

Which are the best practices for MSc programmes in sustainable agriculture?



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ABSTRACT

Programmes of education for sustainable development are important to reformulate and revise educational programmes in Sustainable Agriculture. Higher education institutes emerge as learning places to integrate sustainable development into the educational system, through graduation and MSc programmes, to provide a more effective response to the higher environmental and agriculture concerns. The aim of this study was to identify the best practices to be included in a MSc programme of education for sustainable development in agriculture based on a questionnaire prepared and distributed to agrarian sciences experts. The questionnaires were developed in order to define the fundamental competences/expertise, to identify the best practices and the methods of training/learning that should be taken in consideration in a MSc programme in Sustainable Agriculture. The results showed that the fundamental expertise of MSc programmes should be based on knowledge transfer of agricultural measures to mitigate the impact of climate change on agricultural systems. MSc programmes in Sustainable Agriculture should include interdisciplinary courses related to sustainability and agro-environmental technologies, such as Precision Agriculture, and incorporate adaptive and mitigate practices as those used in the Circular Economy strategy. Traditional face-to-face training methods are considered the most important forms of training/learning in a MSc programme in Sustainable Agriculture. However, due to COVID-19 pandemic, online learning methods, traditionally considered not suitable for MSc programmes in Sustainable Agriculture, became important by providing online education. Information and communication technology and technological tools showed to be important skills to effectively implement online learning and to improve the efficient access and use of up-to-date information of the agricultural sector.

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1. Introduction

One of the great challenges of humanity to the development of Sustainable Agriculture is to feed a growing world population in a

sustainable way, preserving and maintaining a dynamic balance between the economy, society and the environment (Fernandez et al., 2018; Nuttavuthisit 2017). In order to produce changes in agricultural practices towards a sustainable agriculture, Higher

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Education Institutes (HEIs) should integrate agricultural sustainable development in the undergraduate and MSc programmes by teaching and training students, agricultural technicians and researchers with the latest knowledge and practices in sustainable agriculture. In this way, awareness of environmental problems and implementation of measures will lead to sustainable food production to feed an exponentially growing population. In addition, COVID-19 pandemic has affected/destabilized traditional learning methods, forcing a sudden learning shift to online methods. The present study aims to identify the best practices to be taken into account when developing a MSc programme of Education for Sustainable Development (ESD) in Agriculture based on questionnaires developed in order to define the fundamental competences/expertise, the Sustainable Agricultural Practices (SAP) and the methods of training/learning that should be taken in consideration in the MSc programme. This study is expected to contribute for the development of a long-term MSc programme to ensure a safe and sustainable agricultural production, taking in consideration environmental, social and economic aspects.

2. Literature review

Since the 1980s, the concept of sustainable development has been introduced to address the shortcomings of the industrial agrifood model and preserving the environment, biodiversity and ecosystems (Ehrlich and Ehrlich 2013). The industrial agrifood model is characterized by being highly dependent on inputs produced industrially, fossil fuels and water and by an agriculture with intensive use of capital, high production and high yield, specialized and rationalized (Knickel et al., 2017; Fernandez et al., 2018). Thus, a Sustainable Agriculture strategy that promotes the environment should be developed based on agroecological principles in order to solve the problems of poverty, food insecurity and environmental degradation (Altieri, Rosset, and Thrupp 1998). The concept of agroecology effectively addresses these problems of hunger, poverty and inequality, by reducing the loss of biodiversity and providing more resilience to climate change (FAO, 2015; IAASTD 2009; De Schutter 2010). This concept consists of “applying ecological principles to the design and management of agroecosystems through the integration of traditional and scientific knowledge” (Altieri 1995).

In addition, the COVID-19 pandemic exposed the need for robust and resilient EU food systems based on a sustainable bioeconomy prepared to respond to global shocks and disruptions in supply chains, to assure agricultural resources and food availability and to mitigate socio-economic impacts of crises, especially regarding food scarcity (UN-FAO 2020). In order to be prepared to face this type of pandemic situation, all countries need to promote and create healthier, sustainable, equitable and resilient food systems (ESCAP et al., 2020) and include complex systems linking agriculture, food, health and climate (Blay-Palmer et al., 2020; Gunther 2020; Knickel et al., 2017).

Implementing sustainable food production and consumption will boost the economy, improve people's health and quality of life, care for nature and everyone (European Union, 2020). According with Koukios et al. (2018), bioeconomy, an innovative approach to the economy of the future, will act as a driver to enhance the economies and societies of countries that experienced deep and complex systemic crises. Sustainable bioeconomy therefore needs new agricultural practices, new patterns of consumer behaviour, new industrial technologies, new business models, new skill profiles and new regulations and governance approaches to be implemented in order to ensure long-term protection of natural resources (Koukios et al., 2018). Moreover, Mockshell and Kamanda (2018) showed the importance of using the three dimensions of

sustainability (ecological, social and economic) to assess the performance of a Sustainable Agriculture production system and to propose transformation paths.

Other important challenges, but controversial among development partners, scientists and policymakers are achieving food security and improving nutrition (Mockshell and Kamanda 2018). The interest in increasing food production and, at the same time, reducing damage to the environment is captured in the 2030 Agenda for Sustainable Development (UN, 2015) and in the European Green Deal (European Union, 2020). According to the Agenda 2030, agricultural and food systems should be more efficient and sustainable, and society should adopt a more sustainable consumption and production (Knickel et al., 2017). The Agenda 2030 promotes the creation of resilient food systems and the strengthening of markets so that people can access safe and nutritious food (UN 2016). In addition, the second Sustainable Development Goal of the United Nations has the challenge of ensuring Sustainable Agriculture for the long-term food security of a growing world population, to end hunger, achieve food security and improve nutrition (UN 2016). Further, the European Green Deal aims, through the Farm to Fork Strategy, to show how Europeans valorise food sustainability enhancing food systems fair, healthy and environmentally-friendly (European Union, 2020).

Thus, Sustainable Agriculture is urgently needed to promote conservation and sustainable resources use in an equitable manner through integrated management of land, water and living resources (Carlisle et al., 2019). Sustainable Agriculture aims to increase the productivity without affecting the quality of soil and water, preserve the ecosystems, safeguard animal welfare, generate income for farms and improve quality of life in rural areas, support territorial development and contribute to economy (Ciołoş 2012). In this way, the improvement of diverse landscapes, biodiversity and maintenance of ecosystem functions can reduce greenhouse gas (GHG) emissions, halting biodiversity loss and caring for valued landscapes (Knickel et al., 2017). Therefore, to face the current and new challenges and opportunities, farmers, technicians and agricultural workers, need to be provided with know-how and technology to implement the changes, as well as, a smart governance system, fully set up, linking research, support services, farmers and their organizations and markets (Carlisle et al., 2019).

The education in agriculture emerges as a crucial tool for preparing agricultural technicians and researchers, farmers and workers to make productive contributions. Furthermore, it demonstrates the need to reformulate and revise educational programs in the area of sustainability. Since 2014, at the closing conference of the United Nations Decade for ESD in 2005–14 (Aichi-Nagoya, Japan), there is a growing concern on the implementation of programs of ESD or sustainability education (UNESCO 2014; Figueiró and Raufflet 2015; Verhulst and Lambrechts 2015; Lambrechts et al., 2013). At this conference, the Declaration on Higher Education for Sustainable Development was presented, which promotes a ‘transformative role of higher education towards sustainable development’ through ‘transformative learning and research’, produced by representative government and university groups and United Nations organizations (HESD 2014). This declaration reflects the significant degree of international consensus on the importance of HEIs to play a leading role and to transformer in promoting sustainable development worldwide (Pashby and de Oliveira Andreotti 2016). Thus, the HEIs, such as Universities, arise with an important mission of education in the context of social transformation and to integrate sustainable development into the educational system as a scientific subject (Clark 1986; Bursztyn 2008; Axelrod 1994). HEIs should undergo changes in the educational approach by putting in practice the new principles, knowledge, skills, perspectives and values associated with sustainability

for the present and future communities (Faham et al., 2017) to educate new generations of leaders and citizens (Meadows 1997).

One way to implement the know-how in sustainable agriculture is through MSc programmes since public is more aware of environmental problems and the offer of educational courses in the universities is increasing in this area (Azeiteiro et al., 2015). Also, MSc courses revealed to be important advance courses taught at HEIs which should provide effective and useful educational experiences to engage students in the global, economic, environmental, and societal impact of Sustainable Agriculture (Lewis et al., 2011), since pedagogy issues are vital to reorienting education towards sustainability (Holmberg et al., 2008). Consequently, students get better informed and prepared to deal with global issues, such as, food security, climate change, water management, non-renewable energy management, biodiversity, health and social inequality, and better prepared to face a sustainable future. For instance, Faham et al. (2017) showed an improvement in the educational behaviour pattern when integrating sustainability contents into curricula of the agriculture and natural resources disciplines from 1991 to 2011.

3. Materials and methods

This work is the result of research developed under the frame of the SFARM - Sustainable Farming project (www.sfarm-project.eu), an ERASMUS + project. The European partners are universities from Greece, Italy and Portugal, and from Asia universities from China, Indonesia, Laos and Vietnam. The main goal of the SFARM is to develop new curricula for a MSc program in Sustainable Agriculture, that integrate the latest developments in agricultural applied research and with this contribute to improve the skills of academic staff, students and agricultural extension staff in the SFARM Asian HEIs and in general in the society. In particular, this study aims to identify the best practices in Sustainable Agriculture to be implemented in the MSc programmes of ESD.

In order to accomplish the aim of this study, a questionnaire (Supplementary Material 1 – SM1) was prepared by the University of Evora (Portugal) with the contribution of Agricultural University of Athens (Greece) and University of Basilicata (Italy). This questionnaire concerning the agricultural sector was distributed to academics' experts in Agrarian Sciences in Greece, Italy and Portugal, to record their opinion on the best practices to be adopted in a MSc programme in Sustainable Agriculture. The target audience is expected to be academic staff, students and agricultural extension staff (Fig. 1).

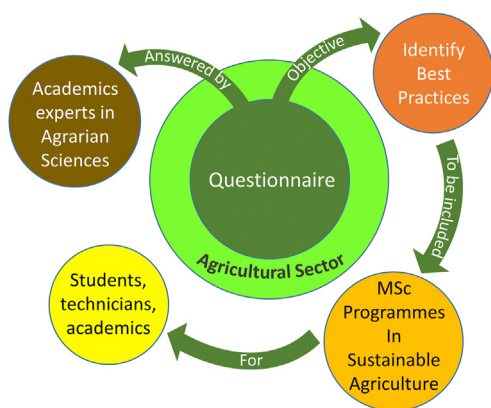


Fig. 1. Conceptual scheme of the questionnaires on the agricultural sector, to be answered by agrarian sciences experts, with the objective to identify the best practices to be included in MSc programmes in Sustainable Agriculture.

The defined objective in the SFARM grant agreement was to have 90 questionnaires answered (30 in each country). However, only 72 were received which corresponds to an achievement of 80% of the initial goal predicted in this task. In Greece 22 questionnaires were completed, in Italy 30 and in Portugal 20. The majority of the respondents in the three countries were male (70.8%) and the average age vary between 35.5 and 56.7 years old.

The main objective of the questionnaire was to identify the best practices based on other similar questionnaires and ideas expressed in EISA (2012), such as:

- 1) Which are the fundamental expertise in a MSc programme on Sustainable Agriculture?
- 2) Which are the most important Sustainable Agriculture practices?
- 3) Which forms of training/learning are adequate? Theoretical, practical classes? Face-to-face, e-learning, b-learning?

The questionnaire was divided in three parts:

- 1) Present and future of Sustainable Agriculture:
 - a. Is there a widespread concern in your area regarding the practice of Sustainable Agriculture? Elaborate (Yes/No);
 - b. Selection of the Sustainable Agriculture practices that already exist or/and are the future trend in your country;
 - c. Grade the level of farmer's expertise in your region;
- 2) Training needs on Sustainable Agriculture:
 - a. Rate the importance of each expertise for the future of Sustainable Agriculture;
 - b. What you think are the overall future training needs in Sustainable Agriculture;
 - c. List the subject(s) in Sustainable Agriculture you think that is (are) important to be taught in a Master Level in Europe;
 - d. Rate the forms of learning/training from not very applicable/not important to very applicable/important;
 - e. How efficient you believe each training method is;
- 3) Personal data:
 - a. Age;
 - b. Gender;
 - c. Expertise.

The questionnaire answers were analysed by country and are presented in percentages to allow the comparison of the results between the countries. Table 1 shows the methodology defined for the analysis of the current practices, future trends, current level of farmers' expertise, training needs, skills with future training needs, forms of learning/training, and training methods.

4. Results

4.1. Existing practices in sustainable agriculture

Fig. 2 shows the opinion of Greek, Italian and Portuguese experts in agrarian sciences (academics) regarding the widespread concerns of Sustainable Agriculture in their regions. It can be seen that there is a widespread concern on practices of Sustainable Agriculture in the three countries. These concerns are mainly related with: i) climate change; ii) soil quality and resources; iii) water resources and management; iv) sustainable production; v) conservation agriculture; and vi) income (Table 2).

Nevertheless, some farmers were considered, by the experts, of not having enough know-how of these practices and/or being specially worried with the profitability of the production. In Greece, the majority of respondents said that farmers do not have enough knowledge in Sustainable Agriculture issues and most of the

Table 1
Methodology defined for the analysis of the best practices of Sustainable Agriculture based on the percentage of the respondents.

Best practices		
Currently existing practices	Present in farms	>60
	With low expression in farms	<30
Knowledge of a subject of farmers' expertise	High level	Sum of medium, high and very high >80
	Medium level	Sum of medium, high and very high >40 and < 80
	Very low level	Sum of none and small >50
Trends for practices	Main futures	>60
	No future	<30
Training needs	Extremely important expertise	Value 5 > 60
	Very important expertise	Sum of values 4 and 5 > 80
	Not important expertise	Sum of values 1 and 2 > 10
Skills with future training needs	Strongly agree	Sum of strongly agree and agree >80
	Not required	Sum of neither agree nor disagree, disagree and strongly disagree >20
Forms of learning/training	Very applicable/important	Sum of values 4 and 5 > 75
	Not very applicable/not important	Sum of values 1, 2 and don't know >10
Training methods efficiency	Extremely efficient	Sum of values 4 and 5 > 75
	Not efficient	Sum of values 1, 2, 3 and don't know >60

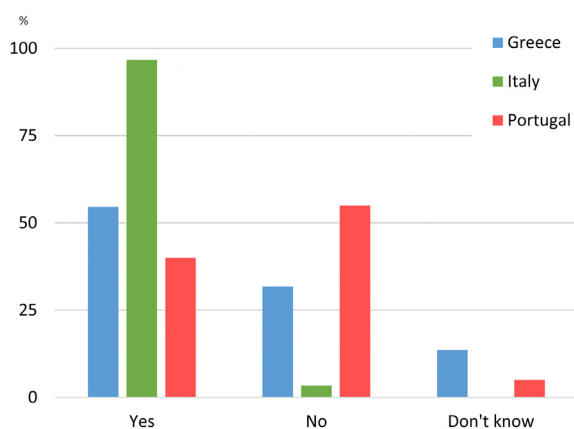


Fig. 2. Present widespread concerns regarding Sustainable Agriculture in Greece, Italy and Portugal.

stakeholders' focus on short-term profit, without taking into account the environmental impact and the sustainability of the

farming systems. In Italy, one questionnaire considered that there is not a widespread concern regarding the practice of Sustainable Agriculture, because their productions - organic agriculture and integrated agriculture - are already regulated by the law. In Portugal, most respondents stated that, despite concerns about Sustainable Agriculture, some farmers are also focused on economic profitability.

The SAP already present in the three European countries are sustainable crop rotation plan, crop protection management and soil management (Table 3). However, crop nutrient management and organic based fertilizers, integrated pest management and reuse of agricultural residues are in the border line and could almost be considered as practices present in European farms. Reduction of methane emissions from livestock and reduction of CO₂ emissions from machinery and fuel use were considered to be practices with low expression in Southern Europe. Precision Agriculture (PA) is a SAP existent in Portugal, with low presence in Greece and in Italy. The low expression practices, identified among the respondents, have been considered to be the main drivers of climate change, i.e. reduction of CO₂ emissions from machinery and fuel use and reduction of methane emissions from livestock.

Table 2
Main concerns related with Sustainable Agriculture referred by the Greek, Italian and Portuguese agrarian sciences experts.

Greece	Italy	Portugal
Agro-ecosystem conservation	Animal husbandry	Agriculture conservation
Bio-production	Biological control (only a few farms)	Biodiversity
Climate change	Biological control of crops	Climate change
Enough food for present and future generations	Biological pest control	Long-time farmers' income
Environmental impact	Climate changes	Soil quality and resources
Environmentally SAP	Consumers demand for environmentally friendly products	Sustainability of edaphic factors
Farmers income	Extensive cropping systems	Sustainable production
New techniques and adapt existing innovative agricultural systems	Homogenization of crops	Water resources
Precision agriculture technologies	Integration of traditional practices with the new technologies	
Production's yield and quality	Knowledge Transfer	
Sustainable agricultural practices	New technologies for agriculture	
Sustainable production	Organic crops	
Sustainable use of energy and natural resources	Organic fertilization	
Water, soil and energy resources	Precision agriculture for irrigation and fertilization	
	Precision farming (fertilization and irrigation)	
	Production costs	
	Remote sensing and GIS	
	Soil protection and conservation	
	Sustainable use of resources and environmental sustainability improved by new tools and methodologies	
	Waste management	
	Water management	

Table 3
Existing sustainable agricultural practices in Greece, Italy and Portugal.

Existing practices	Greece (%)	Italy (%)	Portugal (%)
Whole farm management plan	45	50	45
Farming cooperation	82	53	55
Sustainable crop rotation plan	73	87	75
Soil management	68	60	85
Crop nutrient management and organic based fertilisers	59	67	65
Crop protection management	91	77	85
Management plan for efficient energy use	32	37	25
Farm waste management	18	40	35
Use of renewable energy	36	43	45
Energy production from biomass and liquid manure	41	43	30
Water conservation and management	41	43	85
Irrigation evaluation and monitoring	36	50	75
Reduction of CO2 emissions from machinery and fuel use	14	10	30
Reduction of methane emissions from livestock	18	23	10
Maintenance and calibration of spraying equipment	68	30	85
Use of catch crops	41	60	30
Integrated pest management	59	90	75
Reuse of agricultural residues	55	77	60
Precision agriculture	41	23	70

Table 4 presents the level of farmer’s expertise according to the answers recorded. The highest level of expertise identified is in crop nutrition, health and protection. However, a considerable level of knowledge in animal husbandry, health and welfare, soil management and organization and management were mentioned. The lowest level of expertise was identified to be in climate change and air quality, and waste management and pollution control. These results revealed that academics view shows that in general farmers are experts in every aspect of crop and animal production but not in farming waste and pollutants management, or in climate change impacts and mitigation actions.

4.2. Future training/learning needs on sustainable agricultural

The main future trends of SAP identified were: management plan for efficient energy use, farm waste management, and energy production from biomass and liquid manure (Table 5). Although, the use of renewable energy, reduction of methane emissions from livestock, and PA may be also considered important future trend practices in European farms. Whilst water conservation and management was considered the SAP with lowest future trend. This can be due to the fact that water is already a concern for farmers, especially in the opinion of Italian and Portuguese academics’ expert.

Table 4
Level grade of farmer’s expertise.

Subject	Grecia						Italia						Portugal					
	None	Small	Medium	High	Very high	Don't know	None	Small	Medium	High	Very high	Don't know	None	Small	Medium	High	Very high	Don't know
Energy efficiency	1	12	8	0	1	0	1	15	14	0	0	0	2	9	9	0	0	0
Water use and conservation	0	11	7	3	0	1	1	14	13	2	0	0	0	5	11	4	0	0
Climate change and air quality	6	10	4	2	0	0	6	15	9	0	0	0	2	14	2	1	0	1
Landscape and nature conservation	0	9	11	1	0	1	1	7	15	7	0	0	1	10	5	4	0	0
Animal husbandry, health and welfare	0	7	6	6	2	1	0	2	15	10	3	0	0	3	9	5	1	3
Waste management and pollution control	5	8	5	1	2	1	2	14	11	3	0	0	4	8	5	2	1	0
Soil management	1	6	12	2	1	0	0	9	13	8	0	0	0	7	8	4	1	0
Organization and planning	0	5	11	3	2	1	0	9	14	7	0	0	0	7	9	4	0	0
Human and social capital	0	4	14	2	0	2	0	11	11	6	1	1	2	5	6	4	0	2
Crop nutrition	0	1	7	11	3	0	1	2	13	12	2	0	0	0	9	9	0	2
Crop health and protection	0	0	7	12	3	0	1	4	11	12	2	0	0	0	12	6	1	2

Regarding the training needs in Sustainable Agriculture, the majority of the technological, legislative, management and business, local community leadership and marketing were considered as very important expertise’s (Fig. 3). The technology was the most important expertise, while the legislative was the least important.

The most important subjects in Sustainable Agriculture to be taught in a Master Level reported by the respondents were 1) waste management; 2) animal husbandry; 3) pest management; 4) PA; 5) Remote Sensing and GIS; 6) resources use efficiency (water, energy, nutrients, etc.); 7) soil management and conservation; 8) technological, economic, social and environment issues; 9) water management and conservation; and 10) crop and nutrient management (SM2).

In addition, the future training methods require learning of new agronomical and environmental issues (Fig. 4). However, Greeks and Portuguese respondents strongly agree that management, and information and communication technology (ICT) skills are future training needs, while Italians respondents seem somehow less convinced that these skills require specific future training.

When analysing the training/learning forms, traditional face-to-face learning, experienced farmers as mentors and knowledge sharing mechanisms were rated as very applicable/important by the respondents (Table 6). On the other hand, massive open online courses and apps for learning via a smartphone were considered not very applicable/not important forms for training/learning in Sustainable Agriculture.

Table 5
Future trends in sustainable agricultural practices.

Future trends practices	Greece (%)	Italy (%)	Portugal (%)
Whole farm management plan	55	50	45
Farming cooperation	23	47	40
Sustainable crop rotation plan	23	13	35
Soil management	32	40	20
Crop nutrient management and organic based fertilizers	41	33	40
Crop protection management	55	57	20
Management plan for efficient energy use	73	63	60
Farm waste management	86	60	65
Use of renewable energy	73	57	50
Energy production from biomass and liquid manure	91	90	60
Water conservation and management	14	23	15
Irrigation evaluation and monitoring	50	10	30
Reduction of CO2 emissions from machinery and fuel use	59	57	60
Reduction of methane emissions from livestock	86	77	55
Maintenance and calibration of spraying equipment	32	70	25
Use of catch crops	55	40	35
Integrated pest management	68	50	30
Reuse of agricultural residues	45	23	45
Precision agriculture	77	77	40

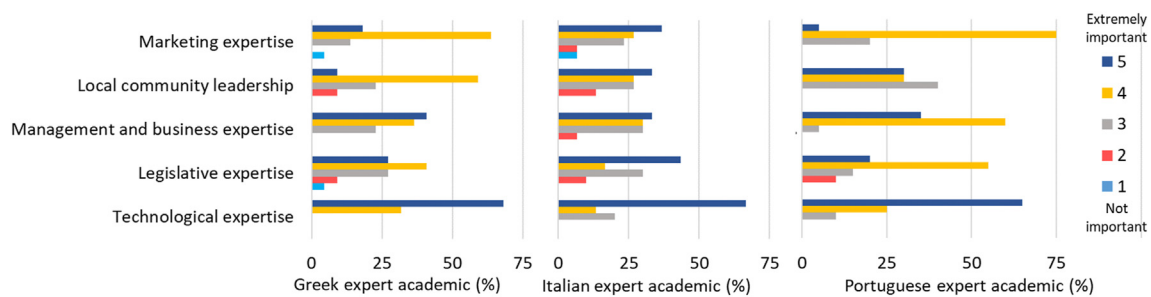


Fig. 3. Expertise relative importance for the future of Sustainable Agriculture.

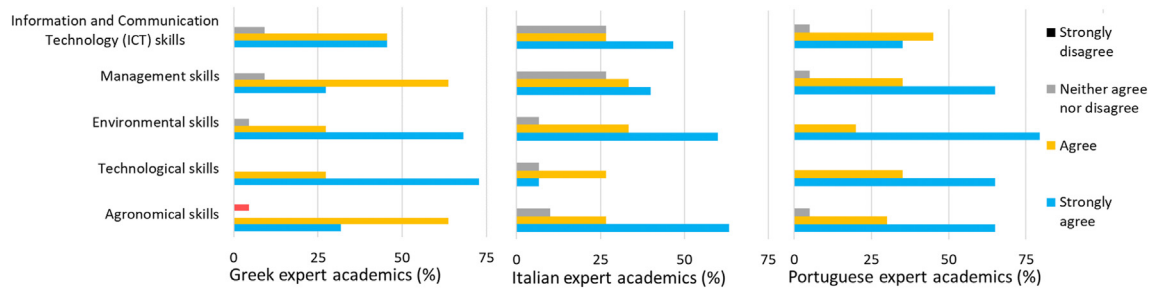


Fig. 4. Future skills in Sustainable Agriculture.

Table 6
Training/learning methodologies in Sustainable Agriculture (1 - not very applicable/not important; 5 – very applicable/important).

Training/learning methods	Greece (%)						Italy (%)						Portugal (%)					
	1	2	3	4	5	Don't know	1	2	3	4	5	Don't know	1	2	3	4	5	Don't know
Traditional face-to-face learning	0	0	14	41	41	0	0	7	10	30	53	0	5	0	10	45	40	0
Virtual and blended learning	0	0	36	27	32	0	3	10	37	37	10	3	0	5	25	40	30	0
Massive Open Online Courses	9	14	27	27	14	5	3	30	13	37	10	7	0	30	60	10	0	5
Peer-to-peer learning	0	0	41	45	9	0	7	23	10	43	13	3	0	5	25	40	30	0
Experienced farmers as mentors	0	5	9	27	55	0	0	0	17	30	53	0	0	0	15	45	40	0
Knowledge sharing mechanisms	0	0	9	50	32	5	0	0	20	40	37	3	0	0	10	45	30	15
Apps for learning via a smartphone	5	9	32	32	18	0	0	13	50	23	13	0	5	5	40	20	10	20

The training methods believed to be extremely efficient in a MSC programme in Sustainable Agriculture by the academics of the three European countries were educational excursions/visits, field

demonstrations, short-term seminars, practical courses/exercises and agriculturalist's visits in farms (Table 7). These academics considered not efficient the training methods broadcasts on radio,

information in the form of forms-brochures, television broadcasts and articles in newspaper.

5. Discussion

5.1. Fundamental expertise

In this study it became clear that agricultural sector is aware of the importance of education in Sustainable Agriculture practices (Fig. 2). To train properly the students, technicians and farmers in Sustainable Agriculture, it is important to provide critical knowledge and skills to enhance the productivity and sustainability (Patil and Kokate 2011). ESD in agriculture plays an important role in preparing academic staff, students and technicians for the changes and adaptations required for a sustainable agricultural production and to increase environmental protection and simultaneously meeting the farmer's needs (McKeown et al., 2002). Recent developments in science and technology, that could be an added value to crop and land management, are still unutilized in many situations because farmers have not been introduced to them or have not been trained to use it. These is in accordance with the agrarian sciences experts when considering that some farmers do not have enough know how on SAP.

Moreover, the main subjects related to Sustainable Agriculture identified (climate change, soil quality and resources, water resources and management, sustainable production, conservation agriculture, income; Table 2) were those that are causing a degree of concern and/or optimism in farmers, according to the political views, region and agricultural group. Based on Grimberg et al. (2018), the political view is the main driver for the perception of changes in the climate and the awareness of potential risks for agriculture, enhancing the use of adaptation and mitigation practices. Farmers are aware of climatic risks in agricultural systems due to the observation of local climate trends, the cultivated area and income (Arbuckle, Morton, and Hobbs 2015; Doll, Petersen, and Bode 2017; Gauchat 2012). Thus, climate changes emerge as one of the serious threats to agricultural sustainability and the ability of food systems to provide adequate nutrition for a growing population. In addition, the identified subjects, by the agrarian science experts, are some of the important aspects to be considered for a sustainable production, which is in agreement with Grimberg et al. (2018). These authors showed the importance of designing sustainable agricultural programmes based on the farmers' socio-

ecological characteristics to reduce barriers for the adoption of climate-resilient agriculture. HEIs are aware of these and in the last years, environmental, economic and social subjects have been incorporating in agricultural courses.

Sustainable agriculture/farming subjects considered as important in a MSc in Sustainable Agriculture (SM2), have been incorporated to undertake better research, improving teaching and support enhanced extension services in order to provide a more effective response to the many environmental and agriculture concerns related to the development of each country. For instance, six of the subjects are included in new specialized curricula and innovative MSc programme and training courses under the frame of two projects, i.e. SFARM - Sustainable Farming (<http://www.sfarm-project.eu/>) and SAGRI - Sustainable Agriculture (<http://www.sagriproject.eu/>). These courses provide knowledge, skills and competencies in the field of agro-environmental technologies for Sustainable Agriculture through a new curricula and teaching programmes that integrate, in a practical way, the latest developments in agricultural applied research (Picuno and Statuto 2018; 2017; Silva, Baptista, and Cruz 2017).

5.2. Important practices

The important practices in Sustainable Agriculture identified as existent in Greece, Italy and Portugal, are mostly related to crop and animal production and management (Table 3), while the future trends in SAP are more focused on the efficient management of waste produced and the efficient resources (e.g. energy, water, etc.) use in crops and animal production (Table 5). The identification of these practices is in accordance with the level of knowledge of farmers, i.e. high knowledge in crop and animal production than in agricultural waste and energy efficiency (Table 4). Thus, skilled agricultural workers are needed to understand how environmental sustainability is applicable to their everyday practice, e.g. managing pesticide and other chemical use, reducing carbon dioxide emissions, using renewable energy, and managing water resources (European Commission 2015). Under this perspective, our results are in accordance with EU (2015) by showing that agricultural practices should change by adopting renewable energy sources and efficient energy use (Table 5).

Furthermore, the agricultural universities and colleges are leaving teaching unsustainable conventional agricultural practices and technologies linked to crop and livestock production, such as

Table 7
Training methods believed to be more efficient for the respondents (1 – not at all efficient; 5 – extremely efficient).

Training methods	Greece						Italy						Portugal					
	1	2	3	4	5	Don't know	1	2	3	4	5	Don't know	1	2	3	4	5	Don't know
Classroom sessions	0	0	36	50	14	0	0	7	17	40	37	0	0	5	35	25	35	0
Educational excursions/visits	0	0	14	36	50	0	0	0	13	30	57	0	0	0	20	45	35	0
Field demonstrations	0	0	0	36	64	0	0	0	3	27	70	0	0	5	10	25	60	0
Short-term seminars	0	0	18	73	9	0	0	3	10	57	30	0	0	0	25	40	35	0
Practical courses/exercises	0	0	5	36	59	0	0	0	7	23	70	0	0	0	10	35	55	0
On-line courses (e-learning)	0	14	50	27	9	0	0	10	57	23	7	3	0	10	45	40	5	0
Education at the individual level/individual contact	0	5	18	50	27	0	3	10	40	30	10	7	0	0	15	50	30	10
Agriculturalist's visit in farms	0	0	0	41	59	0	0	0	20	13	67	0	0	0	15	40	45	0
On-line communication with agriculturalist (real time)	0	9	36	45	9	0	0	17	57	7	13	7	5	0	45	25	20	5
Lectures at physical meetings	0	0	27	64	9	0	0	13	50	20	13	3	0	15	45	30	10	0
Farmers visits to agriculturalist's office	5	5	45	32	9	0	0	0	37	43	20	0	0	20	20	35	15	5
Creating newsgroups	0	27	41	27	5	0	0	17	50	20	7	7	0	15	35	45	0	0
Broadcasts on radio	14	32	45	5	0	5	0	40	40	10	7	3	10	15	60	15	0	0
Information in the form of forms-brochures	5	18	64	9	0	5	0	17	53	20	7	3	10	20	30	30	5	0
Television broadcasts	0	32	41	18	5	5	0	23	43	20	10	3	0	20	35	35	5	5
Articles in newspapers	0	36	36	27	0	0	0	17	57	20	7	0	0	15	50	30	5	0
Agricultural journals	0	9	50	32	5	5	0	13	57	23	7	0	0	10	45	45	5	0
Helpline instructions	9	5	32	32	14	9	0	27	37	23	7	7	0	5	40	15	15	15

crop monoculture and heavy use of chemical inputs. The curricula of HEI include interdisciplinary courses of agricultural practices, technologies and systems linked to climate change adaptation and mitigation. PA is a good example of a course included in the curricula of MSc programmes in the scientific area of Sustainable Agriculture in some European HEIs, such as, in Portugal at the University of Évora in association with New University of Lisbon, and at University of Trás-os-Montes e Alto Douro; in Greece at the University of Thessaly; and in Italy at the University of Padova and University of Perugia. The agrarian sciences experts agree with this assessment by considering PA and technology an important subject and expertise, to be included in the curricula (SM2), being an inter and multidisciplinary course that comprise practical experiences.

Moreover, PA emerges as an important tool which incorporate recent advances in modern agriculture providing evidence for lower production costs, increase farming efficiency and reduce impacts (Koutsos and Menexes 2019; Hassall 2010). In this way, the use of this course in a MSc programme in Sustainable Agriculture will enable to acquire knowledge on new agro-environmental technologies, such as GIS, Remote Sensing, contributing, for example, to improve soil and irrigation management. Also, PA allow farmers to get economic and agronomic favourable results over conventional technologies by increasing yields and/or profitability in a sustainable and environmentally friendly way (Srinivasan 2006; Silva et al., 2007; Takács-György 2008). In this way, academic staff, students and agricultural extension staff will understand and apply new technologies related to primary production for both food and non-food uses, soil science, crop and livestock genetics, agri-chemicals and general purpose technologies such as remote sensors, satellites and robotics.

Circular economy (CE) is another good example of a subject to be taken in consideration for a Sustainable Agriculture MSc. The traditional economy model is based on the intensive extraction of natural resources, which can have negative impacts on the environment. Based on the future SAP, expertise and important subject to be taught in a Master programme (Table 5, Fig. 3 and SM2), this problem may be overcome by applying the CE strategy. CE strategy aims to minimize resources extraction, maximizing reuse, increasing resources use efficiency, recovery and recycling (Stahel 2016) and help to decrease the threats to quality of life, to increase the development of adaptation and mitigation strategies, and hence minimize climate change (Arbuckle et al., 2015). For example, Wijkman and Skånberg (2015) reported that the change of five European countries to the CE has resulted, in some of them, a reduction up to 70% of GHG emissions and an increase of 4% of the workforce. On the other hand, CE, where products are recycled, reused, disassembled and remanufactured, may be one solution for farm waste management, and energy production from biomass and liquid manure (Wijkman and Skånberg 2015). In this way, farmers will know how to handle with the materials and substances resulting from the Sustainable Agriculture activities, which were previously considered to be waste and now become a resource by closing the loop and, consequently, reduce both resource consumption and discharges into the environment (Jurgilevich et al., 2016).

Thus, it becomes clear the need of incorporating adaptive and mitigate practices, as those used in the CE, in the curricula of a MSc programme in Sustainable Agriculture. Since the CE strategy involves different scientific areas, a MSc programme in Sustainable Agriculture should include several courses that focus on mitigation strategies and resource use efficiency, as those identified as the important subjects in Sustainable Agriculture by the agrarian sciences experts (SM2). In this way, academic staff, students and agricultural extension staff, who attend the MSc programme, will improve their skills and acquire knowledge of the entire value chain, particularly on recycling, reuse, disassembly and

remanufacturing, replacing the traditional linear model that dominated the economy until now.

5.3. Adequate training/learning methodologies

Concerning the training/learning needs, traditional face-to-face training methods are considered more important forms of training/learning than online methods (Table 6). This is in accordance with Parr et al. (2007) which showed that students learn better through experiences that link the classroom to field work, engaging a broad range of actors within applied settings. Their study also supports the argument that sustainable agricultural education requires progressive, integrated, experiential, interdisciplinary, systems-based curricula where learning grounds theory to practice in relevant and purposeful social and environmental contexts. On the other hand, Kowalska et al. (2016) showed that students acquire new competences, skills and sensitivity needs to develop actions towards an environmental education when close cooperation between schools and farms exist. This is in line with our results that showed practical classes, such as field excursions, visits and demonstrations in farms, as the most adequate training methods (Table 7).

The importance of face-to-face education is clear in our results which are in disagreement with the new approaches and teaching methods used to facilitate ESD. However, with recent COVID-19 pandemic, HEIs are facing new teaching and learning challenges and many of them had to cancel all face-to-face classes and move to online courses. Although online training methods traditionally considered not suitable for a MSc programme in Sustainable Agriculture, the COVID-19 pandemic highlighted the importance provided by online education as an educational alternative to the traditional face-to-face learning. Therefore, academic staff, students and agricultural extension staff can proceed at home with their studies and teaching. Internet-based distance education offers more opportunities for international and intercultural learning (Barth and Rieckmann 2008; Cörvers and De Kraker 2009) and modes of experiential and service learning that support stronger links between formal and informal learning settings (Brundiars and Wiek 2011; Sutheimer and Pyles 2011). In spite of this, online training methods in agriculture programmes should be seen as complementary tools and not as the main training methodology.

COVID-19 pandemic also reinforced the usefulness and the quality of the ICT and technological tools as a basic need to effectively roll out online learning (Hodges et al., 2020; Ali 2020). Our results support the work of these authors when Greek and Portuguese academics identify the management and ICT skills as the future training needs (Fig. 4). Communication technology gives to academic staff, students and agricultural extension staff greater control over their access and exposure to information. Furthermore, the most widely used mobile data service worldwide and many services or equipment, such as text messaging, can provide real-time information and be very useful for farm management. For example, software can store digital evidence to be presented to national and EU agricultural regulators on the fulfilment of subsidy conditions, contributing for efficient management (European Commission 2014).

6. Conclusions

The best practices identified for the HEIs curricula of MSc programmes in Sustainable Agriculture are the inclusion of interdisciplinary courses of agricultural practices (e.g. animal husbandry; pest management; soil, water, crop and animal management and conservation), technologies and systems (e.g. Remote Sensing and GIS) linked to climate change adaptation and mitigation. These are

the case of Precision Agriculture and courses focuses on mitigation strategies and resource use efficiency, as those off Circular Economy (i.e. resources use efficiency of water, energy and nutrients, farm waste management and energy production from biomass and liquid manure). In addition, future MSc programmes in Sustainable Agriculture will require high level of skills on new agronomic, environmental, management and ICT issues.

For the training/learning methodologies the identified best practices are the use of traditional face-to-face, field and practical methods (e.g., excursions and visits to farms, seminars). However, the COVID-19 pandemic highlighted the importance provided by online education as a suitable alternative, that should be seen as a complementary tool.

In conclusion, this study highlights the transformation needs in the MSc programme in Sustainable Agriculture in strong connection to the proposed training actions with the Agenda 2030 and the European Green Deal. Also, it shows that the new curricula to be developed should consider more flexible and resilient programs to face unpredictable future events, such as worldwide pandemics.

CRediT authorship contribution statement

Patrícia Lourenço: contributed for the questionnaire elaboration, analysed the data, and wrote the manuscript, contributed for the questionnaire elaboration, analysed the data, and wrote the manuscript. **Vasco Fitas da Cruz:** contributed for the questionnaire development and data. **Luís Leopoldo Silva:** contributed for the questionnaire development and data. **José Rafael Silva:** contributed for the questionnaire development and data. **Manuela Correia:** helped to develop the questionnaire. **Pietro Picuno:** contributed to the questionnaire data. **Evangelos Dimitriou:** contributed to the questionnaire data. **Georgios Papadakis:** contributed to the questionnaire data.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jclepro.2021.126914>.

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