REVIEW ARTICLE

Crop Residue Management for Sustenance of Natural Resources and Agriculture Productivity

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Abstract

Crop residue management (CRM) through conservation agriculture can improve soil productivity and crop production by preserving soil organic matter (SOM) levels. Two major benefits of surface-residue management are improved organic matter (OM) near the soil surface and boosted nutrient cycling and preservation. Larger microbial biomass and activity near the soil surface act as a pool for nutrients desirable in crop production and enhance structural stability for increased infiltration. Also, the altered nutrient distribution within the soil profile, changes occur in the chemical and physical properties of the soil. Improved soil C sequestration through enhanced CRM is a cost-effective option for reducing agriculture's impact on the environment. Ideally, CRM practices should be selected to optimize crop yields with negligible adverse effects on the environment. Crop residues of common crops are chief resources, not only as sources of nutrients for subsequent crops but also for amended soil, water, and air quality. Maintaining and managing crop residues in agriculture can be economically beneficial to many producers and more important to society. Improved residue management and reduced tillage practices should be encouraged because of their beneficial role in reducing soil degradation and increasing soil productivity. Thus, farmers have a responsibility in making management decisions that will enable them to optimize crop yields and minimize environmental impacts. Multi-disciplinary and integrated efforts by a wide variety of scientists are required to design the best site-specific systems for CRM practices to enhance agricultural productivity and sustainability while minimizing environmental impacts.

Keywords: Communities of praclice, Indicators, Outreach, Social Learning, Student Central

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Introduction

A minor quantity of somewhat that leftover after the chief portion has gone or been taken or used is called as residue. In agriculture, there are two types of residue: field residue and process residue. Field residues are resources left in an agricultural field or orchard after the crop has been harvested. Stalks, stubbles, leaves, and seed pods are field residues which can be plowed directly into the ground, or burnt in-situ. Decent management of field residues can surge the competence of irrigation and control of erosion. Process residues are materials left after the crop is processed into a usable resource. These residues include husks, seeds, bagasse, molasses and roots. They can be used as animal fodder and soil amendment, fertilizers and in manufacturing sectors.

Annually, 500–550 million tonnes (Mt) of crop residue is produced in Indian agriculture system. The residue production by different crops in India during 2011-12 was like Wheat(93.9 Mt), Rice (104.6 Mt), Maize (21.6 Mt),Sugarcane (357.7 Mt), Cotton, Jute and Mesta(8.1 Mt), Pulses (17.2 Mt), Millets (20.7 Mt) and Oilseeds (30.0 Mt) (MOA 2012). This bulk amount of residue is formed on farm and off farm both.

This crop residue have a great value for farmers because the crop residue is used as feed of animals, mulching of soil, for manuring purpose as well as for industrial and domestic purpose. Annually (90–140 Mt) of crop residue is burnt by the farmers on farm, just for clearing the field to grow the next season crop successfully. The major cause of burning of crop residue on farm is the use of new technology like combined harvester to harvest the crop with less labour and in short period of time. Across the country the residue of crops like wheat, maize, rice, cotton, sugarcane, millets, rapeseed and mustard, groundnut and jute are burnt on farm. In north-west India, this problem is more where the cropping system is generally a rice-wheat (Anonymous 2012).

The burning of crop residue leads to emission of greenhouse gases like CO_2, CH_4 and NO which results in global warming, affects human health, changes soil properties (physical, chemical and biological), depletion of plant nutrients and loss of valuable residues. Now a day, the demand of crop residue at industrial level is increasing. So, to handle the residue in a useful and economical way, good opportunities are offered by conservation agriculture. The crop residue can be used for improving the health of the soil, enhancing the productivity of crop, reducing the pollution, and increasing sustainability by the adopting conservation agriculture-based technologies.

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The minimum tillage, direct seeding of crops, planting on the beds and diversification of crops are the major concepts which come under the resource-conserving technologies. These concepts are the substitute to the conventional energy and input-intensive agriculture (NAAS 2012). To manage the residues in useful and economical manner, the other options are feed of animals (wheat and paddy straw), generation of energy, composting (paddy straw), production of bio-fuel (like sugarcane in Brazil) and soil recycling. In the agricultural system, the use of crop residues as a soil amendment is profitable and productive.

Generation of crop residues in India and their nutritional potential

Every year 500 Mt of crop residue is produced in India. This estimation is given by The Ministry of New and Renewable Energy, Government of India.

According to the table, UP ranks first in the production of crop residue (60 Mt), followed by Punjab (51 Mt) and Maharashtra (46 Mt). Cereals generate maximum residues (352 Mt) followed by fibers (66 Mt), oilseeds (29 Mt), pulses (13 Mt) and sugarcane (12 Mt). A total of 70% of crop residue contributes by cereals, i.e., wheat, rice, maize, and millets, whereas (34%) crop residue is formed by the rice crop individually. Wheat alone contributes (22%) of the crop residue and ranks second in the production of residue while (13%) contribution of fibers in generating the total crop residue. The maximum crop residue is produced by the cotton (53 Mt) which contributes (11%) in total residue production among the fibers. With (12Mt) of production coconut ranks second among the fibers. Sugarcane also produces (12 Mt) of crop residue, which contributes (2%) in the total residue production (MNRE, 2009).

Utilization and on-farm burning of crop residues in India

Commonly, the crop residue has various beneficial uses like animal feed, fuel, fodder, composting, packaging, etc. Cereals residue is majorly used for feed of cattle whereas husk and

Table 1: State wise generation and remaining surplus of crop residues in India (Mt/yr)

State	*Crop residues generation (MNRE 2009)*	*Crop residues surplus (MNRE 2009)*	*Crop residues bumt (based on IPCC coefficients)*	*Crop residues burnt (Pathak et al. 2010)*
Andhra Pradesh	43.89	6.96	6.46	2.73
Arunachal Pradesh	0.40	0.07	0.06	0.04
Assam	11.43	2.34	1.42	0.73
Bihar	25.29	5.08	3.77	3.19
Chhattisgarh	11.25	2.12	1.84	0.83
Goa	0.57	0.14	0.08	0.04
Gujarat	28.73	8.9	9.64	3.81
Haryana	27.83	11.22	6.06	9.06
Himachal Pradesh	2.85	1.03	0.20	0.41
Jammu and Kashmir	1.59	0.28	0.35	0.89
Jharkhand	3.61	0.89	1.11	1.10
Karnataka	33.94	8.98	3.05	5.66
Kerala	9.74	5.07	0.40	0.22
Madhya Pradesh	33.18	10.22	3.74	1.91
Maharashtra	46.45	14.67	7.82	7.41
Manipur	0.90	0.11	0.14	0.07
Meghalaya	0.51	0.09	0.10	0.05
Mizoram	0.06	0.01	0.02	0.01
Nagaland	0.49	0.09	0.11	0.08
Odisha	20.07	3.68	2.61	1.34
Punjab	50.75	24.83	9.84	19.62
Rajasthan	29.32	8.52	3.84	1.78
Sikkim	0.15	0.02	0.01	0.01
Tamil Nadu	19.93	7.05	3.62	4.08
Tripura	0.04	0.02	0.22	0.11
Uttarakhand	2.86	0.63	0.58	0.78
Uttar Pradesh	59.97	13.53	13.34	21.92
West Bengal	35.93	4.29	10.82	4.96
India	501.76	140.84	91.25	92.81

Source: Ministry of New and Renewable Energy Resources (MNRE) Govt. of India, New Delhi. (2009) www.mnre.gov.in/biomassrsources

Table 2: Annual national emissions from rice and wheat straw open burning (All in Gg)

Years	*Production*	*Quantity of dry residue*	*CH4*	*CO*	*N_2O*	*NOx*
1994	145720	150576	102	2138	2.2	78
2000	156485	162125	110	2305	2.3	84

straw of rice are used primarily for fuel purpose at domestic level as well as for parboiling rice in boilers.

Farmers can use the crop residue by themselves, or they directly sell to the middlemen, who can sell to the industry. The surplus residue (total generated residue, a residue used for various purposes) is burnt by the farmers on the farm. Across the country, it is estimated that 93 (Mt) of crop residue is burnt on the farm. During October and November, more than 80% of total rice straw is burnt on-farm annually (Singh *et al*., 2010).

Reasons for on-farm burning of crop residues

The major reasons of crop residue burning are:

- Increase in mechanization (Combines, Harvesters and Reapers, etc.)
- Decrease in numbers of livestock
- Longer time requirement for composting
- Non-availability of substituted economically feasible solutions
- Fast way to clear the field from residue & straw

Adverse consequences of on-farm burning of crop residues

- Burning of crop residues release soot particles and smoke, which cause problems in human and animal health.
- Burning of residues also leads to release of greenhouse gases like carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) causing global warming and loss of major plant nutrients like N, P, K, and S.
- The burning of crop residues is wastage of productive resources which could be a source of carbon, bio-active compounds, feed and energy for rural households and small industries.
- The heat generated from the burning of crop residues increases the temperature of soil which causes death or damage of active beneficial and essential microbial population.
- Long-term burning reduces total N and C content in the soil, and potentially mineralizable N in the upper soil layer.
- The burning of agricultural residues leads to the significant secretion of radioactively and chemically important trace gases, such as carbon monoxide (CO), methane (CH_4), oxides of nitrogen (NOx), nitrous oxide (N_2O), sulfur oxide (SOx) and other hydrocarbons of the atmosphere.
- About (70 %), (7 %) and (0.7 %) of C available in rice straw is emitted as CO_2, CO & CH_4 respectively, whereas (2 %) of N in straw is secreted as N2O during burning.
- A huge quantity of particulates secret during the burning of residues, which are comprised of a wide variety of inorganic and organic species.
- According to Gupta and Sahai (2005), 3 kg of particulate matter is released during the burning of 1 tonne of rice straw, 60 kg CO, 1460 kg CO_2, 199 kg ash and 2 kg SO_2.
- Except for these volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs) and other light hydrocarbons including polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), NOx and SOx are also secreted.
- Burning of crop residues emits dangerous gases which cause serious problems like asthma, tuberculosis, a problem in the respiratory system and lung functioning in human beings as well as in animals.

Competing uses of crop residues

As a livestock feed

Basically, in India, the crop residues are utilized as animal feed such as or by supplementing with some additives. To meet the nutritional requirements of animals, the residues need processing and enriching with urea and molasses, and supplementing with green fodders (leguminous/non-leguminous) and legume (sunhemp, horse gram, cowpea, gram) straws. But straws contain only 3–5 (%) crude protein whereas a level of 8–10 (%) is needed for a young stock for good growth on straw diets.

As compost making

The crop residues have been traditionally used for preparing compost. For this, crop residues are used as animal bedding and then they are heaped in dung pits. The residues of rice crop from one-hectare land, on composting, give about 3 tonnes of manure as rich in nutrients as farmyard manure (FYM). The rice straw compost can be fortified with P using an indigenous source of low-grade rock phosphate to make it value-added compost with 1.5 (%) N, 2.3 (%) P_2O_5 and 2.(%) K_2O (Sidhu and Beri, 2005).

As bio-energy production

In recent years, there has been an increase in the usage of crop residues for the generation of energy and as a substitute for fossil fuels. In comparison with other renewable energy sources such as solar and wind, biomass source is storable, cheap, energy-efficient, and eco-friendly. However, straw is characterized by low bulk-density and low energy yield per unit weight basis. Availability of residues, transportation cost, and infrastructural settings (harvest machinery, modes of collection, etc.) are some of the limiting factors of using residues for energy generation.

As bio-fuel and bio-oil production

Conversion of lignocellulosic biomass into alcohol is of immense importance as ethanol can either be blended with gasoline as a fuel extender and octane-enhancing agent or used as a neat fuel in internal combustion engines. The technology of ethanol production from crop residues is, however, evolving in India. Bio-oil can be produced from crop residues by the process of fast pyrolysis, which requires a temperature of biomass to be raised to 400-500^{0}C within a few seconds, resulting in a remarkable change in the thermal disintegration process. About 75% of the dry weight of biomass is converted into condensable vapors. If the condensate is cooled quickly within a couple of seconds, it yields a dark brown viscous liquid commonly called bio-oil. The calorific value of bio-oil is 16-20 MJ/kg**.**

As biogas generation

Gasification is a thermo-chemical process, in which gas is formed due to partial combustion of crop residues. The crop residues can be used in the gasifiers for 'producer gas' generation. In some states, gasifiers of more than 1 MW capacity have been installed for the generation of 'producer gas,' which is fed into the engines coupled with alternators for electricity generation. One tonne of biomass can produce 300 kWh of electricity. The gasification technology can be successfully employed for the utilization of crop residues in the form of pellets and briquettes. The generated 'producer gas' is cleaned using bio-filters and used in specially designed gas engines for electricity generation.

Management options of crop residues with conservation agriculture

Minimizing mechanical soil disturbance and seeding directly into untilled soil to improve soil organic matter content and soil health

- *Resource conservation technologies for crop residue management:* The resource conservation technologies like (laser-assisted precision land leveling, zero/reduce tillage, direct drilling of seeds, direct seeding of rice, unpuddled mechanical transplantation of rice, raised bed planting and crop diversification) with innovations in residue management avoid straw burning, improve soil organic C, enhance input efficiency and have the potential to reduce GHGs emissions (Pathak *et al*., 2011).

Enhancing organic matter cover on soil using cover crops and/or crop residues. This protects the soil surface, conserves water and nutrients, promotes soil biological activity and contributes to integrated pest management.

- *Crop residues as surface mulch:* Leaving crop residues on the soil surface seems to be a better option as it conserves soil and water and reduces evaporation losses. Surface retained residues also reduce the germination of weeds leading to lower weed infestation. Moreover, slow decomposition also helps in building up of soil organic carbons, a direct indicator of soil health (Sidhu and Beri, 2005).
- *In-situ incorporation of crop residues:* It is another option to incorporate residues into fields to improve soil organic matter levels and return to the soils with the nutrients contained in straw. Singh *et al*. (2006) studied the effect of in-situ green manuring of Sesbania and crop residue incorporation on a yield of rice-wheat cropping system and found that incorporation of 50 and 100% rice residue enhanced the grain yield of wheat by 1.83 and 0.07 (%) as compared to no residue.

- *Diversification of crops in associations, sequences and rotations to enhance system resilience:* Amgain *et al*. (2013) assessed the effect of residue management practices on productivity and profitability of rainy-season pearl millet followed by winter-season crops viz. wheat, chickpea and mustard, and concluded that pearl millet should be followed by chickpea/mustard along with residue retention of crops/ leuceana twigs for higher productivity and profitability under zero-till dryland conditions of North-Western India

Impact of crop residue management on soil health

Crop residues are an important constituent in nutrient cycling and also play an important role in maintaining soil physical, chemical and biological condition-

Chemical soil health:

Soil organic matter is the most important factor in determining soil health. Long term incorporation of crop residues increase the availability of macro and micro nutrients and also build up the level of soil organic matter. The application of crop residue for 3 years increased the availability of P and K in soil over burned straw Gupta *et al. (*2007). The burning of crop residues before the sowing of wheat resulted in a huge loss of N (75%), P (25%), and K (21%) (Naresh 2013). The incorporation of residues before sowing or planting of both crops in the rice-wheat rotation increased the available N, P and K contents in soil over removal and burned of residues.

*Biological soil health**:***

Crop residues provide energy for growth and activities of microbes and substrate for microbial biomass, and provide conditions for source-sink of nutrients. Availability of nutrients like N, P, and S is particularly dependent upon soil microbial biomass (SMB) and microbial activity, which in turn, depend on the supply of organic substrates in soil. The soil microbial biomass (C and N) decrease with decreasing amount of residue retained on the soil surface in the zero-till treatments of both rainfed and irrigated long- term trial (Verhulst *et al.,* 2009). The SMB reflects the soil's ability to store and cycle nutrients (C, N, P and S) and organic matter and plays an important role in physical stabilization of aggregates.

Physical soil health

Crop residues are an important source of soil organic matter and upon incorporation may lead to improve soil physical parameters. The incorporation of crop residues decreased bulk density and increased infiltration rate, water holding capacity, microbe's population and fertility of soil as compared to no residue treatment (Singh *et al.,* 2010b). The residue incorporation with NPK fertilizer resulted in the highest yield, nutrient uptake, improved residual soil fertility and soil microorganism's status. (Sudha and George 2011) studied the effect of cropping systems, residue management and tillage practices on organic carbon sequestration in soils and result the shown that there was an improvement in soil properties like aggregate porosity, stability, bulk density, water holding capacity, which reflected better yield and returns.

Constraints of using crop residues with conservation agriculture-

- Overuse of chemicals(herbicides) develops an unhealthy environment
- Because of high residual level, nutrient management becomes complicated
- At the time of seeding, loss in the basal application of N fertilizers results in small efficiency and pollute the environment
- Issues in sowing, application of fertilizer & pesticides and the problem of pest infestation
- Need more awareness regarding on time placement of nutrients, pesticides, and irrigation
- The major congestion in the rice-wheat system is weed control
- Higher amount of herbicides are required for acquisition of conservation agriculture, which develops problems of environmental hazards and pollution
- Management skills required
- Negative attitudes or perceptions and institutional constraints
- Concerned of lower crop yields and/or economic returns

Research needs for efficient Crop residue management with conservation agriculture-

- Production and utilization of crop residues in different agro-climatic zones of India.
- Effective and approximate use of crop residues and related constraints.
- Effect of crop residues on nutrient and water management in the context of conservation agriculture
- Machinery development for on-farm and off-farm utilization of crop residues.
- Economics of crop residue management.
- Nutrient balance for biological health of soil.

Conclusion

Conservation agriculture, with crop residues as an integral component, is an effective solution to the aforesaid challenges and ensures a strong natural resource base. Crop residues either partly or entirely, must be used for conservation agriculture for ensuring the country's food security, making agriculture sustainable and the soil resource base healthy. Crop residues are of great economic values as livestock feed, fuel and industrial raw material, and in conservation agriculture for which it is a pre-requisite. When we add the crop residues in the soil they add the organic matter in the soil and enhance the organic carbon content. Due to the increase in the nutrient content in the soil, the fertility and productivity of the soil is increased. So, we can say that crop residue management plays a good role in the retention of nutrients in soil.

References

Amgain LP, Shrma AR, Das TK, Behera UK (2013) Effect of residue management on productivity and economics of pearl millet-based cropping system under zero-till condition. Indian J Agron 58 (3):298- 302

Anonymous (2012) Crop residue management with conservation agriculture: Potential, constraints, and policy needs. IARI, New Delhi pp 1-30

Gupta RK, Singh Y, Ladha JK, Singh B, Singh J, Singh G, Pathak H (2007) Yield and phosphorus transformations in a rice-wheat system with crop residue and phosphorus management. J American Soc Soil Sci 71:1500-07

MNRE (Ministry of New and Renewable Energy Resources) (2009) Govt. of India, New Delhi. www.mnre.gov.in/ biomassrsources

MoA (Ministry of Agriculture) (2012) Govt. of India, New Delhi. www.eands.dacnet.nic.in

Mohamed-Saleem, M. A. 1985. "Effect of sowing time on grain and fodder potential of sorghum undersown with stylo in the subhumid zone of Nigeria". In *Tropical Agriculture* 151–153. (Trinidad) 62

Naresh RK (2013). Rice residues: From waste to wealth through environment friendly and innovative management solutions, its effects on soil properties and crop productivity. Int J LifeSc Bt and Pharm Res. 2 (1):133-141

National Academy of Agricultural Sciences (NAAS) (2012) Management of crop residues in the context of conservation agriculture. Policy paper 58

Pathak H, Bhatia A, Jain N, Aggarwal PK (2010) Greenhouse gas emission and mitigation in Indian agriculture-A review, In ING Bulletins on Regional Assessment of Reactive Nitrogen, Bulletin No. 19 (Ed. Bijay- Singh), SCON-ING, New Delhi p 34

Pathak H, Saharawat YS, Gathala M, Ladha JK (2011) Impact of resource-conserving technologies in the rice- wheat system. Greenhouse Gas Sci Tech 1: 261- 277

Sidhu BS, Beri V (2005) Experience with managing rice residue in intensive rice-wheat cropping system in Punjab. In: Conservation Agriculture- Status and Prospects (Eds Abrol IP, Gupta RK and Malik RK) CASA, New Delhi. pp 55-63

Singh *et al.* (2006) Effect of in-situ green manuring of Sesbania and crop residue incorporation on yield of rice (Oryza sativa)-wheat (Triticum aestivum) cropping system. In: National

Symposium on Conservation Agriculture and Environment, October 26-28, 2006, BHU, Varanasi pp 238-239

Singh *et al.* (2010b) Integrated use of crop residues and fertilizers for sustainability of potato (Solanum tuberosum) based cropping systems in Bihar. Indian J Agronomy 55 (3): 203-208

Singh *et al.* (2010a) Options for effective utilization of crop residues. Directorate of Research, Punjab Agricultural University, Ludhiana, India pp 32

Sudha B and George Annamma (2011) Tillage and residue management for organic carbon sequestration in coconut (Cocus nucifera)- based cropping system. Indian J Agron 56(3):223-227

Verhulst *et al.* (2009) In: Innovations for Improving Efficiency, Equity and Environment. Proceedings of the 4 th World Congress on Conservation Agriculture, February, 4-7, 2009 New Delhi India pp 71-79

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