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What Makes Farmers Aware in Adopting Circular Bioeconomy Practices? Evidence from a Greek Rural Region

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Abstract: Action 2 of the European Union's Updated Bioeconomy Strategy, i.e., "Deploy local bioeconomies rapidly across Europe", promotes education and training in all member states. It is a fact that Greece has not yet adopted a national bioeconomy strategy, so stakeholders and farmers cannot benefit from its potential. The adoption of bioeconomy practices is now a prerequisite for receiving funding under the Common Agricultural Policy 2023–2027. Farmers unknowingly use some bioeconomy practices on their farms, and in this study, an attempt was made to investigate how farmers in the region of Western Macedonia would like to be trained in respect of the bioeconomy, knowing the opportunities it offers. The research was conducted through a structured questionnaire answered by 412 farmers from the region. The findings from the subsequent k-means cluster analysis show that farmers can be classified into three clusters: engaged, restricted, and partially engaged. The perceptions that predominate in each cluster are influenced by age, income, and the regional unit in which the farmers reside. In addition, the decarbonization of the Western Macedonia region influences their views and how they would like to be informed about opportunities arising from the bioeconomy. Limitations in this study include the fact that the sample consists only of farmers living and operating in a particular region. In addition, there is an urgent need for political will to establish a national strategy for the bioeconomy. The importance of the present study lies in the fact that few studies have addressed the training of farmers on bioeconomy issues either in Greece or internationally.

Keywords: bioeconomy; training; farmers; bioeconomy practices; regional approach; k-means cluster analysis; Western Macedonia region

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1. Introduction

Strategies for the bioeconomy promote farmer training because educated and skilled farmers are essential to the growth and success of the sector [1–3]. The role of farmers in the production of bio-based products and the adoption of sustainable agriculture practices is critical, and providing them with training and education is necessary to ensure they are equipped to meet the demands of the expanding bioeconomy [4]. To train farmers in respect of the bioeconomy, they need to be educated on the principles and practices of the efficient and sustainable use of biological resources for the production of various products such as food, energy, and materials. This includes teaching them about the latest advancements in biotechnology, agroforestry, precision agriculture, and regenerative farming [5]. Additionally, they should be trained on the economic and business aspects of the bioeconomy, including marketing, branding, and product development [6]. The aim of this training is to empower farmers to play a critical role in the transition towards a more sustainable and resilient future.

The bioeconomy in agriculture has a significant impact on production factors, natural resources, and their potential [7]. The purpose of production factors is to create a favorable environment for the growth and development of farms, influenced by both internal and external variables. Land, the primary production factor in agriculture, determines the productive potential of a farm through its resources [8]. An outdated belief is that land efficiency is related to farm size, but bioeconomics refutes this by linking land efficiency to the farming practices used. Land quality affects production costs, establishes regional comparative advantages, shapes regional structure, and affects the competitiveness of agriculture [9]. The bioeconomy in the agricultural sector generates income comparable to other sectors of the economy, provides the financial resources necessary for modernization, promotes food self-sufficiency, preserves the productive potential of the soil, implements efficient use of agricultural land, reduces environmental risks, and contributes to the production of raw materials with desired quality specifications [10–12].

Sustainable agriculture adheres to the principles of the bioeconomy and ensures that future generations have access to natural resources. It provides opportunities for farmers and the region, enhances quality of life, conserves diversity, offers high-quality employment, emphasizes innovation and education, and fosters social unity through equal opportunities [13,14]. Sustainable agriculture is the definitive solution to the challenges facing the agricultural sector. The utilization of natural resources must be managed in a way that uses renewable resources without depleting or reducing their usefulness [14,15].

Given the above considerations, bioeconomy policies concentrate on training stakeholders, citizens, and farmers on bioeconomy issues [3,16]. In terms of training, stakeholders play an active role in documenting available data sources and identifying gaps in data collection that are crucial for implementing this practice [17]. This will enable the collection and utilization of all existing data by relevant public organizations, which are essential for establishing indicators to monitor training performance [18]. The engagement of these stakeholders is expected to significantly contribute to the overall implementation of the Sustainable Development Goals (SDGs) as outlined in the 2030 Agenda for Inclusive Education [19,20].

In Greece, efforts are also underway to promote the bioeconomy, specifically in the Western Macedonia region. The Cluster of Bioeconomy and Environment of Western Macedonia (CluBE) is working towards the establishment of a bioeconomy strategy at both the regional and national levels through its involvement in the European projects BIOMODEL4REGIONS and CEE2ACT. However, Greece lags behind other European countries in developing a bioeconomy strategy. Although many stakeholders are present, they lack the necessary information and appear hesitant or even resistant to participate in bioeconomy forums, workshops, and hubs. To address this issue, CluBE has assumed the role of engaging and informing relevant stakeholders at both the local and national levels.

The agricultural sector, particularly through the agri-food partnership, is poised to have a significant impact in Western Macedonia, a region undergoing transition [21,22]. To facilitate a seamless and equitable transition, training and capacity-building efforts in the broader agri-food sector are necessary [23]. Essential components include training for farmers, agricultural advice, production of educational materials, and creation of demonstration fields, as well as skill-building activities such as study visits and exchanges [24]. Dividing farmers into separate categories based on their varying perspectives, opinions, and worries could prove beneficial in devising tailored approaches for each group based on their unique characteristics. Cluster analysis can be used as a method to categorize farmers into exclusive groups [25,26].

The aim of this study was to investigate how farmers in the Western Macedonia region would like to be trained and informed in respect of the bioeconomy, based on their profiles, knowing the opportunities it offers, in order to develop a sustainable and acceptable training plan. For this purpose, a structured questionnaire specific to the case was created and presented to farmers in the WM region of Greece. The significance of the current study stems from the limited amount of attention that has been paid to training farmers about bioeconomy-related topics and the potential opportunities that come with the bioeconomy, either within Greece or internationally.

The structure of the study was designed to ensure a comprehensive understanding. Following this introduction, the study area and methodology are outlined in Section 2, the main results are presented in Section 3, Section 4 provides a discussion of the results and potential future avenues of research, and finally, Section 5 reflects on the main conclusions and limitations of the research.

2. Materials and Methods

2.1. Study Area

Western Macedonia, as shown in Figure 1, is the only region in Greece with borders that touch two Balkan countries and is the only region that does not have a coastal boundary [27]. The Western Macedonia region is partitioned into four distinctive regional units, namely Kozani, Grevena, Kastoria, and Florina, each possessing an exclusive economic profile with different industries playing a pivotal role in their respective economies (Figure 1). Over the past 60 years or more, Western Macedonia has displayed a combination of industrial and agricultural attributes due to the utilization of coal reserves for electricity production. This region contributes 2.2% to the national gross domestic product, mainly through the mining industry and agriculture. It is considered a "single activity" region, as it is the primary area for electricity production in the country [27].

Figure 1. Map of Western Macedonia region.

Western Macedonia remains a hub for mining and energy production from lignite, having supplied energy to the nation for numerous decades [28–30]. However, the lignite sector has not generated significant industrial spillover effects that could have further catalyzed industrial growth and offset the losses from the decarbonization process. The region's specialization in other productive sectors remains weak to moderate, with a monoculture of lignite rendering the local economy highly dependent and vulnerable [31]. As a result, the entire region will be directly impacted by the decarbonization process.

Furthermore, the region has a significantly lower expenditure on research and development compared to the national average, according to an OECD study [32]. This indicates a limited capacity for the local research and production base to innovate, for the public sector to support innovation, and for the private sector to make structural adjustments to enhance competitiveness [33]. The decarbonization process is expected to result in the loss of approximately 10,600 jobs in Western Macedonia by 2029, both directly and indirectly, compared to the year 2019. It is also estimated that the region will experience a loss of more than EUR 1 billion in gross value added by 2029, or 26% of the region's GDP, compared to 2019 [34].

The decarbonization process will compound the already challenging socioeconomic situation in the region [35,36]. Western Macedonia is sparsely populated, with negative demographic indicators and an ageing population, as well as high unemployment rates, especially among women and young people, high rates of youth migration, and high poverty rates. Additionally, approximately 42,000 households and businesses in the region rely on district heating, with a total demand of approximately 600 GWh [31].

The majority of the 266,160 inhabitants of Western Macedonia reside in the regional units of Kozani and Florina, where 80% of the regional GDP is produced and the largest concentration of employment is located. According to the OECD [32], approximately 12,000 workers across the region are estimated to be affected by the decarbonization process, with the majority located in Kozani and Florina. The regional units of Kastoria and Grevena will mainly be affected due to indirect impacts on the lignite value chain and the reduction in employment and incomes in the entire region [33]. Thus, the decarbonization process will primarily impact the regional units of Kozani and Florina and secondarily the regional units of Kastoria and Grevena.

The agricultural sector in Western Macedonia, Greece, is a substantial contributor to the region's financial stability [37,38]. The region boasts fertile soil and an advantageous climate, which facilitates the growth of a diverse range of crops, including fruit, vegetables, and grains. The principal crops grown in Western Macedonia include apples, cherries, peaches, pears, tomatoes, peppers, cucumbers, wheat, barley, and corn. Additionally, the region is a noteworthy producer of livestock products, such as meat, milk, and cheese. A feature that distinguishes Western Macedonia from other regions in Greece in terms of farmers' behavior is the relative remoteness and isolation of some of its rural areas. This can impact the behavior of farmers in several ways. Farmers in remote areas may have limited access to markets, which can influence their decisions about which crops to grow and how to sell their products. They may be more likely to focus on crops that have a longer shelf life or are easier to transport. In addition, farmers in remote areas may be more self-sufficient, relying on their own resources and skills to produce food and other goods. This can influence their behavior in terms of how they manage their farms, what equipment they use, and how they market their products. The remoteness of some rural areas in Western Macedonia may also foster a stronger sense of community among farmers. They may be more likely to work together to share resources, such as labor and equipment, and to support each other in times of need.

In recent years, the agricultural sector in Western Macedonia has encountered difficulties due to the decrease in agricultural product prices, the rise in competition from imported goods, and the ramifications of global warming. However, the Greek government has implemented various programs and initiatives aimed at enhancing the competitiveness of local farmers and supporting the industry [39]. Despite these obstacles, the agricultural sector remains a crucial aspect of Western Macedonia's economy and provides employment opportunities for a considerable portion of the population. It is anticipated that the sector will continue to play a vital role in the economic progression of the region in the coming years.

2.2. Procedures and Measurements

The primary objective of this research was to explore farmers' perceptions of the opportunities arising from bioeconomy training. Agriculture is the key sector in which the bioeconomy can be implemented and have a positive impact, such as reducing environmental pollution and dependence on fossil fuels [11,40,41]. To achieve this objective, cluster analysis was employed as a method to categorize farmers based on their unique characteristics and perceptions (Figure 2).

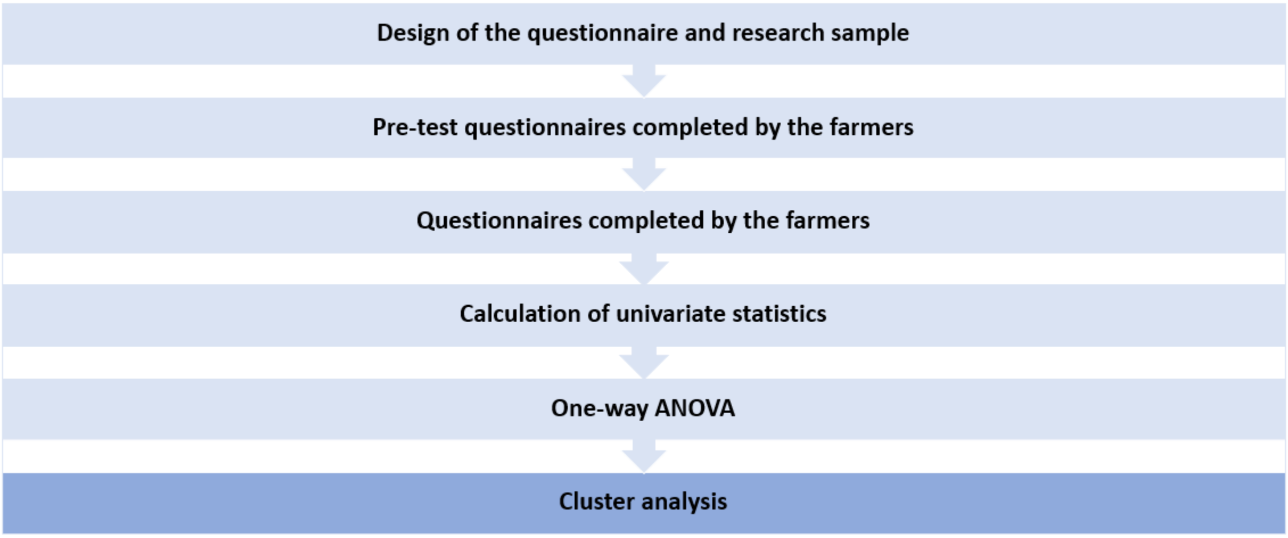

Figure 2. Methodology followed.

Cluster analysis is a technique used to group together statistical units or systems based on their similarities in observed variables, resulting in structures known as clusters [26,42]. The aim of this analysis is to divide the components into groups where the units within each group have high similarities to each other and are distinct from units in other groups [25]. This method effectively highlights relationships and patterns in the data that may not be easily recognizable through other means [43].

For this study, several statistical procedures were undertaken using the Statistical Package for Social Sciences (version 23). The research steps involved the following:

(1) Calculation of univariate statistics for all survey items before conducting any further statistical analysis.
(2) Usage of one-way ANOVA to determine differences between five sociodemographic variables in relation to the 22 items measuring the opportunities arising from the bioeconomy in the agricultural sector.
(3) A nonhierarchical cluster analysis, utilizing the k-means cluster algorithm, was performed on the 22 items measuring the perceived impacts.

This analysis did not take into account the sociodemographic variables, thereby enabling the classification of residents purely based on their perceptions and not their demographic characteristics.

The employment of cluster analysis in this study was validated by an earlier assessment, calculated using Kaiser–Meyer–Olkin statistics [44], yielding a score of 0.777 that surpassed the recommended threshold, and indicating the suitability of both the sample size and the number of variables.

With the stated objectives in mind, data collection was carried out through a questionnaire administered to farmers in all regional units of the Western Macedonia region between February and August 2022. The initial step in establishing the sampling frame was to identify the target population for the survey. A population refers to any comprehensive group of entities, such as individuals or organisms, that share a common set of characteristics that are crucial for the study's objectives. Researchers aim to make generalizable conclusions about this group [45]. The Hellenic Statistical Authority's Census of Agriculture and Livestock provides a numerical estimate of the population, indicating that in 2021, the number of farmers (including both owners and household members who are employed) in the Western Macedonia region was 24,205. A sample of 20 to 30 observations per group is enough to accurately detect subgrouping using k-means, with good precision both in determining the number of clusters in the sample and identifying the cluster membership of individual observations [46]. A total of 420 questionnaires were collected from farmers, with 412 deemed usable and included in the analysis.

Onsite sampling was conducted in the region to meet the needs of the survey, as opposed to online data collection [47]. This was because the physical presence of participants would ensure the accuracy and validity of their responses, thereby enhancing the quality of the results [48]. A researcher visited each community or household and asked potential farmers who were over 18 years old and willing to participate in the survey to share their perceptions about their familiarity with the concept of the bioeconomy. There were no instances of refusal to participate, although a protocol was in place to handle such situations.

A pretest [49] was conducted on 15 farmers between 15 and 20 January 2022. This exercise determined that filling in the questionnaire would take approximately 15 min, among other things. The final questionnaire contained two sections of questions. The first section contained questions on the demographic characteristics of farmers and the second section contained questions on attitudes and perceptions towards the bioeconomy.

Responses were evaluated using a Likert scale, where 1 represented an extremely unfavorable response (strongly disagree) and 5 indicated an extremely favorable response (strongly agree) [50].

3. Results

3.1. Respondents' Profiles and General Data

The survey sample's sociodemographic profile is mainly characterized by the following: 88.3% of the respondents were male, the most commonly represented age group was 46–55 years old (38.3%), 50.5% of respondents had a secondary education, and only 10.7% had a higher level of education. Additionally, the majority of respondents (33.3%) lived in the regional unit of Kozani, and 25.2% had an annual income of EUR 20,001 to 30,000. Detailed information on the respondents' profile can be found in Table 1.

Before delving into the results of the group analysis, it is important to provide some general information about the sample as a whole. By asking the question "Are you familiar with the concept of the bioeconomy" and using a Likert scale, we found that 57.52% of respondents were familiar with the concept and strongly agreed (56.80%) that information and training about the bioeconomy would bring benefits to farmers and their farms. When combining the respondents who agreed, we found that 75.97% held a positive view. Only 6.07% of respondents completely disagreed with this statement. This positive perception of the bioeconomy is not in line with previous findings by Stern et al. [51] and Wensing et al. [52]. However, this belief was found to be more prevalent when dealing with an emerging production model like the bioeconomy.

The belief that adopting bioeconomy practices would increase farmers' income is not widely held. Only 19.4% of farmers thought it would lead to an increase, while 28.9% thought it would lead to a decrease, and 51.7% had no answer. Thus, while farmers in the Western Macedonia region see the bioeconomy as an important opportunity, they are not confident it will benefit them personally. These results may reflect farmers' high expectations of the socioeconomic potential of the bioeconomy, or a lack of understanding of its implications. This is particularly relevant since the region has only one emerging opportunity through decarbonization. It is possible that this also indicates a lack of understanding about the implications of the bioeconomy, to some degree [53].

Table 1. Frequencies of sociodemographic profile of farmers.

Variable	Value	Frequency	Percentage
Sex	Male	364	88.3%
	Female	48	11.7%
Age	18–25	14	3.4%
	26–35	36	8.7%
	36–45	106	25.7%
	46–55	158	38.3%
	56–65	79	19.2%
	66+	19	4.6%
Education	Primary school	48	11.7%
	Secondary school	111	26.9%
	High school	208	50.5%
	University	44	10.7%
	Master's degree	1	0.2%
Regional unit of residence	Grevena	90	21.8%
	Kastoria	104	25.2%
	Kozani	137	33.3%
	Florina	81	19.7%
Annual household income	<EUR 10,000	37	9%
	EUR 10,001–20,000	97	23.5%
	EUR 20,001–30,000	104	25.2%
	EUR 30,001–40,000	64	15.5%
	>EUR 40,000	60	14.6%
	No answer	50	12.1%

Source: Authors' elaboration.

Table 2 displays the findings for the aforementioned questions and the reactions to the 22 declarations of potential opportunities emerging from the bioeconomy through farmer training. The Likert scale ranged from 1 (signifying "strongly disagree") to 5 (signifying "strongly agree") for all items. Upon scrutinizing the data, it is evident that, overall, the farmers surveyed were in concurrence with the affirmative outcomes of the bioeconomy and vehemently opposed certain inadequately financed training techniques.

The ANOVA analysis did not exhibit any statistically significant differences owing to the farmers' highly comparable responses. Nevertheless, the variables of age and education level were identified as the two primary discriminating factors that distinguished the perceived bioeconomic prospects. Specifically, age was determined to be a meaningful discriminator for sixteen of the items. The ANOVA findings outlined in Table 3 established that younger farmers demonstrated a greater inclination towards the potential benefits of bioeconomy training for farmers when compared to their older counterparts. These observations conform to prior investigations by Wensing et al. [52], Soubry et al. [54], and Donner et al. [55], which also indicated that older farmers are inclined to have a pessimistic viewpoint towards changes related to the implementation of a bioeconomic production model.

The level of education emerged as a noteworthy factor in distinguishing the perceived effects of the bioeconomy across fourteen different aspects. As per the findings in Table 4, farmers who possess higher levels of education exhibit greater faith in the opportunities that the bioeconomy can bring to the agricultural sector and demonstrate an interest in receiving local training. These outcomes align with previous research conducted by Petersen and Phuong [56], Tyndall et al. [57], and Poku et al. [58]. Moreover, a study by Case et al. [59]

found that farmers with advanced educational qualifications were more likely to agree on the potential benefits of the bioeconomy in the agricultural sector.

Table 2. Total responses to 2 general questions and 22 questions on opportunities and training in respect of the bioeconomy.

		Likert Scale						
		1	**2**	**3**	**4**	**5**	**M**	**SD**
General questions	Are you familiar with the concept of the bioeconomy?	6.07	2.67	15.29	18.45	57.52	4.19	1.162
	Bioeconomy information and training benefits farmers and their holdings	5.34	2.43	15.05	20.39	56.80	4.14	1.138
Opportunities	Environmental protection	1.46	2.18	5.10	25.97	65.29	4.51	0.812
	Sufficient biomass quantity	1.21	4.37	8.74	22.82	62.86	4.42	0.910
	Existence of policy	3.16	5.34	9.47	26.21	55.83	4.26	1.041
	Technology development	1.70	6.80	12.38	50.49	28.64	3.98	0.915
	Waste reduction	1.21	5.83	19.66	28.88	44.42	4.09	0.988
	Saving water resources	0.73	7.52	11.89	42.96	36.89	4.08	0.922
	Production increase	22.82	7.52	13.83	16.99	38.83	3.42	1.595
	Energy production	17.48	9.47	15.05	20.39	37.62	3.51	1.499
	Improving health	2.18	17.48	14.08	28.16	38.11	3.83	1.179
	Increasing consumption	17.96	6.55	18.69	18.45	38.35	3.53	1.493
	Food and feed production	2.43	5.34	16.50	31.80	43.93	4.09	1.015
	Land use change	2.43	13.35	14.56	19.90	49.76	4.01	1.183
	Financial resources for investments	1.70	5.34	12.38	24.51	56.07	4.28	0.988
	Research and innovation for new products and processes	2.18	11.65	9.47	20.87	55.83	4.17	1.136
	Exploiting renewable resources	4.61	10.19	22.57	25.49	37.14	3.80	1.177
	Climate change mitigation	1.46	10.92	23.06	27.43	37.14	3.88	1.076
	Pollution reduction	3.64	10.19	7.52	35.92	42.72	4.04	1.113
Training	Training programs at local level	58.50	8.50	4.61	9.71	18.69	2.22	1.631
	Training programs at local level (subsidized)	13.83	3.88	6.31	10.44	65.53	4.10	1.454
	Training in a regional center (subsidized)	46.36	9.47	8.98	9.71	25.49	2.58	1.703
	Information in the form of leaflets	86.89	2.91	2.91	3.64	3.64	1.34	0.970
	Theoretical online courses	82.52	4.37	4.85	2.67	5.58	1.44	1.085

Source: Author's elaboration.

Table 3. Mean scores and ANOVA tests by age.

Impact of Bioeconomy in Agriculture	18–25 (n = 14)	26–35 (n = 36)	36–45 (n = 106)	46–55 (n = 158)	56–65 (n = 79)	+66 (n = 19)	F	*p*-Value
Environmental protection	4.43	4.06	4.54	4.59	4.61	4.32	3.127	0.009
Sufficient biomass quantity	4.86	3.89	4.58	4.45	4.48	3.63	7.269	0.000
Existence of policy	4.71	3.75	4.32	4.35	4.38	3.37	5.882	0.000
Technology development	3.86	4.17	3.78	4.02	4.16	3.63	2.636	0.023
Production increase	4.26	3.28	3.27	3.25	3.87	3.26	2.777	0.018
Energy production	4.29	3.61	3.38	3.28	3.99	3.42	3.374	0.005
Improving health	4.50	3.92	4.05	3.55	3.90	3.89	3.611	0.003
Increasing consumption	3.79	3.56	3.90	3.20	3.75	3.00	3.816	0.002
Food and feed production	4.36	3.69	4.17	4.08	4.27	3.63	2.725	0.020
Research and innovation for new products and processes	4.43	3.78	3.75	4.32	4.47	4.42	6.025	0.000
Exploiting renewable resources	4.14	3.69	3.60	3.93	3.65	4.47	2.853	0.015
Climate change mitigation	4.57	3.72	3.55	4.04	3.90	4.11	4.362	0.001
Pollution reduction	4.64	3.72	3.56	4.26	4.25	4.16	7.861	0.000
Training programs at local level	3.00	3.36	1.92	2.25	2.05	1.53	6.078	0.000
Training in a regional center (subsidized)	2.93	4.00	2.54	2.39	2.43	2.21	6.217	0.000
Theoretical online courses	1.00	2.56	1.41	1.35	1.33	1.11	9.757	0.000

Source: Author's elaboration.

Table 4. Mean scores and ANOVA tests for education level.

Impact of Bioeconomy in Agriculture	Primary School (n = 48)	Secondary School (n = 111)	High School (n = 208)	University (n = 44)	Master's Degree (n = 1)	F	*p*-Value
Environmental protection	4.33	4.70	4.44	4.66	2.00	5.538	0.000
Sufficient biomass quantity	4.06	4.56	4.42	4.48	2.00	4.454	0.002
Existence of policy	3.98	4.42	4.31	3.98	2.00	3.776	0.005
Technology development	4.15	3.85	3.97	4.18	2.00	2.738	0.028
Saving water resources	4.04	3.95	4.11	4.32	2.00	2.634	0.034
Production increase	4.40	2.86	3.40	3.84	2.00	9.683	0.000
Energy production	4.29	2.91	3.55	4.00	3.00	9.724	0.000
Improving health	4.21	3.62	3.78	4.14	3.00	3.110	0.015
Food and feed production	3.81	4.33	4.11	3.80	2.00	4.649	0.001
Exploiting renewable resources	4.23	3.60	3.75	4.11	3.00	3.439	0.009
Training programs at local level	2.40	1.62	2.25	3.32	3.00	9.694	0.000
Training in a regional center (subsidized)	3.67	1.90	2.57	3.25	1.00	12.470	0.000
Information in the form of leaflets	1.56	1.13	1.31	1.82	1.00	4.922	0.001
Theoretical online courses	1.31	1.24	1.37	2.48	1.00	12.723	0.000

Source: Author's elaboration.

Few significant differences were found in relation to the perceived opportunities among the remaining three independent variables, namely, sex, regional unit of residence, and income.

3.2. Cluster Analysis

Consistent with prior research [60–64], a nonhierarchical k-means cluster analysis was employed. This particular method is specifically designed to classify cases rather than variables and is more efficient for analyzing larger datasets (n > 200) compared to the hierarchical technique [65]. However, it does require a predetermined specification of the number of groups to be formed.

Adopting the approach employed by Violán et al. [60] and Murray and Grubesic [61], a stepwise methodology was utilized to construct 2–5 groups, founded upon the mean score of 22 items measuring the opportunities arising from farmers' bioeconomy training. Table 5 presents the distribution of the sample percentages among each group and among the various groupings (ranging from two to five groups). As evidenced by the data, the selection of four or five groups yields a minority grouping that accounts for less than 10% of the overall sample. For simplicity and ease of understanding the results, it was decided to limit the clusters to three.

Table 5. Percentage of sample within each group.

	Number of Groups			
Clusters	**2**	**3**	**4**	**5**
1	81%	56%	22%	21%
2	19%	21%	44%	9%
3	-	23%	25%	22%
4	-	-	9%	32%
5	-	-	-	17%

Source: Author's elaboration.

Having completed the nonhierarchical k-means cluster analysis, an alternative cluster approach was employed to test the robustness of the clustering results. In particular, a two-step cluster analysis (TSCA) was additionally employed automatically selecting the number of clusters and including the same predictors as in the nonhierarchical k-means cluster analysis. The selection of the TSCA was based on the qualitative nature of the variables of the research instrument [37,66,67]. TSCA suggests an optimal solution of four clusters very similar to the nonhierarchical k-means cluster analysis, both in size and characteristics. In particular the first cluster includes 22% of the sample members, the second cluster includes 7.5% of the sample members, the third cluster includes 21.5% of the sample members, the fourth cluster includes the 34% of the sample members while 15% of the sample members is not categorized in any cluster although they behave like its fifth cluster of the nonhierarchical k-means analysis. TSCA results verify the robustness of the employed nonhierarchical k-means cluster analysis and thus initial clustering was accepted and included in the multivariate statistical methodology that follows.

The examination of the various clusters involved an analysis of the mean values for 22 elements related to opportunities arising from the bioeconomy (Table 5), which helped to determine the degree of agreement or disagreement among farmers regarding these elements for each cluster. Table 6 also indicates that all impacts made a significant contribution in identifying the clusters (*p*-value = 0.000). Among the impacts that differentiated the clusters the most were "training programs at local level", "Training in a regional center (subsidized)", "information in the form of leaflets", and "theoretical online courses". They all represent the kind of training with which farmers would like to be updated. The issue of "training programs at local level (subsidized)" appears to be a point of agreement for farmer consensus and has been previously observed by other researchers such as Lokhorst et al. [68]. Looking at perceived opportunities, the item that demonstrates a lesser degree of differentiation between clusters is "sufficient biomass quantity".

Table 6. Perceptions about opportunities and training in respect of the bioeconomy among clusters (percentage agreeing [a] and average scores [b]).

	Cluster 1, n = 229 (56%)		**Cluster 2, n = 87 (21%)**		**Cluster 3, n = 96 (23%)**			
	Agree (%)	**Average Scores**	**Agree (%)**	**Average Scores**	**Agree (%)**	**Average Scores**	**F-Ratio**	***p*-Value**
Opportunities								
Environmental protection	90.4	4.54	57.5	3.51	100.0	4.96	72.581	0.000
Sufficient biomass quantity	96.5	4.62	67.8	3.76	100.0	4.96	89.645	0.000
Existence of policy	86.9	4.35	49.4	3.32	100.0	4.91	74.058	0.000
Technology development	91.7	4.36	47.1	3.09	78.1	3.86	87.023	0.000
Waste reduction	74.2	4.21	41.4	3.09	100.0	4.72	95.909	0.000
Saving water resources	90.8	4.33	33.3	3.02	95.8	4.44	111.742	0.000
Production increase	94.8	4.63	13.8	2.75	1.0	1.13	1081.135	0.000
Energy production	94.8	4.62	25.3	2.93	0.0	1.40	829.742	0.000
Improving health	96.9	4.50	21.8	2.83	33.3	3.13	145.195	0.000
Increasing consumption	89.5	4.46	9.2	2.68	21.9	2.06	214.374	0.000
Food and feed production	86.0	4.30	24.1	2.95	97.9	4.64	113.449	0.000
Land use change	74.7	4.12	42.5	3.09	82.3	4.58	47.173	0.000
Financial resources for investments	90.8	4.48	32.2	3.03	100.0	4.94	175.691	0.000
Research and innovation for new products and processes	92.6	4.59	33,3	2,93	78.1	4.28	99.901	0.000
Exploiting renewable resources	72.1	3.94	24,1	2,95	75.0	4.24	36.161	0.000
Climate change mitigation	78.6	4.19	31,0	2,98	61.5	3.95	50.126	0.000
Pollution reduction	93.4	4.42	42.5	3.00	76.0	4.07	68.016	0.000
Training								
Training programs at local level	37.1	2.54	34.5	2.45	2.1	1.23	25.779	0.000
Training programs at local level (subsidized)	79.5	4.22	46.0	2.98	94.8	4.82	47.339	0.000
Training in a regional center (subsidized)	38.4	2.77	58.6	3.45	6.3	1.35	45.862	0.000
Information in the form of leaflets	7.4	1.36	14.9	1.68	0.0	1.00	11.812	0.000
Theoretical online courses	8.7	1.50	13.8	1.69	2.1	1.08	8.138	0.000

Source: Author's elaboration. [a] Percentage agreeing are those answering four or five on the five-point scale. [b] Scale ranges from 1 = completely disagree to 5 = completely agree.

Table 7 presents the results obtained from the cluster analysis, in terms of the demographic and social profile of farmers belonging to the three groups.

Table 7. Demographic profile of the three clusters of farmers.

	Cluster 1		Cluster 2		Cluster 3		Chi-Squared Value	*p*-Value
	N = 229	56%	N = 87	21%	N = 96	23%		
Sex							10.489	0.05
Male	202	88.2%	70	80.5%	96	95.8%		
Female	27	11.8%	17	19.5%	4	4.2%		
Age							18.345	0.049
18–25	11	4.8%	3	3.4%	0	0.0%		
26–35	17	7.4%	13	14.9%	6	6.3%		
36–45	55	24.0%	20	23.0%	31	32.3%		
46–55	82	35.8%	34	39.1%	42	43.8%		
56–65	54	23.6%	12	13.8%	13	13.5%		
66+	10	4.4%	5	5.7%	4	4.2%		
Education							32.944	0.000
Primary school	36	15.7%	12	13.8%	0	0.0%		
Secondary school	48	21.0%	22	25.3%	41	42.7%		
High school	117	51.1%	42	48.3%	49	51.0%		
University	28	12.2%	10	11.5%	6	6.3%		
Master's degree	0	0.0%	1	1.1%	0	0.0%		
Regional unit of residence							185.821	0.000
Grevena	20	8.7%	5	5.7%	65	67.7%		
Kastoria	82	35.8%	16	18.4%	6	6.3%		
Kozani	81	35.4%	31	35.6%	25	26.0%		
Florina	46	20.1%	35	40.2%	0	0.0%		
Income							160.167	0.000
<EUR 10,000	26	11.4%	11	12.6%	0	0.0%		
EUR 10,001–20,000	68	29.7%	23	26.4%	6	6.3%		
EUR 20,001–30,000	75	32.8%	26	29.9%	3	3.1%		
EUR 30,001–40,000	16	7.0%	11	12.6%	37	38.5%		
>EUR 40,000	13	5.7%	7	8.0%	40	41.7%		
No answer	31	13.5%	9	10.3%	10	10.4%		

Source: Author's elaboration.

4. Discussion

According to the findings obtained, the three clusters that were retained can be characterized as the engaged, the restricted, and the partially engaged [69].

Cluster 1—The engaged: They represent the largest group, comprising 56% of the sample. This group exhibits a strong inclination towards bioeconomy opportunities that are aligned with sustainable production and consumption, environmental awareness, and areas that do not have a direct impact on their farms, such as "waste reduction" and "land use change". Over 90% of them acknowledge the potential of the bioeconomy to offer "sufficient biomass quantity", "improving health", "energy production", "pollution reduction", and "technology development".

When compared to the other clusters, the engaged group shows a higher conviction towards the potential of the bioeconomy, with 92.6% agreeing that it contributes to research and innovation for new products and processes, 89.5% seeing it as a means to increase consumption, and 94.8% recognizing its potential for energy production.

However, none of the statements managed to achieve high levels of agreement within the group. In terms of demographics, this group primarily consists of middle-aged men with a high-school education, slightly more so than the other groups. (Table 7 shows the demographic profile).

Cluster 2—The restricted: This group constitutes the smallest percentage (21%) of the farmer sample and is characterized by strong convictions with no expectation of benefits from adopting a bioeconomic production model. They appear largely unconcerned with issues related to production, consumption, and health, but exhibit consensus around the importance of "sufficient biomass quantity" and "environmental protection". Unlike the first cluster, this group is skeptical about the potential benefits of technological development, climate change mitigation, and pollution reduction that the bioeconomy can offer.

This cluster is the most balanced in terms of regional unity and age, primarily consisting of residents of the regional unit of Florina aged between 46 and 55 years old, with incomes ranging from EUR 20,001 to EUR 30,000. Despite their reluctance to embrace the bioeconomy, they express a willingness to participate in subsidized regional programs that offer training in bioeconomic topics. According to the views of the locals, they can accept changes with financial incentives.

Cluster 3—The partially engaged: The second largest group surveyed, comprising 23% of the farmers, holds the most favorable perceptions towards "environmental protection", "sufficient biomass quantity", "existence of policy", "waste reduction", and "financial resources for investments". These opportunities are associated with sustainable and optimal utilization of natural and financial resources. As in cluster 1, the partially engaged farmers show a keen interest in conserving water resources and producing food and feed, and they also prefer to learn about the bioeconomy through subsidized local programs.

Interestingly, in this group, none of the respondents viewed energy production as a bioeconomy opportunity. This could be attributed to the fact that 67.7% of these farmers live in the regional unit of Grevena, which has never had an economy based on energy production, unlike Kozani and Florina. Although there are no investments in renewable energy sources due to the mountainous terrain and lack of plains, the agricultural sector, especially livestock farming, is well developed. This is evident from Table 7, where 41.7% of the farmers in this group reported an annual income of more than EUR 40,000, which is remarkably high, particularly for Western Macedonia and Greece as a whole.

It can be noted that the bioeconomy is a rapidly growing sector with great potential for farmers to increase their productivity and income [5,70–73]. The bioeconomy refers to the sustainable use of renewable biological resources to produce food, feed, bio-based products, and bioenergy [3,74–77]. The bioeconomy not only has economic benefits, but also contributes to environmental sustainability and rural development [24,78–80].

To initiate the training of farmers in respect of the bioeconomy, the foremost task is to impart to them a comprehensive view of the bioeconomy concept and its essentiality. The bioeconomy does not solely focus on augmenting yield, but also emphasizes producing better and more sustainable products [81]. Farmers must acknowledge that the bioeconomy involves utilizing renewable biological resources in a sustainable way to meet human needs and enhance their welfare [82]. Moreover, they should comprehend the advantages of the bioeconomy for their own operations, including amplified productivity and income, decreased dependency on fossil fuels, improved soil and water quality, and lowered greenhouse gas emissions [83]. Additionally, the bioeconomy presents novel opportunities for farmers to broaden their operations and venture into new markets [4].

This study was an initial approach to explore the perceptions of West Macedonian farmers about the opportunities arising from their training and awareness in respect of bioeconomy issues. Future research can be carried out in various areas that can enhance the training of farmers on the bioeconomy and better farming practices. With the increasing availability of digital technology in rural areas, there is an opportunity to create training programs that incorporate technology-based solutions such as mobile applications, e-learning platforms, and virtual reality simulations. Further research can investigate the effectiveness of these methods in improving farmers' learning and adoption of new practices.

Participatory learning approaches that involve farmers in the learning process, encouraging them to share their experiences and knowledge, and facilitating peer learning can also be effective. Research could be conducted to explore the effectiveness of these approaches in promoting the adoption of new practices by farmers and building community knowledge and resilience. In fact, research has shown that farmers are willing to participate in mainly local programs.

Sex inequalities can also limit women's access to resources and opportunities in agriculture. Thus, further research could focus on designing and implementing sex-sensitive training programs that empower female farmers to take leadership roles and improve their productivity.

In addition, climate change is a major challenge to agriculture, leading to changing weather patterns and increased frequency of extreme weather events. Research can explore how to train farmers in climate-smart farming practices such as conservation agriculture, agroforestry, and climate-resilient crop varieties.

Finally, developing bioeconomy value chains requires improving the linkages between farmers, input suppliers, processors, and markets. Hence, research could be conducted to explore how to train farmers to deal more effectively with these factors and to identify and exploit market opportunities.

5. Conclusions

Despite numerous empirical studies conducted at the international level regarding farmers' attitudes towards the bioeconomy and the potential opportunities it presents, Greek researchers have paid little attention to this issue. Moreover, none of the existing research has examined the differentiation of farmers' perceptions. The principal driving force behind this study was to fill this gap. Additionally, agricultural subsidies are currently contingent upon the implementation of the bioeconomy and associated practices, including renewable energy production. Furthermore, agriculture will play a significant role in the study region's transition, since it is the second largest productive sector following energy.

There are several reasons why it is crucial to train farmers. Firstly, the agricultural sector is dynamic, with the introduction of new technologies and practices necessitating that farmers keep up to date with the latest developments to leverage their benefits. Secondly, numerous farmers lack fundamental knowledge about agricultural practices, including soil fertility management, crop protection, and utilization of contemporary inputs, leading to low productivity and reduced income. Thirdly, many farmers confront obstacles such as limited water resources, rising energy prices, and fluctuating climatic conditions, necessitating a comprehensive grasp of modern management practices stemming from the bioeconomy.

Incorporating cluster analysis can provide a targeted strategy for organizing bioeconomy training and awareness initiatives by dividing farmers into distinct groups based on their shared perspectives of bioeconomy prospects. The research findings indicate that, despite varying opinions on the benefits of bioeconomy opportunities, farmers in the Western Macedonia region exhibit substantial support for subsidized bioeconomy training. Given the nascent status of the bioeconomy, it is reasonable to expect farmers to hold diverse views on the advantages it could offer.

The present study is subject to certain limitations, including its narrow focus on farmers from Western Macedonia. While the survey's inclusion criteria were clearly defined, the researchers' potential bias in selecting farmers cannot be completely ruled out. Additionally, the study presupposes that the government will adopt a training strategy to boost the bioeconomy and involve farmers as key participants in this initiative. Given that farmers represent a vital component of the bioeconomy, their inclusion in such a strategy is anticipated.

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