Website : www.asthafoundation.in
Progressive Research : An International Journal
Vol 17 (1) : 1-7 (January-2022), Print ISSN : 0973-6417, Online ISSN : 2454-6003
Society for Scientific Development in Agriculture and Technology, Meerut (U.P.) India

Management of Crop Residues and its implications—An Overview

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Abstract

The amount of surplus crop residue available in India is about 141 million tons a year, out of which 92 mt is burned each year. The two crops as rice and wheat are produced large amount of residues in India. Processing of agricultural produce through milling and packaging also produces substantial amount of residues. Crop residues are natural resources with tremendous value to farmers. These residues are used as animal feed, composting, thatching for rural homes and fuel for domestic and industrial use. About 25% of nitrogen, 25% phosphorus, 50% of sulphur and 75% of potassium uptake by cereal crops are retained in residues, making them valuable sources of nutrients. However, a large portion of the residues, about 141 Mt, is burned in field primarily to clear the field from straw and stubble after the harvest of the preceding crop. The problem is severe in irrigated agriculture, particularly in the mechanized rice-wheat system. The main reasons for burning crop residues in field include unavailability of labour, high cost in removing the residues and use of combines in rice-wheat cropping system especially in the Indo-Gangetic plains (IGP). Primary crop types whose residues are typically burned include rice, wheat, cotton, maize, millet, sugarcane, jute, rapeseed-mustard and groundnut. Farmers in northwest India dispose a large part of rice straw by burning *in situ*.

Key words : *Crop Residues, soil properties, greenhouse gases.*

Introduction

Burning of crop residues leads to release of soot particles and smoke causing human health problems; emission of greenhouse gases such as carbon dioxide, methane and nitrous oxide causing global warming; loss of plant nutrients such as N, P, K and S; and adverse impacts on soil properties. There are several options which can be practiced such as composting, generation of energy, production of biofuel and recycling in soil to manage the residues in a productive manner. Conservation agriculture (CA) offers a good promise in using these residues for improving soil health, increasing productivity, reducing pollution and enhancing sustainability and resilience of agriculture. The resource conserving technologies (RCTs) involving no or minimum - tillage, direct seeding, bed planting and crop diversification with innovations in residue management are possible alternatives to the conventional energy and input intensive agriculture. Various aspects of scientific management of crop residues in the present scenario for context of conservation agriculture. We would focus on the quantity of crop residues available in the country, extent of burning of residues in field and their environmental impacts, identification of possible options for safe and sustainable management of crop residues, assessing their adoption potential and finally developing a policy paper on sustainable management of crop residues. The following questions will raise and explained one by one :

How much crop residues are generated in Indian agriculture?

On an average 500 Mt of crop residue is generated yearly in India. While a majority of it is used for fodder, raw material for energy production, etc., still there is a huge surplus of 140 Mt out of which 92 Mt is burnt each year, mainly in the northern states such as Punjab, Haryana and Uttar Pradesh. Traditionally crop residues have numerous competing uses such as animal feed, fodder, fuel, roof thatching, packaging and composting. Cereal residues are mainly used as cattle feed. Rice straw and husk is used as domestic fuel or in boilers for parboiling rice in states like West Bengal. The uses for various residues are different in different states. Farmers use residue either themselves or sell it to other landless households or intermediaries, who in turn sell the residues to industries. The remaining residues are left unused or burned in field. In states like Punjab and Haryana where rice residues are not used as cattle feed, large amount rice straw is burned in field. Sugarcane tops in most of the areas is either used for feeding of dairy animals or burned in field for ratoon crop. Residues of groundnut are burned as fuel in brick kilns and lime kilns. Cotton, chilli, pulses and oilseeds residues are mainly used as fuel for household needs. Coconut shell, stalks of rapeseed and mustard, pigeon pea, jute and mesta and sun flower are used as domestic fuel. Coconut generates about 3 Mt of husk annually and

Received : November-2021; Revised : November-2021; Accepted : December-2021

about 1.2 Mt is utilized for making coir and 1 Mt burned as fuel (Thimmegowda P. 2021 and Ujjawal *et al.,* 2021).

The surplus residues i.e., total residues generated fewer residues used for various purposes, are typically burned in the field or used to meet household energy needs by farmers. Estimated total crop residue surplus in India is 84-141 Mt yr^{-1} where cereals and fibre crops contribute 58% and 23%, respectively. Remaining 19% is from sugarcane, pulses, oilseeds and other crops. Out of 82 Mt surplus residues from the cereal crops, 44 Mt is from rice followed by 24.5 Mt of wheat which is mostly burned in fields (Table-1). In case of fibre crops (33 Mt of surplus residue) approximately 80% is cotton residue that is subjected to burning.

In some countries crop residues are used as a source of energy, animal feed, composting mushroom cultivation or even burned in field (Table-2). In China 37% of crop residues are directly combusted by farmers, 23% used for forage, 21% discarded or directly burnt in the field, 15% lost during collection, 4% for industry materials and 0.5% for biogas (Liu et al., 2008). Thus burning of crop residues in the field is a major problem in China as well.

What is the extent of crop residue burning?

India, the second largest agro-based economy with year-round crop cultivation, generates a large amount of agricultural waste, including crop residues. In the absence of adequate sustainable management practices, approximately 92 seems a very small number of metric tons of crop waste is burned every year in India, causing excessive particulate matter emissions and air pollution. Crop residue burning has become a major environmental problem causing health issues as well as contributing to global warming. Composting, biochar production and mechanization are a few effective sustainable techniques that can help to curtail the issue while retaining the nutrients present in the crop residue in the soil. The government of India has attempted to curtail this problem, through numerous measures and campaigns designed to promote sustainable management methods such as converting crop residue into energy. However, the alarming rise of air pollution levels caused by crop residue burning in the city of Delhi and other northern areas in India observed in recent years, especially in and after the year of 2015, suggest that the issues is not yet under control. The solution to crop residue burning lies in the effective implementation of sustainable management practices with Government interventions and policies. This manuscript addresses the underlying technical as well as policy issues that have prevented India from achieving a long-lasting solution and also potential solutions that have been overlooked. However, effective implementation of these techniques also requires us to look at other socioeconomic aspects that had not been considered. This manuscript also discusses some of the policy considerations and functionality based on the analyses and current practices. The agricultural waste sector can benefit immensely from some of the examples from other waste sectors such as the municipal solid waste (MSW) and wastewater management where collection, segregation, recycling and disposal are institutionalized to secure an operational system. Active stakeholder involvement including education and empowerment of farmers along with technical solutions and product manufacturing can also assist tremendously. Even though the issue of crop residue burning touches many sectors, such as environment, agriculture, economy, social aspects, education, and energy, the past governmental efforts mainly revolved around agriculture and energy. This sectorial thinking is another barrier that needs to be broken. The government of India as well as governments of other developing countries can benefit from the emerging concept of nexus thinking in managing environmental resources. Nexus thinking promotes a higher-level integration and higher level of stakeholder involvement that goes beyond the disciplinary boundaries, providing a supporting platform to solve issues such as crop residue burning (Bhuvneswari *et. al.,* 2019).

Why do farmers burn the residues in field?

Crop residues are primarily used as bedding material for animals, livestock feed, soil mulching, bio-gas generation, bio-manure/compost, thatching for rural homes, mushroom cultivation, biomass energy production, fuel for domestic and industrial use, etc. However, a large portion of crop residue is burnt 'on-farm' primarily to clean the field for sowing the next crop. The problem of 'on-farm' burning of crop residues is intensifying in recent years due to shortage of human labour, high cost of removing the crop residue from the field and mechanized harvesting of crops. As per available estimates, burning of crop residues is predominant in four states, namely, Haryana, Punjab, Uttar Pradesh & West Bengal (MNRE, 2009).

What are the negative consequences of crop residue burning?

Loss of nutrient : In addition to loss of entire amount of C, 80% of N, 25% of P, 50% of S and 20% of K present in straw is lost due to burning, it also pollutes the atmosphere. If the crop residues are incorporated or retained, the soil will be enriched, particularly with organic carbon and N. Mendal *et al.* studied that the burning of rice and wheat residues contributes to a loss of about 80% of nitrogen, 25% of phosphorus, 21% of Potassium and 4-60% of soil sulphur, although it does destroy unwanted bugs and diseases borne by the soil.

Table-1 : Generation and surplus of crop residues (Mt/Yr) in various states of India.

States	Residue generation (MNRE, 2009)	Residue surplus (MNRE, 2009)	Residue burned (IPCC coeff.)	Residue burned (Pathak et al. 2010)
Andhra Pradesh	43.89	6.96	5.73	2.73
Arunachal Pradesh	0.4	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	6.69	3.81
Haryana	27.83	11.22	5.45	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	2.85	5.66
Kerala	9.74	5.07	0.40	0.22
Madhya Pradesh	33.18	10.22	3.46	1.91
Maharashtra	46.45	14.67	6.27	7.41
Manipur	0.9	0.11	0.14	0.07
Meghalaya	0.51	0.09	0.10	0.05
Mizoram	0.06	0.01	0.01	0.01
Nagaland	0.49	0.09	0.11	0.08
Orissa	20.07	3.68	2.57	1.34
Punjab	50.75	24.83	8.94	19.62
Rajasthan	29.32	8.52	3.58	1.78
Sikkim	0.15	0.02	0.01	0.01
Tamil Nadu	19.93	7.05	3.55	4.08
Tripura	0.04	0.02	0.22	0.11
Uttarakhand	2.86	0.63	13.34	21.92
Uttar Pradesh	59.97	13.53	0.58	0.78
West Bengal	35.93	4.29	10.82	4.96
India	501.76	140.84	83.66	92.81

Impact on soil properties : Heat from burning residues elevates soil temperature causing death of bacterial and fungal populations. However, the death is temporary as the microbes regenerate after few days. Repeated burning in the field, however, permanently diminishes the microbial population. Burning immediately increases the exchangeable NH_4^+-N and bicarbonate extractable P content but there is no build up of nutrients in the profile. Long-term burning reduces total N and C and potentially mineralized N in the 0-15 cm soil layer.

Emission of greenhouse gases : Burning of residues emits a significant amount GHGs. For example, 70, 7 and 0.66% of C present in rice straw is emitted as CO_2, CO and CH_4, respectively, while 2.09% of N in straw is emitted as N_2O upon burning.

Emission of other gases and aerosol : Burning of agricultural residues, represent a significant source of chemically and radiatively important trace gases and aerosols such as CH_4, CO, N_2O, NO_X and other hydrocarbons to the atmosphere affecting the atmospheric composition. It also emits large amount of particulates that are composed of wide variety of organic and inorganic species. One ton straw on burning releases 3 kg particulate matter, 60 kg CO, 1460 kg CO_2, 199 kg ash and 2 kg SO_2 (Walia, 1995). This change in composition of the atmosphere may have a direct or indirect effect on the radiation balance. Besides other light hydrocarbons, volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs) including polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs) and SOx, NOx are also emitted. These gases are important for their global impact and may lead to a regional increase in the levels of aerosols, acid deposition, increase in tropospheric ozone and depletion of the stratospheric ozone layer. They may subsequently undergo trans-boundary migration depending upon the wind speed/direction, reactions with oxidants like OH^- leading to physico-chemical transformation and wash out by precipitation. Many of the pollutants found in large quantities in biomass smoke are known or suspected carcinogens and could be a major cause of concern leading to various air borne/lung diseases.

Table-2 : Mode of crop residue management in other countries.

Mode of utilization	Country
Source of energy	Indonesia , Nepal, Thailand, Malaysia, Philippines, Indonesia, Nigeria
Composting	Philippines, Israel, China
Animal feed	Lebanon, Pakistan, Syria, Iraq, Israel, Tanzania, China, Africa
Mushroon cultivation	Vietnam
Burning	China, USA, Philippines, Indonesia

What are the technologies available to manage crop residue management?

There are several options which can be practiced to manage residues in productive manner. Besides use as cattle feed, large amount of residues can be used for preparation of compost, generation of energy and production of biofuel and mushroom cultivation.

Composting of residues for manure : The residues can be composted by using it as animal bedding and then heaping in dung pit. Each kg of straw absorbs about 2-3 kg of urine from the animal shed. It can also be composted by alternative methods on the farm itself. The residues of rice from one hectare give about 3.2 tons of manure as rich in nutrients as farmyard manure (FYM).

Energy from crop residues : Biomass can be efficiently utilised as a source of energy and is of interest worldwide because of its environmental advantages. During recent years, there has been an increase in the usage of crop residue for energy production and as substitute for fossil fuels. It also offers an immediate solution for the reduction of CO_2 content in the atmosphere. In comparison with the other renewable energy resources such as solar and wind energy, biomass is a storable resource, inexpensive, energy efficient and environment friendly. However, straw is characterized by low bulk-density and low energy yield per weight basis. The logistics of transporting the large volumes of straw required for efficient energy generation represents a major cost factor irrespective of the bio-energy technology. Availability of residues, transport cost and infra-structural settings (harvest machinery, modes of collection, etc.) are some of the driving factors of using residues for energy generation (Poricha *et al,* 2021).

Ethanol from crop residues : The conversion of ligno-cellulosic biomass into bio-based alcohol production is of immense importance and is a researchable issue as ethanol can be either blended with gasoline as a fuel extender and octane-enhancing agent or used as a neat fuel in internal combustion engines. The theoretical estimates of ethanol production from different feedstock (corn grain, rice straw, wheat straw, bagasse and saw dust) varies from 382 to 471 L t^{-1} of dry matter.

Biomethanation : Biomass such as rice straw can be converted to biogas, a mixture of carbon dioxide and methane and used as fuel. It is reported that biogas of 300 m^3 t^{-1} of dry rice straw can be obtained. The process yields good quality of gas with 55-60% of methane and the spent slurry can be used as manure. This process promises a method to utilize crop residues in a non-destructive way to extract high quality fuel gas and produce manure to be recycled in soil.

Gasification of residues : Gasification is a thermo-chemical process in which gas is formed due to partial combustion of residues. The process breaks down biomass completely to yield energy rich gaseous products after initial pyrolysis. The main problem in biomass gasification for power generation is the cleaning of gas so that impurities are removed. The residues can be used in the gasifiers for the generation of producer gas. In some states gasifiers with more than 1MW capacity has been installed for generation of producer gas which is fed to the engines coupled to the alternators for electricity generation. One ton of biomass can be used for generation of 300 kWh of electricity.

Fast pyrolysis : Fast pyrolysis of crop residues requires the temperature of biomass to be raised to 400-500 ^oC within few seconds. This results in a remarkable change in the thermal disintegration process. About 75% of dry weight of biomass is converted into condensable vapours. If the condensate cools quickly within a couple of seconds, it yields a dark brown viscous liquid commonly called bio-oil. The calorific value of bio-oil varies 16-20 MJ kg^{-1}.

Biochar : Biochar is high carbon material produced from the slow pyrolysis (heating in the absence of oxygen) of biomass. It has got advantages in terms of its efficiency as an energy source, its use as a fertilizer when mixed with soil, its ability to stabilize as well as reduce emissions of harmful gases in the atmosphere. Biochar finds use in the release of energy-rich gases which are then used for producing liquid fuels or directly for power and/or heat generation. It can potentially play a major role in the long-term storage of carbon. Biochar increases the fertility, water retention capability of the soil as well as increasing the rate of mineral delivery to roots of the plants.

How can conservation agriculture help in crop residues management?

Conservation agriculture is a viable option for sustainable agriculture. Worldwide about 105 Mha land is under CA and the area is increasing. However the USA, Brazil, Argentina, Canada and Australia occupy about 90% of the area under CA. Permanent crop cover with recycling of crop residues is a prerequisite and integral part of CA, which is advocated as alternative to the conventional production system for improving productivity and sustainability. Recent estimates revealed that CA based resource conserving technologies (RCTs) that include laser assisted precision land levelling, zero/reduced tillage, direct drilling into the residues, direct seeded rice, unpuddled mechanical transplanted rice, raised bed planting and diversification/intensification are being practiced over nearly 3.9 Mha of South Asia. The RCTs with innovations in residue management avoid straw burning, improve soil organic C, are input efficient and have potential to reduce GHG emissions.

New variants of zero-till seed-cum-fertilizer drill/planters such as Happy Seeder, Turbo Seeder and rotary-disc drill have been developed for direct drilling of seeds in presence of surface residue (loose and anchored up to 10 t ha^{-1}). These machines are very useful for managing crop residues for conserving moisture and nutrients and controlling weeds as well as moderating soil temperature.

What are issues in managing crop residues in conservation agriculture?

A series of challenges exist with higher residue levels in Conservation Agriculture (CA). These include different disease, insect or weed problems and difficulties with more residues on the surface to proper seed, fertilizer and pesticide placement. Conservation tillage practices, with their higher levels of crop residue, usually require more attention, timing, placement of nutrients and pesticides and tillage operations. Nutrient management may become complex because of higher residue levels and reduced options with regard to method and timing of nutrient applications. No-till in particular can complicate manure application and may also contribute to nutrient stratification within soil profile from repeated surface applications without any mechanical incorporation.

Major bottlenecks in the current technology that needs attention are placement of seed at proper depth to facilitate germination in the no-tilled plots with residue retained on the soil surface is still a problem. Although a lot of improvement has been done in the zero-till seed-cum-fertilizer drill machinery, but there is still a lot of scope for further improvement to give farmers a hassle free technology. Weed control is the other bottle-neck especially in rice-wheat system. Excessive use of chemical herbicides may not be desirable keeping in view their leakage to the environment. Applying all the fertilizers, especially N, as basal dose at the time of seeding, may result a loss in its efficiency, and cause environmental pollution.

With higher residue levels, however, evaporation is reduced and more water is maintained near the surface, which favours the growth of feeder roots near the surface where the nutrients are concentrated. In some instances, increased application of specific nutrients may be necessary and specialized equipment required for proper fertilizer placement, thereby contributing to higher costs. Similarly, increased use of herbicides may become necessary for adopting CA. The countries that use relatively higher amount of herbicides are already facing problem of non-point source of pollution and environmental hazard. Further limiting factor in adoption of residue incorporation systems by farmers include additional management skill requirements, apprehension of lower crop yields and/or economic returns, negative attitudes or perceptions, and institutional constraints. Farmers or sometime the whole communities demonstrate strong preferences for clean tilled fields. Culturally, they take pride in having their fields “clean” of residue and intensively tilled to obtain a smooth surface in preparation for planting.

What are the research needs?

Management of crop residues in conservation agriculture is vital for long-term sustainability of Indian agriculture. Burning of residues must be stopped and should be used positively for CA for improving soil health and reducing environment pollution. Even in regions where crop residues are used for animal feed and other useful purposes, some amount of residues must be recycled to soil. Several technologies are available; they require improvement for adoption by resource poor, low skilled farmers. For example, Happy Seeder seems to be one of the potential technologies for managing residues. To facilitate adoption of the Happy Seeder, farmers need clear guidelines for optimum irrigation, fertilizer management of wheat, long-term effects of straw mulch on soil quality. The scientists need to quantify the benefits of CA-based practices under different situations over short- and long-term in terms of economic, social and environmental benefits. These can then form a basis for policy level issues in relation to C-sequestration, erosion control, fertilizer use efficiency, incentives to retain residues etc. Some of the areas where research activities could be taken up include the following.

Generation and utilization of crop residues

Developing inventory of amount of residues generated in different crops in different regions of the country.

Identifying the major uses of crop residues and comparative assessment of their competing uses.

Use of satellite imageries could be the best way to estimate the amount of residues burnt in the field.

Quantifying the permissible amount of residues of different crops which can be incorporated / retained depending on cropping systems, soil, and climate without creating operational problems for the next crop or chemical and biological imbalance.

Analysing the benefit: cost ratio and socio-economic impacts of residue retention/incorporation in CA vis-à-vis residue burning for both short and long-term time scale.

Assessing the quality of crop residues and their suitability for various purposes.

Water, nutrient and pest management in CA

Assessing the suitability of residue retention/ incorporation in different soil and climatic situations.

Scheduling irrigation in CA fields (1) with anchored residues, (2) with surface carpet of residues and (3) no residues.

Developing fertilizer management recommendations in CA and developing soil test method designed for CA.

Assessing the role of legume residues in sustaining/maintaining C:N:P:S ratios in soil organic matter.

Developing complete package of practices of CA for prominent cropping system in each agro-ecological region.

Designing long-term trials for evaluating impacts of CA on crop yield and soil quality.

Reducing use of herbicide and other chemicals in CA to minimize cost of production and environmental pollution.

Machinery for Conservation Agriculture

Development of appropriate farm machinery to facilitate the application of residues, and successful planting of a crop in the rotation under a layer of residues on soil surface.

Modifying combine harvester to collect and remove residues from field.

Large volume and transport is a major bottleneck in using the residues where those are required. Machinery for volume reduction would facilitate the process of residue use for CA.

Basic and strategic research for Conservation Agriculture

Developing crop varieties to produce more root biomass to improve the natural resource base.

Developing simulation modelling tools for tillage dynamics, root growth, soil properties, yield and income in CA for prediction and extrapolation.

Enhancing decomposition rate of residues for *in-situ* incorporation.

Designing new generation of long-term experiments to study the impacts CA on soil health, water and nutrient use efficiency, C sequestration, GHG emissions and ecosystem services.

Complete life cycle analysis of residue retention and CA vis-a-vis residue burning other uses of agricultural residues.

What is the current policy, if any of crop residue management in India? And What action are to be taken to make the policies effective?

The CA is a set of principles towards sustainable production systems. These principles of CA need to be translated into practices based on site-specific requirements. The way to go about is to start working with selected farmers in varying situations with the knowledge embedded in CA principles and see what and how much can be achieved and what is needed to make CA a success. The principle of 'recycling the crop residue where it is generated' should be the basic point.

Laws and legislation

Monitoring and discouraging burning of crop residues through incentive and punishment. Legislation on prevention of on-field burning of the crop residues. Legislation may impose restrictions on straw burning and may greatly facilitate large scale adoption of this conservation agriculture practice.

Supplying machineries for CA on subsidized rates and promoting custom hiring systems for agricultural implements. Providing soft loans for purchase of implements and adoption of CA.

Introduction of C-credit to the farmers who follow CA for carbon sequestration and GHG mitigation.

Crop residues should be classified as amendments (like lime or gypsum) and their use in agriculture should attract subsidy like any other mineral fertilizers or amendments. This would stimulate the use of crop residues in various production systems to improve soil health.

The subsidy on the use of crop residues should be based on their application to the soil as an amendment in a group action to improve soil health and conserve environment.

Capacity building and awareness creation

Capacity building through training and teaching in under- and post-graduate levels and also through training of farmers to use residue conservation practices and facilitate technology transfer.

Establishing self-help groups and encouraging unemployed youth to take up custom hiring of CA machineries as profession.

The CA component should be included in soil health card for proper monitoring of crop residue retention/burning.

Familiarization of CA technologies at each KVK and state agricultural departments–awareness and dissemination of these technologies at block level through demonstration.

Govt. aided projects to attract villagers to follow such options. Such projects can be proposed under CDM and the money thus generated can be utilized for development of the community.

Development activities

Each university, research institutes and NGOs committed to sustainable development should start working with some selected farmers in varying situations with the knowledge embedded in CA principles and observe what and how much can be achieved and what is needed to make CA a success. This experience should be used for improving the CA-technology and removing the constraints.

The emphasis should be on recycling of any form of wastes in addition to crop residues. As the availability of such organic resources is site-specific, an inventory should be made of the potentially available materials for use in the target regions in a systematic way. Approximate composition of various residues/wastes would further help to target a proper use of these resources.

Where crop residues have competing uses as fodder or fuel, recycling should be encouraged of the end product (dung, slurry, ash).

In some instances, the use of residues including weeds and other organic resources could be used for preparing manure, enriched manure or vermi-compost whatever is appropriate at a site depending on the nature of the waste and residues.

The use of residues/wastes to add organic matter in an appropriate form should be an integral part of the production systems.

Conclusions

Considering the detrimental influence of lack of proper management practice, the Indian Government should advise farmer on alternative solutions to open field burning of crop residues. In fact, none of the alternatives methods to open burning are perfect, but it is still noteworthy to implement them in a proper way considering geographic location, transportation, economic feasibility, etc. The residues are of great economic value as livestock feed, fuel and industrial raw material. However, problems with the crop residues are different in different region and associated with the socio-economic needs. Thus the policy in north India may not work in eastern India. In northern India, wheat straw whereas in east and south India rice straw are the major feed for livestock. The residues can be put to various uses and is possible if residue is collected and managed properly. The surplus residues must be used for CA, for which it is a prerequisite. There is a need to create awareness among the farming communities about the importance of crop residues in CA for sustainability and resilience of Indian agriculture.

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