EUROPEAN ACADEMIC RESEARCH
Vol. XIII, Issue 5/ August 2025

Impact Factor: 3.4546 (UIF)
DRJI Value: 5.9 (B+)

ISSN 2286-4822
www.euacademic.org

Significance of Transforming Agricultural Residues towards Sustainable Development: An Overview

Dr. H. V. SANKPAL
Assistant Professor Rajarshi Shahu Arts and Commerce College Rukadi
Dr. AMOL CHANDRAKANT KAMBLE
Assistant Professor Rajarshi Shahu Arts and Commerce College Rukadi

Abstract

Agricultural residues are a significant waste product of modern agriculture. These residues mainly include crop residues, industrial processing wastes, livestock wastes, and fruit and vegetable wastes and are usually left to decompose, leading to environmental degradation and health hazards. However, with the growing demand for sustainable agriculture practices, there is a need to find innovative ways to utilize these residues. Transforming Agriculture Residues for Sustainable Development: From Waste to Wealth comprehensively explores the potential of agriculture waste valorization, showcasing innovative technologies and applications that meet the challenges of converting waste materials into valuable resources. By addressing various aspects of the agricultural waste-to-wealth paradigm, this invaluable guide will be helpful for researchers, policymakers, and industry professionals seeking sustainable solutions for agricultural residue management and the transition to a more circular economy.

Keywords: *Agricultural, crop,* Sustainable, Residues, *environmental, degradation, Management, Energy.*

INTRODUCTION

"Rising energy demand and decreasing fossil fuel usage, particularly coal, petroleum, and natural gas, pose significant challenges to energy security, climate change, and social and Political stability. To meet and overcome these problems, it is important to create a cost-effective, environmentally friendly solution. In this regard, using renewable and scattered energy from the sun, earth, water, wind, or biomass should be an alternative option" (Bentsen, Claus, & Thorsen, 2014). "Furthermore, these materials should be economically and commercially attractive and obtained through a naturally occurring process. The gravity of the situation demands that an appropriate policy should be evolved to promote multiple uses of crop residues in the context of conservation agriculture and to prevent their on-farm burning. Under this scenario this bulletin aims to (i) quantify the amount of crop residues generated in the country every year and the extent of their on-farm burning, (ii) assess the environmental impacts of on-farm burning of crop residues, (iii) identify competing uses of crop residues and their adoption potential, (iv) assess the potential of using crop residues for conservation agriculture and constraints involved therein, (v) develop a model plan for managing crop residues at the local and regional scales, and (vi) identify research and policy issues for safe and sustainable management" (Bentsen, Claus, & Thorsen, 2014) of crop residues for productive, profitable and sustainable agriculture.

REVIEW OF LITRATURE

Lignocellulosic biomass can be chiefly divided into two categories, "agricultural crop residues and woody biomass (forest residues). India produces approximately 500 million tons of agricultural crop residues every year as per the estimates of Ministry of New and Renewable Energy. Further, it has been reported an excess of 140 metric ton of biomass is left in open field for burning every year. The residues of cereal crops are treated as natural resources that are conventionally attributed to raise the fertility of soil during ploughing of field or through composting. These residues are also supposed to promote the irrigation efficiency of soil and also regulate the soil erosion. But, during the mass production of crops, these practices are not given sufficient attention which results in utilization of large volume of inorganic fertilizers to regain the fertility of soil. Furthermore, ignorance of these practices also leads to burning of such crop residues in field and in the process, the upper layer of soil gets unfertile and becomes unsuitable for any types of crop production" (R., B., Sakthi, & Chinnasamy, 2024). Maize, wheat, rice, and sugarcane are significant agricultural crops which are grown in most parts of the world and mostly give rise to lignocellulosic biomass

Sahoo et al. (2021) "studied the three different agricultural residues like rice straw, wheat, sugarcane, and bagasse straw to produce biochar and bio-oil in a fixedbed reactor. The experiments were conducted under various operating conditions, including temperature, heating rate, and biomass particle size. Author also studied the biochar physicochemical properties better to understand the pyrolysis mechanism" (Nemtsov & Zabaniotou, 2008) and its practical applicability.

Sedmihradska et al., (2020) investigated the "agriculture crop residue-derived biochar. The two agricultural crop residues, wheat and barley straw, were selected for experimental studies. The biochar was prepared at a temperature of 600 ºC. Authors conclude that the carbon content of wheat straw and barley straw generated char was 67.2 and 67.0%, respectively. The atomic ratio H: C and specific surface" (Nemtsov & Zabaniotou, 2008) area were 0.032 and 0.026, and 217 and 201 m2 /g, respectively.

Windeatt et al. (2014) "produced biochar from eight different crop residues (wheat straw, cotton stalk, coconut husk, rice husk, coconut shell, sugarcane bagasse, palm shell, and olive pomace) through slow pyrolysis process at 600 oC using a laboratory scale fixed bed pyrolysis reactor. The authors determined various physicochemical properties and found that all of the chosen crop residues had mass yields of biochar that ranged from 28 to 39%, while the average carbon content of all produced biochar is about 51%. Most biochars were discovered to be alkaline in nature, with pH values ranging from 6.1 to 11.6. Up to 220 m2 /g of surface area of biochar produced from various residues was measured. The authors also concluded that crop residue-derived biochar has a significant" (Angesom, Asfafaw, & Muyiwa, 2024) potential in sequestering carbon dioxide over an extended period.

RESEARCH GAP

The present study is based on agriculture residue management for their sustainable development and it is the part of circular economy it also explains how agriculture residue management is related to circular economy. The researcher identified the research gap as the majority of the study is related to only agricultural waste management for development and how it is collected. But there are no any previous studies have been done on the relationship between the agriculture residue and circular economy that aids to achieve Sustainable Development through the help of circular economy. Therefore, the current study was conducted to fill this gap.

Concept of Agriculture residue

Agricultural “residues are carbon-based materials generated as a byproduct during the harvesting and processing of agricultural crops. Agricultural residues which are produced during harvesting are primary or field-based residues while those produced along with the product during processing are secondary or processed based residues. Agricultural residues are heterogeneous, varying in bulk density, moisture content, particle size and distribution relative to operational handling. They are usually fibrous, low in nitrogen and vary with geo-graphical location. These field residues are occasionally utilized as fertilizer, for erosion control and as fodder for livestock. Almost half of these resources are combusted” (Atapattu, Ranasinghe, Nuwarapaksha, Udumann, & Dissanayaka, 2024) on the farm prior to the commencement of another farm season.

“Process residues offer high prospect as an energy source. Chemical composition of any crop residue varies depending on several factors among, which may include species, age of residue or period of harvest, physical composition including length of storage and harvesting prac-tices. Agricultural residues are produced as a waste product from food crops such as maize, wheat, sun lowers, and so on. Currently, only small proportion of these residues are being used by farmers as feed for livestock and the rest of these are plowed back into the soil or burned to get rid of the huge volumes of biomass before planting the next crop. The biggest advantage of utilizing agricultural residues is that it does not compete with the production of food, and if it can become a by-product that can be utilized economically” (Angesom, Asfafaw, & Muyiwa, 2024) for the production of energy, it will result in lower food prices. It is estimated that roughly one ton of reside is produced for every of grain harvested

OBJECTIVES OF RESEARCH STUDY

1. To study the concept of Agricultural residues and its impact on sustainability
2. To study the present scenario of Agricultural residues Management in India
3. To analyses the linkages between Agricultural residues management, circular economy and sustainable development in India.

RESEARCH METHODOLOGY

“Quantitative and qualitative methodologies were followed discretely or in a mixed approach for a comparative and descriptive study. Observatory, exploratory, and explanatory analyses of the data and the results, either separately or together, were carried out through analytical methods for describing the data, the results, their interrelationships, and characterizing the residues’ nature as well as their potential. For the tailed discussion of the inference of resource consumption in the case of India, a descriptive, observatory, and explanatory study is followed based on a literature survey and situation analysis of the case. Typically, surplus residue is burnt in-situ from March to May. on farm burning of crop residue becomes a source of greenhouse gases (CO2, CO, CH4, N2O, SO2), aerosols, particulate matters, smoke, volatile organic compound and radioactive gases; thereby they exacerbate global and regional atmosphere harmony. The present paper mainly focuses on the status of crop residue in India as well as recycling of crop residue for economic and also environmental sustainability. The study will be helpful to view the global warming problem associated with residue" (Bowyer & Stockmann, 2017) burning.

Data Collection

In this analytical and descriptive research study the researcher has used secondary data and to obtain this data he has used internet websites, published books, proceedings of various universities and various online and offline published research articles as well as papers. The researcher has also referred to some Ph.D. theses to collect secondary data and also reviewed and collected data from various research documents including ITCC Annual Report and IMD Annual Report along with State Pollution Control Board (SPCB) Annual Report.

RESULTS AND DISCUSSIONS

Crop residues are the plant biomass or remnants of the agricultural crops in the field, "such as rice straw, corn Stover, sugarcane trash, wheat straw, sorghum straw, etc. Every year, because of growing food demand and intensive agricultural practices, more than 5 billion tons of crop residue is produced globally. The Asian continent is the largest producer of crop residues with 47 per cent of the total world production, followed by America (29 %) Europe (16 %) Africa (7 %) and Oceania (1 %). The leading crop residue producing crops are maize, rice, sugarcane, wheat, soybean and barley contributing almost 85 per cent of the global crop residue production (FAO, 2022). Total crop residue production of the world during 2022 is 5280.80 million tonnes (MT) including cereal crops, legume crops, oil crops, sugar crops and tuber crops. Among this major crop residue accumulates" (Bowyer & Stockmann, 2017) for paddy straw 1135.12 MT, maize Stover 1162.35 MT and sugarcane trash 467.43 MT.

Crop residues generation in India

"The Ministry of New and Renewable Energy Govt. of India has estimated that about 500 Mt of crop residues are generated every year (Table 1). There is a wide variability in the generation of crop residues and their use across different regions of the country depending on the crops grown, cropping intensity and productivity of these crops. The generation of crop residues is highest in Uttar Pradesh (60 Mt) followed by Punjab (51 Mt) and Maharashtra (46 Mt). Among different crops, cereals generate maximum residues (352 Mt), followed by fibres (66 Mt), oilseeds (29 Mt), pulses (13 Mt) and sugarcane (12 Mt) .The cereal crops (rice, wheat, maize, millets) contribute 70% while rice crop alone contributes 34% to the crop residues. Wheat ranks second with 22% of the crop residues whereas fibre crops contribute 13% to the crop residues generated from all crops. Among fibres, cotton generates maximum (53 Mt) with 11% of crop residues. Coconut ranks second among fibre crops with generation of 12 Mt of residues. Sugarcane residues comprising of tops and leaves, generate 12 Mt, i.e., 2% of the crop residues in India. Generation of crop residues of cereals is also highest in Uttar Pradesh (53 Mt), followed by Punjab (44 Mt) and West Bengal (33 Mt). Maharashtra contributes maximum to the generation of residues of pulses (3 Mt) while residues from fibre crops are dominant in Andhra Pradesh (14 Mt). Gujarat and Rajasthan generate about 6 Mt each of residues from oilseed" (Esposito, Sessa, Sica, & Malandrino, 2020) Crops.

On farm burning of crop residues and its utilization in India

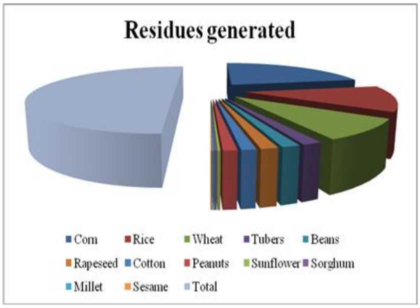
The utilization of "a crop residue varies across different states of the country. Traditionally crop residues have numerous competing uses such as animal feed, fodder, fuel, roof thatching, packaging and composting. The residues of cereal crops are mainly used as cattle feed. Rice straw and husk are used as domestic fuel or in boilers for parboiling rice. Farmers use crop residues either themselves or sell it to landless households or intermediaries, who further sell them to industries. The remaining residues are left unused or burnt on-farm. In states like Punjab and Haryana, where crop residues of rice are not used as cattle feed, a large amount is burnt on-farm. Sugarcane tops are either used for feeding of dairy animals or burnt on-farm for growing a ratoon crop in most parts of the country. Residues of groundnut are burnt as fuel in brick kilns and lime kilns. The residues of cotton, chilli, pulses and oilseed crops are mainly used as fuel for household needs. The shells of coconut, stalks of rapeseed and mustard, pigeon pea and jute and mesta, and sunflower are used as domestic" (Esposito, Sessa, Sica, & Malandrino, 2020) fuel.

The surplus residues i.e., total residues generated minus residues used for various purposes, are typically burnt on farm. "Estimated total amount of crop residues surplus in India is 91-141 Mt. Cereals and fibre crops contribute 58% and 23%, respectively (Fig. 3) and remaining 19% is from sugarcane, pulses, oilseeds and other crops. Out of 82 Mt surplus residues from the cereal crops, 44 Mt is from rice followed by 24.5 Mt from wheat, which is mostly burnt on-farm (Table 1). In case of fibre crops (33 Mt of surplus residue) approximately 80% of the residues are from cotton and are subjected to on-farm burning" (Atapattu, Ranasinghe, Nuwarapaksha, Udumann, & Dissanayaka, 2024)

Table No: 1 Distribution of Potential of Crop Residues.

Crops	**Residues generated**	**Percentage**
Corn	440.64	44.00
Rice	241.45	24.11
Wheat	176.46	17.62
Tubers	30.47	3.04
Beans	28.13	2.81
Rapeseed	27.05	2.70
Cotton	23.15	2.31
Peanuts	21.71	2.17
Sunflower	4.62	0.46
Sorghum	3.22	0.32
Millet	2.36	0.24
Sesame	2.19	0.22
Total	**1001.47**	**100**

Source: - EPWRF India Time



Sources-Computed by the researcher

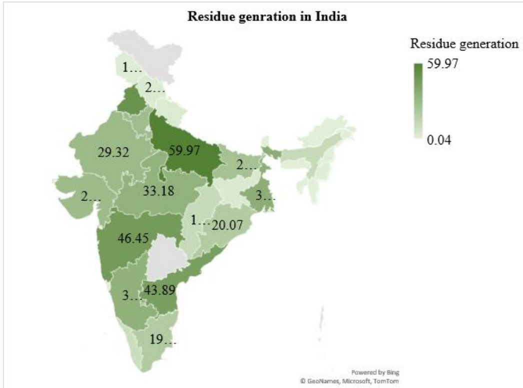
Table No: 2 State-wise crop residue generated, residue surplus and burned

(Crop residue in Million Tonne)

Sr. No	States	Residue generation	Residue surplus	Residue burned
1	Andhra Pradesh	43.89	6.96	2.73
2	Arunachal Pradesh	0.40	0.07	0.04
3	Assam	11.43	2.34	0.73
4	Bihar	25.29	5.08	3.19
5	Chhattisgarh	11.25	2.12	0.83
6	Goa	0.57	0.14	0.04
7	Gujarat	28.73	8.90	3.81
8	Haryana	27.83	11.22	9.08
9	Himachal Pradesh	2.85	1.03	0.41
10	Jammu &Kashmir	1.59	0.28	0.89
11	Jharkhand	3.61	0.89	1.10
12	Karnataka	33.94	8.98	5.66
13	Kerala	9.74	5.07	0.22
14	Madhya Pradesh	33.18	10.22	1.91
15	Maharashtra	46.45	14.67	7.42
16	Manipur	0.90	0.11	0.07
17	Meghalaya	0.51	0.09	0.05
18	Mizoram	0.06	0.01	0.01
19	Nagaland	0.49	0.09	0.08
20	Orissa	20.07	3.68	1.34
21	Punjab	50.75	24.83	19.65
22	Rajasthan	29.32	8.52	1.78
23	Sikkim	0.15	0.02	0.01
24	Tamil Nadu	19.93	7.05	4.08
25	Tripura	0.04	0.02	0.02
26	Uttarakhand	2.86	0.63	0.78
27	Uttar Pradesh	59.97	13.53	21.92
28	West Bengal	35.93	4.29	4.96
	Total	**501.73**	**140.84**	**92.81**

Source: - Ministry of New & Renewable Energy (MNRE, 2009), Govt. of India, New Delhi
$ Pathak Himanshu et.al (2010), Senior Scientist, C.E.S. & C.R., IARI, New Delhi

The above table depicted the information about the State-wise crop residue generated, residue surplus and burned. It is evident that the generation of crop residues is highest in the state of Uttar Pradesh (60 Mt) followed by the other states Punjab (51 Mt) and Maharashtra (46 Mt) with a grand total of 500 Mt per year out of which 92 Mt is burned. Rice and wheat contribute nearly 70% of the crop residues.



Sources-Computed by the researcher

Table No: 3 State-wise major cropped area under rice, wheat and sugarcane - Crops prone to residue burning

(Area in thousand ha.)

Sr. No	States	Area under major cereal crops and sugarcane			
		Rice	**Wheat**	**Sugar cane**	Crops prone to residue burning
1	Andhra Pradesh	3628.0	8.0	196.0	Rice & Sugarcane
2	Assam	2488.2	33.9	28.9	In jhum areas, plants, & bushes are burnt
3	Bihar	3298.9	2207.7	250.3	Rice, wheat and Sugarcane
4	Chhattisgarh	3784.8	101.2	13.5	Rice
5	Gujarat	701.0	1024.0	176.0	Rice and wheat
6	Haryana	1215.0	2497.0	101.0	Rice, Wheat & Sugarcane
7	Himachal Pradesh	76.9	364.2	1.9	No crop residue is burnt
8	Jammu & Kashmir	261.7	290.0	0.0	No crop residue is burnt
9	Jharkhand	1414.5	164.3	6.7	No crop residue is burnt
10	Karnataka	1278.0	225.0	425.0	Rice and Sugarcane
11	Kerala	197.3	0.0	1.7	No crop residue is burnt
12	Madhya Pradesh	1882.6	5300.0	59.5	Rice and wheat
13	Maharashtra	1557.0	773.0	933.0	Rice and Sugarcane
14	Odisha	4022.8	1.0	14.5	No crop residue is burnt
15	Punjab	2845.0	3512.0	83.0	Rice, Wheat and Sugarcane
16	Rajasthan	125.6	3063.2	5.5	No crop residue is burnt
17	Tamil Nadu	1493.1	0.0	347.2	Rice and Sugarcane
18	Uttarakhand	262.8	358.1	109.9	Rice and wheat
19	Uttar Pradesh	5861.0	9734.0	2212.0	Rice, Wheat and Sugarcane
20	West Bengal	5444.3	321.6	16.1	Rice
21	Others	915.4	25.1	17.2	No crop residue is burnt
22	**Total**	**42753.9**	**30003.3**	**4998.9**	
23	**Total (million ha.)**	**42.75**	**30.00**	**4.99**	

Source: Directorate of Economics & Statistics, MOA, DAC, New Delhi (final estimate 2012-13).

The above table No.3 demonstrated that the State-wise major cropped area under rice, wheat and sugarcane Crops prone to residue burning the states with the highest contribution to crop residue burning in India are Uttar Pradesh, Punjab, Haryana, and West Bengal. Rice, wheat, and sugarcane are the main crops that are burned.

Table No: 4 Global Crop Residue Production by Region (2021–2025)

Year	**Asia**	**America**	**Europe**	**Africa**	**Total**
2021	2385.0	1471.0	811.0	355.0	5073.0
2022	2482.0	1531.0	836.0	370.0	5274.0
2023	2520.0	1560.0	850.0	377.0	5364.0
2024	2570.0	1585.0	865.0	382.0	5460.0
2025	2620.0	1610.0	880.0	388.0	5557.0
Average	2515.4	1551.4	848.4	374.4	5345.2
CAGR	**2.38%**	**2.28%**	**2.05%**	**2.23%**	**2.30%**

Source: Food and Agriculture Organization of the United Nations

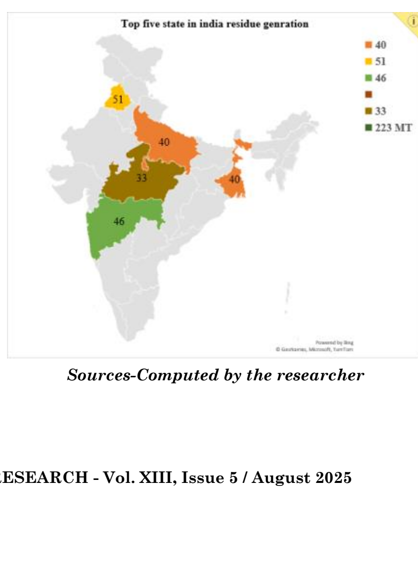
The table No.4 shows global crop residue production from 2021 to 2025, categorized by Asia, America, Europe, Africa, and Total. Asia leads production, increasing from 2,385.0 in 2021 to 2,620.0 in 2025. Africa contributes the least but shows steady growth. All regions show positive Compound Annual Growth Rates (CAGR), with the global total growing at 2.30% CAGR. This data, sourced from FAO reports, reflects agricultural output trends and residue management.

Table No: 5 Major States Contributing to Residue Generation (India)

State	**Residue (MT)**
Uttar Pradesh	40
Punjab	51
Maharashtra	46
West Bengal	40 33
Madhya Pradesh	33
Total (Top 5)	**223 MT**

Source: Ministry of New & Renewable Energy

The top five Indian states in terms of agricultural crop residue generation are Uttar Pradesh, Punjab, Maharashtra, West Bengal, and Madhya Pradesh. Uttar Pradesh generates 60 million tonnes of crop residues annually, primarily from rice, wheat, and sugarcane cultivation. Punjab contributes 51 million tonnes, primarily from paddy and wheat residues, much of which is burned on fields. Maharashtra contributes 46 million tonnes, mainly from sugarcane trash and cotton stalks. West Bengal and Madhya Pradesh each contribute 33 million tonnes.



Sources-Computed by the researcher

CONCLUSION AND POLICY SUGGESTIONS

Social, economic, and environmental sustainability are closely intertwined and necessary components for a truly sustainable agriculture. For example, farmers faced with poverty are often forced to mine natural resources like soil fertility to make ends meet, even though environmental degradation may hurt their livelihoods in the long run. Only by creating policies that integrate social, environmental, and economic interests can societies promote more sustainable agricultural systems.

REFERENCES

1. Bentsen, N. S., Claus, F., & Thorsen, B. J. (2014). Agricultural residue production and potentials for energy and materials services. *elsevier Progress in Energy and Combustion Science , 07* (07), 59-73.
2. R., D., B., K., S. S., & Chinnasamy, S. (2024). Recent advances in sustainable agro residue utilisation, barriers and remediation for environmental management: Present insights and future challenges. *Journal of Industrial Crops & Products , 12* (04), 1-19.
3. Nemtsov, D. A., & Zabaniotou, A. (2008). Mathematical modelling and simulation approaches of agricultural residues air gasification in a bubbling fluidized bed reactor. *Chemical Engineering Journal , 10* (10), 10-31.
4. Atapattu, A. J., Ranasinghe, C. S., Nuwarapaksha, T. D., Udumann, S. S., & Dissanayaka, N. S. (2024). Sustainable Agriculture and Sustainable Development Goals (SDGs). *Journal of Agriculture and Sustainable Development , 07* (08), 1-27.
5. Angesom, G. T., Asfafaw, H. T., & Muyiwa, S. A. (2024). Quantifying Agricultural Residues Biomass Resources and the Energy Potentials with Characterization of Their Nature and Ethiopian Case Consumption Inference. *Agro-crop resuide management research journal Mumbai , IV* (VI), 02-24.
6. Ghidey, F., Gregory, J. M., McCarty, T. R., & Alberts, E. E. (1985). Residue Decay Evaluation and Prediction. *American Society journal of Agricultural & Engineers , 13* (27), 102-105.
7. Update, U. (2011). *Crop Residues and Agricultural.* Maxcico: Oak Ridge National leboratory.
8. Bowyer, J. L., & Stockmann, V. E. (2017). Agricultural residues: An exciting bio-based raw material for the global panels industry. *FOREST PRODUCTS JOURNAL , 51* (01), 01-21.
9. Mohammed, N. I., Kabbashi, N., & Alade, A. (2018). Significance of Agricultural Residues in Sustainable Biofuel Development. Pakistan: Interested in publishing. *02* (03), 01-80
10. Esposito, B., Sessa, M. R., Sica, D., & Malandrino, O. (2020). Towards Circular Economy in the Agri-Food Sector. A Systematic Literature Review. *sustainability , XI* (IX), 1-21.
11. Soliwoda, M., Wieliczko, B., & Kulawik, J. (2020). Circular Economy Vs. Sustainability Of Agribusiness. *Circular economy sustainability of agribusiness jornal of science , 03* (05), 1-13.
12. José, A.-S. A., Joan, M. F., Ingrao, C., Failla, S., Bezamaf, A., Nemecek, T., et al. (2020). Indicators for Circular Economy in the Agri-food Sector. *international journal of homo science , 13* (12), 01-02.
13. Trendov, N. M. (2017). Index of Circular Agriculture Development in the Republic of Macedonia. *Visegrad Journal on Bioeconomy and Sustainable Development , II* (IV), 35-38.
14. ngrassia, M., Bacarella, S., Bellia, C., Columba, P., Adamo, M. M., Altamore, L., et al. (2023). Circular economy and agritourism: a sustainable behavioral model for tourists and farmers in the post-COVID era. *Journal of Frontiers in Sustainable Food Systems , 02* (13), 1-23.
15. Antonioli, D., Ghisetti, C., Mazzanti, M., & Nicolli, F. (2024). The economic returns of circular economy practices. *Journal of Sustainability, Environmental Economics and Dynamics Studies* (15), 1-19.