ROMANIAN AGRICULTURAL RESEARCH, NO. 40, 2023
First Online: November, 2022. DII 2067-5720 RAR 2022-33

# LIGNOCELLULOSIC BIOMASS AS AGRICULTURAL BIORESOURCE AND INPUT TO THE CIRCULAR ECONOMY

**Ionuţ Silviu Beia[1], Roxana Ciceoi[2*], Marius Mihai Micu[1], Violeta Elena Beia[3]**

[1]Faculty of Management, Economic Engineering in Agriculture and Rural Development, University of Agronomic Sciences and Veterinary Medicine Bucharest, Mărăști Blvd., no. 59, District 1, Bucharest, Romania

[2]Research Center for Studies of Food Quality and Agricultural Products, University of Agronomic Sciences and Veterinary Medicine of Bucharest, Mărăști Blvd., no. 59, District 1, Bucharest, Romania

[3]National Sanitary Veterinary and Food Safety Authority, Piaţa Presei Libere, no. 1, District 1, Bucharest, Romania

[*]Corresponding author. E-mail: roxana.ciceoi@qlab.usamv.ro

## ABSTRACT

**Given the global economic issues and environmental pollution, there is a growing interest in research addressing the use of biomasses resulting from agricultural production. One main category of biomass components is lignin, the use of plant waste in the pulp industry being one of the ways in avoiding additional deforestation by suppling inputs for the paper industry. The implementation of a strategy for capitalizing the potential of renewable sources, as, but not limited to, paper production, provides the appropriate framework for decision on renewable alternatives and inclusion in the acquis domains in Romania. The present study analyzed the potential use of waste obtained from field crops, mainly annual, as wheat, sunflower, maize, soy, rape, rye, barley, sorghum, rice, to produce paper. Biomass/waste from field crops is a promising source for paper, primarily because it is renewable and has the potential to exploit over 7 million hectares of arable land, with annual use. The diversity of pedoclimatic conditions in Romania makes possible the cultivation of a wider range of species and, within them, a multitude of varieties and hybrids, with variable amounts of lignocellulosic agricultural waste. In addition, accidental years as 2022, the year with the worst drought in Europe in the last 500 years, reshaped the need of valorizing any available biomass, regardless of the production of the main crop. Our calculations show that for a paper containing 28% of renewable cellulose, with the wheat straws collected from Romania in 2019, 9633.31 thousand tons of paper would have been obtained, with an average per hectare of 2786.62 kg of paper. Our analysis shows the opportunity of using lignocellulosic agricultural waste for use as a raw material for paper production. A throughout analysis is needed in the context of extreme droughts experienced recently, to show which valorization of by-products is the most economically justified.**

**Keywords:** biomass waste/secondary production, drought, pulp yield, paper, environmental protection, circular economy.

## INTRODUCTION

The recent GDO Analytical Report about drought in Europe depicts a ”fire-red Romania” when analyzing the Standardized Precipitation Index for the first six months of 2022 in Europe (Toretti et al., 2022).

In fact, climate change showed us its powers this year, by bringing in the worst drought in a half millennium, wildfires, reduced to zero crop yields, causing electricity shortages, transportation disruptions etc., with 17% of the European area under a state of alert and 47% under warning conditions in the first half of the year, and not at last, hundreds of heat-related deaths (Newburger, 2022).

At the end of August 2022, the Romanian Ministry of Agriculture and Rural Development announced that the affected area exceeded the threshold of 450,000 hectares at the national level, for the autumn crops (Agrointel, 2022). In this context, a lot of crops did not manage to produce their main yields, leaving the fields filled with dry biomass.

There is an important amount of literature on the use of annual plants wastes for fibrous pulp production and their use in obtaining different types of paper (Moisei et al., 2014).

In Romania, the pioneers of using straws in the manufacture of cellulose were Diaconescu and Obrocea (1974) with research on bleached cellulose with a high degree of whiteness and other varieties of

Received 7 September 2022; accepted 14 November 2022.

fibrous pulp. Also, the publications of the time highlighted the influence of the use of cellulose for the manufacture of paper of different qualities. Naturally, the advantages and disadvantages of using wheat straw as a raw material for pulp production were specified. The price of straw, in 2013, was 3 times lower than cellulose wood (Moisei et al., 2014). Considering that straw is less easily descaled than the wood, the other technological aspects (consumption of reagents and the method of obtaining the paste, temperature, and duration of the process, etc.) contribute to obtaining high-yield pastes. The advantages of straw pulp are clearly seen in the uniformity, smoothness, porosity, and opacity of the paper. Among the disadvantages are the seasonal nature of straw harvesting with the implications of storage, distance and transport costs and some difficulties in processing to regenerate reagents, reported by Argyropoulos (1994).

Examples of actions that could be implemented to obtain paper from agricultural pulp include the development and updating of guidelines and best practices for sustainable land and water use, as well as technical reports on current and future technologies for sustainable production, biomass in general.

According to Bran (2019), agriculture manifests its uniqueness as basis of resources by its continuous self-renewal, and agricultural production is the result of the processes of transformation of many substances and forms of energy into material goods with the help of living organisms, under specific conditions (under the influence of natural factors, working conditions etc.). Cereals are grown all over the world, the main three crops considered after the planted area being corn (43%), wheat (29%) and rice (19%), used in human nutrition, as fodder in the livestock sector, but also in industrial activities.

The diversity of soil and climatic conditions in Romania allows the cultivation of a wider range of varieties of wheat and maize hybrids (Mustăţea et al., 2009; Dinu et al., 2019). This genetic diversity is also valid for the other field species, as oilseeds. Genetic resources, now and in the future, are the key to sustaining global production, regardless of plant species. They embody diversity, which is essential for improving and maintaining production potential as it provides new sources of resistance and tolerance to biotic and abiotic stress. As the area sown with wheat is unlikely to increase due to arable land shortage, the productivity gains must come from the development and application of new technologies, which also ensure the stability of the world's first food crop, by meeting sustainability and environmental requirements. In 2013, 106 winter wheat varieties were cultivated in Romania, according to Teodor et al. (2018). The respective varieties are characterized not only by qualitative variability but also by vegetative mass (lignocellulosic biomass).

Plant breeding programs have generated genetic advances in productivity, coupled with important agronomic and physiological properties. According to Horhocea et al. (2021), a significant number of maize hybrids from maturity groups 300-500 were created, registered, and extensively cultivated. Their competitiveness in the market is pursued in terms of productivity and stability, resistance to disease and pests, resistance to falling and breaking of stems, but especially in terms of adaptive features to current climate change. Special attention is given lately to the drought resistance, continuous research being performed in different parts of the world for the evaluation of drought stress tolerance in some genotypes, as for wheat (Racz et al., 2020), barley (Epure et al., 2017; Filip et al., 2020), faba bean (Memari et al., 2022), maize (Petcu et al., 2018; Haş et al., 2022), alfalfa (Tyshchenko et al., 2020) etc.

The identification of some genotypes, which manages to capitalize on the environmental conditions in our country by obtaining high, stable, and quality production is the priority objective of agricultural research. According to Rezi et al. (2021), the identification of a new type of germplasm will allow further genetic progress. Descriptive statistics showed large variations for the agronomic characteristics of soybeans (plant height, insertion of the first pod, weight of 1000 grains) and qualitative

characteristics (linolenic acid). Correlations between traits can help future breeding guidelines, such as the development of varieties for specific purposes (food industry, animal feed, biofuels, even paper). However, by correlating the quality indices of agricultural production with the economic performance of cultivated areas and with cultivated varieties/hybrids, a coherent image can be outlined on the Romanian agricultural sector and its competitiveness. Increasing genetic diversity is necessary to cope with the social, natural, and economic challenges (Ciucă et al., 2018).

Compared to tree vegetation, which takes at least 25 years, depending on the tree species, to exploitation, agricultural land produces at least one crop per year, usually two, and thus agricultural waste becomes available every year. Greater access to the global stock of knowledge about biomass transformation and conversion technologies, the various types of bioproducts and bioenergy generated by these sources and the revenues from these activities must arouse interest for the development of logistics in the field in Romania.

Plant/crop resources are derived from a wide range of biological systems and processing flows in the food, feed, and fiber industries. They are renewable in a short time, by using annual crops, perennials (wood species can be joined with short rotation, but on land unsuitable for field crops). Romania has significant plant/crop resources in the productive agricultural system (concentrated on food and feed production), including forestry, pastures, and hayfields.

Arable crops occupy annually over 9 million hectares of Romanian arable land, of which, in 2019 (the last year with official records), 7.37 million ha were occupied by cereals and oleifers, of which 61% cereals, 20% oleiferous plants and 19% different other crops species from which significant amounts of lignocellulosic waste (biomass or secondary production) are produced. Agro-industrial biomass, as lignocellulosic waste, is cheap, renewable, abundant and offers a unique natural resource for large-scale collection. Biomass is composed of organic material and water, along with which, when collected, impurities may be present. For processing, the biomass must be in dry form, respectively when it reaches a stable equilibrium with the environment, with a water content of 10-15% (Roman et al., 2016).

Based on recent statistics available on the National Institute of Statistics, the present paper represents a scientific substantiation of the use of lignocellulosic biomass of the main nine Romanian arable crops, proposing a transitional business model towards a circular bioeconomy, especially in the context of excessive drought and extreme temperature seasons, when farmers risk being ruined by losses due to excessive drought. The agro-biomass has the potential to bring extra value for farmers (paperwise.eu) and it is up to us if we can valorize this idea or not.

## MATERIAL AND METHODS

As methodology, the study was conducted gradually, based on national statistical data provided by the National Institute of Statistics, in charge of the official statistics in Romania, organized a legal entity subordinated to the Romanian Government and official data provided by FAO or other institutions that provide online data.

To calculate the biomass (waste) production, the “grain: straw ratio” index was used.

To calculate pressure on paper industry, the per capita paper consumption and the structure of paper consumption were used, according to FAO.

To estimate the general trend, the values are adjusted by the average dynamic index method.

The adjustment equation is as follows:

$$Y_t = y_1 \cdot \bar{I}^{(t-1)} \quad (1.1)$$

where:

$$\bar{I} = \sqrt[n-1]{\prod_{t=1}^{n} I_{t/t-1}}$$

n-1 = the number of mobile-based dynamics indices.

The assessments are based on already existing data and statistics, while the processing and interpretation of data and their quantitative and qualitative analysis represent our contribution.

## RESULTS AND DISCUSSION

### *Lignocellulosic biomass production estimation*

Quantitatively, the biomass/waste (previously called secondary production) it is calculated according to the main crop production, as grain production of cereals, oilseeds, and technical plants (Figure 1) and based on the technological index "grain: straw ratio" (Table 1).

Grain production, influenced by pedoclimatic factors fluctuates, but there are also recent production increases due to improved genetic intake. Following the grain: straw ratio, it is observed that significant amounts of waste/biomass with appreciable cellulosic composition are obtained.

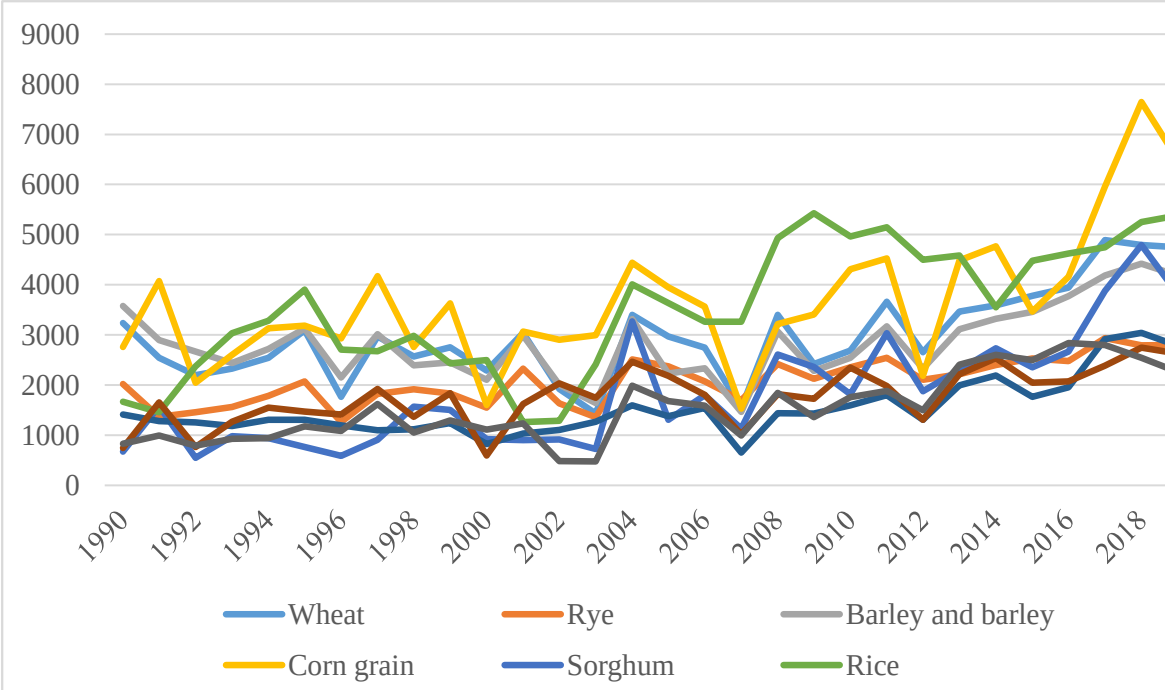



*Figure 1.* Average yields (kg of grain/ha; for 2020 the data are estimated by the INS as provisional)

As illustrated in Table 1, the best crops in term of biomass available for cellulose and the cellulose yield are soy (60%), wheat (40.3- 49.2%), rape (44%), and barley (40%).

*Table 1.* Grain ratio: straw and cellulose yield for cultivated species generating lignocellulosic waste

| No | Cultivated species | Grain ratio: straw | | Cellulose yield | |
|---|---|---|---|---|---|
| | | Grain/straw | Bibliographic source | % | Bibliographic source |
| 1 | Wheat | 1:1.3 | chemarkrom.ro | 40.3 | Martin-Sampedro et al., 2014 |
| | | | | 46.2-49.2 | Sun et al., 2005 |
| 2 | Rye | 1:1.3-1.5 | chemarkrom.ro | 37.9 | Sun et al., 2020 |
| 3 | Barley | 1:1 | chemarkrom.ro | 40 | 37.6%, Sun et al., 2005<br>35-45%, Chen et al., 2007 |
| 4 | Maize | 1:1.6 | chemarkrom.ro | 35.1 | Martin-Sampedro et al., 2014 |
| 5 | Sorghum | 1:3.75 | Roman, 2016 | 34.35 | Saini et al., 2015 |
| 6 | Rice | 1:1.3-3 | Singh et al., 1995 | 35 | Jiang et al., 2011 |
| 7 | Sunflower | 1:3 | chemarkrom.ro | 38.2 | Martin-Sampedro et al., 2014 |
| 8 | Soy | 1:1.5 | chemarkrom.ro | 60 | Batra, 1998 |
| 9 | Rape | 1:3 | chemarkrom.ro | 44 | Martin-Sampedro et al., 2014 |

As wheat is the crop grown on more land area than any other commercial food, it is suggested to develop the paper production from wheat biomass, as the average yield of cellulose may be 780253 kg/ha (Table 2). If 28% of the paper composition is renewable cellulose, with the wheat straw collected from Romania in 2019, 9633,311 thousand tons of paper would have been obtained, with an average per hectare of 2786.62 kg of paper.

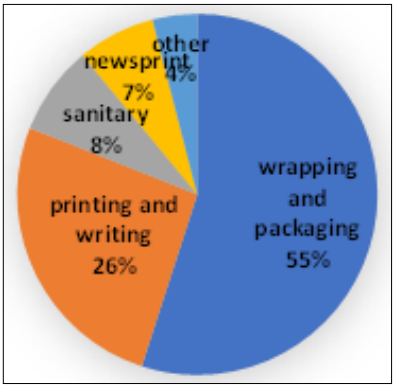
*Table 2.* The amount of cellulose that can be obtained from wheat straw

| Specification | Wheat | 2019, tons | Average for 30 years (1990-2019), kg/ha |
|---|---|---|---|
| Grains | multiannual average | 10297107 | 2978.633 |
| Grain ratio:straw = 1:1.3 | total pay | 1386239.1 | 3872223 |
| Good environmental conditions (40% remain on the ground) + 10% humidity | harvestable straws | 6693119.55 | 1936112 |
| Cellulose yield, 40.3% (Martin-Sampedro, 2014) | wheat straw cellulose | 2697327.179 | 780253 |

***The world paper demand estimation***

According to FAO statistics, in 2016, per capita paper consumption was as follows: North America 215 kg; EU 125 kg; Oceania 113 kg; Asia 44 kg; Latin America 43 kg; Africa 7 kg.

By category, worldwide (FAO), the structure of paper consumption is shown in Figure 2, where packaging is found to be the largest consumer of paper.




Source: tonerbuzz.com

*Figure 2.* Structure of global paper consumption (by paper categories)

The packaging (the business card of the product) that contributes to the realization of the Sustainable Development Strategy of the European Union must meet many requirements (Procarton, 2018):

- be holistically designed with the product to optimize overall environmental performance;
- be made of materials from responsible sources;
- be designed to be efficient and safe throughout its life cycle;
- meet market criteria for performance and cost;
- to meet consumer choice and expectations;
- to be recovered effectively after use.

Such conditions raise demands from the beginning of the paper / cardboard production chain. In addition to the growing demand for paper, pulp is widely used in a variety of economic and technical fields (medicine, gastronomy, and household goods) due to its functionality, recyclability and, most importantly, its biodegradability (Didone et al., 2017; Saxena et al., 2018).

In Romania, the paper industry is relatively rich in specific products (Figure 3) and has a structure in favor of paper, cardboard, and cardboard (Figure 4).

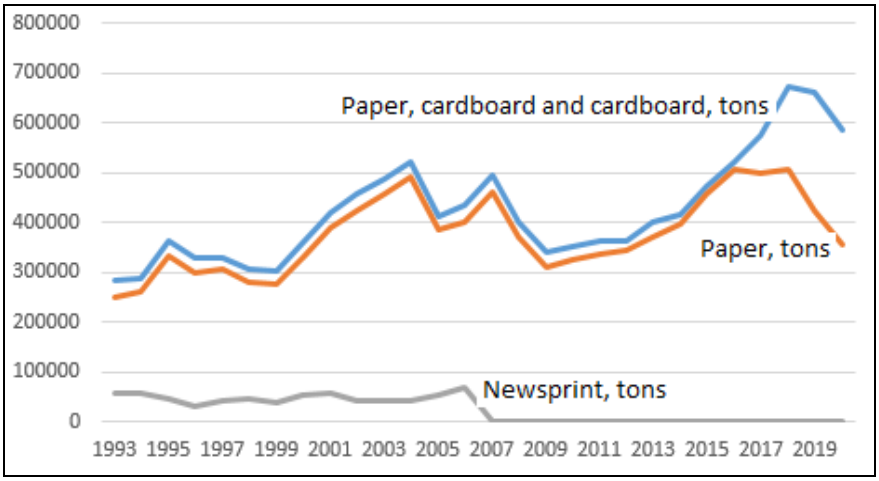



*Figure 3*. Paper production (Source: INS)

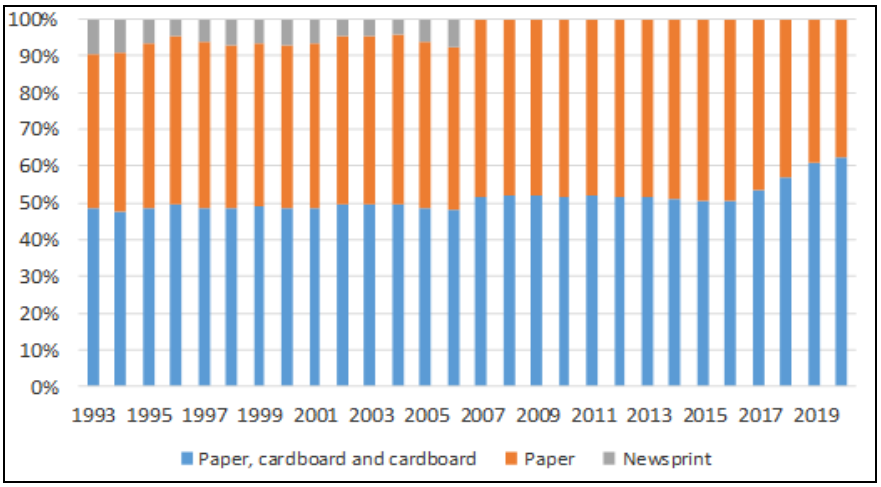



*Figure 4*. Paper production structure (Source: INS)

***The prognosis of obtaining paper from renewable waste***

Regarding the cellulose and semi-cellulose productions in Romania, data of the paper industry are statistically registered until the year 2008, after which data is uncertain.

Still, in the Statistic book, the trend of export and import of wood pulp, paper, and paperboard is ascendent for both activities (Figure 5), while the report between export and import diminished continuously, from 2.81 in 2015 to 2.31 in 2021 (Andrei et al., 2022).

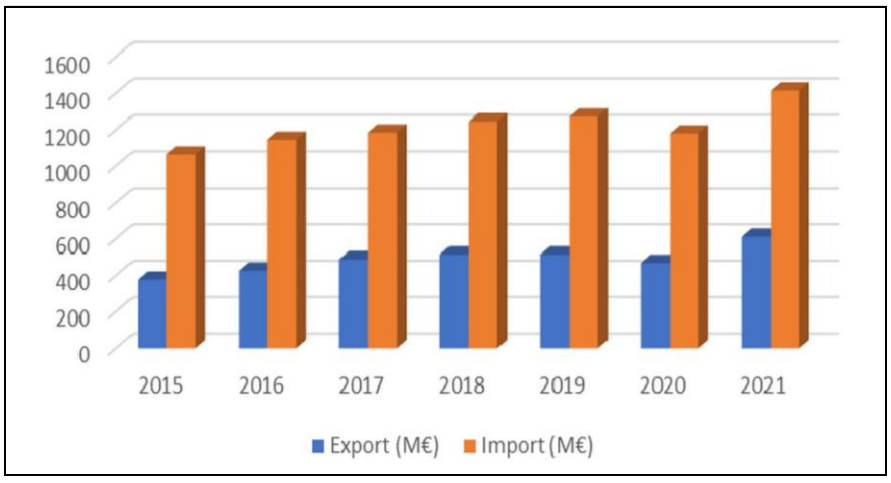



*Figure 5*. International trade (in million Euro) of pulp of wood, paper, paperboard, in 2015-2021 period

Knowing the technological aspects, production statistics, the yield of cellulose in straw and stems and the renewable component of the paper product, the total amount of paper was determined. If of wheat straw collected from Romania in 2019, 2786.62 kg of paper per hectare would have been produced and the same reasoning for the other eight cultivated species would have been maintained, we discovered that the straw and the stems of the cultivated species have a favorable and consistent contribution for obtaining the paper. The actual values of paper production that could have been obtained and the adjusted values calculated based on relation 1.1 are presented in Table 3.

*Table 3.* Adjustment by the average dynamic index method

| Year | Paper (kg/ha) | Time | $Y_t = 2213.88 \cdot 1.0303205^{(t-1)}$ |
|---|---|---|---|
| 1990 | 2213.88 | 1 | 2213.88 |
| 1991 | 2543.49 | 2 | 2281.01 |
| 1992 | 1920.58 | 3 | 2350.17 |
| …. | | …. | …. |
| 2019 | 5264.45 | 30 | 5264.45 |

The extrapolated values for the next five years were obtained using the same adjustment formula, giving the variable t the following values on the time axis, keeping the same origin:

$Y_{2020} = 2213.88 \cdot 1.0303205^{30} = 5424.8$ kg

$Y_{2021} = 2213.88 \cdot 1.0303205^{31} = 5589.3$ kg

$Y_{2022} = 2213.88 \cdot 1.0303205^{32} = 5758.8$ kg

$Y_{2023} = 2213.88 \cdot 1.0303205^{33} = 5933.4$ kg

$Y_{2024} = 2213.88 \cdot 1.0303205^{34} = 6113.3$ kg

A graphic representation of the trend can be seen in Figure 6.

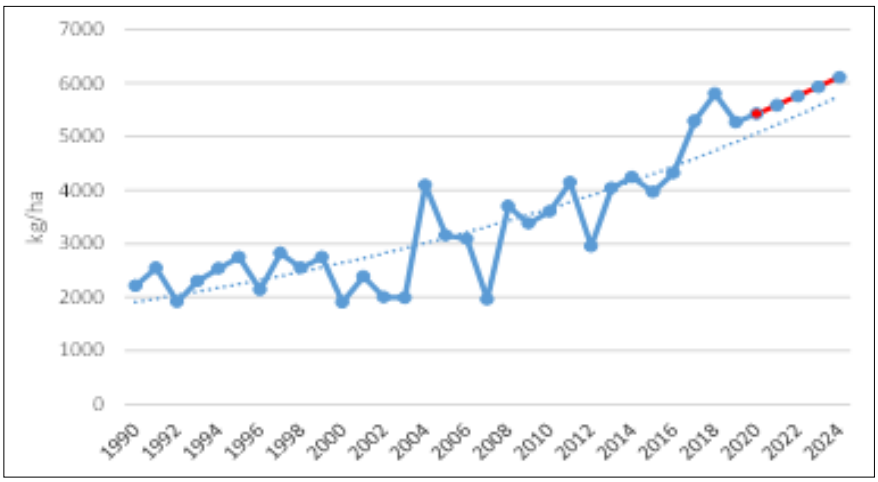



*Figure 6.* Forecast of pulp from agricultural waste (original)

Although the paper production had an oscillating evolution in the period 1990-2019, registering an average annual increase of 1.03 times, for the next 5 years a gradual increase is forecast from 5424.8 kg to 6113.3 kg. The prognosis of obtaining paper from renewable waste being ascending, the confidence in a healthy environment increase.

In Romania, producers of pulp, mechanical pulp, paper and board (paper-world.com) are: SC Ambro S.A., Rossmann Group, Suceava; SC DS Smith Paper Zărneşti S.R.L., Zărneşti Mill; SC Pehart Tec S.A., Pehart Tec Group, in Petreşti; SC Petrocart S.A., in Piatra-Neamţ; SC Vrancart S.A., Adjud; Sofidel Romania S.A., Sofidel Group, in Călăraşi.

If we add up all the categories of companies introduced in the paper-world.com statistics, Romania accounts for 50 companies with concerns in the field of paper: producers of pulp, mechanical pulp, paper, and board; paper and board converters; merchants; waste, recovered paper merchants; trade services; suppliers; associations and institutions; trade journals. Choosing to make paper from the cellulosic part of the plant that supports the food product is an option with multiple advantages, some of them already mentioned. According to paperwise.eu, when crops such as rice, wheat, barley, cereals, corn, hemp, and sugar cane are processed, 80% of the plants (the stems and leaves) are considered agricultural waste and is either left unused, either, even more dramatic, is burned, contributing to atmospheric pollution.

Agricultural waste is available every year; the use of agricultural waste, trees and forests are saved; the processing of agricultural waste in paper has a smaller impact on the environment than the production of pulp from tree timber; the agricultural profit from cellulose is 1.5 times higher per hectare than the hectare of forest; one piece of agricultural land is needed for two products (food and paper raw material) and one plant for the same two products. The same source exemplifies the advantages in numbers: for five boxes of A4 print or copy paper, one tree is saved on average; at 400 boxes, one hectare of forest is saved.

If the copier paper has the format 210 * 297 mm and in a top, there are 500 sheets, and the weight is 80 g/m$^2$, the top has 2,449 kg and the box 24,948 kg. Making the analogy of the advantages listed above, it results with an average per hectare of 2786.62 kg of paper obtained only from wheat straw, 0.285 ha of forest is saved from cutting; only with the paper from the wheat straw production of 2019, 985.16 ha of forest would have been saved.

Skills development, the implementation of sustainable technologies and the use of land and water resources are essential for sustainable production and, together, can increase the volume of raw materials and commodities (paper, pellets, bioethanol, etc.) in a sustainable way.

## CONCLUSIONS

The paper provides a knowledge base to contribute to the regional development of new value chains based on agricultural lignocellulosic resources in Romania, under evaluated and poorly used at the moment. As a methodology, the study was conducted gradually and emphasized the aspect of circularity. It proposes a transitional business model towards a circular economy based on the bioeconomy. This perspective sums up technological, environmental, economic, social, and circular aspects. Information is provided on the availability of lignocellulosic waste of nine crop species with high importance in the Romanian arable land and the existence of experience in the field of obtaining paper. There are already some movements towards annual biomass converted into paper, as by AgroPower-Energy company (AgroPower-Energy, 2013).

Considering the use of local agricultural waste for paper and cardboard, a new value is created, which keeps the carbon stored in a product longer (due to repeated recycling) and amplifies the tendency to combat climate change, while contributing to the circular economy. The impact on circularity is manifested by the efficiency of resources, in the sense of improving land use, exploiting natural favorability and recycling paper several times (seven times according to the literature). Relying on internal raw material resources the vision is to ensure continued economic growth and healthy living standards. Regarding the impact on the economy, it is specified as being influenced not only by the raw material (it is cheap) from which the paper is obtained, but also by the other stages of the supply chain.

The paper industry based on agricultural waste produces an increase in bioeconomic activities, related jobs, and rural incomes.

Bioresources make their mark, specifically, on the environment. Thus, agricultural field species, due to their rapid growth, capture more $CO_2$ than trees, and the transformation of residual lignocellulosic biomass allows the storage of absorbed $CO_2$. By obtaining the paper, the absorbed $CO_2$ can stay in the circuit longer by recycling. As a result, it is important to consider sustainable harvest levels so as not to have a negative effect on soil fertility. The situation was provided for in the calculations undertaken to determine the amount of waste as a raw material for processing. Circular economy approaches provide a way to use resources in a sustainable way so that maximum use of resources can be maintained for future generations.

The challenge now is to materialize the research, to realize the bioeconomy, to create new perspectives for the regional economies in balance with the earth's limits.

## ACKNOWLEDGEMENTS

This work was supported by a private-sector research project, no. 782 /06.05.2022, entitled "Research on the management of the quality of organic production of the Florea Comflor S.R.L. farm, to guarantee food safety in the organic agri-food chain".

## REFERENCES

Agrointel, 2022. *MADR: The area of crops affected by drought exceeded the threshold of 450,000 hectares.* https://agrointel.ro/233591/madr-suprafata-de-culturi-calamitate-de-seceta-a-depasit-pragul-de-450-000-de-hectare/ (accessed September 01, 2022). (In Romanian)

Agropower-energy, 2013. *Biomass from agriculture [Agro-biomasa]*. http://www.agropower-energy.ro/index.php?page=agro-biomasa. (In Romanian)

Andrei, T., Ciuchea, A., Pisică, S., Gheorghe, F., Sinigaglia, L.C., Pintilia, L., Marinescu, A.A.M., Ioniță, A.C., Bălteanu, L., Cambir, A., Alexevici, N., Dima, I., Cîrstea, F., Constantinescu, G., Ștefănescu, D., 2022. *Romania in figures*. National Institute of Statistics, Bucharest.

Argyropoulos, D., 1994. *Quantitative Phosphorus-31 NMR analysis of lignins, a new tool for the lignin chemist.* Journal of Wood Chemistry and Technology, 14(1): 45-63.

Batra, S.K., 1998. *Other long vegetable fibers*. In: Lewin, M., Pearce, E.M. (eds.), Handbook of Fiber Science and Technology, Fibre Chemistry, 4. Marcel Dekker Inc., New York: 505-571.

Bran, Ş.D., 2019. *Bioeconomia şi perspective*, Doctoral thesis, ASE Bucharest.

Chen, Y., Sharma-Shivappa, R.R., Deepak Keshwani, D., Chen, C., 2007. *Potential of agricultural residues and hay for bioethanol production*. Biological Systems Engineering: Papers and Publications, 79.

Ciucă, M., Cristina, D., Turcu, A-G., 2018. *SSR MARKER TSM106 is a convenient tool for identifying wheat-rye 1AL.1RS translocation*. Romanian Agricultural Research, 35: 11-14.

Diaconescu, V., and Obrocea, P., 1974. *Tehnologia celulozei şi hârtiei*. Ed. Tehnică, 1: 17.

Didone, M., Saxena, P., Brilhuis-Meijer, E., Tosello, G., Bissacco, G., Mcaloone, C.T., Antelmi Pigosso, D.C., Howard, T.J., 2017. *Moulded pulp manufacturing: Overview and prospects for the process technology*. Packag. Technol. and Sci., 30: 231-249.

Dinu, M., Bran, Ş.D., Petrescu, E.I., 2019. *The economic and environmental impact of plant resources in Romania*, International Multidisciplinary Scientific GeoConference - SGEM, Sofia, 19: 5.3.

Epure, D.-G., Becheritu, M., Cioineag, C.F., 2017. *Prediction of drought resistant lines of winter wheat using canopy temperature depression and chlorophyll content analysis*. AgroLife Scientific Journal, 6(1): 104-111.

Filip, E., Russu, F., Porumb, I., Muntean, L., Ona, A., Boanta, A., Pamfil, D., Borza, G., 2020. *Research regarding the approach of drought tolerance of two-row spring barley*. AgroLife Scientific Journal, 9(1): 127-131.

Haş, V., Tritean, N., Copândean, A., Vana, C., Varga, A., Călugar, R., Ceclan, L., Simon, A., 2022. *The impact of climate change and genetic progress on performance of old and recent released maize hybrids created at the ARDS Turda*. Romanian Agricultural Research, 39: 99-110.

Horhocea, D., Martura, T., Iordan, H.L., Băduţ, C., Ciocăzanu, I., 2021. *Magnus, semi-early maize hybrid, released by the NARDI Fundulea*. An. INCDA Fundulea, LXXXIX: 3-16.

Jiang, M., Zhao, M.M., Zhou, Z.W., Huang, T., Chen, X.L., Wang, Y., 2011. *Isolation of cellulose with ionic liquid from steam exploded rice straw.* Industrial Crops and Products, 33(3): 734-738.

Martin-Sampedro, R., Eugenio, M.E., Moreno, J.A., Revilla, E., Villar, J.C., 2014. *Integration of a kraft pulping mill into a forest biorefinery: Pre-extraction of hemicellulose by steam explosion versus steam treatment.* Bioresource Technology, 153: 236-244. doi:10.1016/j.biortech.2013.11.08

Memari, M., Reza Dadashi, M., Sheikh, F., Ajamnoruzi, H., 2022. *Evaluation of drought stress tolerance in some faba bean genotypes using drought tolerance indices.* Romanian Agricultural Research, 39: 35-43.

Moisei, N.M., Puiţel, A.C., Gavrilescu, D., Tofănică, B.M., 2014. *Fibre şi energie din paie*. Celuloză şi Hârtie, 63(1), Brăila, Romania.

Mustăţea, P., Săulescu, N.N., Ittu, G., Păunescu, G., Voinea, L., Stere, I., Mîrlogeanu, S., Constantinescu, E., Năstase, D., 2009. *Grain yield and yield stability of winter wheat cultivars in contrasting weather conditions.* Romanian Agricultural Research, 26: 1-8.

Newburger, E., 2022. *Europe is experiencing its worst drought in at least 500 years*. CNBC, https://www.cnbc.com/2022/08/23/europe-drought-worst-in-at-least-500-years-eu-report.html (accessed September 01, 2022).

Petcu, E., Martura, T., Ciocăzanu, I., Iordan, H.L., Băduţ, C., Urechean, V., 2018. *The effect of water stress induced with PEG solution on maize seedlings.* Romanian Agricultural Research, 35: 21-28.

Procarton, 2018. *Sustainability - a concept from yesterday or for tomorrow?* https://www.procarton.com/sustainability-a-concept-from-yesterday-or-for-tomorrow/

Racz, I., Urdă, C., Kadar, R., Tritean, N., Duda, M.M., Muntean, E., Muntean, L., 2020. *Effects of artificially drought induced by chemical desiccation in several winter wheat (Triticum aestivum L.) genotypes*. Romanian Agricultural Research, 37: 25-34.

Rezi, R., Urdă, C., Negrea, A., Russu, F., Păcurar, L., 2021. *Variability assessment of some quantitative traits in several Asiatic and European soybeans genotypes*. An. INCDA Fundulea, LXXXIX: 39-46.

Roman, Gh.V., Ion, V., Epure, L.I., Băşa, A.Gh., 2016. *Biomasa. Sursă alternativă de energie*. Ed. Universitară, Bucharest.

Saini, J.K., Saini, R., Tewari, L., 2015. *Lignocellulosic agriculture wastes as biomass feedstocks for second-generation bioethanol production: concepts and recent developments*. 3 Biotech, 5: 337-353. https://doi.org/10.1007/s13205-014-0246-5

Saxena, P., Bissacco, G., Bedka, J.F., Stolfia, A., 2018. *Tooling for production of the green fiber bottle*. Procedia CIRP, 69: 348-353.

Singh, R.B., Sana, R.C., Singh, M., Chandra, D., Shukla, S.G., Walli, T.K., Pradhan, P.K., Kessels, H.P.P., 1995. *Rice straw - its production and utilization in India*. Handbook for Straw Feeding Systems, ICAR, New Delhi, India.

Sun, J.X., Xu, F., Sun, X.F., Xiao, B., Sun, R.C., 2005. *Physico-chemical and thermal characterization of cellulose from barley straw*. Polymer Degradation and Stability, 88(3): 521-531

Sun, R.C., Fang, J.M., Tomkinson, J., 2020. *Delignification of rye straw using hydrogen peroxide*. Industrial Crops and Products, 12: 71-83.

Teodor, C., Bran, M., Strat, V.A., 2018. *The influence of land structure on performance of wheat production. The case of the Romanian counties-challenging the changes*. Economic Computation and Economic Cybernetics Studies and Research, ASE Bucharest, 52(1).

Toretti, A., Masante, D., Acosta Navarro, J., Bavera, D., Cammalleri, C., De Felice, M., de Jager, A., Di Ciollo, C., Hrast Essenfelder, A., Maetens, W., Magni, D., Mazzeschi, M., Spinoni, J., 2022. *Drought in Europe July 2022*. EUR 31147 EN, Publications Office of the European Union, Luxembourg, doi:10.2760/014884 (online).

Tyshchenko, O., Tyshchenko, A., Piliarska, O., Kuts, H., Lykhovyd, P., 2020. *Evaluation of drought tolerance in alfalfa (Medicago sativa) genotypes in the conditions of osmotic stress*. AgroLife Scientific Journal, 9(2): 353-358.

*** https://chemarkrom.ro/ruinex-pentru-o-mineralizare-mai-buna/

*** https://paperwise.eu/en/vision-and-mission/

*** https://www.paper-world.com/en/business-directory/company-database?countryplace=Romania&ftyp%5B0%5D=1

*** https://www.tonerbuzz.com/facts-about-paper/