

Policy Paper

on

**"Diversification of Cropping System
in Punjab and Haryana through
intensification of Cultivation of Maize,
Pulses and Oilseeds"**



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PREFACE

Rice and wheat have contributed significantly to bring India from a situation of ship-to-mouth to self-sufficiency in food production through the most celebrated phenomenon in agriculture, *the green revolution*. As a result, the food production has risen from 82.02 million tonnes in 1960 to 296.65 million tonnes in 2019. The states of Punjab and Haryana played a crucial role in this regard wherein the acreage under rice-wheat cropping system surpassed of all the crops and cropping systems. Cereal based monocropping is the most common phenomenon in the region. Overdependence of these dual cereal crops (rice and wheat) on tube well irrigation has resulted in depletion of the ground water to its critical level. In addition, wide spread utilization of fertilizers and plant protection chemicals have further contaminated both ground water and its environment causing adverse effects on health of both human and animals. Large scale procurement of rice and wheat, and their storage and distribution have also put huge budgetary pressure on the economy, which has become unsustainable in long run. Besides these, the huge left over crop residue from rice, with poor nutritive value and poor decomposition rate, has become the most challenging task to manage in a sustainable manner. Happy seeder, super seeder, rice-based power plant and paddy straw decomposer have received a lot of attention in recent years with the support from Central Sector Scheme on *In-situ* Management of Paddy Straw. However, this has given limited success. Such schemes alone may not yield desired results unless complemented with diversification of the rice-wheat cropping system with much more viable and profitable cropping systems. Efforts have been made in this Policy Paper on "*Diversification of Cropping System in Punjab and Haryana through Intensification of Cultivation of Maize, Pulses and Oilseeds*" to propose alternate cropping systems for maximization of system productivity and return, which would also address the issues concerning ground water depletion, residue burning and pressure on public exchequer. Implementation of the alternate cropping systems in at least 40-50% of currently area under rice-wheat in Punjab and Haryana could significantly reduce the adverse effects of rice-wheat cropping system. While implementing the policy, ICAR and its constituent institutes will provide the technological stopgap, while implementation will have to be made through respective state governments and state agricultural universities through its network of Krishi Vigyan Kendras and extension agencies under departments of agriculture.

Authors

1. Operating environment and background

The Green Revolution of 1960s transformed the course of Indian agriculture bringing about an exponential growth in agricultural production and helped to achieve food security. The technology-driven revolution comprised a package of subsidized modern inputs – irrigation, improved seeds, fertilizers and pesticides complemented with public procurement and price support policies and extension services.

- The states of Punjab and Haryana became the epicentre of ‘Green revolution’. These two states experienced a rapid expansion of area under paddy, from 4.77 lac ha in 1966 to 45.50 lac ha in 2018 (Fig. 1). The total area under wheat in these two states also increased from 23.53 lac ha in 1966 to 60.73 lac ha in 2018. During the same period, the area under maize declined drastically, in Punjab it has declined from 4.44 lac ha to 1.09 lac ha during the mentioned period, while in Haryana the corresponding figures are 87 thousand ha and 5.9 thousand ha, respectively. The cumulative area under pigeonpea during 1966 was 7.2 thousand ha, which dropped to 4.2 thousand ha. The area under rapeseed and mustard showed a declining trend in Punjab from 116 thousand ha in 1966 to 30.5 thousand ha in 2018. However, in Haryana it increased from 198 to 609 thousand ha during the same period.
- In Punjab alone the rice area increased from 5.5% to about 39.5% of the gross cropped area during the period from 1966 to 2018 (Fig. 2). The rice-wheat cropping pattern inflated from about 37% of the total cultivated area in 1966 to about 84% in 2018 and marginalized the traditional wheat-maize cropping pattern and other coarse cereals and pulses.
- Haryana experienced shift in area share of rice-wheat cropping system from 20% in 1966 to about 61% of the gross cropped area in 2018, further marginalizing prevalent crops like maize, oilseeds and pulses.
- Expansion of canal irrigation system in Punjab has significantly contributed towards initial increase in rice area. However, with the irrigation sources expanded from surface canal systems to tube-well based irrigation the share of canals plunged from 38.5% in 1966 to 28.6% in 2018, while that of tube-wells increased from 21.2% to 71.0% during the period. Rural electrification and subsidised power have caused overdependence on ground water and notably the number of tube-wells increased from 1.92 lakhs in 1970 to 6.0 lakhs in 1980 and to more than 14.76 lakhs in 2018. In other

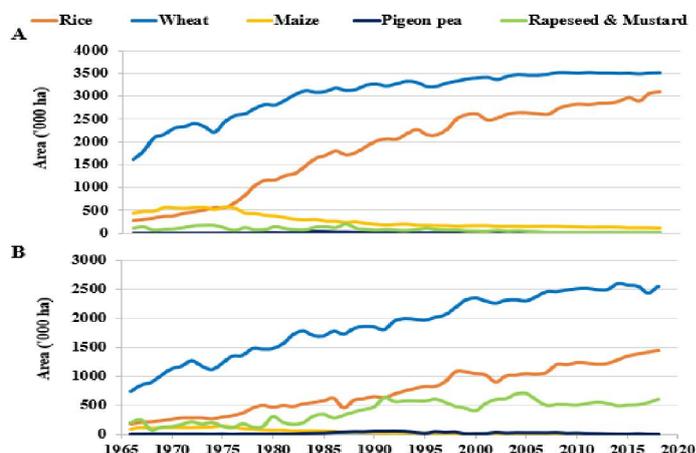


Fig. 1. Trends of area under rice, wheat, maize, pigeonpea, rapeseed & mustard in Punjab (A) and Haryana (B)

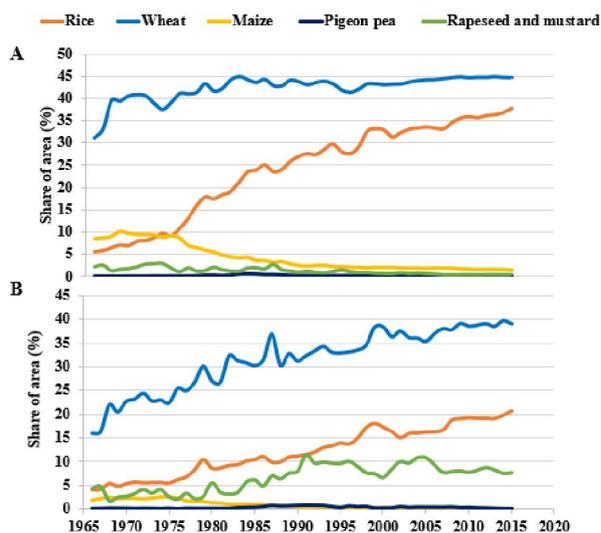


Fig. 2. Trends of share of area(%) under rice, wheat, maize, pigeonpea, rapeseed & mustard in Punjab (A) and Haryana (B)

words, there are about 36 tube-wells per sq. km of the net sown area in Punjab. Out of the total tube wells, 13.36 lakhs (>90%) are electric operated tube wells.

- In Haryana, the share of tube well irrigated area is about 62% in 2018. During 2017, more than 8.21 lakhs tube well were operated for irrigation purpose. About 6.38 lakhs tube wells (>77%) are electricity powered tube wells.
- Over exploitation of groundwater led to the decline in ground water table in north western India between 1973 and 2001 @ ~0.2 m per year, which accelerated by five-fold (@ 1.0 m per year) between 2000 and 2006. This has also led to increased energy demand for pumping and increased costs for installing deep submersible pumps. The Punjab government gave free electricity worth of around Rs.7,180 cr. to the farmers during 2020-21, over 70% of this goes to rice crop cultivation alone. On the other hand in Haryana the electricity supply to farmers is highly subsidized and, on average, farmers pay only Rs. 0.11/kWh against a cost of supply of Rs. 7.34/kWh. The Government of Haryana's annual farm subsidy burden is Rs. 6,196.90 crores, amounting to an average per pump annual subsidy of Rs. 1,01,220.
- The groundwater development (ratio of gross groundwater draft for all uses to net groundwater availability) in Punjab and Haryana is 166.0% (highest in the country) and 137.0%, respectively, which is well above the national average of 63.3%. Out of the 138 blocks in Punjab assessed for ground water, 109 blocks have been categorized as 'Over-exploited', two as 'Critical', five as 'Semi-Critical' and 22 as 'Safe' with no saline block in the state. In Haryana, out of total 128 blocks assessed for ground water, 78 have been categorized as 'Over-exploited', three as 'Critical', 21 as 'Semi Critical' and 26 as 'Safe'(CGWB, 2019).
- With increase in area under rice and wheat in Punjab and Haryana, the rice production increased from 5.61 lakh tonnes to about 173.38 lakh tonnes between 1966 and 2018, while wheat production increased from 35.48 lakh tons to 308.36 lakh tonnes during the same period. Public procurement of rice and wheat has caused tremendous pressure on the capacity of storage of the grains. Both public procurement and storage have incurred huge investment of public money, which often turns out to be unsustainable. During 2018, 152.75 lakh tons of rice and 179.86 lakh tonnes of wheat were procured from these two states, which amounts to Rs. 26731.25 crs and Rs. 33094.24 crs, respectively.
- In addition, rice cultivation created some serious problems and environmental threats, viz., depletion of inherent soil fertility, lowering of water table, degradation of soil structural properties, increased soil and water pollution and degradation of soil properties, enhanced greenhouse gas (GHG) emission and burning of rice residue (rice straw/*Puwal*) resulting in serious threat to human and animal health etc. Off late the growth rates of rice and wheat yields are either stagnating or declining, say rice yield growth rate in Punjab in 1970s was 1.9% (1970-1980) which is currently at 0.3% (2008-2018). During the same time, the growth rates of wheat yields was 2.0% (1970-1980) and 1.5% (2008-2018), respectively. Corresponding figures for Haryana are 1.9% and -0.7% for rice, and 1.3% and 1.2% for wheat, respectively.

2. Candidate crops for diversification of rice-wheat cropping system

The adverse environmental and economic impact of rice-wheat cropping system in the north-western Indo-Gangetic plains calls for immediate diversification of this cropping system through introduction of more sustainable cropping system(s). This requires three considerations, viz., water requirement of the crops, economic return and possible market. With relative low water requirement coarse cereals, pulses and oilseeds can be a potent alternative to water guzzling crops like rice and sugarcane (Fig. 3). Considering water requirement and possible market demands and economic returns major crops which can replace rice during *kharif* season are maize, pigeonpea and soybean, and mustard and chickpea during *rabi* season to replace wheat. Mungbean with short duration can fit excellently well in these alternate

crops-based cropping systems ensuring additional income to the farmers and additional fertility to the soil.

A. Maize

Maize has almost one third water requirement of rice and less than one fourth of sugarcane, with cropping duration (100-110 days) less than rice (120 days) and sugarcane (~300 days). One Kg of maize grain requires 800-1000 lt of water against 3000-3500 lt of water for one Kg rice production. Maize residue with high C:N ratio than rice has faster decomposition,

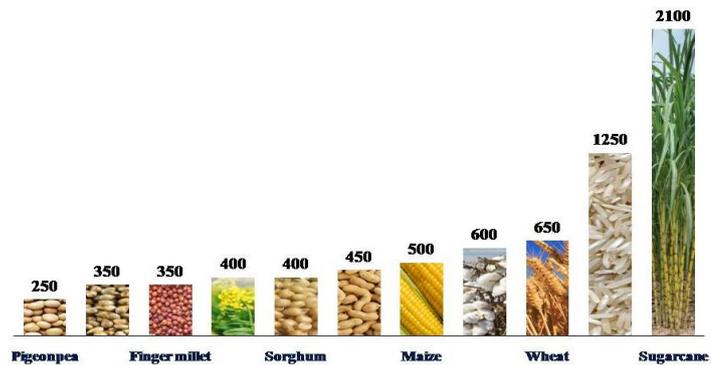


Fig. 3. Relative water requirement of various crops

thus has ability to add organic carbon to the soil and improving soil quality. Maize, particularly specialty corns can effectively be grown under organic system as sole or inter crop with other vegetables in peri-urban agriculture, giving avenue for additional income to the farmers. Maize followed by wheat has higher system productivity than rice-wheat system due to scope for early sowing of wheat crop leading to escape of terminal drought. Maize (900-1400 kg CO₂ eq/ha) has very less global warming potential (GWP) as compared to rice (3700-4700 kg CO₂ eq/ha). Rice production gives nearly 300-400 kg CO₂ eq/ha due to methane emission which is not with maize cultivation. Maize production consumes only 278 kwh/ha electricity as against that of rice with 2925 kwh/ha.

Maize has predominantly industrial uses like in feed, starch and recently for ethanol production, besides having niche area in processed foods in form of breakfast cereals, snacks and pet food in addition to use of specialized maize, viz., baby corn, sweet corn, popcorn and silage maize. Supply of good quality (dry and aflatoxin free) maize in bulk quantity can potentially help in establishment of such industries in the states and encourage contract farming benefitting both maize farmers and the industries besides generating employments and addressing environmental issues.

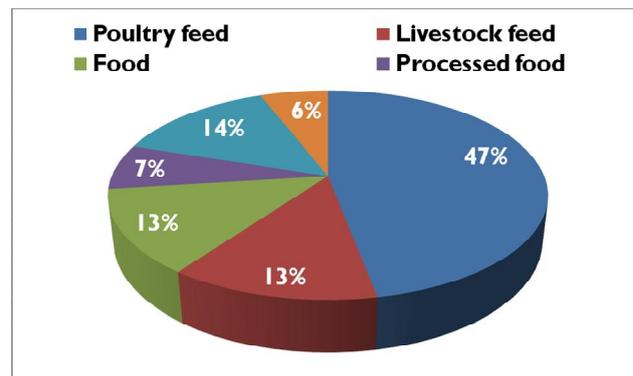


Fig. 4. Pattern of usage of maize in India

- Feed industry:** Maize with high energy value and less anti-nutritional properties like low fibre content has tremendous demand in feed industry. Over 47% maize is currently used in poultry feed and 13% in animal feed (Fig. 4). The current size of feed industry is 85-90 million tonnes. With projected growth rate of 8% in feed sector, particularly in poultry and cattle feed, demand for maize will increase by many folds. Punjab and Haryana can be a major supplier of maize in this regard.
- Starch industry:** The starch industry in India has a crushing capacity of approximately 65 lakhs tonnes. Maize is the most common raw material in starch industry. With projected growth of 5.1% in starch industry, demand for maize is going to increase further. Maize starch has wide utility in food, paper, pharmaceutical, textile industry and it can be used for production of bio-plastics, a way to address the issue of plastic pollution. A steady supply of maize will open up the avenue of employment generation in the region.
- Ethanol industry:** The government has set targets of 10% bio-ethanol blending of petrol by 2022 from current target of 5%, which is further targeted to reach 20% by 2030 to curb

carbon emissions and reduce India's dependence on imported crude oil. With 5% targeted blending the demand for ethanol stands at 4.2 billion litres, which by 2022 with 10% blending target sets to cross 6 billion litres, and by 2030 with 20% blending target the demand will cross 10 billion litres. Against this, the current production of bio-ethanol is around 3.0 billion litres. Sugarcane is the main source of bio-ethanol in India, while across the world maize grains are extensively used for ethanol production. Contrary to maize, sugarcane requires over four times water (Fig. 3) and has a crop duration of 10-15 months against maize of around 100-110 days. The yield of ethanol from sugarcane is ~5000 l/ha (70 t/ha cane yield) while maize gives ~2000 l/ha (5 t/ha grain yield). Thus, per unit time energy output from maize is much higher than sugarcane with a much lesser water footprint. The maize for ethanol also gives a high protein and oil-rich nutritious feed DDGS (Distilleries Dried Grains and Soluble) as a valuable by-product. Ethanol industry with a growth rate of 12.5% can create a huge market for maize grains.

- d. *Processed food industry*: Nearly, 10 lakh tonnes of maize is consumed in the processed food industry to prepare snacks, breakfast cereals and pet foods. The processed food industry with a 11.5% growth rate can absorb a significant proportion of maize produced. The popcorn industry has a current size of 90,000 tonnes with a market cap of around Rs. 550 Crore. However, 40% of the popcorn is imported, mainly from the USA. Baby corn and sweet corn also have huge potential to create rural entrepreneurship and catch the international market with added advantage to supplement the dairy industry with its by-products.
- e. *Silage maize, as an alternate source of fodder and livelihood*: Maize silage has huge potential with a current market size of 4-5 million tons. With a roughly 4.5% growth rate of the dairy sector, silage business is going to play an important role. Silage maize with a duration of around 80 days can increase the cropping intensity significantly and help in doubling farmers' income.

The cumulative demands as food, feed and starch have driven maize production in the country, which has increased by over 12 folds as compared to the 1960s. However, the projected growth rates in respective maize-based industries mean the demand for maize is expected to increase to 33 million tons by 2025 and nearly 43 million tons by 2030 (Fig. 5). Current production levels hover around 27 million tons. Thus, there is immense scope that increased demand in the domestic market itself can absorb the increased production. International demand for maize is also very high and India has a strategic advantage to cater to the needs of maize in south-east Asian countries.

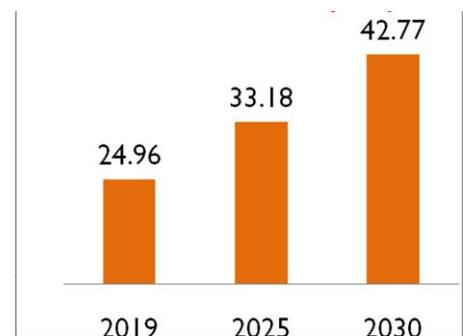


Fig. 5. Projected demand (million tons) of maize in India

B. Pulses

Pulses are a major source of protein for the majority of Indians, particularly the vegetarian population. India is the largest producer, consumer and importer of pulses in the world. The production trend in pulses in Fig 5 indicates that the country produced 12.0-14.0 million tons of pulses till 2010, which has reached at 24.0-25.0 million tons at present.

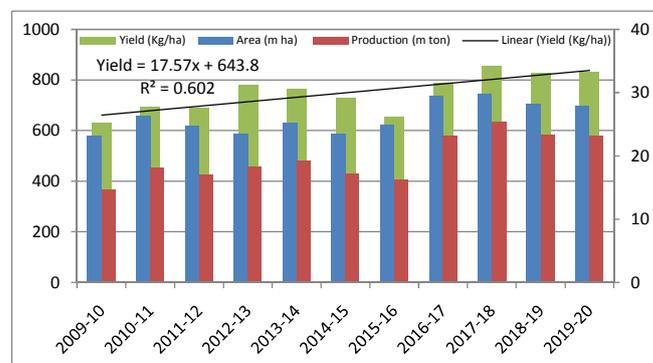


Fig. 6. Area, Production and yield trends of pulses in India

Pulses such as chickpea, pigeonpea, lentils, beans and peas form important part of general food basket in India. Promoting cultivation of pulses can help India overcome problem of malnutrition, improve soil fertility by nitrogen fixation and provide income support to farmers. Though India has attained self-sufficiency in pulse production, India can be a potential exporter of pulses like pigeonpea, chickpea, mungbean etc. Per cent share of different pulses in terms of production is given in Fig. 7 (with the highest of 45% for chickpea followed by 17% for pigeonpea) along with the future target for the commodity (Fig 8).

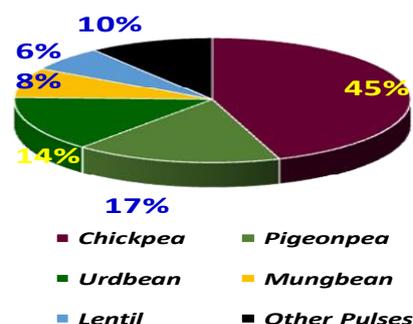


Fig. 7. Share of different pulses in overall pulse production

Pulses consume much lesser water than rice (Fig. 3). Pulses need to be promoted as it plays a crucial role in ensuring food security, public health, promoting environmental sustainability and climate change mitigation. Keeping in view of benefits accrued through pulses, diversification of rice especially with pigeonpea in rice-wheat cropping system assumes greater significance with the following advantages.

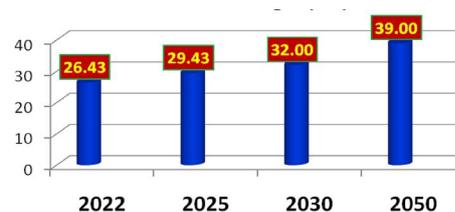


Fig. 8. Trend of demand for pulses in India

- Biological Nitrogen fixation:** Pigeonpea crop fixes around 40 kg N/ha through biological nitrogen fixation (BNF) which is equivalent to 87 kg urea (Rs. 870 without subsidy) leading to direct saving following its cultivation. Besides the crop also has a leaf and flower fall (and root residues) of 2-3 t/ha which supplies around 8-16 kg N, 2.5-5 kg P and 13.5-24 kg/ha of K which are available to subsequent crop(s) in rotation. In addition, pigeonpea crop requires less fertilizer as compared to rice and is regarded as soil building crop.
- Water use efficiency:** Water use efficiency is more than double for pulses (3 kg grain/ha-mm for irrigated rice to 6-8kg/ha-mm for pigeonpea and 12 kg/ha-mm for chickpea).
- Nutritional quality:** Nutritionally superiority of pigeonpea gives it an edge over rice. A 100 gram of rice (white, cooked) contains approx. 130 Cal energy, 28.7 g carbohydrate, 2.36 g protein and 0.19 g fat, while pigeonpea contains 335 Cal energy, 22.3% protein, 57.6% carbohydrate, 1.7% fat, 124 mg Ca, 304 mg P, 5.8 mg Fe, 133 mg Mg and a rich source of amino acids. Pulses are rich in lysine (67.1 mg compared to 30.5 mg of lysine /100 gram protein in cereals). Pulses are also rich in dietary fiber (fiber along with low fat and phytates causing lowering in blood cholesterol), hormone analogs (hypoglycemic effect i.e., lowering of blood sugar) and antioxidants (protection against cancer). Health benefits of pulses are thus huge as these are having high nutritional value. Besides these, these also prevent several chronic diseases such as cardiovascular ailments, diabetes, blood pressure, obesity and cancer. Pulses have low glycemic index (29-48) which is attributed to presence of slowly digestible starches and resistant starches. Therefore, these are considered as nutritionally important crops.
- Multiple uses:** Pulses especially pigeonpea has multiple usages as *dal*, *dal*-mix, by-products for biscuits and other value added products. Traditionally, it has been used with proven diversity including lac production, fuel wood, soil conservation, fodder, food and medicine.
- Cost of production:** Pulses are having lower cost of production (Rs. 6000 to 9000/ha less) over that of rice as rice has a relatively complex process incurring higher expenses for growing it (nursery raising, transplanting etc). Besides these, relative average gross return for pigeonpea is higher (173% for pigeonpea compared to 100% for rice).
- Import bills:** Possibility of lowering down of country's Import Bill through higher production of pulses. In fact, as a result of higher production of pulses, imports of pulses

declined to about 1.8 million tons during April-Dec 2018, as against over 5 million tons during April-Dec 2017. Similarly, pulses especially pigeonpea has a great demand within the country and outside including SE Asia.

C. Oilseeds

India meets 60% of the domestic edible oil requirements valued INR 78000 crores through imports. The country needs 25 million tons of edible oils to meet its present requirement at the current consumption level of 19 kg per person per annum. It has to increase 33.4million tons edible oils from 47.7 million tons oilseed to feed 1.43 billion population by 2025. In this context, during *kharif* season soybean and during *rabi* season mustard can be a very potential crop to replace area under rice and wheat, respectively.

C1. Soybean

Soybean is one of the main oil seed crop and is also the only vegetable crop with high protein content. Soy milk is cheaper than other sources and has a promise for flavoured milk with varieties developed having less beany flavour. Tofu, prepared from soybean is highly nutritious and is complimentary to paneer. Soybean also has many therapeutic usages like overcoming problems related to menopause because of the presence of estrogen like compound and presence of oflavones which protect from cancer. Soybean holds potential as vegetable to be grown between April to July since green peas are not locally available. Indian Soybean deoiled cake too is in high demand and accrues foreign exchange to the worth of Rs.3349 crore during 2019-20, which is extensively used in feed industry along with maize.

- a. *Crop demand in present and future*: Soybean processing industries are being operated only to their 50% capacity and the huge demand for oil and feed exists in the country which may be met by increasing soybean production. Soybean also has high potential in the secondary agriculture sector.
- b. *Industrial Usage*: Soybean has industrial usages apart from edible oil and the food usage such as soy milk, soy chunk etc. Soy isolate may have use as supplement and protein bars. Lecithin is a by-product used in the chocolate industry, fermented soybean, vegetable soybean and feed are other uses wherein soybean may find a niche market.
- c. *Profitability*: The cost of cultivation for soybean is around Rs. 30000/- as compared to that of rice (Rs. 78,000/-).
- d. *Fertilizer subsidy*: The estimated N contributed through residual biomass of soybean (RBNS) that include biological nitrogen fixation, leaf fall, root nodules and rhizo deposition accounts to around 50 kg N/ha which corresponds to roughly 110 kg urea. Moreover, soybean also provides other nutrients like P, K and micronutrients for the subsequent crops. The amount of N applied to soybean is only 25 kg N/ha as compared to rice (120 kg N/ha).
- e. *Organic Production*: With the increasing trend towards organic farming there is great potential of organic food and feed form soybean for use domestic as well as for exports.
- f. *Vegetable protein benefits*: Soybean protein is the most economical source of protein and is considered as a complete protein like milk and egg.
- g. *Multiple uses of the crop*: Soybean has multiple usages for oil, soy isolate, soy chunk, lecithin, vegetable soybean, fermented soybean, neutraceutical and feed.
- h. *Water footprint*: The water use and efficiency with regards to soybean cultivation is around 75-80 cm and 20-25 kg ha-cm⁻¹, respectively and these are much better than 90-250 cm for rice.
- i. *Soil health and addressing environmental issues*: Soybean cultivation improves soil health through symbiotic nitrogen fixation. Soybean residues may be a substrate for mushroom industry and decomposed very fast, not requiring burning unlike the paddy straw. In soybean, maximum values of GHG emissions amount to 59% to 85% are due to N₂O and methane emissions represent less than 3%. In contrast to this maximum GHG emission in rice is from methane which has been estimated to 875 kg/ha/season (Bhat and Beri, 1996) at Ludhiana.

C2. Mustard

Mustard is a potential *rabi* oilseed crop to replace area under wheat with substantial consumption potential in industrial consumption. It has relatively lesser water requirement (300 mm) lesser wheat (600 mm). The crop has good production potential, where the cultivation is supported with suitable technology intervention and knowledge inputs. It can be grown under diverse agro-climatic zones in both irrigated and rainfed areas with ability of salt tolerance. It is suitable for sole and mixed cropping. This gives higher return with low cost of production. Mustard oil has lowest saturated fatty acid and seed meal has high content (36-38%) of quality of protein.

3. Recent APY of plausible diversifiable crops

Among the proposed crops for diversification of rice-wheat cropping system maize has highest percentage, while soybean has extremely limited area under cultivation in Punjab and none reported in Haryana. Among these crops, maize has the highest yield realization (37.1 q/ha and 26.4 q/ha in Punjab and Haryana, respectively). Though the area of maize has dropped substantially in Punjab over last several decades, mainly due to in roads of rice, in recent past it has recorded a positive growth trend in area at 21.1% CAGR from 2017 (Fig 9, Annexure I). The area under other crops are relatively stagnant at around 2.45 thousand ha for pigeonpea, 30.5 thousand ha for mustard. In case of Haryana the area under maize recorded a negative growth of 19.4% CAGR from 2010. The area under other crops in Haryana were around 3.0 thousand ha for pigeon pea and 579 thousand ha for mustard.

4. Value chain of candidate crops

Maize value chain: Maize-based value chain is quite extensive, which principally may be dealt as feed, starch, ethanol, processed food, processed specialty corns (baby corn and popcorn) and silage. While use of feed, starch and ethanol requires establishment of dedicated factories, processing of maize for food like snacks and breakfast cereals or pet food requires smaller processing plants. Baby corn and popcorn processing also can be done in a micro level through aggregation of FPOs and SHGs.

Pigeonpea value chain: The awareness generation regarding BNF, leaf fall and other carryover effects by pulses in addition to less water use can further convince the farmers to reduce the usage of fertilizers especially N fertilizers. To attain socially optimal level of pulses farming, the pulse growers should be provided additional support for their services to environment also. Encouragement could be provided in the form of equivalent subsidy on phosphorus fertilizers as P application in pulses increases nodulation and nitrogen fixation and balanced nutrition besides increasing yield of these crops (Ideal NPK ratio of 4:2:1). On ecology front, this could result in reducing GHG emission and preventing other issues associated with synthetic fertilizers production, like health, eutrophication and pollution. Pigeonpea produced locally can be transported to consumer states for its processing and consumption. It can be processed locally (*dal*) and transported to consumer states (with better transportability/storability due to split *dal*) for sale (under both PDS and Open market). Some of the quality produce can be processed for export (bolder and perfect-colored ones). A part of the produce can be kept as seed for future use. Lot of scope exist for pigeonpea based value addition including its by-product use. Several homemade recipes (barfi, ladoo, sev, kachri, sweet puries, kachauri masala) are made from pigeonpea milling by-product. Biscuit is developed incorporating husk

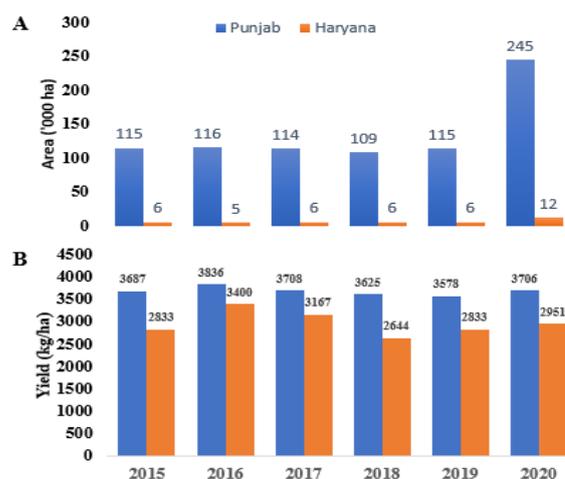


Fig. 9. Change in area under maize in Punjab and Haryana from 2015

Table 1. SWOT analysis of plausible crops for diversification in Punjab & Haryana

Parameters	Maize	Soybean	Pigeonpea	Rapeseed & Mustard
Strength	<ul style="list-style-type: none"> ❖ Mechanized cultivation - Seed to Seed ❖ Industrial uses - Feed, Starch and Ethanol ❖ High yield and highest growth rate among cereals ❖ Water and energy saving - 80% over rice ❖ Low GHG emission ❖ Diverse uses and types - sweet corn, pop corn, baby corn and silage ❖ Livestock promotion - complement well 	<ul style="list-style-type: none"> ❖ Suitable for mechanized cultivation ❖ High protein crop suitable for food usage ❖ Industrial uses - high oil and soy meal for feed industry ❖ Water and energy saving over rice. ❖ Low GHG emission 	<ul style="list-style-type: none"> ❖ Highly nutritive crops ❖ Fixes atmospheric nitrogen ❖ Industrial uses - Dal and by-product making ❖ Water and energy saving (80%) over rice ❖ Diverse uses and types like Food, Value addition and Fuel ❖ Tolerate partial drought and heat condition ❖ Low GHG emission 	<ul style="list-style-type: none"> ❖ Mechanized production, processing and value addition ❖ Suited for diverse agro-ecological situations ❖ Water energy saving (<half of wheat) ❖ Diverse usages - Quality oil (Canola), Medicaments, Lubricants, Super food etc. ❖ Quality oilcake for animal feed ❖ Tolerate to moderate salinity and drought conditions
Weakness	<ul style="list-style-type: none"> ❖ Waterlogging susceptibility, more at early crop stage ❖ High moisture at harvest leading to aflatoxin contamination and lower realized market prices ❖ No policy support 	<ul style="list-style-type: none"> ❖ Lack of market intelligence and linkages ❖ Vulnerable to unpredictable climatic variability ❖ Limited popularity as food ❖ No policy support ❖ Lack of awareness about the soybean crop benefits. 	<ul style="list-style-type: none"> ❖ Susceptible to water logging at initial stage ❖ Vulnerable to unpredictable climatic variability ❖ Lack of market intelligence and linkages 	<ul style="list-style-type: none"> ❖ Susceptible to water logging at initial stage
Opportunity	<ul style="list-style-type: none"> ❖ Market demand: domestic and export ❖ Value addition and employment generation ❖ Enhanced livestock productivity ❖ Demand for bioethanol ❖ Gluten free atta is gaining demand ❖ Climate change 	<ul style="list-style-type: none"> ❖ Demand of processing industries in adjoining states ❖ Opportunity for establishment of high value soy protein isolate industry ❖ Value addition and employment generation 	<ul style="list-style-type: none"> ❖ High demand for consumption due to taste ❖ Opportunity for establishment of processing industry ❖ Value addition and employment generation at block and village level 	<ul style="list-style-type: none"> ❖ Demand in domestic and international market (Canola oil). ❖ Value addition and processing ❖ Quality animal feed
Threat	<ul style="list-style-type: none"> ❖ Damage by wild animals like blue cow, stray cattle ❖ Poor drying and storage facility 	<ul style="list-style-type: none"> ❖ Import of soy and its oil ❖ Unpredictable climate ❖ Appearance of new diseases 	<ul style="list-style-type: none"> ❖ Problem of blue cows ❖ Pod borer infestation ❖ Climate change effect is high 	<ul style="list-style-type: none"> ❖ Biotic stresses like aphid and stem rot ❖ Climate change (early and terminal heat and frost).

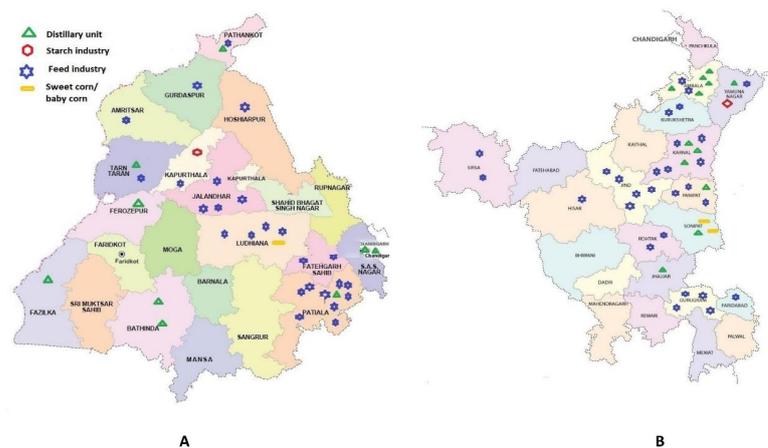
and cotyledon powder mixture in different proportions. Value added products from pigeonpea milling by-product are rich in protein, fiber and phenols, thus, have higher food value. Fractional separation of pigeonpea milling by-product yields 25% cotyledon powder for making *dal* analogue by unheated extrusion. Powder fraction can directly be poured into boiling water to make *dal*. Colour of *dal* is little brownish (due to husk in the mixture) while protein content is similar to dal. Alternatively by-products are useful for soup, gravy thickener and protein enhancer.

Soybean value chain: Soybean is one of the major candidate for crop diversification in Punjab and Haryana with its value chain involving stakeholders at pre-production, production, post production and processing (quality seed, input supplier, mechanization, oil processors, soy food cottage industries for the manufacture of soy products like soy milk, soy paneer (tofu), vegetable soybean, soy protein concentrates, cold oil processing industries) and consumers.

Mustard value chain: Rapeseed-mustard has a broad diversity of oil-types in addition to canola or high-oleic and low-linolenic cultivars. Moreover, its oil contains valuable minor compounds such as tocopherols (vitamin E) and phytosterols. Enhancing such components by breeding may result in value addition. The meal contains relatively high amounts of anti-nutritive fibers, phenolic acids, phytate and glucosinolates. Break down products of glucosinolates such as allyl isothiocyanates, which are present in the seed meal fraction of oilseed Brassica, have anti-cancerous properties. Isolation of these compounds would add value to this crop. The future thrust in quality improvement would be to improve the nutritional and storage quality of rapeseed-mustard seed meal contains high-quality protein that can be used as a valuable animal feed. Biscuits fortified with mustard flour were found acceptable in nutritional, sensory and textural characteristics. Defatted mustard flour replaced wheat flour at 5, 10, 15 and 20% incorporation levels in biscuit preparation. There is scope to establish different value chains from production to processing and supply for quality oil (single zero, double zero, high oleic oils etc.), quality mustard oilcake (primary and secondary products) and secondary oil products (medicinal and medicaments) in the region. Already, Canola mustard is under cultivation in Punjab, which may be increased further to cater the domestic need as well as export promotion.

5. Mapping of diversifiable crop specific processing industries in Punjab and Haryana

Maize: Maize is principally used in the feed industry. There are more than 26 feed factories in Punjab and 28 in Haryana (Fig. 10). The feed, mainly poultry feeds produced by these firms are being locally consumed. There is one starch industry in Jalandhar and Yamunanagar each. However, all these factories predominantly import maize grains from outside the states, viz., Bihar, Madhya Pradesh, Maharashtra and others. There are 9 distilleries in Punjab and 12 in Haryana (Fig. 10). Though these distilleries absorb much of the locally produced grains, they are also dependent on supply of maize grains from outside the state. Thus, these industries assume much potential to process maize



*picture is indicative not to scale

Fig. 10. Mapping of maize based industries in Punjab (A) and Haryana (B)

grains if produced locally. Maize-based food processing plants are not documented yet in these states. The food processors are apprehensive of aflatoxin contamination and soft grain traits in the local produce. Speciality corn processing has immense potential. In Ludhiana there is a baby corn processing unit, which mainly caters the export market in Europe. The baby corn

and sweet corn processing hubs in Sonapat district is a living example of the kind of revolution in rural economy these technologies may bring in.

Pigeonpea: With the rising per capita income and increasing population, demand for pulses has increased over the years. There is very lesser establishment of the processing and value addition industry for pigeon pea in the region owing to very less raw materials availability. The *dal* mills could be established for value addition and the present rice mills establishment could be explored with suitable modification.

Soybean: Punjab is the number one state in utilizing soybean for food usages and where about 200 small scale industries (tofu, soy-milk, soy chap, soy nuts etc.) spread over the state are operating presently. However, oil extraction is at a very low scale (~50 Kg/day) and limited to cottage industry since soybean production from these states is negligible.

Mustard: Mustard is principally consumed as edible oil in human diet. The by-product, oil cake is used in animal feed due to high protein content. Oilcake also used for value added products like fortified biscuits and flour. The mustard oil is rich in certain secondary compounds, which may be separated for medicinal and medicaments usages. Thus, there is lot of potential for both primary and secondary industrial growth in and employment generation in this region. In Punjab and Haryana, more than 100 mustard oil extraction units exist, and processing and branding the oil as organic, value-added, *Kachi Ghani* and refined FSSAI certified oils. However, most of these units run short of produce locally, and source either seed or *Kachi Ghani* oil from Rajasthan and Uttar Pradesh. There is no documented information about secondary value added products industries, however, have great potential in near future. Mustard cake in animal feed may also play significant role in increasing milk production and related industries in this region.

6. Competitive analysis of various crops vis-a-vis rice-wheat cropping system

Any crop substitution should be looked in system perspective, rather than individual crop output. Table 2 makes a comparison of the system perspective of different *khariif* crop base system. It is clearly depicted that alternative cropping systems are much more sustainable than rice-wheat cropping system. Table 3 suggests various cropping systems, which have been compared with the rice-wheat cropping system. It may be observed that the system productivity and profitability from all the alternative cropping systems is higher than that of rice-wheat cropping system with substantial savings on energy/electricity. It is often said that though maize has demand but it has failed to play a key role in diversifying rice in Punjab and Haryana. The realized price difference between rice and maize is key factor in this regard, while rice is procured on assured MSP, maize farmers, on an average receive Rs. 900 per quintal of maize grains in Punjab and Haryana. However, an empirical calculation based on current average productivity of rice and maize shows that rice has marginal advantage over maize provided the MSP is realized in both the crops (Table 4). Thus, to procure maize from one lakh ha vis-a-vis rice there will be additional expenditure of Rs. 89.35 cr in Punjab and Rs. 24.56 cr in Haryana. This cross subsidy can easily be diverted due to the savings in water, electricity and the pollution costs due to rice residue burning. The government can also pay the differential pricing (MSP minus market price) to the farmers directly through direct benefit transfer (DBT) without direct buying and thus expenditure on this can be reduced substantially. The above figures of cross subsidy are with existing productivity of maize in the states. However, extensive introduction of high yielding maize in a cluster manner can potentially increase the average productivity and thus, the cross subsidy may be slowly reduced. However, procurement of maize with this subsidized price needs to be ascertained through implementation of strict law. Considering demands for maize in this region, the price is not expected to be too low in open market.

Table 2. Candidate crop based cropping system (CS) advantages over rice-wheat CS

Parameters	Rice-wheat	Maize-based	Pigeonpea-based	Soybean-based
Water requirement	Very high	Low (8-times lesser than rice)	Low	Low
Water productivity	Low	High	Very high	High
Residue burning	Very high	No such problem.	No such problem.	No such problem.
Ground water pollution	Nitrate and pesticide leaching.	No such problem	No such problem.	No such problem.
Duration	Long (120-130 days)	100-110 days	120-150 days	120 days
Planting/crop establishment	Cumbersome and labour consuming	Easier, only direct seeding	Easier, only direct seeding	Easier, only direct seeding
Per day productivity	Less	Higher	Medium	Medium
Mechanization	Partially mechanized	Fully mechanized	Not possible	Fully mechanized
Soil physical health	Degrading crop	Restoring/improving crop	Restoring/improving crop health	Restoring/improving crop
Agrochemicals	More leaching	Less leaching	Avery less leaching	Less leaching
Cropping system optimization	Subsequent crop is affected, resulting in low system productivity & profitability.	Subsequent crops benefitted and results in higher system productivity and profitability.	Subsequent crops benefitted and results in higher system productivity and profitability.	Subsequent crops benefitted and results in higher system productivity and profitability.
Climate resilience	A photo synthetically less efficient C ₃ plant, results in higher emission of GHGs (methane, nitrous oxide) under increased temperature.	A photo synthetically efficient C ₄ plant, there is no photorespiration under increased temperature results in lesser GHGs emission.	Lesser GHG emission and reduced urea consumption	Lesser GHG emission and reduced urea consumption
Policy intervention	Assured procurement at MSP.	Presently no such policy.	Assured procurement at MSP.	Incentivization to farmers as soybean is not a established crop in this region.
State requirement/demand	Surplus	Highly deficit	Highly deficit	Highly deficit
Use of biomass/ residue	High silicon deters for use in livestock, problem of collection, burning due to less turnover time for wheat seeding.	Green fodder used for animal fodder, easy dry fodder collection, easily decomposable, can be kept on the soil surface with zero-till planting or can be used for mushroom production.	Easily decomposable, can be kept on the soil surface with zero-till planting	Easily decomposable, can be kept on the soil surface with zero-till planting
Livestock promotion	Not much scope as mostly used for food and straw unsuitable for livestock.	Wider scope for livestock promotion as green fodder, silage and grain for feed. The fodder can be used for grazing/feeding to livestock at any stage of crop growth. It has no risk of any anti-nutritional compound.	Not much scope	Soybean meal in livestock feed

Parameters	Rice-wheat	Maize-based	Pigeonpea-based	Soybean-based
Poultry industry growth	Less suitable.	Most suitable as major feed ingredient.	-	Most suitable as an feed ingredient.
Value addition	Lesser opportunity due to more direct food consumption	More opportunity as 1000s of the products can be made from different types of maize.	More opportunity as many products can be made by food processing.	More opportunity as many products can be made by food processing and also for oil extraction.
Export opportunity	Only basmati has competitive market.	Grain, feed, starch and baby corn has great potential for the export in neighbouring countries as well as high value developed economy due to low cost of internal production and high external demand.	Yes	Yes
Conservation agriculture	Very less scope	Highly suitable for conservation agriculture.	Suitable for zero-till wheat growing.	Suitable for zero-till wheat growing.
Electricity and power/energy	Very high requirement for water pumping and urea	Very less requirement (82% lesser water than rice)	Very less requirement owing to lesser water and urea	Very less requirement owing to lesser water and urea
Transportation cost of commodity	Non-basmati rice used in PDS incurs huge transportation cost to make available in whole country.	Extra cost of transportation incurred in import of maize from other state which increases the cost of raw material for industry.	Less due to high demand in each state	Transportation of produce to oil processing industries is required.
Handling and post-harvest losses	High, extra infrastructure for storage of surplus rice is required.	Low, no carry stock due to shortage in the state and multiple industrial uses.	Very low compared to other pulses	Medium, seed viability loses fast and care is required for proper transportation
Silage	Not suitable	Best material for making silage which can be used in livestock and exported after meeting internal requirement.	Not suitable	Not suitable
Intercropping scope	Not suitable	Most suitable crop for growing pulses, vegetables and flowers due to wide spaced rows of the crop.	Can be intercropped with, bajra, jowar, mungbean & urdbean etc.	Can be intercropped with maize
Dietary diversification and nutritional security	Lesser opportunity	Quality protein maize can be integrated in diets of all group person for nutritional security.	Meets the protein requirement at household and National level	Meets the oil and protein requirement and reduced import bill for India.
Overall cropping system profitability	Less	More	More profitable @170% return	More

Table 3. Comparison of rice-wheat vs plausible futuristic cropping system for diversification in North-western IGP.

Cropping systems	Potential yield (t/ha)	Cost of cultivation (lakh/ha)	Net returns (lakh/ha)	Mechanization	GHG	Soil health	Residue burning problem	Water productivity (kg grain m ³)	Market demand	Energy/ electricity saving
Maize-wheat-mungbean with CA	16.04	0.82	1.85	Fully mechanized	4 times lesser than rice	Improves	Residue is used in livestock and easily degradable	2.37(678 ha mm)	Very high and increasing	82%
Maize-wheat-mungbean conventional	14.64	0.87	1.62	Fully mechanized		Improves	Residue is used in livestock and easily degradable	2.07	Very high and increasing	80%
Pigeonpea-wheat-mungbean	10.25	0.32	1.04	Partial mechanized	4 times lesser than rice	Improves	Residue is used in livestock and easily degradable	5.10	Very high and increasing	80%
Soybean-wheat-mungbean	20.94	0.98	2.09	Fully mechanized	Lesser than rice	Improves	Residue is used in livestock and easily degradable	4.35	Very high and increasing	75% as compared to rice
Maize-mustard-mungbean	14.84	0.78	1.80	Fully mechanized	Less	Improve	Residue is used in livestock and easily degradable	7.00	Very high and increasing	90%
Maize-potato-water melon	57.0	3.50	2.50	Partially mechanized	Less	Improves	Residue is used in livestock and easily degradable	Very high	Very high and increasing	80%
Rice-wheat-mungbean	16.19	0.93	1.69	Partially mechanized	Very high	Physical health degrades	Problematic	0.73 (2290 ha mm)	Decreasing	High energy intensive system
Rice-wheat	13.33	0.91	1.28	Partially mechanized	Very high	Deleterious effect	Problematic	0.59 (2340 ha mm)	Decreasing	High energy intensive system

Table 4. Comparative return from rice and maize and compensation requirement for maize in Punjab and Haryana

Crop	Average state productivity (kg/ha)		Return per ha @ MSP (Rs. in thousand)		Additional compensation to maize to equate return comparable to rice on account of savings on ecology, energy and health (in Rs./quintals)	
	Punjab	Haryana	Punjab	Haryana	Punjab	Haryana
Rice	4165	3172	77.8	59.25	240	80
Maize	3723	3070	68.9	56.79		

It may also be bore in mind that maize being more an industrial crop even if government procures and stores, with assured supply the grains will be readily procured by the industries. During peak supply, of maize grains, the government can procure maize under MSP and sell during low supply period, when the price rises. Thus, government can sell the procured grains even at higher prices leading to earning to the government. Overall savings to the government with initial spending on infrastructures like dryers, silos etc. will be much higher than current investment on rice-wheat procurement.

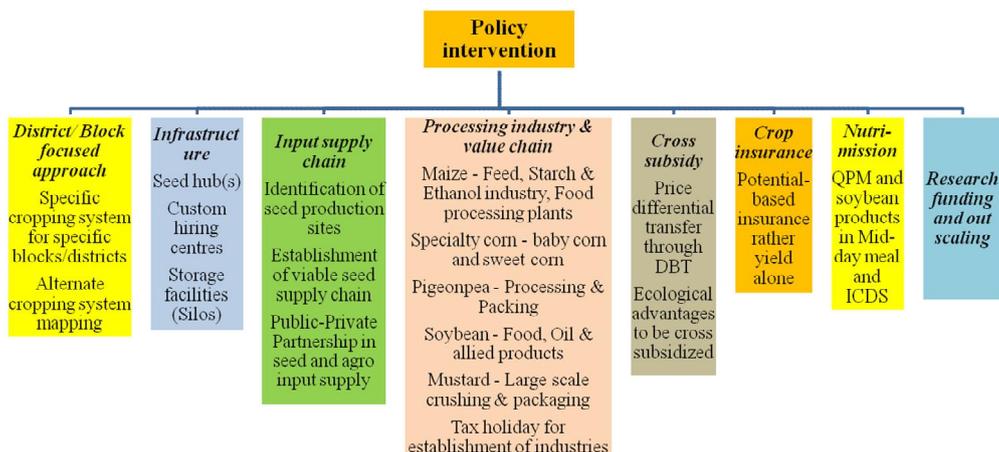
7. Suggested intervention

A. Policy intervention

Prevailing policy support favours the rice-wheat cropping system. In recent past, much policy support is being given to prevent burning of rice straw with limited success. Time has come to divert policy support to those cropping systems, which favours the challenges of depleting water table, fragile ecology and energy with substantial economic return in a sustainable manner. In this regard, the alternative cropping systems need policy support as follows:

- a. **Adoption of district/block approach:** Any alternate crop-based diversification should be intensely focused in selected districts with lighter soil facing stiff challenge of ground water depletion in one hand and availability of processing plants/factory on the other. In Punjab, Hoshiyarpur, Ludhiana, Kapurthala and Jalandhar, and in Haryana Hisar, Fatehabad, Sirsa and Karnal may be focused in first phase. Mapping of alternate cropping systems is given in Annexure II.
- b. **Creation of infrastructure:** Each crop has enabling technologies in terms of high yielding cultivars (Annexure III-VI) and crop production technologies for Punjab and Haryana. Steady supply of quality seed is foremost important. This calls for **creation of seed hub** with adequate linkages with the seed production agencies at various sites. The seed hub may be created in the campus of ICAR-IIMR, Ludhiana to cater the need of all the crops (maize, pigeonpea, soybean and mustard). Seed-to-seed mechanization is well established in maize and soybean, and partially in pigeonpea and mustard. Crop-wise requisite machineries (Annexure X) are to be made available to the selected clusters in a subsidized rate. In this context **farm machinery bank or custom-hire centres** need to be established in cluster mode. Rural youths, FPOs and SHGs are to be encouraged in this regard. Post harvest handling and storage is of particular concern in case of maize. Dryers of moderate capacity (2-4 t per batch) need to be made available at custom-hire centres (CHC). Post-harvest **storage facilities in the form of silos** may be provided at block level on hiring so that the produce (maize grains) may be stored safely and to avoid distress selling.

- c. **Enabling seed supply chain:** Since maize, pigeonpea, soybean and mustard are not a major crop in this region less focus is being given on cultivation of high yielding cultivars by farmers and the availability of seed is less in the region. For example, in the main maize growing belts of Punjab OPVs are frequently cultivated to meet the domestic needs. Hence, special attention is to be given to produce and supply quality seeds timely. National Seed Corporation (NSC) and state seed corporations need to be more actively engaged in seed production of maize and pigeonpea hybrids and varietal seeds of soybean and mustard, which is not receiving much attention of the NSC and SSC at present. Seed production of these crops should be incentivized.



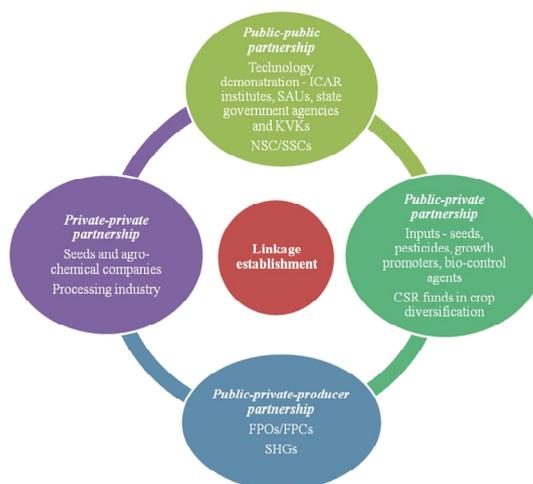
- d. **Establishment of processing industries and facilitation of new value chain:** Farmers will never be encouraged unless proper market is created for sale of their produce. Value chain development will play a crucial role in this regard. Maize is extensively used in feed, starch, processed food and in recent past in ethanol industries. Similarly, pigeonpea needs processing and packaging. Soybean in processed in various forms for food, oil and other products. Mustard processing also needs extensive industrial interventions. Since these crops are not of much relevance in the region, such industries are lacking or running below the capacities. **Tax holidays** to such industries will encourage their establishment and creation of market for these crops. Government-Industry Summits need to highlight these possibilities to encourage private/corporate investment in establishment of such industries in the states. Specialty corn based value chain can create substantial job opportunities and earnings to the farmers. Similarly, apiculture can be integrated with mustard cultivation. FPOs and SHGs need to be incentivized to create maize-based processing plants.
- e. **Cross subsidization of alternate cropping system in lieu of ecological benefits:** Current policy support is in favour of maize-wheat cropping system but with a huge impact on ecology, health and public procurement, storage and distribution. Existing market scenario also supports rice and wheat. Shifting to any other cropping system needs some added tangible benefits to the farmers. Realized market prices of majority of the crops other than rice and wheat are mostly much lower than the MSP. Transfer of price differential directly to the farmers through DBT scheme will provide level a field for the alternate crops. Taking into consideration of the savings on water, energy, ecology and health in one hand and public procurement, storage and distribution on the other, this cross subsidization will cause lesser dent on government overall spending.
- f. **Crop insurance for alternate crops:** The crop insurance policy to be revised for maize, pigeonpea, soybean and mustard based on existing potential of the cultivars.
- g. **Introduction of QPM and Soybean in nutri-mission:** Nutri-mission of government is contributing immensely addressing malnutrition of the country. QPM has proven

benefit in terms of nutrition. It has biological value close to milk. ICAR has QPM hybrids with experimental yield potential of 6-7 t/ha for Punjab and Haryana. However, due to lack of market demand QPM hybrids are not gaining popularity among farmers. Introduction of QPM-based products like grits, porridge etc. in the mid-day meal and other mass nutrition programme like Integrated Child Development Services (ICDS) will help in creation of market for QPM. Similarly, soybean products also may be included in nutri-mission to increase the demand of soybean.

- h. **Enabling policy to support bio-ethanol production from maize:** Bio-ethanol production from maize has immense potential to create huge demand for maize to commensurate the ethanol-blending target envisaged by the government. The bio-ethanol industry is to be delinked from physical intervention of excise department.
- i. **Funding for research and out-scaling projects of diversification:** Though diversification efforts are being made for long, it has made limited success in the states till now. Only during recent past in Punjab the maize area has increased at 21.1% CAGR from 2017, while in Haryana the area under maize recorded growth of 19.4% CAGR during the same period. This indicates that the efforts by the states and ICAR to diversify rice cultivation with maize are giving some yield but this needs to be intensified. Government funding in research on maize and other proposed crops needs to be augmented to meet the changed scenario. Large-scale demonstration of various cropping system will play an integral role in this regard.

B. Establishment of linkages

Awareness and popularization of alternate cropping system will play an important role. Technology demonstration through **Public-public partnership** involving ICAR institutes, SAUs, state government agencies and KVKs will play a key role in this regard. Linkage of NSC/SSCs with the government departments in terms of technology transfer will play a key role in this regard. **Public-private partnership** with private companies in terms of input (seeds, pesticides, growth promoters, biocontrol agents) providers can play a catalytic role in this regard. NGOs working at grass root level will also be an important component in the process. Tapping of CSR funds in crop diversification may also play a key role. **Public-private-producer partnership** to handhold the FPOs and SHGs in alternate value chain can create avenue for entrepreneurship development. **Private-private partnership** enabling contract farming with assured input supply and purchases will catalyze the process of diversification. In the process feed/starch/food processors can join hands with the seed companies to supply right quality seeds, agro-chemical companies for supply of agro-inputs and can directly purchase the farm produce from the farmers' field for local consumption. Partnership between starch and feed industry to utilize starch industry byproduct, DDGS will be mutually beneficial. Even cross commodity linkages like soya processor with maize-based feed processor can significantly benefit the whole ecosystem.



8. Road map for diversification

Action point	Responsibilities	Timeline
Publicity of advantages of alternate cropping systems over rice-based cropping system	State governments, KVKs, ICAR-IIMR, ICAR-IIPR, ICAR-IISR	First fortnight of May
Inclusion of machinery in maize, soybean and pigeonpea cultivation under subsidy net	State governments, DAC&FW	First fortnight of May
Maize/Pigeonpea/Soybean Divas	State governments with participation of SAU, ICAR-IIMR, ICAR-IIPR, ICAR-IISR, Farmer, Seed and input companies/dealers/traders, maize using industries (feed, poultry, starch)	By 15 th May
Training to master trainers of state departments	State governments, SAU, ICAR-IIMR, ICAR-IIPR, ICAR-IISR	By 15 th May
Arrangement of seeds (hybrids for maize and pigeonpea, and varieties for soybean)	State governments or as per directives of the government to farmers for direct purchase from market	By 25 th May
Handover of diversification kit (seed, agrochemical and literature) to farmers	State departments	By 30 th May
Arrangement of machinery for sowing for maize	State governments	By 30 th May
Training to block level officials	State governments	By 30 th May
Training to farmers with lecture, literature and input	State departments in association with SAUs and ICAR-IIMR, ICAR-IIPR, ICAR-IISR	By 05 th June
Reimbursement of seed and agrochemicals for maize, pigeonpea and soybean production through DBT	Dedicated online portal of state government	10 days after sowing of crop
Incentives for adoption of alternate cropping system through DBT	Dedicated online portal of state government	By 30 th July
Provision of harvesting equipment for maize and pigeonpea to CHCs	State departments	By 15 August
Seed availability of early season vegetables in peri-urban interface in maize system	State government	By 15 th September
Procurement of maize, pigeonpea and soybean from farmers	State Government or tax rebate to industry	After harvesting
Publicity of advantages of mustard cropping	State governments, KVKs, ICAR-DRMR	Second fortnight of

Action point	Responsibilities	Timeline
		September
Mustard Divas and training to farmers with lecture, literature and input	State governments with participation of SAU, ICAR-DRMR, Farmer, Seed and input companies/dealers/traders, maize using industries (feed, poultry, starch)	By 15 th October
Training to master trainers of state departments	State governments, SAU, ICAR-DRMR	By 15 th October
Arrangement of seeds	State governments or as per directives of the government to farmers for direct purchase from market	By 20 th October
Handover of diversification kit (seed, agrochemical and literature) to farmers	State departments	By 20 th October
Training to block level officials	State governments	By 20 th October
Reimbursement of seed and agrochemicals for mustard production through DBT	Dedicated online portal of state government	10 days after sowing of crop
Incentives for adoption of alternate cropping system through DBT	Dedicated online portal of state government	By 30 th November
Felicitation of the farmer/village adopting or official efforts towards successful diversification	State government in District/State level function	Continuous
Establishment of corn/pigeonpea/soybean/mustard villages (input and marketing support)	CSR funds of the industries working in the states duly facilitated and documented by State Government	Continuous
Establishment of maize/pigeonpea/soybean/mustard farmer producer organization/SHGs establishment	State government	Continuous
Establishment of quality protein maize villages for nutritious food, feed and silage	Processing industries with incentives by state government	Continuous
Establishment of baby corn, sweet corn and pop corn villages establishment	Processor, exporter and FPOs with incentives by state government	Continuous
Promotion of silage from maize for dairy and export	State government through subsidy/incentive on machinery	On demand of farmer/FPO/SHG

on mechanization may support the CHCs in procuring the implements. Input subsidies for seeds and agro-chemicals may be transferred to the farmers adopting the system through direct benefit transfer (DBT) along with incentives to adopt the cropping system. Farmers Producer Companies (FPCs), Farmers Producer Organizations (FPOs), Self Help Groups (SHGs) and others may act as aggregator to link the farmers to the maize processing companies. Such aggregators may be provided with higher capacity dryers and silos for long-term storage of maize grains. National Rural Livelihood Mission (NRLM) can play a key role in forming FPCs/FPOs/SHGs with and supporting the CHCs. Money directly paid to the farmers based on grain moisture standard online by the FPCs/FPOs/SHGs will energise the farmers. The maize processing industries buying quality maize from the FPCs/FPOs/SHGs will pay them premium price as the grains will be of good quality. The diverse value added products from such processing companies can find place in open market or the FPCs/FPOs/SHGs may buy back the value added products to sell in open market. Say feed industry can supply inputs to dairy and poultry farmers, while the products i.e. milk and egg/chicken may find place in open market or may go back to the FPCs/FPOs/SHGs, who may again act as an aggregator for dairy/poultry farmers and market the value added products. The feed industries can also be linked to the ethanol industry through supply of Dried Distilleries and Grain Soluble (DDGS), a by-product of ethanol production and an ingredient for feed. Such models can bring a much waited revolution in the rural economy, simultaneously addressing the serious problem of ground water depletion, residue burning and other ecological/health consequences.

Pigeonpea: ICAR-Indian Institute of Pulses Research (ICAR-IIPR) is a premier Institute in the country dedicated on pulse research. The institute harbours three AICRPs viz., AICRP on Chickpea, AICRP on Pigeonpea and AICRP on MULLaRP (Mungbean, Urdbean, Lentil, Lathyrus, Rajmash and Fieldpea). The pulses research network across the country through its headquarter and AICRP centres is given in Fig. 12.

The Institute is mandated with basic, strategic and applied research on major pulse crops. It has now six specialized divisions (Crop Improvement, Plant Biotechnology, Crop Production, Crop Protection, Basic Sciences and Social Sciences) and four Regional Research Centres/ Stations (Dharwad, Bhopal, Bikaner and Khordha) to meet the Institute's mandates. Its key role includes developing technologies and materials towards pulses improvement, production, and protection and giving its fruits to our clientele, the farmers, besides tactical linkages and strategic coordination with the network on

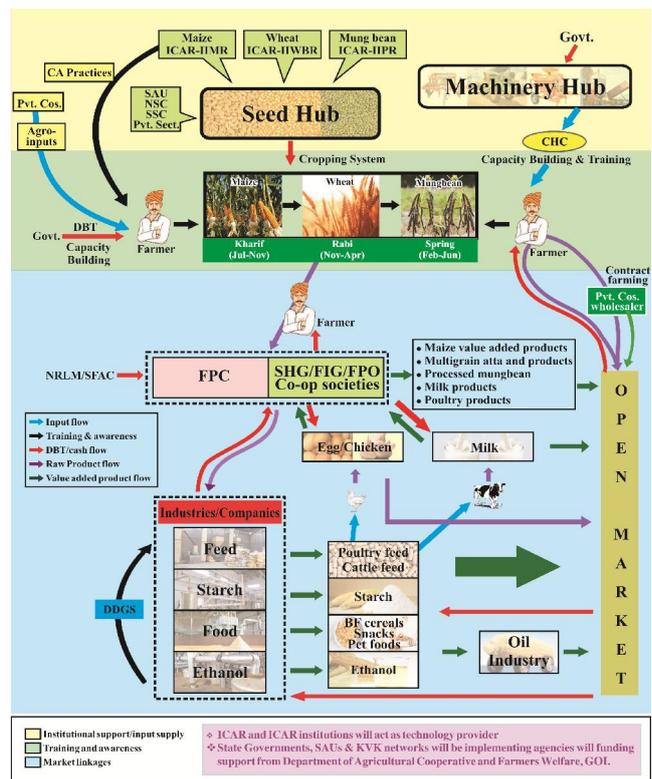


Fig. 11. M-W-Mb cropping system based value chain network

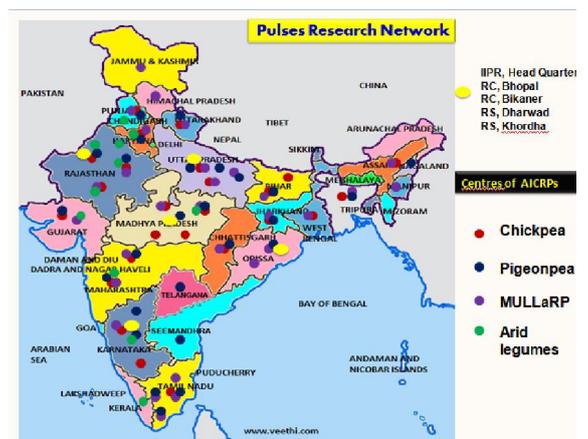


Fig. 12. Pulses research network in the country

pulses research programs across the country and the globe. The varietal trials of pigeonpea are carried out by 26 regular and 5 voluntary centers spread over five Agro-climatic Zones of India as given below. The total cadre strength of 107 including a project coordinator, 70 scientist and 36 technical staffs are working under the scheme.

1. NWPZ: North West Rajasthan, Punjab, Haryana, Delhi, Western Uttar Pradesh.
2. NEPZ: Eastern and Central Uttar Pradesh, Bihar, West Bengal, Assam, Jharkhand
3. Hilly Zone: Uttarakhand, Nagaland, Tripura
4. Central Zone: Gujarat, Maharashtra, Madhya Pradesh, Rajasthan, Chhattisgarh.
5. South Zone: Andhra Pradesh, Telangana, Karnataka, Orissa, Tamil Nadu.

The Institution and AICRP on Pigeonpea bred varieties and hybrids which can be obtained from this institute or its AICRP partners (details are given in Annexure IV). Punjab Agricultural University, Ludhiana and CCSHAU Hisar are the two AICRP centres dedicated on pigeonpea research and technology dissemination in Punjab and Haryana, respectively. The most convincing pulses based cropping system is pigeonpea-wheat-mungbean (P-W-Mb) cropping system. It is similar to M-W-Mb or R-W-Mb except the fact that short duration pigeonpea- a pulse- will replace maize or rice during the *kharif* season. It thus, brings in all the beneficial effect of both the pulses, *viz.*, pigeonpea and mungbean. The Institution and AICRP will support in input supply and training cum awareness and market linkages through various intermediaries. Three most important inputs are needed which include seeds, agro-chemicals and machineries for mechanization of the cropping system. For fulfilling seed need, well established seed hubs at Ludhiana in Punjab, CCSHAU-Hisar, KVK-Bhiwani and KVK-Sirsa are functioning well in addition to breeder seed programme (BSP) on pigeonpea and other pulses. This is supported and coordinated by ICAR-IIPR, Kanpur, its AICRP on Pigeonpea and other crop-based institutes to supply agro-chemicals and agro-machineries will be key to the success of this cropping system. Moreover, custom hiring centres (CHCs) are fully equipped to play a crucial role to provide key implements like bed planter, combined harvesters, pigeonpea strippers, etc. in a affordable rates. Governmental schemes may also support the CHCs in procuring the implements.

In addition, input subsidies for seeds and agro-chemicals may be transferred to the farmers adopting the system through direct benefit transfer (DBT) along with incentives to adopt the cropping system. Famers Producer Companies (FPCs), Famers Producer Organizations (FPOs), Self Help Groups (SHGs) and others (Cooperative or societies) may act as aggregator to link the farmers to pulses processors. In this account, our small scale *dal* mills or IIPR Mini *Dal* Mills could be of immense help to small and marginal farmers including FPCs/FPOs/SHGs supporting the CHCs. Pigeonpea *dal* is not used in the locality. Therefore, the value chain must include fulfilling the demand for the commodity elsewhere in the country. Diverse value added products from such processing locations can find place in open market or the FPCs/FPOs/SHGs may buy back the value added products to market. Such activities can bring additional income generation in the existing rural economy which could address the serious problem accrued as of now (ground water depletion, residue burning and other ecological/health consequences).

Soybean: ICAR-Indian Institute of Soybean Research (ICAR-IISR) at Indore is conducting and coordinating the soybean research in India. ICAR-IISR coordinates the soybean research in India through All Indian Coordinated Research Project on Soybean (AICRPS). In AICRPS, India has been divided into 6 zones (Fig 13), *viz.*, Northern Hill Zone, Northern Plain Zone,

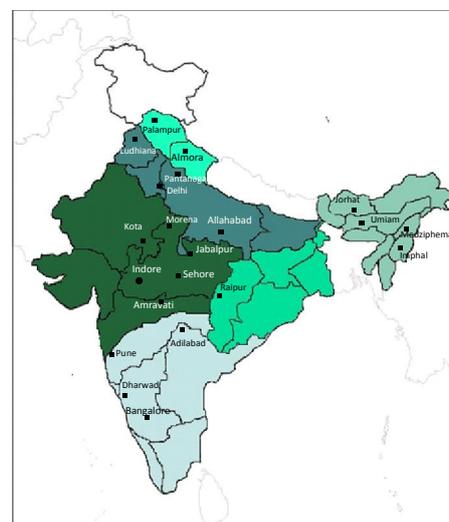


Fig. 13. Soybean research network in the country

North Eastern Hill Zone, Eastern Zone, Central Zone and Southern Zone. Twenty one state agricultural universities are main centres and 12 universities/institutes/KVK/NGO/private companies are need based centres for multi-location AICRPS trials. Punjab is included in Northern Plain Zone and in addition to Punjab Agricultural University Ludhiana, ICAR-Indian Agricultural Research Institute and G B Pant University of Agriculture and technology, Pantnagar are other centres located in this zone. Although the potential of soybean crop in Punjab and Haryana has been successfully demonstrated through AICRPS it is still grown in small pockets. Soybean crop can easily fit in soybean-wheat-mungbean cropping system but requires availability of quality seeds, agro-chemicals, machines, support for the sale of crop. In one of the projects handled by PAU, Ludhiana for 2 years soybean crop became popular when its assured procurement by university @ Rs 5000 per quintal was assured. Seed hub for the crop; custom hiring centres for BFF, FIRBS, combined harvester; farmer producer organizations, self help group for seed availability and popularizing soybean food usages are some of the areas for diversifying cropping system in Punjab and Haryana.

Rapeseed-Mustard: Research and development of rapeseed-mustard in India is spurred by ICAR-Directorate of Rapeseed-Mustard Research, which is located in Bharatpur (Rajasthan). It has one Krihisi Vigyan Kendra in Alwar district of Rajasthan. ICAR-DRMR is nodal point for All India Coordinating Research Project on Rapeseed-mustard (AICRP-RM) which has 22 regular and 13 verification center across 17 states of the country (Fig. 14). The Rapeseed-mustard research under AICRP is being conducted in 6 zones, viz., Zone-I (Kashmir, Himachal Pradesh), Zone-II (Jammu, Punjab, Haryana, Delhi, some parts of Rajasthan and some parts of U.P.), Zone-III (some parts of Rajasthan, Madhya Pradesh, Bihar, UP, Uttarakhand), Zone-IV (Gujrat, Maharashtra, some parts of Rajasthan), Zone-V (Odisha, West Bengal, Jharkhand, Chhattisgarh, Manipur), Zone-VI (Telangana, Andhra Pradesh, Karnataka).

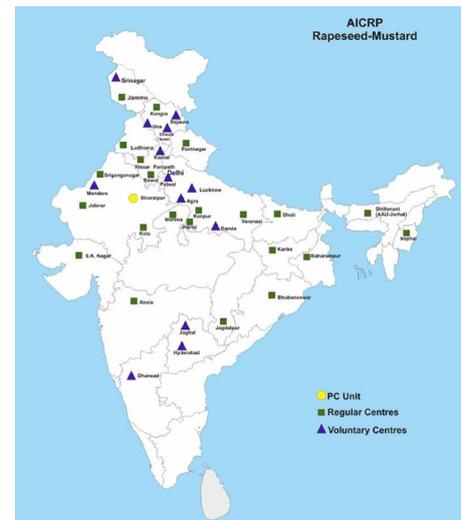


Fig. 14. Rapeseed and mustard research network in the country

Public sector varieties and hybrids developed and released from AICRP can be obtained from its AICRP partners (details are given in Annexure-III). Punjab Agriculture University Ludhiana, CCSHAU, Hisar and RRS, Bawal (Rewari) are the three AICRP centres dedicated on rapeseed-mustard research and technology dissemination in Punjab and Haryana. The rapeseed-mustard group of crops can be more remunerative in maize based cropping systems. Two most important input supplies will be quality seeds and varieties/hybrids and machineries, both for sowing and harvesting, for mechanization of the cropping system including R-M as one crop. A mustard seed-hub at RRS, Bawal (Rewari, Haryana) being supported and coordinated by ICAR-DRMR in the region and other crop based institutes duly complemented with private companies to supply agro-chemicals and machineries will be key to the success of the model. Custom Hiring Centers (CHCs) can play a very important role to provide key implements like ferti-seed-drill, Combine harvester etc. at affordable rates. Govt. schemes likes RKVY, SMAM (Sub Mission on Agriculture Mechanization) etc. may support the CHCs in procuring the implements. Input subsidies for seeds and agro-chemicals may be transferred to the farmers adopting the cropping system through direct benefit transfer (DBT) along with incentives to adopt the cropping system. Farmers producer companies (FPCs), Farmers Producer Organization (FPOs), Self-help groups (SHGs) and others may act as aggregator to link the farmers to Rapeseed-mustard processing industries. The Rapeseed-mustard processing industries, buying rapeseed-mustard from FPCs/FPOs/SHGs, will pay them premium prices for quality mustard (single low/double low). The oil and seed-meal from such processing

companies can find place in open market or the FPCs/FPOs/SHGs may buy back the product and sell in the open market and can fetch premium price since India is deficit in edible oil production by more than 50%. The animal feed industry can be linked to this for rapeseed-mustard seed meal which is very high in good quality protein (30-35%). Such models can bring a much awaited revolution in the rural economy simultaneously addressing the serious problem of ground water depletion, residue burning and nutritional security since rapeseed-mustard is high energy crop.

10. Epilogue

Strong policy intervention coupled with public-private partnership can bring perceivable changes in the predominant rice-wheat cropping system in the states of Punjab and Haryana and address the challenge of water crisis in one hand and residue burning on the other. Spread of maize, soybean, pigeonpea and mustard can ensure steady supply of the raw materials to the industry ensuring employment and entrepreneurship development in the region. Similarly, specialty type and quality produce of these crops also can create enough job opportunities and alternate source of income to the farmers and the rural youth. Policy intervention supporting rice and wheat has brought dramatic changes in the cropping pattern in the states. When the country was in need of food such policies certainly brought the country out of the 'ship-to-mouth' situation to self-sufficiency. However, this has caused some near irreversible damage to the whole ecosystem and the economy. The states have become net exporter of precious ground water. Now it is time to look back and take stringent policy decision to support the alternate crops, which can be very potent crops not only to address the economical and environmental issues but overall profitability of the system. In the process, no crop should be seen in isolation but should be viewed from cropping system perspective and system productivity and profitability, where all aspects encompassing water and energy conservation and conservation of nature should be viewed in a holistic manner. In the process ICAR institutes, viz., Indian Institute of Maize Research, Indian Institute of Pulses Research, Indian Institute of Soybean Research and Directorate of Rapeseed and Mustard can provide proven technologies, while the implementation part will have to be in the hands of state governments supported by Department of Agricultural Cooperation and Farmers Welfare, Government of India. The networks of scientists in the state agricultural universities and the Krishi Vigyan Kendras can play a key role in implementing the schemes.

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Annexure I. Area and yield of rice, wheat, maize, pigeonpea, soybean and mustard in Punjab and Haryana

Year	Area ('000 ha)			Yield (kg/ ha)		
	Maize	Pigeonpea	Mustard	Maize	Pigeonpea	Mustard
Punjab						
2014	126.0	2.6	31.0	3651	923	1248
2015	115.0	2.6	31.0	3687	1000	1348
2016	116.0	5.7	31.7	3836	860	1413
2017	114.0	2.6	30.5	3708	1030	1498
2018	109.0	2.3	30.5	3625	1047	1524
2019*	160.6	2.0	31.2	3589	1082	1492
2020*	245.0	6.2	45.0	3706	1157	1444
Haryana						
2014	8.0	6.1	493.0	2250	1098	1432
2015	6.0	5.0	505.0	2833	1000	1594
2016	5.0	14.2	510.0	3400	915	1853
2017	6.0	4.1	549.0	3167	1097	2018
2018	5.9	1.9	609.2	2644	1211	2058
2019	6.0			2883		
2020	12.2			2951		

*Information accessed from the State Department of Agriculture, Govt. of Punjab

Annexure II. Mapping of alternate cropping systems

Cropping system	Districts		Specific interventions
	Punjab	Haryana	
Maize-wheat-mungbean with CA	Hoshiyarpur, Ludhiana, Kapurthala and Jalandhar	Hisar, Fatehabad, Sirsa and Karnal	IEC, machineries for crop production and medium capacity dryer through CHC, establishment of storage & processing industry
Maize-wheat-mungbean conventional	Gurdaspur, Pathankot, Hosiarpur, SBS Nagar, Roopnagar	Hisar, Fatehabad, Sirsa and Karnal	IEC, machineries for crop production and medium capacity dryer through CHC, establishment of storage & processing industry
Pigeonpea-wheat-mungbean	Gurdaspur, Pathankot, Hosiarpur, SBS Nagar, Roopnagar	Hisar, Fatehabad, Sirsa and Karnal	IEC, establishment of storage & processing industry
Soybean-wheat-mungbean	Ropar, Hoshiarpur, Ludhiana, Jalandhar	Karnal, Kuruksetra, Jind, Ambala	IEC, establishment of storage & processing industry, Sowing Machine
Maize-mustard-mungbean	Kandi belt	Hisar, Kaithal, Jind, Sonipat, Rohtak, Bhimani, Sirsa and Fatehabad	IEC, machineries for crop production and medium capacity dryer through CHC, establishment of storage & processing industry
Maize-Potato-Water melon	Jalandhar and Bhabhar areas	Kurukshetra, Yamunanagar, Karnal, Sonipat, Ambala, Panchkula, Panipat, Rohtak, Jind and Sirsa	IEC, machineries for crop production and medium capacity dryer through CHC, establishment of storage & processing industry

Note: Provision of Seed Hubs for promising cultivars need to be established for all cropping systems.

Annexure III. List of maize hybrids released for the states of Punjab and Haryana through AICRP on Maize

S.NO.	Cultivar	Nature of cultivar	Developer of the cultivar	Public/Private	Release Year	Maturity	Average Yield (t/ha)	Season
Normal Field Corn								
1	CP 858	SCH	Charsen Pokphand Seed (India) Pvt. Ltd., Bangalore	Private	2020	Late	9.50	<i>Kharif</i>
2	HT17169	SCH	Hytech Seed India Pvt. Ltd.	Private	2020	Late	10.00	<i>Kharif</i>
3	PMH13	SCH	PAU, Ludhiana	Public	2020	Late	7.00	<i>Kharif</i>
4	CP. 838	SCH	Charsen PokphandSeed (India) Pvt. Ltd., Bangalore	Private	2018	Late	11.20	<i>Rabi</i>
5	PMH11	SCH	PAU, Ludhiana	Public	2018	Late	6.50	<i>Kharif</i>
6	GK 3150	TWC	Ganga Kaveri Seeds Pvt Limited	Private	2017	Late	11.90	<i>Rabi</i>
7	DRONA (KMH-2589)	SCH	Kaveri seed company limited	Private	2017	Late	10.80	<i>Kharif</i>
8	P3544	SCH	Pioneer Hi-Bred Private Ltd.	Private	2017	Late	10.80	<i>Kharif</i>
9	DKC 9126 (MCH 46)	SCH	Monsanto India Ltd., Bangalore	Private	2016	Late	8.90	<i>Kharif</i>
10	Dragon (NMH-1247)	SCH	Nuziveedu Seeds Limited, Hyderabad	Private	2016	Late	9.90	<i>Rabi</i>
11	KMH-7148	SCH	Kaveri Seed Company Limited, Secundrabad	Private	2015	Late	10.10	<i>Rabi</i>
12	KMH-25K45 (BUMPER)	SCH	Kaveri Seed Company Ltd., Andhra Pradesh	Private	2015	Late	9.00	<i>Rabi</i>
13	NMH-1242	SCH	Nuziveedu Seeds Limited	Private	2015	Medium	7.30	<i>Kharif</i>
14	CoH (M)8 (CMH 08-292)	SCH	TamilnaduAU, Coimbatore	Public	2014	Medium	7.10	<i>Kharif</i>
15	KMH-25K45 (2700) (BUMPER)	SCH	Kaveri Seed Company Ltd., Andhra Pradesh	Private	2014	Late	9.00	<i>Rabi</i>
16	P3522 (X35A019)	SCH	Pioneer Overseas Corporation, Karnataka	Private	2014	Late	9.10	<i>Rabi</i>
17	P 1864 (X8F984)	SCH	Pioneer Overseas Corporation, Karnataka	Private	2014	Early	7.60	<i>Kharif</i>
Quality Protein Maize (QPM)								
18	LQMH-202(LQMH-2)	SCH	ICAR-IIMR, Ludhiana	Public	2020	Medium	7.50	<i>Kharif</i>
19	Pusa HM-4 Improved (AQH-4)	SCH	ICAR-IARI, New Delhi	Public	2017	Medium	6.40	<i>Kharif</i>
Popcorn								
20	GAPCH-21 Mahashweta	SCH	Anand Agricultural University, Anand	Public	2020		3.70	<i>Kharif</i>
21	BPCH-6	SCH	ANGRAU, Hyderabad	Public	2015	Medium	3.20	<i>Kharif</i>
22	DMRHP 1402	SCH	ICAR-Indian Institute of Maize Research, Ludhiana	Public	2018	Early	3.90	<i>Kharif</i>
Sweet Corn								
23	NUZI 260	SCH	Nuziveedu Seeds Limited, Hyderabad	Private	2020	Medium	13.90	<i>Kharif</i>
24	Hi-brix-39 (ADVSW-1)	SCH	Advanta Limited, Hyderabad	Private	2017	Medium	13.80	<i>Kharif</i>
25	Hy-brix 53 (ADVSW-2)	SCH	Advanta Limited, Hyderabad	Private	2017	Medium	13.70	<i>Kharif</i>
26	Central Maize VL Sweet Corn 1	SCH	VPKAS, Almora, Uttarakhand	Public	2016	Medium	10.80	<i>Kharif</i>
27	CANDY (KSCH-333)	SCH	Kaveri Seed Company Limited, Secundrabad	Private	2015	Early	11.90	<i>Kharif</i>
Baby Corn								
28	IMHB 1532	SCH	ICAR-IIMR, Ludhiana	Public	2018	Medium	2.00	<i>Kharif</i>

Annexure III. List of mustard varieties/hybrids released for the states of Punjab and Haryana through AICRP on Mustard (2010-2020).

S.No.	Variety/hybrid	Nature of variety/hybrid	Developer of the cultivar	Public/Private	Release Year	Maturity	Average Yield (t/ha)	Season
Indian mustard								
1.	Pusa mustard -26 (NPJ-113)	Late sown irrigated, tolerant to high temperature at seedling and maturity stage	ICAR-IARI, New Delhi	Public	2010	115-137	1.5-1.9	Rabi
2.	RH 0119	Thermo-tolerance	CCSHAU, Hisar	Public	2010	145-150	1.8-2.0	Rabi
3.	Pusa Mustard 28 (NPJ 124)	Early sown, irrigated, tolerant to high temperature at seedling and salinity	ICAR-IARI, New Delhi	Public	2011	97-131	1.9-2.1	Rabi
4.	Coral PAC 437 (Hybrid)	Hybrid, tolerant to white rust	Advanta India Limited	Private	2011	130-140	2.0-2.8	Rabi
5.	RLC 2	Timely sown irrigated, low erucic acid (< 2%)	PAU, Ludhiana	Public	2011	132- 155	2.0-2.3	Rabi
6.	PBR-357	Timely sown irrigated	PAU, Ludhiana	Public	2011	142-149	2.5-2.8	Rabi
7.	RGN-229	Tolerant to high temperature and salinity at seedling stage, timely sown rainfed	ARS, Ganganagar (SKRAU, Bikaner)	Public	2011	140-150	2.2-2.6	Rabi
8.	RH 0406	Tolerant to high temperature and salinity at seedling stage	CCSHAU, Hisar	Public	2011	136-149	2.1-2.4	Rabi
9.	RGN-236	Tolerant to high temperature and salinity at seedling stage, late sown irrigated	ARS, Ganganagar (SKRAU, Bikaner)	Public	2011	126-128	1.5-1.8	Rabi
10.	Pant Rai-19 (PR 2006-1)	Tolerant to high temperature during early stages, suitable for early sowing.	GBPUA&T, Pantnagar	Public	2012	117	2.1	Rabi
11.	Pusa Mustard- 29 (LET-36)	Low erucic acid (<2%)	ICAR-IARI, New Delhi	Public	2013	143	2.2	Rabi
12.	RVM-2	Rainfed as well as irrigated	ZRS, Morena RVSKVV, Gwalior	Public	2013	194-209	1.7	Rabi
13.	Giriraj (DRMRIJ 31)	Timely sown irrigated	ICAR-DRMR, Bharatpur	Public	2013	137-153	2.2—2.8	Rabi
14.	RH 0725	Timely sown rainfed	CCSHAU, Hisar	Public	2017	141	2.4-2.8	Rabi
15.	CS 2800-1-2-3-5-1 (CS 60)	Tolerant to salinity/alkalinity	ICAR-CSSRI, Karnal	Public	2017	134	1.7-2.2	Rabi
16.	PDZ-1	Quality mustard (00)	ICAR-IARI, New Delhi	Public	2017	142	2.0-2.5	Rabi
17.	DRMR 2017-15 (Radhika)	Late sown, irrigated	ICAR-DRMR, Bharatpur	Public	2020	122-139	1.7-1.8	Rabi
18.	DRMRIC 16-38 (Brijraj)	Late sown, irrigated	ICAR-DRMR, Bharatpur	Public	2020	122-139	1.7-1.8	Rabi
19.	LES 54 (Pusa Mustard 32)	Timely sown irrigated, low erucic acid	ICAR-IARI, New Delhi	Public	2020	142-147	2.6-2.8	Rabi
Gobhi Sarson								
1.	GSC 7	Canola quality	PAU, Ludhiana	Public	2015	154	2.2	Rabi
2.	AKMS 8141(Him Palam Gobhi Sarson 1	Canola quality, timely sown irrigated	CSKHPKVV, Palampur, Himachal	Public	2020	155-177	1.8-2.1	Rabi

Annexure IV. List of Pigeonpea varieties/hybrids released for the states of Punjab and Haryana through AICRP on Pigeonpea (2010-2020)

S.N.	Variety	Pedigree	Developer of the cultivar	Zone	Release year	Traits
1	Pusa 992	Sel. Of 90306	IARI, New Delhi	NWPZ	2002 (CVRC)	Indeterminate, semi-spreading, early maturing (135-140 days), yields about 12-15 q/ha, suitable for pigeonpea-wheat cropping system
2	VLA 1	ICP6 x Pant 2	ICRISAT	Uttarakhand	2006 (SVRC)	Indeterminate, Early maturing and semi spreading
3	PAU 881	H89-5XICPL 85024	PAU, Ludhiana	Punjab	2007 (SVRC)	Indeterminate, early maturing, semi spreading, suitable for pigeonpea-wheat cropping system
4	Pusa 2002	Sel. 90310 x H 88-45	IARI, New Delhi	Delhi	2007 (SVRC)	Indeterminate, semi spreading, early maturing, suitable for pigeonpea-wheat cropping system
5	PA291	UPAS120XKPBR 80-2-1	G.B.P.U.A.&T,	NWPZ (State)	2008 (SVRC)	Tolerant to <i>Phytophthora</i> stem
6	Pusa Arhar 16 (PADT 16)	Population improvement approach involving diverse genotypes viz., ICP 85059, ICPL 390, ICPL 267, Manak, H-92-39 and ICP 85024	IARI, Pusa, New Delhi	Delhi	2018 (SVRC)	Determinate, erect and compact, extra early, matures in about 120 days, yields about >10q/ha
7	Pant Arhar 6 (PA 421)	ICPL 84023 x ICPL 88039	GBPUA&T Pantnagar	NWPZ	2019 (CVRC)	Indeterminate, semi spreading, matures in about 145-150 days, possesses resistant to wilt and sterility mosaic disease. Gives an yield about 15-16 q/ha.
8	IPH 15-03 (Hybrid)	CMS PA 163A x AK 250189R	IIPR Kanpur	NWPZ	2019 (CVRC)	It is an early CGMS based hybrid having the cytoplasm of <i>C. scarabaeoides</i> . It is indeterminate, semi spreading, matures in about 150-155 days. Possesses resistance to Fusarium wilt and has a yield potential of 2.5 t/ha
9	IPH 09-5 (Hybrid)	CMS PA 163A x AK 261322R	IIPR Kanpur	NWPZ	2020 (CVRC)	It is indeterminate, semi spreading, matures in about 150 days. Possesses resistance to Fusarium wilt and has a yield potential of 2-2.5 t/ha

Annexure IV. List of pigeonpea varieties/hybrids released for the states of Punjab and Haryana through AICRP on Soybean (2010-2020).

S. N.	Name of variety	Developer of the cultivar	Public/ Private	Release Year	Maturity	Average Yield	Season
1.	SL 525	PAU, Ludhiana	Public	2007	121 days	2727	<i>Kharif</i>
2.	PS 1347	GBPUA&T, Pant Nagar	Public	2008	123 days	2542	<i>Kharif</i>
3.	SL 688	PAU, Ludhiana	Public	2008	125 days	2435	<i>Kharif</i>
4.	SL 744	PAU, Ludhiana	Public	2012	139 days	2142	<i>Kharif</i>
5.	Pusa 12	IARI, New Delhi	Public	2015	124-131 days	2286	<i>Kharif</i>
6.	SL 958	PAU, Ludhiana	Public	2016	142 days	2282	<i>Kharif</i>
7.	Pant Soya 24	GBPUA&T, Pant Nagar	Public	2017	113 days	2560	<i>Kharif</i>
8.	SL 955	PAU, Ludhiana	Public	2020	126 days	2201	<i>Kharif</i>
9.	SL 979	PAU, Ludhiana	Public	2020	127 days	2335	<i>Kharif</i>
10.	PS 1572	GBPUA&T, Pant Nagar	Public	2020	120 days	1925	<i>Kharif</i>