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Digital and Entrepreneurial Competencies for the Bioeconomy: Perceptions and Training Needs of Agricultural Professionals in Greece, Italy, Portugal, and Sweden

Dimitrios Petropoulos [1,*], Georgios A. Deirmentzoglou [1,2], Nikolaos Apostolopoulos [3], Bas Paris [4], Dimitris Michas [4], Athanasios T. Balafoutis [4], Elena Athanasopoulou [5], Leonardo Nibbi [6], Hailong Li [7], Lara Carvalho [7], Maria Helena Moreira da Silva [8] and Joaquim Fernando Moreira da Silva [8]

1   Department of Agriculture, University of Peloponnese, Antikalamos, 24100 Kalamata, Greece
2   Department of Economics and Business, Neapolis University Pafos, 8042 Pafos, Cyprus
3   Department of Management Science and Technology, University of Peloponnese, 22100 Tripoli, Greece
4   Institute of Bio-Economy & Agro-Technology, Centre of Research & Technology Hellas, Dimarchou Georgiadou 118, 38333 Volos, Greece; b.paris@certh.gr (B.P.); a.balafoutis@certh.gr (A.T.B.)
5   Department of Business and Organizations Administration, University of Peloponnese, Antikalamos, 24100 Kalamata, Greece
6   Department of Industrial Engineering, University of Florence, 50139 Florence, Italy; leonardo.nibbi@unifi.it
7   School of Business, Society and Engineering, Mälardalen University, 723 21 Västerås, Sweden
8   Department of Animal Reproduction, Faculty of Agrarian Sciences and Environment, University of the Azores, IITA-A, 9701-851 Angra do Heroísmo, Portugal; joaquim.fm.silva@uac.pt (J.F.M.d.S.)
*   Correspondence: d.petropoulos@uop.gr; Tel.: +30-27210-45106

Abstract: As the European Union advances its bioeconomy strategy, the agricultural sector emerges as a key domain requiring targeted upskilling in digital and entrepreneurial competencies. This study examines how agricultural professionals perceive the importance of these competencies and identifies related training needs, drawing on the European Commission's Digital Competence Framework (DigComp) and Entrepreneurship Competence Framework (EntreComp). Using a quantitative survey methodology, data were collected from 140 respondents, including farmers, agronomists, consultants, entrepreneurs, and policymakers, in four European countries: Greece, Italy, Portugal, and Sweden. Descriptive and non-parametric analyses (Mann–Whitney U and Kruskal–Wallis tests) revealed strong recognition of digital competencies across all groups, with significant variation by country, while perceptions of entrepreneurial competencies differed mainly by professional role. Moreover, a significant lack of formal bioeconomy-related education was identified. The findings underscore the need for targeted, competence-based education and policy interventions to equip professionals with the skills required for a sustainable and innovation-driven agricultural sector.

Keywords: bioeconomy; agriculture; agricultural professionals; digital skills; entrepreneurial skills; DigComp; EntreComp

1. Introduction

The bioeconomy, defined as an economy utilizing renewable biological resources and processes, has emerged to address pressing environmental challenges, including climate change and resource scarcity largely caused by human activities [1–3]. Its potential is particularly evident in agriculture, where growing food demand intensifies pressure on land, water, and natural resources [4]. If effectively implemented, the bioeconomy

could significantly enhance environmental, economic, and social sustainability, promoting innovation and sustainable growth within the agricultural sector [2,5].

In this regard, the role of agricultural professionals is of paramount importance, as their capacity to adapt to and implement bioeconomy principles has a significant impact on the success of this transition. In order to succeed in this context, which is characterized by intense competition and rapid change in the external environment, agricultural professionals must possess a range of digital and entrepreneurial skills [6,7]. The advent of new digital technologies has the potential to assist farmers and other professionals in the agricultural sector in their entrepreneurial endeavors, facilitating the development of essential entrepreneurial skills [8]. This, in turn, may prove instrumental in advancing bioeconomy initiatives.

While a number of studies have discussed the importance of the bioeconomy, particularly in the context of agriculture [9–11], there is a paucity of research examining the training needs of agricultural professionals to successfully navigate the field of the bioeconomy. This is of greater importance, as the study of Nowak et al. [5] showed that over 50% of all bioeconomy professionals in the European Union were employed in the agricultural sector. Therefore, this study aims to examine the perceptions of agricultural professionals in the bioeconomy with regard to digital and entrepreneurial competencies and to identify their training needs.

This study builds upon the recent review by Paris et al. [12], who examined the current practices of bioeconomy education and training in the EU. It significantly extends this previous research by employing two standardized, widely recognized European Commission frameworks: the Digital Competence Framework (DigComp) [13] and the Entrepreneurship Competence Framework (EntreComp) [14]. These frameworks offer structured approaches for assessing competencies, yet their application in empirical studies addressing bioeconomy competencies has been limited. By applying DigComp and EntreComp, this research introduces a robust and replicable approach, facilitating a precise identification of competence gaps and training priorities among agricultural professionals in four European countries: Greece, Italy, Portugal, and Sweden.

The European Union is the focus of this study due to the bioeconomy being a pivotal concern within the domains of European research, energy, and agricultural policies [15]. This is evidenced by the recent update to the EU's bioeconomy strategy, which was designed to align with the evolving European policy landscape [16].

The following section, Section 2, presents an overview of the concept of the bioeconomy and the digital and entrepreneurial competencies relevant to the agricultural sector. Section 3 outlines the methodology employed in the current study, while Section 4 reports the findings of a survey conducted with agricultural professionals from Greece, Italy, Portugal, and Sweden. Section 4 discusses the main findings of the research. Finally, Section 5 indicates the main implications of the research and suggests avenues for future research.

2. Literature Review

2.1. The Concept of Bioeconomy

The term "bioeconomy" is defined and approached in a variety of ways. These range from a more expansive definition that encompasses biological resources and processes in broad terms to comparatively narrower definitions that limit their scope to particular sectors [12]. The European Commission describes the bioeconomy as "using renewable biological resources from land and sea, like crops, forests, fish, animals and micro-organisms to produce food, materials and energy" [17].

The bioeconomy is a multidisciplinary and interdisciplinary field of study [18]. It encompasses a multitude of interrelated themes, including food and agriculture, forestry and

natural habitats, as well as aquatic and water system bioenergy and biomaterials. Additionally, it bridges the gaps between primary, secondary, and tertiary sectors and connects with other facets of the broader economy. Fundamentally, the bioeconomy espouses an inclusive and comprehensive approach, reflecting a commitment to addressing the shortcomings of traditional production methods that contribute to environmental deterioration and social fragmentation [12,19].

The latest update of the EU bioeconomy strategy identifies the bioeconomy as a crucial driver of economic growth across Europe, establishing it as the foundation for a carbon-neutral future [16]. This approach is expected to enhance business competitiveness and reinforce the industrial base by fostering the development of new value chains. Furthermore, the strategy highlights agriculture as a pivotal organic primary sector industry, with a significant role in biomass production, as a key EU policy priority [20].

The emergence of the bioeconomy is poised to significantly transform product design and operational processes, creating a pressing need for new competencies within the agricultural sector [21]. This paradigm shift calls for a thorough reevaluation of individual practices, mindsets, and skill sets. Such reflection and adaptation inherently require a strong commitment to continuous learning and capacity building [19]. In a recent review of the extant education and training programs pertaining to the field of the bioeconomy within the European Union, Paris et al. [12] reveal that substantial efforts have been made with regard to the creation of education and training programs that are aligned with the evolving needs of the bioeconomy. According to the European Commission [22], bioeconomy skills required for agriculture encompass a wide range of domains, including energy, soil, water, and waste management, as well as cross-cutting and business-related competencies. Furthermore, Papadopoulou et al. [23] emphasize that the increasing accessibility of digital technologies in rural areas offers promising opportunities to design training initiatives that leverage technological tools to enhance farmers' learning and adoption of innovative practices.

Building on these skill requirements and technological opportunities, broader European policy frameworks further emphasize the importance of fostering such competencies. In alignment with European priorities, the Horizon Europe Cluster 6 programmatic documents highlight the critical role of research and innovation in fostering sustainable food systems, a circular bioeconomy, and resource-efficient agriculture, further reinforcing the need for specialized competencies to support these transitions [24].

2.2. Digital Competencies

In light of the paramount importance of technological innovation across a range of business sectors [25], digital skills and competencies are receiving heightened recognition. In a recent study, Pistikou et al. [26] demonstrate that large companies prioritize investments in science, technology, engineering, and mathematics (STEM) education. In Europe, the significance of developing digital skills is exemplified by the conceptualization of the Digital Competence Framework (DigComp). The European Commission developed DigComp with the intention of defining the digital competencies that are necessary for individuals to use digital technologies in a responsible and effective manner across a variety of contexts [13]. Based on DigComp, digital competencies can be grouped into five main areas: information and data literacy, communication and collaboration, digital content creation, safety, and problem solving [27]. While the framework was not originally designed with a specific focus on professionals working in bioeconomy sectors, it can be adapted for use in this field due to its versatility.

The Food and Agriculture Organization (FAO) [28] emphasizes the vital importance of investing in farmers' empowerment, particularly through the adoption of digital tech-

nologies that are reshaping the agricultural sector. Such strategic investment is widely recognized as essential for improving the efficiency, sustainability, inclusivity, and resilience of agri-food systems. In this context, acquiring digital skills emerges as a key driver that positively influences the entrepreneurial initiatives of agricultural professionals [7]. The adoption of digital literacy skills can facilitate disease and pest protection for farmers, increase yields, enhance access to essential resources, enable resilience to climate change, and facilitate access to financial services [29]. Furthermore, recent studies have confirmed that digital literacy has a positive impact on agricultural income [30,31].

The European Bioeconomy Alliance in Farming (RELIEF) [32] indicates that agricultural professionals working in the bioeconomy sector should develop competencies related to the five areas of DigComp. Specifically, it is incumbent upon those engaged in farming to identify and address the technical issues inherent in modern agricultural technologies. In addition, they must explore innovative solutions, such as precision agriculture, and adapt existing tools to ensure operational efficiency. Furthermore, farmers must be able to recognize their information needs, identify gaps in their knowledge, and proficiently search for reliable data. They must also evaluate the credibility of the information they find and manage their data securely. Finally, farmers must utilize digital tools to connect with stakeholders and enhance their professional presence. They should engage with online communities, share their expertise, and use digital platforms to improve their visibility and reach.

2.3. Entrepreneurial Competencies

In order to survive in the modern agricultural sector, farmers are increasingly required to adopt entrepreneurial skills [33]. A substantial body of research links farmer's entrepreneurial behavior with innovation, reorganization, and creative action, as well as the reordering of resources to capitalize on or create opportunities for value creation [34]. Especially in the context of the bioeconomy, entrepreneurial activities are of particular significance in ensuring the efficacy of an innovation system [35].

In order to facilitate the practical application of entrepreneurial thinking, the European Commission introduced the European Entrepreneurship Competence Framework (EntreComp). The framework comprises 15 competencies related to entrepreneurship, which are organized into three domains. The three domains are "Ideas and Opportunities", "Resources", and "Into Action" [14]. In the domain of "Ideas and Opportunities", the competencies range from the ability to identify opportunities and engage in creative thinking to the capacity for ethical and sustainable decision-making. In the domain of "Resources", the competencies encompass self-awareness, motivation, and the ability to mobilize resources, as well as economic literacy. In the domain of "Into Action", the competencies extend to planning and management, along with the capacity to learn through experience.

To foster an entrepreneurial mindset in the agricultural sector, several competencies from the EntreComp framework align closely with the demands of bioeconomy-related agricultural professions. RELIEF [32] identifies that, concerning the first dimension of EntreComp, "Ideas and Opportunities", agricultural professionals need to remain competitive by exploring market trends, diversifying income streams, and adopting innovative practices that balance economic, environmental, and social objectives. These competencies help farmers identify innovative ways to create value, both through resource-efficient practices and new product development. Regarding the dimension of "Resources", agricultural professionals must effectively manage land, water, labor, capital, and technology while ensuring financial stability through sound budgeting and cash flow monitoring. Strong leadership and communication skills further enable professionals to mobilize others, foster collaboration, and build relationships with stakeholders. Finally, for the dimension "Into

Action", agricultural professionals must adopt a proactive approach by setting clear goals, developing detailed action plans, and prioritizing tasks effectively. Continuous learning and networking help agricultural professionals stay informed about industry trends, adopt best practices, and access new markets or resources.

In synthesizing the three critical components discussed, the bioeconomy, digital competencies, and entrepreneurial competencies, this study aims to investigate the integration of these domains within the specific context of agricultural professionals. While previous research in agriculture has typically treated these elements separately, e.g., [36,37], the present study seeks to explore their combined relevance and practical implications through an empirical analysis across four European countries. A key contribution of this research is the application of two official frameworks, DigComp and EntreComp, to systematically assess the perceptions and training needs of agricultural professionals. By this means, this study intends to address a significant gap in the literature by examining the training needs and competency perceptions of agricultural professionals in relation to the digital and entrepreneurial skills required for effective participation in the bioeconomy.

3. Methodology

The objective of the present study was to examine the perceptions of agricultural professionals engaged in the bioeconomy within the European Union (EU) regarding digital and entrepreneurial competencies, with the aim of identifying their training requirements. To this end, the study population comprised agricultural professionals working in the bioeconomy sector in four European countries: Italy, Greece, Portugal, and Sweden. The selection of these countries was made to ensure a diversified representation of agricultural contexts within Europe. This diversity is reflected in the proportion of land used for agriculture, with Greece and Sweden having percentages below the EU average, while Italy and Portugal have percentages above the average [38].

The aforementioned countries' farmers, agronomists, consultants, entrepreneurs, and policymakers were invited to participate in the study. The RELIEF partners, in collaboration with local, regional, and national farmers' associations, universities, and government bodies, facilitated the distribution of questionnaires to their respective stakeholders.

The questionnaire was initially developed in English and subsequently translated into Italian, Greek, Portuguese, and Swedish using a back-translation procedure to ensure linguistic and conceptual equivalence [39]. A total of 230 questionnaires were distributed via email and were also made available in a paper-and-pencil format. Throughout the data collection process, participants were informed that their responses would remain anonymous and confidential. Data collection took place between 12 March 2023 and 12 May 2023. In total, 151 questionnaires were returned, yielding a response rate of 65.6%. The collected data were coded and analyzed using Jamovi software (version 2.3.19.0).

To assess participants' perceptions of relevant competencies, the questionnaire included the following instructional statement: "Please indicate the extent to which the following competences and soft skills will enable you to integrate successfully the bioeconomy dimension within your agricultural practices". This guiding statement contextualized the questionnaire within the specific professional environment of agricultural practitioners, thereby ensuring that the assessment was meaningfully adapted to the study population.

Digital competencies were assessed using one item for each of the five dimensions outlined in DigComp [13]. Entrepreneurial competencies were measured through three latent variables, each corresponding to a dimension of EntreComp: "Ideas and Opportunities", "Resources", and "Into Action" [14]. Each dimension was represented by five items adapted from the EntreComp framework to suit the agricultural context (see Appendix A,

Table A1). Respondents rated each item using a five-point Likert scale, ranging from 1 (not at all) to 5 (extremely important).

Furthermore, in addition to their educational background, participants were requested to provide information regarding the duration of their most recent qualification, the number of curricular units related to the bioeconomy they had taken during their most recent qualification, and the most interesting bioeconomy areas for further training. The participants were also asked to indicate their preferred learning methods for bioeconomy-related training and their willingness to pay tuition fees for such training. Finally, they were asked to identify the most important competencies and skills for a successful career as a "Bioeconomy Specialist in Agriculture".

To analyze the data collected through the questionnaire, both descriptive and inferential statistical methods were employed. Descriptive statistics, including frequencies, means, and standard deviations, were used to summarize participant demographics, educational background, and initial perceptions of competencies. Given that the distribution of the data did not satisfy the assumptions of normality (as confirmed by Shapiro–Wilk tests), non-parametric tests were applied. Specifically, the Mann–Whitney U test was used to examine statistically significant differences in perceptions between two independent groups (i.e., farmers and ACEP professionals), as it is appropriate for non-normally distributed ordinal data [40]. Additionally, the Kruskal–Wallis H test was employed to compare more than two independent groups (i.e., respondents from Greece, Italy, Portugal, and Sweden) on the same variables. This test is suitable for assessing group differences when the assumption of normality is violated in ordinal data.

4. Findings

From the 151 questionnaires, 73 respondents identified themselves as farmers (48%), 33 (22%) as agronomists, 16 (11%) as entrepreneurs, 7 (5%) as consultants, 11 (7%) as policymakers, 5 (3%) as students, while 6 (4%) respondents identified as "other". Responses from students and from respondents who identified as "other" were excluded from further analysis as they did not serve the purpose of this study.

Among the 140 respondents, 43 (31%) were from Greece, 45 (32%) were from Italy, 35 (25%) were from Portugal, and 17 (12%) were from Sweden. In particular, of the Greek respondents, 23 were farmers and 20 were ACEPs (agronomists/consultants/entrepreneurs/policymakers); from the Italian sample, 25 were farmers and 20 were ACEPs; from Portugal, 22 were farmers and 13 were ACEPs; while from Sweden, 3 were farmers and 14 were ACEPs (Table 1).

Regarding the educational qualifications of the learners, 33 respondents (24%) held a bachelor's degree, while 27 (19%) had completed a master's degree. A smaller number, eight respondents (6%), possessed a doctoral degree, and six (4%) had attended a post-graduate course. Seven respondents (5%) participated in summer courses, and two (1%) indicated vocational education and training (VET) as their qualification. Meanwhile, 30 respondents (21%) reported having a high school diploma, while 12 (8.5%) were high school dropouts. Nine respondents (7%) indicated "other" as their educational qualification, and six (4%) provided no response.

When analyzing the duration of the respondents' latest qualification attained, four participants (3%) indicated that it lasted less than three months, and one respondent (1%) reported a duration of 4–6 months. Four respondents (3%) completed a program lasting 7–12 months, and seventeen (12%) completed a two-year qualification. A significant number, 28 respondents (20%), completed a three-year program, while 61 respondents (44%) pursued a qualification lasting more than three years. Notably, 25 respondents (18%) did not report the duration of their qualifications.

Table 1. Professional role by country.

Country	Total Respondents (% of Sample)
Greece	*43 (31%)*
Farmers	23
ACEPs	20
Italy	*45 (32%)*
Farmers	25
ACEPs	20
Portugal	*35 (25%)*
Farmers	22
ACEPs	13
Sweden	*17 (12%)*
Farmers	3
ACEPs	14
Total	
Farmers	73 (52%)
ACEPs	67 (48%)

The data also revealed that a large majority of respondents, 99 individuals (71%), reported having taken no learning units related to the bioeconomy during their most recent degree or qualification. Seven respondents (5%) reported one bioeconomy-related unit, and another six respondents (4%) indicated two units. Four respondents (3%) had taken three units, and one respondent (1%) reported having taken four units. Additionally, four respondents (3%) reported having taken more than five units related to the bioeconomy. One respondent (1%) indicated that this was not applicable, and nineteen respondents (13%) did not provide a response (Table 2).

Table 2. Educational profile of respondents.

Category	Number of Respondents (% of Total)
Educational Qualifications	
Bachelor's Degree	33 (24%)
Master's Degree	27 (19%)
Doctoral Degree	8 (6%)
Post-Graduate Course	6 (4%)
Summer Courses	7 (5%)
Vocational Education and Training (VET)	2 (1.5%)
High School Diploma	30 (21%)
High School Dropout	12 (8.5%)
Other	9 (7%)
No Response	6 (4%)
Duration of Latest Qualification	
Less than 3 Months	4 (3%)
4–6 Months	1 (0.5%)
7–12 Months	4 (3%)
Two Years	17 (12%)
Three Years	28 (20%)
More than Three Years	61 (43.5%)
No Response	25 (18%)

Table 2. *Cont.*

Category	Number of Respondents (% of Total)
Bioeconomy-Related Learning Units	
None	99 (70%)
One Unit	7 (5%)
Two Units	6 (4%)
Three Units	4 (3%)
Four Units	1 (1%)
More than Five Units	4 (3%)
Not Applicable	1 (1%)
No Response	19 (13%)

When asked about the most interesting bioeconomy areas for further training, the respondents highlighted several key fields. Agriculture was the most frequently selected area, with 60 farmers (44%) and 37 ACEP (agronomist, consultant, entrepreneur, and policymaker) participants (27%) expressing interest. Renewable energies was also a significant area of interest, noted by 21 farmers (18%) and 23 ACEP respondents (19%). Other areas of interest included environment and sustainability, which appealed to 15 farmers (13%) and 34 ACEP respondents (29%), and bioenergy, chosen by 12 farmers (10%) and 18 ACEP respondents (15%). The bioeconomy, as a broad area, attracted 13 farmers (11%) and 16 ACEP respondents (13%). Smaller percentages of respondents indicated an interest in forestry, with seven individuals from each group (6%), and in biorefineries or green chemistry, noted by no farmers (0%) but by two ACEP respondents (2%) (Figure 1).
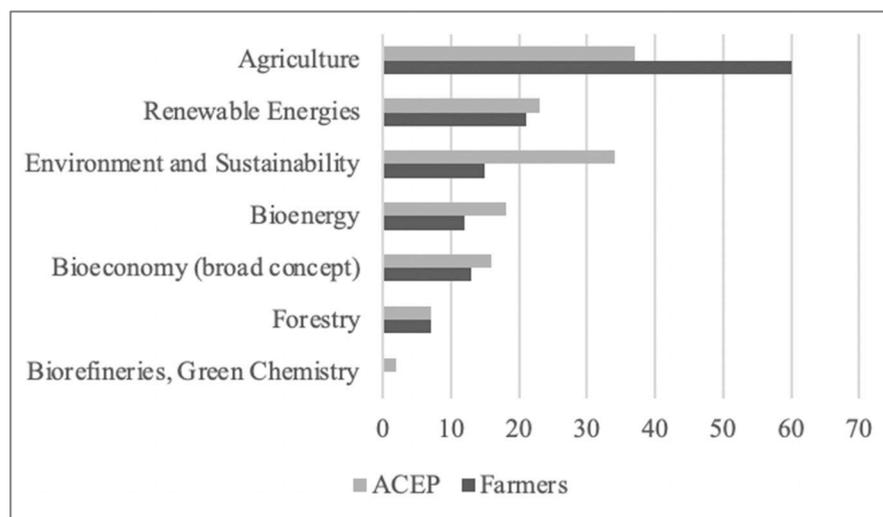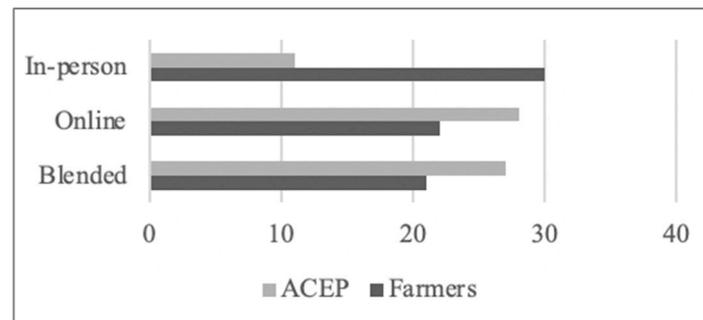

Figure 1. Most interesting bioeconomy area for further training.
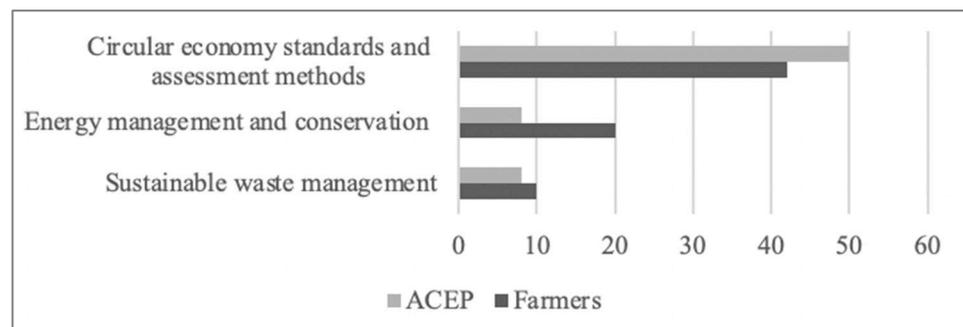
Respondents were also asked about their preferred learning method for bioeconomy-related training. A total of 41 participants (30%) preferred in-person learning, with 30 farmers (22%) and 11 ACEPs (8%) choosing this option. Online training was preferred by 50 respondents (36%), including 22 farmers (16%) and 28 ACEPs (20%). Blended learning approaches were selected by 48 participants (34%), with 21 farmers (15%) and 27 ACEPs (19%) expressing this preference (Figure 2).

Regarding willingness to pay tuition fees for bioeconomy-related training, 24 farmers (17%) and an equal number of ACEP respondents (17%) indicated they were willing to pay. However, a larger proportion of farmers, 48 (34%), and ACEP respondents, 43 (31%), stated they were unwilling to pay tuition fees. One farmer (1%) did not provide a response.

Figure 2. Preferred learning methods for bioeconomy-related training.

When identifying the most important competencies and skills for a successful career as a "Bioeconomy Specialist in Agriculture", circular economy standards and assessment methods were the most highly valued, noted by 42 farmers (30%) and 50 ACEP respondents (36%). Energy management and conservation was the second most frequently mentioned skill, selected by 20 farmers (14%) and 8 ACEP respondents (6%). Sustainable waste management, including waste classification, environmental impact assessment, and supply chain management incorporating the 5Rs (Reduce, Reuse, Refurbish, Repair, and Recycle), was highlighted by 10 farmers (7%) and 8 ACEP respondents (6%). One ACEP respondent (1%) did not provide a response (Figure 3).

Figure 3. Most important skills for a successful career as a "Bioeconomy Specialist in Agriculture".

The next step was to examine the perceptions regarding digital and entrepreneurial competencies. To evaluate the validity, reliability, and internal consistency of each construct, average variance extracted (AVE), composite reliability (CR), and Cronbach's alpha (α) values were calculated. The computed values fell within the acceptable range, and the results are presented in Table 3. Moreover, the discriminant validity met the criteria of Fornell and Larcker [41], as the square roots of the AVEs were greater than the respective correlation coefficients (see Table 4).

The study assessed four key variables: digital competencies (DGT), the "Ideas and Opportunities" dimension of the entrepreneurial competencies (IDO), the "Resources" dimension of the entrepreneurial competencies (RES), and the "Into Action" dimension of the entrepreneurial competencies (ACT). Table 3 provides the means (Ms) and standard deviations (SDs) for these variables, analyzed across countries and professions.

The analysis revealed that all four assessed dimensions received high overall mean scores. Specifically, the mean score for digital competencies (DGT) was 4.17 (SD = 0.72), that for "Ideas and Opportunities" (IDO) was 4.07 (SD = 0.66), that for "Resources" (RES) was 4.35 (SD = 0.58), and that for "Into Action" (ACT) was 4.32 (SD = 0.53) (Table 5).

Table 3. Factor loadings, composite reliability, and AVEs.

Variables	Items	LF	CR	AVE	A
DGT	DGT1	0.72			
	DGT2	0.76			
	DGT3	0.75	0.87	0.56	0.80
	DGT4	0.79			
	DGT5	0.73			
IDO	IDO1	0.64			
	IDO2	0.79			
	IDO3	0.81	0.81	0.56	0.80
	IDO4	0.71			
	IDO5	0.78			
RES	RES1	0.79			
	RES2	0.77	0.62	0.59	0.64
	RES3	0.74			
ACT	ACT1	0.77			
	ACT2	0.76			
	ACT3	0.74	0.85	0.54	0.78
	ACT4	0.72			
	ACT5	0.66			

Table 4. Correlation matrix and discriminant validity.

Variables	DGT	IDO	RES	ACT
DGT	(0.75)			
IDO	0.14	(0.75)		
RES	0.31 ***	0.27 **	(0.77)	
ACT	0.29 ***	0.48 ***	0.37 ***	(0.73)

Note: ** $p < 0.01$ and *** $p < 0.001$.

Table 5. Means and standard deviations.

Variables	M	SD
DGT	4.17	0.72
By Country		
DGT—Greece	3.92	0.69
DGT—Italy	4.59	0.51
DGT—Portugal	4.21	0.57
DGT—Sweden	3.52	0.90
By Profession		
DGT—Farmers	4.22	0.74
DGT—ACEPs	4.11	0.69
IDO	4.07	0.66
By Country		
IDO—Greece	4.09	0.54
IDO—Italy	4.01	0.77
IDO—Portugal	3.99	0.56
IDO—Sweden	4.33	0.80
By Profession		
IDO—Farmers	3.81	0.64
IDO—ACEPs	4.33	0.58

Table 5. *Cont.*

Variables	M	SD
RES	4.35	0.58
By Country		
RES—Greece	4.22	0.65
RES—Italy	4.45	0.49
RES—Portugal	4.39	0.48
RES—Sweden	4.31	0.78
By Profession		
RES—Farmers	4.43	0.56
RES—ACEPs	4.26	0.60
ACT	4.32	0.53
By Country		
ACT—Greece	4.22	0.65
ACT—Italy	4.31	0.37
ACT—Portugal	4.45	0.35
ACT—Sweden	4.31	0.84
By Profession		
ACT—Farmers	4.24	0.55
ACT—ACEPs	4.40	0.51

In order to examine the differences between the farmers and the ACEP group, we used the Mann–Whitney U test [42], as the two groups' data were significantly different from normal (Table 6). The Mann–Whitney U test was chosen as it can examine differences between two independent groups that have non-parametric data [40].

Table 6. Test of normality (Shapiro–Wilk) for DGT, IDO, RES, and ACT variables by profession.

	DGT	IDO	RES	ACT
Farmers	0.87 ***	0.96 *	0.79 ***	0.86 ***
ACEPs	0.93 ***	0.89 ***	0.90 ***	0.90 ***

Note: * $p < 0.05$ and *** $p < 0.001$.

A Mann–Whitney U test was performed for each main variable. The results revealed that there was a significant difference in perceptions of the "Ideas and Opportunities" dimension (IDO) of the entrepreneurial competencies in bioeconomy between the groups ($U = 1140.50$, $p < 0.001$) and the "Into Action" (ACT) dimension ($U = 1908$, $p = 0.044$). Moreover, at the $p < 0.1$ level, there was a significant difference in RES ($U = 1964$, $p = 0.073$). On the other hand, profession did not significantly affect the variables regarding the perceptions about digital competencies in bioeconomy (Table 7).

Table 7. Mann–Whitney U test.

Variables	Statistic	p
DGT	2058.50	<0.222
IDO	1140.50	<0.001
RES	1964.00	0.073
ACT	1908.00	0.044

In order to examine the differences between the countries, we used the Kruskal–Wallis test [43], as the majority of the groups had data significantly different from normal (Table 8). The Kruskal–Wallis test was chosen as it can examine differences between several independent groups that have non-parametric data [40].

Table 8. Test of normality (Shapiro–Wilk) for DGT, IDO, RES, and ACT variables by country.

	DGT	**IDO**	**RES**	**ACT**
Greece	0.93 *	0.96	0.83 ***	0.86 ***
Italy	0.77 ***	0.90 **	0.88 ***	0.90 **
Portugal	0.93 *	0.95	0.89 **	0.93 *
Sweden	0.95	0.80 **	0.84 **	0.78 **

Note: * $p < 0.05$; ** $p < 0.01$; and *** $p < 0.001$.

A Kruskal–Wallis test was performed for each main variable. The results revealed that there was a significant difference in perceptions of digital competencies in bioeconomy between the groups (H (3) = 34.15, $p < 0.001$). On the other hand, country did not significantly affect the variables regarding the perceptions about entrepreneurial competencies in bioeconomy (Table 9).

Table 9. Kruskal–Wallis test.

Variables	χ^2	**DF**	*p*
DGT	34.15	3	**<0.001**
IDO	4.96	3	0.175
RES	3.11	3	0.375
SCT	3.51	3	0.319

In order to gain a better understanding of the differences regarding the DGT, a pairwise comparison was performed. As shown in Table 10, the differences resulted from significant differences between the group from Italy and the other groups.

Table 10. Pairwise comparisons—DGT (Dwass–Steel–Critchlow–Fligner).

Pairs	*W*	*p*
Greece vs. Italy	7.03	<0.001
Greece vs. Portugal	3.03	0.141
Greece vs. Sweden	−2.26	0.378
Italy vs. Portugal	4.73	0.005
Italy vs. Sweden	−5.50	<0.001
Portugal vs. Sweden	−3.68	0.046

5. Discussion

This study set out to explore the perceptions of agricultural professionals working in the bioeconomy regarding their digital and entrepreneurial competencies, with the goal of identifying current training needs. This focus responds to a significant gap in the literature, as most previous studies either addressed digital and entrepreneurial skills separately or in general terms, without systematically integrating them within the bioeconomy context, e.g., [36,37]. Moreover, few empirical studies have examined how these competencies are perceived by diverse professional groups: farmers, agronomists, consultants, entrepreneurs, and policymakers across different European countries.

Our findings underscore the widespread recognition of digital competencies as essential for integrating bioeconomy principles into agricultural practices. This aligns with the broader literature highlighting the transformative potential of digital technologies in agriculture to enhance productivity, climate resilience, and sustainability [6,7,28,44]. Importantly, no significant differences were found between farmers and ACEP professionals, suggesting a shared awareness across roles of the need to strengthen digital literacy.

However, the significant variation in digital competence perceptions across countries, particularly the higher ratings from Italian professionals, raises questions about national-level differences in digital access, training provision, or perceived gaps. This echoes Eurostat [45] data indicating relatively low digital skill levels in Italy, which may drive higher perceived importance in that context.

Entrepreneurial competencies, assessed through the EntreComp dimensions of "Ideas and Opportunities", "Resources", and "Into Action", also emerged as highly valued. Among these, the "Resources" dimension received the highest mean score, reflecting the importance agricultural professionals place on managing financial, human, and technological capital, an insight that aligns with existing findings about the resource-intensive nature of the bioeconomy [46]. Notably, the significant differences observed between farmers and ACEP professionals in the "Ideas and Opportunities" and "Into Action" dimensions may be explained by the differing functions of these groups. ACEP professionals often engage in advisory, planning, or policy roles that necessitate strategic thinking, opportunity recognition, and implementation planning, thereby prioritizing these competencies more explicitly in their day-to-day responsibilities.

Furthermore, the findings concerning educational background highlight a major shortfall in current curricula: 71% of respondents reported that their most recent qualification did not include any content on the bioeconomy. This finding confirms and extends the analysis of Paris et al. [12], who noted fragmented efforts across the EU in incorporating bioeconomy topics in formal education. The lack of structured training in bioeconomy-related content across all four countries studied reflects a systemic issue that may impede the EU's strategic ambitions for a sustainable and innovation-driven agricultural sector.

Equally important are the insights into learning preferences. The high interest in online and blended learning models indicates that flexibility and accessibility are key for engaging working professionals. These preferences are consistent with broader trends in adult learning and lifelong education, particularly in the agricultural sector, where time and location constraints often limit participation in traditional training formats.

Taken together, the study's findings reinforce the notion that while digital and entrepreneurial competencies are widely recognized as important, there is a clear and unmet need for structured, profession-specific training. By applying validated frameworks across a diverse European sample, this study offers a robust foundation for the development of targeted educational initiatives aligned with both policy objectives and practical realities. It contributes to the growing discourse on the future of work in the agricultural bioeconomy by providing empirical evidence on skill gaps, training modalities, and the alignment between professional needs and educational offerings.

6. Conclusions

This study provides valuable insights into the competencies and training needs of agricultural professionals engaged in the bioeconomy, with a particular focus on digital and entrepreneurial skillsets. By surveying farmers, agronomists, consultants, entrepreneurs, and policymakers across four European countries, this research underscores the pivotal role these competencies play in the transition to more sustainable and innovation-driven agricultural practices.

A significant contribution of this study is its structured implementation of two widely recognized European Commission frameworks, DigComp and EntreComp. These frameworks were systematically adapted and operationalized to assess perceptions of agricultural professionals, offering a novel empirical model for identifying competence gaps in the context of the bioeconomy. Contrary to the approaches of preceding studies, which examined digital and entrepreneurial skills in isolation and frequently without the utilization

of standardized frameworks, this research integrates both DigComp and EntreComp into a coherent analytical structure. By addressing this critical gap in the extant literature, the study offers insights into the perception and prioritization of these competencies across diverse national contexts and professional profiles.

The findings indicate a need for the integration of bioeconomy topics into educational and vocational training programs. The development of tailored curricula should prioritize the inclusion of digital and entrepreneurial competencies, with an emphasis on aligning these with the specific needs of diverse professional groups, including farmers, agronomists, and policymakers. It is incumbent upon policymakers to prioritize the allocation of resources and the development of training initiatives that address the identified competence gaps. It is recommended that governments, universities, and private sector actors collaborate to create practical training solutions that combine theoretical knowledge with real-world applications. This approach would foster innovation and sustainability in the bioeconomy.

In countries with lower digital readiness, it is recommended that investment be made in improving infrastructure to facilitate the integration of digital tools in agriculture. This should include the provision of access to technologies such as precision farming tools and data analytics platforms. It is further recommended that future training initiatives incorporate mechanisms to assess the impact of programs on professional performance and bioeconomy outcomes, ensuring continuous improvement and alignment with evolving sector needs.

A limitation of this study is that it exclusively measured the perceptions of agricultural professionals regarding the importance of digital and entrepreneurial competencies. It did not assess their actual skill levels in these areas. Future research could compare the perceived importance of competencies and the actual level of competencies in order to reveal any discrepancies between the two. Additionally, due to its cross-sectional nature, the study captured data at a single point in time. These may not have reflected evolving trends in digital and entrepreneurial competencies or changing needs in the bioeconomy sector. A longitudinal design would provide deeper insights into these dynamics. Furthermore, the study focused on four European countries, limiting the representation of other key agricultural economies such as France, Germany, and Poland, where digital infrastructure and bioeconomy strategies may differ significantly. Future studies should aim to expand the sample size and geographic coverage to improve the generalizability of the results. Finally, the inclusion of qualitative methods (e.g., interviews) would allow for a deeper understanding of structural and cultural factors influencing competence perceptions and training needs.

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Appendix A

Table A1. Scale Items for DGT, IDO, REC, and ACT.

	Please indicate the extent to which the following competences and soft skills will enable you to integrate successfully the bioeconomy dimension within your agricultural practices?
DGT1	Information and data literacy (e.g., evaluating data. information and digital content. Managing data. information and digital content)
DGT2	Communication and collaboration (e.g., Interacting through digital technologies. haring through digital technologies. Managing digital identity)
DGT3	Digital content creation (e.g., Developing digital content. integrating and re-elaborating digital content. programming)
DGT4	Data safety (e.g., Protecting devices. Protecting personal data and privacy)
DGT5	Problem solving skills (e.g., Solving technical problems. identifying needs and technological responses. Identifying digital competence gaps)
IDO1	Spotting opportunities (e.g., Use your imagination and abilities to identify opportunities for creating value)
IDO2	Creativity (e.g., Develop creative and purposeful ideas)
IDO3	Vision (e.g., Work towards your vision of the future)
IDO4	Valuing ideas (e.g., Make the most of ideas and opportunities)
IDO5	Ethical and sustainable thinking (e.g., Assess the consequences and impact of ideas. opportunities. and actions and their implications to a sustainable development)
RES1	Motivation and perseverance (e.g., Stay focused and don't give up)
RES2	Mobilizing resources (e.g., Gather and manage the resources you need)
RES3	Financial and economic literacy (e.g., Develop financial and economic know how)
RES4 *	Self-awareness and self efficacy (e.g., Believe in yourself and keep developing)
RES5 *	Mobilizing others (e.g., Inspire, enthuse, and get others on board)
ACT1	Taking the initiative (e.g., Go for it)
ACT2	Planning and management (e.g., Prioritize. organize and follow-up)
ACT3	Coping with uncertainty, Ambiguity, and risk (e.g., Make decisions dealing with uncertainty. ambiguity and risk)
ACT4	Working with others (e.g., Team up. collaborate and network)
ACT5	Learning through experience (e.g., Learn by doing)

Note: * Excluded during the reliability and validity analyses.

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