BIOMASS VALORIZATION IN ROMANIA: AVAILABILITY AND CURRENT USE OF AGRICULTURAL RESOURCES IN THE CIRCULAR BIOECONOMY

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RESEARCH ARTICLE

Abstract

Agricultural biomass represents a valuable resource for supporting sustainable development, particularly in rural areas. In Romania, large quantities of agricultural residues are generated annually from major crops such as wheat, maize, and sunflower; however, their potential remains insufficiently utilized due to fragmented management practices and limited development of valorization pathways. This paper aims to analyze the availability of biomass in Romania, assess its current use, and explore feasible valorization options within the framework of the circular bioeconomy. The study is based on secondary data from international and national statistical sources, including Eurostat and national databases. A descriptive approach is employed to estimate biomass availability and examine current management practices. The results indicate that a significant share of biomass is used for soil incorporation and animal-related purposes, while inefficient practices such as open-field burning still persist. Several valorization pathways are identified, including energy production, material use, and agricultural applications, each with distinct economic and environmental implications. The findings suggest that improving biomass management and developing integrated value chains could enhance resource efficiency, support rural development, and contribute to the transition towards a circular bioeconomy.

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INTRODUCTION

The transition towards a circular bioeconomy has become an increasingly important objective in the context of sustainable development, resource efficiency, and rural transformation. Within this framework, biomass represents a strategic resource because it can support the replacement of linear production models with more circular and integrated systems. Among the different biomass sources, agricultural residues are particularly relevant, as they are generated in large quantities and may provide additional economic opportunities for rural areas while also contributing to environmental protection (European Commission, 2018).

In Romania, agriculture continues to play an important economic and social role, which makes agricultural biomass a significant resource within the national bioeconomy potential. Large quantities of residues result annually from major crops such as wheat, maize, and sunflower (Eurostat, 2024). However, despite this availability, biomass valorization remains insufficiently developed. A considerable share of agricultural residues is used in traditional ways, such as soil incorporation or animal-related purposes, while other quantities remain underutilized or are managed through inefficient practices, including open-field burning. This situation highlights the gap between biomass potential and actual integration into circular value chains.

The relevance of this topic derives from the fact that biomass valorization can generate multiple benefits, including improved resource efficiency, reduced environmental pressure, diversification of rural income sources, and support for bio-based economic activities (Scarlat et al., 2015). At the same time, the issue should not be approached only from the perspective of resource abundance, but also in relation to current use patterns, management constraints, and realistic valorization options. In this sense, the present paper contributes through an applied analysis focused on Romania, combining biomass availability, current use, and feasible valorization pathways within a circular bioeconomy perspective.

The aim of this paper is to analyze the availability of biomass in Romania, assess its current use, and identify relevant valorization options within the circular bioeconomy. In order to achieve this aim, the study relies on

secondary data from international and national statistical sources, including Eurostat and national databases, and uses a descriptive analytical approach (Eurostat, 2024; FAO, 2024). The main objectives are to estimate biomass availability based on major crop production, to examine current utilization patterns, and to discuss the main opportunities and constraints associated with biomass valorization. The study is limited by its reliance on secondary data and by the fact that biomass use is not always fully captured in statistical records, especially at local level. Nevertheless, the paper provides a clear overview of the role that agricultural resources can play in supporting rural development and circular economic transition in Romania.

MATERIAL AND METHOD

This study is based on the analysis of secondary data regarding agricultural biomass in Romania. The main data sources include international and national statistical databases, such as Eurostat and national statistics, which provide information on crop production and agricultural activity.

The analysis focuses on major crops, including wheat, maize, and sunflower, which represent the main sources of agricultural residues. Biomass availability is estimated using crop production data and standard residue coefficients derived from the literature.

A descriptive analytical approach is employed in order to assess biomass availability and examine current use patterns. The study also includes a comparative analysis of different biomass valorization pathways, considering their economic and environmental implications.

The research is limited by the use of aggregated statistical data, which may not fully capture local variations and specific management practices. However, the approach allows for a general overview of biomass potential and utilization trends in Romania.

RESULTS AND DISCUSSIONS

Agricultural Biomass Availability in Romania

Agricultural production represents the primary source of biomass in Romania, particularly through major crops such as wheat, maize, and sunflower (Eurostat, 2024). These crops generate substantial quantities of agricultural residues, making them essential for the development of biomass-based value chains within the circular bioeconomy.

Table 1 presents the production levels of the main crops considered in this study for the period 2020-2025. The data indicate that maize has the highest production levels among the selected crops, followed by wheat and sunflower. However, production levels show considerable inter-annual variability, especially in the case of maize, which decreased significantly after 2021.

Table 1.

Agricultural production of major crops in Romania (2020-2025)

Year	Wheat (1000 t)	Maize (1000 t)	Sunflower (1000 t)
2020	6,392.37	10,096.69	2,122.87
2021	10,433.75	14,820.69	2,843.53
2022	8,684.24	8,037.13	2,106.57
2023	9,624.07	8,744.00	2,015.62
2024	9,290.88	5,971.85	1,508.00
2025	13,011.07	5,977.93	1,807.93

Source: Eurostat, Crop production database (apro_cp), harvested production in EU standard humidity (1000 t)

Wheat production also shows variability, with a notable increase in 2021 followed by fluctuations in the subsequent years. Sunflower production remains relatively more stable, although a decreasing trend can be observed in recent years. These variations reflect the influence of climatic conditions and other agronomic factors on crop yields.

Overall, the results confirm that Romania has a considerable agricultural biomass base; however, the availability of biomass is not constant over time and depends on both environmental and production-related factors. The most recent data (2024-2025) should be interpreted with caution, as they may be subject to future revisions.

Estimation of Agricultural Residues

Agricultural biomass in the form of residues was estimated based on crop production data and the application of residue-to-product ratios (RPR) (Scarlat et al., 2015). This method allows the conversion of primary agricultural production into secondary biomass, providing an overview of the potential volume of residues generated annually.

The estimation was performed using the following relationship:

$$residues\ (t) = production\ (t) \times RPR$$

For the main crops analyzed, fixed RPR values were used, namely 1.2 for wheat, 1.1 for maize, and 2.0 for sunflower, reflecting differences in crop structure and residue generation potential. Average production values for the period 2020-2025 were used in order to reduce the effect of inter-annual variability.

Table 2.

Estimated agricultural residues based on average crop production (2020-2025)

Crop	Average Production (1000 t)	RPR	Estimated Residues (1000 t)
Wheat	9572	1.2	11,486
Maize	9458	1.1	10,404
Sunflower	2067	2.0	4,134

Source: Author's calculations based on Eurostat data (Crop production database, apro_cp)

Note: Residue estimates are calculated using average production values and standard residue-to-product ratios (RPR).

The estimated quantities of agricultural residues are presented in Table 2. The results indicate that wheat and maize generate the largest amounts of residues due to their high production levels, while sunflower contributes significantly due to its higher residue coefficient.

It is important to distinguish between the theoretical potential of biomass, which represents the total amount of residues generated, and the sustainable potential, which refers to the fraction that can be removed without negatively affecting soil quality and agricultural productivity. preThis distinction is essential for ensuring that biomass valorization remains compatible with long-term sustainability.

Overall, the estimation confirms that Romania has a considerable potential of agricultural biomass; however, only a part of this biomass can be realistically mobilized, due to competing uses and environmental constraints.

Current Use of Agricultural Biomass in Romania

Agricultural biomass in Romania is currently used through a combination of traditional practices and limited valorization pathways. The utilization of crop residues is influenced by farm structure, local practices, and economic conditions, which leads to a heterogeneous pattern of biomass use across regions.

A substantial share of agricultural residues is incorporated into the soil, contributing to the maintenance of soil organic matter and fertility. This practice is particularly important in the context of sustainable agriculture, as it supports long-term soil productivity and reduces the need for external inputs.

Another important use of agricultural biomass is related to livestock, where residues are used as animal bedding or, in some cases, as feed components. These uses are especially relevant in mixed farming systems, where crop and livestock activities are interconnected.

However, not all biomass is efficiently utilized. In some cases, agricultural residues are burned in the field, despite regulatory restrictions, leading to negative environmental impacts such as air pollution and loss of valuable organic matter. Additionally, a portion of biomass remains underutilized due to logistical constraints, including high transportation costs and limited storage capacity.

Overall, the current use of agricultural biomass in Romania reflects a predominance of traditional practices, with limited integration into higher-value valorization pathways. This situation highlights the gap between biomass availability and its efficient use within the circular bioeconomy.

Biomass Valorization Pathways

The valorization of agricultural biomass represents a key component of the transition towards a circular bioeconomy (European Commission, 2018). In Romania, although traditional uses of biomass still dominate, several valorization pathways can be identified, each with specific economic and environmental implications.

Three main categories of biomass valorization are considered in this study: energy production, material use, and agricultural applications. These pathways differ in terms of technological requirements, added value, and level of development.

Energy production represents one of the most common valorization pathways. Agricultural biomass can be used for biogas production or direct combustion, contributing to renewable energy generation and reducing dependence on fossil fuels. However, this pathway is often limited by infrastructure

requirements, investment costs, and logistical challenges related to biomass collection and transport.

Material use offers higher value-added opportunities, as biomass can be transformed into bio-based products such as bioplastics, fibers, or construction materials. This pathway is closely linked to the development of bio-based industries and has considerable potential within the circular bioeconomy. Nevertheless, its implementation is still limited in Romania due to technological constraints and insufficient market development.

Agricultural applications include the reuse of biomass in farming systems, such as composting or mulching. These practices contribute to nutrient recycling and soil improvement, supporting sustainable agricultural systems. While widely applicable, their economic impact is generally lower compared to other valorization pathways.

The main characteristics of these pathways are summarized in Table 3.

Table 3.

Main biomass valorization pathways and their characteristics

Pathway	Advantages	Limitations
Energy production	Renewable energy source; reduces fossil fuel use	High investment costs; logistical constraints
Material use	High added value; supports bio-based industries	Limited infrastructure; market barriers
Agricultural applications	Improves soil quality; low cost	Lower economic return

Source: Author's elaboration based on literature and analysis of biomass utilization pathways

The comparison of these pathways highlights the need for a balanced approach that considers both economic feasibility and environmental sustainability.

Constraints and Opportunities

The effective valorization of agricultural biomass in Romania is influenced by a combination of structural, economic, and environmental factors. Despite the significant availability of biomass resources, several constraints limit their efficient integration into circular bioeconomy systems.

One of the main constraints is related to *logistics*. Agricultural biomass is spatially dispersed, and its collection, transport, and storage involve substantial costs. These challenges are amplified by the fragmented structure of farms, which reduces the efficiency of biomass aggregation and supply chains.

Economic factors also play an important role. In many cases, the costs associated with biomass valorization technologies exceed the potential economic benefits, particularly for small and medium-sized farms. In addition, limited access to investment capital and insufficient development of biomass-based markets further restrict the adoption of advanced valorization pathways.

From an *environmental perspective*, it is important to consider that not all agricultural residues can be removed from the field. A certain proportion must remain in the soil in order to maintain soil organic matter, prevent erosion, and ensure long-term agricultural productivity. This creates a trade-off between biomass extraction and soil sustainability.

At the same time, several opportunities can support the development of biomass valorization in Romania. European Union policies promoting renewable energy and circular economy practices create a favorable framework for investment and innovation (European Commission, 2018). The increasing demand for bio-based products also opens new market opportunities, particularly in the context of sustainable production systems.

Furthermore, the development of integrated value chains could improve the efficiency of biomass use, linking agricultural production with energy and industrial sectors. This would contribute not only to resource efficiency but also to rural development, by creating additional income sources and employment opportunities.

The main constraints and opportunities associated with biomass valorization in Romania are summarized in Table 4.

Table 4.

Main constraints and opportunities for biomass valorization in Romania

Factor	Constraint	Opportunity
Logistics	High transport and storage costs; dispersed biomass	Development of local supply chains
Farm structure	Fragmented farms	Cooperation and aggregation models
Economic factors	High investment costs; limited access to capital	EU funding and policy support
Environmental aspects	Limits on biomass removal (soil protection)	Sustainable biomass management practices

Source: Author's elaboration based on analysis of biomass systems and circular bioeconomy literature

Overall, the transition towards a circular bioeconomy in Romania requires a balanced approach that addresses existing constraints while capitalizing on emerging opportunities.

Therefore, policy support and coordinated actions are essential to unlock the full potential of agricultural biomass within the circular bioeconomy.

CONCLUSIONS

The results of this study confirm that Romania has a significant potential of agricultural biomass, mainly generated by major crops such as wheat, maize, and sunflower. The analysis of production data highlights both the high availability of biomass resources and their variability over time, influenced by climatic and agronomic factors.

The estimation of agricultural residues indicates that cereals represent the main source of biomass, while sunflower contributes significantly due to its higher residue-to-product ratio. However, the theoretical potential of biomass differs from the sustainable potential, as part of the residues must remain in the field to maintain soil quality and long-term agricultural productivity.

Current biomass use in Romania is dominated by traditional practices, such as soil incorporation and animal-related uses, while inefficient practices such as open-field burning still occur. This indicates that a considerable share of biomass is not valorized efficiently within the circular bioeconomy framework.

The analysis of biomass valorization pathways shows that energy production, material use, and agricultural applications offer different opportunities, with material use presenting higher added value but requiring more advanced infrastructure and market development.

Finally, the transition towards a circular bioeconomy in Romania is constrained by logistical, economic, and structural challenges, but also supported by considerable opportunities related to policy frameworks, market development, and rural economic diversification.

Overall, improving biomass management and developing integrated value chains are essential for improving resource efficiency and enabling the transition towards a more sustainable and competitive rural economy.

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