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CONTENT:

SELECTION OF SALES DISTRIBUTION CHANNEL IN AGRICULTURAL ENTERPRISE[1]

Miroslav Nedeljković[2], Lana Nastić[3], Adis Puška[4]

Abstract

According to applied TOPSIS multi-criteria decision-making method (*Technique for Order of Preference by Similarity to Ideal Solution*), in paper was selected adequate sales distribution channel in one enterprise active within the agro-food sector at the territory of Semberija (BiH). Decision makers, in this case represented by employed management in enterprise, have been evaluated five sales distribution channels in enterprise in line to previously defined criteria, i.e. products' characteristics, company's financial situation, consumer habits, production costs, geographic concentration, and products' assortment.

The main goal of research was to create a model for optimal selection of sales channels, while derived results have been showed that the model "producer - seller (retailer) - consumer" is the most adequate towards the predefined selection criteria. In addition to the justified role of used method in selection of offered alternatives, article also represents a base that will serve in further research, whose focus would be on modernizing of existing and searching for new distribution channels in agricultural enterprises.

Key words: Distribution channel, sales, TOPSIS method, multicriteria decision-making, agricultural enterprise.

JEL[5]: Q13, M21, D30

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Introduction

Complexity of doing business activities in agribusiness sector requires special attention to the choice of sales distribution channels. One of key goals of any enterprise's business is reliable and cost-effective delivery of final product to the end user (customer). In this supply chain, it is important to preserve the quality of product, as well as to retain current consumers, while on that way to recommend to the new one. As was noted by Harimurti et al. (2019) with appropriate and efficient distribution, the choice of sales channels will lead to situation that consumers will get their products more easily. Today's market imposes certain requirements according to distribution to end consumers. In line to that Siddharta et al. (2017) conclude that all products must be distributed by certain methods and on realistic basis.

Selecting the proper sales distribution channel is a permanent process in any enterprise. Distribution channels are variable and there are many factors that affect making of adequate decision towards them. Thus, regarding the choice of distribution channels Đalić et al. (2020) recommend the constant monitoring of all factors of influence on distribution channel in certain enterprise. Special attention has been given to distribution channels of agricultural products, whether they represent raw materials, semi-processed agro-food products, or final food products. This stems from the very specificity of agricultural production, as well as from the large number of legal entities that appear in observed chain.

In previous research, many authors have been focused to analysis of sales distribution channels. So, Dent (2011) carefully analyzes the concept and importance of sales distribution channels, while Rosenbloom (2012) explains distribution channels and their relationship with other marketing instruments. In his research Singh (2012) claims that business success and competitive advantage of some enterprise largely depends from decisions linked to sales distribution channels. Several authors are seeking for solution of the best method in choosing a distribution channel that will allow the easiest access to the end users in any sector of production (Vasiliauskas et al., 2010; McCabe et al., 2011; Schegg et al., 2013; Thakran, Verma, 2013).

As the subject of this paper is sales distribution channel in one enterprise active in agribusiness sector at the territory of Semberija region in B&H, as well as the paper goal is to create a model for selecting the best distribution channel for enterprise products' assortment, there will be mentioned some previous researches linked to observed sector of economy.

Miljković and Alčaković (2015) emphasize all specificities of distribution channels in agriculture, which are on other side connected with all characteristics of certain line of agricultural production and legal entities present in channel. Milanović and associates (2020) point up the product's distribution as one of the crucial elements of competitiveness of companies in agriculture, highlighting the specificities that appear during the channel implementation. In their research, Stevanović Tosovic and associates (2020), use the AHP method of multi-criteria decision-making (*Analytic Hierarchy Process*) in order to evaluate distribution channels at small farms. They developed a model that enables a structured and efficient assessment of distribution channel for products delivered from small farms.

In his research Zhu (2020) examines distribution channels in majority of EU member states set at producers of organic agricultural products, while he divides them as direct, indirect and new distribution channels. Also, many other authors make their contribution in analysis and development of distribution channels in agribusiness sector (Ponce-Cueto, Carrasco-Gallego, 2009; Li et al., 2013; Shi et al., 2013; Gajdić et al., 2018).

Methodological Framework

In order to achieve the research goal in paper is used one popular multi-criteria decision-making method TOPSIS (*Technique for Order of Preference by Similarity to Ideal Solution*). Reasons for this lie in fact that the method is simple to apply, as well as its frequently used in research where the emphasis is on decision or choice. Method characterizes that the chosen alternative should has the shortest distance from the positive and the longest distance from the negative ideal solution (Lu et al., 2007). Confirmation of its often use is reflected in many published articles (Ciardiello, Genovese, 2023; Mitra et al., 2023; Azadi et al., 2023; Qin et al., 2023; Nedeljković et al., 2023).

Steps used for method appliance are explained in following paragraphs.

Step 1. Normalization of decision-making matrix

In the first step, there come to normalization of all elements within the matrix, by which all data are transformed and for all criteria are maximizing the set objective function.

$$\begin{matrix} C_1 & C_2 & \cdots & C_m \\ w_1 & w_2 & \cdots & w_m \end{matrix}$$

$$R = \begin{matrix} A_1 \\ A_2 \\ \vdots \\ A_n \end{matrix} \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{nm} \end{bmatrix}$$

Step 2. Multiplying of normalized decision-making matrix with weighted criteria. In this step it has been multiplied normalized matrix with certain weights of the given criteria, what derive the data needed for further analysis.

$$V = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ r_{n1} & r_{n2} & \cdots & r_{nm} \end{bmatrix} \cdot \begin{bmatrix} w_1 & 0 & \cdots & 0 \\ 0 & w_2 & \cdots & 0 \\ \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & \cdots & w_m \end{bmatrix} = \begin{bmatrix} n_{11} & n_{12} & \cdots & n_{1m} \\ n_{21} & n_{22} & \cdots & n_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ n_{n1} & n_{n2} & \cdots & n_{nm} \end{bmatrix}$$

Step 3. Determination of ideal solutions

In this step, it is obtained a positive ideal solution (A*) by which it is maximized a desired function, while by obtained negative ideal solution (A^) it is minimized a desired function.

$$A^* = \left(\max n_{ij} \mid j \in V\right), \left(\min n_{ij} \mid j \in V'\right)$$

$$A^- = \left(\min n_{ij} \mid j \in V\right), \left(\max n_{ij} \mid j \in V'\right)$$

$$V = (j = 1, 2, \ldots, m \mid j \text{ belongs to criteria which are maximising})$$

$$V = (j = 1, 2, \ldots, m \mid j \text{ belongsto criteria which are minimizing})$$

Step 4. Determination of alternative's distances from ideal solutions

In this step, the n-dimensional Euclidean distances of all given alternatives are calculated.

$$S_i^* = \sqrt{\sum_{j=1}^{m} (n_{ij} - n_j^*)^2}$$

$$S_i^- = \sqrt{\sum_{j=1}^{m} (n_{ij} - n_j^-)^2}$$

Step 5. Determination of relative closeness of alternatives to ideal solution. In this step it is determined the relative distance based on the expression where the result should be in range $0 \leq Q_i^* \leq 1$.

$$Q_i^* = \frac{S_i^-}{S_i^* + S_i^-}$$

Step 6. Ranking of alternatives. All alternatives will be ranked by decreasing value of Q_i^*. Chosen alternative will be one that is closest to 1, or equals 1.

All results in case study will be presented by adequate tables and graphs.

Case Study Description

Research was done in form of case study in certain enterprise belongs to the category of small enterprises (up to 20 employees), while it is located at the territory of Bijeljina municipality (BiH). The company is private owned and it was established in 2005. Its main activity is processing of fruits and vegetables (sweet and sour program). In recent years, the enterprise has become widely recognized, primarily thanks to its well-chosen production program and high quality of gained food products.

Through the hot processing of fruits, there are produced different compotes, marmalades, or jams, while through the hot processing of vegetables, company is offering to the market winter salads in sour-salty souse, tomato juice, ajvar and pinjur. The overall foodstuff program is in line to principles of organic production, i.e. besides the organic fruit and vegetables as a raw material, there are no preservatives used, while the food preservation is exclusively done by the process of pasteurization. In addition, the enterprise has available its own vegetable and fruit production, while the part of raw materials is buying at local market from local suppliers, as the enterprise is located in area well recognized by intensive crop and vegetable production.

Using the available resources and previous business experience, enterprise is constantly improving and broadening the products assortment striving to penetrate at new markets. Recently, management has been trying to improve its sales by developing new sales channels, or by modernizing used ones. As this is typical locally or export-sales oriented company (closeness to Serbian border), this research could help in choosing the way of sales that would lower existing sales costs towards the established habits of consumers and make the enterprise business more profitable in upcoming period.

Results with Discussion

All criteria and alternatives considered in research are presented in next tables (Table 1. and 2.). Alternatives were determined based on currently used sales channels in enterprise.

Table 1. Used criteria

Criteria	Description of criteria
Products characteristics	Basic characteristics of products gained in enterprise
Current financial condition in enterprise	Volume of financial assets that company is willing to invest in certain distribution channels
Consumer's habits	Established practice of buying certain enterprise products
Costs	Costs per unit of distributed product

Criteria	Description of criteria
Geographical concentration	Geographical locations at which enterprise is selling its products
Assortment of products	Number of products' lines oriented to selling

Source: Determined by authors.

Table 2. Used alternatives

Alternative	Description of alternatives
Producer-consumer	Producer is selling the products directly to consumers
Producer-retailer-consumer	Producer is selling the products to retailers while he is reselling them to final consumers
Producer-wholesaler-retailer-consumer	Producer is selling the products to wholesaler, while he is then selling them to retailer who is distributing them to final consumers
Producer-selling agent-consumer	Producer is selling the products to final consumers through the selling agent
Other distribution channels (commission, broker, social networks, etc.)	Producer is selling the products through the other distribution channels

Source: Determined by authors.

By the use of Satie's scale with a given explanation, in paper has been determined the weight of selected criteria (Table 3.).

Table 3. Sati scale of values

Importance	Definition	Explanation
1	Equal significance	Two elements have identical importance according to main goal
3	Weak domination	Slightly favorizing one element compared to other
5	Strong domination	Favorizing one element compared to other
7	Demonstrative domination	Dominancy of one element is approved in practice
9	Absolute domination	Dominancy of the highest degree
2, 4, 6, 8	Intermediate values	Compromise required or further division

Source: Puška, 2011.

For that was used the AHP multi-criteria decision-making method (*Analytic Hierarchy Process*), which could be considered highly appropriate method in this case. The evaluation of the criteria's importance was done by employed engineers and managers in enterprise. Criteria "consumers' habits" and "product's characteristics" have the greatest importance/weight towards the statement of evaluators/decision makers (Table 6.). The selected decision-makers made a group decision based on the linguistic scale whose linguistic features are presented quantitatively in next table (Table 4.), that was the base for forming initial decision-making matrix of linguistic values (Table 5.), as well as quantitative ones (Table 6.).

Table 4. Linguistic scale of values

Evaluation of criteria	Linguistic scale
1	VP-Very Poor
2	P-Poor
3	M-Medium
4	G-Good
5	VG-Very Good

Source: Đalić et al., 2020.

Table 5. Linguistic table of initial decision-making matrix

Element	C1	C2	C3	C4	C5	C6
A1	G	M	M	M	G	VG
A2	G	M	G	G	G	M
A3	G	M	M	M	G	G
A4	M	M	M	P	M	M
A5	M	G	M	M	M	M

Source: Determined by authors.

Table 6. Initial decision-making matrix

Weight	*0,24*	*0,05*	*0,26*	*0,05*	*0,2*	*0,2*
Element	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**
A1	4	3	3	3	4	5
A2	4	3	4	4	4	3
A3	4	3	3	3	4	4
A4	3	3	3	2	3	3
A5	3	4	3	3	3	3

Source: Determined by authors.

Normalization of the initial decision-making matrix is shown in Table 7., while by multiplying its values with the obtained criteria weights, it was created the weighted normalized decision-making matrix (Table 8.).

Table 7. Normalization of decision-making matrix

Element	C1	C2	C3	C4	C5	C6
A1	0,492368291	0,416031	0,416031	0,437637	0,492368	0,606355
A2	0,492368291	0,416031	0,554708	0,583516	0,492368	0,363813
A3	0,492368291	0,416031	0,416031	0,437637	0,492368	0,485084
A4	0,369276219	0,416031	0,416031	0,291758	0,369276	0,363813
A5	0,369276219	0,554708	0,416031	0,437637	0,369276	0,363813

Source: Determined by authors.

Table 8. Weighted normalized decision-making matrix

Element	C1	C2	C3	C4	C5	C6
A1	0,11816839	0,020802	0,108168	0,021882	0,098474	0,121271
A2	0,11816839	0,020802	0,144224	0,029176	0,098474	0,072763
A3	0,11816839	0,020802	0,108168	0,021882	0,098474	0,097017
A4	0,088626292	0,020802	0,108168	0,014588	0,073855	0,072763
A5	0,088626292	0,027735	0,108168	0,021882	0,073855	0,072763
Vj +	0,11816839	0,027735	0,144224	0,029176	0,098474	0,072763
Vj -	0,088626292	0,020802	0,108168	0,014588	0,073855	0,121271

Source: Determined by authors.

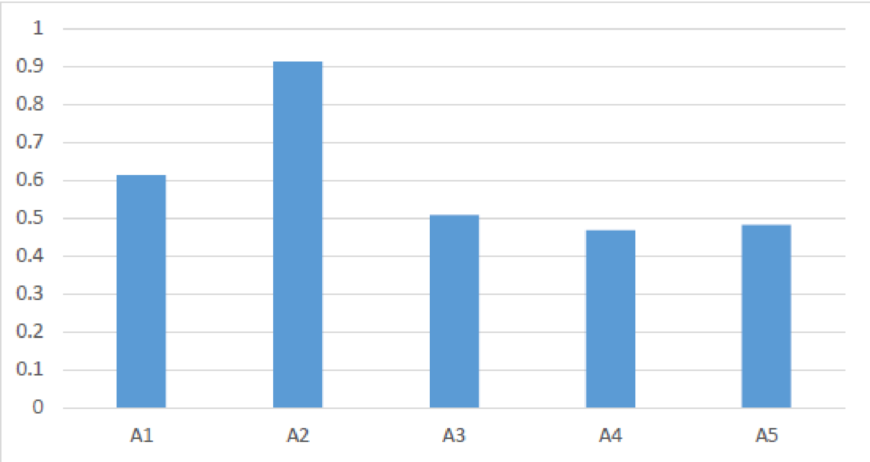
After that, the values for the distances of each of the analyzed alternatives were obtained, where it could be seen that the alternative "producer-retailer-consumer" has the highest value, or the shortest distance from the positive ideal solution (Table 9.). Then there come the values for other evaluated alternatives 1, 3, 5 and 4, what could be seen in Graph 1.

Table 9. Relative closeness of alternatives to ideal solution

S^*_i	S^-_i	$S^*_i+S^-_i$	Q^*_i
0,061274	0,09688	0,158154	0,612567
0,00693	0,073108	0,080038	0,913416
0,044606	0,04604	0,090646	0,50791
0,055137	0,04851	0,103647	0,468031
0,053219	0,04954	0,102759	0,482099

Source: Determined by authors.

Graph 1. Ranking of alternatives



Source: Determined by authors.

Conclusion

In line to previously presented, it could be concluded that the choice of sales distribution channel represents complex issue in every enterprise. Complexity is even greater if enterprise comes from the agribusiness sector. Based to given alternatives in form of currently used sales channels in enterprise, by research is confirmed that in this moment the sales channel "producer-retailer-consumer" represents the optimal solution towards the set selection criteria. It is followed by "producer-consumer" sales method, or direct sales without intermediaries. Gained results are a good basis for further research aimed to development of existing, or searching for new distribution channels/methods of sale, certainly with an accent to modern and the most frequent sales methods in use that would certainly bring the higher profits and lower the current costs to certain enterprise in given conditions of production and with available assortment of products.

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CHARACTERISTICS OF LAND AND CLIMATE INDICATORS AS THE BASIS FOR AGRICULTURAL PRODUCTION PLANNING IN THE MUNICIPALITY OF VLASOTINCE[1]

Branko Mihailović[2], Vesna Popović[3], Katica Radosavljević[4]

Abstract

This study explores the characteristics of land and climate indicators as a basis for planning agricultural production in the municipality of Vlasotince. Aim of the research was to provide concise information about agricultural land, relief, pedological characteristics, and basic climate indicators in this area. Data were collected from relevant strategic documents and scientific papers that address similar topics.

In the field of agricultural land, the analysis encompassed the scope and structure of agricultural land use, agricultural land used by agricultural households, land consolidation, and agricultural land in state ownership within the territory of the municipality of Vlasotince. The relief analysis included the identification of key relief characteristics in municipality, which have a significant impact on microclimate conditions and agricultural production possibilities in mentioned area.

The results of the pedological characteristics of the land indicate the occurance of various types of soil, such as humus-silicate soils (rankers), eutric brown soils (cambisol), alluvial or fluviatile soils, and pseudogleys. The obtained results offer insight into soil fertility and its capability to support growing of various crops. Analysis of basic climate indicators in the municipality of Vlasotince includes temperature, precipitation, and the length of the vegetation period. According to research results and discussion, this study provides a comprehensive overview of the characteristics of land and climate indicators in observed municipality that are of essential importance for agricultural production planning.

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Key words: Agricultural land, relief, pedological characteristics, climate indicators.

JEL[5]: Q15, Q54, O13

Introduction

Agriculture is a key sector for the development of rural areas in the Republic of Serbia. However, climate change poses a significant challenge to this branch of the economy. In line to data from the Republic Hydrometeorological Service of Serbia (RHMS), there has been an increase in the average annual temperature in Serbia by 1.2 °C from 1961 to 2017, while the annual precipitation in this period has decreased by 6.2% (RHMSS, 2023).

At the same time, soil characteristics are of great importance for agricultural production. According to the Development Plan of the Municipality of Vlasotince 2022-2029, the most prevalent soil types in this municipality are humus-silicate soils (rankers), eutric brown soils (cambisol), alluvial or fluvioglacial soils, and pseudogley (OGCL, 2021).

In order to achieve maximum yields, it is necessary to dispose with the soil of good quality, with sufficient organic matter and nutrients. Agricultural land is one of the most important natural resources of any country and fundamental factor in agricultural production, as provides income for the majority of rural population, ensuring food security for the nation, while its responsible management contributes to the preservation of environment (Zubović et al., 2017).

The agricultural sector in the municipality of Vlasotince plays a significant role within the local economy, providing the basic food needs for population. However, in line to increasingly pronounced climate changes and their impact on agricultural production, it is necessary to thoroughly investigate soil characteristics and climate indicators in order to properly plan and manage agricultural production.

On the other hand, the productive capacity of the land is diminished by processes of continuous reduction and degradation of agricultural surfaces (Kljajić et al., 2012). Numerous natural and anthropogenic influences that lead to threats and changes in the use of agricultural land must be therefore understood, anticipated, and, if possible, directed (Dabović, 2022). Due to its significance for ensuring food security for the nation, the agricultural sector is subject to specific legal and institutional regulation compared to other economic activities (Zubović et al., 2016).

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The aim of presented research is to provide a comprehensive overview of soil characteristics and climate indicators as a basis for agricultural production planning in the municipality of Vlasotince. Recognizing the significance of agriculture for the local community, this research aims to identify key factors that affects the success of agricultural production, providing the guidelines for adjustment to changing production conditions. Special attention will be given to agricultural land, topography, pedological characteristics, and basic climate indicators.

Agricultural land represents a fundamental resource for food production and sustainability of agricultural sector, while topography and pedological characteristics have a significant impact on soil fertility and agricultural production possibilities. Significant change in land-use was within basin of the Južna Morava river comprising the abandonment of agricultural land towards the intensive depopulation processes, certain negative economic and social trends that indirectly affects soil degradation and sediment transport (Manojlović et al., 2021). Key morphological characteristic of Serbian relief is in its progressive rising from the north and Pannonian Plain to the south and southeast of Serbia, and the Šar-Prokletije Mountains (Đurović, 2022).

Several studies have been focused on determining the yield of various corn (*Zea mays L.*) hybrids in line to used soil type and its compaction. Field experiment has been performed during the 2016-2017 within the municipality of Leskovac, at the 3 types of soil: alluvium, chernozem, and parapodzol (Biberdžić et al., 2018). The highest average yield for all soil types was obtained by growing hybrids from the FAO-500 maturity group, while the lowest yield was gained with hybrids from the FAO-400 maturity group (Biberdžić et al., 2018). In the area of Vlasotince, various soil types can be found. The dominant are humus-silicate soils (rankers), eutric brown soils (cambisols), alluvial or fluviatile soils, or pseudogleys (OGCL, 2021).

Climate extremes, as are drought and heat waves could drive to large decline in yields, i.e. to jeopardiye life support of agricultural producers, or even to endanger the global food security (Vogel et al., 2019). Climate indicators, such as temperature, precipitation, and length of the growing season, also play a crucial role in determining the potential for successful agricultural production. Analyzing these indicators allows understanding of climate trends, including changes in temperature and rainfalls patterns, and their impact on available agricultural conditions. In recent decades, due to increase in air temperature, prolonged growing seasons, and variable precipitation levels, grassland areas such as meadows and pastures are experiencing more frequently water deficits, what hinders their regeneration (Stričević et al., 2021).

The main goal of study is to gain a comprehensive insight into the characteristics of soil and climate indicators in mentioned municipality, trying to identify key factors for successful agricultural production, as to provide support in planning appropriate agronomic measures in line to adaptation to changing climate conditions.

Used Materials and Methods

In this study, the Descriptive Statistics (DESK) approach is used to analyze the soil characteristics and climate indicators in the municipality of Vlasotince. The DESK approach is a statistical method used for describing and analyzing data from available literature sources.

During the study development, available strategic documents of the municipality of Vlasotince and the Republic of Serbia, as well as adequate scientific papers in this field was analyzed. So, valuable support for research task is provided by the local and national strategic documents, such as the Spatial Plan of the Vlasotince Municipality, the Development Plan of the Vlasotince Municipality for 2022-2029, the Strategic Development Plan of the Vlasotince Municipality for the period 2021-2030, the National Action Plan for Mitigating the Consequences of Drought and Soil Degradation, and the Amendments to the General Regulation Plan of Vlasotince Municipality in 2020.

These documents provide required information on dominant soil types, humus content, basic climate indicators, and other relevant parameters. As was previously mentioned, relevant scientific papers are also used, providing additional information on soil characteristics and impact of climate change on agricultural production.

The collected data allows identification of dominant soil types, fertility assessment, and later understanding of their potential for agricultural production. Furthermore, the analysis of available climate data, such as temperature and precipitation, enables understanding of climate change impact on the agricultural sector in the municipality of Vlasotince. Used methodological approach contributes to obtaine comprehensive insight into the soil characteristics and climate indicators in observed municipality through the description and analysis of available data from strategic documents and literature.

These results better understanding the state of soil, the impact of climate change on agricultural production, and identification of potential approaches for adaptation to these changes.

Research Results with Discussion

This section presents a concise summary of information and discussion of results related to agricultural land, relief, pedological characteristics, and basic climate indicators.

Agricultural land

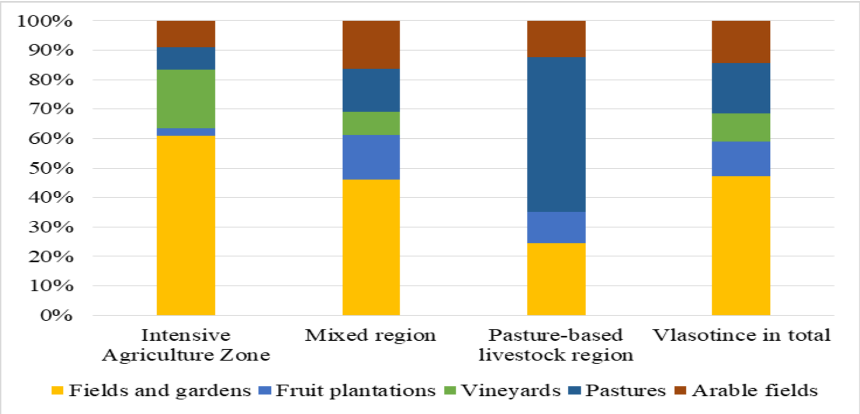
Extent and structure of agricultural land use - According to the data from the Annual Program for Protection, Development, and Use of Agricultural Land in the Municipality of Vlasotince for the agroeconomic year 2023 (AAL, 2023), agricultural land covers 15,638 ha, what represents half of the municipality's territory (50.8%).

The predominant land use types are arable land and gardens, 47.2%, followed by meadows, 17.1%, pastures, 14.3%, orchards, 11.7%, and vineyards, 9.8%.

Development and spatial planning documents[6] have been defined the use, management, and protection of agricultural land in accordance to available natural and economic preconditions for production as like:

- intensive agricultural area, occupying 23.1% of the overall agricultural land areas in municipality, mainly consisting of arable land and vineyards located in valley and basin areas, ranging from 200-350 m.a.s.l.;
- mixed area, covering 65.9% of the total agricultural land surfaces that is mainly consists of arable land, pastures, orchards, and meadows in hilly areas (350-600 m.a.s.l.) and hilly-mountainous regions (600-800 m.a.s.l.);
- pasture livestock area, encompassing 10.9% of the total agricultural land surfaces is located in mountainous areas (above 800 m.a.s.l.), with the meadows as the dominant land use form (Chart 1.).

Chart 1. Structure of the land use in agricultural areas of the Vlasotince municipality (for 2023, in %)



Source: Authors' calculation according to AAL, 2023.

6 The Regional Spatial Plan of the South Pomoravlje Region (OGRS, 2010), Spatial Plan of the Municipality of Vlasotince (Municipality of Vlasotince, 2011), and Development Plan of the Municipality of Vlasotince 2022-2029 (OGCL, 2021).

The best-quality arable land, suitable for intensive crop and vegetable production is mostly located in the valleys of South Morava and Vlasina rivers at the area of Vlasotince up to 350 m.a.s.l., and partly on the slopes of Kruševica, ranging from 350-600 m.a.s.l.

Slight slopes of the Leskovac Basin on the right side of the South Morava, western slopes of Kruševica, and northwest branches of Ostruznica, up to and above 350 m.a.s.l., with well-drained soils and favorable sun exposures, constitute the well-known Vlasotince vineyards as a part of the Leskovac viticultural region (MAFWM, 2013). The vineyards of Vlasotince have gained a reputation towards the exceptional wines, recognized as integral part of the Leskovac viticultural region. The region's rich winemaking tradition, coupled with the unique terroir of Vlasotince, imparts distinct flavors and aroma to the produced wines.

The vineyards in Vlasotince municipality showcase a diverse range of grape varieties, carefully selected to thrive in mentioned microclimate. From robust red to crisp white, the produced wines reflect the passion and expertise of the local winemakers. Visitors can explore the vineyards, indulge in wine tasting, and immerse themselves in rich winemaking heritage of the Leskovac viticultural region.

Higher terrains of the basins and peripheral hills in the elevation zone from 350-800 m.a.s.l. are particularly suitable for establishing orchards. There is concentrated 84.6% of the total orchards area in municipality, as well as the majority of pastures (75.7%), fields and gardens (64.5%), meadows (56.2%), and vineyards (53.2%), (AAL, 2023). In the mountainous zone, above 800 m.a.s.l., in the southern part of the municipality, forests and natural grasslands dominate, which, together with orchards and pastures, provide significant opportunities for the development of pastoral farming, organic agriculture, and agroforestry.

Indigenous fruit varieties have good yield even at higher altitudes, while the production volume and economic potential of fields and grasslands, especially meadows, significantly decline above 600 m.a.s.l., requiring implementation of adequate land improvement and agroecological measures, including partial afforestation. A significant constraint for the successful implementation of mentioned activities is the pronounced depopulation processes (SORS, 2022).

The utilized agricultural land of agricultural holdings. According to data from the Farm Structure Survey in 2018, there are 3,666 agricultural holdings that had in total 6,595 ha of utilized agricultural land (UAL).

Table 1. Available agricultural land of agricultural holdings (in 2018)

Element	Available agricultural land of agricultural holdings (AALAH), (in ha)				
	Total	Utilized agricultural land (UAL)	Unused agricultural land	Forest	Other
Area	14,052	6,595	1,739	5,543	174
Share in AALAH (in %)	100.0	46.9	12.4	39.4	1.2
Number of holdings	3,680	3,666	1,717	3,478	3,645

Source: SORS, 2018.

The share of UAL within the available agricultural land of agricultural holdings (AH) is 46.9%. The uncultivated agricultural land occupies 1,739 ha (12.4% of AH), while it is owned by 1,717 holdings. This land remained unused due to certain economic, social, and other reasons, but it can be reintegrated into the cultivation process by utilizing the resources available to the holdings or by its lease (Table 1.).

In the structure of utilized agricultural land in 2018, the most prevalent were arable land and gardens (57.1%), followed by meadows and pastures (21.9%), orchards (13.6%), and vineyards (6.6%).

Compared to data obtained from the Agricultural Census in 2012 (SORS, 2012), the area under-utilized agricultural land (UAL) have been decreased for 0.4%, while the share of arable land and gardens, orchards, and vineyards have been increased at the expense of permanent grasslands (Table 2.).

Table 2. Structure of utilized agricultural land in 2012 and 2018

Element	Utilized agricultural land (UAL), (in ha)					
	Total	Household plot	Arable land and gardens	Orchards*	Vineyards	Meadows and pastures
2018	6,595	49	3,763	898	437	1,445
2012	6,623	54	3,753	718	411	1,686
2018/2012 (%)	-0.4	-9.3	+0,3	+25.1	+6.3	-14.3
Share in UAL, 2018	100.0	0.7	57.1	13.6	6.6	21.9
Share in UAL, 2012	100.0	0.8	56.7	10.8	6.2	25.5

Note: * Perennial fruit and berry plantations.

Source: SORS, 2018; SORS, 2012.

The average size of UAL per farm was 1.8 ha, while at the level of Jablanica Region it was 2.7 ha, Region of South and East Serbia, 4.4 ha, or Republic of Serbia, 6.2 ha. This indicator had a value of 1.6 ha in 2012, while the increase in last 6 years was mainly the result of decrease in number of farms (Table 3.).

Table 3. Organizational and legal forms of land ownership of UAL and average land size

Element	2018.			2012.		
	Number of households	UAL (ha)	UAL per household (ha)	Number of households	UAL (ha)	UAL per household (ha)
Family agricultural households	3,678	6,470	1.76	4,126	6,510	1.58
Agricultural households of legal entities and entrepreneurs	1	125	125.00	4	114	28.50
Total	3,680	6,595	1.79	4,130	6,623	1.60

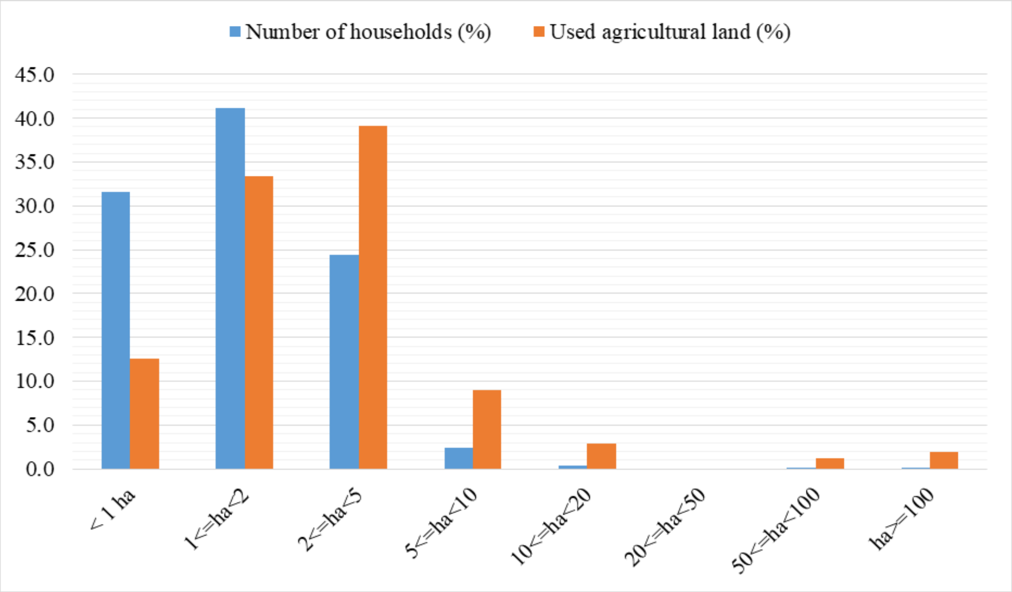
Source: SORS, 2018; SORS, 2012.

The ownership structure is highly unfavorable. In 2018, as much as 97.2% of farms with utilized agricultural land (UAL) had estates smaller than 5 ha, while these farms occupy 85.0% of the total UAL (Chart 2.).

Considering farms smaller than 10 ha, in mnetioned structure they have reached 99.6% and 93.9%, respectively. Medium size farms are extremely scarce, with only one registered with size within the 50-100 ha, or one in category above 100 ha (Chart 2.).

The farm fragmentation is additional constraint for sustainable utilization of agricultural land. According to Agricultural Census from 2012, farms had in average 8 separate parcels of UAL, with average size of each parcel around 0.2 ha (SORS, 2012).

Chart 2. Ownership structure of agricultural holdings (in 2018)



Source: SORS, 2018.

Consolidation. Consolidation has been carried out in multiple cadasters, in total 157 ha, and according to the Spatial Plan of the municipality of Vlasotince, there are areas that need further consolidation, approximately 100 ha (Municipality of Vlasotince, 2011). Meanwhile, measures for the regulation of agricultural land, prescribed by the annual programs for protection, regulation, and utilization of agricultural land, are limited just to the regulation of field roads (AAL, 2023).

Agricultural land in state ownership. According to the data from the Annual Program for Protection, Regulation, and Utilization of Agricultural Land in the Municipality of Vlasotince for the 2023 (November 1st 2022 - October 31st 2023), the total area of agricultural land in state ownership is 668 ha. Currently there are 177 ha under lease contracts, while 198 ha are planned to be leased and later utilized. Remaining 293 ha are excluded due to the discrepancy between the legal and actual status, meaning that instead of agricultural land there are forests, naturally and artificially created infertile land, or land of special purpose (AAL, 2023).

Relief and pedological characteristics

The area of the Vlasotince municipality is clearly divided into the two parts, flatland and hilly-mountainous part, which differ in their geomorphological, climate, hydrogeological, and biogeographical characteristics. From the aspect of morphology there are two main areas: the valley-basin region, which is the most fertile part of the municipality, and the hilly-mountainous region, which has a complex and diverse relief (Municipality of Vlasotince, 2020). The basin region is located on the eastern side of the Leskovac - Vlasotince basin, on the western slopes of Kruševica and the northwestern foothills of Oštrazub. The hilly-mountainous relief is highly developed, dissected, and covers over 80% of municipal territory. The lowest point is at the confluence of the Vlasina River and the South Morava River, with an elevation of 230 m.a.s.l., while the highest peak, Raskrsje, reaches 1,433 m.a.s.l. (Municipality of Vlasotince, 2021). Soil formation in nature is the result of pedogenetic factors: relief, parent material, climate, organic matter, and the age of the terrain. Mentioned factors affect the direction and intensity of pedogenetic processes occurring in the soil, resulting in the formation of more or less fertile soils (Hadžić et al., 2002). Soil is highly diverse and characterized by different types depending on the observed region. Within the territory of Vlasotince municipality, three main types of soil can be distinguished: meadow soils, forest soils, and mountain soils (Municipality of Vlasotince, 2021). Meadow soils are predominantly used for livestock production, while they are characterized by good structure and fertility. Forest soils are rich in humus and highly fertile, while in this areas forests of oak, beech, and pine are most commonly found. Mountain soils are very poor and infertile but play a significant role in preserving biodiversity (Municipality of Vlasotince, 2021). In observed territory, there are different types of soils, with the most prevalent being humus-silicate soils (rankers), eutric brown soils (cambisols), alluvial or fluviatile soils, and pseudogleys (OGCL, 2021).

1. Humus-silicate soils (rankers) are characterized by uneven natural fertility, making them suitable for use as arable land in lower areas, while they are alternated with meadows, pastures, and forests in higher areas. However, this type of soil is sensitive to erosion, so it needs appliance of erosion protection measures such as crop rotation, use of cover crops, and protective walls. Additionally, these soils can be enriched with organic matter to improve fertility.

2. Eutric brown soils (cambisols) are potential soils that can be easily converted into high-quality soils suitable for various purposes, such as agriculture, fruit growing, viticulture, or forestry. However, these soils often require improvement of physical properties and protection against erosion, especially in the case of crop production and vineyards. Protective measures can include implementation of irrigation systems, agrotechnical measures such are crop rotation, use of cover crops, and application of fertilizers and pesticides.

3. Alluvial or fluviatile soils are found in the floodplains, where dominantly maize is cultivated. They have high production value, particularly for cash crops. This type of soil is also susceptible to erosion, so there are certain implementations

for protective measures, such are stream regulation, irrigation systems implementation, deep soil cultivation, and application of fertilizers.

4. Pseudogleys can be found on alluvial terraces in the Vlasina valley and in some hilly-mountainous areas of the Vlasotince municipality. These areas have been often exposed to high precipitation, while due to low temperatures and lack of sunlight, water cannot penetrate deeply into the soil, resulting in formation of pseudogleys. They represent soils with high moisture content and low aeration, which make them less suitable for plant growth compared to other soils. However, they are important for environmental preservation, functioning as natural water filter, preventing groundwater pollution, etc. This type of soil also has potential for organic production, considering the low level of pollution. However, due to low fertility, additional investments in fertilization and soil maintenance are required in order to achieve good productivity.

The Municipality of Vlasotince has a good potential for organic agriculture (OGCL, 2021), what is based on natural production approach that avoids the use of synthetic fertilizers and pesticides. This type of agriculture has a long history in Serbia, especially in rural areas. Organic production in this region could be supported due to proximity of urban markets, which are increasingly interested in healthier and natural produced food. Additionally, the preserved nature of this region, along with a relatively low level of air, water, and soil pollution, makes it ideal for the production of healthy food without harmful chemicals. Land, as a natural resource have to be observed as non-renewable resource, as it takes thousands of years for its formation and regeneration on a geological substrate, while its degradation or loss could be sometimes extremely quick, even in several seconds or minutes (e.g. erosion and other natural or anthropogenic accidents), (MAEPRS, 2015).

Basic climate indicators

Basic climate indicators and pedological characteristics significantly affect agricultural production. Specifically, natural changes and anomalies in weather, water and soil conditions affect all production systems in agriculture (Stričević et al., 2020). For this reason, the analysis of climate and pedological conditions represents an important support in determining the scope and structure of plant and animal production. In altered climate conditions, there often comes to reduction in yield and quality of agro-products (Ilić, Milenković, 2022). Priority should be given to the development of production systems that improve water use efficiency, while they are adapted to warm and dry weather conditions (Ilić, Milenković, 2022). The changing climate is a huge challenge for agriculture within the process of shaping agricultural policies (Marković, 2020). Accordingly, it is important to determine an adequate strategy for climate change adaptation to ensure stable development of plant production (Prodanović et al., 2023). This includes ensuring and favoring conventional practices, early sowing, timing of sowing, seed stocking, use of growth regulators, use of winter crops and more resilient varieties, which farmers have partially practiced (Prodanović et al., 2023).

The municipality of Vlasotince has a moderately continental climate, with an average annual temperature of 11°C in the plains and 6.7°C in mountainous areas. In average, annual precipitation ranges 600-700 mm, while snow typically persists from November to March, with the highest number of snowy days in January (Municipality of Vlasotince 2021). The coldest month is January, with an average minimum temperature of -5°C, while the warmest are July and August, with an average maximum temperature around 28°C (Municipality of Vlasotince, 2021). The seasons are well pronounced and influence the climate conditions and vegetation. Winter is characterized by cold weather, snow, and frost, while the spring is characterized by warmer weather and frequent rains. Summer brings high temperatures and dry weather, while autumns have shorter days and sharper temperature drops.

The seasons represent an important climate indicator in observed municipality, as they affect crops production and animal life, overall agriculture, and other aspects of human life. Moreover, these periods play a significant role in tourism, as tourists often choose destinations according to specific seasonality and characteristic weather conditions. In past few decades, climate conditions in Vlasotince and wider region have been changing under the influence of global climate change. This is manifested through the more frequent and intensified extremes in weather conditions, such are drought, floods, and storms. Therefore, monitoring the change in seasons' conditions and other climate indicators can be useful in adapting to new climate conditions. Precipitation in observed area is uneven throughout the year, with the highest rainfalls in spring and autumn. According to data from the Republic Hydrometeorological Service of Serbia (RHMSS) for the period 1981-2010, the average annual precipitation in the municipality of Vlasotince was around 750 mm. However, data from the last few years show significant deviations related to average. For example, in 2021, in Vlasotince was recorded in total 624 mm of precipitation, what is about 17% less than the average for the observed period. Similarly, in 2020 is showed a total precipitation 739 mm, what is also less than the average. This information indicates that precipitation in Vlasotince municipality has been less frequent and more intense in the last few years compared to observed period. This could be a consequence of global climate change. More detailed analysis of basic climate indicators requires their monitoring over a longer period. Therefore, in Table 4. are presented the average monthly, annual, and extreme values of temperature and precipitation for the last 30 years.

Table 4. Average monthly, annual, and extreme values of weather indicators in last 30 years

Month	Absolute maximum (°C)	Mean maximum (°C)	Mean minimum (°C)	Absolute minimum (°C)	Precipitation - average monthly sum (mm)
January	21.1	4.6	-2.1	-18.3	45.2
February	25.6	7.1	-0.6	-19.4	43.8
March	28.9	11.7	2.1	-10.0	42.8
April	32.2	16.0	6.0	-3.3	52.1
May	36.7	20.8	10.1	1.1	62.8
June	40.0	24.8	13.9	4.4	60.4
July	42.8	27.4	15.6	6.7	50.6
August	41.7	27.0	15.3	6.1	53.6
September	40.0	23.6	12.7	1.1	39.8
October	35.0	18.9	7.9	-4.4	37.3
November	27.2	12.2	2.9	-13.3	49.7
December	24.4	7.1	-0.7	-20.0	53.0

Note: The values are average values recorded over the last 30 years.

Source: RHMSS, 2023.

It is noticeable that the largest temperature fluctuations are observed during the period from December to March, while temperatures are most stable during the summer months, from June to September. The highest average monthly precipitation occurs in May, 62.8 mm, while the lowest are recorded in September, 39.8 mm. This information can be of great use to farmers in Vlasotince, in line to planning and adjusting their activities according to the prevailing climate conditions in the region. For example, information about average precipitation can help farmers to implement irrigation for crops during periods with lower rainfalls, while information about temperatures can be useful in selecting crop varieties resilient to specific climate conditions. Based on analyzed climate and pedological characteristics, agricultural production suitable for this territory includes:

1. Fruit cultivation - Vlasotince and its surrounding offer favorable conditions for growing fruits, especially apples, pears, plums, and cherries. These areas are already known for fruit production, and there are significant areas under orchards that can be further improved with the use of modern technologies and varieties.
2. Vegetable growing - Favorable climate conditions, sufficient rainfall, and fertile soil make this region suitable for growing various types of vegetables. The most common are tomatoes, peppers, potatoes, cabbage, cucumbers, and watermelons.

3. Livestock production - This region has a long tradition in livestock farming, particularly sheep breeding. Mountain pastures provide excellent grazing potential for sheep breeding, while there are also good conditions for raising pigs and cattle.
4. Viticulture - Vlasotince area has an abundance of sunny days and favorable climate conditions for growing grapevines. Region is known for wine production, with the most common varieties being Prokupac, Tamjanika, and Župljanka.
5. Beekeeping - Region has a well-established tradition in beekeeping, while the mountainous areas provide suitable conditions for beekeeping (honey production and other bee-related products).

Agricultural production is largely influenced by climate factors (Popović et al., 2023). With proper organization and the use of modern technologies, agricultural productions can ensure high yields and support the development of entire local economy. Agricultural production should be developed in line with sustainable principles, respecting environmental protection and utilizing available resources in sustainable manner. Adequate infrastructure, such as roads, water supply systems, and irrigation systems, should be also reconsidered to ensure optimal growth and development of agriculture. Generally, agriculture can be a significant factor for the development of Vlasotince municipality, utilizing its natural resources and cultural heritage. There is a need to establish cooperation among local producers, institutions, and enterprises, while supporting the development of rural tourism and markets for agro-products, in order to increase economic benefits and improve quality of life in observed area.

Conclusion

Analyzed information linked to soil pedological characteristics and climate indicators in the municipality of Vlasotince could provide valuable guidance for farmers during planning and adapting their activities towards local climate conditions. Based on derived results it could be concluded that exists favorable preconditions for establishing various lines of agricultural production in observed area. So, available areas are particularly suitable for fruit and vegetable growing, livestock farming, viticulture, and beekeeping.

These areas already have developed production capacities and possess good tradition in many branches of agriculture, while with adequate organization and appliance of contemporary technologies all of them could provide high yields, contributing to local economy. In Vlasotince municipality it will be highly important for agriculture to continue its development in accordance to sustainability principles, including environmental protection and sustainable resource use. In addition, it is necessary to provide adequate infrastructure, such as roads, water supply, and irrigation systems, to ensure optimal growth and development of all agricultural sectors. Achieving full potential of agricultural production requires establishment of cooperation among local producers, institutions, and companies. It is also essential to support the development of rural tourism and create a market for local agricultural products, which will contribute increase in economic benefits and improving of quality of life in entire municipality.

Generaly, agriculture can be a significant factor for the development of the municipality of Vlasotince, utilizing available natural resources and rich cultural heritage recognized in this region. Comprehensive approach that includes sustainable production, infrastructure and market conditions, as well as cooperation among all relevant stakeholders, is crucial for achieving successful and sustainable agriculture in observed area.

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THE IMPORTANCE OF HUMAN CAPITAL IN AGRIBUSINESS AND RURAL DEVELOPMENT OF SERBIA[1]

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Abstract

Human capital represents the most important resource and plays a driving force in the efficient development of economic entities and agricultural farms in agribusiness and rural development. Research in the paper aims to analyze and identify positive and negative trends in the structure and operations of the small businesses and agricultural farms, where human resources play a central role. So, the main goal of article is to emphasize research in the field of demographics (age, gender and educational structure, or migration tendencies), socio-cultural, or employment structures that have an impact on the maintenance, improvement and development of human resources in rural areas. Respecting modern approaches in management, marketing and cultural diversity, their application in the field of human resources will influence better understanding and greater investments and implementation of innovative approaches in human capital management in rural areas. Derived research results indicate the need for applying modern methods and techniques of management and culture in order to stop the negative migration trends and improve working and living conditions in rural space. Besides, its required the integration into innovative educational and technological flows, adaptation to cultural changes, encouragement of entrepreneurship and employment with the aim of sustainable development of human resources in rural areas.

Key words: Human capital, rural population, agribusiness, rural development, innovations.

JEL[5]: Q10, Q13, O15

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Introduction

Economic structure of rural areas is largely depending on agriculture (Loizou et al., 2019). The current state of the economic structure of rural areas shows that agriculture, as a basic activity important for the redevelopment of the rural economy, contributes to the greatest extent to the realization of the GDP and the engagement of active human resources (Barrett et al., 2010).

Serbia, in the economic sense in rural areas, is determined by the development of small businesses and farms (Erić et al., 2015) The level of development of mentioned sector is far below what is possible and satisfactory (Popović et al., 2008). The development of farms and small businesses in agribusiness would contribute to increase in the quality and competitiveness of agro-food products, as well as increase in employment and a more stable development of rural areas (Altukhov et al., 2016). To this end, special emphasis should be placed on activity of management and application of modern management techniques and methods in planning, organizing and managing human resources in rural space.

It is important to point out that the management of human resources in agribusiness sector and rural development is still under-researched area and not so quite present in professional research and scientific literature (Mugera, Bitsch, 2005; Konja, Uzelac, 2015). While a number of researchers place special emphasis on the importance of investing in technological improvement, it is important to highlight the fact that the best investment is in human resources or in so-called "vital machines" (Zečević, 2021).

Business-specific practices and culturally dependent management philosophies indicate that human resources are the driving force in efficient development of economic entities in agribusiness and rural development. That is why the term "human capital" is more frequently used. Term human capital in rural population involves educational, labor, cultural, behavioral and intellectual capital (Yakimova, Streltsova, 2020).

According to many authors, human capital occupies central place and has special importance for the development of agribusiness in rural areas. In addition to technology, natural resources, state and agrarian policy and legislation in agribusiness, human capital directly affects the increase in productivity in agriculture, among other things, because it has the ability to adapt to technological, or innovative changes and modern challenges (Zepeda 2001; Kuznetsova et al., 2018; Diebolt, Hippe, 2019).

The use of modern approaches in management, organizational and economic mechanisms in agribusiness and rural development, along with state support to larger infrastructure projects in rural areas, development of traditional activities, application of IT technology, or improvement of educational structure, directly leads to the cessation of migratory flows, increase in employment and overall activity, or greater competitive advantages in agribusiness and rural areas (Fikhtner, Shvedina, 2019).

Methodology and Data Used

Performing the research, in order to observe and analyze the selected data, comparative and deductive method, or method of induction, analysis and synthesis were used. Research was based on relevant data for the observed ten years period. The structure of the work and conducted research are aligned with the use of relevant data from the Statistical Office of the Republic of Serbia (SORS), as with the review of current scientific and professional literature. Used data and methodological approach aims to indicate trends and possibilities of improving the development of human resources in rural areas through increasing employment, changes in the educational structure, stopping migration movements, etc. This indicates the need for further research and the application of innovative methods and techniques in the development of human resources in agribusiness.

Results and Discussion

Farms in Serbia: The situation in the agricultural sector

The dominant form of economic entities in rural areas is represented by agricultural holdings (Bogdanov, Rodić, 2014). According to the Census of Agriculture in 2012, there are 631,552 agricultural holdings in Serbia. The largest share has family farms (99.5%), while only 0.5% are farms owned by legal entities or agricultural cooperatives. The largest percentage of agricultural farms owned by legal entities are in the Vojvodina region, around 46.7%. The entrepreneurial form in this activity is most represented in Šumadija and Western Serbia, amounting up to 40% (SORS, 2013).

In the period 2012-2018, the number of agricultural holdings has been recorded a pronounced negative trend in Serbia, so their number in 2018 was for 10.6% lower than in 2012 (Table 1.). Observed trend will continues due to unfavorable demographic structure and pronounced migration processes.

It is characteristic that mentioned negative trend was recorded in all regions of Serbia. First of all, this was expressed in the region of Vojvodina, where the number of farms decreased for 13.7%, as well as in the region of Eastern and Southern Serbia, 12.1%. This trend is monitored and correlated with the decrease in the number of farms according to their size structure. So, in observed period, there was negative trend in number of farms from the smallest and largest size group, with the exception of the farms from the category of 2-5 ha, whose number was relatively stable. Meanwhile, the average size of agricultural holdings increased, with the recorded growth of 18.1%. This indicates a sharp trend of concentration of farms' number and areas they cultivate within the segment of medium-sized farms.

Table 1. Basic structural characteristics of agricultural holdings in Serbia

2018.					Index 2018/2012 (%)	
According to the area of UAL	**Farms**	**%**	**UAL (ha)**	**%**	**Farms**	**UAL (ha)**
≤ 0.5	44,678	7.9	9,167	0.3	62.3	85.8
> 0.5 ≤ 1	72,483	12.8	54,801	1.6	68.2	73.5
> 1 ≤ 3	188,615	33.4	358,709	10.3	89.9	93.3
> 3 ≤ 5	100,301	17.8	390,397	11.2	99.3	100.0
> 5 ≤ 8	71,639	12.7	450,259	13.0	79.4	72.7
> 8 ≤ 10	23,892	4.2	212,939	6.1	-	-
> 10	62,933	11.1	1,999,622	57.5	120.3	102.1
Total	564,541	100.0	3,475,894	100.0	89.4	101.1
According to the number of UGS	**Farms**	**%**	**UGS**	**%**	**Farms**	**UGS**
0 LSU	129,489	-	0.0	0.0	91.1	0.0
> 0 ≤ 1	146,004	33.6	79,586	4.1	104.9	106.0
> 1 ≤ 3	155,515	35.7	279,887	14.5	80.9	81.0
> 3 ≤ 5	54,793	12.6	212,558	11.0	75.1	75.8
> 5 ≤ 10	47,026	10.8	326,340	16.9	82.8	84.1
> 10 ≤ 20	21,130	4.9	287,596	14.9	106.6	108.1
> 20 ≤ 30	5,047	1.2	122,381	6.3	121.3	122.7
> 30 ≤ 50	3,201	0.7	121,644	6.3	132.1	133.2
> 50	2,336	0.5	503,848	26.1	127.7	106.4
Total	435,052	100.0	1,933,840	100.0	88.9	95.7
By Economic Size (Standard Output - SO)	**Farms**	**%**	**SO (1,000 EUR)**	**%**	**Farms**	**SO**
<2,000 EUR	156,180	27,7	200.000	3,7	53,9	70,4
2,000–4,000 EUR	132,768	23,5	433.000	8,1	94,2	106,8
4,000–8,000 EUR	130,180	23,1	815.000	15,3	115,5	128,7
8,000–15,000 EUR	83,141	14,7	977.000	18,3	159,3	175,9
15,000–25,000 EUR	34,983	6,2	720.000	13,5	193,1	209,4
25,000–50,000 EUR	18,881	3,3	693.000	13,0	168,7	180,2
>=50,000 EUR	8,408	1,5	1.501.000	28,1	125,3	132,7
Total	564,541	100,0	5.339.000	100,0	89,4	142,8

Source: SORS, 2012; SORS, 2018.

According to the economic size, a relatively high share is made by the farms in the category up to 2,000 EUR (27.7%) and up to 4,000 EUR (23.5%), which together make up to 51.2% of the standard output. These data indicate that in Serbia, the profitable sustainability of farms depends on the income that the employed members of the farms earn outside of agriculture. So, this indicates that other sources of income are still important for the strategy of survival and development of agricultural farms (Subić et al., 2015).

Large number of small farms participate in the market chain, while some of medium and large agribusiness companies operate alongside them. In same time, small farms do not have significant participation in the commercially oriented production chain. Reasons for this should be found in small volume and unhomogenized quality of derived agro-products (Nastić et al., 2014; Veličković, Jovanović, 2021). Contrary to them, large farms whose production and activity is solely market and export oriented are organized into efficiently structured market chains. Farms in rural areas, as specific business entities that provide basic sources of income, influence the increase in employment and activities through the performance of basic activities. They are also playing significant role in preservation of cultural values and local specificities, while they are drivers in the creation of new businesses, and thus the development of alternative sources of income to rural population (Mihailović et al., 2020).

State and trends of human capital development in agribusiness

Farms in rural space represent the main source of human capital (Dimovski et al., 2022). In Serbia, there is a negative tendency in farms' number. This is followed with fact that there is also decline in employment and engagement of human resources in agriculture. From 1,442,628 persons engaged in farms in 2012, it was reduced to 1,336,940 in 2018. Simultaneously, the total volume of work, expressed in full employment equivalent (FEE), has been remained the same. This data can be interpreted from the aspect of the increase in degree of utilization of already existing pool of labor-engaged human resources.

Farms in Serbia are organized as family-oriented business entities (Borychowski et al., 2020), which is indicated by the data in Table 2., where the largest number of employees (98.5%) are members of family households.

In the gender structure, the share of women in the overall human resources at the farms is 59.3% (SORS, 2020). This share is more pronounced at smaller farms where it comes up to 64% (55% is at larger farms). In the management structure, the share of women is low and amounts 19.4%. Despite the fact that the share of women in the management structure has followed a slight upward trend in recent years, these data indicate the unequal position of women in the management structure of farms.

Table 2. Basic structural characteristics of holdings and labor force

Farms according to the age of farm holder	Farms	%
<35	17,384	3.1
35–<45	48,878	8.7
45–<55	99,742	17.7

Farms according to the age of farm holder	Farms	%
55–<65	156,219	27.8
>= 65	240,671	42.8
Total	562,895	100.0
Farm workforce	**No.**	**%**
Persons	1,336,940	100.0
Of which family workforce	1,317,330	98.5
Annual work units (AWU)	645,733	100.0
Of which family workforce	591,770	91.6
AWU/AH	1.14	-
AWU/UAL	0.19	-
AWU/UGS	0.33	-

Source: SORS, 2020.

The management structure at the farms is dominated by older people. This is indicated by the fact that over 40% of managers are in the group of 65 years. There are low percentage of human resources in the management structure that belong to age category of up to 45 years, only 11.8%. Also, the share of farms with younger managers is decreasing. One of the main reasons is migration of younger population from urban space, both as internal (rural-urban) and external emigration. One of the important parameters of the sustainability of human resources in rural areas is educational structure (Table 3.). The educational characteristics of human resources employed at farms are noticeably less favorable compared to the urban population.

Table 3. Demographic indicators and educational structure in rural areas

Element	Serbia	Rural areas
% without formal education	13.7	23.4
% with primary school	20.8	27.7
% with high school education	48.9	42.4
% higher education	16.2	6.1
% unknown	0.4	0.4

Source: SORS, 2018.

According to the data from Table 3., in rural areas there is a dominant share of human resources with completed high school (42.4%). A particularly unfavorable trend is in the structure of human resources in rural areas with the percentage of basic and no formal education amounting up to 51.1%. The educational structure of the workforce due to the low representation of highly educated personnel (6.1%) in rural areas could be a limiting factor of their future development. Formal education of human resources, especially farm managers, is modest and at unsatisfactory level. More than half of managers (54%) perform their duties based on practical experience. A some-what more significant percentage of them are completed high school (38%), while 5% completed college or university, while only 7% was attended specialist courses and other educational programs. In order to stop such trends, there is pronounced need to involve human resources from rural areas in innovative formal and informal educational programs.

One of the key economic, structural and social issues of the overall economy, including rural areas, is unemployment (Vukadinović et al., 2018). Labor market indicators according to activity and employment status, age and gender in rural and urban areas indicate a growth trend. These data also indicate unfavorable features of the labor market in rural areas, as young workers have a higher unemployment rate compared to the total working population. The rate of employment and activity are higher in rural than in urban areas, but this data is not correlated with the quality of employment in rural areas.

Table 4. Population according to employment, activity, type of settlement, age and gender

Element	2016.		2020.		2020. other areas	
	Urban	Other	Urban	Other	Young population	Female population
Activity rate (%)	52.2	55.0	52.3	56.4	35.6	47.1
Employment rate (%)	43.0	48.5	47.2	51.9	26.7	42.8
Unemployment rate (%)	17.6	11.9	9.8	7.9	25.1	9.1
Inactivity rate (%)	47.8	45.0	47.7	43.6	64.4	52.9

Source: SORS, 2016; SORS, 2020.

There are large differences in the structure of human resources in terms of gender, age and employment in rural areas. This is particularly reflected in the level of employment among young people and the female population, which is lower than the average of the population over the age of fifteen. The employment rate of men is 61% and is much higher than women (42.8%). The same result also derived comparing the activity rate, which in rural areas is higher for men, 65.6%, than for women, 47.4% (Table 4.). Slight increase in the share of women in entrepreneurial activities and participation in alternative sources of income indicates the stopping of this trend.

The unfavorable trend is particularly pronounced among young in working age, as was indicated extremely high rates of unemployment (25.1%) and inactivity (64.4%). By establishing certain support measures to stop migration, as for young people returning to the countryside, or encouraging entrepreneurship initiatives in rural areas, mentioned trend could be stopped.

A significant difference is evident in the level of employment and the rate of activity comparing the rural and urban areas, mainly as in rural areas the leading share in the employment is made by the farm owners, while household members represent auxiliary resources employed on the farm. The largest share in the category of auxiliary employees in rural areas is made up by women (16.6%), (SORS, 2020). In rural areas, women have an unfavorable working status, which is reflected in insecure employment contracts (especially for seasonal workers), performing auxiliary jobs and representing an auxiliary source of labor force, which directly affects their social status.

The data indicate evident need to put a special emphasis on the role and importance of human capital in the revitalization programs of rural areas. A special focus should be turned to younger population as the primary source of labor force in rural areas (Grujić, Roljević, 2014) towards the motivation to stay, return and stopping migration flows, improving the educational structure and involving young people in specialized educational programs, greater involvement of female population in farms' management structure and improving social infrastructure. This will directly affect the increased scope of activities and employment in rural areas.

Conclusion

Performed research indicates negative trends in observed parameters regarding the state of human resources in rural areas. In addition to identifying the basic problems, a special focus should be given to increasing employment through the promotion of entrepreneurship, or improving the quality of life by advancement of educational and social programs. Also, some focus is turned to stopping migration processes throughout promoting alternative sources of income, or undertaking several activities and measures aimed to return and retention of human resources in rural areas. In particular, the need for further research in the field of application of modern scientific principles of human resources management should be emphasized, whose application in practice would stop the current negative trends.

Human resources represent an important factor in improving co-currentness in the field of agriculture, i.e. they represent one of the most significant elements that influence the development of economic entities and farms in rural areas.

Human capital management in agriculture includes far more complex procedures that are conditioned by numerous factors such as: market development, regional agricultural policy, physical and soft infrastructure, demographic policy, migratory movements, education, cultural changes, legal and technological environment, etc. In this sense, the philosophy of the marketing strategy indicates the necessity of segmentation and research of geographical, demographic, psychographic, or behavioral characteristics of human resources in rural areas (Zecevic, 2011).

Research, based on official statistic data, indicates the identification of several key problems in the field of human resources in agriculture. One of the main is relating to depopulation and unfavorable age structure in rural areas, which arose as a result of rapid (re)industrialization and urbanization. As a result, intensive internal migration (rural-urban) and external migration (emigration) were expressed in rural areas. A particularly unfavorable trend of migration is present in the structure of young working population, requiring special measures for stopping such a flow. Research also points to the key causes of the outflow of human resources from rural areas, as are the absence and low quality of jobs, low level wages, insufficient motivation, and underdeveloped elements of infrastructure.

One of the important factors in improving human resources is education. In rural areas, especially at farms, the data show a low level of employees' education (specifically expressed in the population of young working personnel). This points to the necessity of motivating and involving younger staff in various formal and informal forms of education, greater availability of information and monitoring of contemporary trends through special training and education.

In addition to the aforementioned factors on the development of rural areas, especially in the sector of agriculture, it is important to point out the need to reduce the gender gap and inequality. In traditional societies, such as Serbian, data show that the activity and employment rates of women are significantly lower than those of men. One of the key indicators that affects the reduction of this gap is represented by changes in culture that affect the abandonment of exclusively men traditional values and the reduction of differences between the genders. Appreciation of these cultural changes in the last decade in rural areas, the trend of women's involvement in farms' management structure has increased, directly affecting the improvement of creativity and introduction of new values in operations of farms and economic entities in agriculture.

There is an obvious need to improve and encourage sustainable local development, with the improvement and prosperity of human resources in agriculture being set as a priority. Primarily, this includes the application of modern methods and techniques of management and culture in order to improve working and living conditions, integration into innovative educational and technological flows, adaptation to cultural changes, promotion of gender equality towards the sustainable development of human capital in rural areas.

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SUSTAINABLE DEVELOPMENT IN AGRICULTURE WITH A FOCUS ON DECARBONIZATION

Daniela Kuzmanović[1]

Abstract

This article examines sustainable agriculture's core objective: reducing environmental impact while ensuring continuity in food production. It distinguishes agroecology from sustainable agriculture and organic food production. The feasibility of sustainable organic food production in controlled settings is explored, especially for animal farming. The paper underscores agriculture's substantial greenhouse gas (GHG) emissions and the pressing need for action. It discusses the intricate relationship between agriculture and climate change, emphasizing the challenges in meeting emission reduction targets within the sector.

In this article, Carbon Capture Storage (CCS) is explored as a viable method to reduce agricultural emissions. Additionally, EU policies such as the Carbon Border Adjustment Mechanism (CBAM) and EU Emissions Trading System (EU ETS), are designed to align agriculture with climate objectives. Integrating agriculture into CBAM presents challenges due to the absence of a carbon pricing mechanism. EU's policies and EU's CBAM in this paper are given just a good decarbonization model that can be implemented worldwide.

Balancing environmental preservation, economic stability, and international relations is complex in agriculture, as a significant emitter of GHGs. Innovative strategies like Agricultural Sector Management and Carbon Absorption offer promise in reducing agricultural emissions.

This study employs a triangulation approach and contributes significantly to the field of sustainable agriculture. It explores various aspects of sustainable agriculture, tackles challenges related to climate change, and presents decarbonization strategies. These findings have relevance for all who are involved in agriculture and environmental sustainability.

Key words: Sustainable agriculture, climate change, decarbonization, CBAM, GHG emissions, CCS.

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Introduction

Sustainable agriculture seeks to produce food while minimizing environmental harm, posing challenges in both conventional and organic farming due to strict chemical avoidance in the latter and difficulties in treating animals organically (Brzozowski, Mazourek, 2018). Agroecology stands apart, offering localized solutions that blend scientific and local knowledge, empowering communities to lead change. While plant-based organic production in controlled environments is viable, its application in animal agriculture remains uncertain (Mie et al., 2017). Agricultural sustainability is grounded in the principle of meeting current needs without compromising the ability of future generations to meet their own needs (Brodt et al., 2011).

Agriculture's significant greenhouse gas (GHG) emissions, including non-carbon gases, require immediate action to meet emission reduction goals and address global climate change (Khatri Chhetri et al., 2022). The Biden Administration has set ambitious targets for achieving carbon-free electricity by 2035 and net-zero GHG emissions by 2050. Their 2021 Long-Term Strategy (LTS) presents pathways involving federal actions and broader societal efforts, focusing on five key transformations including mitigating non-CO_2 emissions like methane, and scaling up CO_2 removal initiatives (USDE, 2022). As the Earth approaches critical temperature thresholds, the relationship between agriculture and climate becomes increasingly critical (Schlenker, Roberts, 2009).

EU data illustrates the challenge of achieving emission reduction targets in agriculture. Carbon Capture Storage (CCS) emerges as a potential solution, securely storing carbon dioxide underground. EU policies, including the Carbon Border Adjustment Mechanism (CBAM) and EU Emissions Trading System (EU ETS), (EC, 2023b), aim to align agriculture with climate objectives. However, including agriculture in CBAM presents complexities due to the absence of a carbon pricing mechanism.

Balancing environmental conservation, economic stability, and international relations remains a delicate task, especially given agriculture's substantial greenhouse gas emissions. Innovative approaches, like Agricultural Sector Management and Carbon Absorption, hold promise for reducing agricultural emissions, underscoring agriculture's crucial role in climate mitigation (Kane, 2015).

Small and organic farms, with their capacity to adopt agroecological practices, address climate challenges, and improve food security, play a pivotal role in this context (Adenle et al., 2019). Policymakers must develop comprehensive policies and support programs tailored to the needs of small farmers, ensuring global sustainability goals are met and food production aligns with environmental preservation.

Methodology

The methodological framework used in this study is the triangulation approach. It encompasses the integration of scientific literature and article reviews, utilization of official data sets, both quantitative and qualitative analyses of climate change and decarbonization policies in the agricultural sector, evaluations of decarbonization technologies, and the seamless integration of research findings. This comprehensive and diverse methodology forms a strong foundation for conducting an extensive exploration of subjects related to sustainable agriculture and decarbonization, enabling a deeper and more holistic understanding of the topic.

The main goal of research is to present the current situation of the agricultural sector towards climate neutrality. To gain the main goal of performed research, the paper is divided into five sub-headings enabling a better understanding of observed topic. In the first sub-heading "Sustainable development in agriculture - Sustainable agriculture" the connection between sustainable development, agricultural value, and organic production is shown through the previous work of several authors. One part of this section is a critical opinion of the author that requires further research on the relationship between organic agriculture on GHG levels and climate change.

Further, in the sub-heading "Climate changes and agriculture" the link between climate changes and agricultural production is presented, while in the third sub-heading "Decarbonization of the agricultural sector" the interpretation of scientific research and correlation with current statistical data is performed. In the last two sub-headings "Carbon Capture Storage (CCS) and Implementation in Agriculture" and the last part, concrete proposals with legal and political mechanisms for decarbonization in the EU are given, but it can be extended to all continents, especially if we want to respect all the international agreements signed so far that protect them from climate change.

In line to scientific and professional contribution of the paper, it provides a comprehensive exploration of various aspects of sustainable agriculture, its challenges and impact on climate change, and potential decarbonization strategies in the EU that can serve as a good decarbonization model. It offers valuable insights for researchers, policymakers, and professionals in the field of agriculture and environmental sustainability.

Sustainable Development in Agriculture - Sustainable Agriculture

The term "sustainable agriculture" is defined as an integrated system of plant and animal production practices (Velten et al., 2015).

To achieve long-term objectives of sustainable development, sustainable agricultural practices and policies should include (Wojewódzka Wiewiórska et al., 2019):

- Meeting human needs for a certain quantity of food and fiber;
- Promoting environmental quality and preserving agriculture's natural resource base;
- More effective use of non-renewable resources and farm resources, while incorporating biological cycles and more effective controls where necessary;
- Ensuring the economic sustainability of farm operations; and
- Improving the overall quality of life for both farmers and society.

Sustainable agri-food systems follow the improvement of agri-food production and needs of the present generation, and at the same time must meet the needs of future generations (Çakmakçi et al., 2023).

Agricultural production, whether conventional or organic, faces many challenges. Organic farming prohibits the use of chemicals from conventional farming. The recovery and reintegration of animals into organic production can take a long time and may even be impossible.

In contrast, agroecology operates differently from sustainable agriculture. It offers customized solutions to local challenges, combining scientific insights with the practical knowledge and local expertise of farmers. This approach enhances the self-sufficiency and adaptability of producers and communities, empowering them to lead transformative change.

Organic farming methods can be applied to plant-based agricultural production in small controlled environments such as greenhouses, but animal agriculture is less practical. Steihoff Wagner and associates pointed out that the growing shift towards organic production and raising animals outdoors with minimal shelter highlights the importance of gathering and analyzing biocide application data. Analysis indicates that the existing Environmental Sustainability Directive (ESD) employs a housing definition that distinguishes between indoor and outdoor environment. Within the context of the ESD, indoor housing is likely interpreted as enclosed, warm stalls. It is noteworthy that animals are usually farmed in open indoor stables designed with sidewalls that enable continuous fresh air circulation. This type of barn generally has open roofs, and low walls, facilitating the exchange of air between the barn and the environment. This architectural design has the potential to result in the release of biocides or their byproducts (Steihoff Wagner et al., 2023).

In the same context, when discussing the nutrition of animals required to be of organic origin, it is essential to clarify that the feed provided to organically raised livestock must comply to strict organic standards, so feed should meet the following criteria: a) Protection from conventional agro-chemicals; b) Uncontaminated water source; and c) Organic fertilization of the produced feed.

This rigorous adherence to organic standards ensures that the nutrition provided to organic livestock remains entirely free from the trace og conventional agricultural practices, preserving the integrity of organic production methods. On the other hand, according to research by Galgano and associates, derived results do not show that organic products are more nutritious and safer than conventional agri-food products (Galgano et al., 2016). This is a very sensitive topic, as the statement "Is it enough for organic farming to be environmentally acceptable and based on carbon neutrality without providing a satisfactory level of nutrients?" should be further scientifically examined.

Climate Changes and Agriculture

The Earth's history has witnessed cyclic fluctuations in greenhouse gases (GHG), while the planet's temperature has displayed a historical pattern of oscillation between ice ages and more temperate interglacial periods (Marotta et al., 2023). This historical context confirms that human-induced CO_2 emissions primarily drive the climate crisis. Despite global efforts, temperatures have dangerously approached the critical threshold of 2.5°C as was set by the United Nations in 1992. Continuing human current behavior risks surpassing the allowable maximum carbon concentration in the existing atmosphere (UN, 1992).

The carbon footprint, also known as the GHG footprint, acts as a metric used to assess and compare the overall quantity of GHG released into the atmosphere, as a cause of specific activity, product use, company, agricultural sector, or even a country's actions (Wright et al., 2011). In the field of agronomic research, there has been a significant focus on the mentioned metric in recent years, due to its significance in evaluating the environmental impact of crops, grown animals, use of agricultural inputs and products, or cropping system. It helps in identifying areas within the agricultural practices that offer the largest potential for improvement in terms of GHG reduction (Plassmann, Edwards Jones, 2010).

Agriculture has emerged as a prominent contributor to Greenhouse gas (GHG) emissions, accounting for approximately 14% of the global GHG emissions, including 58% of global non-carbon GHG, such are methane and nitrous oxide. Without prompt and effective measures, agricultural GHG emissions are projected to rise up to 30% by 2050 (Han et al., 2023). This trajectory is a significant challenge in achieving the emissions reduction goals outlined in the Paris Agreement.

Policymakers of the 21st century globally are facing the delicate task of balancing environmental preservation with economic stability and international relations. The agricultural and forestry sectors shoulder a substantial portion of GHG emissions. While organic farming offers environmental benefits, it cannot fully meet global food demands in the short term. Innovative approaches like Agricultural Sector Management and Carbon Absorption, which involve converting agricultural emissions into biogas, have the potential to significantly reduce atmospheric carbon, making agriculture a crucial player or fighter in climate mitigation (Kuzmanovic et al., 2021).

Carbon sequestration, carbon preservation, and carbon replacement are three categories of strategies that can be utilized, including in agriculture, to minimize the carbon footprint that is evident in the environment (Patel et al., 2023). In this context, there are strong reasons to support small and organic farms globally. Reasons are based on their ability to adopt agroecological practices, face all the challenges of climate change and contribute to the well-being of those most vulnerable to food and nutrition insecurity. Authorities and funding agencies at all levels of governance must develop comprehensive sets of policies and support programs tailored to the needs of small farmers. This is an urgent and necessary step to prevent future food and nutrition crises, and align food production with global sustainability goals and targets (Knezevic et al., 2023).

Climate change represents a global threat to both food production and nutritional security. With the continuous increase in GHG emissions, the greenhouse effect is concurrently leading to a rise in temperature. So, there is a need to be aware that agriculture and climate change share a cause-and-effect relationship, wherein agriculture’s dependence on climate change is proportional to its influence on climate change itself.

Climate change is causing more frequent extreme events like floods and droughts, threatening global crop productivity. These changes also impact soil quality and structure, reducing crop yields. Climate change affects soil physical and chemical properties, leading to soil compaction and reduced nutrient availability. Additionally, it influences soil microbial communities, driving organic matter decomposition. Mentioned represent significant challenges to food security in the 21st century (Bibi, Rahman, 2023).

Decarbonization of the Agricultural Sector

Decarbonization is the process of reducing or eliminating greenhouse gas (GHG) emissions, especially produced by human activities such as burning fossil fuels and deforestation, as well as other activities that are significant GHG emitters, including agriculture (Abbasi, Abbasi, 2011). This process is crucial in mitigating climate change and involves transitioning to cleaner and more sustainable practices to reduce the overall impact of GHG on the environment (Wimbadi, Djalante, 2020).

There is a study (Mielcarek Bocheńska, Wojciech, 2021) that analyzes GHG emissions and reduction (decarbonization) from agriculture in the EU for the period 2005-2018. The research is based on the European Environment Agency (EEA) data and pre-set ambitious GHG reduction goals for 2030, established by the EU. GHG emissions from the agricultural sector in 2018 compared to the initial year decreased just for 2%.

Giannakis and Zittis have noted a relationship between the decrease in greenhouse gas (GHG) emissions over the past 30 years. In the EU-27, GHG emissions decreased by 16% from 1995 to 2018, with only a 3% reduction attributed to the agricultural sector. This reduction occurred despite a 48% growth in the EU-27 economy during the same period. In 2019, the agriculture sector in the EU-27 emitted 3,049 megatons of GHG (CO_2 equivalent). The study mentioned earlier assumes that if the agriculture sector continues to grow without changes in technology or specific policies to reduce GHG emissions by 2030, there will be a total increase of GHG emissions by 4% compared to current level. This increase in GHG emissions in the agriculture sector is significantly lower compared to other sectors of the EU-27 economy (Giannakis, Zittis, 2021).

Slaboch and associates in their study have observed that the EU-28 countries are making progress in reducing their carbon footprint. This positive change is a result of a combination of factors and ongoing trends. They point out that waste management experienced the most significant reduction in GHG emissions, overall around 40%, in industry (17%), in the energy sector (16.2%), and in agriculture (5%), (Slaboch et al., 2021).

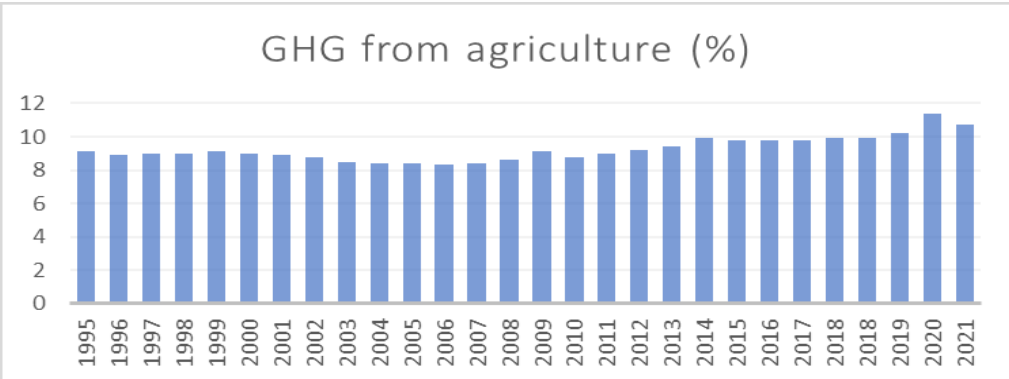
To prove or disprove the aforementioned studies, here is an overview of the official data via the EUROSTAT data search engine. EUROSTAT data provides additional confirmation that, across the EU-27 countries, the EU is still far away from achieving a 30% reduction in GHG levels by 2030. When comparing the data for the observed period, 1995-2018, it could be seen that there was a slight decrease of 0,8% from 1995-2006, while then there was a growth of 2,1% for the period 2006-2018, or in average there was an increase of 1,3%. Moreover, the growth trend continued from 2018-2020. GHG level from agriculture increased from 9.9% to 11.4% in 2021, followed by a slight decrease in last year. Whether the GHG level will continue to decline in the post-COVID period remains to be seen. However, in line with this data, by 2030 the EU countries cannot achieve a 30% reduction in GHG emissions (Table 1. and Graph 1.).

Table 1. Level of GHG from agriculture (in %, EU-27, period 1995-2021)

Year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
GHG from agriculture (%)	9.1	8.9	9	9	9.1	9	8.9	8.8	8.5	8.4	8.4	8.3	8.4	8.6	9.1	8.8	9	9.2	9.4	9.9	9.8	9.8	9.8	9.9	10.2	11.4	10.7
Awerage	9.1																							10.55			

Source: Authors' interpretation according to EUROSTAT, 2023.

Graph1. Level of GHG from agriculture (in %, EU-27, period 1995-2021)



Source: Authors' interpretation according to EUROSTAT, 2023.

Carbon Capture Storage (CCS) and Implementation in Agriculture

Geologic sequestration or Carbon Capture Storage (CCS) is a well-established method for safely storing carbon dioxide (CO_2) underground in deep rock formations and effective prevention of its release into the atmosphere (Bui et al., 2018). It has been refined over decades, supported by various experts in geology, seismology, fluid characterization, engineering, and reservoir modelling, providing a reliable tool for capturing and storing CO_2 at scale. CCS starts with the capture of CO_2, either from industrial facilities or directly from the atmosphere, through technologies like Direct Air Capture (DAC), (Fasihi et al., 2019). This process is followed by purification, compression, and injection into the underground reservoirs over a thousand feet below the surface via high-integrity wells. Once the CO_2 reaches the reservoir, it is securely sequestered through four trapping mechanisms: *Sealed by a Caprock* (Structural Trapping), *Locked in the Pores* (Residual Trapping), *Dissolved in Formation Fluid* (Solubility Trapping), *Turned into Minerals* (Mineral Trapping). So, at the end of the CCS process, the CO_2 becomes part of the rock. DAC technology, which employs high-powered fans to extract air into a processing facility for the chemical separation of carbon dioxide (CO_2) from the atmosphere, enables the secure underground storage of CO_2, or its utilization in the production of low-carbon products (Erans et al., 2022; 1POINTFIVE, 2023).

It has to be mentioned that 1POINTFIVE organization collaborates with Carbon Engineering to implement AIR TO FUELS™ processes, converting atmospheric CO_2 captured by DAC facilities into low-carbon fuels compatible with existing infrastructure and vehicles. It presents a crucial solution for hard-to-decarbonize sectors like aviation, maritime, rail, and long-haul trucking in their efforts to achieve 2050 climate goals. Besides, this method is effective in decarbonizing the CO_2 emitted from agriculture, especially from livestock farming activities.

Sustainable Agriculture and EU's CBAM: A Good Decarbonization Model

European Commission (EC) has outlined a new sustainable growth strategy - European Green Deal (EC, 2020) that aims to transform the European Union (EU) into a fair, prosperous, and resilient society with a modern, resource-efficient, circular, and competitive economy. The main goal is to achieve net-zero GHG emissions by 2050, aligning with economic growth and sustainable resource use.

The European Green Deal is focused on protecting, conserving, and enhancing natural resources, combating biodiversity decline, protecting people's physical and mental health and ensuring their overall quality of life by mitigating environmental hazards and dangers. Additionally, the European Green Deal aligns with the global efforts to achieve the UN 2030 Agenda for Sustainable Development, as well as the goals of the Paris Agreement (UN, 2015).

The polluter-pays principle (PPP) holds a significant role within the EU's legal framework and practice. It is often rather a guiding principle than one enforced in courts. While PPP is featured in various international conventions in different forms, it has not gained recognition as a customary principle of international law (ECA, 2021).

However, according to Kingston, the legal status of PPP in EU law sets it apart. Article 191(2) of the Treaty on the Functioning of the European Union (TFEU) enshrines PPP among the fundamental principles of the EU's environmental policy, granting it constitutional status. The same author in his paper explores the trajectory of this principle within EU law, tracing its development and examining its intersection with the jurisprudence of the Court of Justice of the European Union (CJEU). Moreover, it investigates how this principle has recently been integrated into EU policies, particularly within the framework of the EU's Green New Deal. Additionally, it highlights the prominent role that the polluter-pays principle (PPP) has played in three critical areas of climate-related legal proceedings. These areas include cases related to the EU Emissions Trading System (ETS) and emissions, as well as cases in the realm of EU energy law and EU state aid law. The paper also contemplates the potential applicability of PPP in other contexts, such as climate cases rooted in human and environmental rights, as well as cases involving private entities (Kingston, 2020).

Additionally, the European Commission intends to promote relevant instruments and incentives for the improved implementation of PPP, as outlined in Article 191(2) of the TFEU, as part of its EU Action Plan: Towards Zero Pollution for Air, Water, and Soil (EC, 2021).

In line with the mentioned, EC has set out the Carbon Border Adjustment Mechanism (CBAM): "*The initiative for the CBAM is part of the 'Fit for 55' legislative package. It has to serve as an essential element of the EU's toolbox for meeting the objective of a climate-neutral EU at the latest 2050 in line with the Paris Agreement by addressing the risk of carbon leakage that results from the EU's increased climate ambition. The CBAM is also expected to contribute to the promotion of decarbonization in third countries.*" (EC, 2023a).

The EU ETS represents the policy tool implemented by the EU to fight against climate change and to cost-effectively reduce GHG emissions. The EU ETS covers various sectors, mainly including energy production, heavy industry, and aviation, but agriculture too (Meadows et al., 2015). It is a significant policy tool in achieving reduction emissions and targets under the Paris Agreement. It creates economic incentives for businesses to reduce their emissions, as those who emit less can profit from selling their surplus allowances (Elkerbout, Zetterberg, 2020). Carbon credits are tradable certificates representing a reduction in GHG emissions, allowing businesses and individuals to offset their carbon footprint by supporting projects that reduce emissions elsewhere. Over time, the cap on emissions is lowered, driving the overall reduction in GHG emissions within the EU (Gupta, 2011; Rodrigues et al., 2020).

How CBAM and EU ETS are referred to agriculture is described by certain authors. The Parliament's AGRI Committee has been considering an extension of the CBAM to include agri-food products. While there are concerns about carbon leakage and the potential impact on agriculture, the case for including agriculture in CBAM is not strong. So, agriculture is not part of the EU's ETS and doesn't have a carbon price on emissions. Determining the carbon emissions of agri-food imports and applying taxation is complex, especially for products with deep supply chains. Practical challenges include setting default values for emissions, and these challenges will become clearer as CBAM is implemented for industrial products (Matthews, 2022; Malik et al., 2023).

While replicating EU policies globally is undoubtedly a complex endeavor, it is feasible through cooperation, dialogue, and the exchange of best practices. Such efforts can strengthen existing multilateral climate agreements and promote global sustainability and decarbonization in agriculture. This matter warrants further discussion and collaboration between the EU and other regions to advance global sustainable agriculture and achieve climate neutrality.

Conclusion

Sustainable agriculture aims to minimize negative environmental impacts while providing enough supply of food. This is challenging for both conventional and organic farming due to strict chemical prohibitions in organic farming and the complexity of treating animals. While sustainable plant-based production in a controlled environment is promising, it remains uncertain for animal agriculture.

Agriculture contributes significantly to global GHG emissions, expected to rise to 30% by 2050. Policymakers face the dilemma of balancing environmental preservation, economic stability, and international relations. Supporting small farmers and adopting innovative approaches, like Agricultural Sector Management, or Carbon Absorption, can mitigate GHG emissions.

Focusing on the EU, there are certain difficulties in achieving a 30% GHG reduction up to 2030 across EU-27 countries due to fluctuating emissions trends. Implementation of additional measures may be necessary to meet this goal. Geologic sequestration, or CCS, is a well-established method for the safe storing of CO_2 underground while preventing atmospheric release. The European Green Deal is the EU's sustainability strategy targeting carbon neutrality by 2050. It includes CBAM and EU ETS to address carbon leakage and incentivize emissions reduction. The inclusion of agriculture in CBAM is a challenging activity due to its specificities and lack of a carbon pricing mechanism.

Replicating EU policies globally is possible through collaboration, fostering enhanced climate agreements and global agricultural sustainability, but it necessitates further discussions and partnerships with other regions.

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THE IMPACT OF BIOMASS PRODUCTION ON ECONOMIC GROWTH AT THE EU LEVEL

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Abstract

As the European Union (EU) strives for sustainable economic growth and renewable energy sources, this study investigates the critical relationship between biomass production and economic development. Using rigorous econometric analysis, it was explored the impact of biomass production on GDP per capita as a proxy for economic growth at the EU level. Biomass, as a renewable and environmentally friendly energy source, holds significant potential for shaping the economic landscape of the EU member states. The research employs a comprehensive dataset and econometric models to analyze the dynamic interactions between biomass production and GDP per capita, while considering other relevant economic and environmental factors. By focusing on the EU as a collective entity, the aim of the paper is to provide a holistic view of how biomass production influences economic growth in a region committed to sustainability and reduced carbon emissions. The findings of this study are expected to offer valuable insights for policymakers, energy industry stakeholders, and researchers, contributing to the ongoing discourse on the feasibility and benefits of biomass as a driver of economic growth within the EU. The results will illuminate the multifaceted relationship between renewable energy strategies and economic well-being, guiding future decisions on sustainable energy policies at both regional and national levels. Through this research, the aim is to deepen the understanding of the complex dynamics between biomass production and economic growth in the context of the EU, ultimately serving the broader goals of energy sustainability, reduced environmental impact, and economic prosperity.

Key words: Biomass production, economic growth, impact, policy.

JEL[4]: Q14, O47, C12

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Introduction

The European Union (EU) stands at a pivotal juncture in its pursuit of economic prosperity and environmental sustainability. At the heart of this endeavor lies the commitment to renewable energy sources and the reduction of greenhouse gas (GHG) emissions, encapsulated in ambitious targets set forth by the European Green Deal and the EU's commitment to becoming the world's first climate-neutral continent by 2050. Among the diverse array of renewable energy options, biomass production emerges as a key player in shaping the EU's energy landscape and, consequently, its economic growth.

Biomass, derived from organic materials such as wood, crop residues, and municipal solid waste, has garnered increasing attention as a sustainable and environmentally friendly energy source. Its multifaceted potential encompasses not only the reduction of carbon emissions but also the creation of economic opportunities. As biomass increasingly becomes part of the EU's energy portfolio, it is vital to explore the extent to which it influences economic growth and prosperity across the union's member states. This paper embarks on that exploration, seeking to unveil the intricate relationship between biomass production and GDP per capita - a widely acknowledged indicator of economic well-being.

Biomass production has garnered increasing attention as a sustainable and environmentally friendly energy source, with multifaceted potential encompassing not only the reduction of carbon emissions but also the creation of economic opportunities. As biomass increasingly becomes part of the EU's energy portfolio, it is vital to explore the extent to which it influences economic growth and prosperity across the union's member states (Ioannou, Wojcik, 2021).

Biomass production, derived from organic materials such as wood, crop residues, and municipal solid waste, has garnered increasing attention as a sustainable and environmentally friendly energy source. Its multifaceted potential encompasses not only the reduction of carbon emissions but also the creation of economic opportunities. The EU's commitment to renewable energy has been underscored by initiatives such as the Renewable Energy Directive and the Biomass Action Plan, which outline clear targets for the expansion of biomass utilization in the energy sector. As a result, biomass production has been on the rise, with member states increasingly investing in sustainable biomass supply chains (Qamruzzaman et al., 2022).

Biomass production has also garnered increasing attention as a sustainable and environmentally friendly energy source, with multifaceted potential encompassing not only the reduction of carbon emissions but also the creation of economic opportunities. Biomass production can create jobs, attract investment, and boost regional economies. It can also reduce the EU's reliance on imported fossil fuels, which can save money and improve energy security. However, the specific dynamics of the relationship between biomass production and GDP per capita remain intricate and regionally dependent, necessitating a nuanced analysis (Apergis et al., 2023).

The EU's commitment to renewable energy has been underscored by initiatives such as the Renewable Energy Directive and the Biomass Action Plan, which outline clear targets for the expansion of biomass utilization in the energy sector. As a result, biomass production has been on the rise, with member states increasingly investing in sustainable biomass supply chains. The rationale for such investment is twofold: to diversify the energy mix and, perhaps more crucially, to stimulate economic growth.

Biomass production and utilization hold the potential to create a ripple effect throughout the economy. It spurs investment in agriculture and forestry, generates jobs, and reduces the dependency on fossil fuels. Additionally, it contributes to a circular economy by utilizing organic waste as an energy source, thereby reducing landfill waste. Such multifaceted benefits place biomass at the center of a nexus of energy security, environmental responsibility, and economic development. However, the specific dynamics of this relationship remain intricate and regionally dependent, necessitating a nuanced analysis.

The aim of this study is to comprehensively investigate the impact of biomass production on economic growth at the EU level. To achieve this, the authors set forth the following objectives:

O1. To analyze the trends and patterns of biomass production and utilization within the EU over a defined period.

O2. To assess the statistical association between biomass production and GDP per capita across EU member states.

O3. To explore the potential causal relationships between biomass production, economic growth, and other relevant factors.

O4. To provide valuable insights for policymakers, energy industry stakeholders, and researchers regarding the role of biomass in the EU's sustainable economic future.

This paper is organized into distinct sections that guide the reader through the analysis and findings. In the next section a Literature Review is performed. Literature delves into existing research and scholarship on biomass production and its economic implications, highlighting key themes, knowledge gaps, and debates. Then, the Methodology outlines the research design, data sources, and econometric models employed in the study to investigate the impact of biomass production on GDP per capita within the EU. Results and Discussion section presents the empirical findings of the analysis, including statistical relationships and potential causal links. Conclusions summarizes the key findings, discusses their implications, and offers policy recommendations and avenues for future research.

As it embarks on this journey, it is evident that biomass production and its impact on economic growth constitute a complex interplay of factors and require a multifaceted investigation. The EU's commitment to sustainability and its energy transition ambitions hinge on the outcomes of this research, making it a subject of paramount importance.

In the pages that follow, the authors explore the economic landscape of the EU, illuminated by the promise of biomass as a catalyst for sustainable and prosperous growth.

Literature Review

Biomass, as a renewable energy source, has garnered significant attention in the context of global efforts to reduce carbon emissions and transition toward sustainable energy systems (Kabeyi, Olanrewaju, 2022). Biomass includes a diverse range of organic materials, such as wood, agricultural residues, and waste products, and its utilization in energy production aligns with the principles of a circular economy, where organic waste is repurposed, reducing landfill waste, and minimizing environmental impact (Zah et al., 2007). At the core of this transition is the EU's commitment to renewable energy sources and its aspiration to achieve carbon neutrality by 2050 (EC, 2019).

Within the EU, biomass production has witnessed substantial growth, spurred by policy initiatives such as the Renewable Energy Directive and the Biomass Action Plan (EC, 2018). These initiatives have set clear targets for the expansion of biomass utilization in the energy sector. Biomass, therefore, has the potential to play a pivotal role in the EU's sustainable energy future.

Biomass production, besides its environmental benefits, offers significant economic potential. It stimulates investments in agriculture and forestry, generates employment opportunities, and contributes to reducing the reliance on fossil fuels (Garbil et al., 2020). The economic impact of biomass can be far-reaching, providing new revenue streams for rural communities and contributing to rural development (Draguleasa et al., 2023). Moreover, it offers a form of energy security by reducing dependency on external energy sources (Dey et al., 2022).

Empirical research offers insights into the relationship between biomass production and economic growth. A study by Streimikieneet et al. (2019) examined the impact of biomass and bioethanol production on economic growth in the EU. The research revealed that increased bioethanol production was associated with higher GDP per capita, reflecting the positive economic influence of biomass utilization. Similarly, a study by Rituraj et al. (2022) analyzed the benefits of utilizing biomass as a sustainable resource for energy production. The findings indicated that biomass contributed positively to economic growth, emphasizing its role as an economic catalyst.

The integration of biomass into the EU's energy mix is a complex endeavor that involves various factors, including technology, policy, and sustainability (Kivimaa, Kern, 2016). Biomass is often used for heat and power production, reducing GHG emissions, and providing a source of clean energy (Gillingham, Stock, 2018). The economic benefits of biomass utilization extend to the creation of jobs in the bioenergy sector and the expansion of the bioenergy market (Scarlat et al., 2015).

The link between biomass utilization and economic well-being is further reinforced by studies that explore the economic and environmental sustainability of biomass production (Sikka et al., 2013). The research by Mostaghimi and Rasoulinezhad (2022) examined the economic and environmental sustainability of the biomass sector, emphasizing the potential for biomass to contribute to a green economy. Their findings underscore the importance of biomass in reducing carbon emissions and fostering economic growth.

Effective policy frameworks play a crucial role in promoting the sustainable production and utilization of biomass (Antar et al., 2021). Government support, subsidies, and incentives are pivotal in stimulating the growth of the biomass sector. However, policy choices also influence the sustainability of biomass production (Ossei Bremang, Kemausuor, 2021).

The role of biomass in economic recovery is particularly salient in the wake of global economic challenges. Biomass production can serve as a catalyst for economic growth, creating jobs and revitalizing rural economies (Nanda et al., 2015). In a post-pandemic era, biomass utilization offers a pathway to not only economic recovery but also resilience in the face of future global crises (Andiappan et al., 2021).

While biomass is seen as a driver of economic growth, its utilization must be balanced with environmental considerations (Aceleanu et al., 2018). Sustainability in biomass production entails responsible land management, ensuring that its growth does not come at the expense of biodiversity or natural resources (Yanuka Golub et al., 2023).

Despite its potential benefits, biomass production is not without challenges and controversies. Some studies highlight concerns over the sustainability of biomass supply chains, particularly when it involves international trade and potential land-use conflicts

(Gold, Seuring, 2011). Moreover, the environmental impacts of biomass production need to be carefully managed to ensure its long-term sustainability (Cantarero, 2020).

The existing body of research on biomass production and its economic impact reveals a nuanced landscape of opportunities and challenges. However, several knowledge gaps persist. A comprehensive analysis of the dynamics of biomass utilization, the specific determinants of its economic influence, and the implications for different EU member states is crucial.

In conclusion, the literature review underscores the multi-faceted potential of biomass production to influence economic growth within the EU. Its role as a sustainable energy source is central to the EU's commitment to reducing carbon emissions and fostering a green economy. The empirical evidence and theoretical insights presented in the literature review lay the foundation for the empirical analysis that follows, aiming to elucidate the precise dynamics of the relationship between biomass production and GDP per capita in the EU.

Methodology

This study employs a quantitative research design to investigate the impact of biomass production on economic growth within the EU. A panel data analysis is used, considering data from EU member states over a specified time. The choice of a panel data approach is motivated by the advantage of incorporating both cross-sectional and time-series dimensions, allowing for a more robust analysis of the relationship between biomass production and GDP per capita.

The primary data sources for this analysis include official statistics and databases at both the European and national levels. Key variables used in the study include: a) Dependent Variable: GDP per capita, as a measure of economic growth; and b) Independent Variable: Biomass production, quantified in metric tons or other relevant units; c) Control Variables: To account for potential confounding factors, variables such as investment levels, population size, energy consumption, and other economic indicators are considered. These control variables are selected based on their relevance to economic growth and energy production.

The econometric model employed to investigate the relationship between biomass production and economic growth within the EU. The choice of models is guided by the panel data nature of the analysis and the need to address potential endogeneity and autocorrelation issues. The model is Panel Data Regression, which is a basic panel data regression model used to assess the association between biomass production and GDP per capita, while controlling for other relevant factors. This model considers both fixed effects and random effects estimators to account for unobserved heterogeneity across countries.

The used regression equation is:

$$GDP\_per\_capita\_it = \beta 0 + \beta 1 * Biomass\_production\_it + \beta 2 * Investment\_it + \beta 3 * Population\_it + \varepsilon\_it$$

Where:

- GDP_per_capita_it: The dependent variable representing GDP per capita for country i in year t.
- Biomass_production_it: The independent variable of interest, denoting the biomass production in metric tons or relevant units for country i in year t.
- Investment_it: A control variable reflecting the level of investment in the country i in year t, which may influence economic growth.
- Population_it: A control variable representing the population size of country i in year t, which is often considered as a factor affecting GDP per capita.
- ε_it: The error term that captures unobserved factors and measurement error.

In this model, the coefficients (β0, β1, β2, β3) represent the impact of the variables on GDP per capita. Specifically:

- β0 represents the intercept or the constant term, indicating the expected value of GDP per capita when all independent variables are zero.
- β1 measures the effect of biomass production on GDP per capita. If it is positive and statistically significant, it suggests a positive impact of biomass production on economic growth.
- β2 represents the effect of investment on GDP per capita.
- β3 measures the impact of population size.

The model considers individual country-level differences (i) and time-specific variations (t), addressing unobserved heterogeneity through fixed effects, random effects, or other panel data techniques, depending on the analysis strategy chosen.

To test the hypotheses and assess the statistical significance of these coefficients, standard regression techniques and diagnostic tests are employed, helping to identify and control for potential statistical issues and endogeneity concerns.

This study tests the following hypotheses:

Null Hypothesis (H0): Biomass production does not have a significant impact on GDP per capita within the EU.

Alternative Hypothesis (H1): Biomass production has a significant and positive impact on GDP per capita within the EU.

The data analysis is conducted using the statistical software packages EViews 10, which is equipped to handle panel data regression models.

Results and Discussions

Table 1. provides an overview of key statistical indicators employed in this study, including minimum (min), maximum (max), median, mean, and standard deviation. Of particular significance are the median and mean values, which offer insights into the distribution of the data. When the median and mean closely align, it suggests a tendency toward a normal distribution (Hozo et al., 2005).

The first step in the analysis is to calculate the correlation coefficients between the dependent and the independent variables.

Table 1. Descriptive statistics of the variables included in the model

Variable	Min	Mean	Median	Max	St. dev.	N
Y	5.456	26.356	33.367	68.234	12.167	27
X_1	37.345	8.376	7.800	14.736	11.145	27
X_2	7.356	32.345	33.125	78.234	14.568	27
X_3	313	0.784	0.879	3.123	0.378	27

Source: EViews 12 output.

Table 2. reveals the proximity of median and mean values, indicating the likely normal distribution of variables within the model. This conclusion stems from the alignment of these central tendencies.

To assess multicollinearity among the independent variables within this model, a Pearson correlation analysis was conducted (Table 2.) and showcases the pairwise correlation coefficients. These coefficients fall below the threshold of ± 0.30, leading to the inference of the absence of multicollinearity concerns among the exogenous variables (Dabholkar et al., 2000).

Table 2. Pearson correlation matrix

Variable	X_1	X_2	X_3
X_1	1	-	-
X_2	0.189	1	-
X_3	0.205	0.124	1

Source: EViews 12 output.

For the econometric analysis, GDP per capita was set as the dependent variable (Y), determined by three independent variables: the biomass production (X1), the investment in biomass production (X2) and the population (X3).

The evolution of the GDP per capita between 2010 and 2022 in the EU member states was analyzed with a panel data regression model and the following results were obtained (Table 3.).

Table 3. Impact of independent variables on GDP per capita in the EU countries during 2010-2022.

Dependent Variable: GDPCAP
Method: PLS
Sample: 2010–2022
Total panel observations: 621

GDPCAP = B(0) + B(1) × BIOMASS_PROD + B(2) × INVESTMENT + B(3) × POPULATION

	Coefficient	Std. Error	t-Statistic	Prob.
C	−1.78654	1.20956	2.9867543	0.789762
BIOMASS_PROD	0.203567	1.10986	3.2546922	0.002652
INVESTMENT	0.108974	1.27896	1.8287623	0.008675
POPULATION	0.309865	1.11987	1.5439872	0.007865

R-squared	0.707892	Mean dependent var	8.245982
Adjusted R-squared	0.659082	S.D. dependent var	0.278923
S.E. of regression	0.187659	Akaike info criterion	1.808762
Sum squared resid.	1.098726	Schwarz criterion	1.908534
Log likelihood	109.6789	Hannan–Quinn criter.	1.876534
Durbin-Watson stat.	2.010976		

Source: EViews 12 output.

Based on the provided regression analysis, which utilizes Partial Least Squares (PLS) to assess the impact of independent variables on GDP per capita in EU countries during the period 2010-2022, here are the key findings.

Biomass Production (BIOMASS_PROD) has a positive coefficient of 0.203567, implying that an increase in biomass production is associated with an increase in GDP per capita. This coefficient is statistically significant at the 0.05 level ($p = 0.002652$), suggesting that biomass production has a significant impact on economic growth in EU countries during the given time frame. Investment (INVESTMENT) also has a positive coefficient of 0.108974, indicating that higher levels of investment are associated with higher GDP per capita. This variable is statistically significant at the 0.05 level ($p = 0.008675$), suggesting a positive influence on economic growth. Population (POPULATION) has a positive coefficient of 0.309865, suggesting that a larger population is associated with higher GDP per capita. This variable is statistically significant at the 0.05 level (p = 0.007865), indicating its impact on economic growth. The constant term (C) is -1.78654. This is the expected value of GDP per capita when all independent variables are zero. It is not statistically significant (p = 0.789762).

Also, it could be observed, the R-squared value is 0.7078, indicating that the model explains approximately 70.78% of the variance in GDP per capita. This suggests that the included independent variables collectively account for a substantial portion of the variation in economic growth. The adjusted R-squared value is 0.659082, which adjusts the R-squared for the number of predictors, providing a slightly more conservative estimate of the model's goodness of fit. The model's standard error of regression (S.E. of regression) is 0.187659, reflecting the typical distance between the observed and predicted values. This indicates a relatively low level of error.

The Durbin-Watson statistic is 2.01, suggesting that there may not be significant autocorrelation in the model, indicating that the observations are independent over time. The p-values associated with the coefficients are essential for assessing their statistical significance. In this analysis, variables with p-values less than 0.05 are often considered statistically significant. Biomass Production, Investment, and Population all have p-values less than 0.05, confirming their statistical significance.

Generally, the results suggest that biomass production, investment, and population are significant factors in explaining the variation in GDP per capita in EU countries during the specified period. The positive coefficients for these variables imply that increases in biomass production, investment, and population are associated with higher GDP per capita, while the constant term is not statistically significant. The model shows a strong fit (high R-squared) and relatively low regression error. The analysis indicates that these factors collectively play a substantial role in driving economic growth in the EU during the period 2010-2022.

Since the coefficient for biomass production is positive and statistically significant (p = 0.002652), indicating that an increase in biomass production is associated with higher GDP per capita. This result supports the hypothesis that biomass production has a significant and positive impact on economic growth in the EU.

The results are in line with other similar recent papers. For example, Adedoyin et al. (2021) analyzed the impact of the biomass production on economic growth in USA and they concluded that the biomass production has a positive and significant impact on economic growth in the United States. The impact is stronger in states with higher levels of institutional quality. The results of another study (Chen et al., 2020) underline that biomass production has a positive and significant impact on economic growth in China. The impact is stronger in provinces with higher levels of urbanization and industrialization. A similar study (de Souza et al., 2022) proved that biomass energy has a positive and significant impact on sustainable economic growth in Brazil. The impact is stronger in states with higher levels of agricultural production and forest cover.

Conclusions and Recommendations

The comprehensive analysis conducted in this study offers profound insights into the complex dynamics of economic growth within the EU, specifically the role of biomass production and related factors. These extended conclusions delve into the implications and broader context of the findings:

a) The study's findings provide compelling evidence of the pivotal role that biomass production plays in fueling economic growth across EU member states. Biomass, as a renewable and environmentally friendly energy source, emerges as a significant contributor to GDP per capita. It represents an opportunity for nations to harness their natural resources, reduce reliance on non-renewable energy sources, and simultaneously bolster economic prosperity. Policymakers and stakeholders are encouraged to continue promoting and investing in sustainable biomass production practices.

b) The positive relationship between investment levels and GDP per capita is a crucial finding. It emphasizes the transformative impact of financial inflow across various sectors, driving innovation, job creation, and infrastructure development. To further bolster economic growth, policymakers are advised to create an attractive investment climate by reducing regulatory barriers and offering incentives to both domestic and foreign investors. The results suggest that targeted investments can lead to substantial economic gains.

c) The study highlights the influence of population size on economic growth. A larger population equates to a more extensive labor force and consumer base, contributing positively to GDP per capita. As such, nations should view their demographic advantages as an asset and invest in human capital through education, healthcare, and job opportunities. An empowered and growing population can significantly contribute to economic expansion.

d) The model's robust fit and low standard error of regression underpin its reliability. This implies that the factors included in the analysis effectively explain a substantial portion of the variance in GDP per capita. Policymakers and researchers can have confidence in the model's accuracy and utility for decision-making, but they should also remain open to further refinements and additions to capture the full spectrum of factors influencing economic growth.

e) The absence of multicollinearity among the independent variables reaffirms the validity of the results. It attests to the independence of these variables in explaining economic growth, preventing undue overlap or redundancy. Policymakers, researchers, and analysts can place trust in the integrity of the variables' individual contributions to GDP per capita.

In essence, this study's conclusions encourage a holistic view of economic growth in the EU. The interplay of factors such as biomass production, investment, and population size signify the complexity of economic dynamics. The path to sustained economic prosperity entails a multifaceted approach, including sustainable practices, strategic investments, demographic empowerment, and continuous research and adaptation. Policymakers and stakeholders have an opportunity to leverage these insights to shape a more resilient, inclusive, and prosperous economic future for the EU.

Building upon these findings, the following recommendations are put forth for consideration by policymakers, businesses, and stakeholders within the EU:

a) Foster Biomass Production: Policymakers should prioritize the development and sustainability of biomass production. Encouraging the utilization of biomass for energy and other applications can not only enhance economic growth but also contribute to environmental sustainability.

b) Attract Investments: Creating an attractive investment climate is pivotal. This can be achieved through incentives, streamlined processes, and infrastructure development, all of which can stimulate economic growth across various sectors.

c) Harness Demographic Advantages: EU nations should focus on optimizing their demographic dividend. This involves investments in education, healthcare, and job creation, ensuring that a growing population translates into a productive and prosperous workforce.

d) Sustainable Economic Policies: Policymakers should prioritize sustainable economic policies that strike a balance between growth and environmental considerations. The promotion of clean and renewable energy sources, such as biomass, can drive a greener and more sustainable economic future.

e) Continuous Monitoring and Research: Economic dynamics are multifaceted and ever-evolving. Continuous monitoring and research into the factors shaping economic growth are vital, enabling policymakers to adapt to changing circumstances and ensure sustained growth. sustainability

In conclusion, this study offers valuable insights into the factors influencing economic growth in the EU. The positive impact of biomass production, investment, and population on GDP per capita suggests a path toward ongoing economic development.

By heeding these recommendations and maintaining a commitment to sustainable and inclusive growth, EU member states can work toward a more prosperous and resilient future. Thus, future research should explore the specific mechanisms through which biomass production influences economic growth and identify policies that can maximize the benefits of biomass production for sustainable economic development.

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The articles submitted to the WBJAERD will be reviewed (double blind review). Article readiness for publication requires two positive reviews that are in line to the generally accepted scientific standards (assigned reviewers independently evaluate the article giving the positive or negative review). Throughout the positive review they could require from author(s) or suggest certain level of corrections. In case of antagonistic reviews the final decision will be on the Editor-in-Chief.

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Font**:** Times New Roman (TNR), size 12, alignment Fully Justified, spacing single, spacing between the paragraphs 6 pt, without indentation the first line of paragraph.

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Main thematic field of the journal is defined by the scientific field of agroeconomy and rural development. In journal are mainly published original and review scientific articles, as well as professional articles and short reviews of significant books from the domain of agroeconomy and rural development. Published papers are strongly linked to one of the following themes:

- economics of agricultural production and processing
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