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Review

Improving use of crop residues in India

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ABSTRACT

Agriculture is facing many challenges all over the world and to achieve the sustainability goals of United Nations, it must meet the needs of present and future generations while ensuring profitability, healthy environment and social and economic equity. Agriculture is the backbone of Indian economy. About 52 per cent of Indian population depends directly on agriculture and it accounts for around 18.1 per cent of GDP. With increasing production, a large amount of crop residue is produced which if unsustainably managed leads to loss of a resource that otherwise can be gainfully used. That is why it is said that crop residue is not a liability but an asset. In this context, it is felt that there is an increased need for sustainable use of crop residue more than ever. Hence this review article aims at exploring the improving use of crop residues of major crops in India. Many new technical and policy options for diversified use of crop residue such as central sector schemes, zero tillage, development and promotion of appropriate crop machinery, crop diversification, bio-energy promotion etc have been discussed in the article. It also highlights the recurring problem of crop residue burning which has got the attention of one and all in the northwestern parts of India. It is felt that the farmers must be convinced and motivated to manage their crop residue in the best possible way for which they must be empowered by the government.

Keywords: Crop diversification; crop residue; happy seeder; zero tillage

INTRODUCTION

Agriculture is facing many challenges all over the world from an increasing demand for food due to growing population, adverse global warming effects, overuse of natural resources, loss of biodiversity etc. To achieve the sustainability goals of United Nations, agriculture must meet the needs of present and future generations, while ensuring profitability, environmental health and social and economic equity (http://www.fao.org/sustainability/background/en/). Agriculture is the backbone of Indian economy because of its high share in employment and livelihood opportunities. About 52 per cent of Indian population depends directly on agriculture and it accounts for around 18.1 per cent of GDP (Anon 2018a). With an increasing production, a large amount of crop residue is produced which if unsustainably managed leads to loss of a resource which otherwise can be meaningfully used. In this context, it is felt that there is an increased need for optimum use of crop residue more than ever for economic growth and environmental sustainability.

Crop residues are the biomass left in the field after harvesting of the economic components ie grain (Sarkar et al 2020). Plant material which remains in the field after harvesting including leaves, stalks, roots, husk etc has economic and ecological value and has been used by the farmers in variety of ways. Its unsustainable management practices like burning of the residue has shown adverse environmental impacts on soil, air and water and has led to massive air pollution in northern India during the starting of winter every year. It is only in the last decade that sustainable management of crop residue has received some serious attention in India. This review article aims at exploring the current practices of crop residue management in India. It also highlights the recurring problem of crop residue burning which has got the attention of one and all in the northwestern parts of India. Identifying both

environmentally sustainable and economically viable measures is the need of the hour.

Variations in the generation of crop residues in India

Depending on the types of the crops grown, there are spatial variations in crop residues generated in the different regions of the country. With an increased production of crops (Table 1), the residue is bound to increase which requires its optimum management.

Category-wise cereals account for the maximum residue generation of 58 per cent, sugarcane 17 per cent, oil seeds 5 per cent and fibres 20 per cent. Amongst cereal crops rice, wheat, maize and millets contribute 53, 33, 7 and 7 per cent respectively of crop residue. Further cereal residue generation is the highest in Uttar Pradesh (72 MT) followed by Punjab (46 MT), West Bengal (37 MT), Andhra Pradesh (33 MT) and Haryana (25 MT). Residues from fibre crop are dominant in Gujarat (29 MT) followed by Maharashtra (19.51 MT). Rajasthan and Gujarat generate about 9 and 5 MT each of residues from oilseed crops (Table 2). In many regions surplus crop residues are burnt on-farm. The amount of surplus crop residues available is estimated between 84 and l4l million tons per year (44.5 million tons rice straw and 24.5 million tons wheat straw) (Anon 2020).

Variations in the utilization and on-farm burning of crop residues

Crop residues are important part of any agricultural system with immense value to the farmers (Table 3). For long time, crop residues have been used as fodder, fuel for domestic and industrial use, roof thatching in rural households, packaging and composting. The residues of cereal crops are mostly fed to the cattle. Rice straw and husk are used as domestic fuel. In most sugarcane producing regions, its residue is either used to feed the animals or burned in the field. Cotton, chilli, pulses and oilseeds residues are mainly used as fuel for domestic purposes. Coconut shell, stalks of rapeseed, mustard, jute and mesta are used as household fuel (Anon 2012).

The remaining residues are left unused or burned in the field. In states like Punjab and Haryana where rice residues are not used as cattle feed, large amount of rice straw is burned in the field. The surplus residues are those which are left after all its purposeful uses by the farmers has been made and they have neither the technology nor the means to utilize it further except to choose the easiest path of burning it. Overall, India produces 686 MT gross crop residue biomass on annual basis of which 234 MT (34% of gross) is estimated as surplus for bio-energy generation (Kumar and Singh 2021).

Residue burning

The amount of crop residues that are currently being burnt as waste causes double damage– polluting our environment and eliminating a valuable material that can be used in a multiple ways (Puri 2018). Out of an amount of surplus crop residue of about 141 million tons a year in India, 92 MT is burned each year (Bimbraw 2019). The issue of paddy residue burning has gained importance due to its visible environmental impacts in Punjab, Haryana, western Uttar Pradesh and Delhi, NCR thereby making headlines every year. Burning of paddy and wheat stubble is most common in combine harvested fields because it leaves standing stubbles (25-30 cm height) in the field (Anon 2019d). The total number of combine harvesters in the India, specifically in the Indo-Gangetic Plains (IGP) has increased considerably from nearly 2,000 in 1986 to over 10,000 in 2010. Punjab, Haryana and western Uttar Pradesh have about 75 per cent of the cropped area under combine harvesting. They are also used in the central and eastern Uttar Pradesh, Uttarakhand, Bihar, Rajasthan, Madhya Pradesh and in some parts of southern India for harvesting rice and wheat crops. The main reasons for burning crop residue are to get rid of the residue, the difficulty in soil preparation, to save labour cost, to eradicate weeds and pests and to facilitate timely sowing of the next crop. Also, the time lag between the harvest of the rice crop and the sowing of the wheat in northwest India is only 15-20 days. Farmers are not motivated enough to collect the residues from the field and instead they burn it in situ. Total paddy straw produced in Haryana and Punjab together is 28.10 million tonnes (2018 estimates) out of which 11.3 million tonnes was burnt in the fields and 59.79 per cent of the straw was managed through incorporation in the soil and other measures. In Haryana, 16.9 per cent of the straw was burnt while in Punjab it was 49.47 per cent. Haryana accounts for 11.85 per cent of the straw while Punjab accounts for 88.15 per cent of the straw burnt in these two states (Anon 2021). The burning of crop residue is detrimental to the soil fertility (Table 4).

Table 1. Production of major crops (million tons) 2017-18

Wheat	Rice	Maize	Sugarcane	Cotton	Jute & Mesta	Pulses	Oilseeds
99.70	112.91	28.72	376.90	34.89	10.14	25.23	31.31

Source: Directorate of Economics & Statistic

Table 2. Crop-wise residue generated (million tons/year) in various states of India

State/UT	Cereal crops	Fibre crops	Oilseed crops	Sugarcane
Andhra Pradesh	33.07	16.07	2.50	5.80
Arunachal Pradesh	0.56	0.00	0.06	0.01
Assam	8.15	2.01	0.29	0.41
Bihar	19.87	3.27	0.20	1.87
Chhattisgarh	8.87	0.01	0.11	0.01
Goa	0.24	0.00	0.01	0.02
Gujarat	8.18	28.62	5.06	5.85
Haryana	24.73	7.58	2.15	1.93
Himachal Pradesh	1.95	0.00	0.01	0.02
Jammu & Kashmir	2.76	0.00	0.11	0.00
Jharkhand	7.34	0.00	0.09	0.13
Karnataka	11.73	3.55	0.81	8.80
Kerala	1.14	0.01	0.00	0.10
Madhya Pradesh	16.05	3.51	2.13	1.12
Maharashtra	8.75	19.51	0.57	22.87
Manipur	0.78	0.00	0.00	0.01
Meghalaya	0.44	0.13	0.01	0.00
Mizoram	0.10	0.00	0.00	0.01
Nagaland	0.89	0.01	0.06	0.07
Orissa	13.38	0.56	0.16	0.24
Punjab	45.58	9.32	0.08	1.76
Rajasthan	22.19	2.96	9.26	0.15
Sikkim	0.14	0.00	0.01	0.00
Tamil Nadu	11.69	0.78	1.56	12.37
Tripura	1.22	0.02	0.00	0.02
Uttar Pradesh	72.02	0.04	2.49	41.13
Uttarakhand	2.40	0.00	0.03	2.11
West Bengal	37.26	24.43	0.95	0.62
A&N Islands	0.04	0.00	0.00	0.00
D&N Haveli	0.05	0.00	0.00	0.00
Delhi	0.17	0.00	0.00	0.00
Daman & Diu	0.01	0.00	0.00	0.00
Puducherry	0.10	0.00	0.00	0.06
All India	361.85	122.37	28.72	107.50

Source: Jain et al (2014)

Efforts taken so far

Government of India's intervention through legislation and policy framework aimed at resolving the issues related to the management of crop residue has started yielding results. Some of the laws that are in operation pertaining to crop residue burning are the Section 144 of the Civil Procedure Code (CPC) to ban burning of paddy, the Air Prevention and Control of Pollution Act, 1981 burning of any material which is not fuel and the Environment Protection Act, 1986 prohibits any person to carry out activities that cause environmental pollution more than the prescribed national standard.

The Ministry of Agriculture, Government of India prepared a national policy for the management of crop residue in 2014. The policy emphasis is on the prevention of burning of crop residues by in situ conservation and its mixing in the soil to increase soil fertility and various other uses by adopting latest

Table 3. Residue available for 1 kg of crop

Crop	Residue name	Quantity (kg)	Major producers (2017-18)
Bajra	Cobs	0.33	Rajasthan, UP, Gujarat
	Husk	0.3	
	Stalk	2	
Barley	Stalks/straw	1.3	Rajasthan, UP, Haryana
Coconut	Fronds*	4*	Kerala, Karnataka, Tamil Nadu
	Husk & pith	0.53	
	Shell	0.22	
Cotton	Boll shell	1.1	Gujarat, Maharashtra, Telangana
	Husk	1.1	
	Stalks*	3.8*	
Groundnut	Shell	0.3	Gujarat, Rajasthan, Andhra Pradesh
	Stalks	2	
Jowar	Cobs	0.5	Maharashtra, Karnataka, MP
	Husk	0.2	
	Stalks	1.7	
Mustard	Stalks	1.8	Rajasthan, Haryana, MP
Maize	Cobs	0.3	Karnataka, Maharashtra, MP
	Stalks	2	
Oilseeds	Stalks	2	MP, Rajasthan, Gujarat
Paddy	Husk	0.2	West Bengal, Punjab and UP
	Stalks	1.5	
	Straw	1.5	
Pulses	Stalks	1.3	MP, Rajasthan, Maharashtra
Ragi	Straw	1.3	Karnataka, Tamil Nadu, Uttarakhand
Sugarcane	Bagasse	0.33	UP, Maharashtra, Karnataka
	Top & leaves	0.05	
Wheat	Pod	0.3	UP, Punjab, MP
	Stalks	1.5	

*Quantity in tons/ha; Residue data source: Biomass Resource Atlas of India; Producer states from https://agricoop.gov.in/sites/default/files/agristatglance2018.pdf

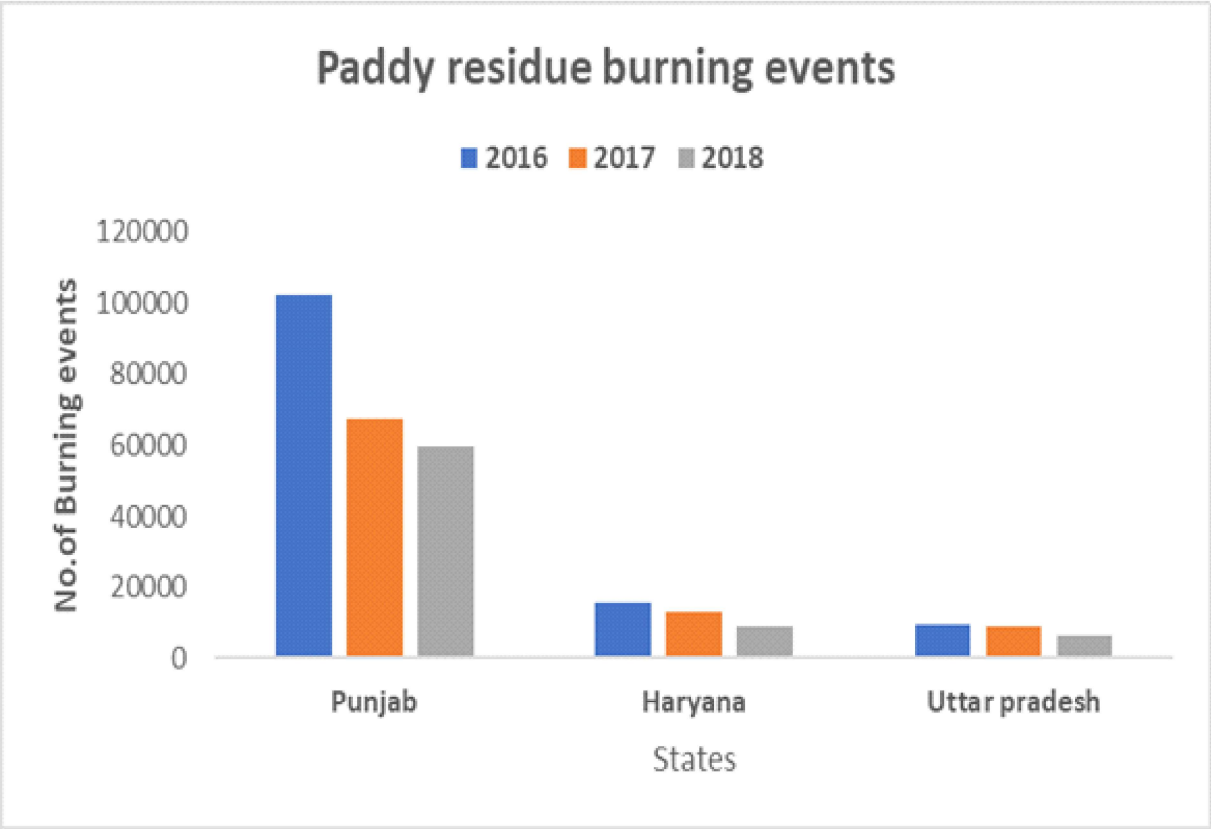
Table 4. Loss of nutrients (million tons/year) due to burning of crop residues

Crop residue	N loss	P loss	K loss	Total
Rice	0.236	0.009	0.200	0.45
Wheat	0.079	0.004	0.061	0.14
Sugarcane	0.079	0.001	0.033	0.84
Total	0.394	0.014	0.295	1.43

Source: Jain et al (2014)

technologies. The document talks about the use of satellite-based data to monitor and deduct real time crop residue burning, its management and development of cost-effective farm machinery (Datta et al 2020).

The National Green Tribunal (NGT) has laid down certain directives to the states for curbing crop residue burning through spreading awareness among the people. In 2015, the NGT banned crop residue burning in Rajasthan, Uttar Pradesh, Haryana and Punjab. These states have imposed fines in the range of Rs 2,500 to 15,000 on farmers found to burn crop residue (Chakravartty and Nasim 2015). It further advises that every state will provide machines and mechanism or its cost to the farmers to remove, collect and store residue. Various steps need to be taken by state governments and NCT, Delhi to make farmers aware through media and Gram Panchayats about the utilization of agricultural residue. During 2019-20, the Punjab government distributed Rs 19 crores among 29,343 non-basmati cultivating small



Data source: Ministry of Agriculture & Farmers Welfare

Fig 1. Residue burning events 2016-18

and marginal farmers (Rs 2,500/acre) who did not burn paddy residue as an incentive (Anon 2019a). The Conference of Indian Industries (CII) has adopted 1,00,000 acres of farm area in Punjab and Haryana to ensure zero crop residue burning by providing farm machineries, technical training and through awareness campaign. The results of its intervention are very promising clearly indicating that the problem of stubble burning can be resolved (Pandey et al 2020).

The Commission for Air Quality Management (CAQM) in the national capital region created by an ordinance promulgated on 28 October 2020 had asked Delhi and its neighbouring states to ensure the adoption and application of a standard protocol developed by Indian Space Research Organisation (ISRO) for estimation of burning of crop residue events using satellite data and to send a compliance report on the adoption of the protocol by 30 August 2021. The CAQM is responsible for executing plans to prevent and control air pollution in the Delhi-NCR region and adjoining areas (Anon 2020).

New initiatives for diversified use of crop residue

Central sector scheme: Government has taken a number of steps to persuade farmers to stop burning crop residue such as notifications banning burning of crop residue, subsidy to farmers to acquire farm machinery that could promote in situ crop residue management, use of paddy straw in power plants and other industries etc. However due to the limited impact of these measures, the Government of India in the year 2018 decided to launch a central sector scheme on the promotion of agricultural mechanization for in situ management of crop residue in the States of Punjab, Haryana, Uttar Pradesh and NCT of Delhi. The cabinet committee for economic affairs approved Rs 1,151.80 crores under this scheme (Rs 591.65 crores in 2018-19 and Rs 560.15 crores in 2019-20). As per the scheme, during 2018-19, the funds amounting to Rs 269.38, 137.84 and 148.60 crores were released to the government of Punjab, Haryana and Uttar Pradesh respectively for distribution of in situ crop residue management machinery to the farmers on subsidy, establishment of custom hiring centres (CHCs) and

undertaking information, education and communication related activities for creating awareness among farmers. The scheme made a provision for higher level of subsidy to farmers for purchasing machineries for in situ crop residue management. Subsidy of 50 per cent of the cost of machines to individual farmers and 80 per cent for cooperative societies and farmers' interest groups was considered. The entire funding for the scheme was provided by the government of India.

Through the various efforts under this scheme it is noted that paddy residue burning events in 2018 were reduced by 29.5, 24.5 and 11.0 per cent in the states of Haryana, Uttar Pradesh and Punjab respectively as compared with the paddy residue burning events in the year 2017. In 2017, KVKs of Punjab converted 25 villages as zero stubble burning villages whereas in 2018, the number of zero stubble burning villages increased to 76.

The burning events detected in Punjab were 1,02,379, 67,079 and 59,695 in the years 2016, 2017 and 2018 respectively. Haryana detected 15,686, 13,085 and 9,232 burning events in the years 2016, 2017 and 2018 respectively. In UP in the years 2016, 2017 and 2018, the burning events detected were 9,709, 8,784 and 6,636 respectively (Singh et al 2019) (Fig 1).

Zero tillage: Zero tillage (ZT) implies planting crops in previously unprepared soil. The modern concept of ZT tends to imply seeding a crop mechanically in undisturbed soil-covered plant residues (Laxmi et al 2007). Food and Agriculture Organization (FAO) of the United Nations recognizes this as a lead model for improving productivity and sustainability. ZT implies the retention of crop residues as mulch on the soil surface and its year-round application to all the crops on the field (Mandal et al 2014).

The addition of crop residues in the soil leads to an increase in the organic matter content which improves the soil health. Generally crop residues of different crops contain 80 per cent nitrogen, 25 per cent phosphorus, 50 per cent of sulphur and 20 per cent potassium (Bhuvaneshwari et al 2019). Over the past two decades, tillage has been significantly reduced across large areas used for wheat and maize production. On the Indo-Gangetic plains, wheat farmers using minimum tillage have reaped the benefits of higher grain yields. With the decreasing availability of labour and water, many farmers in irrigated rice systems are shifting to the dry-seeding of rice with zero tillage which eliminates soil puddling. Efforts to promote conservation agriculture in rice in India are drawing on new technologies.

However since only 10 per cent of the farmers owned drill seeders, most rely on service providers. Many farmers are unable to carry out dry seeding because demand for services exceeded the supply. To discourage burning off and encourage zero tillage, the governments of Punjab and Haryana states are now upscaling a new technology, the Happy Seeder which can drill wheat seed through heavy loads of rice residues.

Development and promotion of appropriate crop machinery: Development and promotion of appropriate crop machinery in farming practices have been taken up as a top priority for the sustainable development of agriculture all over the world. A very big challenge is to sow a crop in the presence of residues of preceding crop. New variants of zero till such as Happy Seeder and Turbo Seeder have been developed for direct drilling of seeds even in the presence of crop residues on the fields. The Happy Seeder or zero tillage technology cuts paddy straw, sows wheat and puts straw over the sown area ensuring that the nutrients in the soil are restored (Nandi 2019). Happy Seeder can cut pollution and increase profit. Farmers in Punjab, Uttar Pradesh and Haryana can increase their income by over 20 per cent using Happy Seeder and also reduce greenhouse emissions per hectare by 78 per cent (Anon 2019c).

There are some issues with these machines as they are able to manage the entire paddy crop residue within 25-30 days which may delay the sowing of wheat (Datta et al 2020). Even the cost of Happy Seeder machines has almost doubled from Rs 95,000 to Rs 1.7 lakhs and the cost of a rotavator was Rs 80,000 earlier but it has now jumped to Rs 1.3 lakhs. The Government of India distributed 55,762 machines. During 2018-19, 9,758 Happy Seeders were distributed in Punjab and 2,376 in Haryana and in the year 2019-20, 2,936 and 1,500 Happy Seeders were distributed in the two states respectively. Accordingly these Happy Seeders addressed about 50 per cent of unmanaged paddy crop land area in Punjab (19.3 million ha) and about 42 per cent in Haryana (7.31 million ha) (Kumar and Ladha 2011).

Number of various machines distributed to individual centres and custom hiring centres like happy

seeders is 28,609, 10,747 and 16,401 in Punjab, Haryana and UP respectively. Area managed by in situ machinery purchased under individual category component and custom hiring centres in the year 2018-19 was16,02,822 and 7,05,023 hectares in Punjab and Haryana respectively.

Initiatives to utilize crop residue for bio-energy promotion: India has ambitious renewable energy targets outlined in both its energy policy as well as its climate policy. India aims to increase its renewable energy capacity from 35 GW in 2015 to 175 GW by 2022. This target includes a bio-energy specific target of 10 GW (Anon 2018b). National Policy on Biofuels, 2018 recognizes crop residues as a potential source of bio-energy and promotes its enhanced utilization. Also National Remote Sensing Centre (ISRO) in collaboration with the department of science has developed a Spatial Information System- BHUVAN JAIVOORJA to assess the biomass availability (https://bhuvan-app1.nrsc.gov.in/bioenergy/home/).

The Ministry of Power had brought out a policy for biomass utilization for power generation in November 2017. As per the policy, power generating units shall use 5-10 per cent blend of biomass pellets made primarily of agro-residue along with coal. In tune with the policy, Central Electricity Authority (CEA) had issued an advisory to all concerned state governments, power plants utilities, power equipment manufacturers and other stakeholders to promote use of biomass pellets. It further decided that the states of Haryana and Punjab shall issue bids for all coal-based thermal power plants to use minimum 5 per cent of biomass pellets and up to 10 per cent to be co-fired with coal.

Biomass co-firing is well proven technology. With increasing environmental awareness, power plants all over the world have adopted biomass co-firing as a strategy to combat pollution. United Nations Framework Convention on Climate Change (UNFCCC) recognizes biomass co-firing as a carbon neutral technology for mitigation of carbon emission from coal-based power plants (https://cea.nic.in/wp-content/uploads/2020/04/Biomass-Utilization-Advisory.pdf). In fact, a 2019 report by NITI Aayog says that utilisation of biomass by power producers will result in reduced instances of stubble burning in northwestern India through utilisation of surplus biomass and associated air quality in the region. It will also lead to significant job opportunities in rural northwest (Anon 2019b).

In terms of crop residues, maize stalks, rice straw, sugarcane bagasse and cotton stalk have a very high potential for the generation of bioenergy. The government is promoting biomass gasifier-based power plants for producing electricity using locally available biomass resources such as small rice husk, arhar stalks, cotton stalks etc in rural areas. The focus of the biomass gasifier programme is to meet electrical and thermal needs of rice mills and other industries which in turn help in saving conventional fuels such as coal, diesel etc. In addition, it helps in meeting the unmet demand of electricity for villages for lighting, water pumping and mini-enterprises. Capacity of 3,150 kWh equivalents during 2018-19 has been installed in industries in Uttar Pradesh and Madhya Pradesh for meeting demand of electricity and for thermal application. A model paddy straw biogas plant was installed at Krishi Vigyan Kendra (KVK), Patiala, Punjab in the year 2013 which has been providing trainings and demonstrations to the farmers for the domestic use. But the cost of its installation for individual farmer is high. It is observed that in near future as the technology will become cheaper and affordable, its adoption will be easier at the community level (https://mnre.gov.in/img/documents/ uploads/file_f-1618564141288.pdf).

Kalpataru Power Transmission Limited (KPTL), a leading global engineering, procurement and construction player in power sector, is successfully generating energy from crop residues in Ganganagar and Tonk districts of Rajasthan for the past several years. At Tonk, the plant utilizes 80,000 tons of biomass mostly from mustard crop annually and generates 1.5 lakh kWh energy per day. However the plant produces a large amount of bio-ash requiring its management in a profitable manner. In another effort, Sardar Swaran Singh National Institute of Bio-Energy (SSS-NIBE), Kapurthala, Punjab is an autonomous institution under the Ministry of New and Renewable Energy (MNRE) set up for research and developmental activities (https://www.nibe.res.in/).

Untapped potential of crop residue: Solid bio-fuels come in several forms; the most popular being briquettes and pellets. Briquetting of paddy straw could be another sustainable choice to manage it. Besides being environment friendly, it could help create gainful employment opportunities in the rural areas and become a source of income. The transport cost of the crop residue is a significant factor in its use as a source of bio-energy and hence for large scale applications, straw can be packed in the field into bales or briquettes

(Porichha et al 2021). About 30 million tons of cotton stalk is generated annually in India. Most of it is treated as waste despite a portion of it is used as fuel by rural masses. Indian Council of Agricultural Research has developed a new process which has resulted in premium grade cotton stalks pellets comparable with that of any other biomass pellets.

Composting is a biological process where organic waste is converted into compost that can be used as a fertilizer. Bio-compost technology developed by Indian Council of Agricultural Research is a carrier-based formulation of consortium of four lignocellulolytic fungi. This can be used to convert diverse crop residues of almost all field crops like wheat, rice, mustard, maize and soybean into mature compost within 65-70 days. This composting technology has been disseminated among more than 1,000 farmers in more than 24 villages in UP by ICAR. Composting technology neither requires capital investment nor machinery. A little support of the labour force may make this lucrative to the small farms. Depending upon the requirement of the farmers, the government agencies can offer options like to collect and transport the crop residue from the fields to the processing units where it is used as a raw material. In this endeavour, farmers can be encouraged to make their own organizations at the village level and take up this in their own hands.

Diversification of crops: Diversification from cereal monocropping to other high value crops would conserve soil and water. There can be a lasting solution if the paddy-wheat combination is broken. It is suggested that instead of subsidies on paddy in the form of fertilizers, electricity etc it should be given on fruits and vegetables. In the northwest, sugarcane, mung, beans, mint, maize and potatoes are now cultivated as part of rotations in the rice-wheat system. On the eastern plains, where winters are shorter there is a growing trend towards replacing wheat with potato and maize which offers higher economic returns. In Andhra Pradesh, following rice, bean gram and black gram are planted while the rice stubble decomposes on its own. To discourage this paddy-wheat system, government should procure pulses and oilseeds which are suitable for the northern region in good quantities (Nandi 2019).

Punjab Agro Industries Corporation (PAIC) set up in 1966 and Punjab Foodgrains Corporation (PAFC) set up in the year 2002-03 have been working with farmers to promote diversified cropping pattern by providing seeds, other inputs and extension services in a number of commodities. Crop diversification has also been recommended by expert committees set up by Haryana. The report suggests a number of cropping patterns for the agro-climatic zones of Haryana. It indicated that hybrid maize, soybean, vegetables, agro-horticulture and agro-forestry could be promoted in some of the paddy growing areas (Kumar and Singh 2021).

Crop Diversification Programme (CDP), a sub-scheme of Rashtriya Krishi Vikas Yojana (RKVY) is being implemented in original green revolution states to divert the area of paddy crop to alternate crops and in tobacco growing states to encourage tobacco farmers to shift to alternate crops (https://nfsm.gov.in/ReadyReckoner/CU2/CUII_Brief.pdf).

CONCLUSION

At a first glance it may be argued well that the responsibility of dealing with the crop residue in a sustainable way is the sole responsibility of the farmers as they are the owners of it. This is true in more developed countries where environmental laws are strictly implemented and extensive farming is done. However when it comes to developing countries like India, majority of the farmers do not have the capacity or the ways to handle the residue. For them it has always been an economic rather than an environmental issue. Farmers in India have used the residue in limited number of traditional ways till now. Whichever way suited to them, they opted for that method. The change in the thinking and management in contemporary ways will not happen overnight. This mind set needs to change and the farmers should understand that it is their responsibility to adhere and adapt the innovative ways. It is only possible through proper awareness raising campaigns. These efforts should go hand in hand with empowering them not only technically but also economically.

Collaboration of the state governments with the private players in public-private partnership may prove to be successful in the implementation of various schemes. The government of India has started some pilot projects to raise awareness about crop residue burning and to promote its sustainable utilization as a resource. Government support to the farmers is very important until farmers get used to this concept. There

are many schemes and research projects launched by the government. It is the responsibility of the states to approach the farmers and disseminate the technical knowhow and motivate them.

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