a pulse oilseed and a food crop by the scientists in their respective fields. It is primarily a kharif season crop. In India soybean is being grown successfully over a wide range of temperature conditions with 27°C mean maximum temperature for July and August. Nearly all soybean cultivation is rainfed. Sixty mm of rainfall during growing season is estimated to be enough for the crop (Peters and Johnson, 1960). Water is often the primary limiting factor in soybean production and this is an important management concern. Except in critical periods such as germination, flowering and pod formation, soybean is generally considered to be tolerant to shortages of moisture. Moisture stress during vegetative growth may be very detrimental causing the plants to be too small for high

yields. The stress during seed development often reduces seed yield. Excessive continuous rainfall may delay planting or impair germination, increasing pathogen activity and anaerobic conditions. Shanmugsundaram (1980) reported a 28% reduction in soybean plant establishment due to flooding that occurs immediately after sowing. Field observations (Lawn and Byth, 1979) and laboratory studies (Stanley et al., 1980) suggest that soybean compared with other legumes is relatively tolerant to temporary waterlogging and in the absence of disease it recovers quickly after waterlogging ceases.

Soybean in spatio-temporal frame

Soybean is not a new crop to India. Black soybean has been cultivated for ages in the low hills of the Kumaon and Garhwal regions of UP as well as on the foothills of the Himalayas and in some scattered pockets of central India. However, strangely enough the crop did not become popular till the eighties when total soybean area in the country was only 33000 ha distributed in UP and M.P. Since then the area under soybean has been increasing progressively. Real breakthrough came around 1989-90 with the discovery of short duration, early maturing (90 days) high yielding soybean varieties. From 1980 to 1990 the share of soybean crop in total cultivated area of the country rose from 0.45% to 1.31%.

The results of the experiment of All India Coordinated Research Project on soybean reported by Trikha (1986) indicate that soybean as a rainfed kharif crop has a significant potential in all the four agronomic zones of India viz., Northern hills, Northern plains, Central and Southern zones either

replacing low-yielding crops such as finger millet, sorghum or as an intercrop with them or as a filler crop during kharif fallow periods. The state level crop area analysis shows that the only important states for soybean in '94- 95' were M. P., Maharashtra and Rajasthan, accounting for approximately 97% of the area i.e., 3.5 million ha producing 94% of the country's production of 3.7 million tones. Recent statistics reveals that soybean area in M. P. has decreased from 42 lakh ha in 2001-02 to 37 lakh ha in 2004-05. In contrast, soybean has achieved a dominating position in the kharif cropping system of Maharashtra, where the area under soybean in 2001-02 was 9.8 lakh ha which rose to 19.3 lakh ha in 2004-05. While impressive, these figures belie the fact that major improvements are required both in area planted to soybean and in average per ha productivity. The study of long term trend of growth does not indicate any appreciable contribution of technological knowledge in soybean cultivation.

The mean yield in 1983-84 was 646 kg/ha which increased to 1000 kg/ha in 1991-92 and in 2003-04 the yield was 1074kg/ha. The state mean yield in Maharashtra is highest i.e. 1.25 t/ha, and Kolhapur division reports the record yield of 1.56 t/ha. It can thus be concluded that production growth pattern in India as a whole, has been dominantly area-led. This implies that either research strategies or extension has been inadequate to provide knowledge based soybean production technology at the farm level to generate yield-led growth pattern.

Soybean agro-ecosystems

The classification of cropping systems into types (agricultural typology) is considered

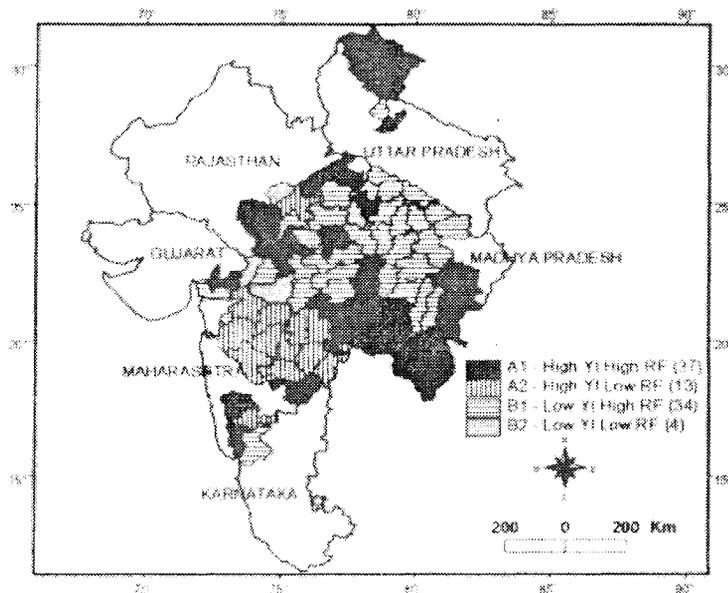


Fig. 2

to be of primary importance in agricultural planning. It provides better understanding of the inherent agricultural characteristics and the tendencies in the changing spatial organization of agriculture. The clusters of 88 soybean growing districts obtained at each of the four steps described earlier are discussed in the following text.

Productivity clusters

Two groups are identified as high and low productivity regions (Table 1 and fig. 2). It is important to note that all soybean growing districts of Maharashtra belong to high yield category.

Table 1

Yield Index

Typology	Mean	CV	No of Districts
A - High	1.2	16.26	50
B - Low	0.73	18.61	38

Productivity-Rainfall clusters

Four YI-RF clusters were formed as follows (Table 2 and Fig. 3). High yield in low rainfall environment is a conspicuous feature of soybean agro-ecosystem of North Maharashtra and Marathwada, while Vidarbha, Kolhapur division and adjoining east M.P. region report high soybean yield under high rainfall conditions. Most of the districts in M.P. are characterized by low yield high rainfall soybean typology.

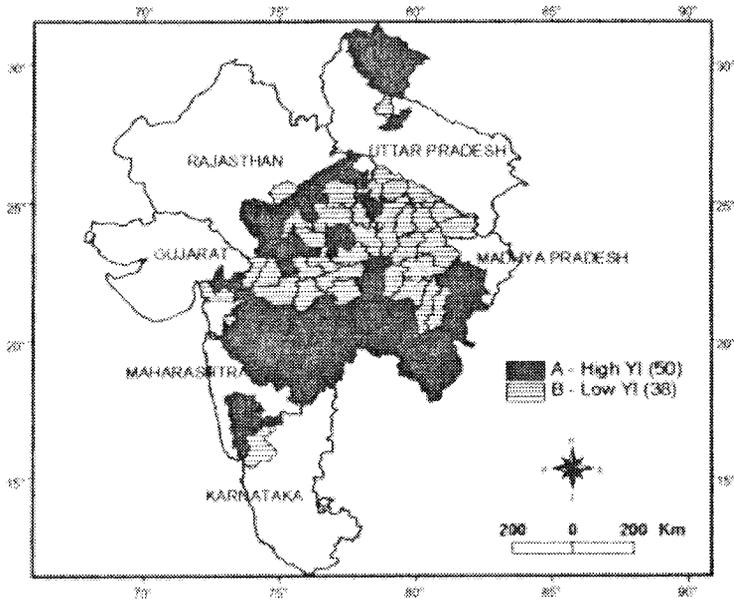


Fig. 3

Table 2

Yield Index and Rainfall

Typology	Mean	CV	No of Districts
A 1 - High YI High RF	1.15	14.17	37
A2 - High YI Low RF	1.34	15.72	13
B 1 - Low YI High RF	0.72	18.95	34
B2 - Low YI Low RF	0.86	6.92	4

Distribution of moisture adequacy during soybean growing season indicated by monthly MAIs would bring out subtle moisture relationships with soybean crop. Low yield in the high rainfall regions of M.P. could be attributed to high mean MAI of 1.9 in the months of July and August that correspond to vegetative and reproductive growth stages of rainfed soybean crop.

Against this, high yield in the low rainfall regions of North Maharashtra and Marathwada is marked by mean MAI in those growth stages as 0.8. High mean MAI of above 1.2 is observed in 4 low rainfall districts of M. P. which indicates the high concentration of seasonal rainfall in two months viz., July and August leading to low yield.

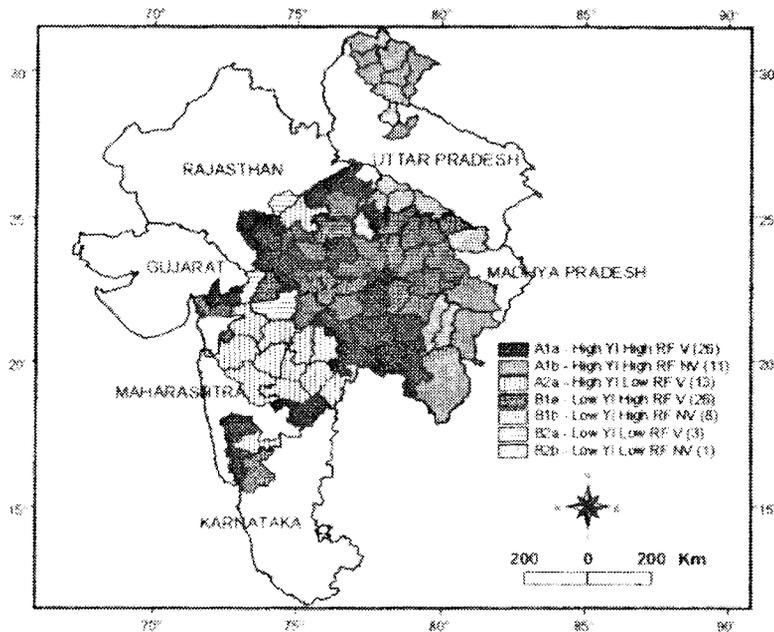


Fig. 4

Table 3

Yield Index, Rainfall and Soil type

Typology	Mean	CV	No of Districts
A1a - High YI High RF V	1.16	15.58	26
A1b - High YI High RF NV	1.11	9.16	11
A2a - High YI Low RF V	1.34	15.72	13
A1b - High YI Low RF NV	NIL	NIL	NIL
B1a - Low YI High RF V	0.71	19.14	26
B1b - Low YI High RF NV	0.75	18.87	8
B2a - Low YI Low RF V	0.85	8.48	3
B2b - Low YI Low RF NV	0.86	NIL	1

Productivity-Rainfall-Soils cluster

The MAI computations assume that all precipitation enters the soil profile and becomes available for plant use. If intensity of precipitation significantly exceeds the infiltration rate, then surface runoff will be

considerable. Soils vary in their capacity to store and carry over readily available moisture in the crop root zone. The amount of water available to the crop from soil moisture depends upon the crop rooting characteristics under prevailing conditions

Table 4

Yield Index, Rainfall, Soil Type and Concentration Index

Typology	Mean	Stdev	CV	No of Districts
A1a1 - High YI High RF V High C	1.1	0.13	11.42	19
A1 all - High YI High RF V Low C	1.33	0.21	15.73	7
A1b1 - High YI High RF NV High C	1.38	NIL	NIL	1
A1b11 - High YI High RF NV Low C	1.08	0.05	4.32	10
A2a1 - High YI Low RF V High C	1.35	0.16	11.56	3
A2a11 - High YI Low RF V Low C	1.34	0.23	17.33	10
A2b1 - High YI Low RF NV High C	NIL	NIL	NIL	NIL
A2b11 - High YI Low RF NV Low C	NIL	NIL	NIL	NIL
B1a1 - Low YI high RF V High C	0.73	0.12	16.72	19
B1a11 - Low YI high RF V Low C	0.65	0.16	24.80	7
B1b1 - Low YI high RF NV High C	0.9	NIL	NIL	1
B1b11 - Low YI high RF NV Low C	0.73	0.14	19.00	7
B2a1 - Low YI Low RF V High C	0.85	0.07	8.48	3
B2a11 - Low YI Low RF V Low C	NIL	NIL	NIL	NIL
B2b1 - Low YI Low RF NV High C	0.86	NIL	NIL	1
B2b11 - Low YI Low RF NV Low C	NIL	NIL	NIL	NIL

and the capacity of soil to store moisture and make water available within that depth. Seven clusters are identified and presented in Table 3 and Fig. 4.

Rainfed soybean agro-ecosystem of India is predominantly associated with vertic soils which have high moisture retention capacity. In eastern M. P. and U. P. soybean is also cultivated in non-vertic soils particularly in those areas where seasonal rainfall is above 800 mm. High yield low rainfall non - vertisol typology (A2b) is not represented. It is important to note that 26 districts report high yield in high rainfall vertisol regime however the same number of districts under same regime report low yield. The perusal of monthly mean MAIs in the critical soybean growth stages reveals that low yield are noted for the agro-envi-

ment having very high mean MAIs > 2.0 whereas high yields are associated with mean MAIs <1.5.

The non-vertic high rainfall regions (11 districts) report high yield inspite of the higher July and August MAIs (>1.6) as compared to those of high yield vertic high rainfall regions. Non-vertic soils are moderately well drained soils with fairly good aeration and therefore support a good soybean growth under higher MAI conditions. Productivity-Rainfall-Soils-Concentration clusters: This resulted in classification of the soybean growing regions into 16 eco-units. Four of them are not represented in the soybean growing region of India. Twelve typologies along with their statistical parameters are denoted in the Table 4 and Fig. 5.

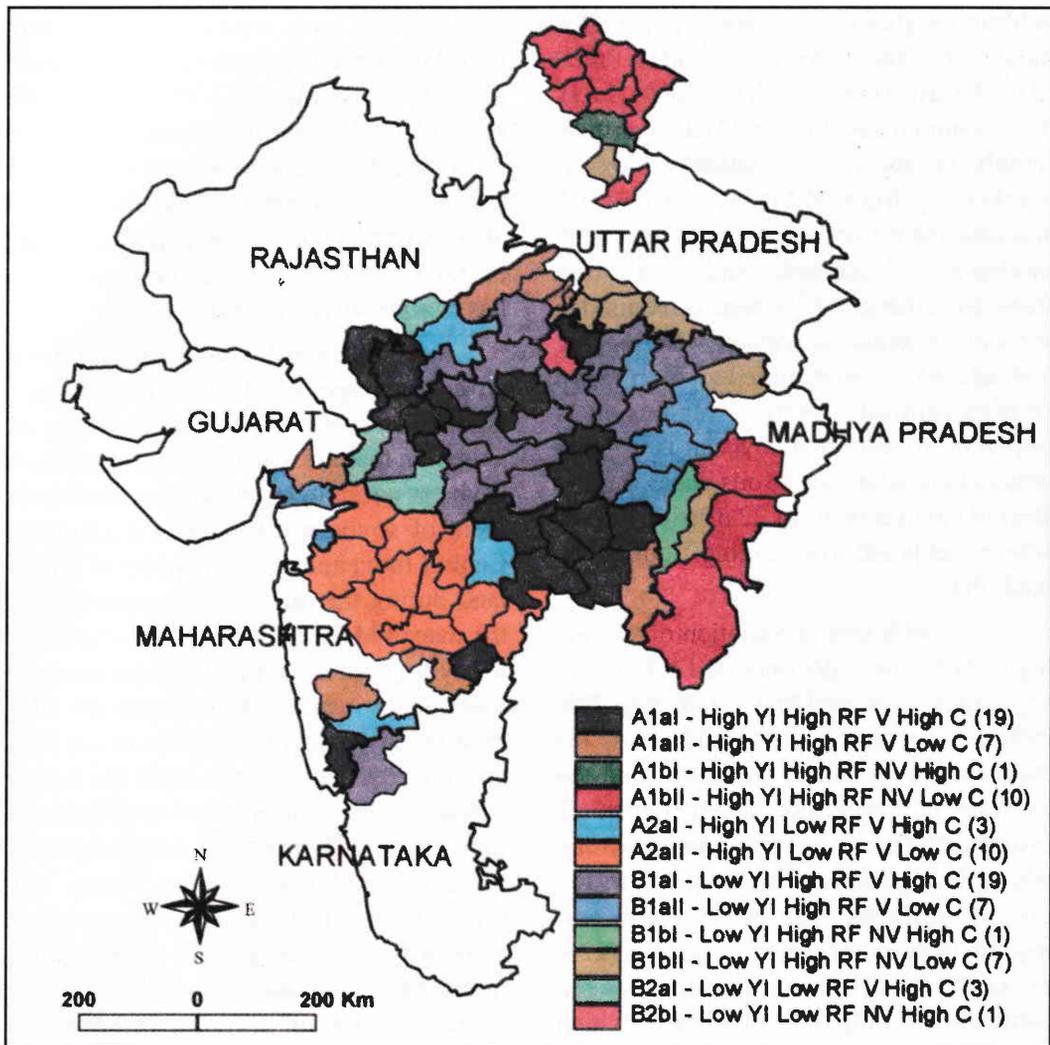


Fig. 5

The table 4 illustrates that in vertic soybean region (68 districts) 44 districts have soybean as a major crop (high concentration) cultivated during rainy season; and 35% of them report low yield of < 1.0 t/ha regardless of their soil and rainfall environments. Sixty-eight soybean-growing districts are situated in vertisol soil region;

of which 44 districts have soybean as a major crop indicated by their high proportion in their respective gross cropped areas. One-third (22) of the soybean districts in vertic soil region are characterized as high yielding districts. Among high productivity soybean clusters (19 + 7 + 3 + 10) 13 districts with low rainfall (A,2,a,I and A,2,a,II) have

achieved higher yields (mean yield 1.34 t/ha) as compared to the mean yield (1.1 t/ha) of the 19 districts with high rainfall (A,1,a,I). The examination of mean MAI for critical months reveals that the latter typology is marked by high MAIs as 1.5 and 1.6 whereas, the former agro-ecosystem reports modest mean MAIs as 0.7 and 0.9. It is thus imperative that good drainage is required in vertisols in order to prevent waterlogging and reduced yields of rainfed soybean grown in high rainfall - vertisol regions. It is important to note that soybean is a major crop cultivated in vertic soils under varying rainfall environments of 22 districts (19+3) where yields are low ranging from 0.7 to 0.85 t/ha.

The coefficient of variation of yield is high (24%) for 7 districts (B 1 aII) where soybean is a low-yielding minor crop. This indicates a wide range of yield across the districts in that cluster resulting from the interplay of a multitude of environmental, institutional and socio-economic factors, which have not been considered in the present analysis. The non-vertisol soil regions have relatively smaller area (22% of soybean districts) under soybean cultivation as only three districts with high concentration of crop. However, in 7 districts soybean is a minor crop producing 0.73 t/ha yield while 10 districts produce 1.08 t/ha.

Concentration of soybean area

The concentration of soybean crop had mainly been in vertisols of central Peninsular India, in general, and in M.P., in particular. Annual average rainfall in soybean growing areas ranges from 500 to 1500 mm. In this region soybean is cultivated in combination with rice, pigeon pea and sorghum. Shurpali

et al. (2000) have reported the declining trends (compound growth rates) in sorghum area of 7% during 1983-1995. They also highlighted the decreasing trends in rice and pigeonpea during that period as 4.0 and 2.2% respectively. Nonetheless, the fallow land also declined in the post-90 period at the rate of 3.6% per year. The area under soybean has continuously increased.

Reasons for such a leap-frog shift in the cropping pattern of M. P. during the mid-eighties and later are the development of irrigation facilities, higher cash return from soybean agriculture, concurrent establishment of soybean oil extraction plants in Central India and the availability of fallow land during the rainy season especially in the state of M. P.. The farmers switched over to soybean-wheat cropping pattern from the traditional sorghum-wheat system. Introduction of early maturing varieties of soybean and improved tillage practices for heavy vertisols which otherwise are unworkable in rains prompted farmers to intensify soybean-wheat cropping system in the country. The recent decade has witnessed phenomenal growth in soybean area in Maharashtra replacing rainy season sorghum and pearl millet. Kolhapur division in southern Maharashtra has reported the highest mean yield of 1.56 t/ha in the country. There soybean is a gap crop fitted after two cycles (first planting and second ratoon) of sugarcane crop which is again followed by two cycles of sugarcane.

Spatial variability in productivity

As discussed earlier, we have found wide regional disparity with respect to soybean productivity as well as spread of soybean area. Based on the growing environment in

terms of soil and rainfall, 12 soybean agro-ecosystems have been identified. The high mean yield of 1.34 t/ha is observed for 13 districts having low rainfall vertisol system, which include districts from North Maharashtra and Marathwada. The region receives rainfall of 500 to 650 seasonal mean rainfall with a monthly mean MAI varying between 0.35 and 0.9. Low productivity of the order of 0.6 to 0.74 t/ha is noted for high rainfall vertic (B1 aI and B1 all) as well as non-vertic (B1 bII) typologies. The monthly mean MAIs for July and August are more than 2.0 for these typologies. Majority of the farmers do not use recommended integrated plant protection, soil fertility management or water management measures. In addition, rain events mismatching with the water needs of different growth stages associated with inappropriate on-farm practices have resulted in soybean yield below its genetic potential.

It is well-observed from the analysis that soybean yield has been high in regions with vertic soils where mean seasonal rainfall is characterized by monthly MAIs for the critical months of July and August varying below 1.2.

Improvement in yield

The yield potential of soybean is around 3.5 t/ha giving a yield gap between the farmer's field and the researcher's trial plots of some 2.5 t/ha which may be attributed to cultivar and management. Management practices contribute nearly 56% to the variability in the yield between the sites (Whigham et al, 1978). In low rainfall vertisol region short period drought situations need to be managed by adopting moisture conservation practices, while in

high rainfall vertisol zones there is a need to apply water management technology to drain excess water from the root zone. Thus if a farmer has a dependable system for removing excess water and applying water when needed, he will invest in the other necessary inputs for improved agricultural production. There is a need to develop more suitable, area-specific varieties that are high-yielding, resistant to pest and diseases, and drought tolerant. More efficient methods are needed to control widespread diseases like rust in high rainfall/irrigated - vertisols region. Following are the soybean agro-ecosystems where vertical expansion in the yield should be attempted on priority basis.

1. Nineteen plus seven districts where soybean is cultivated in high rainfall and vertic soils (B,1,a,I and B,1,a,II) suffer from low productivity (0.7 t/ha) vis-a-vis 19 plus 7 districts (A, 1,a,I and A1 all) with similar environment can produce > 1.0 t/ha soybean.
2. Similarly 3 districts (0.85 t/ha) (B,2,a,I) need to be managed to produce as high as 1.34 t/ha which is the mean yield of 10 plus 3 districts under the same typology (A2aI and A2aII).

Area expansion

The spread of soybean crop in the gross cropped area of the district (C) is considered for future expansion of soybean area. Ten districts mostly from Maharashtra having a high yield under low rainfall and vertisol regime (A2aII) are characterized by high potential for area expansion. Besides 10 districts from non-vertic high rainfall zone of eastern M.P. (AlbII) also indicate substantial scope for expansion of soybean areas.

As with any other crop, the future of soybean in India depends upon economic considerations as well as upon its adaptation to climate, soil and other natural conditions. Farmers seem to be convinced about soybean's suitability and profitability in comparison with other dryland crops and landuses. Agronomic packages suitable for the individual soybean agro-eco-typologies are needed to achieve potential yield. For this, micro level research, and analysis of natural resource base and socio-economic aspects of cultivators in promising soybean growing districts is needed. These eco-units would provide a systematic sampling frame for the selection of primary, secondary and tertiary soybean units for micro analysis.

References

- Bhalla, G. S. and Gurnail Singh (1997) : Recent Developments in Indian Agriculture. A State Level Analysis. Economic and Political Weekly, March 29, 1997, A-2 to A-18.
- Bhatia, S. S. (1965) : Patterns of Crop Concentration and Diversification in India, Economic Geography, 40, 41, 53 & 56.
- Hargreaves, G. H. (1977) : *World Water for Agriculture*, Contract AID/ta-c-1103, Utah State University and Agency for International Development, Washington, D.C., 177.
- Lawn, R. J., and D. E. Byth. (1979) : Soybeans. In: A. Lazenby and J. V. Lovett, eds. Australian Field Crops II, Publ. Angus and Robertson, Sydney. 198-231.
- Peters and Johnson L. C. (1960) : Soil Moisture Use by Soybeans, Agronomy Journal, Vol 52, 687-689.
- Raut V. M., Halvankar G. B. and Taware S. P., (1997) : Technology for Increasing Soybean production. Kisan World. Vol 24,9,11-12.
- Shafi, M., (1972) : Measurement of agricultural efficiency in Uttar Pradesh, Economic Geography, Vol 36,296-305.
- Shanmugasundaram, S., (1980) : *Suggested Cultural Practices for Soybean*. International Cooperator's Guide, Asian Vegetable Research and Development Center, Shanhua, Taiwan.
- Shurpali, N.J., K. Srinivasa. S.M. Virmani and K.S. Prasad, (2000) : *The Eco-Regionalization of Soybean Growing Regions in India*. A Report of Natural Resource Management Programme, ICRISAT, Patancheru.
- Stanley, C. D., T. C. Kaspar, and H. M. Taylor (1980) : Soybean top and root response to temporary water tables imposed at three different stages of growth. Agronomy Journal, Vol 72: 341-346.
- Trikha, R.N., (1986) : *The Potential of Soybean in Indian Cropping Systems*, in Proceedings of a Symposium on *Soybean in Tropical and Subtropical Cropping Systems* held during 26th Sept.-1st Oct. 1983, Tsukuba, Japan.
- Whigam, D. K., H. C. Minor, and S. C. Carmer, (1978) : Effects of Environment and Management on Soybean Performance in the Tropics. Agronomy Journal, Vol 70: 587-592.

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