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Guidelines Towards Sustainable Agriculture in Small Mediterranean Islands

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Abstract
The objective of the present paper is to provide guidelines towards sustainable agriculture in small islands, with emphasis on the cultivation of Pistacia vera L. in Aegina island, Greece. The guidelines refer among others to the characteristics of the island, pressures from other sectors such as tourism, current cultivation practices, land uses and take into account the risk for groundwater contamination. Special attention is paid on agricultural waste management at farm scale for the production of compost and biochar and their subsequent application to soils, in order to improve soil quality parameters (e.g soil organic matter, soil aggregate stability, water holding capacity, cation exchange capacity), increase soil carbon sequestration and reduce the risk of groundwater contamination. Also, the role of the most important stakeholders towards sustainable agriculture is emphasized and discussed. The proposed approach will assist towards identification of pressures, environmental hotspots, potential lack of synergy between stakeholders and thus indicate mid- and long-term measures to mitigate impacts and contribute to sustainable agriculture.

Keywords: sustainability, agriculture, Pistacia vera L., compost, biochar

1. Introduction

High application rates of chemical fertilizers and water are used today in agriculture to meet the increasing demand for products and thus its environmental footprint is rated as high. It should be also emphasized that the increased application rates of fertilizers do not necessarily result in proportional increase of crop production and for many crops decreased yields are often observed. It is known that the key pillars of sustainable agriculture, as defined in the European Union's (EU) Common Agricultural Policy (CAP), include the sustainable use of natural resources, the protection of soils against erosion and the maintenance of soil organic matter and soil structure in order to protect and enhance soil quality and its functions. In order to meet these goals actions including (i) recycling of nutrients present in agricultural and urban organic waste streams, and (ii) adoption of sustainable agricultural practices, modern market strategies and energy minimization concepts, are required (Borrelli et al., 2016).

Agriculture has always been vulnerable and sensitive to climate change, while today it is considered as one of the major contributors of greenhouse gas (GHG) emissions (EAT, 2015). Thus, in order to reverse this situation agriculture should focus on the use of sustainable practices (Cardozo et al., 2015). Among them, the option of using compost or biochar produced from agricultural and/or municipal wastes may be considered and promoted. The use of compost may result in substitution of chemical fertilizers and savings of raw materials, while biochar is recalcitrant against decomposition and remains in soil for centuries, since around half of its dry biomass weight is pure carbon. Biochar

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is also characterized by chemical and biological stability and when applied to agricultural soils improves their fertility and water holding capacity while it reduces washout of contaminants to water reservoirs (Komnitsas et al., 2015 and 2016). Furthermore, in several Mediterranean countries water is becoming scarce and thus the demand for its sustainable management is very urgent (Alcon et al., 2013).

The pistachio industry is rapidly growing worldwide. The annual production of pistachios in Greece is around 10,000 tonnes, while the annual world production reaches 1,000,000 tonnes. During the period 2003-2013, 77% of the total world pistachio production was recorded in Asia, 20% in the U.S.A and only 2% in Europe (FAOSTAT, 2016). Pistachios contain bioactive compounds and are rich in fat, proteins, dietary fibers, trace elements and nutrients (Fe, Zn, Cu, Mn, Ca, P, K, Mg and Na). Their antioxidant activity is mainly related to the presence of phenolic compounds (Zarei et al., 2014).

The present study aims to provide guidelines towards sustainable agriculture in the small island of Aegina, Greece, where *Pistacia* vera *L.* is cultivated, by taking into account site specific factors and waste management options that can be implemented at farm level. These guidelines may be also considered for other areas with similar characteristics.

2. Area Under Study

Aegina is a Saronic Gulf island of Greece, is situated 15 nautical miles south of the port of Pireaus (Figure 1), has a population of 14,000 people and occupies an area of 87.4 km². The soil layer is shallow in most parts of the island, while its quality is under pressure from other activities including tourism and urbanization.

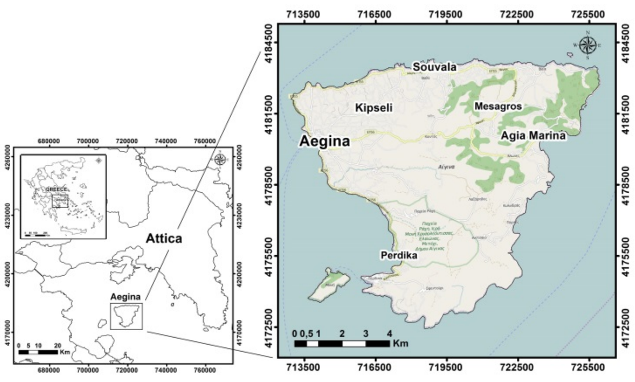

Figure 1. Map of Aegina island

The island is characterized by semi-arid Mediterranean climate, with annual temperature of 19 °C and annual rainfall of about 400 mm. Water shortage is the most important environmental issue in the island. The underground aquifers gradually deteriorate due to over-pumping, whereas the capacity of other surface water reservoirs is limited. With respect to land uses, 32% of the total cultivated area is irrigated and involves the cultivation of pistachios (63%), olive trees (20%), lemon trees (4%), vineyards (2%) and others 11% (Agrostrat project, 2017). Pistachios produced in Aegina are of high quality, have particular organoleptic characteristics, excellent flavor and are designated as Protected Designation of Origin (PDO) products.

As a result of intense agricultural activities, pressures from tourism, increased water demand during the long summer period, limited groundwater availability and salinity problems the risk for groundwater contamination is in some parts noticeable (Agrostrat project, 2017). This risk is particularly high in the NW part of the island where most pistachio orchards are present (Figure 2). Thus, immediate action needs to be taken in order to improve soil and water quality and enable a good balance between agriculture and tourism.

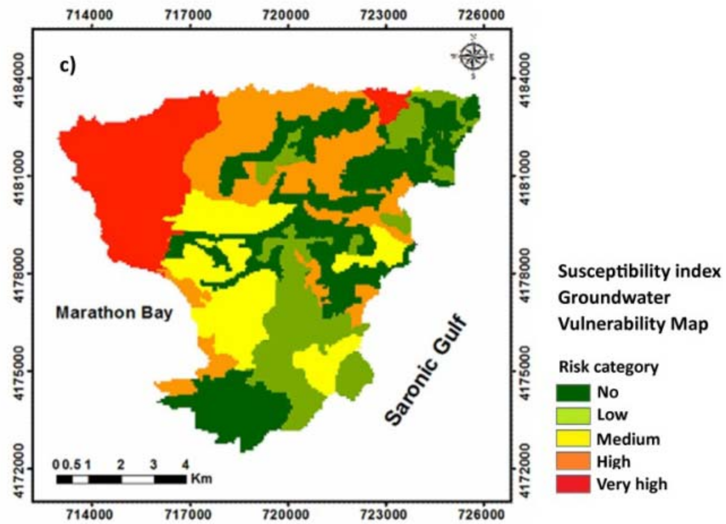

Figure 2. Groundwater vulnerability map

3. Guidelines for sustainable agriculture

The proposed guidelines towards sustainable agriculture in Aegina take into account the potential of using agricultural wastes for the production of compost and biochar, while they also consider the involvement and contribution of the most interested stakeholders.

3.1 Composting of agricultural wastes

Agricultural wastes (AW) are usually characterized by large volumes, varying pH and often substantial contamination potential. Thus, their management should focus on valorization, elimination of their disposal in landfills or other uncontrolled areas and reduction of GHGs emission (Council Directive 1999/31/EC).

Composting of biodegradable agricultural wastes is the main management option and results in the production of a soil amendment which, when carefully applied, may improve soil properties (e.g soil organic matter, aggregate stability, water holding and

cation exchange capacity). Compost also provides useful crop nutrients, increases microbial activity, enhances the degradation of pesticides and immobilizes organic and inorganic contaminants present in soils (Aquilanti et al., 2014).
An issue that requires particular attention is the formulation of a framework for assessing human and ecosystem risk when compost produced from AW is applied on soil (Jorge-Mardomingo et al., 2015; Komnitsas and Zaharaki, 2014). The assessment of the long term benefits and impacts of compost application on soil requires the anlaysis of reliable soil quality data that can only be obtained after well designed monitoring surveys (Doula et al., 2016; Komnitsas and Zaharaki, 2012).
For the assessment of the benefits of AWs utilization in Aegina at farm scale, pistachio wastes (57% w/w), manure (29%), straw (9%) and natural zeolite (clinoptilolite) (5%) were composted in two pilot farms. These percentages were selected based on the outcomes of previous tests carried out in the frame of other projects. Clinoptilolite was used to adsorb the excess salts and act as "slow-release" fertilizer after compost application to soils. Composting took place in windrows of 1.5 m height and 4 m long, while temperature was maintained between the optimum range, i.e 55 - 70^o C. In each farm 4m^3 of compost were produced after 3 months with the following average characteristics (Table 1).

Table 1. Compost characteristics

Parameter, unit	Value	Parameter, unit	Value
Moisture, %	58	Na, g/kg	3.5
pH	7.90	K, %	1.3
EC, mS/cm	2.6	B, mg/g	0.39
Organic matter, %	50	Ca, %	8.4
Organic carbon, %	28	Mg, %	0.72
Polyphenols, mg/kg	340	Fe, mg/kg	3500
Cl^-, mg/kg	2350	Zn, mg/kg	139
P (as P_2O_5), %	0.81	Mn, mg/kg	199
N, %	4.3	Cu, mg/kg	20
C:N	6.5	As, mg/kg	2.7
NO_3, mg/kg	5800	Cd, mg/kg	0.25
PO_4, mg/kg	795	Pb, mg/kg	18
SO_4, mg/kg	245	Ni, mg/kg	1.7
NH_4, mg/kg	60	Cr_t, mg/kg	9.5

Table 1 indicates that the quality of compost is quite good, since it is characterized by high content of nutrients and organic matter, while its electrical conductivity is well below the limit of 4 mS/cm (USCC, 2002) and its pH is within the proposed range (7.2-8.5) (Watson, 2003). This indicates that compost can also be applied to improve the properties of saline soils which exist in several parts of the island. The total nitrogen content exceeds the reference value of 2%, while its phosphorus content is low but within the suggested range (0.5 and 2.8% as P_2O_5) (Faithfull, 2002). The content of polyphenols and salts is acceptable; it has to be noted that the initial polyphenols content in the raw material was 2.2 g/kg. It is mentioned that in case where the content of polyphenols and salts in compost is high, soil degradation may take place if uncontrolled disposal takes place. The compost is also rich in Ca and Mg and has very low content of heavy metals and metalloids such Zn, Mn, Cu Cr_t, Cd, Pb, Ni, and As. Finally, the produced compost has no phytotoxicity, as resulted from the application of standard tests (Doula et al., 2014). Thus, the compost produced at farm level in Aegina meets not only the criteria of the three main EU pistachio producing countries (i.e. Greece, Italy and Spain), but also the EU Eco Label thresholds (Commission Decisions 3 Nov. and 15 Dec 2006).

3.2 Biochar production at farm scale

Biochar is a carbon-rich, fine-grained, porous material, which is produced through thermal decomposition of biomass at temperature varying between 350 and 700 °C (Komnitsas et al., 2015). The International Biochar Initiative (IBI) defines biochar as a charcoal which when applied to soil offers agricultural and environmental benefits (Luo et al., 2015). Biochar is produced by several thermochemical processes including conventional carbonization or slow pyrolysis, fast pyrolysis, flash carbonization, and gasification (Manya et al., 2012).

The addition of biochar into soil can modify its physical properties including structure, pore size distribution, bulk density, texture and surface area, which in turn affect soil aeration, workability, water holding and nutrient retention capacity. The quality of soil aggregates can be also improved, as a result of the related interactions between Soil Organic Matter (SOM), minerals, clay, and microbiological activity (Fabbri et al., 2012). The cation exchange capacity (CEC) of a given soil indicates how well nutrients can be bound to it and, therefore, become available for plant uptake (Doan et al., 2015). The stability of biochar in soil may reach hundreds of years as indicated in recent studies, and is considered as a key parameter to evaluate its potential for CO_2 sequestration (Nguyen et al., 2010; Sarkhot et al., 2014). On the other hand, the potential of biochar for soil contamination has been only briefly considered. Recent studies indicate that the risk for soils, surface water and crops may exist only if high rates of biochar (>250 t ha^{-1}) produced at high pyrolysis temperature (>700 ^oC) are used (Komnitsas et al., 2015; Komnitsas et al., 2016, Komnitsas and Zaharaki, 2016).

In order to investigate biochar production in Aegina at farm scale, pistachio shells (PI) were collected, crushed to -1cm, soaked for 6 hours in warm water (60 ^oC) to remove any dirt and then oven-dried at 80 ^oC for 24 hours to remove moisture. Afterwards, pyrolysis was carried out in a furnace for 60 min under inert atmosphere at two temperatures, namely 350 ^oC (low temperature) and 650 ^oC (which is a high temperature). Table 2 shows the characteristics of raw pistachio shells as well as biochars produced at 350 and 650^oC (PI350 and PI650 respectively).

It is seen from this data that high pyrolysis temperature decreases yield (26% at 650^oC) and results in a product with increased (alkaline) pH and EC. The decreased yield indicates that bigger quantities of AW need to be collected in order to obtain the required quantity of biochar. The pH values indicate that biochars produced at lower pyrolysis temperature may be used as soil amendments in alkaline soils, while biochars produced at higher temperatures are beneficial for acidic soils.

The volatile matter (VM) content drops substantially (13.9% at 650 ^oC) with the increase of pyrolysis temperature due to decomposition of aliphatic-C structures, thus biochar is considered as a suitable organic amendment. Increase of pyrolysis temperature results also in increased char and fixed carbon (FC) content, reaching at 650 ^{o}C 86.1% and 84.4% respectively. The ash content, which is calculated as the difference between char and FC content and indicates the inorganic matter content, practically is not affected by the pyrolysis temperature. Increase of pyrolysis temperature results also in a substantial increase of porosity for the final product, due to the transformation of aliphatic C structures to aromatic C structures. Increased porosity facilitates the use of biochar as slow release fertilizer and as medium for maintaining soil moisture. Increased pyrolysis temperature also results in decreased hydrogen, nitrogen and oxygen content. The beneficial effects of biochar as soil additive and organic fertilizer indicate that a revision of the Fertiliser Regulation (Reg. EC No. 2003/2003) may be considered. Finally, biochar may be combined with compost and limited amounts of inorganic fertilizers (when required, after careful consideration of the soil quality and the crop in question) in intensively cultivated areas to optimize the management of carbon and nitrogen towards improving sustainability of agriculture.

Table 2. Characteristics of raw pistachio shells (PI) and biochars PI350, and PI650

	PI	PI350	PI650
y_P, %	-	31.6	26.0
pH	4.3	5.1	8.8
EC, mS/cm	7.7	21.5	33.9
VM, %	86.0	48.1	13.9
Char, %	14.0	51.9	86.1
FC, %	12.4	50.2	84.4
Ash, %	1.6	1.7	1.7
Porosity, %	15.2	27.9	34.1
% C	45.9	70.0	79.3
% H	6.0	3.3	1.3
% N	0.4	0.2	0.05
% O	48	26	19

Preliminary investigations at Technical University Crete (TUC), indicate that the addition of biochar to compost (biochar to compost ratio 0.05 and 0.1 v/v) improves seed growth potential and reduces further the low toxicity of the compost and compost leachates. Furthermore, the addition of biochar to compost becomes more beneficial if the mixture is matured for a period of 1-3 months (unpublished data).

3.3 The role of stakeholders

The need for resource conservation, eco-efficiency and increased sustainability in agriculture, highlights the importance of quantifying the environmental and social impacts of the entire agricultural sector (Bartzas et al., 2015). Emphasis should be given on Priority 5 of the Rural Development Policy, namely "Resource efficiency and the shift towards a low carbon and climate resilient economy". This priority concerns the supply and use of renewable sources of energy, by-products, wastes and residues and other non-food raw materials in the frame of bio-economy, as well as the increased efficiency in water use, the reduced GHGs and ammonia emissions and issues pertinent to carbon conservation and sequestration in agriculture and forestry.

Furthermore, in islands such as Aegina where diverse activities, such as agriculture and tourism are carried out, sustainability can be only guaranteed in the long term only if all interested stakeholders are actively involved. An important aspect in the process of stakeholder identification is the accurate identification of all stakeholder group representatives. Representatives from these groups include local and regional politicians and officials, elected in local or regional councils, local organizations, NGOs, cooperatives, social groups as well as secondary or higher education institutions.

The authors of this paper consider important the establishment of an initiative entitled "Towards Sustainable Agriculture (TSA)" which may include sustainability principles, sets of commitments that address all important issues of agriculture as well as the importance of the sector to the regional and national economy. This initiative will enable farmers, in islands such as Aegina, to gain and maintain the "social license".

Involvement of all interested stakeholders is an integral part of the "social license" required for sustainable development, which is difficult to be earned, but when earned allows the society to monitor and measure the performance of the sector throughout its entire life cycle and more easily manage social risk. The "social license" is not a legal document issued by the government, but is granted by the public. It is a statement that the community accepts the presence of diverse activities in a proper balance. The primary objective of gaining a social license is to minimize all kinds of risk associated with agricultural activities. It is believed that people will understand that activities will promote economic and social development and this can only be achieved through an effective consultation and participation process. Two of the most important aspects to gain a "social license" are education of local stakeholders about the process and ensuring open communication amongst all stakeholders.

In Aegina, in the frame of the ongoing LIFE Agrostrat project, structured questionnaires were produced and distributed to farmers. The data were collected and analyzed in order to assess among others the main cultivation practices, the quantities of agrochemical used, the needs for irrigation water, the perspective of the farmers in terms of management of solid wastes and wastewaters as well as their will to adopt more sustainable practices for the production of pistachios. Newsletters and media communications were also considered to inform and persuade all involved stakeholders about the benefits of sustainable agriculture and develop trust among different stakeholder groups. Furthermore, a number of workshops were organized in which the main stakeholders, namely farmers, agricultural associations, touristic associations, people involved in tourism, local, regional and national authorities as well as policy makers, were invited and exchanged views. In these workshops risk maps for soils and waters, land use maps, options to compost agricultural wastes as well as land suitability maps regarding the application of compost to farms were presented and all implications were discussed. Also, the results of an initial Life Cycle Analysis (LCA) study were presented and analyzed. Finally, impacts on soil, surface- and groundwater were discussed and the anticipated mitigation of GHG emissions was predicted when good agricultural practices and different waste management scenarios are considered.

Special emphasis was given to sustainability issues related with agricultural waste management, mainly including the production and use of compost and biochar at farm

scale. Farmers need to be persuaded that these activities will have a noticeable effect on their income through reduction of production cost, but most importantly on the long term benefits, including maintenance and improvement of soil quality, minimization of groundwater contamination and water savings. Reduction of GHG emissions and carbon sequestration are definitely no priority issues for the farmers, but their longer term benefits need to be highlighted and justified. A proposal for the production of "Green Pistachio" which will be labelled through a certification system was well accepted, but this requires a number of additional steps as well as education of the farmers and other interested stakeholders and support from regional and national authorities.
Based on all previously analyzed aspects, Figure 3 proposes a framework that will improve sustainability in agriculture especially in small islands, such as Aegina.

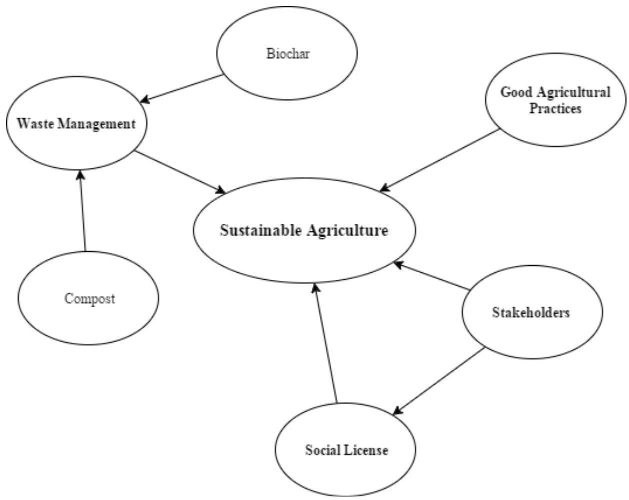

Figure 3. Proposed framework towards sustainable agriculture in small islands

4. Conclusion

The present paper provides specific guidelines that may be followed in agricultural areas and more specifically in small islands, where agriculture faces pressures from other sectors such as tourism. The proposed guidelines include good agricultural practices, waste management options towards zero-waste and recycling of nutrients and highlight the role of stakeholders towards sustainable agriculture.
Special emphasis is given on agricultural waste management practices at farm scale, namely production of compost and biochar from agricultural wastes and their controlled application on soil, as well as risk assessment studies that assess the potential of water contamination especially in areas that are characterized by water shortage and poor water quality.
Finally, the establishment of an initiative entitled "Towards Sustainable Agriculture (TSA)" that will take into account sustainability principles, sets of commitments addressing all major issues of agriculture as well as the importance of the sector to the

regional and national economy will definitely result in environmental and socio-economic benefits and will enable agriculture to gain more easily the required “social license” towards sustainability.

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