

# Working Group Report on Conservation Agriculture for Sustainable Crop Production in Haryana


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# Working Group Report
# on
# Conservation Agriculture
# for
# Sustainable Crop Production in Haryana

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# Foreword

In the State of Haryana, despite significant success on all fronts of agriculture, it is increasingly being realized that the strategies adopted in the past for faster agricultural growth would require a relook to address the second generation problems of Green Revolution. In the areas having good quality of ground water, where predominantly high water requiring crops like rice, wheat, sugarcane and cotton are being grown, the water table is depleting at an alarming rate. On the other hand, in areas with brakish ground water in inland basin, introduction of canal irrigation with poor on-farm water management has resulted in the rise of water table, soil degradation, salinization, resodification and water logged conditions. Cultivation of rice-wheat system has led to an over-exploitation of fresh ground water reserves, poor soil health, low carbon content and multiple nutrient deficiencies. The increased cost of cultivation, labour shortage and climate change all pose additional threats to the sustainability of major crop production systems in Haryana. Therefore, it is necessary to have an introspection of the past accomplishments and undertake a SWOT (strengths, weaknesses, opportunities and threats) analysis in order to reorient existing agro-technological packages as well as research for development agenda for resource conservation and sustainable agriculture. We now need innovations that can cut cost on inputs and help in increasing the overall income of resource poor farmers.

It gives me immense pleasure that a Working Group on Conservation Agriculture (CA), led by Dr. Raj Gupta, has analyzed the problems of major cropping systems, identified the sustainability issues and suggested policy interventions around conservation agriculture practices that are input use efficient for sustainable crop production in the State. The Working Group had conducted series of meetings facilitated by Haryana Kisan Ayog, with researchers, field functionaries, policy makers and farmers for coming out with these recommendations. I congratulate Dr. Raj Gupta and his team for their sincere efforts and timely action in bringing out this valuable report entitled "**Conservation Agriculture for Sustainable Crop Production in Haryana**". I am sure the Department of Agriculture, Govt. of Haryana, Chandigarh, CCS Haryana Agricultural University, Hisar and the Farm Advisory Agencies in general and farmers in particular will take full advantage of available technologies as recommended in this report. I also believe that this important publication will be of immense use to the planners, administrators, scientists and other users for efficient management of soil, water and other resources for sustainable crop production and betterment of resource poor small farm holders of Haryana.

**(R.S. Paroda)**
**Chairman, Haryana Kisan Ayog,**
**Govt. of Haryana**

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# Abbreviations

| | |
|---|---|
| AAREM | Agricultural Research and Education Management |
| ADF | Acid Detergent Fiber |
| AWD | Alternate Wetting and Drying |
| B:C | Benefit Cost Ratio |
| CA | Conservation Agriculture |
| CCS- HAU | Chaudhary Charan Singh Haryana Agricultural University |
| CIMMYT | International Maize and Wheat Improvement Center |
| CSISA | Cereal Systems Initiative for South Asia |
| DAP | Di-Ammonium Phosphate |
| DDA | Deputy Director Agriculture |
| DM | Dry matter |
| DSR | Direct Seeded Rice |
| EE | Ether extract |
| ET | Evapo-transpiration |
| FAQ | Frequently asked questions |
| GHG | Green House Gas |
| GO | Government of |
| GS | Green Seek er |
| GW | Groundwater |
| HKA | Haryana Kisan Ayog |
| IARCs | International Agricultural Research Centers |
| ICAR | Indian Council of Agricultural Research |
| IFFCO | Indian Farmers Fertilizer Cooperative limited |
| IFS | Integrated Farming System |
| IGP | Indo-Gangetic Plains |
| INM | Integrated Nutrient Management |
| IPM | Integrated Pest Management |
| IRRI | International Rice Research Institute |
| IT | Information Technology |
| ITI | Industrial Training Institute |

| | |
|---|---|
| IVDMD | In-Vitro Dry Matter Digestibility |
| KVK | Krishi Vigyan Kendra |
| LCC | Leaf Colour Chart |
| LQ | Low Quality |
| M ha | Million Hectares |
| M | Million |
| NBDMD | Nylon Bag Dry Matter Digestibility |
| NDF | Neutral Detergent Fibre |
| NDVI | Normalized Difference Vegetation Index |
| NE | North-East |
| NGO | Non-Governmental Organization |
| NRM | Natural Resource Management |
| NUE | Nutrient use Efficiency |
| RB | Raised Bed |
| RCT | Resource Conservation Technologies |
| RRS | Regional Research Station |
| RSC | Residual Sodium Carbonate |
| RKVY | Rastriya Krishi Vikas Yojna |
| RWC | Rice-wheat Consortium |
| RWCS | Rice-Wheat Cropping System |
| SAU | State Agricultural Universities |
| SF | Small farmers |
| SHC | Soil Health Card |
| SPAD | Soil Plant Analysis Development Meter |
| SSNM | Site-Specific Nutrient Management |
| TAR | Technology Assessment and Refinement |
| UFI | Unique Farmer Identity |
| UnTPR | Unpuddled Transplanting |
| ZT | Zero-Tillage |
| ZT-DSR | Zero-Till Direct Seeded Rice |
| ZTR | Zero-Tillage with Residue |

# Executive Summary

Haryana has made tremendous progress on all fronts of agriculture after its formation as a new State with the bifurcation of Punjab on November 1, 1966. After the formation of new State, the Govt. of Haryana has put its major emphasis on improving irrigation and road networks. During the era of Green Revolution, agro-technological packages generated by the scientists and practiced by hard working farmers increased the food grain production from just 2.6 million tonnes in 1966-67 to 16.6 million tonnes in 2010-11. Currently, the State of Haryana is confronted with complex problems of soil and water management, ecological imbalances, shortages of labour, inefficiency of current production practices in major cropping systems, increase in cost of cultivation and decrease in factor productivity of inputs. Therefore, it is an opportune time to address these second generation problems of Green Revolution and reorient our research and development agenda for sustaining high crop production and improved agro-ecological environment in the State. Keeping these objectives and problems in view, the Haryana Kisan Ayog constituted a Working Group on "Conservation Agriculture for Sustaining Crop Production in Haryana" under the leadership of Dr. Raj Gupta in August 2010. The TOR, composition of Working Group and other details are given in Annexure I.

Haryana, with just 1.4% (4.4 M ha) of the total geographical area of the country, is the second largest contributor of foodgrains (17.6% in 2009-10) to the national food basket. Green Revolution technologies practiced by small and marginal farmers (~ 67% of total farmers) increased foodgrain production from 2.6 million tonnes (MT) in 1966-67 to 16.6 MT during 2010-11. Increases in wheat and rice production were 11 and 16 folds, respectively, during this period. Extensive cultivation of rice and wheat has led to over-exploitation of aquifers, soil nutrient reserves, multi-nutrient deficiencies and increase in production costs. Obvious climate change, depleting fresh water aquifers and labour shortages now pose serious threats to sustainability of crop production systems in Haryana.

The report of the CA Working Group provides a brief account of farming situations in Haryana, identifies the sustainability issues and strategic entry points for CA for resolution of the issues enumerated earlier. While retaining the sustainability focus, the report has given due considerations to short-term objectives of the farmers.

In late 1990s, CCS HAU recognized the need for participatory approaches to working with poor rural households, and there was financial support from research institutions such as from USAID, ACIAR, RWC and CIMMYT. Many on-farm trials and demonstrations were laid out with direct involvement of the farmers and extension workers. The Secretary of Agriculture, Gov. of Haryana also fully supported these new on-farm trials. These initiatives of the State Agricultural University and Agriculture Department, Govt. of Haryana gave CA, a kick start and about half a million hectares of wheat was sown using minimum or zero tillage technology by 2005. However, the CA programme received a setback thereafter, because the climate variability and weather aberration and zero or minimum tillage practices remained confined to wheat only. Farmers also realized that minimum tillage options were cheaper for weed management than safe use of herbicide molecule like glyphosate. Excessive tillage had led to emergence of *Phalaris minor*, a problematic weed of the rice-wheat cropping system. Inadvertent introduction of rotavator as an implement for reduced tillage further constrained the spread of CA in Haryana. Farmers have reported reduced water intake rates, temporary waterlogging and crop lodging in fields wherein rotavator has been used only for few seasons. There is good evidence that problems arising from use of rotavator are gradually increasing. These problems are a consequence of soil compaction due to continuous use of rotavator. Afraid of crop lodging upon irrigation at flowering and grain filling stages, farmers generally avoid irrigating their wheat crop. In the absence of adequate soil moisture, wheat is unable to tolerate heat stress. The yield losses in wheat due to climate change had become more apparent after 2000.

The report dwells on the low-cost conceptual model 'crop per drop' based on the use of conservation agriculture practices. The report highlights the opportunities in different cropping systems wherein CA based measures can be adopted to save water use and improve factor productivity of external inputs, improve soil health and prevent environmental and ecological degradation. For enhancing productivity, farmers need both new research information and ready access to quality agri-inputs and CA machinery. In emerging scenarios, the extension system has to deliver knowledge intensive and dynamic cropping system specific technical knowledge to farmers in a short time. This requires an efficient extension system.

The Haryana State has established excellent soil testing laboratories. The department is currently operating a Soil Health Card (SHC) Service. The soil test based recommendations need to be updated and must keep pace with new research inputs. Half a dozen districts consume more than half the fertilizer used in Haryana. Properly targeting the inputs can improve productivity of other districts. It will be highly beneficial if the SHC service can be linked to Unique Farmer Identity (UFI), which in turn can be reached through a 'single click' mobile cell phone service. By the use of (IT) tools, farmers can benefit from cropping system following soil test recommendations. UFI will be a step forward in knowledge sharing which focusing on various farm schemes, since farmers are in need of effective delivery of new technologies. This will allow convergence of 'bottom-up and top-down' approaches for speedy delivery of the benefits of CA to the farming communities, including its proper monitoring and fine tuning. The suggested measures, once adopted, will improve productivity and help bridge water demand-supply gap at low costs for the major cropping systems in Haryana.

# 1. Introduction

The Green Revolution, (GR), an example of how technological innovations provide better alternative for the nature's limit across social and political boundaries, was spread over the period from1967/68 to 1977/78. The GR changed India's status from a food-deficient country to one of the world's leading agricultural nations. The term 'Green Revolution' is a general one that is applied to successful agricultural experiments in many developing countries. India is one of the countries where maximum gains were harnessed especially in North-western Indo-Gangetic Plains (IGP) including Haryana and Punjab. In Haryana State of India, agriculture is practiced on nearly eighty-six percent (86%) of the state's total geographical area (4.42 million ha). Haryana, with just 1.4% (4.4 M ha) of the total geographical area of the country, is the second largest contributor of foodgrains (17.6% in 2009-10) to the national food basket. Green Revolution technologies practiced by small and marginal Haryana farmers (~ 67%) increased food-grain production from 2.6 million tonnes (MT) in 1966-67 to 16.6 MT during 2010-11. Increases in wheat and rice production were 11 and 16 folds, respectively during the period. The cropping intensity in Haryana is around 180%. Good network of canal water supplies, tube well irrigation, road network, market infrastructure and policy support proved very helpful in transforming agriculture in Haryana from the times of Green Revolution. As a consequence, Haryana was awarded the "Krishi Karman Award" for the best performance in wheat production (11.6 mt) and productivity (4624 kg ha-1) during 2010-11 by the Government of India.

However, the use of GR technologies showed signs of ecological imbalances. The recent agricultural trends show signs of stagnating production due to (i) decline in factor productivity, (ii) degrading soil health, (iii) inefficiency of current production practices, (iv) scarcity of resources, especially good quality water and labour, (v) changes in land use, driven by socio-economic factors and resource constraints, and good fertile lands going out of cultivation for roads, urban development and industrial uses, etc. and (vi) policy fatigue. The problem is likely to be further exacerbated by the climate change. Climate extremes and poor water availability will necessitate growing more food with less and less water in coming years. An average 1°C rise in temperature will increase the demand for irrigation water by 2-3 per cent to sustain production at the current level (Reeve *et al.* 2010). In last few decades, rice-wheat cropping system has emerged as a major production system in Haryana. Rice, sugarcane, wheat and cotton crops are major consumers of irrigation water supplies in the State.

# 2. From Issues to Actions: Increasing Agricultural Production

## 2.1 Bridging yield gaps

Agriculture production of essential commodities can be increased by adopting a two-pronged strategy to deal with gaps in production and productivity. First, there exists significant yield gaps between climatic potentials, attainable/experimental stations/frontline demonstration and actual/average yields at farmer's field (vertical gaps). Secondly, significant yield gaps also exist between different geographic regions/districts in different crops (horizontal gap). In IGP, the climatic/total yield gap (difference between climatic potential yields and district average yield) in three major cereal crops i.e. rice, wheat and maize are 61%, 45% and 76% respectively, whereas, the respective management yield gaps (difference between of experimental plot yields to district average yield) are 58%, 26% and 68% (Fig. 1). The majority of these gaps are due to poor crop management practices, untimely availability of quality seed and other inputs and power supplies. In Haryana, the climatic yield gaps (Fig. 1) in three major cereal crops i.e. rice, wheat and maize are 67%, 32% and 65% respectively, whereas, respective management yield gap are 60%, 14% and 57% (Saharawat et al. 2010). These yield gaps can be bridged through timely planting, adoption of conservation agriculture based practices, balanced use of nutrients and good quality seed of disease resistant crop cultivars and hybrids. It is imperative to target districts having low productivity on priority to bridge yield gaps and increase the total production in the state.

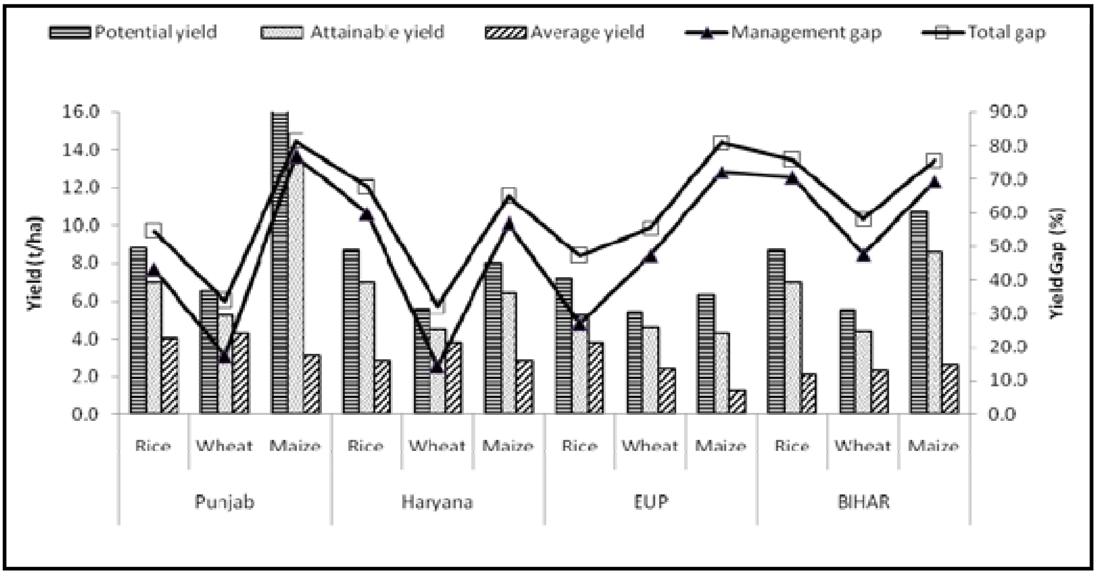


**Fig. 1.** Yield gaps for rice, wheat and maize in Punjab, Haryana, Eastern UP and Bihar

For addressing management yield gaps in wheat, district-wise planning is required with special emphasis on zero or minimum tillage and residue management, timely planting, balanced use of fertilizers including micro-nutrients and introduction of micro-irrigation systems (drip and sprinkler). Micro-irrigation can save water, improve water use efficiency by 30-50% and yield by 5-28%. Further, promotion of zero till seed drills, seed-cum-fertilizer drills, raised bed planter, diesel pump sets, integrated weed management for the control of *Phalaris minor* and integrated disease management, especially for rusts, Karnal bunt, and loose smut will be required. Rusts are gradually emerging as a serious threat to wheat in North-western plains. Haryana should immediately introduce rust resistant wheat cultivars particularly in the Shivalik foot hills and Yamuna flood plains of Haryana.

Rice is another main food grain crop of Haryana. Production of rice during *kharif* season mainly depends on monsoon rains and tubewell water supplies. Like wheat, there exists a wide variation in inter-state/inter-district productivity. In order to improve production and productivity of rice, improved package of practices such as direct-seeded rice or zero till transplanting of rice, intermittent wetting and or micro-irrigation, balanced fertiliser use and quality seed need to be promoted together with proper disease and pest management. Initial results of farmer participatory trials conducted using micro-irrigation systems (drip and sprinkler) have been very encouraging. However, more concerted efforts are still required for fine tuning the technology and convince the rice farmers.

Hybrid maize is an option for partial replacement of rice in *kharif* season, to address declining water table in fresh aquifer zones. Intercropping of pigeonpea, cowpea, and soybean in maize planted on raised bed system in *kharif* and green pea and other vegetables in winter season are economically viable and competitive system, beside increasing biodiversity and improving water productivity.

Overall, the challenge in Haryana is to increase and sustain productivity with less water in each succeeding year. This can be achieved by adopting agronomic practices which increase water use efficiency such as timely planting, laser levelling, direct seeded rice, zero till residue retained wheat and maize, use of sprinkler, micro-irrigation, zero or minimum tillage, raised bed planting, crop diversification/ intercropping and developing crop cultivars tolerant to soil moisture and N and P nutrient stresses. In central and western canal irrigated area having brackish ground water (Hisar, Sirsa, Rohtak, etc.), water tables are rising rapidly. There is an urgent need to promote conjunctive use of brackish and canal water supplies in these districts. Farmers in Mahendergarh and a few other districts in southern Haryana having light textured soils, use brackish ground water conjunctively and have been successful in avoiding any significant rise in ground water tables.

# 3. Natural Resources in Haryana

## 3.1 Geographic domain of river basins

Geographic domain of Haryana comprises the 3 basins, namely, the Ghaghar, Yamuna and the Inland Basins (Fig. 2). Inland basin is virtually covered with salt-affected soils. A great majority of these soils are primarily sandy loam and some of them belong to loamy textural class. Annual precipitation is high in the northeast (~ 1000mm/year) and declines in the north-westerly and southwesterly directions, where climate is arid to semiarid. The north-east and south-west parts of Haryana drains into saucer shaped Inland Basin, leading to secondary salinization of a vast stretch of land before the brackish ground water flows enter in to deserts of Rajasthan. For this reason, it is only natural that Haryana will continue to face perpetual salinity problems as there is hardly any option available. Haryana is likely to face difficulties in discharging salty drainage water into Yamuna river or drainage systems or collect salts in evaporation ponds or in natural large open lakes. When rivers are flowing at a minimum level in summer, there is not sufficient fresh water to dilute the saline drainage water and this will be a problem for many cities/ towns situated all along the river course and depend on river for fresh drinking water supplies. In general, the groundwater flows are toward southwest leading to shallow and saline water tables. The ground water quality deteriorates in the same direction as in figure 3. During the monsoon season, Yamuna river does not have sufficient capacity to carry additional discharge of drainage water. In the absence of an aqua duct, it is difficult to take saline waters to the Arabian sea. Thus, agriculture in Haryana has to depend mainly on improved resource management practices, crop diversification and input use efficiency for sustainability of agriculture in the State.

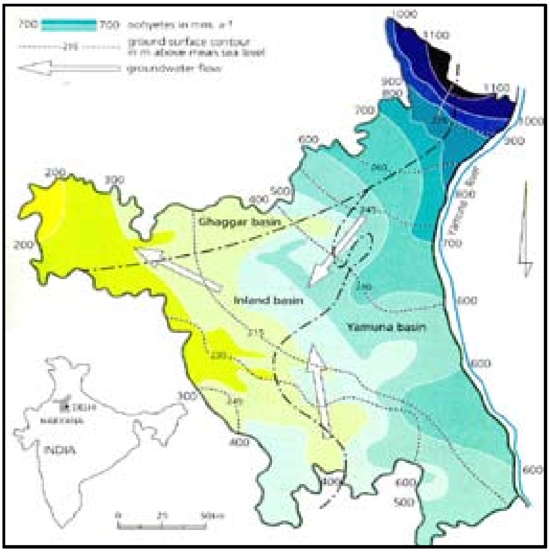


**Fig. 2.** Geographic domain of Haryana
(3 basins – Ghaghar, Yamuna & Inland Basins)

## 3.2 Ground water aquifers quality

The ground water quality is fresh in north-eastern parts of Haryana. This is also the region where excessive pumping of ground water for irrigating rice-wheat cropping systems is resulting in rapid decline of ground water tables (Fig. 3). In general, water table is declining at the rate of one meter per year (1m yr-1) in rice-wheat belt of Haryana covering north-eastern districts. In semi-arid and arid districts of Haryana i.e. Mahendra Garh, Rewari and parts of Bhiwani Districts, also marginal brackish ground water is being excessively pumped. Farmers in this region use brackish water for sprinklers irrigation on light textured soils. In the central and south-western parts of Haryana, aquifers are saline and water tables are rising in the absence of effective drainage system and poor water management practices in canal commands. The seepage and deep percolation losses from canal water supplies are contributing to rise in ground water tables. Reluctance on parts of the farmers to use marginal quality brackish aquifers for irrigation only adds to the salinity and waterlogging problems. A large part of Haryana inland basin, described previously, has poor quality brackish ground water. Good land and crop management practices together with conjunctives use of multi-quality waters (rain, brackish and fresh waters) can sustain productive agriculture in inland basin of Haryana until new drainage water disposal options become available.

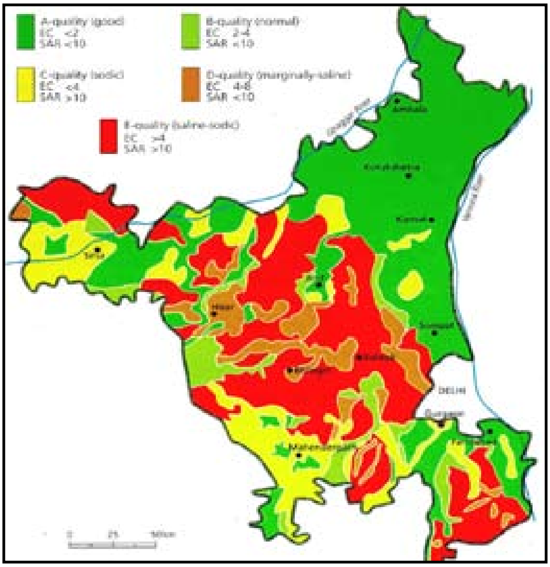


**Fig. 3.** Ground water quality

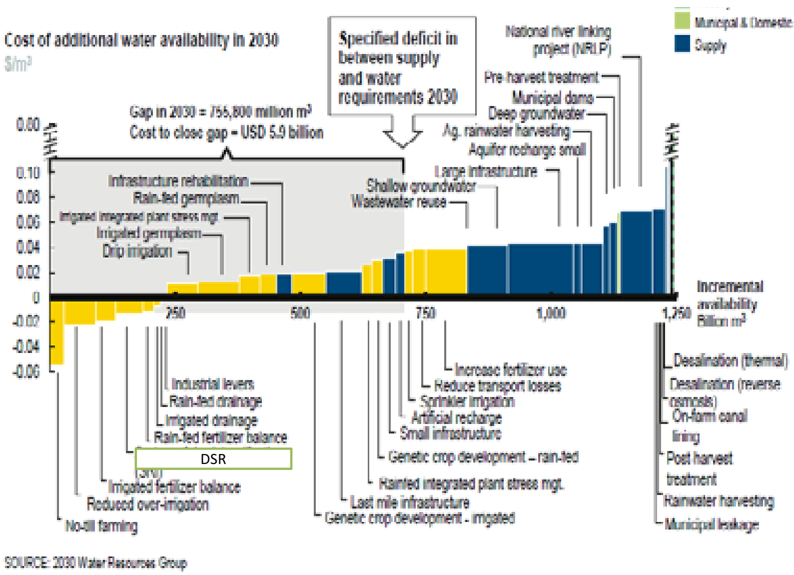


**Fig. 4.** India specific - water availability cost curve

Recent reports brings out that between 13-17 billion m3 of ground water is lost permanently from the north-western plains of Punjab, Haryana and western Uttar Pradesh (Rodell *et al.* 2010; WWRG, 2011). Estimates of the World Water Resource Group indicate that India will have a projected deficit of 755 billion m3 of water by 2030. The three fundamental ways to bridge demand- supply gap of water include (a) increase water supplies, (b) improve water productivity 'crop per drop', and (c) make economic choices- reduce water withdrawals, and make crop substitutions.

Measures such as laser assisted precision land leveling, raised-bed planting, mulching, zero-tillage and surface seeding, etc. can save irrigation and improve water productivity. The mixed and intercropping systems in vogue can also potentially improve water productivity and crop yields. India specific report of the World Water Resource Group published recently in 2011 provides information about "water availability cost curve". In the Fig. 4 above, width of the block/ column represents amount of additional water that will become available due to adoption of the specific water saving measures and the height of blocks refers to unit costs ( $/ m3 of water).

It is worth mentioning here that the least cost set of levers on left hand side (LHS) of the water availability cost curve can collectively be referred to agricultural measures. These measures have the potential of bridging 80% of the projected gap in irrigated and rainfed ecologies in India. In addition to agricultural opportunities, low cost supply measures (e.g. last mile completion of water courses, repair and cleaning of canals etc.) have the potential of bridging the remaining 20% gap as per the report of the World Water Resources Group.

## 3.3 Fertility status of soils

Haryana is one of the first State in India having geo-referenced database and map on soil nutrient status and groundwater and fresh water quality (http://www.agriharyana.nic.in). But the information on salt affected soils and poor water quality tube-wells is scanty. An analysis of total fertilizer consumption in Haryana revealed that more than half the total fertilizer is consumed in just 7-8 districts of the State. In the intensive rice-wheat cropping system of Haryana, NPK use ratio is highly distorted and varies widely between districts. Therefore, the geo-referenced soil fertility maps are very important to maintain the proper balance between different nutrient usage in Haryana. Out of the total 1.7 lakh analyzed samples between 2010-2011, 12% showed up iron deficiency, 9% zinc deficiency and 2% manganese deficiency (Table1). In the districts where there is less NPK use, micro-nutrient deficiency is prevalent such as in Rewari, Gurgaon, Faridabad, Hisar, Rohtak, Kaithal, Fatehabad, and Sirsa. In districts like Jhajjar, in spite of high NPK use, micro-nutrient deficiencies are prevalent (Table 1), constraining crop production. Thus, soil test based NPK recommendations may not help. Significantly enough, iron deficiency is emerging in several districts in coarse textured soils and in alkali and saline situations. It has been observed that continuous

**Table 1.** District-wise micronutrient deficiencies in Haryana in year 2010-11.

| Name of Distt. | Soil samples analyzed/ year | Number of soil samples analyzed and found critical (%) | | | | | |
|---|---|---|---|---|---|---|---|
| | | Samples for Zinc (Zn) | % critical (Zn) | Samples for Iron (Fe) | % critical (Fe) | Samples for Manganese (Mn) | % critical (Mn) |
| Ambala | 16564 | 733 | 4.4 | 834 | 5.0 | 262 | 1.6 |
| Yamuna Nagar | 4966 | 446 | 9.0 | 307 | 6.2 | 57 | 1.1 |
| Krukshetra | 11897 | 812 | 6.8 | 653 | 5.5 | 270 | 2.3 |
| Kaithal 2350 | 196 | 8.3 | 277 | 11.8 | 49 | 2.1 | |
| Karnal 24432 | 1825 | 7.5 | 2594 | 10.6 | 342 | 1.4 | |
| Panipat | 2100 | 222 | 10.5 | 168 | 8.0 | 25 | 1.2 |
| Sonepat | 4040 | 441 | 10.9 | 470 | 11.6 | 97 | 2.4 |
| Rohtak 4714 | 438 | 9.3 | 433 | 9.2 | 63 | 1.3 | |
| Jhajjar | 4018 | 520 | 12.9 | 597 | 14.9 | 164 | 4.1 |
| Gurgaon | 3616 | 286 | 7.9 | 433 | 12.0 | 77 | 2.1 |
| Mewat 1766 | 209 | 11.8 | 292 | 16.5 | 96 | 5.4 | |
| Faridabad | 2642 | 276 | 10.4 | 359 | 13.6 | 178 | 6.7 |
| Rewari 17988 | 1213 | 6.7 | 2394 | 13.3 | 395 | 2.2 | |
| Mahendergarh | 10931 | 1271 | 11.6 | 1888 | 17.3 | 343 | 3.1 |
| Bhiwani | 5558 | 663 | 11.9 | 964 | 17.3 | 209 | 3.8 |
| Jind | 17686 | 1967 | 11.1 | 2761 | 15.6 | 176 | 1.0 |
| Hisar | 9035 | 578 | 6.4 | 674 | 7.5 | 101 | 1.1 |
| Fatehabad | 11395 | 1547 | 13.6 | 2177 | 19.1 | 209 | 1.8 |
| Sirsa | 15875 | 1403 | 8.8 | 2021 | 12.7 | 413 | 2.6 |
| **Grand Total** | **173413** | **15046** | **8.6** | **20480** | **11.8** | **3636** | **2.1** |

use of zinc and phosphate fertilizers over the years has improved the soil availability status of these elements. Thus, all the fields no longer may require application of zinc sulfate or P in every season crops.

Therefore, an integration of conservation agriculture based site-specific nutrient management (SSNM) with the available soil fertility maps, groundwater quality maps and soil salinity maps of Haryana and it can play a vital role in order to promote balanced use of external fertilizer nutrients. With the help of State Soil Testing Laboratory facility at Karnal, soil health care service can be integrated with the CA based practices in major cropping systems to reduce fertilizer input usage and improve nutrient use efficiency. An integrated soil test and SSNM based fertilizer recommendations will help in reducing production costs and improve productivity. Further, these recommendations need to be updated with CA based practices like in presence/absence of residues, planting time, water availability and its quality as well as for irrigated or rainfed situations; and for crop and cultivar or hybrid choices.

## 3.4 Land degradation

Some reports suggest that around 54% of total geographical area in Haryana suffer from land degradation processes of different types. Wasteland map of Haryana (Fig.

5), published in 2005-06, puts the estimates of such lands at nearly 3000 km$^2$ area (3 lakh ha). These lands can be rehabilitated through technology targeting and sharply focusing the planned state schemes meant for reclamation. For example, amount of gypsum sold/distributed in the State cannot be a criterion of number of acres of alkali soils reclaimed. Therefore, business as usual is neither helpful nor desirable. Current farming practices are neither in tune with new technological innovations nor contemporary to new emerging challenges. Hence, there is a need of a serious reassessment of production system constraints, and technological options to chalk out strategic entry points for new conservation agriculture practices. The objective of such a reassessment should be to produce more food at less cost, boost farm incomes and reduce risk; improve input use efficiency (land, labour, water, fertilizer nutrients, seeds and pesticides) improve quality of the natural resource base; mitigate greenhouse gas (GHG) emission through CA based technologies; enable farmers to adapt alternate approaches of diversification and intensification through intercropping/relay cropping that can be adapted to mitigate impact of climate change on agriculture including benefit of carbon credit in a longer term perspective.

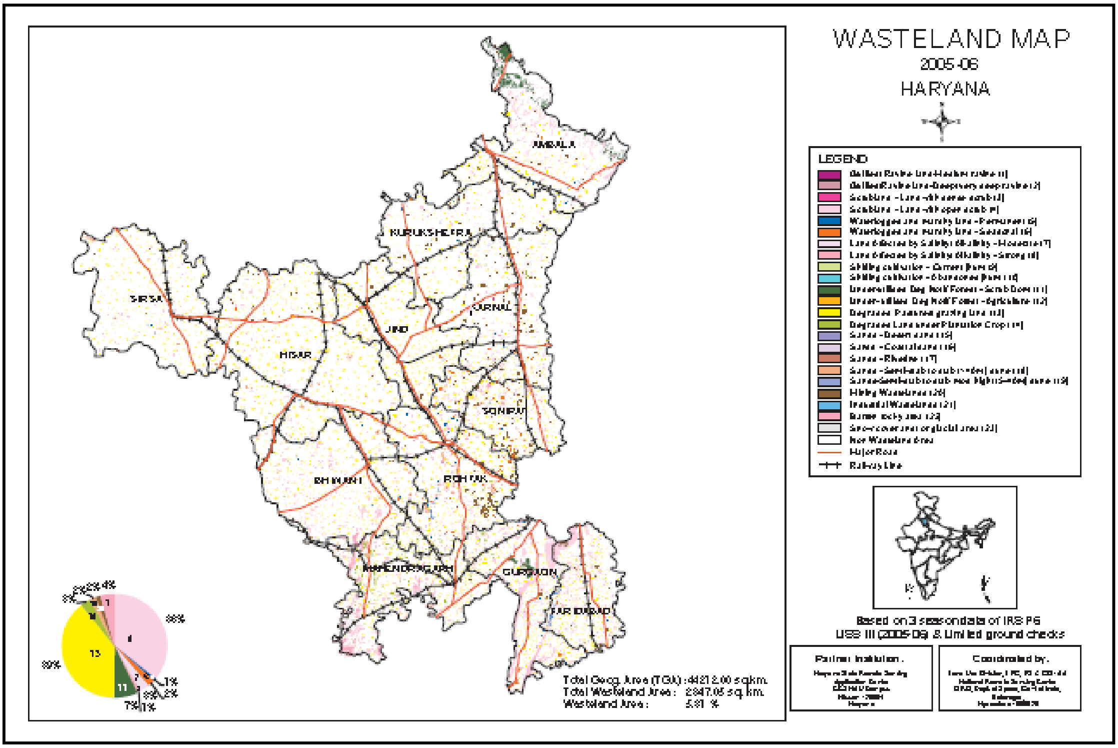


**Fig. 5.** Wasteland map of Haryana

# 4. Production System Constraints and Potential Technical Options

Current natural resource management problems are complex and require site specific management solutions. Production system constraints and technological options were identified by the Working Group during a series of meetings, field visits, and interactions of farmers organized with CCS HAU Hisar, Department of Agriculture (DOA), ICAR institutes, KVK's, Haryana Kisan Ayog, private sector, and NGOs. The prioritized stakeholders based Natural Resource Management (NRM) solutions/ strategies/action plans for Haryana state along with constraints have been summarized in the Table 2 below:

**Table 2.** Crop production constraints and potential NRM solutions in Haryana

| Production system constraints | Potential solutions |
|---|---|
| 1. High production cost, resource fatigue, low factor productivity | • Conservation agriculture based RCTs |
| 2. Water scarcity, declining water tables | • Laser leveling, ZT& Raised bed, Alternate Wetting and Drying (AWD), avoid puddling, DSR, skip furrow irrigation, pressurized system of irrigation, diversification, mulching |
| 3. Late planting of cereals and other crops | • Mechanization, DSR-ZT, Double ZT, relay seeding, short duration cultivars, use of high clearance tractor frames for relay sowing of wheat in cotton |
| 4. Imbalanced fertilizer use, multiple nutrient deficiencies & low NUE, nitrate pollution | • Conjunctive use of organics ( residue recycling , brown manuring), Nutrient expert linked to soil health Card and SMS service, customized fertilizers, Mop up nitrates by spring cropping |
| 5. Herbicide resistance and weed escapes | • Crop rotations, rotate herbicides, residue mulching, herbicide resistant crops, zero tillage, avoid rotavator |
| 6. Low profitability in Sugarcane-Wheat | • Autumn planting in paired rows grow inter-crops |
| 7. Residue burning, air quality | • Attach straw spreaders with combines, use Turboseeder |
| 8. Low diversification of RWCS | • Intercrops/relay crops, new cultivars, diversification |
| 9. Labor / energy shortages | • Zero tillage, Mechanization, land leveling , DSR, Unpuddled transplanted rice (UnTPR) |
| 10. Low productivity, sodicity, alkalinity and water logging, nutrient deficiencies | • Application of gypsum, phosphogypsum/distillery spentwash, diversification, cultivar choices, fertilizer schedules, targeted applications, drainage/irrigation schedules. Link watershed with CA in dry land areas. |
| 11.Mismatched perceptions (e.g. rotavator use) | • Use IT for wider scale delivery of Technologies, Link schemes to location specific farmers |
| 12. Low Public-Private sector linkages, trained personnel for CA | • Capacity building, study tours/traveling seminars, networking |
| 13. Use of poor quality waters | • Cyclic and conjunctive uses of multi-quality waters, salt tolerant crops, treatment of industrial and sewage waters for irrigation, mulching |
| 14. Low productivity of wheat in cotton –wheat system | • Relay wheat in cotton in western and south-west Haryana using surface seeding and relay planter |
| 15. Impending Ug 99/yellow rust threat, low seed replacement rate | • Farmer participatory seed systems, Seed cooperatives, seed village concept and quality seed production, etc. |
| 16. Crop based management | • Diversification, location specific models of IFS |
| 17. Post-harvest losses | • Post-harvest solutions (drying, silos , superbags),value addition and processing, improved market intelligence |

## 4.1 Strategic entry points for transformation: CA as a strategy

Conservation agriculture (CA) - based resource conservation technologies (RCTs) including new cultivars are more efficient, use less input, improve production and income, and address the emerging problems (Gupta and Seth, 2007; Saharawat *et al.* 2009, 2010, 2011). In Haryana, the RCTs involving no- or minimum-tillage with direct seeding, and bed planting, innovations in residue management to avoid straw burning, and crop diversification need to be advocated as alternatives to the conventional production technologies for improving productivity and sustainability.

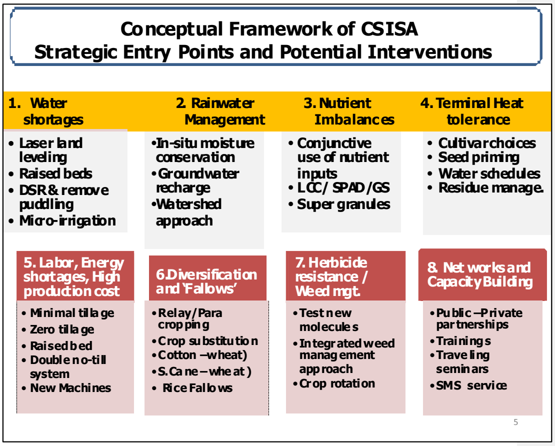


**Fig. 6.** Strategic entry points and potential interventions

In Haryana, no-till wheat and some other RCTs are being adopted by the farmers on large scale. However, there is a need to adopt these technologies in a cropping system approach instead in individual crop to harness the maximum benefits, especially for improving water use, labour and energy efficiencies. Conservation agriculture may not be a panacea for all the present day ills, but has bailed out Latin American agriculture out of downward spiral and poverty trap, almost 20 years ago. Based on stakeholders' consultations, the entry points of CA based technologies in Haryana have been depicted in Fig. 6 above.

The key suggested elements of the transformation strategy are:

| | | |
|---|---|---|
| a) | Uneven field levels | Precision laser assisted land leveling |
| b) | Excessive tillage | No till / drastically reduced tillage |
| c) | Residue burning or incorporation | Surface retention of residues |
| d) | Use of *ex situ* FYM/composts | Use of *in situ* organics/composts |
| e) | Green manuring (incorporated) | Brown manuring (surface drying) |
| f) | Free-wheeling of farm machinery | Controlled traffic |
| g) | Single or sole crops | Inter cropping / relay cropping |
| h) | Monotonous RW cropping system | Diversified cropping system, IFS |

## 4.2 Success stories of conservation agriculture in Haryana

In Haryana, zero till (ZT) technology was introduced to tackle the menace of *Phalaris minor* in early 90s. Since then, Haryana has been at the forefront of zero-till revolution. It paid rich dividends to the farmers. It increased production and average yields by 18% within one decade (Fig. 7).

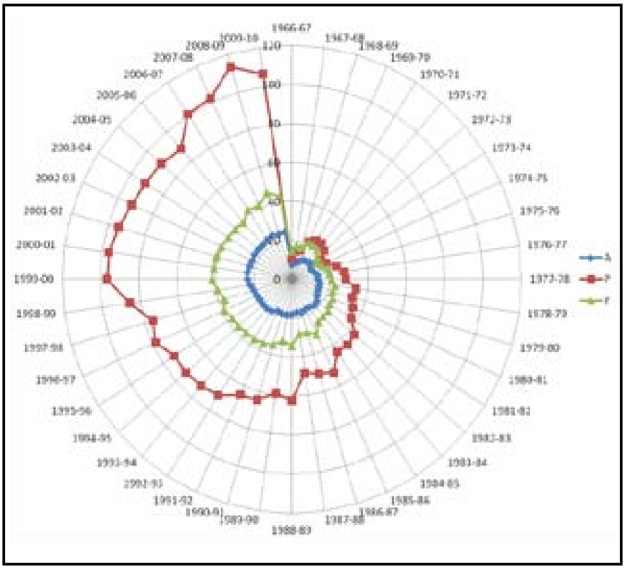

**Fig. 7.** Wheat area, production and yields in Haryana

The figure 7 shows the year-wise break up of wheat acreage, production and productivity. A very significant change noticed was that the farmers who could not practice zero-tillage, drastically reduced the number of tillage operations in wheat from 8-10 to 2 or 3. By 1999-2000, about 1/2 million ha was planted to wheat in Haryana in reduced-till or no-till situations. The prime driver of the ZT technology in Haryana was herbicide resistance of the *Phalaris minor*, a problematic weed in wheat crop.

CA/ ZT helped control this weed. Researchers came on board, identified new molecules for weed management, and develop new zero tillage practices and started working on farm machinery to enable planting in presence of loose and anchored crop residues of rice. CCS HAU Hisar, DOA, KVK's, ICAR institutes, private sector and NGOs aggressively promoted conservation agriculture to help farmers come out of a downward productivity spiral.

Wheat yield in farmer fields continued to improve in zero-till situations until 2000 when terminal heat stresses began to adversely affect production system, particularly the wheat crop (Fig. 7). The Researcher-extension workers-farmers continuum as such could not precisely assign sound reasons for the yield losses in wheat over past several years and or relate them to climate change, and fortify the earlier fact finding report of Sinha *et al.* (1998). During 2009-10, in Haryana, terminal heat stress decreased the production by 6.5%. Terminal heat stress effects on wheat yield declines were generally misinterpreted by farmers as due to zero tillage. Results of multi-location trials, conducted in farmers' fields by RK Malik and his team from CCS HAU Hisar were reanalyzed by Rajaram *et al.* (2010) to show that wheat yields were invariably more in zero till plots than the conventional tilled fields (Fig. 8). Ironically, scientists did not assign the yield declines to climate change. The Rice-Wheat Consortium (RWC) first time suggested that yield declines were not due to use of zero-till technology but because of climate changes.

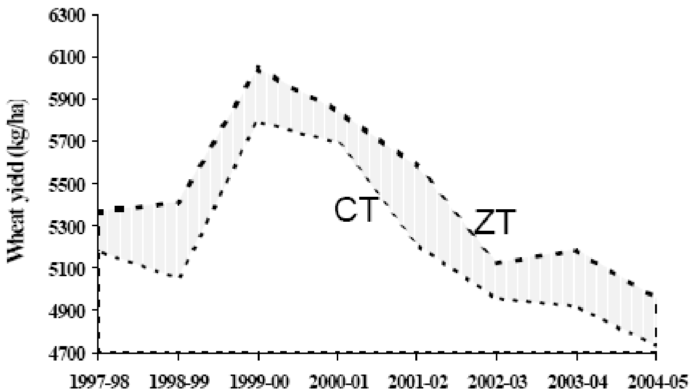


**Fig. 8.** Wheat yields and climate change over time in Haryana

Another reason for our inability in pinpointing terminal heat stress effects on wheat yield declines was because of a near lack of any long-term trial on CA in All India Coordinated Research Project. Thus, the climate change effects went unnoticed and misinterpretations reduced the zero till area in Haryana as well as wheat yields across the IGP. Experience with the introduction of zero tillage system in Latin America shows that there is a lag period between the adoption of the technology and observation of its results. Unfortunately this lag period in India got complicated due to climate change effects since 2000-01 when wheat yields began to decline.

# 5. Constraints in Adoption of Conservation Agriculture

The success of zero tillage technology adoption in Haryana was not without road blocks. Some major factors contributed to the set back of this new tillage revolution led by Haryana.

The concerns of farmers that stagnated the growth of the tillage revolution included as under:

- Poor quality drills pushed into market place
- ZT drill usage was recommended and restricted to just planting of wheat only
- Non-availability of planters that can seed into loose residues
- Non-availability of straw spreaders with harvester combines. Width of

the combines also doesn't match tractor width, creating ruts in wet / moist conditions, forcing farmers to practice tillage even in *rabi* season.

- Government of Haryana introduced rotavator to promote tillage, seeding and fertilization by broadcasting and burning of crop residues, introduced mainly for incorporation of green manure crops.

# 6. Current Status of CA Knowledge

Concerted efforts of the CCS HAU Hisar, KVK's, ICAR, and CIMMYT convened (RWC) and later IRRI convened CSISA project however have generated enough local expertise on:

- New machine prototypes to seed in full residue conditions,
- Information on new herbicide molecules,
- IPM related issues in system perspectives,
- Nutrient and water management practices fine tuned to suit mulched situations,
- Diversification/intensification of rice-wheat systems to improve productivity,
- Intercropping wheat/ onion/garlic in sugarcane to improve profitability,
- Introduction of short duration legumes as relay crop/ during the fallow period,
- New varieties/hybrids for the no-till residue systems,
- CA based systems for reduced salinity and alkalinity problem,
- DSR, mechanical transplanting of rice in unpuddled soils to overcome labor problem,
- Soil test database fertilizer recommendations, geo-referenced and SSNM/ nutrient expert being developed to account for crop cultivars/ hybrid and management practices and soil constraints, and
- Cell phone based interactive technical support service Agriplex with 'single click' provision is ready to provide last-mile technical solutions to farmers during the cropping season.

Although different pieces of information vital for last mile delivery are available but the full benefits of the different state schemes is difficult to extend to the needy without individual farmer database. This can happen if the available natural resource database (soils, crop, water and farmers) is geo-referenced in structured manner for targeting the new technologies. Farmers can be identified with a "Unique Farmer Identity (UFI) Number" who in turn can be associated with different state schemes prepared to address specific issues. This will enable effective implementation and monitoring the progress of the different schemes.

In order to collate 'better bet' CA based practices, the best option is to involve practitioners of zero tillage. Farmers recognize early benefits of zero tillage (reductions in production costs due to tillage, timely planting, savings in seed and water and band placement of fertilizer nutrients) but it usually takes two-three years, before other benefits due to reduced loading of chemical molecules (herbicides and insecticides etc.), stabilization in ground-water table and soil microbial activity due to good soil health become visible in CA to farmers. In the beginning, some farmers face challenge of production losses due to erroneous use of new machinery or poor weed control. However, as the system gets established and the farmers gain experience and the soil cover is retained for several years, the benefits such as, improved soil fertility, soil organic matter, improved water retention and reduction in run-off losses of rain water, better root mass development and biological activity in the soil results in higher productivity and production.

# 7. Key CA Technologies For Large Scale Adoption

Significant efforts have been made through on-station and farmers participatory research by the CCS HAU Hisar, DOA, ICAR Institutions together with IARCs (CIMMYT, IRRI, RWC) to develop customized solutions on conservation agriculture based technologies to address the issues of natural resource fatigue, declining water tables, decelerating factor productivity, terminal heat stress and shrinking farm profitability. The promising and proven CA based technologies ready for large scale adoption are described as below:

## 7.1 Laser land leveling

The laser assisted precision land leveling has been evaluated under large number of (N=92) trials/farmers in Haryana. The study at farmers fields, research stations and demo field shows that on an average laser land leveling saves 30% irrigation water, improves yields by 17%, saving in operational time of farm machinery, and increase in net sown area due to removal of bunds and channels (post leveling increased plot size for irrigation) in different cropping systems of Haryana (Fig. 9).

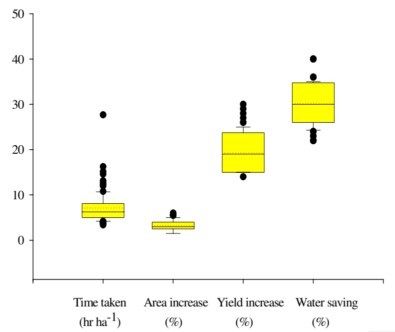


**Fig. 9 .** Benefits of laser over conventional leveling in RW system

The benefit of laser land leveling in vegetable/potato systems are much more than the cereal systems. Despite significant benefits of the laser land leveling, adoption rate is slow in Haryana as compared to neighboring states like Punjab and Western UP. There is an urgent need of policy initiative to promote custom service providers to boost laser land leveling in large domain of Haryana State. Suitable policy interventions can accelerate the adoption of this technology in most parts of the state.

## 7.2 Double no-till in rice-wheat systems

### 7.2.1 Direct seeded rice (DSR)

The DSR eliminates puddling, saves on water (~30%) and labour, and also improves soil health and system productivity. As a first step, the State needs to ensure that good quality multi-crop planter prototypes are available in villages in good numbers. Also farmers have to be educated about new DSR practice for large scale adoption of this technology.

### 7.2.2 Zero till wheat with full residues

For managing residues, the first step should be equipping all the combine harvesters with straw spreaders (must be mandatory for all). Wheat crop can be planted with zero time lag using turbo seeder that eliminates residue burning and making optimal use of residual moisture. There is a need to create machinery banks and promote single window custom services in private-public partnerships.

The potential benefits of double no-till (CA) in rice-wheat rotation over conventional tillage based management practices are given below in Table 3.

**Table 3.** Comparative benefits of CA based management over farmers practice in RWCS

| Variables | Crop management practices | | |
|---|---|---|---|
| | **Farmers Practice (PTPR-CTW)** | **CA based practices (ZT DSR - ZTW)** | **+/- with CA** |
| Rice yield (t/ha) | 8.0 | 8.0 | 0 |
| Wheat yield (t/ha) | 5.0 | 5.5 | + 0.5 t/ha |
| Total cost in RW system(Rs/ha) | 84105 | 80415 | Rs 3690/ha |
| Net income in RW system (Rs/ha) | 78435 | 89505 | Rs 11070/ha |
| Total water use in rice (mm) | 1943 | 1352 | -591 mm (30 %) |
| Total water use in wheat (mm) | 346 | 327 | -19 mm |
| Carbon sustainability index (C input /output ratio) | 5.66 | 7.91 | + 2.25 |

*Source: Mahesh Gathala. 2010. CSISA Research platform at CSSRI, Karnal*

*FP refers to farmer practice, PTPR=Puddle transplanted rice, CTW= Conventional till broadcasted wheat, ZT=Zero till direct seeded rice, ZTW=Zero till wheat*

### 7.2.3 Relay cropping of mungbean in wheat

Irrigation management particularly scheduling last irrigation has a great role in mitigating terminal heat stress in wheat. Abrupt rise in temperature at grain filling coincided with dry westerly winds which enhance the drying processes leading to forced maturity, and shrivelled grains in wheat. Terminal heat stress reduces the seed test weight (1000-grain weight) and fraction of ear heads having grains more than 50 grains/ear head and ultimately the grain yield. The terminal heat stress in March 2010 resulted in yield loss in full season wheat cultivars planted late and under conditions wherein last irrigation did not match with grain filling stage. Results of

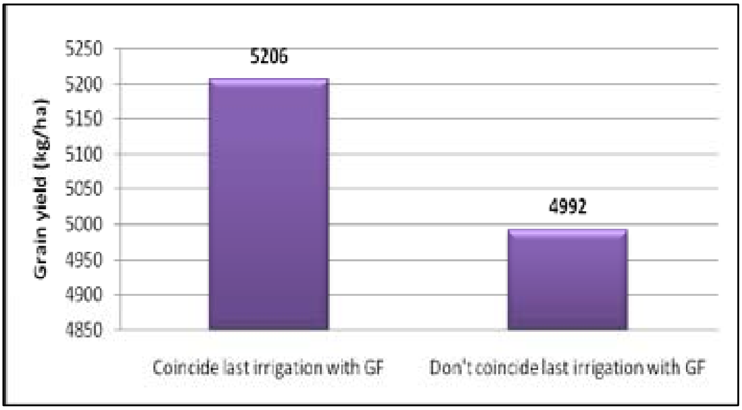


**Fig. 10.** Effect of irrigation on wheat yield, used for relay planting of mungbean in 2009-10 in Karnal (N=09)

farmers participatory field trials (N=09) conducted in Haryana (Fig. 10) suggest that irrigation at grain filling stage in wheat if matched, proves beneficial for surface seeding mungbean and wheat as well. Relay planting of green gram (CV. SML 668) enthuses farmers to irrigate wheat at grain filling to facilitate germination of the pulse crop. Irrigation for relay crop of mungbean proved an enabling factor for wheat to tolerate the heat stress. Mungbean helps in absorbing residual NO3-N of the wheat crop before it joins the water table (aquifer) in monsoon season. Therefore, it appears to be a good strategy to promote relay planting of mungbean in wheat to have twin benefits of increased wheat yield and reduced NO3-N pollution of aquifers which is on the rise in north-western parts of the Indo-Gangetic Plains (Chandna *et al.* 2010).

However, there is a need to conduct additional efforts to fine-tune the technology to match emerging weather conditions and also train farmers to enable them get consistently good yield of mungbean crop.

### 7.2.4 Intensification in sugarcane production systems

In Haryana, sugarcane is sown in nearly one lakh hectares. Sugarcane is planted generally in autumn/winter season and spring season. The sole sugarcane crop is mostly sown after wheat harvest leading to delayed planting, reduced germination, low profitability, low factor productivity, reduced sugar recovery. Experience has shown that autumn planting of sugarcane should be promoted with conservation

**Paired row planting of sugarcane in wide beds**

agriculture based intercropping systems including wheat, vegetables and flowers. The cost of cultivation of sole sugarcane crop is at par with intercropping of garlic, wheat, onion, cauliflower, gram and lentil (Table 4). Cane productivity in intercropping system with garlic, onion and lentil was at par with sole sugarcane crop but farmers benefited most from an additional yield of intercrops (equiv. to Rs. 128250, 64350, 53280, 44325, 37980 and 32985 from garlic, cauliflower, lentil, gram, wheat and onion, respectively). Therefore, the State should ensure policies for promotion of autumn planted sugarcane intercropped with garlic, vegetables and pulses.

The policies should also be put in place to initiate the timely sugarcane crushing in mills to promote diversification. Eighty per cent sugarcane area in Sonepat, Panipat and Yamunagar districts can be brought under intercropping with onion, garlic and wheat.

In Rohtak, Jind, Kaithal and Gohana districts, raya can be intercropped with sugarcane. In Sonepat and Yamunanagar districts, winter sugarcane can be intercropped with maize and vegetables. Additionally, there is a urgent need to promote efficient irrigation systems i.e. drip and furrow irrigation systems in sugarcane based systems to improve water use efficiency and better germination of crop. This will fetch an additional income to farmers and increase area under sugarcane in Haryana. It is also worth mentioning here that CCS HAU Regional Station in Uchani has been a front runner for developing cane planting methods. It seems that a major drawback of most planting methods so far has been their inability to facilitate mechanization in sugarcane. It seems that beds spaced 134-145 cm apart allows tractor to operate in wide furrows, later used for paired-row planting of cane sets. It is best suited for tractor based inter-culture operations and to facilitate intercropping between widely spaced cane rows. This method is very popular in Tamil Nadu and can be adopted with advantage with little bit refinement, if needed in Haryana.

**Table 4.** Productivity and profitability of sugarcane (SC) intercropping systems in Haryana

| Cropping system | Productivity (kg ha-1) | | Gross returns (Rs. ha-1) | Cost of cultivation Rs. ha-1) | Net returns (Rs. ha-1) |
|---|---|---|---|---|---|
| | Sugarcane | Intercrop | | | |
| Sole Sugarcane | 91250 | 0 | 228105 | 91800 | 136305 |
| SC+Garlic | 90000 | 5000 | 374985 | 110430 | 264555 (+128250) |
| SC+Wheat | 87500 | 4750 | 277020 | 102735 | 174285 (+37980) |
| SC+Onion | 90000 | 17500 | 295020 | 125685 | 169290 (+32985) |
| SC+Cauliflower | 89000 | 25000 | 297495 | 96840 | 200655 (+64350) |
| SC+Gram | 87500 | 2000 | 272745 | 92115 | 4014 (+985) |
| SC+Lentil | 88000 | 1250 | 282510 | 92925 | 4213 (+1184) |

## 7.2.5 Relay planting of wheat in cotton

There is a relatively higher productivity and greater returns in relay planting of wheat in cotton. However, there is a need to demonstrate this technology by using high clearance tractor frames for relay sowing of wheat in late planted BT and long duration composits of cotton in Haryana.

Availability of the high clearance tractor frame is a serious bottleneck in extending this technology to the farmers. The State can facilitate the availability of the prototypes to farmers.

**Table 5.** Wheat grain yield and net returns under different planting methods under cotton-wheat system (Results from Bhatinda, Punjab)

| Planting practices | Wheat grain yield ( t $ha^{-1}$) | | | Cost of cultivation (Rs. $ha^{-1}$) | Net profit (Rs. $ha^{-1}$) | B:C ratio |
|---|---|---|---|---|---|---|
| | 2009-10 | 2010-11 | Mean | | | |
| Relay planting | 4.97a | 4.84a | 4.91a | 19350 | 60885a | 3.15 |
| Conventional (farmers practice) | 3.52b | 4.33b | 3.93b | 20835 | 44010b | 2.11 |

*Source: HS Sidhu 2010. D Within a column, means followed by the same letter are not significantly different at the 0.05 level of probability by the Duncan's multiple range test (DMRT)*

## 7.2.6 Dual purpose wheat technology

Dual purpose wheat refers to growing of wheat for green fodder until 55-60 days after sowing and then for grain and dry straws (*bhusa*). In order to have increased biomass, dual purpose wheat is planted with Egyptian clover (*berseem*) in late October. The

55-60 days old crop mixture is harvested at 2-3 inches above ground or above second node to facilitate regeneration of the wheat crop. *Berseem* crop can be knocked out using 2,4D sprays 3-4 days after harvesting of green fodder. This allows *berseem* to have some foliage for effective absorption of the chemical molecule, thereby allowing wheat to grow as a sole crop. This practice is very useful in peri-urban interface where there is demand for green fodder by dairies.

Often farmers and researchers have apprehensions that wheat crop after cutting for green fodder will not regenerate or this practice may result in heavy yield penalty in grain production. Results from the field trials have indicated that wheat crop regenerates very fast when cut above second node as reflected by dynamic NDVI measurements taken with GreenSeeker optical sensors (Fig. 11).

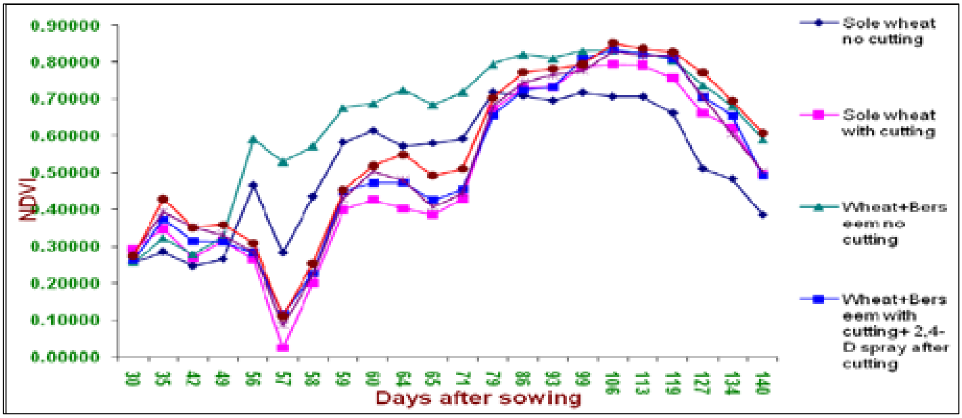


**Fig. 11.** Regeneration of wheat after cutting (57 DAS) in 2007-08

*Source: Mahesh Gathala 2010. Personal Communications*

Dual purpose wheat technology allows integration of crop-livestock production systems. The quantity and quality of green fodder early in the winter season holds the key for higher productivity of cattle/ livestock. Small farmers are unable to put required area under green fodder due to scarce land resource and generally end up feeding their livestock with dry stover and *straw* and their reduced milk productivity. Dual purpose wheat + Egyptian clover could be a good option to address this problem. In multi-location farmer participatory field trials, mixed stands of wheat and Egyptian clover were grown for green fodder. After one cut for green fodder, the wheat crop was allowed to grow for grain and *straw*. *Berseem* was knocked down with 2,4D after harvesting of green fodder. It may be mentioned that it is best to use 2,4D after the *berseem* crop has developed few leaves for absorption of the chemical molecules. The results of the farmers' participatory field trials (Table 6) revealed that with dual purpose wheat sole or in mixed stand with Egyptian clover, can yield an additional 12 to 15 t/ha green fodder for livestock feeding and increased the farm gate return by more than 10620 Rs/ ha.

**Table 6.** Dual purpose wheat + Egyptian clover system

| Treatments | Green fodder (kg/ha) | Grain yield (kg/ha) | Straw yield (kg/ha) | Wheat equiv. yield | Total cost, Rs/ha | Gross returns, Rs/ha | Net returns Rs/ha |
|---|---|---|---|---|---|---|---|
| 1. Wheat+Berseem, (With cut fb 2,4-D) | 15025 | 4539 | 6752 | 6465 | 56790 | 90225 | 33435 |
| 2. Wheat+Berseem,cut | 15025 | 4528 | 6183 | 6454 | 55980 | 88785 | 32805 |
| 3. Wheat+Berseem, (No cut but fb 2,4-D) | 0 | 4819 | 7206 | 0 | 88785 | 32805 | 18720 |
| 4. Wheat+Berseem, (No-cut) | 0 | 4764 | 7583 | 0 | 52965 | 71685 | 18720 |
| 5. Sole Wheat With- cut | 12267 | 4639 | 6250 | 6212 | 53955 | 85995 | 32040 |
| 6. Sole Wheat (control) | 0 | 4917 | 7275 | 0 | 52200 | 71955 | 19755 |

*Source: BR Kamboj, 2011. Personal communications*
*Green fodder price INR 150/q & Wheat grain price INR 1170/q*

The green biomass of wheat plus *berseem* or wheat fodder varied between 12-18 tonne/ ha. Variations in green biomass and wheat yield penalty depended on the cutting schedules, N replenishment removed in green fodder and irrigation water availability for N fertilization. The green fodder, sold in the market, usually fetches around Rs.900-1000 per tonne in the last week of December. Studies conducted by Singhal *et al.* (2006) at National Dairy Research Institute, Karnal have confirmed that wheat green fodders have higher crude protein (22.5% protein on dry weight basis) than the same age oat green fodder (12.5% crude protein) . This is because wheat is better fertilized than oat or berseem. They have further reported that crude protein digestibility of green wheat fodder, irrespective of its form, was significantly better than that of green oats fodder.

### 7.2.7 Micro-irrigation systems

Farmers tend to believe that rice prefers continuous pond water conditions during the growing season for maximum yields. Such a practice results in very low irrigation efficiency. Due to over-exploitation of groundwater in rice-wheat belt (Rodell 2010), there is immense pressure on the agricultural sector to reduce its water consumption. Researchers have been evaluating if cereals such as rice and wheat can be grown with micro-irrigation systems. Very recently direct seeded rice crop was grown with drip and sprinkler system in Haryana and Punjab. Compared to flood puddled transplanted rice, drip and sprinklers saved nearly 60% and 48% irrigation water, respectively. With micro irrigation yield gains averaged to 19% (Table 7). Similarly, micro-irrigation systems saved 42% irrigation water in wheat and improved crop yields by 28%. The results presented in Table 7 clearly brings out that there is huge potential for growing cereals with micro-irrigation systems. CCS HAU and ICAR institutes should set up additional research trials for reducing initial investments and improve fertilizer use efficiency.

**Table 7.** Potential of micro-irrigation systems in improving water use efficiency in rice-wheat cropping system

| S.No. | Irrigation method | Rice culture | | Wheat (Zero tillage) | |
|---|---|---|---|---|---|
| | | Applied water(mm/ha) | Yield (t/ha) | Applied water(mm/ha) | Yield (t/ha) |
| 1 | Flood irrigation (PTPR-ZTW) | 580a | 4.60b | 360a | 3.61c |
| 2 | Drip Irrigation (DSR- ZTW) | 211c | 5.49a | 206b | 4.63a |
| 3 | Sprinkler Irrigation (DSR- ZTW) | 269dc | 5.50a | 206b | 4.2b |
| 6 | Flood irrigation (DSR-ZTW) | 470b | 5.35a | 354a | 4.32b |

Source : Saharawat, Y. 2011. Personal communication from IRRI, India

# 8 Avoiding Soil Compaction in No-till Situations

## 8.1 Diagnostic surveys on the effect of rotovator

In order to avoid compaction in zero-till fields, it is best to stop free-wheeling of the tractor. This can be best achieved by practicing controlled traffic wherein tractor tyres move in the same ruts like a train on the rails. In Punjab, rotavator was first introduced as a tool for certain situations, but farmers started using it as an implement for tillage and crop establishment tool. The rotavator has led to promoting residue burning; of broadcast seeding and fertilizers. The hard hitting actions of the fast moving L-shaped blades causes sub-soil compaction (hard pan) at 15-20 cm depth. To overcome the problems, the farmers either go for chiseling or use additional fertilizer nutrients to overcome ill effects of temporary waterlogging after an irrigation or rainfall event. After rice harvest, rotavator can't work in full or half straw load.

A simple questionnaire was developed and farmers were interviewed for their opinion on observations/parameters as shown in Table 8. The key findings of this survey are as under:

- 67% farmers had opinion that rotavator sown field take more time in first irrigation (more volume of irrigation water, more time).
- 39% farmers opined that yellowing of leaves occurs in rotavator sown fields after first irrigation.
- 24% farmers had indicated that uneven germination occurs in rotavator sown fields.
- 46% farmers indicated use of extra dose of DAP (42.5% more) than that of state recommendation under rotavator sown wheat
- 61% farmers used extra dose of urea (36% more than recommended) to compensate the yellowing after first irrigation.
- In general, it was noticed that farmers are using more dose of DAP and urea, but they are getting same yield.

**Table 8.** Farmers perception on rotavator use for wheat seeding

| Parameters | Number of farmers in time slots responding affirmatively | | | | | | | % |
|---|---|---|---|---|---|---|---|---|
| | 180 days | 1 yr | 2 yr | 3 yr | 4 yr | 5 yr | 6 yr | farmers |
| Heavy irrigation | 4 | 261 | 268 | 110 | 31 | 17 | 3 | 67.2 |
| Yellowing of leaves | 3 | 111 | 196 | 60 | 22 | 11 | 4 | 39.4 |
| Uneven germination | 3 | 111 | 196 | 60 | 22 | 11 | 4 | 24.4 |
| Extra use of DAP (kg/ha) | 100 | 49 | 52 | 46 | 62 | 63 | 38 | 46 |
| Extra use of Urea (kg/ha) | 175 | 81 | 97 | 159 | 74 | 72 | 38 | 61.2 |

## 8.2 Rotavator and soil compaction

For proper operation of rotavator, farmers generally have to clean their fields through burning of residues of the previous crops. Rotavator is known to consume more energy and fuel than a conventional tillage operation because of more load on the tractor. A field study was conducted by HS Sidhu *et al.* (2010, personal communications) on differentially tilled (conventional, rotavator and zero-till) 113 fields identified in Ludhiana, Fatehgarh Sahib, and Sangrur districts.

Soil compaction was recorded using a precision digital Cone Penetrometer. Soil compaction increased with rotavator use over time. Soil compaction was minimal in zero tilled fields with surface residues (ZTR) and conventional methods (Fig. 12). So if farmers adopt ZTR technology, not only they benefit from reduced tillage costs but also improve health of their fields.

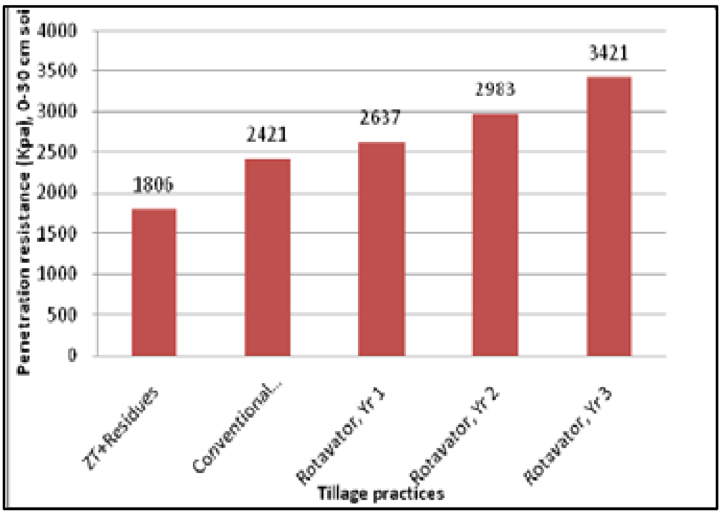


**Fig. 12.** Effect of tillage practices on penetration resistance of soils in Punjab (average of n=563)

# 9. Leveraging Subsidies

During the meeting of CCS HAU and CIMMYT-CSISA scientists with the Director Agriculture, and Senior Officers of Government of Haryana on December 03, 2010 in the Directorate, Panchkula, Chandigarh, it was agreed that the subsidy on rotavator will be discontinued from next year. If there is any availability of left over funds in machinery head for the current year, DOA will relocate them on Turbo-Happy Seeders and the Multi-crop Planters. (Ref. - Memo No. 188-192 dated 14.2.2011 of the DG, Department of Agriculture, Government of Haryana).

# 10. Research for Development Needs for Refinement of CA based Technologies

In order to accelerate the pace of adoption of conservation agriculture based management practices, there is an urgent need for extending the zero or minimum tillage to non rice-wheat cropping systems. These cropping systems include the pearlmillet-mustard/ wheat, clusterbean-wheat, and Sorghum-wheat systems. Also, there is an urgent need for strengthening the research information base on the following aspects:

- Geo-referenced farmer tube well water quality surveys in all villages
- Fine tuning of old soil test based recommendations. New recommendations should be cropping system based and consider crop/ cultivar choices, inter-cropping systems and nutrient management in relation to tillage and residue management options.
- Water management for mulched plots in CA based systems
- Pest dynamics under CA based systems
- Introduction of CA in course curricula of SAUs for developing a new generation of scientists specialized in CA.

# 11. Generic Business Model for Agricultural Transformation

A business model is a description of operational and implementation processes and how and where these operations generate value. It describes key activities, key resources needed, products and services offered by business and how it delivers them to the target clientele. For accelerated uptake of technologies, any business model must define and consider partnership networks, outline operational costs and revenue streams resulting from the business. While generic business model must meet institutional mandates and business motives of the partners, it must improve agro-eco-regional sustainability, and profits for the farmers.

A generic business model described in (Fig.13) was developed and tested by CIMMYT under aegis of the CSISA project large scale roll-out of the conservation agriculture based resource conserving technologies in NE Haryana. It emphasizes the importance of characterizing production system domains, identify constraints and prioritizing the interventions (technical options for the prioritized problems), and identifying the strategic entry points for introduction of the integrated solution for resolution of the problems of natural resource management. It brings together the public and private sector/ NGOs for a common call to improve the comfort zone of farmer groups for an accelerated adoption of geographically differentiated technologies specific to each zone in the state (Kumar *et al.* 2011).

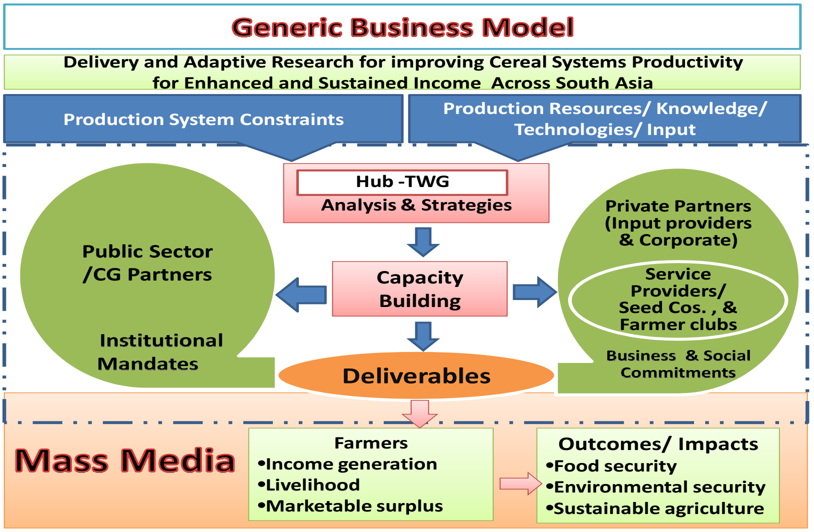


**Fig. 13.** Generic business model of operations in Karnal Hub

The emphasis is also placed on bringing together knowledge (technologies) and inputs at farmers' door steps to facilitate easy adoption for improved yields and farm gate incomes on sustainable basis particularly when the project withdraws from the targeted areas. Due attention has been paid to involve small machinery manufacturers, millers, Self Help Groups (SHGs), seed growers and seed associations, thrift credit societies/ cooperatives, input dealers and retailers to facilitate easy access and timely supply of the quality inputs to the growers. Whereas public sector institutions achieve their institutional mandates, private sector is able to generate new business through enhanced sales of inputs and value added services. The generic business model presented in the figure 13 also brings out that the farmers get the benefits of higher yields at lesser costs, generate marketable surplus and achieve better livelihoods at reduced risks.

The business model mentioned above has been tested to improve last-mile delivery of technical advisories, and inputs in public- private partnership. In Table 9, issues, technical options, possible interventions and targeted areas have been summarized to enable focus on investments.

**Table 9.** Issues-Options and Targeted Actions

| Issues | Technical Solutions | Targeted Area and Possible Interventions |
|---|---|---|
| 1.Declining water tables, water scarcity and GW pollution with nitrates | • Laser levelers, precision leveling<br>• Raised beds<br>• Skip furrow irrigation<br>• Sprinkler and drip irrigation<br>• Conjunctive use of LQWs with amendments in cyclic modes<br>• Residue management<br>• Promote DSR and UnPTR rice<br>• Ground water recharge in transition zones<br>• Rainwater management/ field levelling<br>• Direct seeding of winter crops without pre-sowing irrigation<br>• Crop diversification<br>• Treatment and use of problematic waters for irrigation. | • Training of laser leveler service providers<br>• Govt. places laser units to service providers<br>• Enhance availability of amendments for land reclamation and water treatments<br>• Link CA to water shed and soil conservation measures<br>• Introduce spring para-cropping in wheat and or / cover crop in NE Haryana<br>• Fifty per cent ( 50%) area under basmati rice be placed in DSR with pre and post sowing herbicide molecules<br>• Joint evaluation of short duration hybrids from public and private sector.<br>• More proactive role of RRS, Kaul in promoting DSR / CA technologies<br>• Encourage custom-hire services for mat type nursery<br>• Subsidy on paddy transplanter |
| 2. Labour shortages and late planting in winter season and high production costs | • Promote ZT / RB planting in wheat based systems with some residue management<br>• Promote DSR<br>• Introduce new quality machines Turboseeder / happy seeder<br>• Reaper -harvester -binder<br>• Try out relay crop of wheat in rice and relay crop of moong in wheat | • Fifty per cent wheat area (1.2 million ha) be targeted and maintained for long-term under CA.<br>• Double No till system be introduced in Sorghum-wheat cropping system.<br>• South-West Haryana may be given focused attention with more residues on the surface. Leadership position of Haryana should be maintained.<br>• Withdraw subsidy on rotavator. |
| 3. Nutrient imbalances and low factor productivity of external nutrient supplies | • Brown manuring in rice<br>• Paracropping of mungbean in wheat, balanced nutrition<br>• LCC/ SPAD/GS<br>• Improve NUE in ratoon cane | • Promote spring planting of mungbean / relayed mungbean in wheat<br>• Promote spring maize in NE Haryana<br>• Promote off barring machine and deep fertiliser placement in cane<br>• Promote residue retention and discourage residue burning<br>• Create cold chain for bio-inoculants |
| 4.Crop diversification and Intercropping and raised bed planting | • Crop substitute – rice with maize /Soybean as sole crop or intercrop with pigeonpea on raised beds<br>• Cotton –wheat/vegetable<br>• Sugarcane –garlic/vegetable/ wheat<br>• Intercrop of vegetable with maize etc<br>• Spring maize/ SF<br>• Dual purpose wheat with CA<br>. | • Promote autumn planting of cane<br>• Regulate cane crushing season<br>• Fifty per cent ( 50%) of 0.15 million hectare sugarcane can be brought under intercropping<br>• Sonepat, Panipat and Yamunagar areas can be brought under onion, garlic based intercropping or wheat based agroforestry /agro horticulture systems.<br>• Rohtak, Jind, Kaithal Gohana can be brought under raya based cropping systems<br>• Winter maize in Sonepat and Yamunanagar can be brought under vegetable based intercropping.<br>• Intercropping of bajra and moong in dry areas covering about 4.0 lakh ha.<br>• Introduction of castor in Bhiwani and Mohindergrh areas<br>• Timely sown wheat can be used for dual purpose to reduce green fodder shortages for dairying in Jan. |

| | | |
|---|---|---|
| 5. Herbicide resistance, and weed escapes | • Crop rotations<br>• Rotate herbicide use<br>• Residue mulching<br>• Herbicide resistant crops<br>• Do not till the fields | • Introduce flat fan tip nozzle (3-4) sprayers and train farmers on use of sprayers<br>• Research on herbicide usage for pre-emergence situations in presence of residue mulches |
| 6. Terminal heat stresses | • Timely planting of DSR rice in mid June to allow timely planting of winter crops.<br>• New cultivars<br>• Irrigation management<br>• Residue management | • New CA machines be promoted by Department and KVKs.for timely wheat planting in rice and cotton growing areas.<br>• Fine tune irrigation at anthesis / grain filling<br>• Promote of Mb paracropping in wheat to encourage last irrigation in ZT wheat |
| 7. Low profitability of cane-wheat systems | • Planting time<br>• Planting methods<br>• Wheat/legume/vegetable/ oilseed intercropping in cane | • Promote the mulching to save on inter-culture costs/ herbicide costs in most of the cane belt in Sonepat, Panipat and Yamunagar |
| 8. Low productivity, sodicity, alkali and saline-sodic water, nutrient deficiencies | • Gypsum/phospho gypsum usage<br>• Cultivar choices<br>• Fertilizer methods/ schedules, targeted applications.<br>• Rain water recharge (injection) technology of tubewells in brakish group water areas.<br>• Link watershed with CA in dry land areas | • Most areas where sodic/ ground waters with higher RSC are found (eg.Kaithal, Panipat etc.)<br>• Promote gypsum / phospho gypsum usage in oilseed belts<br>• Proper weed management in oil seed *Brassica* for orabanche<br>• Promote Bee keeping as pollinator<br>• Promote ZT and mulching in cotton / pearl millet and guar belt<br>• Promote agro forestry /forestry system under problematic soils and water conditions. |
| 9. Networking, human resource development for technology dissemination | • Public private partnerships<br>• Involve service providers and retailers<br>• Organize net works with KVKs<br>• Organize helplines, Cellphone networks and farmers visits.<br>• Organise travelling seminars, capacity building, networking<br>• Strengthen research backstopping on CA with the CCSHAU. | • AAREM at CCSHAU Hisar and training centers of line departments should organize special courses to gear up farmers in adoption of Conservation Agriculture in the state.<br>• AAREM at CCSHAU should take up studies on policy issues on CA together with KVKs<br>• KVKs should create training cum demonstration hubs in each KVks<br>• Strengthen Cell phone and help lines and monitor them for correctness<br>• Encourage ITIs and Cooperatives to set up service and repair centers for agricultural implements in each block. |

Therefore, business as usual is neither helpful nor desirable. Current farming practices need a reassessment of production system constraints, and technology options to chalk out strategic entry points.

# 12. Policy Interventions and Financial Support Needed for CA

There are large number of policy issues which would require political intervention and financial support for timely delievery of location specific packages of conservation agriculture to help the farmers of Haryana. It will require development of infra-structure facilities, promotion of public-private partnership and fruitful linkages between stakeholders, educational institutions, Government and Non-governmental developmental agencies, planners and administrators to address and resolve the short and long term issues for timely implementation of various technologies of conservation agriculture for sustainable crop production in Haryana. These are as under:

- Promote in situ rainwater conservation rather water harvesting.
- Launch campaigns for timely sowing of the crops and residue retention / avoid residue burning.
- Develop ecology specific good quality seed banks at block level and avoid distress sales of good quality truthfully labeled seed, where ever possible. Set up silos for seed storage at block level to maintain seed quality
- Create CA Machinery Banks with Farmer Cooperatives in the Blocks; reduce/ eliminate incentives from tillage machinery (such as rotavator) that enhance soil degradation and compaction. Introduce new prototypes of cultivator, double disk openers and harrows, off baring machine for fertilizer application in cane, sugarcane-wheat crop planter and harvester and cotton stubble cutters etc..
- Create a policy environment that enables farmers to buy quality machines from nearby retail outlets of Haryali, IFFCO, Kribhco Tata Sansar, and KVKs etc. at subsidized rate. This can facilitate development of new implements based on quality and allow open competition in the industry. It will also increase the access to appropriate planting machinery, remove subsidy on out dated versions.
- Encourage ITIs and Cooperatives to set up service and repair centers for agricultural implements in each block. A course can be introduced in the ITIs to promote self employment of the rural youths.
- Encourage the State Agricultural University to include CA in the course curricula.
- Encourage the University and the KVKs to develop longer term CA platforms for inclusive deployment of the multi-disciplinary scientists/ students and link these platforms to champion farmers in each of the districts.
- Encourage & provide boron steel for development of the double disk openers.
- Provide tax break incentives for CA farmers for water use efficient technologies and also that build soil carbon (carbon credits).

- Promote ground water recharge through in situ soil rainwater conservation and other technologies in *kharif* season.
- Encourage pressurized systems of irrigation for use of low quality waters following experiences in south Haryana.
- Promote agro-forestry/forestry system on problematic salt affected soils and common property land resources.
- Promote treatment of industrial effluent and swage waters for irrigation purposes.
- Ask the KVKs to work more aggressively with private sector in technology assessment and refinement (TAR) and develop FAQs database for easy and correct responses on toll free help lines. Cell phone based advisory services (on weather, pests, diseases, cultivar choices, seed and markets - contents etc.) should be made mandatory for each of the KVK and the DDA in the district and work in close collaboration with each others.

## 12.1 Integrating conservation agriculture with state schemes

Department of Agriculture has been implementing some of the following major schemes of the Government of Haryana as well as of Government of India as under:

- National Food Security Mission (NFSM) – 33.75 crore,
- Rashtriya Krishi Vikas Yojana (RKVY) – 180 crore,
- National Horticulture Mission – 101.7 crore,
- Accelerated Fodder Development Programme – 15.0 crore; and other minor schemes and may be several others.

Recently, Department of Agriculture has refocused and re-prioritized its investment to support CA activities. The major focus of these schemes is on:

- Soil health improvement through soil health cards issued by the state soil testing laboratories;
- Promotion of water saving technologies viz. laser leveling, direct seeded rice, residue management, zero tillage and micro irrigation systems;
- Farm mechanization focused on CA machinery;
- A scheme has been introduced in the State to promote cluster bean (*Cyamopsis tetragonaloba*) and maize. The scheme can be used as an opportunity for crop diversification of rice-wheat system by incorporating a legume (mungbean) into cereal system and also maize to replace rice in some area or maize with short season crops green pea etc. in winter season or introduce intercrops in sugarcane systems using CA technologies. Summer mung (*Vigna radiata*) has been promoted as an "opportunity crop" in between wheat and rice, which has unprecedented growth and expanded to more than 40,000 hectares in one season

alone. Horticultural and vegetable crops have been promoted to diversify the cropping system and improve the nutritional status of the people.

- Similarly, the profit margins of the cotton farmers can be significantly improved through timely relay planting of wheat in cotton-wheat system and also encourage transplanting of cotton amongst farmers located in the tail-ends of irrigation commands. These farmers receive water late and suffer heavy losses in wheat productivity.

## 12.2 Future road map

In order to promote CA strategy as a vehicle of change in agricultural production and sustainability of agriculture in the State, the Working Group observed that there is an urgent need to undertake the following activities:

- Haryana Govt. must provide high priority to promote CA in the State
- Using the funds placed with Department of Agriculture, laser assisted land leveling should cover at least 3.0 m ha of irrigated and dry lands by promoting custom services. Also at least 50% of the cultivated area (~ 1.5 m ha) could be brought under CA based crop management practices.
- Direct seeded rice (DSR) should be promoted in 50% of the basmati rice areas and all of the rice-potato/vegetable systems, no-till mechanical transplanting can be promoted as well on 10% of the rice area.
- 'Single Window Services' for zero-till planting with residue retention in wheat and other crops need to promoted to avoid residue burning in 50% of the wheat / sugarcane areas using the Turbo/Happy Seeder and double disk planters through creation of CA machinery banks.
- The Department of Agriculture should mount a baseline survey on tube well water quality, and manage the data base in GIS framework, to delineate problematic areas and link this with soil health cards/ soil testing service. Water quality, tillage and crop establishment and residue management practices and crop and cultivar choices be considered to make fertilizer recommendations in cropping system perspectives.
- Problem soils (saline, alkaline, water-logged) should be mapped using remote sensing and GIS tools.
- Soil testing, Food Security Mission and *Rojgaar Yojna* programs should be linked for the reclamation of such soils so as to make them productive.
- Dual purpose wheat for green fodder should be linked to program meant for improving productivity of livestock. Dual purpose wheat may specially be promoted on peri-urban interface where diaries are located.
- Acreage of rice needs to be decreased to release some pressure on scarce water resources. Intensification of hybrid maize (*kharif* and *rabi*) and pulses or vegetable

crops are some of the possibilities. The new cropping system will also save irrigation water.

- Subsidize good quality tillage machinery prototypes (multi-crop planters, multi-purpose turbo happy seeders and multi-crop double disk planter, sugarcane cutter planter) to promote CA.
- Promote system based technical advisories to farmers using modern Information and Communication Technologies (ICT).
- Link available database to Unique Farmer Identity (UFI) to soil testing and other schemes of the Department
- Department of Agriculture need to encourage and support farmer cooperatives based on CA and to facilitate and subsidize the purchase of CA equipments and other inputs.

# 13. Epilogue

Present day agriculture in the State of Haryana is confronted with formidable problems of hydrological imbalances, soil degradation, labour shortage, inefficient input use, decrease in factor productivity, high cost of cultivation and low returns to the farmers. The ill effects of climate change and deterioration in quality of resource base (soil, water) and environment poses new threats for sustainability of major cropping systems in Haryana. In the State, more than two third ground water is of poor quality, while the fresh acquifers are over-exploited. The fresh streams of water are also polluted with industrial effluents and sewage waters. The inland basin of Haryana suffers from major problem of soil salinization and water logging due to poor on-farm water management and insufficient drainage in canal irrigated areas having underground brackish aquifers. All these warrant conserving and saving fresh water and arrest degradation of resource base by adopting appropriate management practices to sustain higher crop productivity of major cropping systems in Haryana.

The conservation agriculture based agro-technological package not only saves substantial quantity of water at no extra cost but also helps in producing more at low costs, improves soil health, promotes timely planting and ensures crop diversification, reduces environment pollution and adverse effects of climate change on agriculture. The key conservation agriculture technologies identified for large scale adoption by the farmers of Haryana include laser land leveling, double till no-till in rice-wheat system (direct seeded rice, zero till seeding with full residues), avoiding soil compaction by turbo seeder/ happy seeder, intensification of sugarcane production system, relay cropping of *mung* bean in rice-wheat and relay wheat crop in cotton-wheat systems, dual purpose wheat technology for fodder and grain production, diversification and adoption of micro- irrigation technology in irrigated areas, and watershed management in arid areas.

The conservation agriculture based technologies, as defined in this report, would enable the farmers to cope with rapidly growing demand for labour, to conserve and improve natural resources and environment, to mitigate adverse impact of climate change and to improve the productivity of major crops and cropping systems. Hence, outscaling of CA for large scale benefits and impact on soil health is a must in the present context. However, concerted policy initiatives and reorientation of research and development agenda will be required for large scale adoption and popularization of conservation technologies for sustainable agriculture in Haryana.

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# Annexure I

In mid-2010, Dr R.S. Paroda, Chairman, Haryana Kisan Ayog, Government of Haryana convened a meeting of agriculture experts for a study to explore policy and technology options having potential for transforming agriculture in Haryana. The major concerns were on enhancing and sustaining the productivity of rice and wheat. The concerns stemmed from uncertain future of water availability as the current water levels were not encouraging, resource fatigue, climate variability and aberrations in the weather. Haryana Kisan Ayog firmly believes, and rightly so, that conservation agriculture (CA) has to be an important component of State's strategy for improving productivity, conserving natural resources and protecting environment and ecology. Considering its objectives and mandate, Haryana Kisan Ayog constituted a Working Group on Conservation Agriculture in August 2010. The Working Group was requested to undertake a strategic review of the farming situations in Haryana and suggest conservation agriculture practices, having potential for transforming agriculture in the State. The group members looked into both short-term (for 5 years) and long-term strategies. In addressing the framework of reference, the Working Group on Conservation Agriculture (CA), studied and analyzed a comprehensive literature in the contextual framework of the Ayog. The group met farmers, researchers, field functionaries and policy makers to get necessary inputs for its recommendations. An executive summary is given in the foregoing section.

## 1. Composition of Working Group on Conservation Agriculture

| | | | |
|---|---|---|---|
| • Dr. Raj Gupta,<br>Head, CIMMYT,<br>India | Chairman | • Dr. R. P. Narwal,<br>Director research,<br>CCS HAU Hisar | Member |
| • Dr. M. L. Jat,<br>Senior Cropping Systems<br>Agronomist, CIMMYT | Member | • Dr. Yashpal Sahrawat,<br>Senior Scientist,<br>ICAR | Member |
| • Dr. R. K. Malik,<br>Hub Coordinator, CSISA EUP,<br>CIMMYT-IRRI | Member | • Dr. H. S. Sidhu,<br>Hub Coordinator CSISA<br>Punjab, CIMMYT-IRRI | Member |
| • Dr. Saroj Jaipal,<br>Head RRS, CCSHAU<br>Uchani (Karnal) | Member | • Dr. Madhurama Sethi,<br>Principal Scientist,<br>CSSRI Karnal | Member |
| • Dr. Ashok Yadav,<br>Senior Scientist,<br>CCS HAU,<br>Hisar | Member | • Dr. Samar Singh,<br>Senior Scientist,<br>RRS CCSHAU<br>Uchani (Karnal) | Member |

## 2. Terms of Reference (ToR)

The Working Group on Conservation Agriculture for Sustainable Crop Production in Haryana will deliberate on and recommend measures to sustain natural resources (water, land), increase agricultural production and productivity, improve input use efficiency and suggest suitable strategies/action plan/policies, *inter-alia*, for

1. Producing more food at less cost and by bridging yield gaps
2. Boost farm income and reduce risks of climate change through CA based practices
3. Suggest ways to improve input use efficiency (land, labor, water, fertilizer nutrients and pesticides)
4. Strategy for improving the natural resource base,
5. CA based strategies to mitigate greenhouse gas (GHG) emissions,
6. To suggest alternate approaches for diversification and intercropping
7. Potential CA practices to conserve and economize the use of scarce irrigation water in major crop production systems

## 3. Meetings Held

The first meeting of the Working Group was held on 6 November, 2010 at Chaudhary Charan Singh Haryana Agricultural University (CCS HAU), Hisar, Haryana under the Chairmanship of Dr R.S. Paroda, Chairman, Haryana Kisan Ayog (HKA), to discuss the TORs and other related issues. The meeting was also attended by Mr. Roshan Lal, Principal Secretary Agriculture and Finanace Commissioner, Govt. of Haryana, Dr K.S. Khokhar, Vice-Chancellor, Deans, Directors and select Faculty of Agricultural University. The conservation agriculture working group shared their common thoughts and received valuable inputs. A subsequent meeting was organized at the Directorate of Agriculture, with Mr. Ashok Yadav, Director General Agriculture, Govt. of Haryana in the chair. Individual members of the CA Group also met many stakeholders, particularly those practicing irrigated farming of rice, wheat, maize, sugarcane and cotton crops. In order to finalize the recommendations, the Working Group met on 6 August, 2011 at CCS HAU, Hisar, Haryana under the Chairmanship of Dr R.S. Paroda. This meeting was intended to seek inputs of the senior level field functionaries of the Department of Agriculture, faculty of the university, consultants and members of the Ayog. The report reflects the major outcomes of these consultations.


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