STRATEGY PAPER 4

Sustaining Soybean Productivity and Production in India

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Preface

Soybean is a rich legume crop with protein (40%) and oil (20%), which can contribute to the twin concerns of food and nutrition security issues of India. The crop is mainly raised in black cotton soils (Vertisols and associated soils), in dryland /rainfed agro ecologies (only 5% of the soybean area is irrigated).

Soybean is an environment friendly crop; fixes nitrogen via BNF; needs low to medium inputs of fertilizers; sheds most of its leaf matter on maturity, thus acting as soil mulch; it is resilient to mild droughts and needs little care during its growth cycle.

Extension of soybean production and productivity is an important priority of our agricultural agenda. Until now most of the increases in soybean production have come from the extension of the area under the crop. It is now time to move the productivity bar from about 1000 kg ha^{-1} to 1500-2000 kg ha^{-1} with the available technologies.

In order to deliberate in detail on various issues such as challenges, opportunities and prospectus relating to soybean, the NAAS organized a BSS on 28 November 2014 at NAAS, New Delhi involving all stakeholders. This discussion was aimed at developing a strategy and action plan to increase the productivity and livelihood security of soybean farmers, in view of the fact that this crop would also help in making our agriculture resilient to climate variability.

I wish to express my sincere thanks to Dr S.M. Virmani convener and his colleagues for collating and analyzing the extensive soybean crop and soil data presented in this document. The co-conveners, Drs K.V. Rao, G.P Reddy, G. Ravindra Chary, V.S. Bhatia and P. Padmavati have provided valuable inputs to the document. Apart from co-conveners, very important contributions have been made by Drs Ch. Srinivasa Rao, S.K. Singh, M.P. Jain, Sharan Bhoopal Reddy to the document and the Academy is thankful to each one of them. Thanks are due to the experts including Dr Mangala Rai, Former DG, ICAR, Dr A.K. Sikka, Former DDG (NRM) ICAR and Dr P.L. Gautam, Former Vice-President NAAS who participated in the BSS and contributed immensely to the deliberations. As a follow up of major recommendations of the BSS, the Academy would appropriately support data bank creation for launching a mission project on soybean. My thanks are also due to Dr K.K. Vass and Prof V.K. Gupta for their editorial support.

Panjab Singh
President

Sustaining Soybean Productivity and Production in India

The Context / Preamble

Soybean is a protein rich (~40%) oilseed crop with an oil content of 20%. Globally, the major regions of the production of the crop are the United States of America (31 Mha), Brazil (22 Mha), Argentina (17 Mha), India (11 Mha) and China (9 Mha). Infact about 25 countries of the world report over a million tons of soybean production annually. It is sometimes referred to as a *miracle crop* or *golden bean*, because it is a major source of protein in South East Asia, in Africa, in the United States of America and elsewhere. Its protein is consumed both as human food and as animal feed. The total area under soybeans worldwide is 103 million ha, with an annual production of about 260 m.t; giving an average productivity of about 1600 kg ha^{-1}. In India the productivity of soybean has varied between 1000 – 1200 kg ha^{-1} during the recent years. It is about 60% of the world average, and it is amongst the lowest of the major soybean producing countries of the world. The crop has the potential to address the food and nutrition security concerns of our country provided appropriate scientific management plan is put in place and implemented in a mission mode.

The Challenge

The questions that are uppermost in the minds of agricultural scientists, land use planners and the food nutritionists in India are (1) “Do we have to live with this low productivity of soybeans”, and (2) “How to get out of this syndrome” and increase the per hectare productivity at least to touch the world average.

1.0 Production Zones and distribution

Soybean is a major crop cultivated during the *kharif* season (July-October) in the rainfed (dryland) areas of central and peninsular India. Initially it was recommended to meet shortage of pulses in the country and was introduced in Madhya Pradesh and Uttar Pradesh in *kharif* fallow lands. With high imports of edible oil during 1980s, soybean was found to be more remunerative for different categories of farmers and large scale expansion took place. The by-products of soybean (oilcake and oil meal) are either being exported or used as feed for livestock (Ramesh Chand, 2007). Large scale expansion has taken place in states such as Maharashtra and Rajasthan besides Andhra Pradesh, Gujarat, Karnataka and Chhattisgarh.

The crop is cultivated in different cropping systems like soybean-wheat, soybean-chickpea, soybean-maize, soybean-sorghum, etc. The crop has substituted *kharif* cereals including rice in Madhya Pradesh, Sorghum and Bajra in Maharashtra. The crop is being cultivated in areas with rainfall ranging from 500 mm to 1500 mm with varying productivity levels.

Assessment of crop districts was made through GIS for various crops and cropping systems linking biophysical, livestock, etc. information for identifying the target districts to improve total production in the country under Rainfed Production Systems (Vittal, 1998; Rao, 2003). The assessment was made through identification of dominant districts for each crop covering top 85% of cultivated area. Prioritized interventions in terms of natural resource management such as augmenting the rain water resources either through supplemental irrigation and draining out excess water with suitable land treatments and crop based interventions such as introduction of new varieties where the yield gap is high or promotion of better soil health, pest and disease management practices, etc. were chosen for project interventions under different themes of research (Srinivasarao *et al*., 2014).

1.1 Spatial trends in cultivation

Data on district-wise area, production and productivity available from DACNET of Ministry of Agriculture, was used for the analysis. A total area of 9.484 Mha is under Soybean in the country (average of 4 years from 2008-09 to 2011-12) in the states of Madhya Pradesh, Maharashtra, Andhra Pradesh, Gujarat, Karnataka, and Jharkhand, with 5.0 Mha area in Madhya Pradesh alone. The productivity of Soybean ranges from 400-2300 kg/ha across the country with a median of 1000kg/ha. The area, production, and productivity of soybean in different states is given Table 1.

Madhya Pradesh and Maharashtra contribute 88% of total soybean production in the country with an average productivity of 1125 kg/ha and 946 kg/ha, respectively. Andhra Pradesh has an average productivity of 1280 kg/ha, which is 20% more than country's average.

Table 1: Average area, production and productivity of soybean growing states in India (2008-09 to 2011-12)

State	Area ('000 ha)	Production ('000 t)	Productivity (kg/ha)
Madhya Pradesh	5488	6200	1035
Maharashtra	2909	2909	1163
Rajasthan	685	685	1099
Karnataka	155	85	524
Andhra Pradesh	137	175	1352
Gujarat	45	36	795
Chhattisgarh	79	78	976
India	9496	10128	1052

Although Karnataka occupies 4th position in area cultivated, the average productivity was only 549 kg/ha, almost 50% of national productivity. Rajasthan cultivated soybean in an area of 0.68 Mha with an average productivity of 1172 kg/ha, second highest in the country after Andhra Pradesh.

Soybean is cultivated in about 130 districts across the country, about 40 districts account for 85% of total soybean cultivated area and about 74 districts have more than 10,000 ha soybean cultivated area and their productivity, the details are given in Annexure.

Analysis of the productivity among these districts reveals significant variation among districts and states. The districts were grouped into 3 classes with Class 1 representing districts with less than 500kg/ha and Class 2 with a productivity range of 501-1000 kg/ha and Class 3 with a productivity of >1000 kg/ha. The number of districts, area, production, and productivity in each class for different states based on this classification is given in Table 2.

Table 2: Classification of districts based on productivity in major soybean growing states [(a) *No. of districts* (b) *Area cultivated* (c) *Production* (d) *Productivity*]

a) No. of districts

State	Class-1	Class-2	Class-3	Total
Andhra Pradesh			2	2
Chhattisgarh		2	1	3
Gujarat		2		2
Karnataka	1	3		4
Madhya Pradesh	2	13	19	34
Maharashtra		10	13	23
Rajasthan		1	5	6
India	3	31	40	74

b) Area ('000 ha)

State	Class-1	Class-2	Class-3	Total
Andhra Pradesh			136.9	136.9
Chattisgharh		47.2	31.5	78.7
Gujarat		44.6		44.6
Karnataka	28.7	125.8		154.5
Madhya Pradesh	80.5	1691.5	3715.7	5487.7
Maharastra		1970.2	938.5	2908.7
Rajasthan		20.6	663.9	684.5
India	109.2	3900	5486.4	9495.6

c) Production ('000 t)

State	Class-1	Class-2	Class-3	Total
Andhra Pradesh			175.3	175.3
Chattisgharh		43	34.7	77.7
Gujarat		35.5		35.5
Karnataka	12	72.8		84.8
Madhya Pradesh	34	1443.8	4722.5	6200.3
Maharastra		1564.8	1187.4	2752.2
Rajasthan		16.8	785.2	802
India	46	3176.7	6905.1	10127.7

d) Productivity (kg/ha)

State	Class-1	Class-2	Class-3	Average
Andhra Pradesh			1352	1352
Chattisgharh		914	1101	976
Gujarat		795		795
Karnataka	418	559		524
Madhya Pradesh	412	781	1274	1035
Maharashtra		801	1440	1163
Rajasthan		815	1155	1099
India	414	777	1313	1052

In Karnataka and Madhya Pradesh, total of three districts are having a productivity of less than 500 kg/ha. Similarly a total of 31 districts (13 from Madhya Pradesh and 10 from Maharashtra, 3 from Karnataka, 2 each from Gujarat and Chhattisgarh and 1 from Rajasthan) covering an area of 3.88 Mha (a bulk of 1.7 Mha from Madhya Pradesh, 1.97 Mha from Maharashtra) are having a productivity of 777 kg/ha (range of 559-914 kg/ha). The average of different states in this class are 781 kg/ha in Madhya Pradesh, 801 kg/ha in Maharashtra, 914 kg/ha in Chhattisgarh, 795 kg/ha in Gujarat, 559 kg/ha in Karnataka and 815 kg/ha in Rajasthan.

Another 40 districts (19 from Madhya Pradesh, 13 from Maharashtra, 5 from Rajasthan and 2 from Andhra Pradesh and 1 from Chhattisgarh) covering a total of soybean cultivated area of 5.5 Mha (3.77 Mha from Madhya Pradesh, 0.94 Mha from Maharashtra, 0.66Mha from Rajasthan, 0.14 Mha from Andhra Pradesh and 0.03 Mha from Chhattisgarh) are having an average productivity of 1313 kg/ha (1274 kg/ha in Madhya Pradesh, 1440 kg/ha in Maharashtra, 1352 kg/ha in Andhra Pradesh, 1155 kg/ha in Rajasthan and 1101 kg/ha in Chhattisgarh).

50% of soybean cultivated area is in 17 districts (11 districts in Madhya Pradesh, 6 districts in Maharashtra and 1 district in Rajasthan) and contributes 50% of total soybean production in the country. Ujjain district of Madhya Pradesh has the largest soybean cultivated area (0.45 Mha, 4.75% of total area) in the country and contributes 6.23% of total soybean production.

Among the 17 districts having a cultivated area of more than 0.2 Mha each, the average productivity ranges from 612 kg/ha in Yavatmal to 1400 kg/ha in Ujjain district. Eight districts (3 districts Hoshangabad, Sagar, Rajgarh of Madhya Pradesh and (5) districts, Yavatmal, Wasim, Amravti, Buldhana and Nagpur of Maharashtra) are having a productivity of less than 1000 kg/ha i.e. lower than the national average productivity.

Analysis of dominant soybean growing districts indicated that seven districts (2 from Madhya Pradesh, 4 from Maharashtra and 1 from Andhra Pradesh) recorded an average district productivity of more than 1500 kg/ha with maximum productivity recorded in Kolhapur district (2275 kg/ha) of Maharashtra. Among the 7 seven districts, in Chindwara of Madhya Pradesh, soybean is cultivated in average area of 1, 52,000 ha.

Among 32 districts having an average productivity of more than 1000 kg/ha, 13 districts of Madhya Pradesh, 3 districts each of Maharashtra and Rajasthan the crop is cultivated in more than 1,00,00 ha in each district.

Districts having a cultivated area more than 1,00,000 ha but the average production is less than 1000 kg/ha include 8 districts from Madhya Pradesh (Khandwa, Hoshangabad, Sagar, Rajgarh, Raisen, Shirpuri, Neemach and Seoni) 9 districts of Maharashtra (Chandrapur, Amravati, Wardha, Nagpur, Nanded, Yavatmal, Buldhana, Akola and Wasim.

Khandwa and Hoshangabad of Madhya Pradesh and Chandrapur, Yavatmal, Washim and Wardha of Maharashtra districts are the priority districts for productivity enhancement as they cover more than 1,00,000 ha each but their average productivity is 30-40% lower than the national average productivity.

Analysis was made understand the contribution of each district in terms of percent area and productivity at the national level. There is close agreement between the percent area contributed by different districts and their total productions. It is important to note that districts with higher percentage of area are contributing high percentage of production at national level indicating the trend of higher productivity in these districts compared to national average.

1.2 Temporal trend analysis

Data on area, production and productivity for soybean growing states at national level were collected from DACNET and analysed for their temporal trend. Soybean was cultivated in about 2 Mha during 1986-87 and increased to 10 Mha by 2010-12 indicating a substantial increase in area. Except for the period 1998 to 2004, during which the area was almost stagnant, there is a continuous increase in the area under cultivation. The increase in area at national level almost matches with increase in area in Madhya Pradesh till 2000 and subsequently matches with increased area in Maharashtra.

With the increased cultivated area in Maharashtra since 1990's, contribution from Madhya Pradesh decreased from 80% during late 1980's to 55% during 2011-12. Madhya Pradesh ranked first in terms of cultivated area (about 5.8 Mha) followed by Maharashtra (2.5 Mha) during 2011-12. Maharashtra's share in cultivated area increased from 5% during late 1980's to 30 per cent by 2012-13. Rajasthan's share in cultivated area is about 5-10% during last 15 years.

Soybean production in the country increased from 1Mt during 1986-87 to 12 Mt during 2011-12. Since large acreage is cultivated in Madhya Pradesh and Maharashtra, the production trends at national level also reflect the production trends in these two states. Contribution of Madhya Pradesh in soybean over a period of 25 years decreased from 75 to 50% and during the same period the share of Maharashtra increased from 5 to 30% and the share of Rajasthan almost remained at 10%.

Although states like Andhra Pradesh, Gujarat, Chhattisgarh and Karnataka are also cultivating soybean, their individual contributions in terms of area cultivated and production are still less than 5% at national level. The promising productivity levels in states such as Andhra Pradesh, Chhattisgarh indicate the scope for rapid increase in area and production, which could happen with sustained efforts of Government and private sector organizations with active support for soybean oil processing.

1.3 Trends in crop and water productivity

Rainfall received during this crop growing season (i.e. June to October) and productivity data of dominant soybean cultivated districts for 4 years was analysed for assessing the rainfall impact on crop production. The data on monthly rainfall for each year corresponding to the dominant district were obtained from IMD Website (http:\\imd.gov.in).

Crop productivity data across different rainfall zones indicates that during last 4 years, these dominant districts received a rainfall of 500 mm-1500 mm during the crop growing period and increase in rainfall from 500 mm to 1000 mm resulted in higher productivity.

But increase in rainfall beyond 1000mm resulted in lower productivity. Rainfall received during June to July months impacted the productivity which was clearly visible during 2008-2009 in Maharashtra, when the individual and total rainfall of June and July was much less compared to later years and also reflected in the reduction of overall state production. Districts such as Kolhapur having a very high rainfall also had the higher productivity.

Rainwater productivity, defined as productivity per unit amount of total rainfall received during the crop growing period indicates a general trend of decreases in water productivity with increase in rainfall. In case of Rajasthan, the productivity is influenced by not only rainfall but also irrigation as soybean area is irrigated to a large extent.

The water productivity of soybean crop ranged from 0.5 to 3.5 kg/ha-mm with significant influence of seasonal of rainfall. Majority of districts showed a water productivity of 1.0-2.5 kg/ha/mm with maximum being observed in the rainfall range of 700-1000 mm. As evident from crop productivity statistics, similar trend of water productivity is observed in case of Maharashtra where water productivity is lower i.e. less than 1 kg/ha-mm when rainfall during crop growing season is about 500-600 mm but increased substantially (1.5-2.5 kg/ha-mm) when rainfall received is more than 800 mm during crop growing season (Fig. 1).

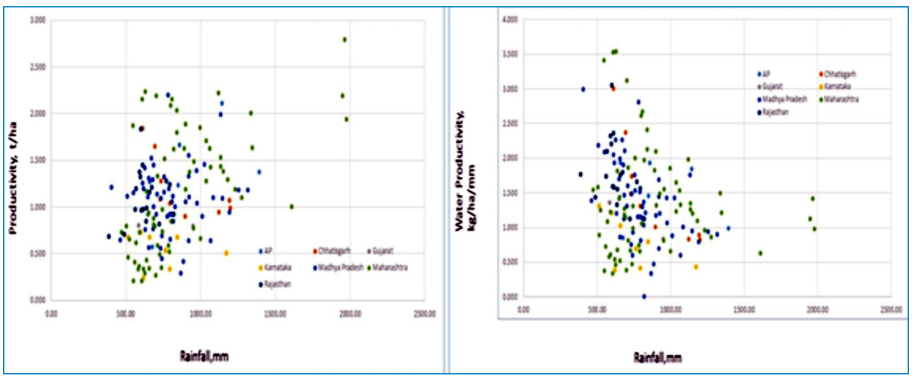


Fig. 1: Crop and water productivity estimates for dominant soybean growing districts

1.4 Cropping system assessment

Based on the information on *rabi* cropped area, an effort was made to understand the possible *rabi* crops grown in soybean cultivated areas. Major crops grown in *rabi* in these districts are wheat, chickpea and sorghum. Utilizing the individual crop cultivated area information, districts across different states were grouped into different soybean cropping systems and presented in Table 3.

Table 3: Predominant *rabi* crops grown in soybean cultivated areas

State	Dominant Rabi Crop(S)		
	Chickpea/Sorghum(1) Chickpea/Maize(2) Chickpea/Wheat Chickpea(3)	**Sorghum/Chickpea Sorghum/Wheat(1) Sorghum(2)**	**Wheat/Chickpea Wheat/Sorghum(1) Wheat(2)**
Andhra Pradesh	Nizamabad (2)	Adilabad	-
Chhattisgarh	Durg, Raj Nandgaon Kawardha (Kabirdham) (3)		
Gujarat	Dohad		Vadodara (2)
Karnataka	Bidar (1)	Belgaum (1), Haveri (2)	Dharwad (1)
Madhya Pradesh	Ashok Nagar, Damoh, Narsimpur, Sagar, Shajapur, Ujjain		Betul, Bhopal, Burhanpur, Chhatarpur, Chindwara, Dewas, Dhar, Guna, Harda, Hoshangabad, Indore, Jhabua, Khandwa, Mandsaur, Neemach, Raisen, Rajgarh, Ratlam, Rewa, Satna, Sehore, Seoni, Sheopur Kala, Shivpuri, Tikamgarh, Vidisha Barwani (2), Khargaon (2)
Maharashtra	Latur (1) Akola, Amravati, Buldhana, Chandrapur, Hingoli,Jalgaon, Nagpur, Nanded, Washim, Yavatmal	Jalna, Kolhapur, Nandurbar, Osmanabad, Parbhani, Sangli Ahmednagar (1), Beed (1), Satara (1)	Dhule, Nasik, Wardha
Rajasthan			Banswara, Baren, Bundi, Chittor Garh, Jhalawar, Kota

The predominant *rabi* crops grown in soybean districts could be broadly put under 3 categories: as given below:

Category 1: *Rabi* crop was dominant with chickpea crop. Other crops grown in these districts during *rabi* include sorghum, maize, wheat.

Category 2: Rabi crop was dominant with sorghum crop. Other crops grown in these districts during *rabi* include chickpea, wheat.

Category 3: Rabi crop was dominant with wheat crop. Other crops grown in these districts during *rabi* include chickpea, sorghum.

Chickpea and wheat are predominantly grown in soybean growing districts in Madhya Pradesh with majority of them having wheat as dominant crop in *rabi*. Farmers prefer to grow wheat when *kharif* rainfall is more or under irrigation and chickpea is restricted to areas where *kharif* rainfall is less or un-irrigated areas.

Chickpea, sorghum and wheat are dominant *rabi* crops in soybean districts of Maharashtra. Sorghum (In 9 districts) and chickpea (11 districts) are cultivated as *rabi* crops. Soybean growing districts of Rajasthan had wheat as *rabi* crop under irrigated conditions. In case of Chhattisgarh, chickpea is the dominant crop in soybean growing districts. Soybean growing districts of Andhra Pradesh, Gujarat and Karnataka have chickpea, sorghum or maize as major *rabi* crop.

From the data available on area and production statistics for soybean, wheat, chickpea and sorghum for the dominant districts, it is not possible absolutely to differentiate the cropping system, but possible systems such as soybean-chickpea, soybean-wheat, soybean-sorghum could be identified. Sub district level inventory is essential to characterize these systems in an efficient manner. Irrigation provision and *kharif* rainfall also influence the *rabi* crop choices.

1.5 Resource characterization and enhancement strategy

In order to plan for improvements in the productivity, it is necessary to understand the crop growing environments across districts. The crop growing environments in terms of soil resources and constraints such as degradation were assessed to identify the opportunities for enhancing the productivity in these dominant soybean districts. Soil resource maps of each state were used for this analysis (Source: NBSSLUP). Soybean cultivated area productivity information was overlaid on these resource maps (soil type, depth and degradation and visual interpretation was made to prioritize the districts for productivity enhancement.

1.5.1 Prioritization of districts

In order to improve the total production in the country, it is necessary to address the constraints for crop growth in 74 districts located in 7 states. The type of interventions planned for these districts could vary from seed replacement, fertilizer management, improving natural resource management systems, etc. Since the variability in the productivity is high, it is also necessary to prioritize these districts so that productivity can be enhanced in short period of period of time. The methodology followed for prioritizing districts includes taking State as a unit, Identification of districts under the Class-1 (low productivity), selection of a reference district with similar crop growing environments and proximity to the target districts. These reference districts could be used as fields for demonstration and also in educating the farmers from target districts on management practices being followed in reference districts through facilitation of farmer to farmer interaction, the above process could be repeated for each state and then for Class -2 districts as well.

In order to improve the productivity in Class-3 districts (high productivity), new high yielding cultivars need to be promoted along with better management of natural resources and by addressing pest and disease management problems and improving the cropping systems. The list of target districts and reference districts (which could be used for educating the farmers through farmer to farmer interaction) in each state are given in Table 4.

Table 4: Priority districts for transfer of management technologies across states

State: Madhya Pradesh		
Priority	**Target district**	**Reference district**
1	Barwani	Jhabua
2	Chhatarpur	Tikamgarh
	Shivpuri	Gwalior
	Shajapur	Rajgarh
	Rewa	Narsimhapur
	Seoni	Chhindwara
	Hoshangabad	Chhindwara
	Satna	Chhindwara
	Sidhi	Chhindwara
	West nimar (khargone)	Indore
	East nimar (khandwa)	Dewas
	Jhabua	Dhar
	Mandsaur	Ratlam
	Neemach	Ratlam
3	Sheopur	Gwalior
	Raisen	Narsimhapur
State: Maharashtra		
Priority	Target district	Reference district
2	Buldana	Akola
	Amravati	Akola
	Wardha	Nagpur
	Chandrapur	Nagpur
	Yavatmal	Nagpur
	Nanded	Hingoli
	Osmanabad	Latur
	Bid	Jalna

3	Ahmadnagar	Satara
	Nashik	Satara
	Akola	Jalgaon
	Nandurbar	Jalgaon
	Dhule	Jalgaon
	Nashik	Jalgaon
State: Karnataka		
1	Bidar	
2	Belgaum	Haveri

The targets for productivity enhancement could be planned in different ways such as bridging the yield gap between farmer fields and multi location trials, etc. In this exercise it has been targeted to achieve the production contribution on par with area contribution at national level for each district. The possible gain from this approach could be about 8% increase in the total production. By combining the above two approaches, it is possible to increase production by 20% easily from these districts itself.

2.0 Technological Interventions for Bridging Yield Gaps

Soybean (*Glycine max*), an oilseed legume, has emerged as the third important oilseed crop in India as evidenced by area, production and productivity during the past 40 years. Initially, soybean in India was recommended to meet shortage of pulses and was introduced in Madhya Pradesh and Uttar Pradesh in *kharif* fallow lands. With high imports of edible oil during 1980s, soybean was found to be more remunerative for different categories of farmers. With its promising returns and acceptance by farmers, the crop is cultivated in diverse agro-ecologies i.e. rainfall regions from 500 mm to 1500 mm and soil types viz. shallow to very deep black soils (Entisols, Inceptisols, Vertisols) and red soils (Entisols and Alfisols) and with cropping systems such as soybean-wheat, soybean-chickpea, soybean-maize, soybean-sorghum, etc. The crop has substituted *kharif* cereals including rice in Madhya Pradesh, and sorghum and pearlmillet in Maharashtra. The by–products of soybean (oilcake and oil meal) are either being exported or consumed as feed for livestock (Ramesh Chand, 2007).

In India, the nutritional security of the households is an important issue which has to be met through low cost and high quality foods. In view of the high nutritional advantage of soybean, through value addition such as soymilk, tofu, soyflour, etc. there is a vast scope to supplement to nutritional demand in rural and urban household diet and contribute to alleviation of malnutrition of majority, particularly child malnutrition. To meet the demand for more crop appropriate interventions can be based on assessing constraints in achieving higher productivity.

2.1 Production constraints

Aberrant weather (drought and heavy rains)

Droughts as well as excess rainfall are becoming equally important weather aberrations in soybean cultivating states particularly in Madhya Pradesh, Maharashtra, Gujarat and Rajasthan. Every year, soybean suffers from drought of variable intensity. Midseason drought, which affects the crop at critical stages and reduces the productivity, is common in soybean growing areas. Change in south-west monsoon pattern, mainly onset, duration, intensity, and distribution of rainfall in the recent past has led to aberrant weather situations such as heavy rains leading to water logging during 2013 *kharif* season when soybean crop was extensively damaged. The 2014 *kharif* crop experienced late onset of monsoon as well as deficient rainfall.

Soil related constraints

Major soil types under soybean cultivation are clayey and loamy soils. Soils in Madhya Pradesh and Maharashtra are deep clayey black soils and shallow black soils. These soils with swell-shrink characteristics are prone to severe erosion, improper drainage, slow infiltration rate that impact on root distribution, nutrient and water uptake capacity, and aeration of roots and root respiration of crop. Multiple nutrient deficiencies and low organic carbon are very common in soybean growing areas.

Multi-nutrient deficiencies

Soybean growing soils are poor in fertility and incapable of providing adequate nutrition to the crop for realizing its yield potential. Most of the soils are low in soil organic carbon especially in the states of Madhya Pradesh, Maharashtra, Gujarat, Rajasthan and Telangana. Many soils are deficient in sulphur, which is considered to be important nutrient for soybean. Emerging multi-nutrient deficiencies have become one of the important constraints in soybean production (Table 5). Site specific integrated balanced nutrient management practices are not being practiced. Potassium, sulphur and zinc applications need to be included in fertilizer recommendations given to farmers.

Quality seed

Availability of quality seed is an important factor for improving soybean production in India. Timely sowing and good management of the crop are equally important for obtaining higher soybean productivity. Non-availability of good quality seed in 2014 *kharif* was a clear indication of the magnitude of the problem and research and extension departments must have clear contingency plans for various inputs required. During 2013 *kharif*, soybean

Table 5: Emerging nutrient deficiencies in soils of soybean growing regions of India

Limiting Nutrient (Low/Deficient)	Location/State
Macronutrients	
Nitrogen	Adilabad (Telangana); Bhopal, Rewa, Jabalpur, Sehore, Indore, Dewas, Vidisha (Madhya Pradesh); Parbhani, Akola (Maharashtra); Kota, Bundi (Rajasthan)
Phosphorus	Adilabad (Telangana); Bhopal, Rewa, Jabalpur, Sehore, Indore, Dewas, Vidisha (Madhya Pradesh); Akola (Maharashtra); Kota, Bundi (Rajasthan)
Potassium	Akola (Maharashtra); Bundi (Rajasthan)
Secondary nutrients	
Calcium	Parbhani (Maharashtra)
Magnesium	Parbhani (Maharashtra)
Sulphur	Adilabad (Telangana); Bhopal, Rewa, Jabalpur, Sehore, Indore, Dewas, Vidisha (Madhya Pradesh); Akola (Maharashtra); Kota, Bundi (Rajasthan)
Micronutrients	
Zinc	Adilabad (Telangana); Bhopal, Rewa, Jabalpur, Sehore, Indore, Dewas, Vidisha (Madhya Pradesh); Parbhani, Akola (Maharashtra); Kota, Bundi (Rajasthan)
Boron	Adilabad (Telangana); Dewas (Madhya Pradesh); Parbhani, Akola (Maharashtra)

Source: (Srinivasarao and Vittal, 2007)

crop failed due to excess rains in many regions of the country which also contributed to insufficient seed availability in 2014 *kharif*. Therefore, region-specific, high yielding varieties tolerant to various abiotic and biotic stresses need to be developed and made available to farmers. The seeds of about 30 improved varieties are in the seed chain. Further, only few verities are popular with the farmers. Seed longevity is another major problem in soybean due to which the storage and availability of the seed in the ensuing season is a major constraint.

Biotic stresses

Root and foliar diseases, blue beetle, green semi lopper, girdle beetle, defoliators and stem borers, etc,. are the major insect-pests and diseases affecting soybean production and productivity. Whitegrub (*Holotrichia consanguinea*), spotted bug (*Eysarcoris ventralis*) and stink bug (*Plautia fimbriata*), were also reported to cause damage to soybean. The soybean crop is affected by sucking and biting type of insects (blue beetle) which feed on tender leaves at early stage i.e., 15-20 days after sowing. *Myrothecium* leaf spot, *Alternaria* leaf spot, rust, collar rot, pod and stem blight, anthracnose and pod blight, bacterial pustule, yellow mosaic, etc, are some of important diseases in soybean.

Market linkages and inadequate awareness

Apart from above some other factors known to influence production and productivity of soybean such as, low adoption of new technologies, small land holdings, lack of machinery for land treatment or limited use of farm machines, limited market linkages and infrastructure, inadequate awareness about role of soybean in human health and nutrition, and labour shortage for farm operations.

2.2 Yield gap analysis

The yield gap analysis is done considering potential yield, best farmers yield and average farmers yield (Table 6). Yield gap-I is the difference between potential yield and best farmers yield, whereas yield gap-II is the difference between potential yield and average famers yield. Among the soybean growing districts, Rewa, Barwani districts of Madhya Pradesh and Nanded, Wardha districts of Maharashtra had higher yield gaps of both classes.

Table 6: Yield gap (%) in soybean growing districts of Madhya Pradesh and Maharashtra

Sl. No.	District	Yield Gap-I (%)	Yield Gap-II (%)
	Madhya Pradesh		
1.	Rewa	80.0	88.0
2.	Guna	70.0	74.0
3.	Barwani	60.0	76.0
4.	Satna	56.0	68.0
5.	Gwalior	52.0	64.0
6.	Shajapur	50.0	64.0
7.	Khandwa	48.0	68.0
8.	Jhabua	48.0	52.0
9.	Tikamgarh	48.0	64.0
10.	Sehore	48.0	64.0
11.	Vidisha	44.0	64.0
12.	Rajgarh	44.0	64.0
13.	Raisen	44.0	64.0
14.	Hoshangabad	40.0	68.0
15.	Khargaon	36.0	56.0
16.	Sagar	36.0	56.0
17.	Chhatarpur	32.0	44.0
18.	Harda	32.0	56.0
19.	Seoni	28.0	48.0
20.	Burhanpur	20.0	52.0

Sl. No.	District	Yield Gap-I (%)	Yield Gap-II (%)
21.	Damoh	20.0	64.0
22.	Indore	20.0	46.0
23.	Narsimpur	20.0	36.0
24.	Chindwara	14.0	28.0
25.	Shivpuri	12.0	40.0
26.	Sheopur Kala	12.0	36.0
27.	Bhopal	12.0	44.0
28.	Dewas	0.0	36.0
29.	Neemach	-28.0*	48.0
30.	Mandsaur	-12.0*	32.0
31.	Ashok Nagar	-8.0*	20.0
32.	Betul	-20.0*	20.0
33.	Ratlam	-12.0*	44.0
34.	Ujjain	-12.0*	42.0
35.	Dhar	-12.0*	36.0
	Maharashtra		
36.	Nanded	64.4	60.0
37.	Nadurbar	44.4	55.6
38.	Sangli	44.4	71.6
39.	Wardha	44.4	70.7
40.	Parbhani	40.0	45.6
41.	Osmanabad (Tuljapur)	22.2	36.6
42.	Kolhapur	17.8	40.0
43.	Ahmednagar	13.3	20.0
44.	Jalgaon	11.1	20.0
45.	Satara	0.0	22.2

2.3 Technology interventions

Doable technologies are likely to address the production related constraints for bridging the yield gaps in soybean cultivated areas. Technologies related to soil fertility improvement, adoption of new varieties, soybean based cropping system, location specific and efficient *in-situ* and *ex-situ* rainwater management, etc. are available to augment production and productivity of soybean in various states.

Land treatment to cope with seasonal drought and excess water

Impact of various doable rainfed technologies that enhanced the productivity of soybean across rainfall and soil types are presented in Table 3. Management of water within field is a major task to improve soil water status and to extend the period of water availability to crop. Ideal land preparation for cultivation of crops minimizes soil erosion, checks loss of fertile surface soil from field, extends water retention time, enhances safe disposal of impounded water, etc. Land configuration includes mainly ridge and furrow system, field bunding/land leveling, sowing across slope, raised and sunken bed system, broad bed furrow (BBF), vegetative barriers, etc.

In-situ moisture conservation practices like opening of conservation furrows, crop residue mulching, ridge and furrow system, sowing across the slope, etc. enhanced the moisture conservation, rainwater use efficiency and soybean yield (Table 7). Cultivation of soybean

Table 7: Impact of various land treatments on soybean productivity and economics

Location, rainfall, soil type	Years	Treatment	Yield (kg/ha)	Control yield (kg/ha)	B:C ratio
Indore, Madhya Pradesh (Rainfall: 954 mm; Soil type: shallow to deep black soils)	5	Polythene mulching	2506	1944	2.47
		Gliricidia mulch @ 2 t/ha	2424		2.50
		Weed biomass mulch @ 5t/ha	2410		2.55
		Straw mulch @ 4 t/ha	2361		2.43
	6	BBF at 45cm	1647	1159	2.77
		Ridge and furrows 60cm	1644		2.44
		Ridge and furrows 45cm	1573		2.03
Parbhani, Maharashtra (Rainfall: 607-940mm; Soil type: (Deep black soils)	5	Opening of furrow after every 4 rows + RDF (soybean-pigeonpea)	1330	699	6.46
		Flat bed with RDF	1134		5.65
	5	Soybean+ pigeonpea	1068	-	2.89
		Conservation furrow after 6 rows (soybean+ pigeonpea)	1569	1121	2.95
		Conservation furrow after 12 rows of soybean	1507		2.78
		Conservation furrow after 4 rows of soybean	1441		2.33
	4	Opening of furrow after four rows of soybean	2340	1942	-

Rewa, Madhya Pradesh (Rainfall: 700mm; Soil type: medium deep to deep black soils)	4	JS 93-05	1353	-	5.17
		JS 335	1316	-	5.33
	3	Soybean JS 93-05 + pigeonpea (Asha) in 4:2	1592	-	5.61

Source : Annual Reports, AICRPDA.

on a flat bed system at 45cm row spacing in Malwa region of Madhya Pradesh resulted in moisture stress situation or water-logging in black soils leading to poor performance and low productivity of soybean crop. To overcome this, broad bed furrow (BBF) of 105 cm was made by light bund making implement or modified *Desi* plough. Soybean was sown on bed with 25 per cent reduced seed rate i.e., about 55-60 kg/ha resulting in higher productivity of 1647 kg/ha.

High yielding cultivars

Varieties resistant to pod shattering, seed longevity, tolerance to water logging and high temperature need to be developed. Although 3752 accessions of soybean are being maintained at Directorate of Soybean Research, Indore only 93 varieties have been developed so far for different agro-climatic zones of the country out of which about 30 are in seed chain. Further, only few varieties are popular with the farmers. The on- station trials at AICRPDA centre, Indore indicated that, with improved varieties, higher soybean productivity can be achieved up to 2t ha^{-1}, while soybean yield attained in farmers fields was up to 1.8 t ha^{-1} (Table. 8).

Table 8: Soybean yield attained on farmer's fields, Nignoti village, Indore district, M.P

Soybean grain yield (kg/ha)-Indore							
Variety	**2008**	**2009**	**2010**	**2011**	**2012**	**Mean**	**%Yield increase over local**
Local	1683	1450	956	1270	1151	1302	
JS 93-05	2200	2054	1240	1820	1458	1754	25.8
JS 95-60	2100	2224	1312	-	1631	1817	10.4
JS 335	1800	-	1198	1700	1619	1579	17.5

Source: Annual Report, ORP Centre, Indore

Remunerative cropping systems

Adopting suitable cropping systems and combination of compatible crops with acceptable row proportion which bring in higher benefits are major strategies to upgrade soybean production and productivity. Intercropping of soybean with different crops such as pigeonpea, cotton, etc practiced in different parts of soybean growing areas yielded better with satisfactory returns.

At Indore, Akola and Parbhani, intercropping of three rows of soybean (JS-93-05/JS-335) and one row of pigeonpea (Asha) i.e., in Bundelkhand region of Madhya Pradesh gave soybean seed yield of 985 kg/ha and pigeonpea yield of 2365 kg/ha. This system gave overall net returns of Rs. 38100/ha with a B:C ratio of 2.71 as against 1.62 with sole soybean.

Soil based technologies

Mismanagement of nutrient application in soybean has resulted in declining soil fertility. Application of 50% RDN (15 kg/ha) through green leaves of gliricidia + 50% through urea (15 kg/ha) + 75 kg P_2O_5 + 25 kg K_2O/ha along with seed treatment with biofertilizers (*Rhizobium* and PSB @ 25 g/kg seed) is recommended as improved technology. The fresh loppings of gliricidia are applied manually between the rows of soybean. The yield of soybean was better with INM (1760 g/ha) as compared to RDF i.e., 30: 75: 00 (1618 kg/ha) with 13 % higher returns. This practice helped to improve the fertility status of soil, especially N and K status of soil. Gliricidia loppings improved soil physical and biological properties besides adding 21 kg N.

Basal application of $ZnSO_4$ at 25 kg/ha along with recommended dose of fertilizer and/or two doses of Mo (foliar) at 0.1 % or soil application of ammonium molybdate at 0.5 kg/ha had a positive impact in soils with respect to sulphur, zinc and molybdenum deficiencies of Indore region. The beneficial nutrient management options for soybean productivity are given in Table 9.

Sulphur and micronutrient

Sulphur is an important secondary nutrient recommended in oilseeds. Farmers in most of the soybean cultivated areas do not apply sulphur. Continuous monocropping of soybean in Malwa region of Madhya Pradesh has lead to severe deficiency of sulphur resulting in low yields and net returns. Hence, it is recommended to apply sulphur @ 30 kg/ha in rows by band placement through agriculture grade gypsum @ 200 kg/ha at the time of sowing along with 30 kg N/ha and 60 kg P_2O_5/ha. Application of sulphur along with recommended dose of N and P increased soybean seed yield by 66% and net income by 124% with B:C ratio of 2.30 compared to farmers practice (no sulphur application, 729 kg/ha soybean seed yield and Rs. 3129/ha net income) (Srinivasarao *et al*., 2014).

Table 9: Beneficial nutrient management options for soybean productivity

Years	Treatment	Mean soybean grain yield (kg/ha)	Control yield (kg/ha)	B:C ratio
Akola, Maharashtra				
2	100% RDF + 25 kg/ha K + Biofertilizers	1426	1099	-
	100% RDF + 25 kg/ha K	1351		-
Indore, Madhya Pradesh				
4	RDF + 20 kg Sulphur through gypsum	1114	714 (Farmers practice *i.e.,* 50kg DAP/ha)	2.13
	RDF i.e. 30 kg N + 60 kg P_2O_5 / ha	1085		2.10
	50% RDF + 4 t FYM/ha	1049		2.03
7	100% RDF in 4:4 (maize+ soybean)	1973 (SEY)	1300	1.65
	50% RDF	1810		1.83
5	RDF +30 kg Sulphur/ha	1209	729 (Farmers practice)	2.30
	RDF(30kg N+60 kg P_2O_5 / ha)	1087		2.15
6	FYM 6t/ha + N20 P13	2697	1539 (N0P0)	3.67
	N60 P35	2515		3.77
	FYM 6t/ha	2441		3.36
	N40 P26	2361		3.57
3	S @ 60 kg/ha to soybean followed by chickpea in *rabi*	2343	1721	4.02
	S @ 40 kg/ha to soybean- chickpea	2107		3.47
2	RDF of NPKS + Mo 0.5 kg/ha	2450	1331 (control) 1731 (farmers practice)	4.07
	RDF of NPKS +25 kg ($ZnSO_4$)	2471		4.00
	RDF of NPKS + Mo 0.1% (ammonium molybdate) two sprays	2376		3.94
	Recommended dose of NPKS + Zn Foliar Application	2209		3.72
Rewa, Madhya Pradesh				
5	$N_{20}P_{40}$ Zn_{10}	2032	1510	2.83
2	50% N (organic) + 50% N (inorganic)	1827	-	5.09
	100% N (organic) through 8t FYM/ha	1545		4.99
	100% N (inorganic) through	1610		4.49

Source: AICRPDA centres : Akola Indore and Rewa

Biofertilizers

Use of biofertilizers in soybean is proven to be advantageous as this is a legume crop known to fix atmospheric nitrogen. Use of *Rhizobium japonicum* in soybean enhanced its growth and also reduced fertilizer nitrogen requirement. Biofertilizers, along with balanced nutrition yielded better i.e., application of 100% RDF+ 25 kg/ha K+ biofertilizer recorded significantly higher soybean grain yield (1426 kg/ha), straw yield (3068 kg/ha) and RWUE of 3.64 kg/ha-mm compared to control (1099, 2664 and 2.80 kg/ha-mm).

Soil amendments

Application of tank silt is an age old method practiced by farmers in villages. In the recent past, use of tank silt in agriculture as a soil amendment is being widely practiced to enhance water retention in the soil which helps to cope with mid-season droughts. However, care needs to be taken before applying to ensure that the tank silt is not saline. Tank silt should not be applied to heavy clay soils and highly recommended for shallow black soils and degraded lands.

Foliar sprays for mid-season droughts

Foliar application of nutrients (mainly inorganic fertilizers) is a widespread practice followed by farmers all over India as nutrient supplementation during critical stages and as drought mitigation strategy. Fertilizers such as KNO_3, thiourea, etc. proved to be successful in mitigating mid-season droughts. Foliar spray of nutrient solutions to plant canopy is effective as most of the sprayed nutrient is utilized by plant for its growth and development.

At Indore, foliar spray of VAM C 50% SL @ 375 ml/ha recorded significantly higher seed yield (2365 kg/ha), NMR (Rs. 56452/ha) and BC ratio of 4.89 followed by polythene mulching as compared to the control (Table 10).

Plant protection

Protection of crop from pests, diseases and weeds is an important management activity which has a considerable influence on plant growth and yield. Control of weeds in soybean by farmers is usually done manually. Even this poses problems of high wage and shortage of labour. Weeding in black soils is difficult due to continuous rains and non-workability of soils and weeds compete intensely with crop. Early post emergence soil application of Imazethapyr 750 ml/ha at 16-18 DAS of soybean efficiently controls both grasses and broad leaf weeds in Malwa region of Madhya Pradesh. This has proven to be very effective and increased soybean yield by 49%.

Table 10: Effects of foliar sprays on soybean yield

Treatments	Soybean (JS-95-60)		
	Seed yield (kg/ha)	NMR (Rs/ha)	BC ratio
Spray of VAM-C 50 % SL @ 3.75 l/ha	2365	56452	4.89
Spray of potassium Solution @ 2%	2148	49944	4.44
Spray of thiourea @ 250 g/ha	2098	48437	4.34
Polythene mulch	2331	55421	4.82
Control	1817	40024	3.76
Mean	2152	50056	4.45
CD (5%)	Main (42.5), Sub (30.3) and Int. M X S (60.7)	Main (923), Sub (860) and Int. M X S (1720)	Main (0.07), Sub (0.06) and Int. M X S (0.12)

Source: Annual Report, AICRPDA, 2012-13

Certain varieties were developed with plant protecting traits against major pests and diseases of soybean (Table 11). Varieties such as NRC-7 and NRC-12 are the best varieties resistant to almost all insect pests attacking soybean crop viz., girdle beetle, defoliators, blue beetle, tobacco caterpillar, Bihar hairy caterpillar, stem fly, etc.

Table 11: Varieties with plant protecting characters

Character	Resistant/tolerant varieties
Disease	
Collar rot or sclerotial blight (*Sclerotium rolfsii*)	NRC 37, PS 1225
Rust (*Phakospora pachyrhizi*)	Ankur, PK 1024, PK 1029, JS 80-21, Indira Soya 9, MAUS 61-2 or early maturing varieties
Myrothecium leaf spot (*Myrothecium roridum*)	Bragg, JS 71-05, JS 335, MACS 13, MACS 124, MAUS 47, NRC 7, PK 564
Yellow mosaic	PK 416, PK 472, PK 1024, PK 1029, PK 1042, SL 525, SL 688, PS 1347, Pusa 9712, JS 97-52
Mung bean yellow mosaic virus	
Insect pests	
Girdle beetle (*Obereopsis brevis* Swedenbord)	NRC 12, NRC 7, Bragg, Indira Soya 9, JS 93-05, RAUS 5, PK 262, Punjab 1
Defoliators	NRC 12, NRC 7, JS 80-21, JS 90-41, MACS 450, MAUS 47, Monetta, RAUS 5, Pusa 16, JS 95-60
Blue beetle (*Cneorane* sp.)	
Tobacco caterpillar (*Spodoptera litura* Fabricius)	
Bihar hairy caterpillar (*Spilosoma obliqua* Walker)	
Stem fly	JS 335, NRC 12, NRC 7, MACS 124, JS 90-41, Indira Soya 9, JS 93-05, MACS 124, MAUS 47, PS 564, JS 95-60

Source: Directorate of Soybean Research, Indore

2.4 Best Management Practices (BMP's)

Three major soybean producing states (M.P., Maharashtra and Rajasthan) contribute about 96% of total soybean production in the country. Gujarat and Telangana contribute lesser share, but among them the productivity in Gujarat is low (about 794 kg/ha) while two districts of Telangana (Adilabad and Nizamabad) showed high productivity levels of about 1368 kg/ha). Several technologies are available for improving soybean productivity in India, but they are not implemented appropriately. Under rainfed conditions, better seed available now, fertilizer, water and other management practices have potential to increase the soybean yields by up to 130% (Table-12).

Table 12: Percent share of different agricultural inputs in increasing the yield over traditional systems in rainfed conditions

Practice	Increase in yield over traditional system (%)
Seed	40
Fertilizer	50
Seed + fertilizer	95
Seed + fertilizer + water management	130

(Source: AICRPDA centres)

To bridge yield gaps in soybean best available management practices i.e rainfall/crop/nutrient management, contingency measures to cope with weather aberrations, farm mechanization and plant protection are depicted in (Tables 13 and 14).

Table 13: Suggested Best Management Practices (BMPs) for improving soybean productivity in Madhya Pradesh State

Current Practice	Suggested BMPs
Rainwater Management: *In-situ*: Intercultural operation with *doura*, Soil mulching and weed control with *doura*. *Ex-situ*: Need based irrigation by lift irrigation, Protective irrigation by lift irrigation from wells/tube wells and tanks. *Excess rainfall:* Ridge & furrow sowing, Use drainage channel Draining of excess water.	**Rainwater Management:** *In-situ*: BBF or ridge sowing, if probability of gaps in rains. Intercultural operation with *doura* for conserving the moisture followed by uprooting the intra row weeds manually. *Ex-situ*: Create water harvesting structures with silpaulin lining Store water in the tank and irrigate the crop, if needed, by sprinkler/or drip irrigation system. Apply need based irrigation from open well or tube wells if available. *Excess rainfall: BBF, Ridge and furrow system,* Immediate provision for drainage of water. Safely drain the water by channels and collect the water in farm pond etc.

Current Practice	Suggested BMPs
Crop Management: Sowing: High seed rate i.e. 100-120 kg/ha are used. Spacing: Inter row spacing: 30 cm, a few farmers follow line sowing with 22 cm inter row spacing. Varieties: JS 95-60, JS 97-52,JS 93-05, JS 335. (60% area under broad casting and 40% area under line sowing) Intercropping system: Intercropping of 2-3 crops (maize, sorghum, cotton). Weed management: Intercultural operation with *doura* (small blade harrow), spraying of Imazethapyr 10% SC@ 75 g ai/ha by 75-80 % farmers with tank mixing of Triazophos insecticide.	**Crop Management:** Sowing: Seed rate should be 80 kg/ha. Spacing: Inter row spacing should be kept 40-45 cm to facilitate interculture operation. Varieties : JS 95-60, JS 20-34, JS 20-35, JS 335, JS 71-05, JS 97-52, JS 20-29, JS 80-21, JS 94-60, JS 93-05, RVS 2001-04. (Should be line sown with 40 cm inter row spacing). Intercropping system: Intercropping of soybean with other crops choosing high yielding cultivars of all crops. Weed management: *Doura/Kulpa* between rows with bullock drawn implement or by tractor (narrow tyre) drawn cultivator with adjusted tines. Early post emergence spraying of Imazethapyr 10% SC@ 75 g ai/ha or Kloben + Targa super without mixing any insecticide or hand weeding with hand operated hoe. Do not depend only on one weedicide. Other weedicides are Chlorimuron ethyl 9 g ai + Fenoxaprop-p-ethyl 100 g/ha sprayer with flat fan nozzle or Pendimethalin 30 EC @ 1 kg a.i./ha. as pre-emergence followed by interculture operation between rows. Prefer use of blade harrow for moisture conservation and to control weeds.
Contingency Crop Planning: Delayed onset of monsoon: Not aware of short duration varieties; Early / midseason / terminal drought: Farmers are not irrigating the crop as they presume that crop will wither/get dry, few farmers give protective irrigation by flood method particularly at terminal stage drought, hand hoeing, spraying of Lihocin at flowering. Weather aberrations: Excess rainfall: No proper way to drain excess water.	**Contingency Crop Planning:** Delayed onset of monsoon: Select extra early maturing varieties *viz.,* JS 95-60, JS 93-05, JS 20-29, JS 20-34; increase the seed rate by 25% and reduce the inter row spacing to 30 cm; sowing with BBF seed cum fertilizer drill; seed dressing with Thiram + Carbendazim in equal ratio @ 3g/kg seed followed by Thiamethoxam @1g/kg seed and bacterial culture @ 10g/kg seed, respectively. Early season drought: Frequent intercultural operation must be done with *doura* (small blade harrow), avoid post emergence herbicide spray; gap fill with improved seed if the plant population is 60%, spray of 2% solution of MOP during dry spell, green leaf mulch subabul/gliricidia, intercultural operation must be done with *doura* (small blade harrow). Midseason drought: Spraying of thiourea @ 250g/ha or VAM-C @ 375 ml/ha or 2% KCl solution, spray Quinalphos @2 ml /l water to control girdle beetle, uproot unwanted plants and use as biomass mulch, give protective irrigation. Terminal drought: Irrigate the crop immediately from water source, spraying of thiourea @ 250 g/ha or VAM-C @ 375 ml/ha or 2% KCl solution, supplemental irrigation, harvest at physiological maturity. Excess rainfall: Safely drain the water by channels and collect in WHT.

Current Practice	Suggested BMPs
Nutrient Management: The farmers currently apply different doses of DAP to soybean at the time of field preparation either with seed or broadcasting. Viz., 20-25 kg, 50-60 kg, 80 kg or 100 kg DAP, some of the farmers do not apply any fertilizer, imbalanced fertilization, no practice of organic manure/ bio fertilizer application, nutrient application through SSP+ muriate of potash. Sulphur and micronutrient application: Not in practice Foliar spray: Not in practice.	**Nutrient Management:** Incorporation of FYM/Compost @ 4 t/ha in soil after every 2 years, application of 20:60:20 kg NPK/ha as basal dose, application of PSB @ 10 kg/ha. Seed dressing with *Rhizobium* culture. S and micronutrient application: application of sulphur @ 30 kg/ha through gypsum should be done, broadcasting and incorporation of 25 kg Zinc sulphate at the time of field preparation in alternate years. Foliar spray: application of $ZnSO_4$ @ 0.5% at 30 and 45 DAS, if basal application is not done.
Farm Mechanization: Maximum sowing through bullock drawn *tifan* and some farmers sow the seed by tractor drawn seed drill, sowing by bullock drawn *dufan, u*se tractor drawn implements for field preparation, sowing, harvesting; use of reversible mould board plough, seed drill with inter row spacing 22cm.	**Farm Mechanization:** Seed cum fertilizer BBF seed drill be used, intercultural operations with tractor drawn cultivator after tynes adjustment and using narrow tyres; harvesting by reaper/combine harvester; seed cum fertilizer drill with inter row spacing 40 cm.
Plant Protection: Pests: Spraying of Quinalphos insecticide with low volume of solution, phorate granules application @ 10 kg/ha. Diseases: New and improved resistant varieties not in practice.	**Plant Protection:** Pests: Need based application of Quinalphos/ Triazophos/ Chlorpyriphos @2 ml/lit water. Diseases: Seed treatment with fungicide, growing of new resistant varieties such as JS 20-29, JS 20-34; use Carbendazim spray to control brown spot disease.

Source: AICRPDA centres, Indore and Rewa

Table 14: BMPs for bridging yield gaps in Maharashtra

Current Practices	Suggested BMPs
Rainwater Management: *In-situ*: no specific practices are followed *Ex-situ* : No such practice currently Excess rainfall: Through drains	**Rainwater Management:** *In-situ* : BBF or Ridge furrow planting or conservation furrow; Delayed onset of monsoon- Early maturing varieties – JS 95 60, JS 93 05, MAUS 47. *Ex-situ*: Narrow row spacing and increased plant population (25%) Early/midseason/terminal drought: Protective irrigation Excess rainfall: BBF or Ridge furrow planting or conservation furrow

Current Practices	Suggested BMPs
Crop Management: Sowing: High seed rate i.e. 100-120 kg/ha are used. Spacing: Inter row spacing: 30 cm. Varieties: JS 335, JS 93-05, MAUS 81, NRC 37 Intercropping system: Intercropping of 2-3 crops (maize, sorghum, cotton). Soybean +pigeonpea Weed management: manual, interculture and pre-emergence herbicides i.e. Pendimethalin. Diseases: Seed treatment with Carbendazim + Thiram for seed and seedling diseases.	**Crop Management:** Sowing: Seed rate should be 80 kg/ha. Spacing: Inter row spacing should be kept 40-45 cm to facilitate the inter culture operation. Varieties: NRC 86, NRC 77 JS 20-29, JS 20-34, Phule Kalyani, MAUS 158, MAUS 162, MACS 1188, JS 97-52, RKS 18. Intercropping system: Soybean + maize/sorghum under irrigated conditions and soybean + pigeonpea for rainfed conditions Weed management: Post emergence herbicides- Imazethapyr@ 100g ai/ha or Quizalofop ethyl @ 50 g ai/ha.
Contingency Crop Plan: Delayed onset of monsoon: No specific practices are followed. Early / midseason / terminal drought: No specific practices are followed.	**Contingency Crop Plan:** Delayed onset of monsoon: Early maturing varieties – JS 95 60, JS 93 05, MAUS 47; Narrow row spacing and increased plant population (25%) Early season drought: Protective irrigation Midseason drought: Protective irrigation Terminal drought: Protective irrigation
Nutrient Management: INM: Application of only NPK @ 20:60:20 kg/ha is being followed by farmers Sulphur and micronutrient application: Not in practice Foliar spray: Not in practice	**Nutrient Management:** INM: 50%RDF + FYM @ 5 t/ha or poultry manure @ 2.5 t/ha S and micronutrient application: S@ 20 kg/ha Foliar spray: Spray of 0.5% $ZnSO_4$ if needed 30-35 days after sowing
Farm Mechanization: Only sowing and harvesting operations	**Farm Mechanization:** BBF seed cum fertilizer drill
Plant Protection: Pests: For defoliators: Spray of Triazophos 40 EC @ 800 ml/ha or Lembda cyhalothrin 5 EC @ 300 ml/ha; For girdle beetle: Spray of Triazophos 40 EC @ 800 ml/ha or Profenophos 50 EC @ 500 ml/ha. Spray volume used ~300 l/ha. Diseases: Seed treatment with Carbendazim + Thiram for seed and seedling diseases.	**Plant Protection:** Pests: Regular monitoring of crop, removal of egg masses of S. litura followed by spray of microbial insecticides viz. Bt or B. Bassiana or NPV at early insect stages. Need based application of insecticides specific to insects. For defoliators- Spray of Rynaxypyr 20 SC @ 100 ml/ha or Indoxacarb 40 SC @ 500 ml/ha. For girdle beetle- Spray of Thiacloprid 21.7 SC @ 650 ml/ha. Spray volume recommended 500 l/ha. Diseases: Seed treatment with ready mix of Thiram and Carboxin or Trichoderma viride for seed and seedling diseases. Spray of Carbendazim or Thiophanate methyl (.05 %) for the management of foliar and pod diseases

(Source: AICRPDA centres, Akola and Parbhani)

2.5 Up-scaling strategies

Target and reference district identification

Productivity of soybean in soybean growing districts was found to range from less than 500 kg/ha to more than 2300 kg/ha under diverse agro-ecological situations and management practices. Districts were classified into three productivity classes (Class-I <500 kg/ha; Class-II 500-1000 kg/ha; Class-III >1000 kg/ha), Target and reference district identification and the productivity levels In Madhya Pradesh and Maharashtra states, defined soybean growing states, the target districts under 3 classes of soybean productivity for considered to identify (Table15) the nearest reference districts to achieve target deals of soybean. This is to enhance the productivity levels i.e., from last class-III to class-II and class-II to class-I for which best management practices have been identified to bridge the yield gaps.

A reference is the district higher soybean yields are achieved in a resource domain. A target district is the adjoining districts of reference in which the best management practices for higher soybean yield of reference district have to be disseminated in similar resource domains of reference district (Table-15).

Table 15: Prioritized districts for technological interventions to bridge soybean yield gap in Madhya Pradesh and Maharashtra states

Sl. No.	Target district	Target district yield (kg/ha)	Reference district	Reference district yield (kg/ha)
Madhya Pradesh				
Class-I (<500 kg/ha)				
1	Chhatarpur	489	Tikamgarh	1041
2	Barwani	359	Jhabua	721
Class-II (500-1000 kg/ha)				
3	Satna	546	Chhindwara	1661
4	Rewa	618	Narsimhapur	1792
5	Jhabua	721	Dhar	1376
6	Neemurch	941	Ratlam	1181
7	Mandsaur	1150	Ratlam	1181
8	Seoni	999	Chhindwara	1661
9	Rajgarh	971	Shajapur	1058
10	Hoshangabad	708	Chhindwara	1661
Class-III (>1000 kg/ha)				
11	Betul	1161	Harda	1359

Sl. No.	Target district	Target district yield (kg/ha)	Reference district	Reference district yield (kg/ha)
12	Ratlam	1181	Ujjain	1401
13	Raisen	917	Narsimhapur	1792
Maharashtra				
Class-II (500-1000 kg/ha)				
1	Beed	697	Jalna	1133
2	Yavatmal	705	Nagpur	935
3	Chandrapur	668	Nagpur	935
4	Nanded	911	Hingoli	1030
5	Wardha	755	Nagpur	935
6	Buldana	956	Akola	1020
7	Osmanabad	821	Latur	1102
8	Amravati	923	Akola	1020
Class-III (>1000 kg/ha)				
9	Akola	1020	Jalgaon	2029
10	Ahmadnagar	1144	Satara	1928
11	Dhule	1298	Jalgaon	2029
12	Nandurbar	1406	Jalgaon	2029
13	Nasik	1299	Satara	1928
14	Nasik	1299	Jalgaon	2029

Packaging technological options for cross district transfer

The technologies adopted in a reference district with high productivity can be transferred to a neighboring target district with similar agro-ecological settings but with low productivity. However, the practices / interventions from land preparations to post harvest operations have to be transferred as a technology package with viable options to enhance not only the soybean productivity and income but also to sustain the soybean based agro-enterprises with overall enhancement of the livelihoods of soybean farmers. Therefore, technology package option should be need based, viable and environmental friendly.

Master trainers

Some of the progressive farmers from the soybean growing districts who are achieving higher soybean productivity levels with efficient management of resources (bio-physical, inputs, capital, etc.) could be the master trainers for sensitizing, guiding and capacity building of the other soybean farmers. This mechanism can facilitate capacity building of large number of soybean farmers in the respective domains.

Farmer to farmer interaction

There is considerable yield gap (yield obtained in demonstration plot – yield obtained in farmers' fields) in Malwa Region of Madhya Pradesh. This necessitates interaction among field demonstration farmers and other farmers to understand the impact of technological interventions, quality seed and market mechanism.

Exposure visits

A continuous learning process regarding soybean production and related activities could happen by facilitating Exposure Visits of the farmers from the areas having low soybean productivity to the farmers fields with higher productivity levels, on-station experiments/ demonstrations by research stations or KVKs, showcasing improved management practices. The visits further facilitate organic linkages among the various stakeholders.

Cross centre visits

The visits to the centres like research stations of Directorate of Soybean, Rewa, Indore, centres of AICRPDA for soybean, SAUs, KVKs, ATMA, soybean seed farms, soybean processing units etc by not only the farmers but also the researchers and extension officials can provide ample opportunities by expanding knowledge base and further sharing with other stakeholders. In this regard, mandatory programmes by the research and extension agencies need to be developed and to be implemented on a regular basis.

Literature in local languages

The technical information on doable management practices in soybean production has to be published in local languages in the form of pamphlets, leaflets, brochures, etc for distribution for various stakeholders including farmers for popularization of the proven practices.

2.6 Convergence stratégies

The convergence of critical stakeholders related to various activities in enhancing the soybean productivity in the respective domains could be as follows:

Activity	Scheme / Programme	Implemented by	Convergence for
Primary and Secondary tillage	MGNREGA	Central / State Govts.	Leveling, bunding
In-situ moisture conservation practices	MGNREGA, Watershed Programmes, Community Land Development Programme, other land related programmes	Central / State Govts., Watershed programmes implemented by various agencies / organizations	BBF, Ridge and furrows system, inter-plot rainwater harvesting etc.

Activity	Scheme / Programme	Implemented by	Convergence for
Seed	RKVY, NFSM, NSP, Mega Seed Product	Central / State Govts., State Seed Development Corporation,	Quality seed of suitable soybean varieties
Fertilizers	RKVY, NFSM	Central Govt., Fertilizer Corporation	Suitable fertilizer grades, macro-nutrients and bio-fertilizers
Supplemental / Life saving irrigation from the harvested rainwater in farm ponds (Lined/ Unlined) with energy efficient lifting pumps and pressurized irrigation systems	MGNREGA, IWMP, NHM, Climate adaptation programmes, Balram and Laxman Talab Programmes / Scheme of MP, DLFM of Maharashtra State, Rural Development Programme, Watershed programmes implemented by various organizations	Central / State Govts., NABARD, International Projects	Farm ponds, percolation tanks, other water harvesting structures, lining material, anti-evaporation materials, lifting pumps, drip / sprinkler irrigation systems
Proper drainage	As above	As above	Draining excess water from the crop fields, strengthening the farm bunds, providing diversion channels, straightening the galleys etc.
Foliar sprays for balanced nutrition and to cope with mid-season and terminal drought	RKVY	Central/State programmes	Liquid fertilizers, KCl, KNO_3, VAM-C, Thiourea etc.
Value addition	As above	Central/state Govts., SOPA, other private organizations	For various products like oil, soy meal, cake etc.,
Marketing	State /Central Govts, SOPA	State, Central Govts., SOPA, soy farmers associations, village level soya marketing association/self help groups etc.,	For timely and remunerative marketing
Research	International, SAU for prioritized research	International institutes, ICAR institutes such as DSR, AICRPS like AICRP on soybean, AICRP on dryland agriculture etc, SAUs and private research	For developing doable technologies for higher productivity of soybean, the resource use efficiency, profitability quality of the produce, environmental quality

Activity	Scheme / Programme	Implemented by	Convergence for
Technology up-scaling	Various Central / State Govts., programmes, NARS (ICAR & SAU) extension programmes, FLDs, FFS etc.,	Central/state Govts., ICAR institutes/AICRPs, state line departments, sopa, input agencies, agro industries etc.,	For wider up-scaling of proven / doable technologies/ practices including mechanization in soybean
Capacity building	As above	As above	For enhancing the knowledge based primary (farmers) and secondary stake holders
Mechanization	Various Central / State Govt, Schemes	Central / State Govts., Agro Industries	Supply of improved bullock drawn / tractor drawn implements for various agricultural operations and also for establishing custom hiring centres.
Harvesting	Various Central / State Govt, Schemes	Central / State Govts., Agro Industries	Custom hiring centres, providing threshers
Seed storage	As above	Central / State Govts., Warehouse Corporations	Storing the seeds for marketing and also for next season.

3.0 Resource domains of major growing areas

Cropping systems of a region are decided, by and large, by a number of soil and climatic parameters, which determine overall agro-ecological setting for suitability of a crop or set of crops for cultivation. Soil information is a vital component in the planning process, reflecting directly upon land-use suitability (Coleman & Galbraith, 2000). The utility of soil-land resource information for proper agricultural land use was proposed by Dumanski *et al*. (1987). The land evaluation system of FAO (1983) was based on land qualities as related to individual crops that was used to develop the crop requirements based on experience in tropical areas (Sys *et al*. 1993). Suitability of land is assessed considering rational cropping system, for optimizing the use of a piece of land for a specific use (FAO, 1976; Sys *et al.,* 1991). The suitability is a function of crop requirements and land characteristics and it is a measure of how well the qualities of land unit match the requirements of a particular form of land use (FAO, 1976). Integration of the biophysical parameters with knowledge based criteria in Geographic Information System (GIS) can help land-use planners and managers to improve decision-making processes (Malczewski, 1999). The soil based crop suitability plans could help to bridge the yield gap through crop management and conservation and use of natural resources of the target region. Alternatively, crop simulation models could be used to estimate the potential yields provided the required soils and climatic input data for the site are available for model execution. Land degradation caused by water erosion, soil fertility depletion, and water-logging are the major constraints limiting crop yields and sustainability on relatively high water-holding capacity soils. The existence of biotic and socio-economic constraints in the regions needs to be assessed to overcome the production constraints. In the present study, attempt has been made to identify core soybean growing areas in Central India.

3.1 Core growing areas in different Agro-ecologies

The identified core soybean growing areas were superimposed with agro-ecological regions (AER) (Sehgal *et al.,* 1995) and agro-ecological sub regions (AESR) (Velayutham, *et al.,* 1999) of India as established based on physiography, soil type, agro-climatic conditions, length of growing period and land use, in order to analyse the agro-ecological settings of the core soybean growing areas. The districts covered under core soybean growing areas and soils of these regions at agro-ecological regions and sub regions were identified. Agro-ecological regions 5 (5.2 agro-ecological sub region), 6 (6.1, 6.2 and 6.3 agro-ecological sub regions), and 10 (10.1, 10.2, 10.3 and 10.4 agro-ecological sub region) were identified under core soybean growing areas. In Madhya Pradesh, soybean is mainly grown in Malwa plateau, part of Deccan plateau and Central Highland (Tamgadge *et al.,* 1996). Both Madhya Pradesh and Maharashtra grow soybean largely on Vertisols and associated soils.

The systematic appraisal of agro-ecological regions and sub regions encompassing relatively homogenous regions in terms of soil, climate and physiography and conducive moisture availability periods i.e. length of growing period (LGP) will help in planning of soybean crop. An agro-ecological zone is the land unit carved out of agro-climatic zone superimposed on landform which acts as modifier to climate and length of growing period. AER 5 constitutes parts of Gujarat, and Kathiawar peninsula, hot semi-arid ecoregion, AER 6 encompasses Deccan plateau, hot semi-arid ecoregion and AER 10 covers mainly Central Highlands (Malwa, Bundelkhand and Eastern Satpura), hot sub-humid ecoregion. In these three ecological regions, soybean crop is primarily cultivated in the states of Madhya Pradesh, Maharashtra and Rajasthan. Agro-ecological region and sub regions and their description and the districts identified in each AESR are shown in Table 16.

Table 16: Agro-ecological regions and sub regions of core soybean growing areas in Central India

AER	Description of Agro-ecological regions (AERs)	AESR	Description of Agro-ecological sub regions (AESRs)	Districts covered
5	Central (Malwa) highlands, Gujarat plains and Kathiawar peninsula, hot semi-arid ecoregion, with medium and deep black soils and GP 90–150 days	5.2	Madhya Bharat Plateau, Western Malwa Plateau, Eastern Gujarat Plain, Vindhyan and Satpura range and Narmada Valley, hot moist semi-arid ESR with medium and deep, clayey Black soils (shallow black soils as inclusions), medium to high AWC and LGP 120-150 days (I5Dm4).	Dhar, Diwas, Indore, Jabhuva, Khargoan, Mandsaur, Ratlam, Ujjain of Madya Pradesh and Bundi, Jalwar and Kota of Rajasthan
6	Deccan plateau, hot semi-arid ecoregion, with shallow and medium (with inclusion of deep) black soils and GP 90–150 days	6.1	South Western Maharashtra and North Karnataka Plateau, hot dry semi-arid ESR with shallow and medium loamy Black soils (deep clayey Black soils as inclusion), medium to high AWC and LGP 90-120 days (K4Dd3),	Ahmadnagar, Beed Osmanabad of Maharashtra
		6.2	Central and Western Maharashtra Plateau and North Karnataka Plateau and North Western Telangana Plateau, hot moist semi-arid ESR with shallow and medium loamy to clayey Black soils (medium land deep clayey Black soils as inclusion), medium to high AWC and LGP 120-150 days (K4Dm4)	Nashik, Jalna, Parbhanai, Hingoli, Lathur and Nanded of Maharashtra and Adilabad and Nizamabad of Telangana state.
		6.3	Eastern Maharashtra Plateau, hot moist semi-arid ESR with medium land deep clayey Black soils (shallow loamy to clayey Black soils as inclusion), medium to high AWC and LGP 120-150 days (K5Dm4)	Akola, Amravati, Bhuldana, Jalgaon, and Washim, Yavatmal of Maharashtra
		6.4	North Sahyadris and Western Karnataka Plateau, hot dry subhumid ESR (K4Cd5)	Sangli, Satara and Kholhapur
10	Central Highlands (Malwa, Bundelkhand and Eastern Satpura), hot sub-humid ecoregion, with black and red soils and GP 150–180 (to 210) days	10.1	Malwa Plateau, Vindhyan Scarpland and Narmada Valley, hot dry subhumid ESR with medium and deep clayey Black soils (shallow loamy Black soils as inclusion), high AWC and LGP 150-180 days (15Cd5)	Bhopal, Damogh, Guna, Hoshangabad, Nasimpur, Raisen, Sehore, Rajgarh, Sagar and Vidhisha of Madhya Pradesh
		10.2	Satpura and Eastern Maharashtra Plateau, hot dry subhumid ESR with shallow and medium loamy to clayey Black soils (deep clayey Black soils as inclusion), medium to high AWC and LGP 150-180 days (K4Cd5)	Betul of Madhya Pradesh and Nagpur and Wardha districts of Maharashtra
		10.3	Vindhyan Scarpland and Bundelkhand Plateau, hot dry subhumid ESR with deep loamy to clayey mixed Red and Black soils, medium to high AWC and LGP 150-180 days (I6Cd5)	Chhatarpur, Satna, Rewa And Tikamghar of Madhya Pradesh
		10.4	Satpura range and Wainganga Valley, hot moist subhumid ESR with shallow to deep loamy to clayey mixed Red and Black soils, low to medium AWC and LGP 180-210 days (K6Cm6)	Chindawara and Seoni, of Madhya Pradesh

3.2 Resource domain –characterization

Climate

Soybean grows well in warm and moist climate. A temperature of 26.5 to 30°C appears to be the optimum for most of the varieties. Soil temperatures of 15.5°C or above favour rapid germination and vigorous seedling growth. The minimum temperature for effective growth is about 10°C. The time of planting is a very important consideration in soybean. In central India, soybean can be planted from third week of June to first fortnight of July. Another important factor is the day length as most soybean plants are short day plants and are sensitive to photo periods, thus time of planting is very important factor. If there were a long spell of drought at the time of pod filling, one irrigation would be desirable. During excessive rains, proper drainage is also equally important.

Length of Growing Period (LGP)

Depending on climate, soils, crop variety and management practices, the total water requirement of the soybean crop has been reported to vary between 45 and 70 cm (Doorenboos and Kasam, 1986). In core soybean growing areas, hot semi-arid ecoregion (AER 5), with medium and deep black soils have the LGP from 90 to150 days, whereas the hot semi-arid ecoregion (AER 6), with shallow and medium (with inclusion of deep) black soils have the LGP from 90 to 150 days. The hot sub-humid eco-region (AER 10), with black and red soils have LGP ranges from 150–180 (to 210) days.

Soil Depth

Deep and well-drained soil with a fine but firm seedbed that is high in fertility and has good water-holding capacity is needed for good soybean yields. Soybeans are generally better adapted to heavier soils and better able to utilise water at lower soil depths than most other crops. The analysis of soil resource data (1:250,000 scale) of Maharashtra (Challa *et al.,*1995), erstwhile Madhya Pradesh, (Tamgadge *et al.,* 1996), Karnataka (Reddy *et al.,* 1998) and Rajasthan (Shyampura and Sehgal,1995) in conjunction of AESR's for core soybean growing areas indicate that extremely shallow soils (<10 cm) occur in Nashik, Yavatmal and Chindwara districts in AESR 6.2, 6.3 and 10.4, respectively, very shallow soils (10-25 cm) mainly in Bidar, Nashik and Hingoli in AESR 6.2, Yavatmal in AESR 6.3 and Chindwara in AESR 10.4 and shallow soils (25-50 cm) in Osmanabad and Beed districts in AESR 6.1, Latur and Nanded districts in AESR 6.2, Yavatmal and Buldana districts in AESR 6.3 and Chindwara and Seoni districts in AESR 10.2. Moderately shallow soils (50-75 cm) are noticed in majority of the districts in core soybean growing areas, particularly in Satara, Ahmadnagar and Jalgoan districts in Maharashtra and Jabhua, Shivpuri, Tikamgarh and

Damoh districts of Madhya Pradesh. Most of the core soybean growing area in Maharashtra and Madhya Pradesh is under deep soils (75-100 cm). Very deep soils (>150 cm) are observed in Belgaum and Haveri districts of Karnataka and Bundi and Jhalawar districts of Rajasthan. Soybean grown in extremely shallow, very shallow and shallow soils could be prone to tress conditions during droughts. Adoption of proper soil and water management practices can conserve soil moisture and improve the soybean yields

Soil Texture

Soil texture is the major soil component governing the amount of water available to plants during the growing season. Clay loam, silty loam, loam, clay soils are favourable for soybean cultivation. Under core soybean growing areas, majority of the area is under clayey soils particularly in Osmanabad and Beed districts in AESR 6.1, Latur and Parbhani districts in AESR 6.2, Jalgaon, Buldana and Amravati in AESR 6.3, Shajapur, Rajgarh and Vidihisha in AESR 10.1, Dhar, Ujjain, Indore and Mandsaur in AESR 5.2 . Loamy soils are mainly noticed in Satara and Belgaum districts in AESR, 6.4, Bidar, Nanded, Hingoli and Nashik districts in AESR 6.2, Yavatmal district in in AESR 6.3, Chandrapur and Nagpur districts ion AESR 10.2, Chindawara, Seoni and Betul districts in AESR 10.4, Damogh, Raisen and Hoshangabad districts in AESR 10.1, Chhatarpur and Tikamgarh districts in AESR 10.3 and Bundi and Chitaurgarh districts in AESR 5.2. Sandy soils are observed in isolated patches in Damoh and Sagar districts of Madhya Pradesh. The districts having the clayey and loamy texture with 0-1 per cent slope, and low land areas, could be prone to water-logging.

Soil Drainage

Soil drainage is primarily determined by the water holding capacity of the soil profile and the amount and distribution of rainfall in addition to other factors such as soil texture, soil porosity, infiltration capacity, and slope of the land. Soil drainage is the major concern in core soybean growing areas in India since majority of the soils in these regions are characterized with Vertisols or Vertic integrades. Well drained and fertile loamy soils with a pH between 6.0 and 7.5 are most suitable for the cultivation of soybean. Moderately well drained soils are noticed mainly in Mandsaur, Ujjain and Indore districts in AESR 5.2, Parbhani, Akola and Amravati in AESR 6.3, Raigarh and Vidhisha in AESR 10.1 and Nagpur and Chandrapur in AESR 10.2. Well drained soils are observed in Chitaurgarh and Banswara districts of AESR 5.2, Ahmadnagar and Osmanabad in AESR 6.1, Yavatmal district in AESR 6.4 and Seoni district in AESR 10.4. Somewhat excess drainage is observed in Bidar and Nanded districts of AESR 6.2, Belgam district of AESR 6.4 and Chindwara district of AESR 10.4. Excessively drained soils are noticed in Nashik, Jalna and Ahemadnagar districts of AESR of 6.2, Jalgaon and Buldana districts of AESR 6.3 and

Rajgarh district of AESR 10.1. Districts with moderately well drained soils could be prone to water-logging while medium rainfall districts with somewhat excessive and excessive drainage could be prone to stress conditions.

Soil Erosion

Land degradation caused by water erosion and soil fertility depletion affect the yields of soybean. Soil erosion is high in the Vertisol areas of Central India, thus reducing plant nutrients in the soil. Loss of the fine, nutrient-rich topsoil through erosion results in lower productivity, and silting of water bodies and streams (Black, 1968). Under core soybean growing areas, slight erosion is noticed in Bundi and Kota districts of Rajasthan falling under AESR 5.2, Haveri and Dharwad districts of Karnataka and Ahmadnagar district of Maharashtra. Majority of the core soybean growing areas in Central India is under moderate soil erosion, especially Latur and Parbhani districts in AESR 6.2, Amravati and Jalgoan districts in AESR 6.3, Dhar, Mandsaur and Ujjain districts in AESR 5.2 (Fig.5). Severe soil erosion is observed in almost all the AESR's especially, Jalna and Nashik districts in AESR 6.2, Buldana and Yavatmal districts in AESR 6.3, Chindwara, Nagpur and Betual districts in AESR 10.4, Chitaurgarh and Jabua districts of AESR 5.2. Very severe erosion is noticed mainly in Raisen, Sehore and Hoshangabad districts in AESR 10.2. Major constraints for sustaining the soybean productivity of these soils are high runoff and associated soil erosion and depletion of soil nutrients, which leads to a decline in the productivity of the soybean crop. Districts with moderate, severe and very severe soil erosion need improved land management practices to reduce the top soil and nutrient loss.

Soil Reaction (pH)

Soil pH can have a strong impact on nutrient availability, root growth, and overall plant health. Soil characteristics are essential to determine the availability of micronutrients to plants, and therefore the crop yield potential and crop quality. The factors that affect the contents of such micronutrients are organic matter, soil pH, lime content, sand, silt, clay content (Srinivasarao and Sudharani, 2013). Under core soybean growing areas, soils with moderately acidic pH (4.5 -5.5) are noticed mainly in Durg, Kawardha and Rajnandgoan districts of Chhattisgarh and parts of Hoshangabad, Betul and Chindwara districts of Madhya Pradesh. Soils with slightly acidic pH (5.5-6.5) are observed mainly in seoni, Chhindwara and Betul districts in AESR 10.2 and Chhatarpur and Tikamgarh in AESR 10.3 (Fig.6). Soils with neutral pH (6.5-7.5) are noticed in majority of soybean growing districts in AESR 6.1, 6.2, 6.3, 6.4 and 10.2. Soils in Satna and Rewa districts in AESR 10.3, Kota and Chituargarh districts in AESR 5.2 also have neutral pH. Soils with slightly alkaline pH (7.5-8.5) have been observed in Belgaum, Dharwad, Gadag and Haveli in AESR 6.4. Soils with strongly alkaline pH (>9.5) are noticed in Chitaurgarh district. In districts with moderately and strongly alkaline soils, germination of seeds and yields of soybean are affected.

3.3 Major bio-physical constraints

At around one tonne per hectare, the productivity of soybean in India is much below its potential. There is a wide gap between the national productivity (1t/ha) and the production potential of soybean varieties in India (3 to 4 t/ha). The yield levels achieved in frontline demonstrations under real farm conditions have been around 2 t/ha i.e. almost double of the national average yield (Tiwari *et al.,* 2001). Unbalanced nutrition is one of the important reasons of low productivity (Sharma *et al.,* 1996; Tiwari, 2001a). There are several biophysical, technical, and socio-economic constraints that limit the productivity of soybean, which need to be mitigated to enhance the productivity.

Since cropping season of soybean coincides with the south-west monsoon period, the uneven distribution of seasonal rainfall poses problems, such as drought in the early stages of crop growth and floods in the middle stages. In core soybean growing area, about 98 percent of the area under soybean cultivation is rainfed, the soil moisture requirement during sowing and the growth period is very important and it determines many other agronomic operations at the time of sowing. The crop is becoming more and more risk prone as the amount and distribution of rainfall are becoming erratic. Submergence or flooding is also one of the major harmful abiotic stresses in low-lying areas and crop losses due to water-logging are considerable. Lack of oxygen supply for the plant is the main reason for damage of soybean in water-logging condition, which hampers nutrient and water uptake resulting in wilting. Soybean requires relatively large amounts of phosphorus and it is taken up by soybean plant throughout the growing season. The period of great demand starts just before the pods begin to form and continues until about ten days before the seeds are fully developed. The soil should be tested for the availability status of phosphorus to meet the requirement of the crop. Soybean also requires a relatively large amount of potassium. The rate of potassium uptake climbs to a peak during the period of rapid vegetative growth then slows down about the time the beans begin to form. Mixed cropping of soybean with maize is found to be feasible and more remunerative. Soybean has tremendous scope as an intercrop in arhar and cotton in northern India.

4.0 Summary

4.1 Productivity can be improved

In the states of Madhya Pradesh (34 districts), Maharashtra (23 districts), Rajasthan (6 districts) and Karnataka (4 districts) have in total more than 9 million ha under the crop annually during the *Kharif* season. The productivity of soybeans however, varies widely: As an example, the range of soybean productivity in Madhya Pradesh varies between 350 to

2300 kg ha^{-1}; in Maharashtra it varies between 670-2300 kg ha^{-1}, in Rajasthan from 825-1300 kg ha^{-1} and in Karnataka from 550 – 630 kg ha^{-1}.

The yield analysis by utilizing soybean growth and development model (soygrow model) which utilizes daily weather, edaphic characters including soil water holding capacity, radiation and crop growth and development characters, showed that yield Gap A, for soybean growing regions of India is 1000-1500 kg ha^{-1} (modeled yield - the national average). The yield Gap B; between research station's and farmer's yields harvested by adopting best soybean growing practices, is also of about the same order.

Soybean farmers (because it is a new crop) generally grow improved cultivars (though they may not renew the planting material at regular intervals). The crop is exposed to few biotic stresses, which on an average may reduce crop productivity by 10-30%, but most importantly the abiotic stresses potentially reduce potential crop productivity by 50-70%. Thus, if the abiotic stresses, in particular the soil water deficit / excess, the soil quality and available nutrients are well managed, in most districts where soybeans currently produce between 500-1000 kg ha^{-1}, the productivity could be easily raised to an average of 1500 kg ha^{-1}; and in districts currently harvesting over 1000 kg ha^{-1}, the productivity levels could reach 2000 kg ha^{-1} if all the 'best practices' of land and water are introduced step-by-step.

4.2 Smart technologies and use of remote sensing tools

The introduction of precision farming technologies for sustainable soybean-based agriculture would require an intensive delineation of the resource base – the land and water resources, the hypsometry and lay of the land, the soil quality (its fertility, erosivity, organic matter content) and landscape characteristics.

For advising the farmers on the adoption of '*best practices*' for a given eco- natural resource domain, the use of geo-informatics will have to be intensively employed to '*cluster*' and aggregate areas with similar resource characteristics and abiotic stresses. Further, during the soybean growing season, the real-time information of the crop growth and development will have to be monitored for biotic / abiotic stresses on a short interval basis. Improved soybean cultivars capable of producing up to 2500 kg ha^{-1} or more are available. These have been extensively tested by the crop variety approval committees at several levels.

4.3 Launching Mission – Mode Initiative

The area under soybean, which was around 10,000 ha in India in the early 1990's has now peaked to around 11 million ha (and has continued to increase), but the productivity of the crop for the last 15 years has not moved much; the annual rate of increased productivity is hardly 50 kg ha^{-1} $annum^{-1}$, but the increase in area is 1000 fold or more of this figure in the recent years.

In order to increase the productivity of soybeans, it is suggested that the Indian Council of Agricultural Research in cooperation with the SAU's located in Central Peninsular India, State Departments of Agriculture, Oil processing industry and some non-governmental organizations should develop and launch a *Mission Mode Project*. By its very frame; the project would have to be inter-institutional. ICAR and SAU's will have to work closely with the Space Research Organizations (eg. NRSC), the DDGs of NRM, Agricultural Extension, and Crops Divisions at ICAR headquarters; the ICAR institutions like CRIDA and NBSS & LUP and KVK's will have to work hand-in-hand to plan and carryout teach farmers of new set of '*Best Practices*' for each cluster of NRM domains, and modify these practices on real time basis during the crop season. The extension staff in the KVK will be trained as "*Land Managers*" so that they are able to operationally use remotely sensed information and use geographical Information System (GIS) and Geo-Positioning System (GPS).

4.4 Advantage soybean

The first generation Green revolution in 1960s under rice and wheat (R-W) cropping system as an example, ushered food self sufficiency but, considering the downside of R-W chemical intensive agriculture, it has ravaged our soil quality, the water aquifers have been depleted, the lakes have been polluted, and huge subsidies are be doled out to keep the R-W rotation going. Its costs to environment are huge.

Now, just consider a green revolution (the ecological green revolution) with soybean based farming systems. Little or no subsidies for power, little chemicalisation of land/ soil resources; saving of 50 million – 100 million tons of top soil from the ravages of soil erosion, benefits of fixing environmental N to the tune of 300-500 million tons through BNF, increasing carbon foot-print (soybeans sheds about 10 tons of leaf matter on the soil surface) and ensuring nutritional security to our people and dairy cattle. These are multiple environmental benefits.

Further, imagine that by intelligently introducing science-based smart soybean production technologies, we will be able to harvest 4 m. t of protein (from 20 m.t of soybean) in the coming 10 year time-frame and get all the additional benefits of environmentally safe and eco-friendly conservation agriculture – a harbinger of our move towards the second generation eco-green revolution technologies.

5.0 Significant Recommendations / Conclusions

Recognizing that soybean is an important crop for food, nutritional, environmental, livelihood, and economic security of our country, the participants of the BSS after detailed deliberations recommended:

First, that soybean crop is grown in over 10 million ha of land and produces about 10-12 million tones of soya grain in peninsula Indian states, primarily in dryland/rainfed systems. It s productivity level is about 50-60% of the world average. *Efforts should be made to increase its productivity to about 2 tons ha^{-1} in the next 5-10 years time frame;*

Second, the soybean crop is grown in ecological sensitive eco-regions where soils (Vertisols) are highly prone to sheet erosion. *All efforts should be made to increase the production of the crop per unit area;*

Third, available improved soybean varieties are tolerant to biotic stresses and can withstand abiotic stresses (particularly, short term droughts), and have a potential to produce up to 2500 kgha^{-1} under well managed conditions. *The spread of suitable cultivars should be encouraged and its seed made available to the farming communities;*

Fourth, soybean crop can withstand some water logging, but if water congestion is prolonged, the loss in productivity is irretrievable – *all efforts should be made to extend production of soybean on broad bed and furrow land management system (BBF) in watershed configuration,* where drainage water ways are interlinked, and field drains are laid on contours;

Fifth, reliable abiotic stresses information on real time basis is essential to assure high soybean productivity. High Science tools like GIS, GPS, and remotely observed data by unmanned aerial vehicles (drones – UAV's) are basic requirements. *A set of UAV's will have to be placed progressively in each of the soybean growing districts;*

Sixth, *the KVK's staff will have to be trained in the reading of GIS and remotely sensed maps,* use of GPS and in collecting, collating, and relaying UAV's observed information to the soybean growers on a real time basis;

Seventh, the ICAR institutes, Ministry of Agriculture, state SAU's and Departments of Agriculture and the Soybean Growers Associations *will have to work closely and in coordination in order to extend the best soybean production practices;*

Eighth, farmer to farmer contact is essential for the transfer of soybean production techniques. High soybean productivity districts and farmers reaping high yields will have to be identified and benchmarked. *The best practices adopted by these districts and farmers will have to extended to other similar resource domains*.

Ninth, *human resource development of the assigned staff* for taking forward the message of increasing soybean productivity *will have to be trained and retrained,* from time to time in the use of high science tools on an operational basis;

Tenth, *a Mission Mode Project be framed in cooperation* with the ICARs pulses and oil seeds project, and put up to concerned ministries of GOI including Niyti Adyog and the Ministry of Environment for support in the due course. The proposed Mission Mode Project, would needs close working relationship between different government and non government agencies *for increasing production and productivity of soybean in India over the next 5-10 years.*

Eleventh, soybean replaced major *kharif* cereals such as rice in Madhya Pradesh and sorghum and bajra in Maharashtra while impact of soybean crop in replacing cotton crop is not visible. In order to reduce the dependence on cotton, special measures could be considered to promote Soybean in cotton growing areas. This could be achieved with active industry promotion through value addition and incentives for soybean crop cultivation. *This could reduce the import burden on edible oil and also wean away farmers from cotton crop which is considered to be risky.*

Twelfth, *there should be local convergence of national/state programmes /schemes* like IWMP, MGNREGA, RKVY, NFSM, etc. which enable for prioritizing the programmes for right investments in research, extension and capacity building of soybean farmers *for achieving sustained productivity with a two pronged strategy.*

Thirteenth, a national seed policy to include farmer to farmer seed distribution, for *fast track seed replacement. A farmer friendly nutrient based fertilizer policy,* a PPP (Procurement, Processing and Pricing) and *a small farm friendly mechanization policy* at local level are needed.

Fourteenth, Land degradation caused by top soil loss, soil fertility depletion and water-logging are the major constraints limiting crop yields and sustainability on relatively high water-holding capacity soils. *Therefore, soil resource database and thematic maps could be effectively used for soil-based agro-technology transfer.*

Fifteenth, Promoting integrated nutrient management and balanced nutrition, return of crop residues to the soil and its facilitation through the availability of necessary implements at the farm level to be encouraged. *Therefore, critical assessment of micro-nutrients requirement for soybean and soybean-based cropping systems is needed in different soils/agro-climatic regions of the country.*

Sixteenth, the region specific a-biotic, biotic and socio-economic constraints need to be assessed *to overcome the production limitations.*

6.0 Proposed Model Mission mode Project

6.1 Background

Soybeans serve as one of the most valuable crops in the world. It is not only an oil seed crop, but also a feed for livestock and aquaculture. Globally India ranks fifth with an annual soybean production of about 12 million tons (MT) from an area of 10 Mha under the crop.

To meet its vegetable oil needs, India imports over Rs 8000 crores of soy oil annually, but at the same time it exports substantial quantity of soy cake, principally to China. The global value of this commodity in Chicago futures market increased from about 190 USD per ton in 2002 to over 500 USD per ton in 2012-14. In short, soy crop is important for the economy of India as also for the livelihood security of the farming community farming this crop.

6.2 Trends in soybean production and yields at global level

The analysis of relative share to the world soybean production during 1970-2010 showed that despite the increase in total production, the share of the USA was reduced to almost half from 70 to 34% over a period of 40 years. At the same time, the relative share of China also decreased from 20 to 5.64%. Whereas, the global share by Brazil increased significantly from 3.5 to 25.6%. Similarly, the share of Argentina increased from 0.06 to 20%. The share of India in global production increased from 0.03 to 3.67% during the same period.

The world average soybean yield doubled from 1060 kg ha^{-1} in 1961-62 to 2490 kg ha^{-1} in 2010-11. The analysis of soybean yield trends in the USA and India during 1970-71-2010-11 show that the yields of soybean increased from 1780 kg ha^{-1} to 2570 kg ha^{-1} in the USA, whereas in India, the soybean yield increased from 420 kg ha^{-1} to 1320 kg ha^{-1}. It was observed that during 1975-76 to 1978-79, the yield of soybean in India reached an average of 1000 kg ha^{-1}, whereas in the subsequent years, the yield declined to a low of 582 kg ha^{-1} in the year 1987-88. Thereafter, highest average yields increased to 1138 kg ha^{-1} in the year 1999-2000 and the highest yield of 1327 kg ha^{-1} was recorded in the year 2010-11. Notably, India was able to produce only 23 % of the USA soybean yields per ha in the year 1970-71, and it reached to 52% in the year 2010-11.

6.3 Soybean in India

With promising returns and acceptability by the farmers, the crop is being cultivated in different cropping systems such as soybean-wheat, soybean- chickpea, soybean-maize, soybean-sorghum among others. The crop has substituted *kharif* cereals including rice and pulses in Madhya Pradesh; sorghum, pearl millet and pulses in Maharashtra.

The crop is being cultivated in rainfall regions with 500 to 1500 mm annual rainfall with varying productivity. Under the Rainfed Production Systems Research of National Agricultural Technology Project (Vittal, 1998; Rao 2003), GIS-based assessment was made of the crop districts for various crops and cropping systems linking bio-physical and other natural environment conditions for identifying the target districts for improving total production in the country.

6.3.1 Spatial Trends in soybean cultivation

A total area of 9.5 Mha is cultivated under soybean in the country [an average of of four years (2008-09 to 2011-12)] in Madhya Pradesh, Maharashtra, Andhra Pradesh, Gujarat, Karnataka, and Jharkhand. An area of 5.0 Mha is devoted to soybean cultivation in the state of Madhya Pradesh. The productivity of soybean ranges from 400 to2300 kg ha^{-1} across the country with a median of 1000 kg ha^{-1}.

The states of Madhya Pradesh and Maharashtra contribute 88% of total soybean production in the country with an average productivity of 1125 kg ha^{-1} and 946 kg ha^{-1} respectively. In Andhra Pradesh, the average productivity is 1280 kg ha^{-1} which is 20% more than the country's average productivity. Though Karnataka occupies 4^{th} position in terms of area under soybean after Madhya Pradesh, Maharashtra and Rajasthan, the average productivity is 550 kg ha^{-1} which is almost 50 % lower than the national productivity. In Rajasthan, soybean is cultivated in an area of 0.68 Mha with an average productivity of 1172 kg ha^{-1}, it thus ranks second based on average state highest productivity in the country following Andhra Pradesh.

6.3.2 Delineation of core soybean domains

In order to delineate the core soybean domains in the country, district-wise available data on area, production and productivity were collected for the years 2000-01 and 2005-06 (Agristat, 2013). The collected data at the district level on area, production and productivity were entered in geospatial GIS framework and the temporal database for spatial analysis. The top districts covering more than 10,000 ha under soybean were identified and grouped into six categories i.e., 10 to 50, 50 to 100, 100 to 200, 200 to 300, 300 to 400 and greater than 400 thousand ha of the total soybean cropped area in the district.

6.3.3 Core soybean domains in different Agro-ecologies

The identified core soybean domain maps were superimposed with agro-ecological regions (Sehgal *et al.*, 1995) and agro-ecological sub regions (Velayutham, *et al.*, 1999) of India, based on physiography, soil type, agro-climatic conditions, length of growing period and land use to analyze the agro-ecological settings of the core soybean domains. The districts covered under the core soybean growing areas and soils of these regions at agro-ecological regions and sub regions were identified. In Madhya Pradesh and Maharashtra states, soybean is largely cultivated on shallow vertic intergrades and Vertisols occupying diverse physiographic units such as rolling to very gently sloping lands.

The systematic appraisal of agro-ecological regions and sub regions encompassing relatively homogenous soybean domains in terms of soil, climate and physiography and conducive moisture availability periods i.e., the length of growing period (LGP) helped in prioritizing soybean growing sub- domains for achieving higher productivity, and for identification of best management interventions for both enhancing productivity and soil quality. The agro-ecological settings of the core soybean growing areas in Central India are given in Table 17.

Table 17: The suggested best practices for improving productivity under (3) productivity zones

Yield	**< 500 kg ha^{-1}**	**500-1000 kg ha^{-1}**	**>1000 kg ha^{-1}**
Land scape	Rolling	Flat- Rolling	Flat-Rolling
Soils	Inceptisols	Vertic Integrades	Vertisols
Soil depth	Shallow black soil	Medium deep	Medium deep- Deep
Soil quality	Poor	Moderate-Good	Good-Very Good
Drainage	Well drained	Poor-medium	Well drained
Water logging	Low	Medium	High
Objectives of best practices	Renewal of soil quality	Sustain and upgrade soil quality	Introduce intensive conservation agriculture practices
Productivity objectives	Sustain at current levels and upgrade to 1000 kg ha^{-1}	Increase productity to >1500-2000 kg ha^{-1}	To harvest >2000 kg ha^{-1}
Land use	Soybean-Agro Forestry or Soybean- Pigeon pea based system. (30% area under soybean + 70% area under agro forestry)	Soybean- Pigeon pea based system. (70% area under soybean + 30% area under pigeopea on ridges and furrows with drainage, conservation furrows with mechanised equipemnt	Soybean - BBF system with well drainage, conservation furrows with mechanised equipment
Genotypes	Best suited/ hybrids	Best suited/ hybrids	Best suited/ hybrids
Seed renewal	As recommended	As recommended	As recommended
Surveillance			
a. weather	Automatic weather recording -low density network	Automatic weather recording -Medium density network	Automatic weather recording -High density network
Insurance	Broad level insurance products to be developed	Insurance products suiting to weather variations	Insurance products to cover weather variations and biotic pressures
b. Real time abiotic	By use of unmanned remotely controlled drones (URCD's)	By use of unmanned remotely controlled drones (URCD's)	By use of unmanned remotely controlled drones (URCD's)
c. Contacts with farmers in affected NRM domains	By telephones/Cell phones	By telephones/Cell phones + Visits by KVK team	By telephones/Cell phones + Visits by KVK team and scientists
d. Response time	One week	2-3 days	Immediately (1 day)

As a comparison, the rice-wheat growing area in the north-west area is a prominent system. It occupies approximately 10 Mha of land and is contributing to food security. However, the systems' productivity *vis-a-vis* the use of natural resources needs a critical appraisal.

The soybean based system is a better alternative, because it addresses both food and nutritional security with lower effect on environmental quality. The soybean based system acts complimentarily to the rice-wheat based land use system (Table 18).

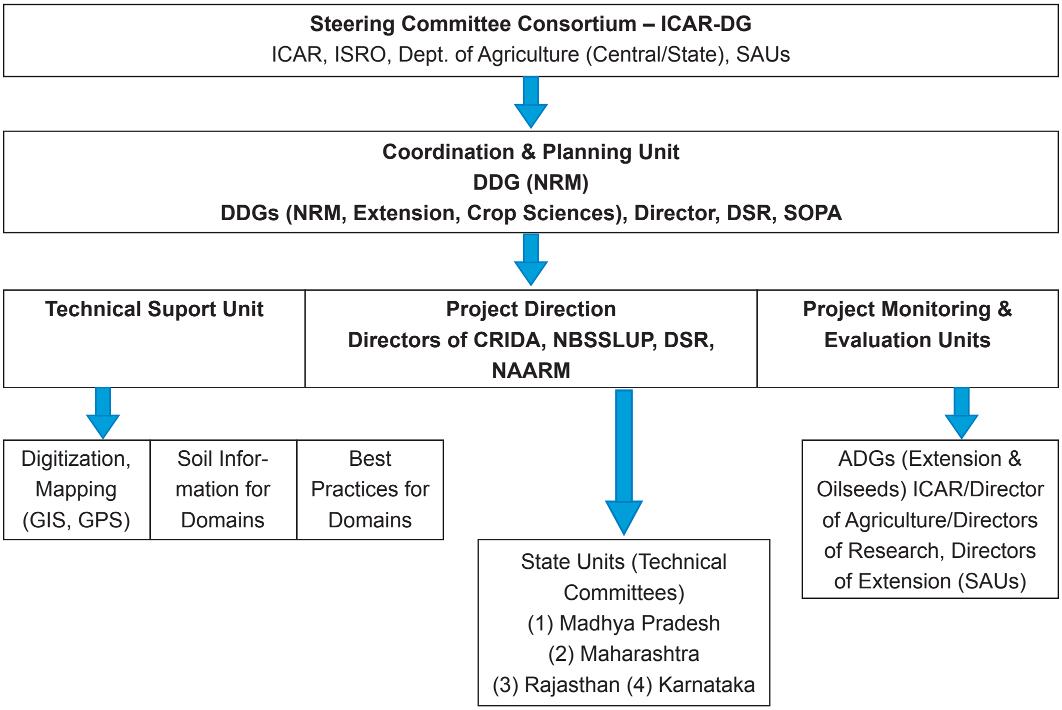
Table 18: A comparison of the Rice-Wheat and Soybean Production System in India

Time Frame	Attribute	Rice-Wheat system	Soybean System
Current	Area (Mha)	10	10-12
	Production (t ha^{-1})	8-9	1
	Protein produced (t ha^{-1})	1	0.4
	Carbohydrates (t ha^{-1})	8	-
	Oil produced (t ha^{-1})	Little	0.2
	Calorific value		
Future			
	Production (t ha^{-1})	Stable to decline	1.5 to 2
	Protein produced (t ha^{-1})	1	0.6-0.8
	Carbohydrates (t ha^{-1})	8	-
	Oil produced (t ha^{-1})	Little	0.3 - 0.4
	Calorific value (Kcal kg^{-1})	3430	9430
Environmental Impacts	Fertiliser use	High- Very High	Low- Very Low
	Global warming gaseous emission	High	Little
	BNF	-	Medium to High
	Land quality	Highly damaging, reduces soil C accretion, degrades soil structure destroyed	Land binding legume crop-shedding of all leaf litter at maturity, increases soil C accretion
	Water	Aquifers drying up, high water use	Little impact- dryland crop (95% rainfed)
	Global warming	High inputs - High carbon footprint	Negligible -low carbo footprint
	Carbon accretion in the soil	Negative	Positive
	Pollution	High pollution due to fertilizer leaching into groundwater/ gases emission into atmosphere	No such impact
	Subsidy	High on power provided and on fertilisers	Majorly a dryland crop coupled with low fertiliser usage
	Soil erosion/ development of soil salinity/ waterlogging etc variation	Medium to high damage to soil quality due to sheet erosion	None to Low, soil conserving croppig system
	Complimentarily for future agricultural development	Provides food security	Provides nutritional security

6.4 Technology Mission on Soybean (TMS) - Proposed Framework

To achieve higher and sustained soybean productivity, there is a need to address the issues in a consortia mode involving the public private sector organizations, NGOs and farmers groups. A schematic frame work is given below.

Schematic Framework of Suggested Mission- Mode Project



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Note: The designations and affiliation of the participants are as on the date of BSS.

Area, Production and Productivity trends of prioritized districts

State	District	Area (000 Ha)	Production (000 ton)	Yield (Kg/ha)
Madhya Pradesh	Ujjain	450.18	630.610	1401
Madhya Pradesh	Shajapur	346.23	366.826	1059
Maharashtra	Amravati	321.30	275.200	857
Madhya Pradesh	Dewas	313.92	392.957	1252
Madhya Pradesh	Sagar	308.23	286.247	929
Madhya Pradesh	Rajgarh	298.14	287.912	966
Madhya Pradesh	Sehore	285.39	364.366	1277
Maharashtra	Nagpur	276.90	254.700	920
Maharashtra	Yavatmal	274.03	167.800	612
Madhya Pradesh	Dhar	268.83	369.455	1374
Madhya Pradesh	Mandsaur	264.76	305.676	1155
Rajasthan	Jhalawar	240.18	280.069	1166
Madhya Pradesh	Vidisha	228.15	259.121	1136
Maharashtra	Buldhana	226.10	213.767	945
Madhya Pradesh	Indore	223.70	299.051	1337
Maharashtra	Washim	219.40	152.067	693
Madhya Pradesh	Hoshangabad	216.46	152.969	707
Madhya Pradesh	Betul	210.95	245.421	1163
Madhya Pradesh	Ratlam	210.77	249.405	1183
Maharashtra	Latur	207.77	221.800	1068
Madhya Pradesh	Guna	200.80	245.147	1221
Rajasthan	Baren	199.40	257.617	1292
Maharashtra	Wardha	188.87	133.900	709
Maharashtra	Nanded	177.57	161.467	909
Madhya Pradesh	Harda	173.52	236.065	1360
Maharashtra	Chandrapur	170.00	110.133	648
Madhya Pradesh	Khandwa	161.85	106.056	655
Madhya Pradesh	Chindwara	152.04	253.898	1670
Madhya Pradesh	Raisen	145.14	129.423	892
Maharashtra	Hingoli	138.53	145.867	1053

State	District	Area (000 Ha)	Production (000 ton)	Yield (Kg/ha)
Maharashtra	Akola	138.53	137.900	995
Madhya Pradesh	Shivpuri	134.65	132.456	984
Madhya Pradesh	Neemach	122.65	115.421	941
Rajasthan	Kota	122.22	136.924	1120
Madhya Pradesh	Seoni	118.60	118.404	998
Madhya Pradesh	Bhopal	106.16	130.101	1225
Maharashtra	Parbhani	95.13	103.933	1093
Karnataka	Belgaum	83.75	48.235	576
Andhra Pradesh	Adilabad	83.42	85.357	1023
Madhya Pradesh	Ashok Nagar	80.68	93.356	1157
Madhya Pradesh	Narsimpur	73.88	131.834	1784
Maharashtra	Beed	70.20	48.833	696
Madhya Pradesh	Damoh	68.54	88.311	1288
Rajasthan	Bundi	62.37	64.041	1027
Maharashtra	Sangli	56.33	108.133	1920
Maharashtra	Kolhapur	55.67	126.633	2275
Maharashtra	Ahmednagar	54.73	61.367	1121
Andhra Pradesh	Nizamabad	53.47	89.899	1681
Maharashtra	Nasik	50.57	65.800	1301
Madhya Pradesh	Satna	49.49	27.003	546
Madhya Pradesh	Chhatarpur	47.26	22.110	468
Madhya Pradesh	Khargaon	46.95	28.804	614
Maharashtra	Osmanabad	45.83	46.933	1024
Madhya Pradesh	Jhabua	44.48	31.875	717
Maharashtra	Jalana	42.00	49.533	1179
Rajasthan	ChittorGarh	39.73	46.549	1172
Madhya Pradesh	Tikamgarh	35.93	37.031	1031
Gujarat	Dohad	34.50	27.500	797
Maharashtra	Satara	33.93	64.433	1899
Madhya Pradesh	Barwani	33.23	11.858	357
Karnataka	Dharwad	31.75	19.598	617

State	District	Area (000 Ha)	Production (000 ton)	Yield (Kg/ha)
Chattisgarh	Kawardha (Kabirdham)	31.47	34.656	1101
Maharashtra	Mandurbar	30.07	42.633	1418
Madhya Pradesh	Rewa	29.91	18.235	610
Karnataka	Bidar	28.72	11.993	418
Chattisgarh	Durg	26.60	23.779	894
Madhya Pradesh	Sheopur Kala	21.23	23.918	1127
Rajasthan	Banswara	20.65	16.832	815
Chattisgarh	Raj Nandgaon	20.59	19.217	933
Maharashtra	Dhule	18.53	25.433	1372
Maharashtra	Jalgaon	16.70	33.933	2032
Madhya Pradesh	Burhanpur	14.97	8.947	598
Karnataka	Haveri	10.31	4.984	483
Gujarat	Vadodara	10.10	8.000	792