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# Agricultural resources and practices in the circular bioeconomy adoption: evidence from a rural region of Greece

Christina-Ioanna Papadopoulou and Efstratios Loizou
*School of Economic Sciences, University of Western Macedonia, Kozani, Greece*
Fotios Chatzitheodoridis
*Department of Regional and Cross-Border Development, University of Western Macedonia, Florina, Greece, and*
Christos Karelakis
*Democritus University of Thrace Department of Agricultural Development, Orestiada, Greece*

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## Abstract

**Purpose** – This study aims to assess the factors influencing the adoption of circular bioeconomy practices by crop farmers.

**Design/methodology/approach** – Data collected from 303 farmers in the region of Western Macedonia (WM) were used to identify the adoption factors of the circular bioeconomy. Principal component analysis (PCA) and exploratory factor analysis (EFA) techniques were applied through a custom-designed and specially structured questionnaire.

**Findings** – The results reveal four main motivations that lead farmers to adopt circular bioeconomy practices in their farming activities: interest in physical-economic resources and factors related to production and consumption; technology and renewable energy and the environment.

**Research limitations/implications** – This study is based solely on farmers in WM. Furthermore, this study assumes that there will be a strategy to promote a circular bioeconomy under the auspices of the government.

**Originality/value** – Few studies have focused on the perspectives of crop farmers and what encourages them to adopt circular bioeconomy practices in their crops. Existing barriers are related to economic incentives and constraints. The more circular bioeconomy practices farmers adopt, the greater the positive impact on the environment and rural development, and the factors influencing the adoption of these practices are investigated here.

**Keywords** Crop farming, Circular bioeconomy practices, Adoption factors, Exploratory factor analysis

**Paper type** Research paper

## 1. Introduction

According to Directive (2015)/614/EC, a prerequisite for the continued development of a society and the assurance of the sufficiency, stability and sustainability of natural resources is the pursuit of an alternative economic development model that reduces waste while also reducing the need for new resources and ultimately leading to sustainable development. Sustainable development means improving living standards through the optimal use of resources and creating a modern economy that contributes to the well-being of citizens (Carus and Dammer, 2018). In particular, the transition to a circular economic model, including a

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circular bioeconomy, is a major opportunity to create competitive yet sustainable advantages (European Commission, 2018). According to the European Commission's reflection paper, "Towards a Sustainable Europe by 2030", implementing circular economy principles across various economic sectors has the potential to generate net economic benefits of €1.8tn by 2030, create more than one million new jobs in the European Commission and play a central role in reducing greenhouse gas emissions (European Commission, 2019).

Achieving a circular and climate-neutral bioeconomy will only be possible if relevant industries are universally mobilized, as it takes 25 years to transform an industrial sector and all its value chains. The extraction of mineral resources and materials tripled annually between 1970 and 2017 and continues to increase, posing a major global risk. About half of all greenhouse gas emissions and more than 90% of biodiversity loss and water stress come from the extraction and processing of resources for materials, fuels and food (Cabernard *et al.*, 2019). European Union (EU) industry has led this change, but still produces 20% of the EU's greenhouse gas emissions. Dependence on mining remains linear, and the movement of new materials that are then extracted, transported, and processed into goods generates waste and emissions (Fernandez-Mena *et al.*, 2020). Only 12% of materials are recycled. The transition to a circular bioeconomy offers an opportunity to expand sustainability and create new jobs in existing economic activities. There is significant potential for low-emission technologies, sustainable products and services (Loizou *et al.*, 2019). Similarly, the circular bioeconomy offers great potential for new activities and jobs. However, the transformation is very slow and progress is neither widespread nor uniform. The European Green Deal will support and accelerate the transition of EU industry to a sustainable and inclusive growth model.

It is now clear that the linear "supply-manufacture-dispose" production model on which our economy has been based, in which every product inevitably reaches what is referred to as the end of its useful life, is no longer sustainable (Turner *et al.*, 2019). Circular economy practices are a response to the need for sustainable development, given growing concern about the depletion of natural resources and degradation of the environment (Velenturf and Purnell, 2021).

Greece was the first country to announce its complete decarbonization in the European policy for the transition to a climate-neutral economy. The National Energy and Climate Plan includes a number of targets, including the phasing out of lignite for electricity generation by 2028 and the simultaneous use of renewable energy sources to combat climate change. The energy transition affects the region of Western Macedonia (WM) (NUTS2), whose economy is directly linked to the operation of coal-fired power plants. This region has experienced one of the most critical periods in recent decades (Papadopoulou *et al.*, 2023).

As agriculture is the second largest gross value-added sector in the region, crop farmers can strengthen the local economy while minimizing environmental impacts by adopting circular bioeconomy practices in crop farming. Interest in adopting circular bioeconomy practices in crop production has increased as the potential of biomass and the use of other co-products offers solutions. Public policies are trying to harmonize the sectors involved in crop farming, as biomass can be used as a substitute for fossil resources for energy production (Ben Fradj *et al.*, 2020). The development of bioenergy production can promote crop production, increase crop farmers' income, address fossil fuel supply issues (gas and oil) and reduce greenhouse gas emissions. However, there is mistrust among crop farmers. The reluctance of farmers to adopt circular bioeconomy practices in their crops can be attributed to several factors, such as lack of know-how and equipment (Lewandowski *et al.*, 2016), long rotation periods, low productivity on less fertile soils (Ben Fradj and Jayet, 2018), high establishment costs (Adaku and Amanor-Boadu, 2023; Mola-Yudego and Aronsson, 2008) and projections of future agricultural and energy markets.

To date, few studies have focused on the views of crop farmers and what encourages them to adopt circular bioeconomy practices in their crops. As mentioned above, disincentives

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largely correlate to economic incentives and scarcity. But are there other factors that influence farmers to adopt circular bioeconomy practices, such as waste management or improving their health? In this context, the aim of this study is to investigate the factors that influence crop farmers to adopt circular bioeconomy practices. The more circular bioeconomy practices crop farmers adopt, the greater the positive impact on the environment and rural development. A structured questionnaire was designed and administered to crop farmers in the region of WM in Greece. The methodology used is exploratory factor analysis (EFA), which facilitates the investigation of relationships between variables by examining them against more general factors. The most important adoption factors of the circular bioeconomy were selected as input variables to explore and derive the most important adoption factors.

Circular bioeconomy practices used by crop farmers are an area of increasing interest and research because of their potential for sustainable agricultural systems. The originality of the study in this area can vary depending on the specific focus and context of the research. Aspects that contribute to the progress of the study are the consideration of the unique challenges and opportunities of implementing circular bioeconomy practices in a specific geographical area, taking into account local agricultural systems, resources and socio-economic factors. Innovation also includes the assessment of the effectiveness and feasibility of practices, such as the amount of biological resources, use of renewable resources, mitigation of climate change, etc (Kirchherr *et al.*, 2018; Lewandowski *et al.*, 2016).

This paper is divided into five sections. Section 2 provides a brief background on the circular bioeconomy and its practices. Section 3 presents the scope of the study and the methodology. Section 4 discusses the limitations of the study, and section 5 presents the conclusions and suggestions for further research.

## 2. Circular bioeconomy practices and crop farming

The circular bioeconomy is defined as a part of the circular economy, an intersection of the circular economy and the bioeconomy, and more than either the circular economy or the bioeconomy as stand-alone concepts (Stegmann *et al.*, 2020). There is no explicit definition, but the circular bioeconomy could be termed as "the more efficient management of renewable resources of biological origin by integrating circular economy principles into the bioeconomy" (D'Amato *et al.*, 2020). Since its emergence in 2010, the term has been used again in the updated Bioeconomy Strategy in 2018; in the European Circular Bioeconomy Fund in 2019, which aims to provide €250m for the development of the circular bioeconomy; and by the European Forest Institute in 2020, which will publish its study on the contribution of the bioeconomy in the post-COVID-19 era (Hadley Kershaw *et al.*, 2021; Suresh *et al.*, 2022). In contrast to a linear economy, a circular economy is characterized by the reuse and replacement of resources (Gedam *et al.*, 2021). The philosophy of the circular bioeconomy aims to reduce the use of scarce resources for economic activities; additionally, companies are required to adopt circular bioeconomy practices (Lazaridou *et al.*, 2021).

Both academia and industry have recognized the potential of the circular bioeconomy to play a key role through the utilization of waste, greenhouse gasses and the production of biosynthetic chemicals and fuels (Venkata Mohan *et al.*, 2016). However, the existing debate on the circular bioeconomy has so far been oriented towards natural resource management (e.g. forestry) rather than biotechnology in general, which reinforces its differentiation from a targeted bioeconomy as biomass (Bugge *et al.*, 2016; Kitney *et al.*, 2019). The dangers of a science-driven circular bioeconomy with economic value are thus evident, but it neglects the opportunities of biotechnology and its potential to address complex environmental challenges and consequently create social value (Wilde and Hermans, 2021).

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In order to accelerate the adoption and development of the circular bioeconomy, it is necessary to assess the effective use of resources, the understanding of the basic principles of the circular bioeconomy and the influence of their interconnections. However, there is still no consensus on the key factors that accelerate sustainable development. According to Salvador *et al.* (2021), the three key success factors for a sustainable bioeconomy are (1) raising public awareness of the environmental benefits of sustainable bioeconomy solutions and establishing and implementing social contracts between producers and consumers; (2) developing cooperation between different sectors and organizations to define the necessary responsibilities and ensure circularity in production processes; and (3) attracting new entrepreneurs to develop traditional sectors of the bioeconomy.

Adamseged and Grundmann (2020) propose five success factors for the performance and development of the bioeconomy: (a) strategy, (b) business structure, (c) collaboration, (d) processes and (e) learning and innovation. Strategy refers to the strategic direction of actors, objectives and processes resulting from the consultation process. Structure refers to the choice of a specific form of governance based on communication and interaction between different stakeholders. The right structure involves resource management, strategy, decision making, coordination and risk management. Collaboration refers to the networks of people and organizations needed to facilitate change. A clear understanding of with whom the organization is working, or should be working, can enable it to achieve its objectives more effectively. Processes are essential to ensure the acceptance and sustainability of change, forming a key component to the success of the bioeconomy. Finally, learning and innovation refer to the ability of individuals to adopt and implement new strategies, structures, collaborations and processes.

Based on the Delphi-type qualitative research on the critical factors for the development of the bioeconomy in crop farming, conducted with expert participants by Rampasso *et al.* (2021) key factors were found to be databases, regionalization of data, vocational training, public policy, public resources, consumer market, understanding concepts, case reports and knowledge dissemination.

The initiative to adopt a bioeconomy involves a relatively high level of inherent risk (de Assis *et al.*, 2017). This risk stems mainly from the need to compete with mature and highly-efficient markets dominated by companies that continue to base their value creation on mineral resources. As a result, factors such as limited data and limited knowledge of market conditions (e.g. consumer acceptance of new organic products) put crop farmers (and by extension, adopting the bioeconomy) at risk. The answer to this challenging situation lies in crop farmers' specific approach to innovation management, which clearly differs from the way established companies organize their innovative initiatives and can be described as "entrepreneurial experimentation" (Lazarevic *et al.*, 2020; R L, 2021; Scordato *et al.*, 2018). In this way, crop farmers adopting the bioeconomy reduce risk and uncertainty by rapidly testing new technologies, developing applications and new products based on these technologies, and learning quickly as both products and farms are exposed to market dynamics (de Lauwere *et al.*, 2022). Such business processes involve consumers at an early stage (Lilja and Moen, 2017). The simultaneous use of tactics such as rapid prototyping can also ensure that R&D can quickly and cheaply deliver results, while simultaneously reducing risk (Flores Bueso and Tangney, 2017). Therefore, innovation, technological development and market acceptance are key factors for the adoption of the bioeconomy (Kuckertz *et al.*, 2020).

In contrast, Ben Fradj *et al.* (2020) studied the bioeconomy's contribution to sustainable development and concluded that, based on the weight of environmental, technological and socio-economic factors, the latter are the most important because they are components of rural development and sustainable food production.

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Similar to Stratan (2017), adding more value and designing a framework for companies adopting bioeconomy and circular economy principles interviewed 50 companies and identified the following success factors: strong leadership, motivation, management commitment, legal and regulatory frameworks, a business model, appropriate human resources (key people), local community involvement, economic sustainability, innovation and rational use of resources.

A study conducted in New Zealand, which has been practicing the bioeconomy since 1980, found that the factors affecting life sciences actors included access to capital, regulatory frameworks, marketing and lack of distribution channels. When asked to rank several potential benefits of embracing the bioeconomy, respondents argued that the highest potential benefit was the move away from fossil fuels and their associated environmental impacts. This was followed by resource efficiency, less waste in landfills, improved health and nutrition, energy security, job creation, urban-rural connectivity and the holistic role of the primary sector, which seemed to touch on a greater social/cultural dimension (Wreford *et al.*, 2019).

National bioeconomy strategies aim to replace fossil resources with biomass alternatives and, despite their positive intentions, ignore the disruptions that would occur in complex systems based on fossil resources (Papadopoulou *et al.*, 2022). Society, producers, farmers and citizens should support rather than shape a circular bioeconomy strategy (Kelleher *et al.*, 2021). Social inclusion and acceptance of the strategy is inclusive development, and according to the Organisation for Economic Co-operation and Development, social aspects are not well-captured in bioeconomy sustainability assessment tools (Kitney *et al.*, 2019). It is therefore necessary to move towards a new circular bioeconomy strategy.

## 3. Material and methods

### *3.1 Study area*

WM (Figure 1) is the only enclosed region of Greece with two Balkan countries at its external borders, and it is the only region not bordered by the sea. For more than 60 years, it has had a mixed industrial and agricultural character, due to the exploitation of coal deposits for electricity production. The regional economy contributes 2.2% to the national gross domestic product, mainly from mining and agriculture. It has strong single activity characteristics as the main electricity-producing region in the country (Western Macedonia Region, 2021).

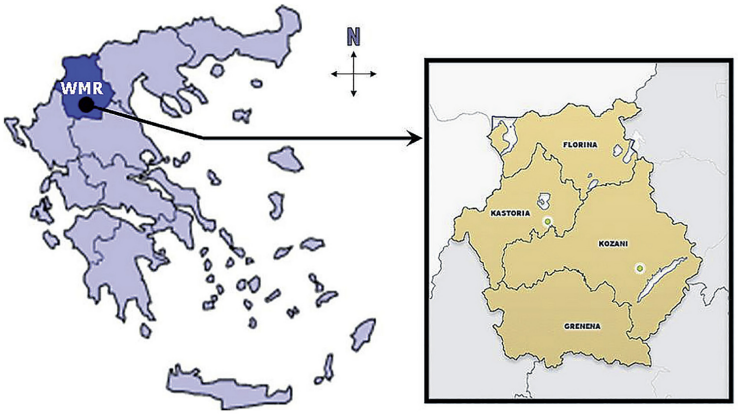


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**Figure 1.**
Map of the region of Western Macedonia

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In the transition to the post-lignite era, the position of the energy sector in the regional economy was no longer dominant, despite the fact that the region had the largest reserves of indigenous solid fuels (lignite). The need to reduce the use of lignite in power generation, as reflected in the National Energy and Climate Plan, creates an immediate need for a transition to the post–lignite era, with measures to develop alternate power methods using new technologies. In this context, the objective of reducing $CO_2$ emissions by strengthening district heating networks has been significantly strengthened, and a large biomass district heating project to establish pilot biomass power plants in order to district heat settlements made progress (Western Macedonia Region, 2021). In the region, there is a shift towards the adoption of a circular bioeconomy in crop production, although no specific strategy has been drafted with direct reference to this. However, according to official data from the Hellenic Statistical Authority, unemployment is extremely high and the crop sector employs around 20% of the region's workforce. For this reason, in the context of the region's ongoing transitional period, the authorities are funding young crop farmers' efforts to develop their own crop farms.

### *3.2 Procedures and measurements*

As mentioned above, the main objective of the current survey is to investigate and assess the factors that influence crop farmers' adoption of circular bioeconomy practices. Crop production is a sector where circular bioeconomy practices can be applied to reduce pollution and the impact of fossil fuel combustion. The intention is to isolate the main factors by focusing on the overall structure rather than individual variables. To achieve the purpose of this research, the EFA method was chosen, which is more appropriate for the following reasons (Donner *et al.*, 2022; Raimondo *et al.*, 2021; Vainio *et al.*, 2019; Zaleski and Michalski, 2021): a) the procedures of EFA facilitate a better understanding of the subject under consideration by revealing the structure of the relationships between variables; b) principal component analysis (PCA) helps to eliminate non-significant variables; c) the Kaiser–Meyer–Olkin (KMO) test is a measure of sampling adequacy and d) the EFA statistical method aims to identify and correlate the set of variables under consideration with the more general factors. EFA is particularly appropriate when the aim is to explore the underlying factors or dimensions of a complex phenomenon. If the study is exploratory in nature and seeks to understand the key factors that lead to the adoption of circular bioeconomy practices, EFA can be justified as an appropriate technique. Furthermore, if there is limited existing research or a lack of established theoretical frameworks regarding the adoption of circular bioeconomy practices, EFA can be a valuable approach as it allows for data-driven exploration and the identification of underlying factors, helping to build a foundation for future research and theory development.

To identify and uncover the key drivers behind the adoption of circular bioeconomy, a factor analysis was conducted using a selection of crucial factors as input variables. This step involves two statistical tests. First, the Kolmogorov–Smirnov test was used to determine the distribution of the collected data, which showed a non-normal distribution. Principal component analysis (PCA) was used to identify the significant indicators. A brief illustration of these steps is given in Figure 2.

*3.2.1 Defining the survey population and sampling.* The first step in defining the sampling frame was to define the survey population. A population is defined as a complete group of entities, such as people or organisms, distinguished by a common set of characteristics that are important for the purpose of the study and about which the researcher wishes to draw conclusions that can be generalized (Heinrich *et al.*, 2009). A numerical estimate of the population is provided by the Census of Agriculture and Livestock of the Hellenic Statistical Authority, which states that the number of farms (owners and employed members of their households) in the WM region was 24,205 in 2021.

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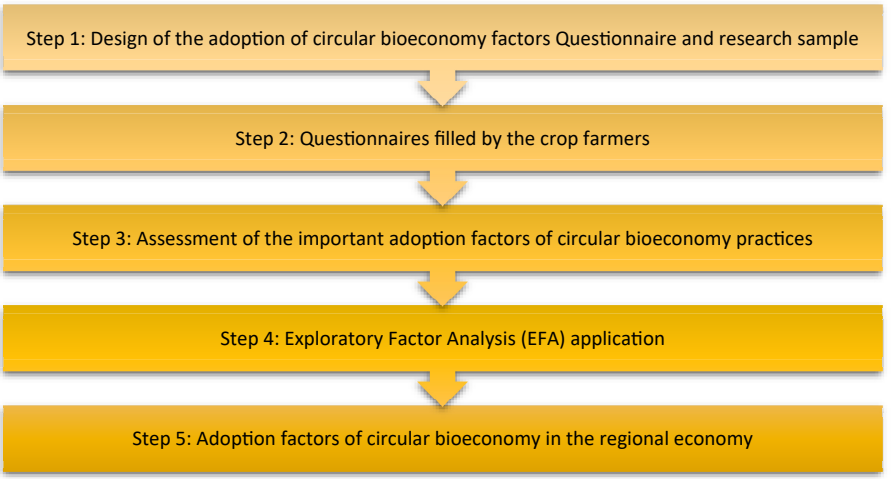


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**Figure 2.** Research methodology steps

An advantage of quantitative methods is the ability to use smaller groups of people to draw conclusions about larger groups that would be economically prohibitive to study (Webb *et al.*, 2013). Samples were used to generalize to the survey population. Ideally, samples were selected using a random process to represent the survey population. Sampling involved taking a part of a larger set. Two types of sampling are distinguished: probability and non-probability sampling (Buelens *et al.*, 2018). Non-probability sampling involves selecting individuals who are available and can be studied (Uprichard, 2013). Furthermore, an important distinction is made between purposive and representative samples. Representative samples are primarily used for quantitative analysis, either to draw conclusions about the size or frequency of a population characteristic, or to measure and test the extent to which survey variables are related to the population (Grafström and Schelin, 2014).

On the basis of the above distinctions, it could be said that the sample of this survey is a non-probability sample, as it was not taken from a random selection of a complete list of the population. The nature of the research population is not predetermined, but could only be cataloged at the end of the day when the farmers were no longer available for the study in the given spatial setting (with dubious success, as it would require the names and contact details of the farmers), making it particularly difficult, if not impossible, to obtain a random sample. The survey sample is therefore representative, but it is also characterized as a convenience sample because it includes factors of the researcher's choice (e.g. choice of villages/settlements, choice of sampling interval and sample size). No criteria for stratification of the population were adopted, as it was not considered appropriate to represent the demographic characteristics of the sample in specific proportions.

*3.2.2 Sample size in exploratory factor analysis.* In literature, a general rule of thumb for factor analysis is a sample size of 300 cases. However, if we have a factorial solution in which there are variables that are highly-correlated with a single factor (marker variables) and the loadings on that factor exceed 80%, then a sample of 150 cases is sufficient (Guadagnoli and Velicer, 1988). However, Sapnas and Zeller (2002) suggest that in some circumstances, a sample size of 100 or even 50 cases may be sufficient. MacCallum *et al.* (1999) related the sample size to the extraction of the number of true and reliable, real and misinterpretable factors in the final analysis. They suggested ten cases per variable in a total sample of at least 300 cases.

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Therefore, it was decided that adopting a larger proposed sample from the above recommendations would help to maintain a satisfactory level of statistical power. At the same time, it would provide greater security during the analysis, due to potential problems that may arise during the statistical analysis, such as deviations from normality. The data collection process therefore aimed to collect 300 valid questionnaires. A total of 307 questionnaires were collected from crop farmers in the WM region, of which 303 were considered useable and included in the analysis.

To meet the needs of the survey, on-site sampling was used in the region. On-site sampling was preferred to online data collection because the physical presence of participants would not seriously compromise the accuracy and appropriateness of responses, generating undeniable consequences for the quality of the results. In each community or household, the researcher asked if potential farmers were over 18 years old and if they were willing to participate in the survey to explore crop farmers' knowledge of the circular bioeconomy. There were no instances of refusal to participate in the survey, although a protocol was in place to attempt to reconcile refusals. The questionnaire took an average of 15 min to complete.

In addition to demographic and farm data, the survey instrument included eight questions on crop farmers' attitudes towards the circular bioeconomy and seven questions on adoption factors of the circular bioeconomy, all based on the relevant literature from which they were drawn. The measures of crop farmers' attitudes towards the circular bioeconomy included 55 items, while the measures of adoption factors of the circular bioeconomy included 31 items.

Responses were rated on a Likert scale, with one indicating an extremely negative response (strongly disagree) and five indicating an extremely positive response (strongly agree) (Joshi *et al.*, 2015).

### *3.3 Analysis*

*3.3.1 Participants.* Between February and May 2022, a quantitative survey was conducted in the region using a suitably structured questionnaire with a sample of 303 crop farmers. The aim was to explore their perceptions of the circular bioeconomy. Of the total respondents, 84.8% were male and 15.2% were female. In addition, 76.2% of the crop farmers were married and 20.1% were single. The educational level of the respondents consisted of 53.5% high school graduates, 19.1% secondary school graduates and to a lesser extent primary school graduates, university graduates and postgraduates. The annual income of most respondents ranged from €10,000 to €30,000. Finally, most crop farmers (the largest percentage) were in the 46–55 age group. All were permanent residents, having lived in the region for at least one year (Table 1).

*3.3.2 Data analysis.* A reliability analysis (Cronbach's Alpha) was conducted to test the reliability of the collected data with the potential adoption factors of a circular bioeconomy. The study covered a range of variables selected to assess different aspects of sustainability, climate change and financial resource management. Sustainable and optimal use of natural economic resources focuses on understanding how effectively and efficiently natural and economic resources are used to achieve sustainability goals. It can include factors such as waste reduction, energy efficiency and resource management practices. Sustainable production and consumption involves assessing production and consumption patterns in a sustainable way. It also involves examining practices that minimize environmental impact, promote renewable and clean energy sources, reduce emissions and waste and encourage responsible consumption. Capacity building and action on climate change focus on assessing the skills and knowledge needed to address the challenges of climate change and to promote sustainable actions. It includes understanding the level of awareness, education and training available to individuals and organizations on climate change mitigation and adaptation

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| | Crowd | Percentage |
|---|---|---|
| Gender | | |
| Male | 257 | 84.8% |
| Female | 46 | 15.2% |
| Marital status | | |
| Single | 61 | 20.1% |
| Married | 231 | 76.2% |
| Divorced | 11 | 3.6% |
| Educational level | | |
| Primary school | 40 | 13.2% |
| Secondary school | 58 | 19.1% |
| High school | 162 | 53.5% |
| University | 42 | 13.9% |
| Master' degree | 1 | 0.3% |
| Annual income | | |
| <10.000€ | 31 | 10.2% |
| 10.001–20.000€ | 75 | 24.8% |
| 20.001–30.000€ | 94 | 31% |
| 30.001–40.000€ | 46 | 15.2% |
| >40.000€ | 35 | 11.6% |
| no answer | 22 | 7.3% |
| Age | | |
| 18–25 | 12 | 4% |
| 26–35 | 34 | 11.2% |
| 36–45 | 81 | 26.7% |
| 46–55 | 106 | 35% |
| 56–65 | 53 | 17.5% |
| 66 and above | 17 | 5.6% |

**Source(s):** Author's own creation

**Table 1.** Demographic characteristics of respondents, $N = 303$

strategies. Finally, environmental protection initiatives encompass various actions and measures such as policies, regulations, conservation programmes, restoration efforts and community engagement activities aimed at conserving ecosystems, biodiversity and natural resources. The results showed an alpha coefficient of 0.910, which is considered acceptable as a measure of the reliability of the baseline survey (Bonett and Wright, 2015). The Kolmogorov–Smirnov normality test was carried out to check the distribution of the data collected. The hypotheses of the test are as follows:

*H0.* The sample does not come from a normal population.

*H1.* The sample comes from a normal population.

The results of the Kolmogorov–Smirnov (K-S) test showed that the indicators did not follow a normal distribution. Table 2 shows the results of the K-S test for the factor "existence of policy", i.e. the extent to which this factor influences the adoption of the bioeconomy. The results for the other factors in the questionnaire were similar (the significance of all factors was set at $< 0.05$).

| Adoption of circular bioeconomy factors | Number of respondents | Kolmogorov–smirnov Z | Sig |
|---|---|---|---|
| Existence of policy | 303 | 9.178 | 0.000 |

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**Table 2.** K-S test result for one of the indicators

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Finally, an EFA was conducted with 18 variables representing circular bioeconomy adoption. All variables were factor analyzed using principal component analysis with orthogonal VARIMAX rotation to identify the underlying dimensions or factors of circular bioeconomy adoption. The steps involved were the application of the factor analysis technique (Williams *et al.*, 2010), factor extraction, rotation to increase interpretability and final selection of the number of factors. Bartlett's test of sphericity and KMO test of sampling adequacy were used to obtain the results of the EFA.

The results of the KMO and Bartlett's tests are presented in Table 3. The overall KMO measure of sampling adequacy was 0.853 (Kaiser, 1974). As the KMO was above 0.7, the variables were related and shared common factors. The overall significance of the correlation panel was 0.000 with a chi-square value of Bartlett's sphericity test of 3,716.707, suggesting that the data table had sufficient correlation for factor analysis. It seemed unlikely that the population correlation matrix was identical, and the use of factor analysis was considered appropriate.

The communalities ranged from 0.506 to 0.874, suggesting that the variance in the baseline values could be explained by common factors. PCA suggested a 4-factor solution and explained more than 70% of the variance in the data, with eigenvalues greater than one (Figure 3). Table 4 shows the final rotated factors and the adoption of circular bioeconomy indicators for each factor, as well as the statistical factors and indicators. Reliability analysis (Cronbach's Alpha) was carried out to test the reliability and internal consistency of each factor.

The results of the factor analysis resulted in a four-factor solution with high loadings and a clear structure, indicating the associations between the variables and the factors to which they belong. The set of variables was highly associated with each factor, indicating that there was minimal overlap between the factors and that all factors were independently structured. Furthermore, the alpha coefficients of the four factors ranged from 0.787 to 0.910, well above the minimum value of 0.50, which is considered an acceptable indication of reliability for basic research (Bonett and Wright, 2015). Figure 4 shows the model of the main adoption factors of the circular bioeconomy by the crop farmers who participated in the survey.

## 4. Discussion

The adoption of bioeconomy principles in agriculture offers a promising path towards sustainable development and resource optimization. The region of WM can use various metrics to assess and promote the adoption of the bioeconomy in agriculture. The ability to take into account variables such as the availability of sufficient biological resources, like biomass, is the backbone of a thriving bioeconomy in agriculture. In WM, there is a diverse range of agricultural resources available, such as crop residues, organic waste and energy crops. By harnessing these resources, the region can promote the production of bio-based products, bio-energy and sustainable raw materials, leading to resource optimization and waste reduction. Supporting policies and regulations also play a central role in promoting the

| Tests | Results |
|---|---|
| Kaiser–Meyer–Olkin measure of sampling adequacy | 0.853 |
| Bartlett's Test of sphericity | |
| Approx. chi-square | 3,716.707 |
| df | 153 |
| Significance | 0.000 |

**Source(s):** Author's own creation

**Table 3.**
KMO and Bartlett's test of EFA

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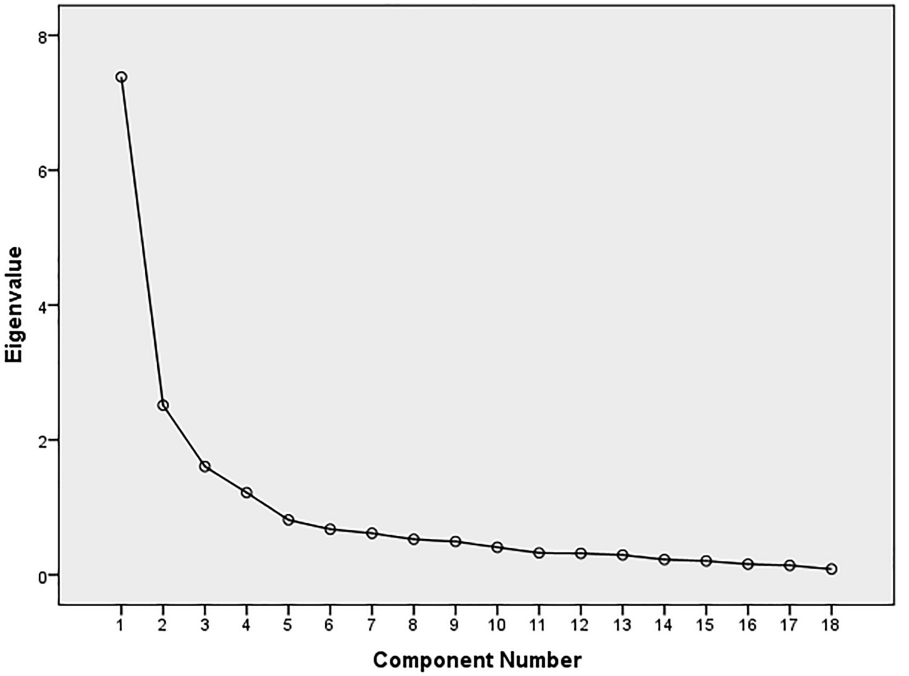


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**Figure 3.**
Components with eigenvalues greater than 1

adoption of bioeconomy practices in agriculture. By formulating and implementing strong policies, the region can create an enabling environment that incentivizes sustainable agricultural practices, facilitates research and development and attracts investment. These policies should emphasize the circularity of agricultural systems, promote resource efficiency and ensure responsible land use, ultimately fostering a thriving bioeconomy.

The bioeconomy in agriculture prioritizes sustainable food and feed production. By employing environmentally sustainable methodologies, reducing reliance on chemical substances and optimizing the utilization of resources, the locality can ensure the generation of wholesome and nourishing sustenance while concurrently alleviating ecological repercussions.

Responsible land use is a critical aspect of bioeconomy adoption in agriculture. The region of WM should carefully assess land use changes with the aim of minimizing deforestation, preserving biodiversity and optimizing land use. By striking a balance between food production and the need for biological resources, the region can protect natural habitats while meeting the growing demands of a sustainable bioeconomy.

The availability of financial resources, including investment and financing opportunities, is crucial for the successful adoption of bioeconomy practices in agriculture. By emphasizing opportunities for sustainable rural development, research and innovation, as well as the generation of fresh employment prospects, WM has the potential to draw in investments. These resources will enable the implementation of cutting-edge technologies, infrastructure development and capacity building.

One of the main pillars of the bioeconomy is the production of renewable energy from biomass. The region of WM can use its biomass resources to produce bioenergy for

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| Adoption of circular bioeconomy factors | Factor loading | EV | Variance explained | Communalities |
|---|---|---|---|---|
| Sustainable and optimal use of physical economic resources ($\alpha = 0.831$) | | 7.382 | 3.447 | |
| 1 Sufficient biological resources (e.g. biomass) | 0.648 | | | 0.669 |
| 2 Existence of policy | 0.830 | | | 0.715 |
| 3 Food and feed production | 0.640 | | | 0.537 |
| 4 Land use change | 0.636 | | | 0.506 |
| 5 Existence of financial resources for investment | 0.758 | | | 0.739 |
| Sustainable production and consumption ($\alpha = 0.910$) | | 2.514 | 3.399 | |
| 1 Production increase | 0.916 | | | 0.874 |
| 2 Energy production for consumption | 0.880 | | | 0.823 |
| 3 Improvement of health | 0.741 | | | 0.714 |
| 4 Increase in consumption | 0.893 | | | 0.864 |
| Skills development and climate change action ($\alpha = 0.860$) | | 1.606 | 2.975 | |
| 1 Research and innovation for new products and processes | 0.615 | | | 0.772 |
| 2 Exploitation of renewable resources | 0.753 | | | 0.729 |
| 3 Climate change mitigation | 0.755 | | | 0.776 |
| 4 Human resources training and education | 0.649 | | | 0.587 |
| 5 Pollution reduction | 0.742 | | | 0.711 |
| Environmental protection initiatives ($\alpha = 0.787$) | | 1.218 | 2.898 | |
| 1 Environmental protection | 0.740 | | | 0.636 |
| 2 Waste reduction | 0.832 | | | 0.779 |
| 3 Water resources | 0.721 | | | 0.694 |

**Source(s):** Author's own creation

**Table 4.**
The final results of the exploratory factor analysis

consumption in the agricultural sector and beyond. This transition to renewable energy sources reduces dependence on fossil fuels, increases energy self-sufficiency and reduces greenhouse gas emissions, mitigating climate change and encouraging a cleaner environment.

Achieving sustainability requires the adoption of practices that promote the production or management of agricultural activities (Khan and Ali, 2022). However, the adoption of these practices depends on the social and environmental conditions of a particular area (Piñeiro *et al.*, 2020). Social, economic and technical factors are crucial in determining whether or not new methods or technologies are practically feasible (Kirchherr *et al.*, 2018). To this end, policy makers need to create an enabling environment in which crop farmers and investors are encouraged to adopt circular bioeconomy practices (Duque-Acevedo *et al.*, 2020).

For sustainable practices to prevail in the agricultural sector, it is very important that local farmers receive incentives, technical assistance and government training to make it economically feasible for them to adopt environmentally-friendly practices (Piñeiro *et al.*, 2020). The use of residual biomass is a key principle of the circular bioeconomy (Nguyen *et al.*, 2020). The EU is developing policies to promote the reuse and recycling of this waste (Alexandri *et al.*, 2020).

The rationale for adopting circular bioeconomy practices in crop production stems from social concerns combined with environmental stewardship, where cost minimization is linked to value recovery from waste (Mpofu *et al.*, 2021), and optimizing resource use is secondary. Improving people's living standards, creating jobs, increasing wealth, growing quality food at affordable prices and improving people's health are critical factors in adopting a circular

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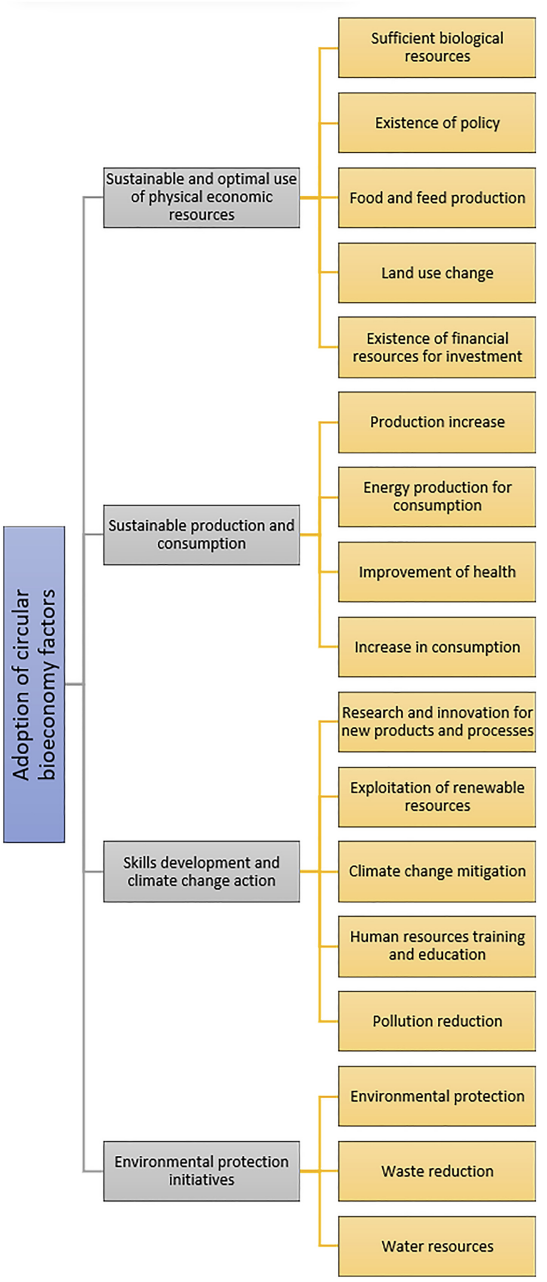


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**Figure 4.**
Adoption of circular bioeconomy factors identified by means of factor analysis

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bioeconomy (Lwesya and Achanta, 2022; Salvador *et al.*, 2022). In addition, protecting the environment, reducing greenhouse gas emissions, creating a competitive advantage by reducing costs and reducing import dependency are incentives for adopting a circular bioeconomy (Clauser *et al.*, 2021; Tsegaye *et al.*, 2021). One of the main limitations of the present study is its exclusive reliance on crop farmers in WM. Although the inclusion criteria for the survey were explicitly defined, the selection of crop farmers may have been subject to researcher bias. In addition, this study assumes that there will be a government led strategy to promote a circular bioeconomy. The inclusion of crop farmers in this strategy is expected, as they are a primary part of the bioeconomy.

## 5. Conclusions

After decades of environmental degradation in specifics regions due to mining and burning coal, the contribution of agriculture in the post-coal era is extremely important. Current unsustainable practices in crop farming can be replaced by the adoption of circular bio-economic practices. Although there are other studies on the adoption of circular economy practices, the value of this study lies in extending what has already been found in crop farming to assess its contribution to regional development, unemployment reduction, environmental protection, health improvement and natural resource sufficiency.

According to crop farmers in the region, there are four factors that can lead to a sustainable production model that will benefit both farmers and the environment by mitigating climate change. To achieve this, farmers need financial support, policies and government support. In addition, the adoption of circular bioeconomy practices in crop production would contribute to increased consumption, better use of natural resources and reduced pollution. The circular bioeconomy offers many operational, strategic and competitive advantages. It is advantageous to strive for farms that are free of material and energy cycles (Barros *et al.*, 2020). In the future, this survey could be repeated, exploring the experts' views on the adoption of bioeconomy practices in crop farming, in order to obtain an overall picture and formulate a strategy.

Other issues identified as requiring further investigation include are as follows:

1) Development of indicators to measure the circular bioeconomy on farms. The current indicators, as mentioned in the existing literature, do not focus on a specific economic sector, but refer to the circular bioeconomy in a broad sense. These indicators can be objective, but are not data-driven; as such, they have been developed to measure the development of circular bioeconomy initiatives.

2) Explore technological developments that would enable a faster transition to a circular bioeconomy model. There is a need to accelerate and guide the transition to green growth through innovative, people-centered technologies. The new digital era needs to support sustainable systems, traceability and the development of sustainable, productive, climate-neutral and biodiversity-friendly agricultural systems. Blockchain can contribute to this.

3) Exploring the existing difficulties in the transition from farms to a circular bioeconomy. There are many aspects to consider, starting with the farm's size. At present, it is not feasible for small- and medium-sized farms to adopt a bioeconomy production model because they do not have the economies of scale to absorb the additional costs or possible reduction in production. In addition, consumers are not prepared to pay a higher price for a product resulting from a circular process. The lack of a national strategy has exacerbated this situation.

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**Corresponding author**
Christina-Ioanna Papadopoulou can be contacted at: aff00579@uowm.gr

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