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CROP RESIDUE MANAGEMENT FOR IMPROVING SOIL QUALITY & CROP PRODUCTIVITY IN INDIA

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Abstract: *Crop residues, usually considered a problem, when managed correctly can improve soil organic matter dynamics and nutrient cycling, thereby creating a rather favorable environment for plant growth. The intelligent management and utilization of crop residues is essential for the improvement of soil quality and crop productivity under rice-based cropping systems of the tropics. Viable option is to retain residue in the field; burning should be avoided. The major issue is adapting drills to sow into loose residues. Strategies include chopping and spreading of straw during or after combining or the use of disc-type trash drills. Residues rich in lignin and polyphenol contents experience the lowest decay. A part from the higher quantity of rice and wheat residue, the residue of sorghum, maize, barley, chickpea, groundnut, rapeseed and mustard, sugarcane trash, potato, soybean, sunflower and some other minor cereals also contribute substantially towards total amount of about 462.93 million tonnes in India in 1997-98. Three-Forth of the total residue are produced by rice, wheat and oil seed crops and remaining One-Forth are from sugarcane and sorghum. Of the available residue for incorporation 53% are available in Kharif and 47% in Rabi season. The availability of crop residue in India would be 300, 343 and 496 million tonnes in 2000, 2010 and 2025, respectively. Crop residue (CR) is important components of low external input of sustainable agriculture without sacrificing productivity. Crop residue improves the physical, chemical and biological properties of soil. Crop residue increased the crop productivity. Crop Residue can be partially substituting the fertilizer nutrient but not completely replacing them. Crop residue has potential to improve fertility status of soil.*

Introduction: After green revolution natural fertility of the soil has been degraded due to intensive cultivation, use of high doses of chemical fertilizers and insufficient use of organics i.e. farm yard manure, compost, crop residue, green manure, biofertilizers etc. At present time we face many challenges to achieve sustainable food security and quality of food material. In addition to advancing food security and minimizing malnutrition, agriculture must also be an important solution to environmental issues including global warming, non-point source pollution, hypoxia, etc. In this regard, the impact of managing crop residues in conjunction with no-till (NT) farming and conservation agriculture (CA) cannot be over-emphasized. Land is a shrinking resource for agriculture and we have to produce more food to feed the increasing population of the country. For achieving sustainable food security to country, maintenance of soil health is essential. The fertility of soil is highly related with soil organic matter. Organic matter is an important soil constituent influencing a number of constraints linked with crop productivity. It is widely accepted that high soil organic matter means high potential productivity and health of soil. Intensive cropping and tillage system have led to substantial decrease in soil organic matter levels of Indian soil. This decrease in soil organic matter levels seems to be associated with the decline in soil fertility and crop production. Soil organic matter may be maintained by the addition of crop residues. So the crop residues management (CRM) is very important for soil health and crop production. Crop residues are defined as the non economic plant parts that are left in the field after harvest and remains that are generated from packing seed or that are discarded during crop processing. Sustainable agriculture is defined as an agricultural system "capable of maintaining [its] productivity and usefulness to society indefinitely. Such systems must be resource-conserving, socially supportive, commercially competitive, and environmentally sound [3]. In other words, sustainable agriculture is an alternative to industrial agriculture, and thus tries to avoid the use of chemical pesticides and fertilizers, monoculture, mechanization, biotechnology, and government subsidies. The three tenets of sustainable agriculture are: i. economic sustainability (reduce dependence on machinery and chemical fertilizers), ii. environmental sustainability (mimic the natural ecological processes by using natural fertilizers and pesticides, minimizing tillage and water usage, rotating crops yearly, etc.), iii. Social sustainability (use available labor) [4].

Decomposition of crop residues occurs at a rapid rate about 80% of crop residue carbon is lost in the first year under the warm and humid conditions of the tropics. Factors that control carbon decomposition also affect the N mineralization from the crop residues. A considerable area under rice and wheat in Indian Punjab is now harvested by combine. The rice and wheat straws left in the field after combine harvesting are generally burnt by the farmers to facilitate seed bed preparation and seeding. Crop residues contain large quantities of nutrients accumulated by rice and wheat crops. Burning causes loss of organic matter and plant nutrients, and environmental pollution. Decomposition of poor-quality residues with low N contents, high C: N ratios, and high lignin and polyphenol contents generally results in microbial immobilization of soil and fertilizer N. Nutrient cycling in the soil–plant ecosystem is an essential component of sustainable productive agricultural enterprise. Although during the last three decades, fertilization practices have played a dominant role in the rice-based cropping systems, crop residues—the harvest remnants of the previous crop still play an essential role in the cycling of nutrients. Incorporation of crop residues alters the soil environment that in turn influences the microbial population and activity in the soil and subsequent nutrient transformations. Incorporation of cereal straws of wide C: N ratio, however, is reported to immobilize soil N and adversely affects the yield of the succeeding crop[1]. Recycling of crop residues without adversely affecting crop yields has been attracting the attention of soil scientists as well as agrarian community. Improvements in soil structure in terms of aggregation from GM and wheat straw incorporation have already been reported in literature [2].

Definition of Crop Residue: Crop residue, traditionally considered as “trash” or agricultural waste, is increasingly being viewed as a valuable resource. Corn stalks, corn cobs, wheat straw, paddy straw and other leftovers from grain production are now being viewed as a resource with economic value. If the current trend continues, crop residue will be a “co-product” of grain production where both the grain and the residue have significant value. The emergence of crop residue as a valuable resource has evolved to the point where there are competing uses for it. “Crop residue, in general, are parts of plants left in the field after crops have been harvested and threshed or left after pastures are grazed. These materials have at times been regarded as waste materials that require disposal but it has become increasingly realized that they are important natural resources and not wastes”[3].

Crop Residue Management Practices: Maintenance of highly productive cropping requires effective protection of soils against erosion, conservation of relatively high amounts of soil organic matter, provision of optimum conditions for soil biota, and, to prevent undesirable environmental effects of high-level fertilizer applications, the highest possible rate of recycling of plant nutrients. At the same time, minimizing the human impacts on troposphere chemistry requires lower emissions of greenhouse and other gases, and avoiding serious health hazards posed by smoke necessitates severe restrictions, or outright elimination, of all unnecessary phytomass burning. Appropriate field management of crop residues can help to achieve all of these goals.

Residues in excess of carefully determined recycling requirements can make a major difference at both the local and regional levels in producing high-quality animal and fungal protein or fiber. Better ways of compacting residues would lower their transportation costs and improve their nutritional value, making their off-field use for feed, fiber, or substrate more economical. Perhaps the best way to promote these rational ways of dealing with straws, stalks, and leaves is to see them not as residues as often undesirable leftovers of much more highly prized crops but as valuable resources that provide irreplaceable environmental services and assure the perpetuation of productive agro-ecosystems and sustainable food production.

Crop Residue Production and Potential: Estimates of A large number of crops are grown in India. After making use of their economic parts, the remaining portion is mostly wasted except for a few crops. The adoption of mechanized farming in many advanced regions in the country has resulted in leaving a sizable amount of crop/stalk in the field after harvesting. The potential of crop residue of major cereals, pulses, oilseeds and commercial crops for recycling of valuable plant nutrients for sustained crop production is enormous. On national basis, not more than one third of this residue is available for utilization and in general, 50 per cent of the nutrients are mineralized in the soil on decomposition in a cropping season. The potential of crop residue of principal crops in India is given as under: crop residue production is made on the basis of data on the area and production of different crops and research information on the straw/grain ratio- Residue production = Grain Production × Straw/Grain Ratio.

Large quantities of residues are generated every year by agriculture. Cereals, grass, sugar beet, potatoes and oilseed rape are arable crops that generate considerable amounts of residues. In aggregate, figures of the total amount of residues look very attractive if not staggering. A distinction, however, has to be made between residues remaining in the field and those generated after harvesting and during processing.

Table 1: Estimation of crop residue production of major crops in India

S. No.	Crop	Area (M ha)	Residue: Grain ratio	Residue production (Mt)
1	Wheat	25.1	1.5	93.5
2	Rice	42.7	1.5	180.0
3	Barley	0.8	1.5	2.7
4	Maize	6.2	1.0	8.9
5	Millet	13.5	1.5	15.8
6	Sorghum	11.7	1.5	15.8
7	Beans	10.6	1.0	4.1
8	Chickpea	7.3	1.0	6.0
9	Soybean	4.9	1.0	4.2
10	Groundnut	8.0	1.0	8.0
11	Sunflower	2.2	1.0	1.5
12	Total	133.0		340.5

Source: Advances in Agronomy. (2006)

Field residues occur in smaller quantities, are spread over large(r) areas and remain in the field; examples are stubble, straw, stalks and leaves depending on the crop and the farming practice. Biomass and harvested residues are used for many often site-specific purposes: food, fodder, feedstock, fiber, fuel and further use such as compost production. These purposes are often not mutually exclusive; for example, straw can be used as animal bedding and thereafter as fertilizer. After processing residues can be concentrated which make their further use for compost production and soil amelioration easier?

The data on harvest indices, root/shoot ratios and effective organic carbon content are combined with cropping areas and crop production such that the amount of agricultural residues generated can be calculated. The harvest index (HI in Table 1) of the crop, i.e. the ratio of harvested product such as grain to above-ground crop biomass, determines the amount of above-ground crop residues [4, 5, 6].

The amount of total residue produced will vary from year to year depending on variations in *inter alia* weather, water availability, soil fertility and farming practices. The rooting system, root: shoot ratio and residue management ultimately determine the level of agricultural crop residue that can be left on the field to contribute to soil organic matter. The residue left on the field equals the total crop biomass, both above ground and below ground, minus the harvested products. For cereals the harvested products may be grain and straw. The residues can be calculated using the harvest index, the root: shoot ratio and the yield.

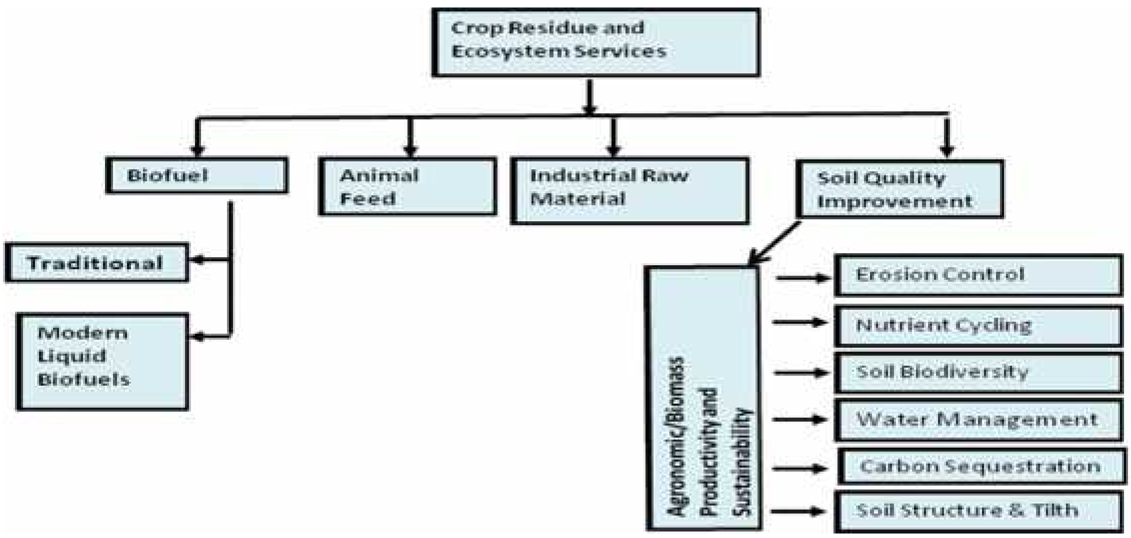
Utilization of Crop Residues: Crop residues have traditionally been used for animal feed. In many parts of the country, beef cows are placed in corn fields after harvest to graze on the residue and any grain remaining in the field. Also, crop residues are harvested, stored and fed to livestock during the winter. Crop residues, especially straw from small grains, are used for livestock bedding. A variety of commercial uses for crop residues are in various stages of development. Crop residues can be a feedstock for composite products such as fiberboard, paper, liquid fuels and others. Several straw-to-fiberboard business ventures have emerged in recent years with mixed success. Likewise, crops residues have been investigated as a feedstock for pulp for making paper.

Table 2: State wise production of crop residue and that available for incorporation as manure

S. no.	State	Total crop residue production (mt)	Crop residue available for incorporation (mt)
1	A.P.	24.6	12.4
2	Assam	5.0	1.9
3	Bihar (including Jarkhand)	17.7	6.5
4	Gujarat	11.1	6.0
5	Haryana	15.5	6.3
6	M.P.	29.4	13.0
7	Maharastra	27.8	13.3
8	Punjab	29.9	10.5
9	U.P.(including Uttaranchal)	60.0	26.0
10	W.B.	18.4	6.9
11	Delhi	0.2	0.2
12	Total	312.72	136.44

Conservative estimates indicate that there are enough crop residues to expand the supply of papermaking fiber by up to 40 percent. Crop residues can be used as a feedstock in the gasification (thermo-chemical) process for making syngas (synthetic gas) which contains carbon monoxide (CO) and hydrogen (H2). Syngas can be used for several purposes including producing electricity, producing certain chemicals and making ethanol, gasoline and diesel.

Biomass can be used in the production of biogas, which is composed mainly of methane (CH_4) and carbon dioxide (CO_2). Biogas can be used in many parts of the world for low-cost heating and cooking. It can also be used to generate mechanical or electrical power. Biogas can be compressed, much like natural gas, and used to power motor vehicles. Crop residues can also be burned directly to produce heat and steam. The investigation of alternative uses for crop residues to make commercial products will continue to grow as traditional feedstock's become limited and the need for renewable sources of feedstock expands. Unfortunately, we cannot either accurately quantify this enormous harvest or satisfactorily account for its fate, which may help to explain why so little attention has been paid to crop residues. With the emergence of the ethanol industry, considerable attention is focused on utilizing crop residues as a feedstock for cellulosic ethanol production.



It is often referred to as Phase 2 of the biofuels industry with corn ethanol being Phase 1. Cellulosic ethanol has been highly touted as superior to corn ethanol due to its improved energy balance (more Btus produced per Btu of fossil fuel used in the process), lower carbon emissions and less direct competition with food production.

Decomposition of Crop Residue: The decomposition of crop residues is a microbial mediated progressive breakdown of organic materials with ultimate end products of carbon and nutrients released into the biological circulation in the ecosystem. Microbial degradation is mainly responsible for Residue decomposition and it is also depend on environmental (temperature and precipitation), soil (available nutrients, pH, and aeration), residue (C/N ratio, chemical composition, size, age, lignin content, polyphenol content and species or cultivar type), or management factor include the loading rate, tillage and irrigation. Crop residue decomposition although physical breakdown, removal by wind or water, or use by soil fauna also can significantly affect residue loss as well carbon loss [7]. Rates of decomposition of cereal, oilseed, and pulse crop residues were primarily influenced by their N content. The process of decomposition is controlled by the interaction of three components i.e. i. the soil organisms or biological processes, ii. The quality of crop residues, iii. The physical and chemical environment. Microbial communities of plant residues are greatly influenced by crop type and differ in quantity and structure from the communities in the soil below. The ecology of microbes colonizing residues is very dynamic.

Soil Quality and its Concept: The capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality and support human health and habitation [8].

Because of the numerous alternative uses of soil as a living resource, the meaning of the terms soil health and soil quality depend on the defined purpose such as for agricultural use In agriculture, we mainly pay attention to plant and animal productivity as these would be of greatest importance in cultivated soils [9] as opposed to urban soils [10]. Our ability to assess soil quality is complicated by many physical, chemical, and biological processes and their interactions in time, space, and intensity. It is not usually possible to directly measure the rate of soil processes; instead they can be inferred by measuring specific soil properties that are indicative of these rates. These measurements then can be used in simulation models to predict future changes in process rates and, in turn, soil quality.

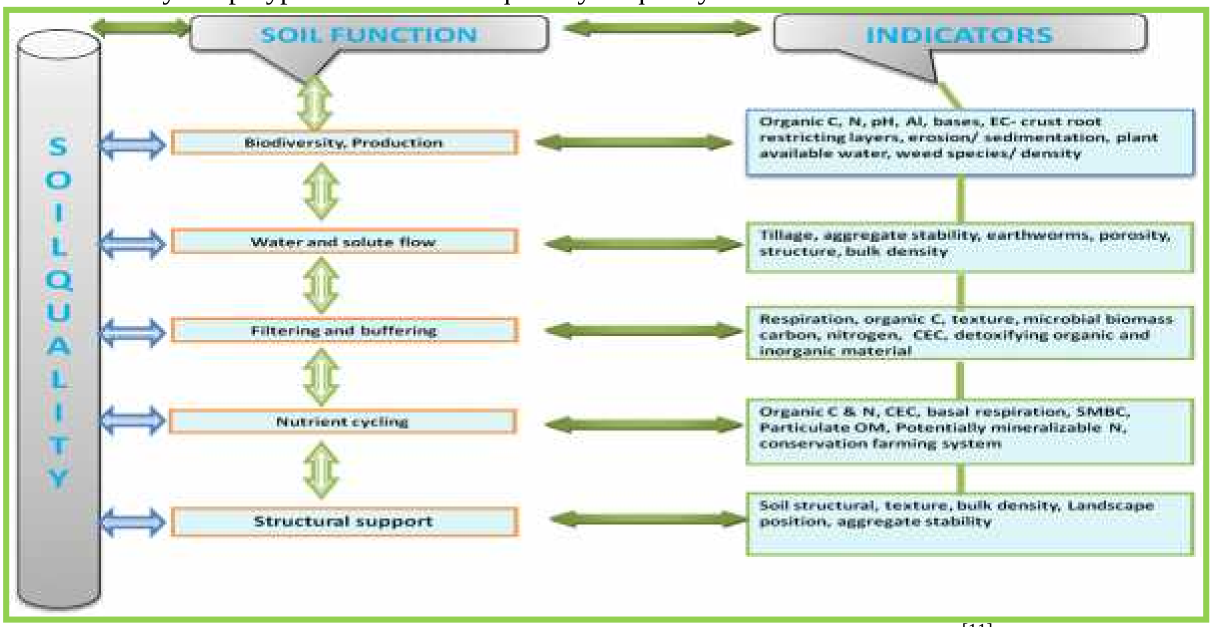


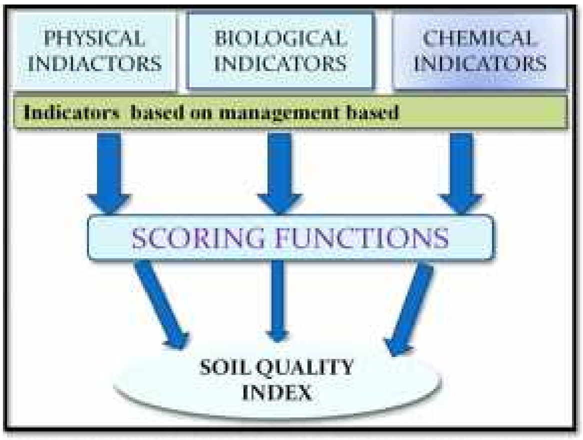
Figure. A schematic representation of the concept of soil quality [11]

Impact of Crop Residue on Soil Quality: A virtually universal consequence of converting grasslands to croplands has been an appreciable decline in concentrations of soil organic matter. In most cases, the rapid loss of soil organic matter during the years immediately following the conversion was replaced by slower, but continuing declines due to inappropriate agronomic practices. Long-term records show soil nitrogen content falling by 25–70 % over periods ranging from 30 to 90 years; these records also show soil carbon declining by up to 50% over similar time spans [12, 13].

When Crop Residue incorporated in to Field it Helps in Improving

- Organic carbon and N content in soil.

- Acts as a buffer in soil against rapid change in soil pH.
- Reclamation and management of saline and alkaline soil.
- Incorporation of organic materials the pH and ESP in the soil and improved crop yields.
- Acts as a reservoir for plant nutrients and prevents leaching of elements, which are essential for plant growth.
- The incorporation of straw along with application of FYM, reduce the bulk density of soil and increases the porosity of the soil.
- Provide energy for growth and activities of microbes.
- Improving soil and water conservation and sustaining soil fertility and enhancing crop yields
- Raised the soil temperature in winter and lowered it in summer season.



Crop residues of common cultivated crops are an important resource not only as a source of significant quantities of nutrients for crop production but also affecting soil physical, chemical, and biological functions and properties and water and soil quality. When crop residues are returned to the soils, their decomposition can have both positive and negative effects on crop production and the environment. Our aim as agricultural scientists is to increase the positive effects. This can only be achieved with the better understanding of residue, soil, and management factors and their interactions, which affect the decomposition and nutrient release processes. Data on nitrogen benefits and nitrogen recoveries from residues show that a considerable potential exists from residues, especially leguminous residues, not only in meeting the N demands of the succeeding crops, but also in increasing the long-term fertility of the soils. In addition, crop residues and their proper management affect the soil quality either directly or indirectly. Intensive cropping systems are very diverse and complex, so no one residue management system is superior under all situations. Ideally, crop residue management practices should be selected to enhance crop yields with a minimum adverse effect on the environment. It is suggested that in each cropping system, the constraints to production and sustainability should be identified and conceptualized to guide toward the best option. Multidisciplinary and integrated efforts by soil scientists, agronomists, ecologists, environmentalists, and economists are needed to design a system approach for the best choice of crop residue management system to enhance both agricultural productivity and sustainability.

Effect of Crop Residue on Crop Production: The available crop residue have been managed in many ways like removal, in situ- incorporation, burning and retained, The removed residue find their way in off- field uses like fodder, card board industry, surface mulch in no-till agriculture. In Indo-Gangetic plains, no till agriculture is still a question mark in the rice-wheat cropping system. The combine-harvested residue is difficult to collect and remove from the field for other purpose, the feasible options being in situ burning or incorporation. Observed that burning of crop residue resulted in higher grain yield of rice[1] and wheat (5.57 and 4.12 t ha^{-1}) than physical removal (5.53 and 4.02 t ha^{-1}) and incorporation (4.51 and 3.72 t ha^{-1}).

Management of Crop Residues: Crop residue returns fertility back to the soil. So, the nutrients need to be replaced, probably with commercial fertilizers. Although commercial fertilizers prices are quite volatile, recent prices indicate that the use of commercial fertilizer is needed to replace. Crop residue management include mulching, composting and Tillage practices.

Limitation of Crop Residue: Using crop residues as a feedstock for producing renewable energy and other valuable products has received considerable attending in recent years. However, these uses must be balanced against the long-term benefits of maintaining and improving the productivity of our soils. Our soils are a valuable resource critical for meeting the challenges of the next century. Physical removal of stubble is not cost effective. Straw burning, though the easiest and cheapest disposal, has harmful environment effects and also nutrient losses. Immobilization of nutrient and formation of toxic substances and hinders with the smooth running of seed drill and transplanting of rice. In cropping system where the previous crop is infected with pests and diseases, incorporation is not a good practice.

Conclusion: Crop residues should be seen not as wastes but as providers of essential environmental services, assuring the perpetuation of productive agro-ecosystems. More than 2000 million tones per annum crop residues are produced globally from different cropping systems Nutrient recycling in soil plant ecosystem is an essential component of sustainable productive agricultural enterprise. Management of crop residues regulates the efficiency of fertilizers, water and other reserves are used in a cropping system, removal of crop residues leads to low soil fertility. Suitable manipulations of processes such as nutrient immobilization, are an important component of efficient CRM programme CRM is known to affect directly or indirectly most of the soil quality indicators. Incorporation of straw increased the formation of water stable aggregates particularly > 2mm size over fertilizer N treatment.

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