ISBN: 978-81-973427-0-7

13. Crop Residue Management for Sustainable Agriculture

Shivendra Singh, Pradeep Kumar,
Dhruvendra Singh Sachan

Research Scholar, Department of Agronomy,
Chandra Shekhar Azad University of Agriculture and Technology,
Kanpur, U.P., India.

Naushad Khan

Professor, Department of Agronomy,
Chandra Shekhar Azad University of Agriculture and Technology,
Kanpur, U.P., India.

Abstract:

India is an agriculture-based economy. A large share of the land is used for agriculture, and in its different agroecological regions a wide variety of crops are cultivated. India is among major crop producing countries and harvesting of several crops leads in generation of large amount of crop residues in On and Off farm. According to estimates by the Ministry of New and Renewable Energy, about 500 million tons of residue from crops are generated annually. As a result of the rapid transition from traditional agriculture to high input intensive modern farming methods, crop residue production is often increased. In India Rice-wheat system is a major dominating cropping system of India. The irrigated rice-wheat system produces a lot of crop wastes because of its high yields. Burning rice straw results in significant air pollution and nutrient loss in northwestern India, both of which are harmful to human health and contributing to climate change. In order to prevent straw burning, innovations in agricultural residue management should enable farmers to reduce risk associated with climate change, lower nutrient and water inputs, and achieve sustainable productivity. Significant amounts of plant nutrients are present in crop wastes, and their careful application will improve crop production's nutrient management. This chapter advances knowledge of crop residue management by using a multidisciplinary approach. It also offers suggestions for enhancing agricultural sustainability in light of changing social and environmental trends.

Keywords*: agriculture, crop residue, management. Sustainable, rice.*

13.1 Introduction:

Crop residues are those material which are left over in the field after harvesting of the crops and are not economically important plant parts. The harvest which are refuses from the field include straws, stubbles, stovers and haulm of different crops. The residue of the crop shall also be from the crushing shed or from the discarding of the crop during the processing of the crop. It includes the waste of processes such as groundnuts shells, different oil producing oil seed cake, rice husks, wheat straw and cobs of maize or sorghum. India is a farm-based economy, estimated at around 500-550 million tons of crop residue On and Off the land in addition to 110 million tons of wheat, 122 mt of rice, 71 mt of maize, 26 mt of bajra, 141 mt of cane, 8 mt of sugarcane fibers, Jute Mesta and Cotton and 28 mt of pulse.

These residues earlier used to be considered waste, but having better knowledge, research and further study it has become evident that these are an essential natural resource rather than a waste. In order to convert surplus agricultural waste into usable materials, the recycling of crop residues could be used. These items may contribute to nutrient absorption, soil fertility improvement and ecological balance which is beneficial for the production of crops. Many farmers are utilizing wheat straw for providing feed for animal, but using rice straw is still a problem because of rice contains high silica, which makes it unfit and poor for animal consumption and due to unavailability of fodder for animal the number of animals in rural areas is decreasing. The combine harvester machine left a lot of residues of loose paddy that create interferes with the sowing of wheat with drills. Burning of Paddy straw as In-situ burning is a widespread management method in North India. Farmers are using crop residue burning to overcome this problem, which wastes a great deal of biomass and contaminates the soil.

In addition to nutrient loss, in-situ crop residue burning in the field affects a variety of soil characteristics, including pH, soil temperature, soil moisture, soil organic matter content, and available phosphorus. Burning rice straw is a fast and low-cost way for farmers to prepare their fields for wheat planting. It is estimated that 16 Mt of rice stubble will burn in Punjab each year in a few short weeks. According to findings from Gadde *et al.,* (2009) show that 0.05% of India's total greenhouse gas emissions came from burning rice straw. Significant amounts of biomass, or organic carbon and plant nutrients, were lost as a result, and the chemical, biological, and physical characteristics of the soil as well as the flora and fauna that live there were negatively impacted.

A range of agro-based applications and other industrial processes can both benefit from the usage of agricultural waste. The organic nature of crop leftovers makes them a valuable component of agricultural waste that can be utilized for the good of society. With the utilization of crop leftover residue management techniques, residues are used to manage soil in a number of ways, such as breaking down the residues, lowering soil erosion, recycling nutrients and making them available to plants, managing weeds and pests, and increasing crop yields through the use of various tillage related conservation techniques. Crop residue also helps in promoting soil organic matter which requires incorporation of crop residues for improved Carbon sequestration, applying crop residues in the right amounts and locations, and using Nitrogen fertilizer as efficiently helps in managing the residues (Lal 2005). This chapter will discuss the key and major difficulties with crop residue management, detailed exploration of crop residue management, alternate applications, and mechanized residue management options for reducing crop residue burning.

13.1.1 Crop Residue Burning and Effects:

Crop residue such as paddy straw /stubbles, Stover’s of maize, wheat straw, mustard stubbles, pulse stubbles, groundnut shells etc. are burnt openly in the field by farmer to dispose them from the field. The reason for burning a lot of agricultural residues and paddy straw in Punjab, Haryana, western Uttar Pradesh, and neighboring states is to provide room for the next crop to be sown after the previous crop is harvested. Because it's a quick and simple way to get rid of it, paddy straw is burned in the field. The paradoxical coexistence of crop residue burning and fodder scarcity in this nation has resulted in a notable spike in fodder prices in recent years. The following adverse effect of burning crop residues are:

A. Adverse Effect on Air Quality:

Crop residue burning emits harmful gases such as CH_4, CO, N_2O, and NOx, as well as particulates, non-methane hydrocarbons, volatile organic compounds, and semi-volatile organic compounds (Mittal *et al.,* 2009; Zhang *et al.,* 2011). A tons of rice straw burned releases 2 kilogram of Sulphur dioxide, 199 kg of ash, 60 kg of CO, 3 kg of particulate matter, and 1460 kg of CO_2. It also generates a significant number of particles, which are made up of both organic and inorganic species. Paddy straw contains roughly 70%, 7%, and 0.66% carbon that is released as carbon dioxide, carbon monoxide, and methane respectively, however, 2.09% of the N in straw as nitrous dioxide is released after incineration (Hays *et al.,* 2005).

B. Adverse Effect on Soil Health and Fertility:

Burning paddy straw releases heat that rises the soil's temperature from 33.8 to 42.2 ºC to a depth of one centimeter (Gupta *et al.,* 2004). Due to increase in temperature the bacterial and fungal populations that are essential to healthy soil are destroyed in this way. Burning of crop leftover and residue in the field damages the organic matter in the uppermost layer of the earth as well as other microorganisms. Crops are become increasingly susceptible to illness as a result of the growing wrath of "enemy" pests, which is a result of the loss of farmer-friendly pests. There has also been an overall reduction in the top soil layers' capacity to breakdown materials (Kumar *et al.,* 2015). According to estimates, burning one tons of rice straw results in the loss of 1.2 kg S, 25 kg of K, 2.3 kg of P, and 5.5 kg of N in addition to organic carbon. In general terms, crop leftovers from various crops comprise 80% N, 25% P, 50% S, and 20% K. If crop residue is integrated or kept in the soil, it becomes enriched, notably in organic carbon and Nitrogen.

C. Adverse Effect on Human and Animal Health:

Crop residue burning adds to the emissions of air pollutants that could have a serious negative impact on human health, including exacerbation of lung and chronic heart disease, as well as respiratory issues like coughing and asthma that are especially harmful to children, the elderly, and expectant mothers (Pathak *et al.,* 2010).

Animal health suffered as well by inhaling fine particulate matter (FPM). It resulted in inflammation of the cornea, transient blindness, and chronic bronchitis that resembled asthma. Burning of residues kills the pests and organisms that farmers' friends have, such as bacteria, earthworms, and others pests. Because to this behaviour, bird nests are also broken. One of the main reasons for the extinction of vultures, eagles, and sparrows is stubble burning (Kumar *et al.,* 2015).

13.2 Crop Residue Management Options:

There are two categories of crop residue management options: in-situ and ex-situ. Farmers have a number of choices for managing agricultural residues, some of which are covered below. Every managerial decision must be weighed in terms of pros and cons.

13.2.1 In-Situ Management:

The possible methods for managing crop residues in-situ are either utilizing consortia of microbes to break down the residues or retaining, integrating, or mulching them in the field. They are discussed as:

A. Livestock Feed:

In India, crop waste has long been used as animal feed, either on their own or in combination with other ingredients. Global population growth has resulted in a greater area being used for grain production, which has constrained the amount of land that can be used to produce fodder. Because agricultural residue includes important nutrients, it can therefore be an important source of feed for cattle. The main issue farmers have with managing their feed can be somewhat alleviated if field-grown agricultural leftovers are sent to the dairy business to feed animals. Enhancing the feed efficiency of dairy cattle using crop leftovers can boost farm profitability while lowering pollution levels in the environment.

However, crop leftovers cannot provide livestock with their whole diet because they are unpleasant and poorly digestible. Crop residues consist of low-density fiber components that are low in lignin, which acts as a physical barrier and obstructs the process of microbial decomposition. They are also low in nitrogen, soluble carbohydrates, minerals, and vitamins. The wastes must be processed, enhanced with urea and molasses, and supplemented with green fodders (leguminous and non-leguminous) and straw made from legumes (sunhemp, horse gram, cowpea, and gram) in order to meet the nutritional needs of the animals.

B. Compost Making:

Composting has long been accomplished using crop leftovers. Crop leftovers are piled in dung pits and utilized as animal bedding for this purpose. Crop leftovers that have collected in various places are to be carried to the compost yard and stacked in a corner for additional processing in order to make compost. It is advisable to shred all crop residues used for composting after accumulation, which is easily accomplished with a shredder machine. A maximum particle size of 2 to 2.5 cm is advised for expedited composting. Narrow C: N ratio helps in composting easily and it can be done by adding carbon and nitrogen rich material should be mixed together. Green residue materials like glyricidia leaves, parthenium plants and leaves, freshly harvested weeds, sesbania leaves are rich in nitrogen, whereas brown colored waste material like straw, coir dust, dried leaves and dried grasses are rich in carbon. Litter and waste from animals are also excellent sources of nitrogen. To speed up the composting process, alternate layers of carbon-rich material, animal excrement, and nitrogen-rich material should be heaped together.

Utilizing crop leftovers that are readily available on the farm to create high-quality compost contains both microorganisms and nutrients. Because bio-compost is regularly added, the physical, chemical, and biological qualities of the soil will all be improved. By increasing the amount of organic matter in the soil, composting contributes to the preservation of soil fertility and improves soil biodiversity.

C. Retaining, Incorporating or Mulching the Crop Residues in The Field:

Crop residue mulching lowers soil heat during summer owing to shade impact and raises soil temperature the least in the winter via decreasing soil heat flow. In soil by adding bases like hydroxyls during the breakdown of crop residues with higher C: N, crop residues significantly improve soil acidity.

Conversely, applying residues from lower C: N crops, such as legumes, oilseeds, and pulses, increases soil alkalinity (Pathak *et al.*, 2011). According to Jain *et al.*, (2007), crop residue also aids in the soil's ability to sequester carbon. Crop residues have a broad C: N ratio of 70:1 to 100:1, especially those from wheat and rice crops. Crop residues supplemented with around 30–40% of the Carbon decomposes in about two months (Beri *et al.*, 1992). Retaining crop residues on the soil surface has several advantages, including:

- The growth of weed is decreased.
- The cost of using weedicides is decreased.
- It improves properties of soils *viz*. physical, chemical, and biological.
- It helps in recycling of Plant nutrient.
- It also helps in overcome and reduced fertilizer uses for next crops.
- Increased cation exchange capacity (CEC).

13.2.2 Ex-Situ Management:

Crop residue ex-situ management refers to the removal of crop residue from the field for use as a source of fuel, fodder. ex-situ management methods can help reduce air pollution caused by burning crop residues and help in harnessing the energy requirement for the future. Here are some commonly used ex-situ crop residue management methods:

A. Biofuel and Bio Oil Production:

The past few decades have seen an astounding amount of research on renewable sources of liquid fuels to replace fossil fuels due to rising concentrations of greenhouse gases, fuel costs, and environmental concerns. Fossil fuel combustion, including the burning of coal and oil, releases carbon dioxide into the atmosphere, a major cause of global warming.

Biofuels made from lignocellulose materials like wood and agricultural waste (such as corn stover, sugarcane bagasse, and wheat straw) can be a useful addition to or replacement for gasoline. The process of turning ligno-cellulosic biomass into alcohol is crucial because ethanol can be used straight in internal combustion engines or combined with gasoline to improve its octane and extend its fuel life.

Bio-oil can be developed from agricultural residue using the fast pyrolysis process, which requires raising the temperature of the biomass to 400-500°C in a few seconds, resulting in a significant change in the thermal disintegration process. Approximately 75% of the dry weight of biomass is transformed into vapors that condense. The condensate produces a dark brown, viscous liquid known as "bio-oil" if it is rapidly cooled in a matter of seconds. Bio-oil has a calorific value of 16–20 MJ kg^{-1}.

Cellulose, hemicellulose, lignin, and pectin make up around 90% of the dry weight of most plant materials. Ethanol derived from biomass resources and cellulosic ethanol have been shown to have the capacity to reduce greenhouse gas emissions by 86%.

Bio oils and Bio Fuels are the potential solution for enhancing energy security and lowering greenhouse gas emissions is the conversion of plentiful lignocellulose biomass to biofuels for use as transportation fuels (Yat *et al.,* 2008; Wyman, 1999; Wang *et al.,* 2007).

B. Briquetting:

Briquetting technique can be used to manage various loose agricultural leftovers by turning them into solid biofuels that have been densified (Werther *et al.,* 2000). By tightly compacting the leftover crop debris, a technique known as briquetting makes it possible to substitute wood for fuel (Setter *et al.,* 2020). It is simpler to transport, store, and use agricultural waste as biofuel when it is densified through briquetting.

C. Bio char:

Bio char It is a porous, finely grained product rich in carbon that is made by pyrolyzing solid biomass that has been heated to 350–500°C without the presence of oxygen (Sakhiya *et al.,* 2020). It is a powdered, dark-colored product with a number of special qualities, including high porosity and a high cation exchange site, which improve soil conditions for bacteria and raise the soil carbon pool. It is mostly recognized for optimizing the soil's bulk density. Applying bio char to the soil enhances its overall qualities and increases soil fertility by acting as a soil amendment.

According to Singh *et al.* (2012), bio char has the potential to be utilized as an input to enhance traditional agricultural output and reduce greenhouse gas emissions from agricultural soils due to its improved physical, chemical, and biological qualities. Because of this, scientists studying agriculture have become more interested in using bio char as a soil amendment and in creating it from bio-residues. Bio char can also be advantageous to the agriculture industry since it improves soil and aids in the removal of animal and crop waste. Numerous studies have suggested bio char as a potential solution for energy, carbon storage, and ecosystem function (Lori *et al.,* 2013).

D. Biomass Pellets:

The biomass pellets are made up from crop residue at palletization plants using several specialized machines which make pellets. They are preferred in thermal power plants due to their small diameter and size, as well as their high binding strength. In addition, they burn extremely easily with coal, which is a typical fuel in power plants. One common process for turning biomass into high-density, solid energy carriers is the creation of biomass pellets. Different types and grades of pellets are produced for use as fuel in homes, businesses, and electric power plants. A range of sizes and types of pellets producing equipment are available, enabling production at both home and industrial levels. Pellets are round, measuring between 6 and 25 mm in diameter and 3 and 50 mm in length. When compared to coal, biomass pellets emit 80% less CO2 and have lower amounts of sulfur, chlorine, and nitrogen during combustion. As much as 85% combustion efficiency can be achieved with biomass pellets when they are utilized in high-efficiency wood pellet burners and boilers.

E. Production of Mushroom Crop:

Generally, for production of mushroom farmers utilize wheat straw as a base material, however in Punjab, paddy straw is an essential component for usage as a raw matter for mushroom production (Chaudhary *et al.,* 2009). Button mushroom production requires a few steps, including cleaning the straw, removing any leftover water, cutting the straw, and getting the bundles ready. According to recent research on paddy straw management (Roy *et al.,* 2016), the projected cost of these activities was 11$ per quintal when wheat straw was utilized as the base material, as opposed to 7$ per quintal when paddy straw was used as the raw material. As a result, the growers of mushrooms benefit greatly from the usage of paddy straw, which generates net savings of $3.75 per quintal. Additionally, paddy straw can be utilized to make floor tiles, paper, pulp board, and cushioning material for packaged manufactured goods (Kumar *et al.,* 2016).

13.3 Mechanization in Crop Residue Management:

The reduction in laborers and farm employees makes room for farmers to adopt mechanization in order to manage crop residues. Large quantity of farm residue management cannot be done easily based on labors, so to overcome this problem mechanization is necessary. Recent advanced farm machinery helps in mitigate to manage farm residue and helps in overcome the labour shortage. Resource conservation technologies (RCT’s) based farm implements proved to be helpful in better result in managing crop residues for rectifying soil health, production, productivity, overcoming pollution and maintaining sustainable agriculture (Jat *et al.,* 2011).

A. Happy Seeder:

Happy Seeder is a machine-based implement that directly drills seed through the soil in absentia burning or cleaning crop debris from the previous harvest. Happy Seeder is a composite equipment that combines a sowing unit with a straw handling unit. In order to prepare the ground for the next crop to be sowed, this tractor-mounted tool chops and lifts straw. The raised straws are dispersed across the soil like mulch. With the happy seeder technique, sowing accounted for around 97 percent of the total energy input utilized for crop establishment, making it the primary energy source. Taking into account the happy seeder machine's 0.3 ha h^{-1} effective field capacity (EFC) and 30-day season of operation. In Northwest India region, the happy seeder machine technology marked a quantum leap for the paddy-wheat crop rotation.

B. Baler:

Baler is a machine that facilitates ex-situ crop residue management has been in demand in Punjab, Haryana and adjacent regions. This machine makes bales with the residues into rectangular or round bales shapes. This helps in maintaining crop residue for applications such as animal feeding, fuel and fiber for paper and pulp manufacturing industries. Approximately 2,000 baler machines are in use in Punjab and have been for the past ten years. 1,268 of these are heavily subsidized (between 50 and 80 percent) by the Crop Residue Management (CRM) program of the Centre. In order to compress crop leftovers into compact, manageable bundles, balers function as hydraulic presses, which is a crucial part of stubble compression. Twine, wire, or strapping are used to firmly attach these compressed stubbles. Farmers use a tractor-mounted cutter to trim the crop residue prior to utilizing a baler machine. Using netting, a tractor-mounted baler machine compacts the stubble into little bales. By removing the need to burn crop residue, these bales assist to lessen air pollution and soil deterioration. Stubble is effectively compressed using balers, which facilitates handling, storing, and transportation. It enables farmers to plant the following crop and plough the field right away. It creates opportunities for making money by selling compressed stubble as a useful resource.

C. Hay Rakes:

The hay rake is an implement that precisely uses long arms in conjunction with a reduction gearbox to create the highest quality windrows with the least amount of pollution. The smoothly formed, fluffy windrows aid in the formation of compact bales. It functions well under practically all circumstances and is built with exceptional durability. Hay should be raked when it has between 35 and 45 percent moisture content. When straw is divided into windrows and bales are formed with a baler, a hay rake functions similarly to a baler. To sum up, burning crop residue has created a significant risk for both air pollution and climate change. More harmful and hazardous compounds are released into the air when crop residue is burned. Many greenhouse gases, including SO_2 and NO_2, as well as gases from carbonaceous materials are emitted.

Therefore, it is important to superintend the crop residues in a sustainable manner. Rather of being burned, leftover material can be used and repurposed in a number of ways, including the growth of mushrooms, cow feed, and biofuel. Is in order to guarantee efficient residue management and avoid the detrimental consequences of agricultural residue burning, the annual number of residues grown out should be routinely observed.

13.4 Residue Management Effects on Soil Dynamics and Crop Productivity:

A. Effect On Rice-Wheat Productivity:

The use of machinery during sowing has a considerable effect on the phenology, growth, and development of wheat. When it comes to comparing with wheat sown with help of a rotator and conventional tillage, wheat sown with using Happy seeder develops 5-7 days later (Singh *et al.,* 2007). Because of the improved soil moisture regime that remained available for a longer duration of time with reduced evaporation, wheat sown with the

Happy Seeder took more time to mature while paddy straw was remain on the soil's surface. Half of heading will be late by six and ten days, respectively, if rice residues are retained at 5–7.5 t ha^{-1} and 10–12.5 t ha^{-1} (Sidhu *et al.*, 2017). Because crop leftover residue mulch act as a physical interruption on the surface of the soil, there is reduced weed dynamics due to enhanced and improved soil physical status, increased soil moisture regime, and enhanced nutritional availability status to the plants (Singh *et al.*, 2013). Furthermore, to these advantages, zero tillage with residue retention produced higher rice and wheat yield parameters than conventional tillage, including the No. of spikes, length of spikes, and test weight (Khalid *et al.,* 2014). When compared to traditional tillage methods, crop residue incorporation in Zero Tillage plots employing the Happy seeder implement enhanced wheat grain production by 4.60 to 9.30% (Zamir *et al.*, 2010). Crop yields are raised due to the integration of rice residue, which also improves soil pulverization, nutrient availability, and enhanced organic matter content.

B. Effect on Weed Dynamics:

Conservation agriculture (CA) promotes the least amount of soil disturbance possible through ploughing, and crop diversity inhibits weed growth and properly handles leftovers. According to Nandan *et al.,* 2020, a grand density of weed grasses and weed sedges at the start of the season and broad-leaved weeds emerges later on is caused by Zero Tillage-DSR followed by Zero till wheat system. Thus, in terms of lowering weed biomass, crop residue retention outperformed residue removal. Remainder retention modifies the physical and chemical properties of the seed environment, which impacts the germination of seed (Zhang *et al.*, 2021), (Teasdale *et al.,* 1993), and (Singh *et al.*, 2012) because it decreases light penetration and soil surface insulation.

C. Effect on Soil Bulk Density and Soil Porosity:

Bulk Density of soil is decreased when crop residue is added. When crop residues are added to the soil, the microbial activity rises, and the products of residue breakdown encourage greater aggregation, which lowers Bulk Density. Moreover, Bulk Density should decrease with dilution because the residue is lighter than mineral particles (Shaver, 2010). Because of the straight inverse relationship between Soil porosity and soil Bulk Density, porosity tends to rise as Bulk Density falls. Cavities develop and widen inside and between aggregates as they start to form and get bigger. When these cavities are joined, a conduit for fluid transfer is produced (Shaver, 2010). In a long-term study conducted in Punjab, India, (Singh *et al.,* 2007) observed a decrease in Bulk Density in the rice straw managed treatment compared to the control. A highest reduction in Bulk Density (1.65 Mg m^{-3}) was seen among the different treatments when the residue of both crops was incorporated into the treatments comprising of wheat straw + urea + rice straw inclusion.

D. Soil Organic Carbon (SOC):

The amount of soil organic carbon present in the soil biota increases when residue is integrated into the soil. (Benbi *et al.*, 2012) observed that after 11 years of continuous rice-wheat rotation, the Soil organic carbon content increased by 34% when rice straw and FYM were applied. According to Singh *et al.*, (2009), sandy loam soil with low baseline Soil organic carbon has a large potential for boosting Soil organic carbon content. This was demonstrated by a 29.6% rise in Soil organic carbon content in straw-retained treatments when compared to 11.60 percent in silty loamy soil, and by comparing the results with straw burning. In contrast to full and partial residue removal, Crop residue retention and application of residue resulted in increased Soil organic carbon stock, according to a different study conducted in the USA (Villamil *et al.*, 2015). Long-term studies (Bhat *et al.*, 1991) demonstrated that applying rice straw at a rate of 12 t ha^{-1} and wheat straw at a rate of 6 t ha^{-1} considerably raised the soil organic carbon content of the soils.

E. Effect on Soil Available Nutrient:

Crop residue increases the amount of nutrients available in the soil, which helps to lessen the need for chemical fertilizer application. Sidhu *et al.*, (1989) discovered that the addition of crop residue led to a greater concentration of total nitrogen in comparison to treatments involving residue removal or burning in a long-term study conducted in Ludhiana, Punjab. In a similar vein, plots with residue incorporation had higher available phosphorus contents than those with its removal or burning. Because phosphorus is lost to the sky during crop residue burning, the amount of phosphorus that is readily available has decreased. According to Gotoh *et al.* (1984) and Cassman *et al.* (1995), adding rice straw greatly increased the total nutrient concentration as compared to burning crop residue. The Vertical soil type showed considerably higher total nutrient and mineralizable N in 0–10 cm soil depth when treated with no-tillage residue retention and rising fertilizer N level, according to Dalal *et al.*, (1989).

F. Effect on Crop Productivity:

Crop productivity and output are increased when crop residue is applied to the soil. This was primarily ascribed to increased soil organic carbon levels, decreased water evaporation loss, and enhanced water infiltration, all of which enhanced the physical properties of the soil and decreased nutrient losses. The use of rice straw and N fertilization significantly increased grain output, as demonstrated by Yuana *et al.* (2014). Another study by Wilhelm *et al.* (1986) found that for every Mg ha^{-1} of residue removed, the grain production of soybean and maize could decrease by roughly 0.10 Mg ha^{-1}. In Pakistan, Shafi *et al.* (2007) reported that residue of crop incorporation boosted maize kernel production by 23.70 percent when it is compared to removal of residue methods. Same findings regarding as 37 percent production of cereals grain increase with using crop residue incorporation when we compared to without applying crop residue have been reported by Kouyaté *et al.*, 2000. While several research has shown that residue management increases grain output.

13.5 Constraints of Crop Residue Incorporation:

Managing crop left-over in the fields comes with a lot of difficulties. These include challenges with fertilizer and pesticide application and seeding, as well as problems with pest infestation. These crop wastes require a lot of labour and money to remove. In order to conveniently avoid having to deal with residue cleanup, farmers typically burn these residues. According to reports, Rice-wheat cropping system in the Indo Gangetic plains burn over 75% of their crop wastes, which has a detrimental impact on the ecology and soil

(NITI Aayog 2015). The main problem with residue management is the small amount of crop residues that are utilized in industry and household settings. Because of its greater carbon nitrogen ratio, straw of rice immobilizes nitrogen and reduces grain production when added to soil (Nannipieri 1994). Farmers typically destroy crop residues by burning them into their fields to get rid of them and ensure that the next crop is sown on time since they view crop residue as a problem in their fields. Because of its greater C: N ratio, rice straw immobilizes nitrogen and reduces grain production when added to soil (Nannipieri 1994). owing to ignorance of methods such different decomposers, which facilitate easy residue breakdown and lower the C: N ratio.

Emerging weed population is also the major constraint, In the rice-wheat cropping system weed management is major problem. When we use chemical pesticide in excess amount it has negative effects for a healthy ecosystem. Nutrient management may get more complicated as a result of greater residue levels and fewer possibilities for applying nutrients, especially through manure. Fertilizers, especially N, that are administered fully at the time of seeding have the potential to lose their effectiveness and contaminate the environment. Additional obstacles to the adoption of residues integration systems include the need for more managerial expertise, the presumption of lower crop yields and/or economic returns, unfavorable attitudes, and institutional hurdles. Moreover, farmers like well-kept, spotless fields to run-down ones that have been tilled.

13.6 Conclusion:

India faces a difficult challenge in 2050: feeding the world's most populous nation with one of the worst rates of malnutrition. In addition, farming in the future needs to be environmentally sustainable and multifunctional in order to provide producers and society with a means of subsistence as well as ecosystem products and services. Crop leftovers are an essential part of conservation agriculture, which effectively addresses the aforementioned issues and guarantees a robust basis of natural resources. Conservation agriculture lays out the fundamentals of sustainable production systems, which need to be used in accordance with the requirements of each individual site. Crop trash have significant economic significance as fuel, animal feed, industrial raw materials, and as a necessary component of conservation agriculture. Crop leftovers must be applied, in whole or in part, to conservation agriculture to provide food security for the nation, sustain agriculture, and maintain a healthy base of soil resources. To ascertain the sustainability and resilience in agriculture in India, it is imperative that all relevant stakeholders such as farmers, service providers of supply and value chain, researcher workers, extension agents, policymakers' peoples, public servants, and consumers of India engage in comprehending and fully utilizing these invaluable resources. We think that the development, training, awareness programme, policy, and research initiatives will be very helpful in managing agricultural residues on a local and regional level.

13.7 References:

1. Benbi DK, Toor A and Kumar S. 2012.Management of organic amendments in rice-wheat cropping system determines the pool where carbon is sequestered. *Plant Soil* 360:145-62.

2. Bhat AK, Beri V and Sidhu BS. 1991. Effect of long-term recycling of crop residues on soil productivity. *J Indian Soc Soil Sci.* 39:380-82.
3. Cassman KG, Datta SK, Olk DC, Alcantara J, Samson M, Descalsota J and Dizon M. 1995. Yield decline and the nitrogen economy of long-term experiments on continuous irrigated rice systems in the tropics. Adv Soil Sci. 25:181-18.
4. Dalal RC. 1989. Long-term effects of no-tillage, crop residue, and nitrogen application on properties of a Vertisol. Soil Sci Soc Am J. 53:1511-15.
5. Gadde B, Menke C and Wassmann R. 2009. Rice straw as a renewable energy source in India, Thailand, and the Philippines: Overall potential and limitations for energy contribution and greenhouse gas mitigation. Biomass and bioenergy, 33(11), 1532-1546.
6. Gotoh S, Koga H and Ono SI. 1984. Effect of long-term application of organic residues on the distribution of organic matter and nitrogen in some rice soil profiles. Soil Science and Plant Nutrition, 30(3), 273-285.
7. Gupta PK, Sahai S, Singh N, Dixit CK, Singh DP, Sharma C, Tiwari MK, Gupta RK, Garg SC. **2004**. Residue burning in rice-wheat cropping system: Causes and implications. *Current Science*, 87(12):1713-1717.
8. Pathak H, Saharawat YS, Gathala M and Ladha JK. 2011. Impact of resource-conserving technologies on productivity and greenhouse gas emissions in the rice-wheat system. Greenhouse Gases, Sc Tech 1 (3): 261–277.
9. Sidhu HS, Singh M, Humphreys E, Singh Y, Singh B, Dhillon SS, Blackwell J, Bector V, Singh M and Singh S. 2007. The Happy Seeder enables direct drilling of wheat into rice stubble, Aust J Exp Agric 47: 844–854.
10. Hays MD, Fine PM, Geron CD, Kleeman MJ, Gullett BK. **2005**. Open burning of agricultural biomass; physical and chemical properties of particle-phase emissions. *Atmospheric environment*, 39:6747-6764.
11. Khalid U, Ahmad KE, Niamatullah K, Abdur R, Fazal Y and Saleem UD. 2014. Response of wheat to tillage plus rice residue and nitrogen management in rice-wheat system. *Journal of Integrative Agriculture*, *13*(11): 2389-2398.
12. Kouyaté Z, Franzluebbers K, Juo AS and Hossner LR. 2000. Tillage, crop residue, legume rotation, and green manure effects on sorghum and millet yields in the semiarid tropics of Mali. Plant and soil, 225: 141-151.
13. Kumar R and Sangeet. 2016. Crop residue generation and management in Punjab state, Indian J Econ Dev 12 (1a) (2016) 477–483.
14. Kumar P, Kumar S and Joshi L. **2015**. Socioeconomic and environmental implications of agricultural residue burning: A case study of Punjab, India. *Springer Nature*, 144.
15. Lal R, 2005. World Crop Residues Production and Implications of Its Use as a Biofuel. *Environ. Int.* **2005**, 31, 575-584.
16. Lori A, Biederman W and Stanley H. 2013. Biochar and its effects on plant productivity and nutrient cycling: a meta-analysis. Global Change Biology Bioenergy 5(2): 202-214.
17. Choudhary M, Dhanda S, Kapoor S and Soni G. 2009. Lignocellulolytic enzyme activities and substrate degradation by Volvariella volvacea, the paddy straw mushroom/Chinese mushroom. Indian Journal of Agricultural Research, 43(3): 223-226.
18. Jat ML, Saharawat YS and Gupta R. 2011. Conservation agriculture in cereal systems of South Asia: nutrient management perspectives, Karnataka J Agric Sci 24 (2011) 100–105.

19. Mittal SK, Susheel K, Singh N, Agarwal R, Awasthi A and Gupta PK. **2009**. Ambient air quality during wheat and rice crop stubble burning episodes in Patiala. *Atmospheric environment*, 43:238-244.
20. Jain N, Pathak H and Bhatia A. 2014. Sustainable management of crop residues in India, Curr Adv Agric Sci 6 (**2014**) 1–9.
21. Nandan R, Singh V, Kumar V, Singh SS, Hazra KK, Nath CP and Poonia SP. 2020. Viable weed seed density and diversity in soil and crop productivity under conservation agriculture practices in rice-based cropping systems. Crop Protection, 136, 105210.
22. Nannipieri, P. 1994. The potential use of soil enzymes as indicators of productivity, sustainability and pollution. *Soil biota: management in sustainable farming systems.*, 238-244.
23. NITI Aayog. India. 2015. Available online: https://www.niti.gov.in/sites/default/files/2019-03/EOI_on_the_Topic_of_A_Researsh_Study_on_Mass_Production_of_Manure_Fertilizer_form_Agriculture_Bio-Mass.pdf (accessed on 20 November 2022).
24. Roy P and Kaur M. 2016. Economic analysis of selected paddy straw management techniques in Punjab and West Bengal, Indian J Econ Dev (12) (2016) 467–471, [1a].
25. Pathak H, Bhatia A, Jain N and Aggarwal PK. **2010**. Greenhouse gas emission and mitigation in Indian agriculture-A review. *ING Bulletins on Regional Assessment of Reactive Nitrogen, Bulletin*, 19:1-34.
26. Sakhiya AK, Anand A and Kaushal P. 2020. Production, activation and applications of biochar in recent times. Biochar 2(3): 253-285.
27. Setter C, Silva FTM, Assis MR, Ataíde CH, Trugilho PF, Oliveira TJP. 2020. Slow pyrolysis of coffee husk briquettes: Characterization of the solid and liquid fractions. Fuel, 261:116420.
28. Shafi M, Bakht J, Jan MT and Shah Z. 2007. Soil C and N dynamics and maize (Zea may L.) yield as affected by cropping systems and residue management in North-western Pakistan. Soil and Tillage Research, 94(2), 520-529.
29. Shaver T. 2010. Crop Residue and Soil Physical Properties. Proceedings of the 22nd Annual Central Plains Irrigation Conference, Kearney, NE, 2010.
30. Sidhu B S and Beri V. 1989. Effect of crop residue management on yields of different crops and soil properties. Biol Wastes 27:15-27.
31. Sidhu HS, Humphreys E, Dhillon SS, Blackwell J and Bector V. 2007. The Happy Seeder enables direct drilling of wheat into rice stubble. *Australian Journal of Experimental Agriculture*, *47*(7), 844-854.
32. Singh G, Jalota S K and Singh Y. 2007. Manuring and residue management effects on physical properties of a soil under the rice-wheat system in Punjab, India. Soil Till Res. 94:229-38.
33. Singh Y, Humphreys E, Kukal SS, Singh B, Kaur A, Thaman S and Gajri PR. 2009. Crop performance in permanent raised bed rice–wheat cropping system in Punjab, India. Field Crops Research, 110(1), 1-20.
34. Singh A, Kang JS, Kaur M and Goel A. 2013. Root parameters, weeds, economics and productivity of wheat (Triticum aestivum L.) as affected by methods of planting in-situ paddy straw. *International Journal of Current Microbiology and Applied Science*, *2*(10), 396-405.
35. Singh A and Kaur J. 2012. Impact of conservation tillage on soil properties in rice wheat cropping system. Agric. Sci. Res. J. 2012, 2, 30–41.

36. Singh BP, Cowie AL, Smernik RJ. 2012. Biochar carbon stability in a clayey soil as a function of feedstock and pyrolysis temperature. Environmental Science and Technology 46(21):11770-11778.
37. Singh VK, Dwivedi BS, Singh SK, Mishra RP, Shukla AK, Rathore SS and Jat ML. 2018. Effect of tillage and crop establishment, residue management and K fertilization on yield, K use efficiency and apparent K balance under rice-maize system in north-western India. *Field Crops Research, 224,* 1-12.
38. Teasdale JR and Mohler C.1993. Light transmittance, soil temperature, and soil moisture under residue of hairy vetch and rye. Agron. J. 85, 673–680.
39. Beri V, Sidhu BS, Bhat AK and Singh BP. 1992. Nutrient balance and soil properties as affected by management of crop residues, in: M.S. Bajwaet, et al. (Eds.), Nutrient Management for Sustained Productivity. Proceedings of International Symposium, vol. II, Department of Soil, Punjab Agricultural University, Ludhiana, India, **1992**, pp. 133–135.
40. Villamil MB, Little J and Nafziger ED. 2015. Corn residue, tillage, and nitrogen rate effects on soil properties. Soil Till Res. 151:61-66.
41. Wang M, Wu M and Huo H. 2007. Life-cycle energy and greenhouse gas emission impacts of different corn ethanol plant types. Environmental Research Letters, 2(2):024001.
42. Werther J, Saenger M, Hartge EU, Ogada T and Siagi Z. 2000. combustion of agricultural residues. Progress in energy and combustion science, 26(1):1-27.
43. Wilhelm WW, Doran JW and Power JF. 1986. Corn and soybean yield response to crop residue management under no-tillage production systems. Agron J. 78:184-89.
44. Wyman CE. **1999**. Biomass ethanol: technical progress, opportunities, and commercial challenges. Annual review of energy and the environment, 24(1):189-226.
45. Yat SC, Berger A and Shonnard DR. **2008**. Kinetic characterization for dilute sulfuric acid hydrolysis of timber varieties and switch grass. Bio resource technology, 99(9):3855-3863.
46. Yuan L, Zhang Z, Cao X, Zhu S, Zhang X and Wu L. 2014. Responses of rice production, milled rice quality and soil properties to various nitrogen inputs and rice straw incorporation under continuous plastic film mulching cultivation. Field Crops Research, 155, 164-171.
47. Zamir MSI, Ahmad AH and Nadeem MA. Behavior of various wheat cultivars at tillage in Sub-tropical conditions. *Cerc. Agron. Moldov.* **2010**, *4*, 13–19.
48. Zhang H, Hu D, Chen J, Ye X, Wang SX, Hao J, Wang L, Zhang R and Zhi A. **2011**. Particle Size Distribution and Polycyclic Aromatic Hydrocarbons emissions from Agricultural Crop Residue Burning. *Environmental Science and Technology*, 45:5477-5482.
49. Zhang J and Wu L.-F. 2021. Impact of tillage and crop residue management on the weed community and wheat yield in a wheat–maize double cropping system. Agriculture 2021, 11, 265.