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Management of Crop Residues in the Context of Conservation Agriculture

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Preface

India produced a record of 257.4 million tonnes of foodgrains in 2011-12, a significant step towards rendering the nation self-sufficient and food-secured. It also produces a large amount of crop residues (more than 500 million tonnes) annually. These crop residues are extremely valuable as they are used as animal feed, thatching for rural homes, and fuel for residential cooking and industry. However, a large portion of them is burnt in field primarily to clear the remaining straw and stubble after the harvest. The problem is more severe in the irrigated agriculture, particularly in the mechanized rice-wheat system of the northwest India. Burning of crop residues is environmentally unsafe as it leads to release of soot particles and smoke causing human health problems and emission of greenhouse gases adding to global warming and climate change. It also results in loss of plant nutrients such as N, P, K, S and carbon, which are so important for soil health. Conservation agriculture offers an option in using them for improving soil health, increasing productivity, reducing pollution, enhancing sustainability and increasing resilience of agriculture. However, there are several constraints in using crop residues with conservation agriculture.

The National Academy of Agricultural Sciences (NAAS) organized a Brainstorming Session on '*Management of Crop Residues in the Context of Conservation Agriculture*' to identify strategies in research, policy and development programmes with a goal to promote sustainable use of crop residues with conservation agriculture. Twenty nine distinguished invitees including leading experts in the fields of crop residues management, conservation agriculture, soil fertility, animal nutrition and climate change participated in the Session.

The Academy appreciates the efforts of Dr. Himanshu Pathak in convening the event and compliments the contributions of all the distinguished participants of the Brainstorming Session. Grateful thanks are due to Resource Persons, Reviewers and Editors of the policy paper. I hope that this publication will contribute towards developing research and policy agenda on management of crop residues in context of conservation agriculture.

(R.B. Singh)
President, NAAS

Management of Crop Residues in the Context of Conservation Agriculture

1. PROBLEM DESCRIPTION

Indian agriculture produces about 500-550 million tonnes (Mt) of crop residues annually. These crop residues are used as animal feed, soil mulch, manure, thatching for rural homes and fuel for domestic and industrial purposes and thus are of tremendous value to farmers. However, a large portion of these crop residues, about 90-140 Mt annually, is burnt on-farm primarily to clear the fields to facilitate planting of succeeding crops. The problem of on-farm burning of crop residues has intensified in recent years due to use of combines for harvesting and high cost of labours in removing the crop residues by conventional methods. The residues of rice, wheat, cotton, maize, millet, sugarcane, jute, rapeseed-mustard and groundnut crops are typically burnt on-farm across the country. This problem is severe in irrigated agriculture, particularly in northwest India where the rice-wheat system is mechanized. Burning of crop residues leads to plethora of problems such as release of soot particles and smoke causing human health problems; emission of greenhouse gases such as carbon dioxide, methane and nitrous oxide adding to global warming; loss of plant nutrients such as N, P, K and S; adverse impacts on soil properties and wastage of valuable crop residues.

It is a paradox that burning of crop residues and scarcity of fodder co-exists in this country, when fodder prices have surged significantly in recent years. Much of the paradox owes it to non-availability and easy access of the quality crop planters which can seed into loose and anchored residues. There are several options such as animal feed, composting, energy generation, biofuel production and recycling in soil to manage the residues in a productive and profitable manner. Use of crop residues as soil organic amendment in the system of agriculture is a viable and valuable option.

2. POLICY IMPERATIVES

A policy should be developed with a goal to promote multiple uses of crop residues in the context of conservation agriculture and prevent their on-farm burning. The specific objectives of this paper are to quantify the amounts of crop residues available in the country and extent of on-farm burning, assess the potential and constraints of using crop residues with conservation agriculture and identify research and policy issues for environmentally safe management of crop residues for profitable and sustainable agriculture.

3. GENERATION AND USE OF CROP RESIDUES IN INDIAN AGRICULTURE

According to Ministry of New and Renewable Energy (MNRE, 2009), Govt. of India approximately 500 Mt of crop residues are generated every year. Depending on the crops grown, cropping intensity and productivity in different regions of India, there is a large variability in generation and end use of these crop residues. The crop residues generation is the highest in Uttar Pradesh (60 Mt) followed by Punjab (51 Mt) and Maharashtra (46 Mt). Among different crops, cereal crops generate 352 Mt residues followed by fibre crops (66 Mt), oilseeds (29 Mt), pulses (13 Mt) and sugarcane (12 Mt). The cereal crops (rice, wheat, maize, millets) contribute 70% (rice 34% and wheat 22%) of crop residues. Among fibre crops, cotton generates maximum (53 Mt) with 11% of crop residues. Coconut ranks second among fibre crops with 12 Mt of residues generation. Sugarcane generates 12 Mt i.e., 2% of crop residues (comprising of tops and leaves) in India. A large amount of residues are, in addition, generated from fruit, vegetable and fodder production.

The unutilized crop residues i.e., total residues generated minus residues typically used for various purposes are burnt on-farm. Estimated total crop residues unutilized in India is 84-141 Mt yr^{-1} where cereals and fibre crops contribute 58% and 23%, respectively. Sugarcane, pulses, oilseeds and other crops contribute to the remaining 19%. Out of 82 Mt surplus crop residues from the cereal crops, 44 Mt is from rice crop followed by 24.5 Mt from wheat crop, which is mostly burnt on-farm. In case of fibre crops (33 Mt of unutilized residues) approximately 80% is cotton residues and are subjected to on-farm burning.

There are large uncertainties in the data on generation of crop residues, their uses, the remaining surplus and on-farm burning. Besides the estimates of MNRE (2009), Pathak (2004) estimated that annually about 525 Mt crop residues are available in India, out of which about 125 Mt are surplus. Pathak *et al*. (2010) estimated that about 90 Mt of crop residues are burnt on-farm and this figure is close to 85 Mt when the coefficients developed by the Inter-Governmental Panel on Climate Change (IPCC) are used.

4. USE OF CROP RESIDUES WITH CONSERVATION AGRICULTURE

Conservation agriculture (CA) aims at achieving sustainable agriculture and improved livelihoods of farmers through the application of the three basic principles: minimal soil disturbance, permanent soil cover and crop rotations (FAO, 2007). No-till agriculture is considered as a revolutionary step in the direction of preventing land degradation and rehabilitation of the resilient but fragile lands (Kasam, 2011). Frameworks such as ‘conservation agriculture’ (FAO, 2007), ‘ecological intensification’ (Cassman, 1999)

and ‘evergreen revolution’ (Swaminathan, 2000) share a view of cropping systems as agro-ecosystems designed to make maximum use of fixed resources (land, light, temperature, etc.) and optimum use of agri-inputs for attaining sustainable production levels. These systems tap traditional knowledge of the farmers and add new information relevant to the specific ecologies for the intensification process (Matson *et al.,* 1997). The conservation agriculture systems (i.e., zero-till systems) are ‘flexible’ in operation allowing farmers to benefit from them under diverse situations. Conservation agriculture-based resource conserving technologies (RCTs) are ‘open’ approaches, easier to mainstream and be adapted even in conventional agriculture systems.

The conservation agriculture is an innovative process of developing appropriate implements, early maturing crop cultivars, etc. for an iterative guidance and fine-tuning of crop production technologies. Many variants of reduced till and cropping systems have been adopted by farmers in tropical/subtropical and temperate regions of the world for improved yields. The conservation agriculture has steadily increased worldwide to cover about 7% of the world arable land area, i.e., about 105 million ha. However, only few countries i.e., USA, Brazil, Argentina, Canada and Australia share about 90% of this area (Derpsch and Friedrich, 2010). The Food and Agricultural Organization (FAO) of the United Nations has adopted the conservation agriculture as a lead model for sustainable production intensification (FAO, 2007).

Permanent crop cover with recycling of crop residues is a pre-requisite and an integral part of conservation agriculture. However, sowing of a crop in presence of residues of preceding crop was a problem. But new variants of zero-till seed-cum-fertilizer drill/planters such as Happy Seeder, Turbo Seeder, rotary-disc drill and easy seeder have since been developed to facilitate direct drilling of seeds in the presence of surface retained residues (both loose and anchored residues upto 10 tonnes ha^{-1}). The crop residues retained on surface help conserving moisture and nutrients and controlling weeds in addition to moderating soil temperature.

Several studies conducted across the production systems under varied ecologies of South Asia have revealed potential benefits of conservation agriculture-based crop management technologies on resource conservation, use-efficiency of external inputs, yield enhancement, soil health improvement, and adaptation to changing climate (Gupta and Seth, 2007). Results of farmers’ participatory field trials across Indo-Gangetic Plains have revealed that zero tillage helps in timely sowing of wheat crop. The terminal heat effects are also less in zero tillage compared to conventional till even under late planting. Zero-till drilling in crop residues keeps canopy temperatures lower by 1-1.5ºC during grain filling stage and sustains soil moisture availability to the plants (Jat *et al*., 2009). Surface retention of crop residues increases N uptake and yield and improves the soil physical properties in rice-wheat systems (Mandal

et al., 2004). Though residues incorporation leads to immobilisation of inorganic N but addition of 15-20 kg N with straw incorporation increases the yield of rice and wheat.

In the areas, for example, eastern India, where crop residues have competing uses such as animal feed, roof thatching and domestic fuel, at least some parts of the stubble should be left in the fields to contribute to soil organic C. The value of crop residues retained over soil surface in crop production *vis-a-vis* livestock production has been demonstrated locally and globally through several reports in recent years (Joshi *et al.*, 2010).

Due to limited production of biomass, competing uses of crop residues and shortage of firewood, farmers often find it hard to use crop residues to cover soil surface in dryland eco-systems. However, Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad showed that in dryland eco-systems, where only a single crop is grown in a year, it is possible to grow a second crop with residual soil moisture in the profile under conservation agriculture with soil cover with crop residues. It is, however better to use the chopped biomass of semi-hard woody perennial plants instead of crop residues to cover the soil surface.

Sustainability is a concern in today's agriculture and conservation agriculture constitutes a sound approach for moving in this direction (Hobbs *et al.*, 2008). There are three major benefits from conservation agriculture: (1) increase in organic matter, (2) increase in water availability and (3) improvement of soil structure (FAO, 2007). The task of the scientists is to convince farmers that retaining crop residues has both short and long term advantages which outweigh the benefits which they might otherwise be getting.

It is always a challenge for the farmers to place seed at appropriate soil depths in the moist soil zone and band place the fertiliser nutrients to avoid any damage to seed. In presence of the loose straws retained over the soil surface, planter begins to rake the crop residues making it extremely difficult to drill the seed properly. Presence of crop residues on the soil surface also makes it difficult to top dress the fertilisers in the root zone. Although a lot of improvement has been made in the zero-till seed-cum-fertilizer drill machinery, there is still a lot of scope for further improvement to give farmers a hassle-free technology. Although crop residues mulch helps in reducing weed population, it requires special efforts to mechanically control weeds early in the season in presence of the crop residues. Nutrient management may become complex because of higher crop residues levels and reduced options with regard to method of nutrient applications. No-till in particular can complicate manure application and may also contribute to nutrient stratification within soil profile from repeated surface applications without any mechanical incorporation.

With higher crop residues levels, however, evaporation is reduced and more moisture is maintained near the soil surface favouring the growth of feeder roots where the nutrients are concentrated. In some instances, increased application of specific nutrients and specialized equipment for proper fertilizer placement may be necessary, thereby contributing to higher costs.

The limiting factor in the adoption of crop residues incorporation by farmers includes additional management skill requirement, apprehension of lower crop yields and/or economic returns, negative perceptions, and institutional constraints. Farmers often prefer clean tilled fields to obtain a smooth surface for planting.

5. STRATEGIES FOR MANAGEMENT OF CROP RESIDUES WITH CONSERVATION AGRICULTURE

A set of strategies including research, policy and development programmes may be formulated to achieve the goal of promoting multiple uses of crop residues in the context of conservation agriculture and prevent their on-farm burning.

5.1. Research

5.1.1. Generation and utilization of crop residues

- ✦ Developing geo-referenced residues inventry in major crop production systems across the country including total production, current and potential uses, and amounts burnt on- and off-farm.
- ✦ Developing satellite-based remote sensing technologies to monitor conservation agriculture farms and identify regions where burning is a major practice.
- ✦ Assessing the quality of various crop residues and their suitability for off-farm (eg. animal feed, compost, energy, biogas, biofuel) and on-farm (eg. conservation agriculture) purposes.

5.1.2. Basic and strategic research

- ✦ Developing crop varieties to improve palatability and digestibility of the crop residues for improved livestock production.
- ✦ Replacing the existing longer-term trials which have outlived their utility through initiation of new conservation agriculture experiments for dynamic monitoring of soil health, improved water and nutrient use efficiency, carbon sequestration, ecosystem services including dynamics of soil biology and biodiversity and greenhouse gases emissions.

- Developing simulation models for tillage dynamics, root growth, soil properties, yield and income in conservation agriculture for prediction and extrapolation.
- Encouraging research on the life cycle analysis of crop residues incorporation in soil with conservation agriculture.

5.1.3. Optimizing competing uses of crop residues

- Based on the analysis of benefit : cost, socio-economic and technical feasibility of on-farm and off-farm uses of crop residues, where the crop residues have competing uses as fodder or fuel, the end products (dung, slurry, ash) should find a way in conservation agriculture.
- Optimizing the utilisation of crop residues that can be retained for conservation agriculture without affecting the crop-livestock system, particularly for the regions such as eastern India, where residues are the main source of fodder. Crops whose residues are not used as fodder should be used with conservation agriculture.
- Assessing the suitability of crop residues retention/incorporation in different soil and climatic situations. Generally retention of crop residues on soil surface should be encouraged in alluvial soils of the Indo-Gangetic Plains (IGP). However, in certain situations such as in Vertisol, this needs validation.
- Quantifying the permissible amount of residues of different crops which can be incorporated/retained depending on cropping systems, soil and climate without creating operational problems or chemical and biological imbalance of nutrients for the next crop.
- Assessing benefit:cost and environmental impacts of residues retention/ incorporation with conservation agriculture vis-à-vis residues burning for short- and long-term time scales.
- A holistic study on all aspects of crop residues use including soil biodiversity and environmental economics to formulate future policies. Understanding conservation agriculture practices impacting soil nutrient and environmental quality in the long run may further help the sustainability issues.

5.1.4. Water and nutrient management

- Developing innovative package of practices for conservation agriculture for major cropping systems in each agro-ecological region, particularly in rainfed and dryland eco-systems.
- Developing new information on irrigation schedules for conservation agriculture

systems with anchored residues/surface carpet of residues and no residues to save water.

- Developing soil-test methods, fertilizer recommendations and customized fertilizer application for conservation agriculture taking into account nutrient requirement of the cropping system and nutrient content in residues.
- Assessing the role of legume residues in sustaining C:N:P:S in soil organic matter.

5.1.5. Pest management

- Developing package of practices for integrated pest management (IPM) involving crops, tillage, residues, modified planting methods and pesticides in conservation agriculture to reduce the use of pesticides to minimize cost of production and environmental pollution.
- Evaluating weed dynamics (i.e., shift and virulence in weed flora, biology), their interference potential and suitable management practices with low-cost, environment-friendly herbicide in crop residue-based conservation agriculture.
- Developing technologies for termite control in order to enhance the yield and study the impacts of residues left on surface during long interval period between two crops.

5.1.6. Machinery for using crop residues with conservation agriculture

- Development of appropriate farm machinery to facilitate collection, volume reduction, transportation and application of residues, and sowing of succeeding crop under a layer of residues on soil surface.
- Modifying combine harvester to collect and remove crop residues from field. Twin cutter bar type combine harvester for harvesting of top portion of crop for grain recovery and a lower cutter bar for straw harvesting at a suitable height and windrowing should be developed for proper management of straw.
- Developing straw spreaders for uniform distribution of the crop residues.

5.2. Policy and development programmes

The policy and development programmes such as creating awareness, human resources development, providing incentives through investment, subsidies and compensation, developing and disseminating technologies and implementing legislation should be put into practice to promote the use of crop residues with conservation agriculture.

5.2.1. Capacity building and awareness creation

- Capacity building through training and teaching for under- and post-graduate students and training of farmers. Every agricultural university should have courses on crop residues management and conservation agriculture at under- and post-graduate levels.
- Establishing self-help groups and encouraging unemployed youth to take up custom hiring of conservation agriculture machineries as profession.
- Including the component of conservation agriculture in soil health card for proper monitoring of crop residues retention/burning and its impact on soil health.
- Familiarizing conservation agriculture technologies at Krishi Vigyan Kendras (KVKs) and state agricultural departments for creating awareness and dissemination at village level.
- Intensive collaborative research on effect of conservation agriculture on pests and their natural enemies in different cropping systems.

5.2.2. Development programmes

- Each university, research institute and NGOs committed to sustainable development should start working with some selected farmers in varying situations with the knowledge embedded in conservation agriculture principles and observe what and how much can be achieved and what is needed to make conservation agriculture a success. This experience should be used for improving the conservation agriculture-technology and removing the constraints.
- The emphasis should be on recycling of any form of wastes in addition to crop residues. As the availability of such organic resources is site-specific, an inventory should be made of the potentially available materials for use in the target regions in a systematic way. Approximate composition of various residues/wastes would further help to target a proper use of these resources.

5.2.3. Laws and legislation

- Developing a crop residues management policy for each state clearly defining various competing uses.
- Developing and implementing legislation on prevention and monitoring of on-farm crop residues burning through incentives and punishment. If burning is

necessary, it can be permitted for some conditions, for which guidelines based on meteorological conditions should be developed.

- ✦ Supplying machineries for conservation agriculture on subsidized rates, promoting custom hiring systems and providing soft loans for purchase of implements.
- ✦ Introducing and providing carbon-credit to the farmers practicing conservation agriculture for carbon sequestration and greenhouse gas mitigation.
- ✦ Classifying crop residues as amendments (such as lime or gypsum) and their use in agriculture should attract subsidy like any other mineral fertilizers or amendments.

6. CONCLUSIONS

Crop residues are of great economic values as livestock feed, fuel, industrial raw material and for conservation agriculture for which it is a prerequisite. Crop residues, either partly or fully should be used for conservation agriculture for ensuring the country's food security, making agriculture sustainable and the soil resource base healthy. All stakeholders i.e., farmers, supply and value chain service providers, researchers, extension agents, policy makers, civil servants, consumers need to be engaged in understanding and harnessing the full potential of using crop residues with conservation agriculture for sustainability and resilience of Indian agriculture. The research, policy and development programmes as outlined in the paper should be put into practice for managing crop residues at local and regional scales.

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