Industrial and Domestic
Waste Management

Review Article
Volume 2(2), 2022, 113-124
https://doi.org/10.53623/idwm.v2i2.112

Evaluation of Agricultural Waste Management Mechanism in Iran

Mohammad Reza Zargaran Khouzani[1]*, Zahra Dehghani Ghahfarokhi[2]

[1]Plant Production and Genetics Department, Khuzestan University of Agricultural Sciences and Natural Resources, Iran
[2]Payam Noor University, Ahvaz Branch, Iran

*Correspondence: mr.zargarankh@gmail.com

SUBMITTED: 24 August 2022; REVISED: 1 December 2022; ACCEPTED: 3 December 2022

ABSTRACT: The unfavourable situation of waste management in Iran can be seen in different sectors, and agriculture is not excluded from these sectors. The wastes of the agricultural industry can be used in a beneficial way in various agricultural applications and other industrial processes. However, the cost of collection, processing, and transportation can be much higher than the income from the beneficial use of such waste. Incineration of crop residues creates numerous environmental problems. The most important side effects of burning crop residues include the emission of greenhouse gases that lead to global warming, air pollution, and things like soil degradation, loss of soil fertility, loss of beneficial microorganisms, intensification of soil erosion, etc. In the current research, which is a review based on library sources, the mechanism of agricultural waste management in Iran has been evaluated. There are other consequences of such actions. The criteria for action are laws regarding the burning of product residues in Iran, the most important of which are the Waste Management Law and the Clean Air Law. Among these methods are sustainable management methods for product residues, including compost production, biochar production, and waste management at the production site.

KEYWORDS: Agricultural waste; compost; air pollution; greenhouse gases

1. Introduction

The agricultural industry plays a major role in the economic growth of the whole world. However, there are limited published studies on agricultural waste management. This could be related to the fact that residues from the agricultural industry are not considered municipal solid waste. Many agricultural activities increase the number of crops produced, and this has led to a significant increase in environmental pollution and waste production. The nature of the activities used and the waste produced depends on the geographical and cultural factors of a country. Large parts of barren lands have been converted into agricultural lands due to progress in water management systems, modern cultivation technologies, and the use of chemicals on a large scale [1]. Various agricultural operations are defined as agricultural waste. According to the United Nations definition, agricultural waste usually includes manure and other waste materials from farms, poultry farms, and slaughterhouses. Also considered agricultural waste are harvest waste, fertiliser runoff from fields, pesticides that enter the water, air, or soil, and salt and silt that are discharged from fields [1,2]. According to the declaration of the World

Energy Council, in addition to the mentioned cases, agricultural waste can also consist of spoiled food waste [3]. Harvested waste, colloquially known as crop residue, can include field residues left after harvest in agricultural fields or orchards, as well as processing residues left after the crop has been processed into a usable resource. It is a farm. Sugarcane bagasse and molasses are good examples of process residues [3-5].

Types of product residues produced by grain and sugarcane cultivation include husk, bran, bagasse, and molasses. These crop residues, especially farm residues, are a natural resource that traditionally contributes to soil stability and fertility through direct ploughing or composting. Good management of farm residues can also increase irrigation efficiency and control erosion. However, the mass scale and rapid pace of production of plant products have imposed economic and practical limitations on these traditional sustainable practices. Burning surplus crop residue is a common practise in many developing countries, especially in Asia. while burning these residues causes environmental problems. Plowing farm residues over millions of hectares of land in a short period of time requires new and expensive technical assistance. The product residues produced due to agricultural activities are exploited in different ways by several countries. Depending on the type of end use, they are used in processed or unprocessed form. Possible options include its use as animal feed, compost, bioenergy production, and deployment in other agricultural activities such as mushroom cultivation [6–8].

According to Lohan et al., many countries such as China, Indonesia, Nepal, Thailand, Malaysia, Japan, Nigeria, and the Philippines use their crop residues to produce bioenergy and compost. Many researchers have worked on lignocellulose biomass pretreatment techniques for fuel conversion [8,9]. Biological treatment of agricultural waste can be done effectively by anaerobic and aerobic processes, through some related methods such as composting, vermicomposting, biogas production, biomethanation, and biological cultivation [10]. Anaerobic digesters can convert biomass into biogas, a renewable energy source that contains approximately 50% methane, and the final solid residue can be used as a nutrient-rich fertilizer. Anaerobic digestion is a promising value-added technology due to its ability to convert almost all biomass sources, including various types of organic waste, slurry, and animal manure, into highly energetic biogas. This process is an effective and attractive route for the environment and is a promising option for recycling agricultural by-products because these materials contain a high percentage of biodegradable materials. Anaerobic digestion involves microbial transformation in an aqueous environment and can be processed without any pretreatment [11,12]. In addition to that, there is also a complex biological process known as the aerobic degradation of biomass. Degradation and transformation in individual phases are carried out by different groups of special symbiotic microorganisms. Biogas produced through the anaerobic biodegradation of municipal solid waste and agricultural waste contains about 40–70% methane, which can be injected into the natural gas network or used as fuel for transportation. The methane production potential of wheat straw is 0.390 to 1.145 kg/m^3, and rice straw has a methane production potential of 0.367 to 1.241 kg/m^3. Dublin and Steinhauser (2008) reported the biogas production potential of rice straw biomass at about 0.550 to 0.620 cubic metres per kilogramme with about 50% content. Likewise, the reported biochemical methane production from sugarcane biomass ranges from 0.226 to 0.314 cubic meters/kg [13]. Based on the available statistics, 116 million metric tonnes of agricultural products are produced from the total of 118,629,029 hectares of agricultural land (including the area allocated to the second crop) that is dedicated to agriculture and horticulture in Iran. Certainly, the production leads to several times the amount of agricultural waste, which must be managed in a principled way.

2. Negative effects of burning product residues on the environment

Incineration of crop residues creates numerous environmental problems. The most important side effect of burning the remains of agricultural products is the release of greenhouse gases that lead to global warming. The increase in the level of suspended particles and smoke poses health risks, while the loss of biodiversity in agricultural lands and the destruction of soil fertility are other negative consequences of this incorrect practise [14]. The published results of a study in South Korea in 2016 on the release of air pollutants from burning agricultural waste indicate that the release of air pollutants from burning agricultural biomass is 14,828 tonne per year of carbon monoxide, 5,220 tonne per year of nitrogen oxides, 11 tonne per year of sulphur oxides, 59,767 tonne per year of volatile organic gases, 21,548 tonne per year of disodium phosphate, 8,909 tonne per year of inhalable coarse particles, and 5 tonne per year of ammonia gas [15].

Figure 1. A view of burning crop residues in the field by the farmer.

Burning the remains of agricultural products on a large scale in the country of Iran during the cultivation of summer crops can cause major environmental and economic problems. Its first impact is in the soil sector, where it disrupts the physical properties of the soil and makes the soil particles very vulnerable to erosion and moisture retention. In other words, fires increase the apparent weight and electrical conductivity of the soil, greatly reduce its stability, and destroy the pores that could hold water and moisture and help increase the yield. As a result, previous research indicates that pores larger than 1.5 mm in soil in unburned lands are more than four times greater than those in burned lands [16]. The second most important effect it has on the soil is that it increases the chemical properties of the soil, such as the acidity of the soil and the soluble salts in the soil; on the other hand, it increases the amount of organic matter in the soil as well as soluble and nutritious compounds in water and fat. reduces Of course, according to scientific sources, burning the remains of the wheat plant increases the amount of nutrients available to the plant, but this access is less than two weeks, so that after two weeks there is a sharp decrease in the nutrients required for the plant, especially the amount of potassium and phosphorus, as has been proven [17]. The third negative effect of burning plant residues is the destruction of microorganisms that contribute to soil fertility and higher crop yields. Studies show that as a result of burning wheat, more than 50% of the microorganisms that exist up to 2.5 cm deep in the soil are destroyed, and this is a disaster in itself. There is not much information about the effects that fire has on the diversity of the structure, composition, and function of microorganisms, but a sharp decrease in the positive biological activities of the soil has been proven. Since another important effect of burning plant residues is a sharp decrease in organic matter, it affects the properties of the soil, such as soil strength, specific gravity, granulation composition, and the natural structure of the soil, so that with the reduction of organic matter and the increase in productivity of the land, the soil is significantly pounded or compressed, and this compaction of the soil causes The pores of the soil become filled, and as a result, the conditions of ventilation and gas exchange are greatly reduced, and finally, the fertility of the soil and the activities of beneficial soil microorganisms are lost. So that after several periods of using the field for ploughing and tilling the soil, large clods are formed, which indicates a decrease in the amount of organic matter in the soil [18]. On the other hand, burning everything in nature produces large amounts of carbon dioxide gas, which increases greenhouse gases and causes the earth to gradually warm. Although the burning of plants, straw, and stubble in a short period of time and with a small expenditure causes the destruction of weeds and, to some extent, the pests and diseases of the field, at the same time, this event has a direct effect on the reduction of soil fertility and causes the destruction of The departure of beneficial insects and predators disturbs the balance of the environment and ecosystem, resulting in the loss of many plant and animal species and, ultimately, the loss of biodiversity. Air pollution, the increase in the amount of dust, and finally the increase in respiratory diseases are all reasons why, every year in Iran, more than 100 people are injured due to the burning of their fields [19].

3. Laws related to preventing the burning of plant remains in Iran

Figure 2. Iranian MPs banned the burning of crop residues after harvest.
(ISNA: Mahmoud Rahimi)

Strict measures to reduce product burning and more effectively regulate product waste management require the involvement of appropriate government agencies and organizations. Some of the laws that are criteria for burning product residues in Iran are: accumulation of hospital and industrial waste in public roads and open spaces or burning them; accumulation of household and construction waste in public roads and open spaces outside the places designated by municipalities. It is also forbidden to burn the remains of agricultural land after harvest, and the violator is sentenced to a fine of the sixth degree under Article 19 of the Islamic Penal Code. The Ministry of Agricultural Jihad is obliged to inform the users of the agricultural, nomadic, and natural resource sectors in an appropriate manner. In exceptional cases where the burning of plants or plant remains is the only way to get rid of pests, diseases, and plant pollution, it is done based on the conditions formulated and communicated by the Ministry of Agricultural Jihad with the approval of the organisation [1]. It is forbidden to burn waste in the open environment or in a non-standard waste incinerator, contrary to the rules and regulations of the relevant regulations [2]. If the corrective measures are not carried out, the executive management of the waste and the organisation can make the necessary corrections and collect the costs from the violator with the opinion of the official judicial expert [20]. The executive management of agricultural waste is obliged to comply with the relevant laws and regulations to implement the following:

Choosing one or a combination of methods of purification, disposal, and disposal of special agricultural waste and its implementation after the approval of the organization's annual compilation of the executive management programme and training programme based on production waste statistics and presenting it to the representatives of the organisation or the Ministry of Agricultural Jihad The training programme for normal waste must be approved by the Provincial Agricultural Jihad Organization, and the programme for special waste must also be approved by the organization. compilation and implementation of incentive support programmes for farmers to cooperate in agricultural waste management with the cooperation of the provincial agricultural jihad organization. submitting the performance report of the collection under its management to the General Department of Environmental Protection and the Agricultural Jihad Organization of the province at the end of each year. Identification of new tools and technologies that will cause optimal separation of waste at the source Training on the separation of normal and special waste in the agricultural sector with the cooperation of the Ministry of Agricultural Jihad and the construction of waste processing units with an emphasis on useful separation and paying attention to the feasibility and compliance with environmental principles in order to reduce the physical volume of recycled and buried waste In order to develop the activities and encourage the non-governmental sector in education and promotion, as well as identify and reform waste management, the executive bodies are required to predict the necessary areas for investment in this sector in the five-year development plans. The Broadcasting Organization of the Islamic Republic of Iran and the information media affiliated with government agencies are obliged to prepare and broadcast educational programmes subject to this regulation under the supervision of the organisation and the Ministry of Agricultural Jihad. The organisation and ministries of industries and mines, science and technology research, agricultural jihad, country, and education are obliged to take the necessary measures regarding the implementation of the required training for agricultural waste management. The Ministry of Agricultural Jihad is obliged to provide the organisation with an annual report on the actions taken in the implementation of these regulations. The executive management of waste, the organization, and the Ministry of Agricultural Jihad are responsible for the instructions on how to implement and the steps to prepare and communicate waste operations in the agricultural sector related to their organisational duties within six months after the notification of this resolution. The Ministry of Energy is obliged to provide information related to the sensitivity and vulnerability of water sources (names, locations, and distribution of all underground and surface water sources) to natural and legal persons subject to this article in order to formulate relevant guidelines [16-20].

4. Sustainable management methods for agricultural residues

As discussed in the previous section, most government interventions so far have focused mainly on energy production from crop residues, especially biogas production [14]. Some residues are processed for use in construction operations, such as rice husk ash in cement mixes. Banana peel and sugarcane are used in the paper industry, while bagasse husk and ash are used for mushroom cultivation [3]. If the solution is to produce another product from product residues, such a product must have a secure market to succeed in this solution. In certain cases, logistical issues with transporting materials over longer distances also add to the cost. At In this context, it is believed that the best options are those that cause the final products to be used by the agricultural industry itself and, if possible, on the spot. In this section, three methods of agricultural waste management are further investigated. They include composting, biochar, and mechanical on-site residue management.

4.1. Composting.

While small-scale backyard composting and composting from organic materials are common in solid waste management, there is no evidence in studies that this is also true in developing countries, particularly Iran.In a recent review, Hatirachi et al. (2018) found out about the common challenges faced by organic waste composting projects and found that the challenge is not mainly technical, but the practise is not justified from an economic point of view because the final product always guarantees a stable market. does not. The high organic content of the crop residue makes it an ideal raw material for compost, similar to animal manure and food waste. Composting is the natural process of the rotting or decomposition of organic matter by microorganisms under controlled conditions [21,22].

Figure 3. Amirkabir sugarcane cultivation and industry in Khuzestan, the largest compost production site in Iran. (ISNA: Amin Nazari)

As a rich source of organic matter, compost plays an important role in maintaining soil fertility and thus helping to achieve sustainable agricultural productivity. Adding compost to the soil improves its physical-chemical and biological properties and can completely replace the use of agricultural chemicals such as fertilisers and pesticides. More potential to increase yield and resistance to external factors such as drought, disease, and toxicity is one of the beneficial effects of soil amended by compost [23,24]. Because of increased microbial activity in the soil, these techniques also aid in increasing nutrient absorption and active nutrient cycling. Composting is done by various microorganisms that are activated in an aerobic environment. Bacteria, fungi, actinomycetes, algae, and protozoa that occur naturally in organic biomass or are artificially added to facilitate decomposition This is biological maturation under aerobic conditions, where organic matter of animal or plant origin is broken down into substances with shorter molecular chains. Stable compost that is healthy, rich in humus, useful for agricultural products, and capable of recycling soil organic matter is finally formed [25].

4.2. Biochar production.

The agricultural research community is constantly looking for ways to effectively increase the natural rate of carbon sequestration in soil as a measure to control greenhouse gas emissions. This has led to increased interest in using charcoal, carbon black, and biochar as soil amendments to stabilise soil organic content. These techniques are considered a viable option to reduce greenhouse gas emissions while significantly reducing the volume of agricultural waste. The process of carbon sequestration basically requires increasing the retention time and oxidation resistance of biomass chemical oxidation against carbon dioxide reduction or methane reduction, which leads to the reduction of carbon dioxide or methane emissions in the atmosphere [26,27]. The burnt relative products are carbon and pyrogenic carbon, and with a very slow chemical transformation, it turns into a long-term carbon deposition, which is ideal for soil amendment [27,28]. Biochar is a porous product rich in fine-grained carbon obtained from a thermochemical transformation called pyrolysis at low temperature in an oxygen-free environment [28,29]. This material is a combination of carbon, sulfur, nitrogen, oxygen, hydrogen, and ash in different proportions, and when added to the soil, its highly porous nature helps to improve water retention and increase the soil surface. It mainly interacts with the soil matrix, soil microbes, and plant roots [30], helps retain nutrients, and initiates a wide range of biochemical processes. Many studies have found that increasing acidity increases earthworm populations while decreasing fertiliser consumption [31,32]. Biochar is specifically used in water treatment, the construction industry, the food industry, the cosmetic industry, metallurgy, wastewater treatment, and many other chemical processes.

4.3. Management of plant residues in the environment mechanically.

Application of crop residues is practised by many farmers because it is a natural process. This method also brings special benefits to the soil. There are two main methods of implementing on-farm programs, but both involve leaving crop residues on farmland after harvest. In the first method, planting occurs in the next season without tillage or with little tillage, and in the other method, crop residues are placed in the soil during tillage using a mechanical method. While on-site management of crop residues can provide long-term savings in equipment and labour costs, both methods require special (new) equipment [32]. North America is done, and about 40% of cropland across the U.S. is cultivated with no-till alone. This method has many benefits, such as a cooling effect, increased moisture, a carbon source, and erosion protection for the soil. However, this method also has negative consequences, for example, microbial invasion, formation of phytotoxins, and immobilisation of nutrients that lead to yield reduction and may cause additional use of agrochemicals [32,33]. To improve soil organic matter, crop residues are introduced into the soil by ploughs. Adding nitrogen fertilisers when ploughing at a depth of 20–30 cm can enrich the soil with humus and prevent nitrogen depletion [32].

5. Analyze

Agricultural industry waste can be beneficially used in various agricultural applications and other industrial processes. However, the cost of collection, processing, and transportation can be much higher than the revenue from the beneficial use of such waste. Of course, this issue should not be viewed only from an economic point of view, but considering that crop residues are one of the most important components of agricultural waste, which are useful due to their organic compounds, and on the other hand, in the case of unstable management measures for crop residues, the effects caused on the environment are adverse and should be taken into consideration. As stated earlier, burning plant residues has become an environmental disaster not only for Iran but also for the Asian region. Considering the existence of many relevant laws in this regard that were briefly presented and the existence of potential solutions, the air pollution observed in the harvest season in various parts of the country clearly shows that the issue of burning crop residues has not been solved by anyone. One of the previous cases has not been resolved. The question to ask is "why not?" Answering this question will help identify better options to implement. The main issues related to policy or performance identified based on the above analysis are presented in the following sub-sections:

5.1. The need for an executive mechanism.

Regarding the issue of urban waste, it is easier to manage because it is specified in the law. The management of solid waste generated by households in a community is collected and disposed of by the municipality (at least, this mechanism is supposed to exist). This means that regardless of its efficiency or sustainability, the known process is a solid waste management system. The municipality is responsible for keeping the community clean and safe, and residents pay taxes or other fees as their share.

When crop residues are produced by farmers, who should be responsible for managing them? According to the law, the producer of waste must dispose of it in principle, which must be the farmer. This is often the case in large agribusinesses, especially in developed countries where environmental laws are strictly enforced. However, when it comes to small-scale agriculture in developing countries, individual farmers do not have the capacity to manage their own waste. According to the example of solid waste management, what is missing here is an organised mechanism for managing product residues. However, the government's interventions can provide the necessary support to farmers in creating an organised network, the documents of which are mentioned above. For example, the government can establish a service to manage crop residues in exchange for a reasonable fee from the farmer. Even until farmers get used to the concept, providing such a service with a government subsidy is worth it. Based on the needs of the community or region, government agencies can provide different options, such as collecting and transporting crop residues from farms to areas of need or using them as raw material for compost, biogas, or biochar production plants. The same entity can provide a service for renting machinery to those who need the necessary equipment to incorporate crop residues into the soil before the next season. The government does not necessarily have to accept responsibility. Instead, this responsibility can be given to a people's organisation based on the educational and organisational skills of the farming community. Like the farmers' union, he gave up. For example, this method has been used for years in the country and in some countries with water stress to distribute agricultural water.

5.2. Empowerment of beneficiaries.

The government has initiated some pilot and research projects to raise awareness about crop residue incineration and promote its sustainable use as a resource. While these efforts are necessary, one must question why they have not yet had a significant impact. One reason could be the difference between how much work is done by the government versus how much it is felt or perceived by farming communities. Education and empowerment of agricultural stakeholders are two important steps to creating a significant impact. Currently, the view of the farmers, according to what they have seen for different generations, is that they are only responsible for the production of crops, and the management of crop residues is not their responsibility, and getting rid of it with the option of burning is not the least expensive. This thinking must change, and farmers must feel responsible for the residue they produce. This is possible only through awareness. Raising technical knowledge, on the other hand, only makes sense if it is accompanied by a practical solution to their questions about how to control crop residues without spending a lot of money, or, even better, how to make money using it.For example, when farmers know that the equipment required to do such work is very expensive, even having technical knowledge about how to combine waste in the soil and the amount of nutrients in it cannot have a significant impact. Farmers should also be made aware of the benefit of reduced chemical costs due to the use of crop residues on farmland. Therefore, awareness campaigns should always be parallel to the implementation of a practical solution that empowers them not only technically but also economically.

5.3. Avoiding partiality and focusing on relational thinking.

Incineration of crop residues is an issue beyond agriculture. Some issues are clearly visible, including environmental impacts such as air pollution. But for farmers who can't afford to pay more for proper crop residue management, it's always an economic issue. Even if the farmer is aware of the environmental damage it can cause, when the rental price of the equipment is very high or there are no such facilities at all and the price of a matchbox is only a few rials, it is an economic decision for the farmer. It is easy to get To solve this problem, it is necessary to provide the economic justification for the correct management of agricultural waste through the creation of relational mechanisms between the use of these products and other processes or productions. Compost, biochar, or biogas can be the best examples to explain how to use relational thinking well when fighting crop residue burning.

6. Conclusion

Considering the increasing environmental problems in the country in all fields, including water, soil, and air, more serious measures should be implemented to solve these problems. The real reasons for crop residue burning have economic-technical roots rather than agricultural or waste management roots. Any solution that involves long transportation, expensive technology, or high investment will be less successful. In this context, sustainable solutions that include methods of feeding residual crop nutrients to the same agricultural fields promise better success. Biomass-based products such as biogas, compost, and conservation agriculture management methods are relatively neglected as suitable options for using agricultural residues. Large-scale containment of methane gas from waste through biogas plants should be done. Ministries, government organizations, and private companies can create a natural gas network to use this biogas. Due to the existence of sufficient laws in the country, unfortunately, we still see the non-implementation of most of them, which should be taken into consideration by the people involved in this sector.

References

[1] Nagendran, R. (2011). Agricultural Waste and Pollution. *Waste*, 341–355. https://doi.org/10.1016/B978-0-12-381475-3.10024-5.

[2] Agrilcultural waste. (accessed on 10 November 2018) Available online: https://stats.oecd.org/glossary/detail.asp?ID=77.

[3] Hoornweg, D.; Bhada-Tata, P. (2012). What a Waste: A Global Review of Solid Waste Management; World Bank: Washington, DC, USA.

[4] United Nations (1997). Glossary of Environment Statistics, Studies in Methods; Series F, 67; Department for Economic and Social Information and Policy Analysis, Statistics Division: New York, NY, USA,Volume 96.

[5] Obi, F.O.; Ugwuishiwu, B.O.; Nwakaire, J.N. (2016). Agricultural Waste Concept, Generation, Utilization and Management. *Nigerian Journal of Technology*, *35*, 957–964.

[6] Hayashi, K.; Ono, K.; Kajiura, M.; Sudo, S.; Yonemura, S.; Fushimi, A.; Saitoh, K.; Fujitani, Y.; Tanab, K. (2014). Trace gas and particle emissions from open burning of three cereal crop residues: Increase in residue moistness enhances emissions of carbon monoxide, methane, and particulate organic carbon. *Atmospheric Environment*, *95*, 36–44.

[7] Monforti, F.; Bódis, K.; Scarlat, N.; Dallemand, J.F. (2013). The possible contribution of agricultural crop residues to renewable energy targets in Europe: A spatially explicit study. *Renewable and Sustainable Energy Review*, *19*, 666–677. https://doi.org/10.1016/j.rser.2012.11.060.

[8] Bhuvaneshwari, S.; Hettiarachchi, H.; Meegoda, J.N. (2019). Crop Residue Burning in India: Policy Challenges and Potential Solutions. *International Journal of Environmental Research and Public Health*, *16*, 832. https://doi.org/10.3390/ijerph16050832.

[9] Kumar, P.; Barrett, D.M.; Delwiche, M.J.; Stroeve, P.(2009) Methods for pre-treatment of lignocellulosic biomass for efficient hydrolysis and biofuel production. *Industrial and Engineering Chemistry Research*, *48*, 3713–3729. https://doi.org/10.1021/ie801542g.

[10] Zargaran Khouzani, M.R. (2019). Herbal refinementtehran. Merzdanash Publications. Tehran. Iran- 89-93.(In Persian).

[11] Meegoda, J.N.; Li, B.; Patel, K.; Wang, L.B.(2018). A Review of the Processes, Parameters, and Optimization of Anaerobic Digestion. *International Journal of Environmental Research and Public Health*, 15, 2224. http://doi.org/10.3390/ijerph15102224.

[12] Ward, A.J.; Hobbs, P.J.; Holliman, P.J.; Jones, D.L. (1999). Review: Optimization of the anaerobic digestion of agricultural resources. *Bioresource Technology*, *99*, 7928–7940. https://doi.org/10.1016/j.biortech.2008.02.044.

[13] Deublein, D.; Steinhauser, A. (2008). Biogas from Waste and Renewable Sources: An Introduction; Wiley-VCH Verlag GmbH & Co. KGaA: Weinheim, Germany.

[14] Lohan, S.K.; Jat, H.S.; Yadav, A.K.; Sidhu, H.S.; Jat, M.L.; Choudhary, M.; Jyotsna Kiran, P.; Sharma, P.C .(2018). Burning issues of paddy residue management in north-west states of India.

Renewable and Sustainable Energy Review, 81, 693–706. https://doi.org/10.1016/j.rser.2017.08.057.

[15] Kim, D.Y., Choi, M., Han, Y.H. y Park, S.K. (2016). A Study on Estimation of Air Pollutants Emission from Agricultural Waste Burning. *Journal of Korean Society for Atmospheric Environment, 32*, 167-175. http://doi.org/10.5572/KOSAE.2016.32.2.167.

[16] Aazami, J.; Pourhashemzehi, S. (2018). The Effect of Arson in Agriculture on the Environment (Case study: Esfahan Province). *Human & Environment, 16*, 113-124.

[17] Robichaud, R.; Lewis, A.; Wagenbrenner, W.; Ashmun, E.; Brown, E. (2013). Post-fire mulching for runoff and erosion mitigation: Part I: Effectiveness at reducing hillslope erosion rates. *Catena, 105*, 75-92. https://doi.org/10.1016/j.catena.2012.11.015.

[18] Choromanska, U.; DeLuca, T. (2002). Microbial activity and nitrogen mineralization in forest mineral soils following heating: evaluation of post-fire effects. *Soil Biology and Biochemistry, 34*, 263-271. https://doi.org/10.1016/S0038-0717(01)00180-8.

[19] Van der Werf, R.; Randerson, T.; Giglio, L.; Collatz, G.; Mu, M.; Kasibhatla, P.S.; Leeuwen, T. (2010). Global fire emissions and the contribution of deforestation, savanna, forest, agricultural, and peat fires (1997–2009). *Atmospheric Chemistry and Physics, 10*, 11707-11735. http://doi.org/10.5194/acp-10-11707-2010.

[20] Rastegari, M.; Akbarpour, F.(2021). Pathology of agricultural waste management in Iran. The 1st National conference on Green Waste Management. Mohaghegh Ardabili University.

[21] Lei, Z.; Chen, J.; Zhang, Z.; Sugiura, N.(2010). Methane production from rice straw with acclimated anaerobic sludge: Effect of phosphate supplementation. *Bioresource Technology, 101*, 4343–4348. https://doi.org/10.1016/j.biortech.2010.01.083.

[22] Misra, R.V.; Roy, R.N.; Hiraoka, H. (2003). On Farm Composting Methods; Food and Agricultural Organization of the United Nations: Rome, Italy.

[23] Tuomela, M.; Vikman, M.; Hatakka, A.; Itavaara, M. (2000). Biodegradation of lignin in a compost environment: A review. *Bioresource Technology*, 72, 169. https://doi.org/10.1016/S0960-8524(99)00104-2.

[24] Sequi, P. (1999). The role of composting in sustainable agriculture. In The Science of Composting Blackie Academic & Professional; Bertoldi, M., Sequi, P., Lemmens, B., Papi, T., Eds.; London, UK; pp. 23–29.

[25] Srinivasarao, C.H.; Venkateswarlu, B.; Lal, R.; Singh, A.K.; Sumanta, K. (2013). Sustainable management of soils of dryland ecosystems for enhancing agronomic productivity and sequestering carbon. *Advances in Agronomy, 121*, 253–329. https://doi.org/10.1016/B978-0-12-407685-3.00005-0.

[26] Izaurralde, R.C.; Rosenberg, N.J.; Lal, R. (2001). Mitigation of climate change by soil carbon sequestration: Issues of science, monitoring, and degraded lands. *Advances in Agronomy*, 70, 1–75. http://doi.org/10.1016/S0065-2113(01)70003-X.

[27] McHenry, M.P. (2009). Agricultural biochar production, renewable energy generation and farm carbon sequestration in Western Australia, Certainty, uncertainty and risk. *Agriculture*, *Ecosystem and Environment*, *129*, 1–7. https://doi.org/10.1016/j.agee.2008.08.006.

[28] Amonette, J.; Joseph, S.(2009).Characteristics of biochar: Micro-chemical properties. In Biochar for Environmental Management: Science and Technology; Lehmann, J., Joseph, S., Eds.; Earth Scan: London, UK, pp. 33–52.

[29] Biochar Production Technologies (accessed on 6 March 2019). Available online: http://www.geos.ed.ac.uk/sccs/biochar/documents/BiocharLaunch-OMasek.pdf.

[30] Lehmann, J.; Joseph, S. (2009). Biochar systems. In Biochar for Environmental Management: Science and Technology; Lehmann, J., Joseph, S., Eds.; Earthscan: London, UK, pp. 147–168.

[31] Gaunt, J.; Cowie, A. (2009). Biochar greenhouse gas accounting and emission trading. In Biochar for Environmental Management: Science and Technology; Lehmann, J., Joseph, S., Eds.; Earthscan: London, UK; pp. 317–340.

[32] The Best Practices for Using Plant Residues, Agrivi. (accessed on 6 March 2019). Available online: http://blog.agrivi.com/post/the-best-practices-for-using-plant-residues.

[33] Singh, Y.;Sidhu, H.S .(2014). Management of cereal crop residues for sustainable rice-wheat production system in the Indo-gangetic plains of India. *Procedings of the Indian National Science Academy*, *80*, 95–114. http://doi.org/10.16943/ptinsa/2014/v80i1/55089.