Natural Resources Management in Punjab Agriculture: Challenges and Way Forward

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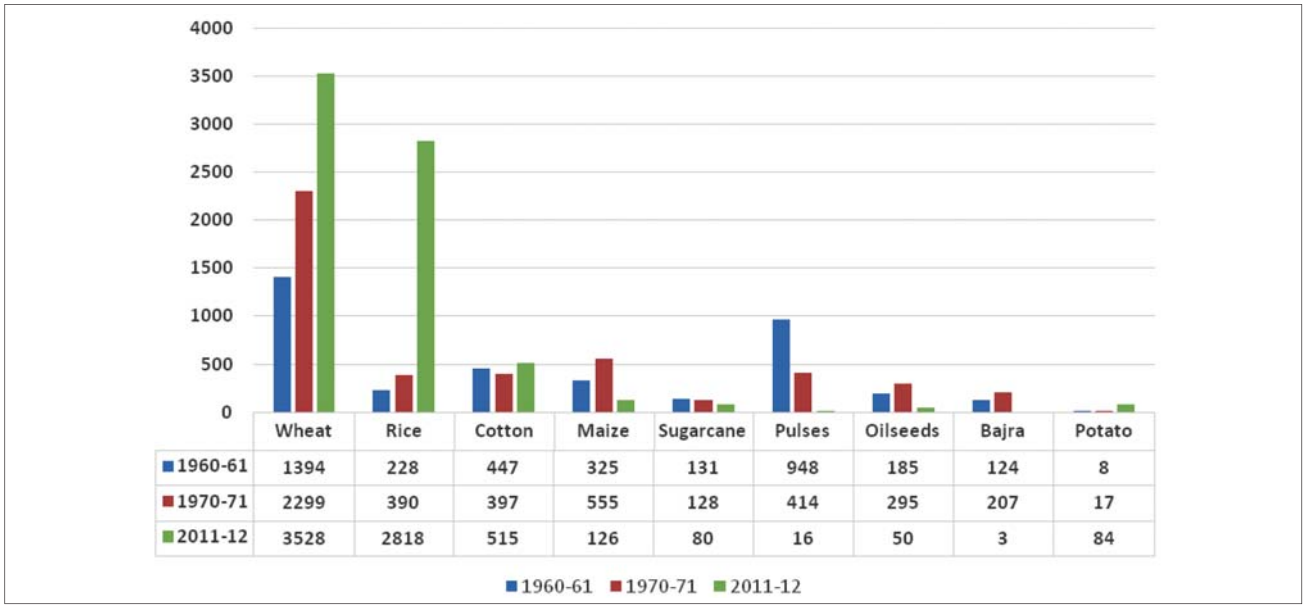
Background

Punjab is one of the smallest states of India with 5.03 million hectare of land which accounts for only 1.5 percent of the total area of the country. Of this 4.2 million hectare is the net cultivated area, leaving less than 17 percent of the area under habitations, roads, rivers, canals, waste lands etc. However, with intensity of cropping at 190 percent, the cropped area amounts to around 8 million hectare which accounts for 4.5 percent of the cropped area in the country. Although cropping pattern of the state incorporates multiple numbers of crops in Rabi (autumn planting) and kharif (summer planting) seasons, yet two crops, wheat and rice in rotation occupy the largest area as shown below in figure 1.

Figure 1: Change in area under different crops in Punjab ('000ha)



	Wheat	Rice	Cotton	Maize	Sugarcane	Pulses	Oilseeds	Bajra	Potato
1960-61	1394	228	447	325	131	948	185	124	8
1970-71	2299	390	397	555	128	414	295	207	17
2011-12	3528	2818	515	126	80	16	50	3	84

An important feature of the change in cropping pattern is that over five decades, area under major crops has increased from 3.79 million hectare to 7.22 million hectare i.e. an increase of over 90 percent. More importantly the area under wheat increased from1.394 million hectare to 3.528 million hectare (1.53 times increase) and area under rice crop increased from 0.228 million to 2.818 million hectare (11.36 times increase) over this period. Thus these two crops became dominant in the cropping pattern of the state.

On production side, total production of food grains increased from 3.2 million tonnes in 1961 to 29.2 million tonnes in 2011-12, an increase of over nine times. Rice production during this period increased from 0.24 million ton to 10.54 million tons and wheat increased from 1.77 million ton to 17.98 million ton. The increase in area and enhanced crop productivity contributed 39 percent and 61 percent, respectively towards the overall increase in food grain production, especially rice and wheat. Wheat productivity in the state increased from 1.24 ton per hectare in 1960-61 to 4.35 ton in 2011-12 (3.5 times increase) and rice (paddy) productivity increased from 1.5 ton to 5.74 ton per hectare over this period.

Many factors were responsible for such large increase in food grain production in the state, which are depicted in Table 1. Cropping area in the state increased through vertical expansion with cropping intensity increasing from 126 percent in 1960-61 to 190 percent in 2011-12. This happened through provision of irrigation for additional 4.4 million hectare of cropped area. Increased production could not have been achieved without the use of fertilizers and protection of crops with pesticides. As a result, the use of fertilizers in terms of NPK nutrients increased from only one kg per hectare to 246 kg per hectare over this period and simultaneously the use of pesticides increased from negligible level to 6150 ton technical grade. Punjab farmers speedily resorted to the mechanization of farm operations. Number of tractors which were just a few in 1960-61 increased to 53 thousand in one decade and the number exceeded half a million by 2011-12. Mechanization facilitated timely and speedy farm operations which enabled the farmers to increase the intensity of cropping and improve productivity. Punjab currently realizes land productivity of more than 11 ton per hectare from wheat and rice in one year, which is comparable to the productivity of developed countries.

The effect of the technology improvements in terms of improved seeds, higher use of fertilizers and pesticides and agronomic practices being in the nature of divisible technologies, benefited all the farmers, big, small and marginal ones. Yet, the benefits accrued more to the larger farmers and less to the smaller ones according to the size of the farms. Larger farmers had the additional advantage of owning farm machinery and implements that allowed reaping of higher profits through timely planting and thereby increase in cropping intensity. Further they had better access to the institutional credit, which facilitated the adoption of improved technologies more effectively and at a faster pace.

An important change that has taken place over the last decade is that the share of Punjab in total procurement of food grains has been decreasing constantly. From the highest of 48 percent share in rice procurement in 2002-03, Punjab share came down to 22 percent in 2011-12. In case of wheat from highest share of 75 percent, the Punjab share came down to 34 percent in 2011-12. This is largely because of central government emphasis and investment in the Eastern states in the basins of river Ganges and Yamuna and Central states, where production of wheat and rice has improved.

This has created a sort of paradox for Punjab in the sense that while wheat and rice remain the most profitable crops from the point of view of the farmers on the strength of distorted real economic cost of crops due to free supply of power and water to the farm sector. In view of increasing

Table 1: The scenario of intensive agriculture in Punjab, 1961 through 2011-12

Year	Food grain production (million ton)	Cropping intensity (%)	Irrigated area (thousand ha)	NPK use (kg/crop ha)	Pesticide use (tons of tech. grade)	Number of tractors (thousands)
1960-61	32	126	54	1	NA	NA
1970-71	73	140	71	38	NA	53
1980-81	119	161	93	113	3200	119
2011-12	292	190	98	246	6150	504

production in the deficit states and consequent decreasing demand in these areas and built up of stocks much higher than what the country can absorb for domestic consumption, India has to resort to exports. India held food grain stocks of 41.2 million tons as on 1st January, 2014 which included 17 million tons of wheat and 24.2 million tons of rice against the buffer and strategic stocks requirement of 25 million tons only on that date. This is the date when stock requirements are the lowest, because of next harvest just three months ahead. The stocks were brought this low after exporting 22 million tons of food grains by the countryin 2013-14. These exports have depressed the world prices also in the international market.

Effect on natural resources

However, this has been achieved at a great cost in terms of degradation of agricultural ecology and exhaustion of scarce resources, specially the underground water in the state. Environmental degradation has resulted in air pollution. Withdrawal of ground water is upsetting the water balance of the state and soil and underground water is getting toxic through excessive use of chemical fertilizers and pesticides.

Soil health

Two crop rotation of wheat followed by rice has necessitated the use of chemical fertilizers and pesticide on an increasing scale over a very high base in order to achieve higher and higher levels of yield. Punjab has achieved a very high yield of 5 tons of wheat per hectare compared with national average of 2.9 tons and 6 ton per hectare of paddy compared with national average of 3.2 tons (2011-12). This has been achieved with highest use of chemical fertilizers and pesticides as indicated earlier in Table 2. The use of farm yard manure has fallen to the negligible level, which has depleted the organic content of the soil to a disquieting level reducing efficiency of nutrient uptake further and necessitating higher and higher use of chemical fertilizers to achieve the same level of output.

Imbalanced use of nutrients

Use of chemical fertilizers is very high in the state. Punjab state uses about 450 kg/ha of N+P+K (2012-13) but application is not balanced as per requirements of the crop. Wheat and paddy are the most commonly grown crops in the state and the recommended application of N, P and K is 4:2:1. Since the Punjab soils are rich in K content, the application of N:P is recommended in the ratio of 2:1. However, nitrogen is applied in much higher ration while P application is lower. Unfortunately, the ratio of N and P is worsening over time. It leads to increased cost of production, deficiency of important elements in soil, etc.

Deficiency of major and micronutrients

Intensive cultivation had led to deteriorating soil health in terms of major and minor nutrients. Sixty percent Punjab soils have been tested to be deficient in N and 40 percent in P. Due to the non-application of micronutrients, there have also been increasing incidences of soil micronutrient depletion. Based on soil samples tested in the Punjab Agricultural University, Zinc deficiency was noted in 20 percent samples, Manganese in 18 percent and Iron in 12 percent soil samples. This continuous deterioration in micro-nutrient content of the soil also adversely affects the efficiency of NPK fertilizer use. It is almost a vicious circle - no or low use of farm yard manure or organic fertilizers leading to low carbon content - higher use of chemical fertilizers - depletion of micronutrients - low productivity - urge to apply higher doses of chemical fertilizers. Answer to the problem lies in making balanced use of chemical fertilizers and also in substitution of organic fertilizers for chemical fertilizers to the maximum extent possible, including farm yard manure, compost, green manure, ploughing in crop residues and bio-fertilizers. In order to avoid overuse of fertilizers it is essential that fertilizers be applied as per the need of the soil and the crop, based on soil tests. There is also a need of apprising the farmers of the economics of the fertilizer use. There is a difference between maximizing the yields and optimizing the resource use for highest net returns. Without this realization the farmers emphasizing on maximization of yield as at present would remain a misplaced emphasis.

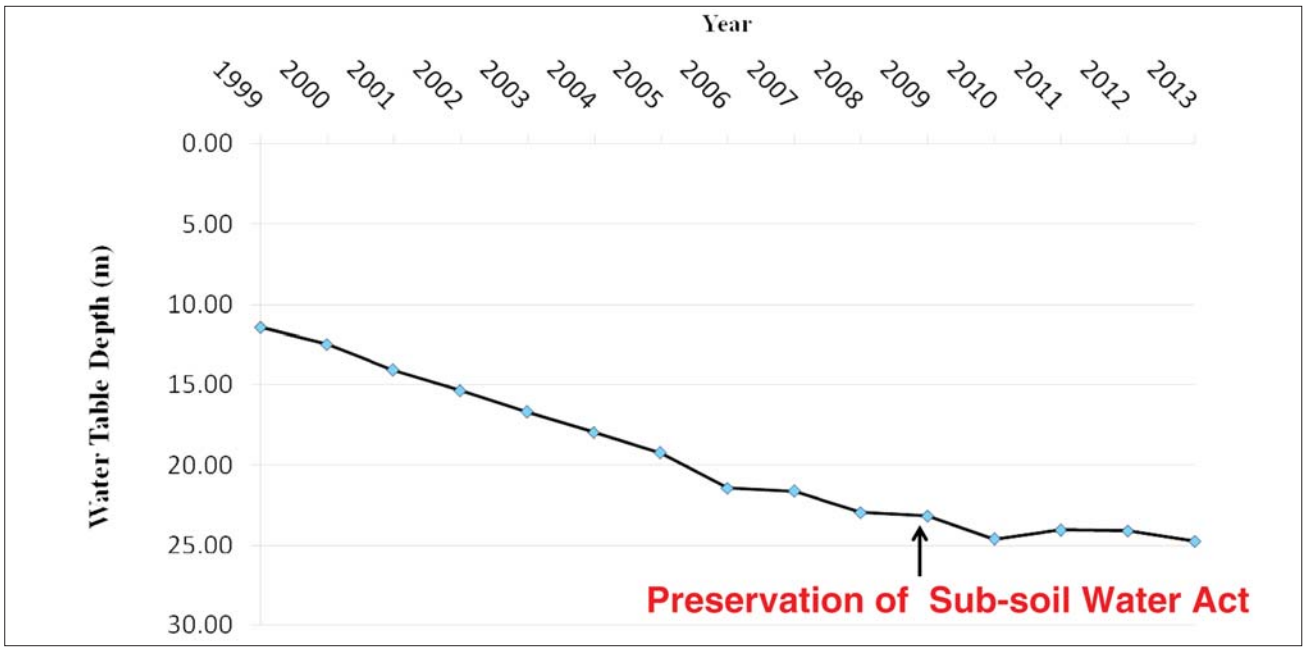
Underground water resources

In Punjab, more than 98 percent of area is irrigated, out of which 76 percent is irrigated by groundwater and remaining by surface (canal) water. Increase in cropped area from 5.68 million hectares in 1970-71 to over 7.88

Table 2: Use of Nutrients

	1980-81	1990-91	2000-01	2011-12
N : P : K ratio	18.1 : 7.1 : 1	58.5 : 21.9 : 1	43.8 : 12.3 : 1	26.2 : 8.3 : 1
N:P ratio	2.5 : 1	2.7 : 1	3.6 : 1	3.2 : 1

Figure 2: Decline in Groundwater table



million hectares in 2011-12 and area under rice crop from 0.39 million hectares to 2.85 million hectares in this period, which relatively requires more water, has led to over exploitation of the water resources. On an average, total demand for water in agriculture stands at 4 million ha meter against the supply of 3 million ha meter from all sources. As a result, groundwater table is receding at a very fast rate as is shown in the graph. Recently, fall in the rate of decline has occurred due to the enactment of 'Sub soil water preservation act' of 2008 which prohibits the transplantation of rice nursery in the field before 10th June.

In 80 percent of the development blocks of the state,groundwater is over exploited compared with rechargeable capacity. In the central Punjab, the major wheat and rice producing areas, 96 percent of the blocks are over exploited.

Rice crop with existing technology is grown in ponded water. It is estimated that through evapo-transpiration, the plants consume about 5 thousand liters of water to produce one kilogram of rice. Wheat consumes about 3 thousand liters of water for production of one kilogram of grains. Punjab contributes about 20 million tons of food grains to the central pool annually. This amounts to the state packing 160 billion gallons of water into grains annually and exporting it outside of the state. The canal water hardly meets one-fourth of the water requirements of the crop grown in the state. Three-fourth of the water requirements are met through pumping the under-ground water. The main river (Satluj) flowing through the state and its basin has been dammed and more than half of the dammed water has been taken out of the basin feeding Haryana and Rajasthan states. Also the excess water flowing into the river has been controlled with the earthen (Dhusi) dams around the river, channelizing the water like a canal. As a result, there occur no floods and no recharge of the sub-soil aquifer. Minor seasonal flood streams (Choes) from the lower hills have also been dammed. Thus all the sources of flood water recharge have been effectively choked. The only possibility of recharge with clean water is the roof top flows, but here again the water flows to the village ponds. Village ponds too are mostly polluted with sewerage, street drain flowing into these water bodies. Thus, the excessive withdrawals from and inadequate recharge of aquifer is affecting the water balance of the state negatively.

Another factor leading to depletion of groundwater reserves is the highly subsidized power to the farming sector to pump out groundwater. The polity in the state remains unconcerned about the deteriorating water balance and is not prepared to stop free supply of electricity to farm sector, which puts no check on over use, misuse and wastage of water from the tube wells. Unfortunately there is serious policy disconnect in the state. Free power and water to the farm sector has seriously distorted the economic cost of production of various crops. Because farmers do not pay anything for water use and power for tube well, the rice crop remains at a clear advantage. If water and power are rightly priced, the rice crop, guzzler of water, could be at a disadvantage. This policy disconnect is not allowing the urge to save

water besides hindering the diversification of cropping patterns in Punjab. Most unfortunate is the approach that even the large farmers growing commercial crops like potatoes, vegetables, etc. on thousands of acres also get free power supply. Small and marginal farmers who deserve to be assisted, as many of them do not have tube wells, have to buy water for irrigation from the adjoining farms. Not only the overuse and wastage of water but also fast declining water table in the central Punjab is necessitating submersible pumps replacing the centrifugal pumps involving huge costs. Another important aspect of the submersible pumps is that the efficiency of many of the centrifugal pumps around the submersible pumps goes down and many of them dry up. As a result, small and marginal farms may be financially incapable of installing submersible pumps.

Given this serious policy constraint, the research plant of the state, Punjab Agricultural University, the technocrats of the department of agriculture of the state and researchers elsewhere are endeavoring to develop rice varieties of shorter duration that would require lesser application of water and are developing agronomic practices aiming at saving water without losing on productivity. Also efforts are being made to introduce crops like soya and expand acreage under crops like maize in the cropping pattern to save water. On technology side, various innovations have been attempted by the agricultural technologists and researchers in the state and elsewhere.

The basis of these attempts is that *"although only rice out of major cereal crops grows well in standing water, yet it does not mean that this crop cannot be grown without standing water."* The Punjab Agricultural University in collaboration with the Centers for International Projects Trust (CIPT), India and Columbia University, USA have conducted experiments on the potential of water saving technologies and practices and promoted the use of tensiometers for water-efficient irrigation scheduling in rice and direct seeding of rice.These interventions were carried out in the IDRC funded project on "Improving Food and Livelihood Security in Punjab through Water-Energy-Agriculture Management under Climate Change and Variability."

There is a significant potential to save water in rice cultivation through tensiometers use. A tensiometer is a simple device designed to measure soil moisture or water potential, i.e. the energy plants need to exert to pull in water from the soil at the current moisture condition. The idea behind the use of tensiometer is that if the indicated soil moisture is below what the plant needs to grow, there is need to apply irrigation water, otherwise not. Such irrigation scheduling can reduce water use in a crop. A total of 1,848 tensiometers were installed at farmers' field under the IDRC project and the smallholders accounted for 21 percent of the total farmers. Majority of the farmers installed the tensiometers in paddy rice. The adoption rates for two years of experiment were encouraging at around 40 percent. The use of tensiometers resulted into water savings of 14-15 percent in rice with corresponding power saving of 101 kwh/acre in 2012 and 70 kwh/acre in 2013. The adoption of such technologies at large scale, therefore offers the potential of huge amount of water and energy savings in Punjab agriculture and can also reduce the subsidy burden of the state government (see Table 3).

Table 3: Impact of tensiometers on the water and energy use in rice cultivation

Particular	Values
Volume of water saved (litres per acre)	372,042
% water savings	15
Power savings due to reduced water use (kwh/ acre)	70

In DSR, flat seeding with rice seeder after careful laser-levelling of land is done preferable with short duration variety of rice. It helps save irrigation water and removes drudgery of work. Laser leveling is itself responsible for considerable water saving. Yield is not impacted adversely under DSR compared with that in the traditional system. This system saves lot of labour and associated costs. It was just like sowing and harvesting of wheat. The tractor-driven drill could easily seed five to six acres of land in a day. At the early stage the crop looks weak, but picks up after one month or so and compensates with stronger tillers. The conspicuous advantage in DSR is that in case of delayed application of water the crop does not wilt because the root system develops deeper in the loose un-puddled soil. In the event of untimely rain another trial was made by transplanting of nursery plants in un-puddled fields in standing water. This system of direct seeding is suitable for heavier soils only. Other essentials are laser levelling of fields, use of specially designed seed drills that ensures uniform shallow seeding. Control of weeds through careful application of pre-mergence and post-emergence weedicides is a must. Otherwise the system will lead to an avoidable failure.

The results of the field experiment on DSR are quite encouraging. The experiment was laid in a paired design

Table 4: Experiment results of IDRC project						
	PUSA-44			PR 118/PR 116		
	DSR	Non-DSR	Difference	DSR	Non-DSR	Difference
Water use (meters^3/ha)	5684	7433	(-) 23.5%	5861	7234	(-) 19%
Yield (q/ha)	73.9	74.7	(-) 1.07% ^{NS}	71.35	70.94	0.58%^{NS}

under which one plot was cultivated under traditional flooding method of irrigation while the other plot was cultivated following DSR approach. Both the plots were monitored very closely and information on irrigation water use, labour use and other production variables was collected on fortnightly basis. It was observed that the water saving was by 19 to 23.5 percent in non-basmati rice without any adverse impact on yield (see Table 4).

Adoption of direct seeding of rice is suggested as one of the important alternatives in order to save water on the crop. The suggestion is in the right direction, but as yet the system suffers from a few trepidations. Therefore, it is essential to debug the system to suit various area and time specific situations. This requires dispassionate evaluation of the experimentations made by various organizations and individuals including the results obtained from the university project sponsored by the International Development Research Centre (IDRC), Canada, the technocrats of department of agriculture, experiences of corporate set ups including PepsiCo India, which is trying to promote DSR in the state, and the university researchers. The system has considerable potential.

Environment

The paddy crop is not only a guzzler of water; it is environmentally hazardous crop under the Punjab conditions. First, puddling of the fields creates hard pan at the depth of 10 inches, which does not let the crop roots penetrate deeper and the crop needs more frequent irrigations for all the following crops. In the months of June, July, August and upto mid-September, temperature runs between 39 to 43 degree centigrade and relative humidity 95 to 99 percent. This is the time when demand for power is at peak and electricity plays truant. Punjab living conditions become highly intolerable during this period.

Punjab lacks severely the proper management of crop residues especially rice straw. While wheat straw is used as dry fodder for animals, rice stubbles are burnt fully in the fields causing loss of nutrients and air pollution. Punjab produces around 20 million tons of paddy straw, 85 percent of which is burnt. Due to burning, more than 80 percent of C, N and S are lost while loss of other nutrients like P etc. is 10 to 20 percent. Besides, soil microbes, which are critical to maintain good soil properties and enhance its fertility, are lost in this process. Other major causality in residue burning is high level of air pollution during that season which leads to severe health hazards like higher incidence of asthma and eye related problems. Often in late October and November smoke is trapped under the clouds. It becomes extremely suffocating, especially for the persons suffering from breathing problems like asthma. Twice it happened during the last three years. If it had not rained, it could prove to be fatal for persons with breathing problems.

Policy Options

A few of the policy prescription detailed below, if adopted, can go a long way in saving scarce production resources of the state and rationalize the resource use as well as put the production patterns on an optimum growth path.

Water

1. Keeping in view the declining water table of the state due to negative water balance, it is essential that Punjab adopts the approach of “maximizing returns to the most scarce resource i.e., water” rather than maximizing the returns to land. It is a matter of emphasis and priority both for the government and the farmers. This requires the change in mindset on the part of the policy makers, researchers, extension agents as well as farmers.

2. To pursue this line of action, first requisite is that free supply of water and power to the farm sector must be stopped in order to avoid catastrophic situation, which may arise on lack of adequate water availability in the near future.

3. No doubt farmers need subsidies. It is an admitted fact that in no country farm sector can survive on a sustainable basis without subsidies. Developed countries such as USA, Japan, UK and European countries provide subsidies to the farm sector in amounts that the developing countries cannot even

think of. Yet it is the question of kind of subsidies and focusing of the subsidies to really deserving ones. Across the board subsidies, irrespective of the size of the farms as is being done in Punjab, flow mainly to the larger farmers, who do not need these subsidies. It is, therefore, essential that subsidies must be carefully targeted to benefit the small and marginal farmers only. A large chunk of small and marginal farmers do not even have the tubewells and they buy water from other farmers around who have tubewell mainly with submersible pumps. It is therefore of paramount importance that acrosstheboard subsidy on water should be stopped and if so desired this subsidy must not be provided beyond certain limit of acreage, say five acres.

4. There must be some charge on the supply of water/ power to the farm sector even for the farmers that are subsidized. One way is that farmers are given subsidy on all capital costs incurred by the supply agencies and working costs be charged from them on per unit basis.

5. Flat rate charges do not help save the water. Flat-rate system is as harmful as the free supply of power, because there is no incentive for the farmer and no urge on him to save water/power. Since the amount charged does not vary with the use of power, farmer tends not to save on use of power. It is therefore essential that some charges, even if partial, must be there for farmers to pay on metered supply of power.

6. Providing subsidies on inputs is not the right choice, because such subsidies have only one shot effect and have to be continued time after time, because such subsidies do not build the capacity of the farmer to stand on his own feet. Moreover, such subsidies distort the economic costs of different crops differently and also distort the price structures in the international market and affect the competitiveness of the products from different countries. Such subsidies are not consistent with WTO provisions. Preference, therefore, should be the investment subsidies that build the capacity of the recipients for a longer period and help in the elimination of the need for input subsidies in the long run. For instance, subsidies can be given for land development, laying of underground water pipe lines for field level irrigation, installation of pressure irrigation systems like sprinklers and drip irrigation, farm machinery and appropriate implements, thrashers, harvesting machines etc.

7. If Punjab state is genuinely interested in diversification of its production patterns away from rice crop, which is the need of the day, and at the same time wishes to continue subsidies to the farmers, the one stroke policy prescription to be followed is to calculate total subsidy that costs the government in the farm sector including that on water, power etc. and transfer this amount (or whatever amount the government wishes to or afford to pass on to the farmers) direct to the farmers through bank accounts. This transfer should be in a focused manner either upto some limit of farm size or on a graded basis. Then, let the farmers pay the market price for the inputs they use. This will (i) rationalize the decisions of the farmers on production patterns based on economic costs of production of agricultural commodities, (ii) benefit the farmers direct and subsidies intended to flow to the farmers will not leak down to consumers as is happening today through lower minimum support prices of crops (especially rice and wheat) for them and corresponding lower issue prices for the consumers and (iii) incentivize the farmers to save on cost through rational use of inputs by spending lesser than the subsidy they receive. It is to be realized that under the present system of farm subsidies and increasing output prices, the benefit directly translates into increase in land rents. It is the owners of land that benefit and the cultivator (especially the tenant cultivator) does not benefit, because he has to pay higher rents correspondingly. In the case of direct payments of subsidy, it will not increase the rents, rather may have a depressing effect and the cultivator will gain. At the same time the costs of cultivation of food grains will be estimated realistically and the farmers will gain on higher minimum support prices. This subsidy policy will make the process of crop diversification self-propelling and there will be lot of savings on scarce production resources including water and power.

8. Techniques like direct seeding of rice (DSR) and use of tensiometer for optimum application of water to the rice crop need to be standardized and upscaled, and there is a need for focused research on these aspects.

9. There is a dire need for the research to focus on developing agronomic practices and crop genotypes that consume lesser water without losing on productivity and quality of production. Also, the production risks must be reduced to the minimum in respect of probable alternative crops to the rice crop.

10. Price structure of different competing crops has been tilted in favor of rice and wheat because of the procurement needs of the government. The alternative crops have been put on a disadvantage both in terms of competitive price and market uncertainty. Therefore, a balance price structure for agricultural crops needs to be evolved taking into consideration such factors.

Soil

1. There is dire need to detoxify the soils, by reducing the use of chemical fertilizers and pesticides through integrated pest management and integrated nutrient management, based on soil tests and threshold level identification of pests for applying pesticides to the crops. Farmers most of the time use pesticides that are not recommended by the university. They do so on the recommendations of pesticide dealers or commission agents. They recommend whatever is available with them. This results in use of wrong pesticide and in over-doses. Decision support system needs to be developed to guide the farmers in the application of fertilizers and pesticides.
2. There is a need to promote balanced use of fertilizers on the basis of soil tests is the need of the day. Further, It is the time to shift to the application of bio-fertilizers including farm yard manure, green manure and microbes based preparations. The use of FYM and microbial formulations like bio-fertilizers improves the physical and nutritional characteristics of soil and enhances productivity and quality of the output.

Environment

Although, government of Punjab by its order has banned the burning of stubbles, but the orders have never been implemented and burning of stubbles goes unchecked and often the fire from the fields burn out the trees and bushes on the sides of the roads. This burning will not stop, whatever the orders, unless some viable and easily adoptable alternatives to manage crop residue especially rice straw are made available to the farmers.

1. One alternative is to popularize the use of shredders after combining the crop and seeding next crop (wheat) with zero tillage through "happy seeders." The technology is quite standardized, yet because the shredders and happy seeders are quite costly, individual farmers cannot afford to buy these implements. Government is providing subsidy on these implements between 50 to 70 percent of the costs, but small and even medium farmers still cannot afford that investment. The right policy will be to create service centers both in public and private sectors where these implements along with other machinery and costly implements are made available on subsidized rents on first-come-first- serve basis.
2. Second option is that after harvest, the stubbles are contracted out to the specially promoted entrepreneurs for recycling this bio-mass. Farmer is paid on per acre basis and the contractor is required to bale the stubble and clear the field within short stipulated time so that next crop is sown in optimum time period. If these and such other alternatives are provided to the farmers, only then the government orders banning the burning of stubbles can be easily implemented.

In nutshell, the farming sector at present faces many complexities on economic and environment fronts, for which solutions are neither easy nor can be found through technology and innovations within agriculture. A multipronged strategy focusing on 'technology driven agriculture' actions complimented by rational policy is necessary. The sufficient condition for this to succeed is the political will to implement such policies. Otherwise, Punjab agriculture will continue to be caught in the quagmire of degrading natural resources and endangered livelihood in future.

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