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A REVIEW

Recent ways of management and disposal of agricultural waste - A Review

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Abstract : With the development of agriculture in India, the production of agricultural wastes increased rapidly. Basically these wastes are bio products and are very important for survival of animals and human beings. The occurrence of agricultural wastes is unique in the different areas. The agricultural straw and livestock excrement are considered to be potential resources. These substances are widely available on earth and can be a good source of energy or be converted into useful products. The wastes generated from crop have a good potential to convert to energy through related energy sector. The waste produce from animal or from crop residue is called biomass which has an interdependent relationship with ecosystem from production to disposal and has physicochemical properties. The recycling and utilization of agricultural wastes are considered to be the important step in environmental protection, energy structure and agricultural development. The present review deals with the research work carried out in the conversion of biomass and agricultural waste and to illuminate the potential environmental risk, recycling and utilization pathway, influencing factors and policy suggestions in the recycling and utilization progress of agricultural wastes. An attempt is carried out to increase the economic value of agricultural waste into useful product. The survey provided the development mode of industrialization and scale of agricultural waste recycling. The recycling and utilization pathway of agricultural wastes were also analysed. The crucial suggestions may be proposed, such as cultivating new industry, building economy incentive standard, improving laws and regulations, and creating rural market strengthening medium and long-term plans of agricultural waste recycling. The resource consumption, ecological crisis and other issues caused by agricultural wastes were evaluated.

Key Words : Agriculture waste, Recycling, Resource consumption, Residue, Ecological crisis

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INTRODUCTION

Globally, there are major factors like rising population, consumer culture; urbanization, industrialization and technologic advancement have resulted in worrisome challenges associated with increasing solid waste production. Over the last 50 years agricultural production has increased more than three times as a result of the expansion of soils for agricultural use; the technological contribution of the green revolution which influenced productivity and the accelerated growth

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of population (FAO and OECD, 2019). Agriculture produces an average of 23.7 million food tons per day worldwide (FAO, 2017a). This growth in worldwide production has created greater pressure on the environment, causing negative impacts on soil, air and water resources and also health of ecosystems are put at risk (FAO, 2017b). Large quantities of agricultural wastes, resulting from crop cultivation activities, are a promising source of energy supply for production, processing and domestic activities in the rural areas. In our country agricultural residues are either burnt in the open to clear the fields or being used inefficiently. On an average 1.5 tons of crop residue are generated for processing 1 ton of the main product in addition to substantial quantities of secondary residues. Annually over one billion tonnes of solid wastes are generated, ending up unscientifically in the environment and posing a big challenge for humankind. Waste management is a multidimensional problem that requires technology, economics, sociocultural and political activities to go hand in hand.

In India, the agricultural waste, generated in vast quantities can be used as prospective feedstock for biogas production. This agri-waste to biogas based circular economy requires an integration of agri-waste management, biogas production and utilization and policy support. In simple terms an agricultural waste is defined as unwanted waste, produced as a result of agricultural activities e.g. wheat straw, rice husk, rice straw, sugarcane bagasse, corncob and oil palm empty fruit bunch. The production of corncob, oil palm empty fruit bunch, rice husk, rice straw, and sugarcane bagasse and wheat straw in the crop year 2017/2018 reached approximately 230, 67, 136, 510, 510, and 640 million tons, respectively. Forest waste generated from hardwoods and softwoods reached about 58 million tons in 2013 and 166 million tons in 2016, respectively. The "waste-to-energy" conversion processes like heat and power generation, transport fuel production can have good economic and market potential. Agricultural waste or we can say agro-waste is comprised of animal waste, crop waste, hazardous and toxic agricultural waste (pesticides, insecticides and herbicides). Increasing agricultural production has directly resulted in increased quantities of livestock waste, agricultural crop residues and agro-industrial by-products. Globally, if developing countries continue to intensify farming systems, there is likely to be a significant increase in agricultural wastes also (Agamuthu, 2019).

Stringent measures to regulate crop waste and to mitigate crop burning require involvement of the appropriate Government agencies and polices. Recently, The Ministry of Agriculture of India developed a National Policy for Management of Crop Residue (NPMCR) with objectives to promote the technologies, crop machinery and to monitor crop residue management by using satellite-based remote sensing technologies in collaboration with National Remote Sensing Agency (NRSA) and Central Pollution Control Board (CPCB). The Government of India directed the National Thermal Power Corporation (NTPC) to mix crop residue pellets (nearly 10%) with coal for power generation (The Hindu, 2018). These measures surely are beneficial in crop residue management.

Value of Agricultural waste and environmental risk:

Agricultural waste is referred to the residues or by-products of the harvesting food crops such as rice, wheat, corn, beans, cotton and sugar crops (Zeng *et al.*, 2007). Most of the agro waste has potential to be used in various industries. Some examples are: corn residues (stalks, cobs and leaves). They have been reported to produce bio-butanol by converting them into fermentable sugars (Cai *et al,*, 2016). Mohapatra *et al*., 2010 explained that whole banana plant is useful in feed, food, pharmaceutical, packaging and many other industrial application. This plant is also used in social and religious ceremonies; the peel is used as animal feed, for extraction of pectin and lignin and also as base material for alcohol production. Fibre obtained from pseudo stem of banana can be used for making biodegradable ropes. Its leaves can be used for feed, wrapping material and thatching material. In many tropical countries sugarcane residues are used for the production of bioethanol and other biofuels such as biochar (Krishnan *et al.,* 2010 and Chandel, 2012).

According to Varma *et al.,* 2015 and Karak *et al.*, 2015, burning of manure and straw will generate many harmful gases, smoke and dust and animal manure also contains many pathogens, parasite eggs and heavy metals. The problems caused by poultry and animal faces are of global attention (Liu *et al.*, 2015). The wastes have been directly discharged into water, leading to serious contamination of aquatic environment. The occurrence of agricultural wastes was unique in the different areas. The resource consumption, ecological crisis and other issues caused by agricultural wastes were illuminated. The amount of agricultural straw and animal wastes in

India increased steadily. According to the survey data farmer's input and output index system can be built to illuminate the conversion efficiency of agricultural waste utilization and deeply explore the regional differences, factors and so on (Asim *et al.,* 2015). Crop Residue Burning generates numerous environmental problems. The main adverse effects of crop residue burning include the emission of greenhouse gases (GHGs) that contributes to the global warming, increased levels of particulate matter (PM) and smog that cause health hazards, loss of biodiversity of agricultural lands and the deterioration of soil fertility (Lohan *et al.*, 2018). Air pollutants like CO_2, CO, NH_3, Non-methane hydrocarbon (NMHC), volatile organic compounds (VOCs), semi volatile organic compounds (SVOCs) significantly increases as a result of crop residue burning (Zhang *et al.*, 2011). According to NPMCR and Jain *et al.*, 2014, residue burning accounts for the loss of organic carbon, nitrogen, and other nutrients. They also reported that burning of 98.4 Mt of crop residue has resulted in emission of nearly 8.57 Mt of CO, 141.15 Mt of CO_2, 0.12 Mt of NH_3 and 1.46 Mt NMVOC, 0.65 Mt of NMHC, 1.21 Mt of PM during 2008–2009, where CO_2 is 91.6% of the total emissions. Remaining 8.43% consisted of 66% CO, 2.2% NO, 5% NMHC and 11% NMVOC. Crop burning increases the particulate matter (PM) in the atmosphere and contributes significantly to climate change. The particulate matter emitted from burning of crop residues in Delhi is 17 times as compared to other sources such as vehicle emissions, garbage burning and industries (Jitendra *et al.*, 2017). As such the residue burning in the northwest part of India contributes to about 20% of organic carbon and elemental carbon towards the overall national budget of emission from agricultural waste burning. Hayashi *et al.*, 2014 predicted that cumulative CO, CO_2, N_2O and NOx emissions from rice and wheat straw burning are 0.11, 2.306, 0.002 and 0.084 Mt, respectively. Street *et al.*, 2000 have estimated that approximately 730 Mt of biomass was burned annually from both anthropogenic and natural resources in Asia and 18% of that is from India. The WHO standard for permissible levels of PM 2.5 in the air is 10µg/m^3 and according to the India's National Ambient Air Quality Standard, the permissible level for PM 2.5 is set at 40µg/m^3. However, the National Capital territory of Delhi recorded a mean value of 98µg/m3, which is at least twice more than the Indian standard and ten times higher than the WHO standard. There is continuous deterioration of soil fertility due to burning because of heat generated from burning of residues raises the soil temperature and causes depletion of the bacterial and fungal population. The residue burning increases the subsoil temperatures to nearly 33.8–42.2 %C at 10 mm depth and long-term effects can even reach up to 15 cm of the top soil. Frequent burning reduces nitrogen and carbon potential of the soil and kills the micro flora and fauna beneficial to the soil and further removes the large portion of the organic matter. With crop burning the carbon-nitrogen equilibrium of the soil is completely lost. According to NPMCR, it is reported that burning of one ton of straw accounts for the loss of entire amount of organic carbon, 5.5 kg of nitrogen, 2.3 kg of phosphorous, 25 kg of potassium and 1.2 kg of sulphur. On an average crop residue of different crops contain approximately 80% of nitrogen (N), 25% of phosphorus (P), 50% of sulphur (S) and 20% of potassium (K). If the crop residue is retained in the soil itself, it can enrich the soil with C, N, P and K as well.

Strategies for waste management:

Fig. 1 shows development of biofuel generation with highlights on the second generation biofuels produced by biomass residues and waste and their conversion pathways to produce a wide variety of bioenergy. Some strategies for paddy and wheat waste management are shown in Fig. 3. Sugarcane trash is usually fed to animals

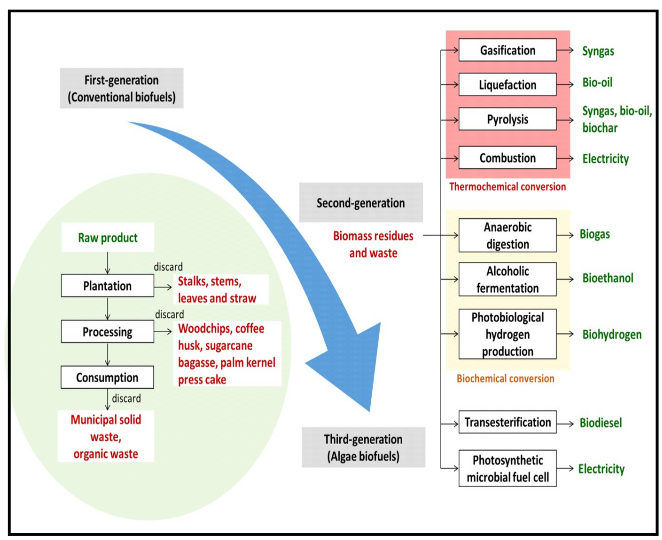

Fig. 1: Development of biofuel generation with highlights on the second generation biofuels produced by biomass residues and waste and their conversion pathways to produce a wide variety of bioenergy (Sze Ying Lee *et al.*, 2019)

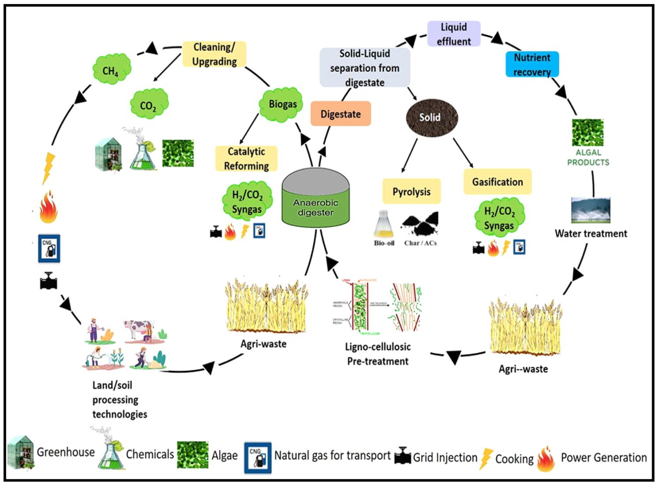

Fig. 2: Agricultural waste for biogas based circular economy in India (Rimika Kapoor *et al.*, 2020)

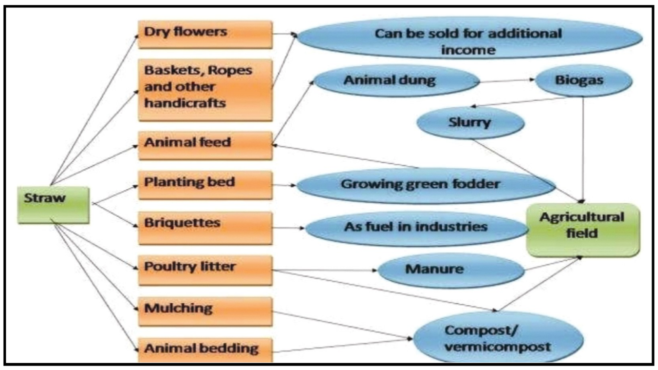

Fig. 3: Various methods of using paddy and wheat straw

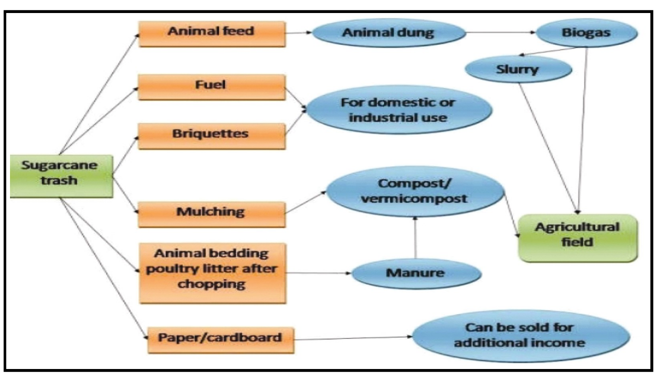

Fig. 4: Explains various possible ways of utilizing sugarcane trash

by all the farmers. Fig. 4 shows other possible ways of utilizing sugarcane trash; as source of energy in sugar industries making briquettes, which can further be used as fuel, as mulching material since ages. Also can been used for mulching, compost making. Another possible use is using it for animal bedding and poultry litter. The animal bedding and poultry can again be used as manure or fed to biogas plant in order to generate biogas. It is also advisable to use it in making cardboard and paper.

Crop residue:

India, the second largest agro-based economy with year-round crop cultivation, generates a large amount of agricultural waste, including crop residues. In the Table 1, general types of crop residues produced by the main cereal crops and sugar cane are summarized. These crop residues, specifically as a field residue is a natural resource that traditionally contributed to the soil stability and fertility through ploughing directly into the soil or by composting. It is a common practice in many of the developing countries, especially in Asia to burn the surplus crop residue (Gadde *et al.*, 2000 and Mendoza *et al.*, 2016). While burning creates environmental issues, ploughing field residue into the ground for millions of hectares within a short time requires new and expensive technical assistance.

Table 1: Crop residues produced by major crops (Phonbumrung *et al.*, 1998 and Arvanitoyannis *et al.*, 2008)

Source	Composition
Rice	Husk, bran
Wheat	Bran, straw
Maize	Stover, husk, skins
Millet	Stover
Sugarcane	Sugarcane tops, bagasse, molasses

Crop residue burning in India :

According to the Indian Ministry of New and Renewable Energy (MNRE, 2015-16), India generates on an average 500 Million tons of crop residue per year. The same report shows that a majority of this crop residue is in fact used as fodder, fuel for other domestic and industrial purposes. However, there is still a surplus of 140 Mt out of which 92 Mt is burned each year. Agricultural waste generated by selected Asian countries in Mt/year is shown in Table 1 (NPMCR and Jeff *et al.*, 2017). 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. It is also interesting to note that the portion burnt as agricultural waste in India, in volume is much larger than the entire production of agricultural waste in other countries in the region. The random straw burning and livestock excrement in the agricultural country have caused a series of environmental problem. And direct combustion and arbitrary discard even become common ways, a serious threat to India's rural ecological environment and improvement in agricultural production and farmers' living conditions (Wang *et al.*, 2015).

Table 2 : Agricultural waste generation in India compared to other select nations in the same region

Country	Agricultural waste generated (million tons/year)
India	500
Bangladesh	72
Indonesia	55
Myanmar	19

Sustainable management practices for management of sgricultural waste:

Over the past decade many alternative measures have been suggested by scientists and agriculturalists to counter crop residue burning, but due to a lack of awareness and social consciousness among the farmers these measures have not been fully implemented. The concept of minimizing waste reduces the quantity and ill-effects of waste generation by reducing quantity of wastes, reusing the waste products with simple treatments and recycling the wastes by using it as resources to produce same or modified products. This is usually referred to as '3R'. Some waste products can be consumed as resources for production of different goods or the same product, meaning recycling the same resource. When wastes are reused time and again, it offsets harvesting of new similar or same products. This saves fresh resources exploitation and reduces waste generation. Agricultural waste management system (AWMS) consists of six basic functions (Fig. 5) as noted by USDA, 2012. These are production, collection, storage, treatment, transfer, and utilization. Production is a function of the amount and nature of agricultural waste generated.

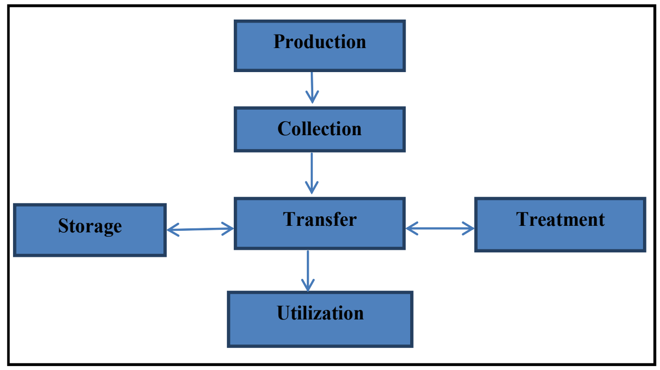

Fig 5: Agricultural waste management functions

In a hierarchical order as in Fig. 6 - Reduce, Reuse and Recycle (3R^s) waste use efficiency can be increased, this hierarchy refers to the "3R^s" classify waste management strategies according to their desirability. The 3R^s are meant to be a hierarchy, in order of importance. If a solution involves making another product out of crop residue, such a product should have a secured market for this solution to succeed. In certain cases, a logistic issue in transportation of the materials to larger distances also adds to the cost. In this context, it is believed that the best alternatives could be the ones that make end-products to be used by the agricultural industry itself and on-site if possible.

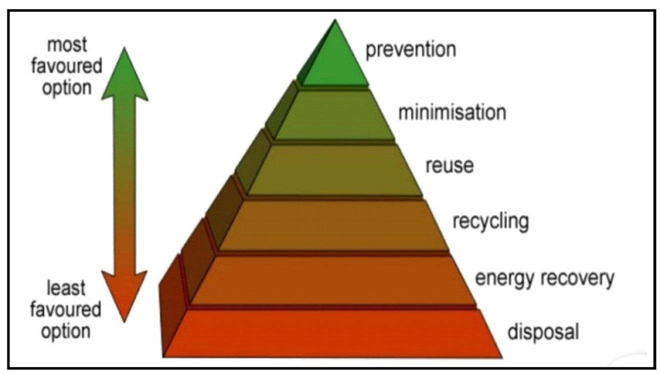

Fig 6: The 3 Rs. hierarchy

In this section information on three such agricultural applications that have either been overlooked or skipped due to various reasons are presented. They are:

Composting :

Composting is the natural process of rotting or decomposition of organic matter by micro-organisms under controlled conditions (Misra *et al.*, 2018). As a rich source of organic matter, compost plays an important role in sustaining soil fertility because it is the rich source of organic matter. It improves soil physio-chemical and biological properties. Higher potential for increased yields and resistance to external factors such as drought, disease and toxicity are the beneficial effects of compost amended soil (Lei *et al.*, 2010).

Biochar :

Biochar is a fine-grained carbon rich porous product obtained from the thermo-chemical conversion called the pyrolysis at low temperatures in an oxygen free environment. According to Amonette *et al.*, 2009 and Masek, 2009, biochar is a mixture of carbon (C), hydrogen (H), oxygen (O), nitrogen (N), sulphur (S) and ash in different proportions. Highly porous nature of the biochar helps in improving water retention and increased soil surface area. Biochar is used in various applications such as the water treatment, construction industry, food industry, cosmetic industry, metallurgy, treatment of waste water and many other chemical applications. In India currently, the biochar application is limited and mainly seen in villages and small towns. Based on its wide applicability it could be more valuable to promote biochar method in India.

***In-situ* management through mechanical intensification:**

According to Marjanovic (2016), crop residue retention with no-tillage is mostly practiced in the North America and about 40% of the cropland across the United States alone is cultivated with no-till practice. In-situ application of the crop residue is adopted by many farmers as it is a natural process. This method also imparts certain benefits to the soil. The National Policy for Management of Crop Residue (NPMCR) specifically mentions in-situ management through methods such as direct incorporation into soils and mulching as methods that should be promoted in India not only to control crop residue burning but also to prevent environmental degradation in the croplands.

Government intervention:

Government of India made several attempts to introduce and educate the agricultural community about the best practices of agricultural waste management. Biogas plants are a progressive step taken by the Government of India to curb crop burning and to prevent pollution. Several programmes are run by the National Biogas and Manure Management Program-off grid biogas power generation programme to provide renewable energy for electricity generation, cooking and lighting purpose. These programs were implemented by the Government under the "waste to energy mission". This is also a part of India's action plan on climate change (Ministry of New and Renewable Sinha, 2015). The setting up of a biogas plant combined with commercial farms and processing units that was set up in Fazilka, Punjab as a novel initiative towards green energy. This plant generates biogas using rice straw through bio-methanation technology. 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; The Environment Protection Act, 1986; The National Tribunal Act, 1995; and The National Environment Appellate Authority Act, 1997. Particularly, in the states of Rajasthan, Uttar Pradesh, Haryana and Punjab stringent measures have been taken by the National Green Tribunal (NGT) to limit the crop residue burning (Kumar *et al.*, 2015 and Lohan *et al.*, 2018).

Conclusion:

Waste management involves collecting, sorting, treating, recycling of energy and resources. Therefore, it has a huge economic potential that needs to be leveraged by public and private entities. The main advantage of sustainable waste management is to improve air and water quality and also reduction of greenhouse gas emissions. The sustainable management of agricultural waste has become a great challenge, especially for developing countries such as India with an increasing population, production rates and economic growth. Crop residues are one branch of agricultural wastes that have posed especial challenges due to their vast volume and lack of capacities to manage them. Biomass residues and waste can be converted into transportation fuels and bioelectricity using trans-esterification, thermochemical and biochemical pathways. The choice of process technology depends on the end product desired and the feedstock. Nevertheless, the production of biofuels from biomass waste is still considered more robust in material handling, transportation, and conversion technology, when compared to traditional editable food crops-based biofuels. Still, on-going research studies are devoted to fill up the inadequacies of the existing technologies and improve the efficiency and economics of the production technologies employed.

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