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Non-Market Ecosystem Services of Agricultural Land and Priorities Towards a More Sustainable Agriculture in Italy

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Abstract: Ecosystems provide a range of services, commonly called Ecosystem Services (ESs), which are of fundamental importance to human well-being, health, livelihoods, and survival. One of the largest and most productive ecosystems is agricultural land. Agro-Ecosystems provide a range of services directly linked to the market (e.g. food and raw materials production) but also many others of high ecological value, which have an indirect economical contribution in the GDP (non-market ESs). These non-market services are not usually taken into account in the development of agricultural management strategies while their contribution is reduced due to non-sustainable agricultural practices. The aim of the study is to assess the potential economic contribution of the non-market services at national, regional, and provincial level in Italy and to propose a simplified index-based method for setting priorities at different scales of administration units for the implementation of sustainable agricultural practices (SAPs). The results of the study showed that the potential non-market value of agro-ecosystem services (AESs) in Italy can reach ~46.2 billion USD$2007. This estimate shows that non-market AESs can play an important role in the national GDP if SAPs are followed. Finally, a priority ranking scheme for the implementation of SAPs was proposed at regional and provincial level which can be a valuable decision support tool for promoting sustainable agriculture policies.

Keywords: Ecosystem services, Agricultural land, Non-market services, Priority index.

1. INTRODUCTION

Ecosystems provide a range of services, which are of fundamental importance to human well-being, health, livelihoods, and survival. The economical contribution of such services can be evaluated using valuation methods such as those provided by Costanza *et al*. [1,2] and de Groot *et al*. [3] etc., which are extremely useful tools in the development of landscape management plans [4]. These methods consider fourteen main types of ecosystems/biomes (such as marine, coral reefs, coastal systems, coastal wetlands, inland wetlands, freshwater river/lakes, tropical forests, temperate forests, woodlands, grasslands, deserts, polar regions, cultivated lands and urban areas) and many other sub-biomes. For each biome, monetary values have been set based on the ecosystem services (ESs) they provide, which are divided in four main categories, such as provisioning, regulation, supporting and cultural services. One of the main problems is that the economical value of many services provided by the ES approach cannot be validated easily because it is not directly linked to the market (non-market services). For example, the effects of forests on erosion control, water supply etc., are representative cases of non-market ecosystem services.

One of the largest and most productive ecosystems are agricultural lands, which are both providers and consumers of ecosystem services [5]. Agro-ecosystem services (AESs) can also provide a wide range of non-market services of high ecological value and indirect profit that are not usually taken into account in the development of agricultural management strategies. In long-term, such strategies lead to environmental quality degradation due to unsustainable agricultural practices that aim to increase the high direct profit [6,7].

The aim of the study is to assess the potential economic contribution of the non-market services at national, regional, and provincial level in Italy and to propose a simplified index-based method for setting priorities at different scales of administration units for the implementation of sustainable agricultural practices. The results of the study can be used as tools for decision making towards a more sustainable agriculture.

2. AGRO-ECOSYSTEM SERVICES (AESs)

2.1. Provisioning Services

The contribution of agricultural ecosystems in the provisioning services is mainly associated to food production, production of raw materials (fiber and biomass for bioenergy), provision of genetic resources, and water supply. Farmers' efforts are focused on provisioning services since they are strongly linked to

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the market that generates income. Especially food and raw materials production are fundamental since they are considered the most important elements of management strategies to support the growth of local economies in developed countries through short production chains [8,9].

The role of agriculture in the production of raw materials dates thousands years back where plant fibers were used for clothing, artifacts manufacturing, building etc. (e.g. papyrus, ropes, baskets, straw bricks etc.). Fibers can be produced from seeds, leaves, bast fibres, barks, fruits and stalks (e.g. cotton, bamboo, jute, coir, bagasse, hemp, flax, kapok, sisal, jute, kenaf) [10,11]. The last decades, the production of raw materials (biomass) has also been used for energy production since biomass can be converted into three main product types of bioenergy: electrical/heat energy, transport fuel and chemical feedstock [12,13].

As concerns the AES from genetic resources, agricultural lands host a vast variety of soil microorganisms/bacteria and invertebrates, plants, animals, insects, fungi, viruses etc., which are sources of unique biological material that can be used in medicine, products for materials science, genes for genetic improvement etc. [14].

The contribution of agricultural land on water supply is mainly associated to the reduction of water losses by runoff and water evaporation from soil that contribute to higher water retention and groundwater recharge. The reduction of runoff is succeeded through typical land leveling, contour barriers and ditches, bench terraces, furrow channels and drainage canals [15.16] while evaporation losses can be reduced by the crop canopy or by synthetic geotextiles and organic mulching materials (e.g. pine bark, vine pruning residues, straw etc.) deposited on the soil surface [17]. The aforementioned interventions in combination with best management tillage practices and cover or winter crops can significantly increase the specific AES [18,19].

2.2. Regulation Services

The most important regulation services provided by agro-ecosystems are climate regulation, erosion control, waste treatment, and biological control. Climate regulation considers the regulation of global temperature, precipitation, and other biologically mediated climatic processes at global or local levels [1]. The contribution of croplands in this AES type is associated to the regulation of green house gasses such as carbon dioxide through carbon sequestration [20,21] and to the absorption of solar radiation for photosynthesis. Erosion control is associated with the same interventions for the AES of water supply (see previous section) that reduce runoff, particularly in steep slopes. In the case of waste treatment, the contribution of agricultural land is mainly associated to the use of wastes as fertilizers (e.g. manures), mineralization of organic matter, and nutrient absorption through microbial and aquatic flora processes in the field (e.g. rice fields) and in the drainage canals [22-25]. The AES of biological control concerns the control of pests and diseases based on natural enemies' interactions [26,27].

2.3. Supporting Services

The supporting AESs include pollination and soil formation. Pollination provided by animals (mainly insects) significantly contributes in sustaining the thirty-five percent of global production from crops including at least 800 cultivated plants [28]. Pollination also depends on the presence of natural habitats surrounding the farm. Within the crop field, the conservation of crop genetic diversity by promoting differentiated cultural patterns has shown to be useful not only for pollination but also for pest and disease management [29]. The contribution of agricultural land to the AES of soil formation can be performed through the following processes: a) soil weathering by crops' rooting systems and rhizosphere microflora [30-32], b) soil fragmentation/aggregation by the combined effects of tillage, incorporation of residues and intense wetting-drying cycles due to irrigation especially during summer [33-35].

2.4. Cultural Services

Additional services provided by agricultural landscapes include cultural benefits whose valuation can be especially difficult [36]. Cultural services are of significant importance for the role they can play in regional economies of local communities [37,38]. This AES is associated to tourism activities (e.g. agricultural museums and exhibition parks, traditional localities, agro-tourism etc.) related to cultural heritage, new technologies, recreation activities such as hunting, or other artistic activities related to agricultural landscape (e.g. professional photography, painting etc.).

2.5. Degradation of AESs

The aforementioned AESs are of significant ecological and economical value when agronomic practices are performed with respect to environmental quality.

Unfortunately, the intensification of agriculture during the last decades through monoculture systems, extensive use of agrochemicals and intensive tillage has led to extensive deterioration of environmental quality. These activities can succeed high direct economic profit through specific provisioning services (e.g. food production and raw materials) but at the same time are responsible for a) the loss of biodiversity that supports genetic resources and pollination services [28,39], b) extremely high water consumption with a negative impact on water supply (e.g. reduction of ground and surface water reserves, saltwater intrusion in lowlands etc.) [40,41], c) water pollution and eutrophication by nutrients and agrochemicals losses with severe impact on water supply and waste treatment services [42], d) nitrous oxides emissions (green house gas) which negatively affect climate regulation services [43] and e) exhaustive absorption of soil macro and micro nutrients and degradation of soil physico-chemical properties that may lead to gradual decline of soil quality through salinization, codification or desertification [44,45]. The aforementioned environmental problems suggest an extensive negative impact especially on non-market AESs. Thus, integrated management strategies towards a more sustainable agriculture are required in order to preserve and increase the potential value of non-market AESs.

3. DATA AND METHODS

3.1. Data

The analysis was performed for the Italian territory, which is divided in 20 administrative regions and 110 provinces, using the most recent Corine Land Cover raster map of 2012 (CLC2012) developed by the European Environment Agency (EEA). The CLC2012 is provided with a geometric accuracy better than 100m and a thematic accuracy of at least 85% (http://land.copernicus.eu/pan-european/corine-land-cover). Agricultural land was extracted by the level 3 classification of CLC2012 at national, regional, and provincial level. The administrative boundaries of the Italian country, regions and provinces were obtained by the GADM database (http://www.gadm.org).

Additional data of the period 2010-2012 about the economical contribution of agriculture in the national GDP of Italy were also used. The data were obtained from FAO database (http://faostat.fao.org/site/613/DesktopDefault.aspx?PageID=613#ancor). The economic data were converted to USD$2007 values using the online monetary inflation calculator (http://www.usinflationcalculator.com/) in order to be comparable with the monetary units used in ESs approach of Costanza *et al*. [2].

3.2. AESs Assessment and Priority of Sustainable Agriculture Index

For AESs assessment, the agricultural land coverage was multiplied by the monetary values of each AES in USD$2007 proposed by Costanza *et al*. [2] for croplands (Table **1**). The total value of the agricultural GDP provided by FAO at national level was compared with the total value of AESs in order to assess the potential non-market value of AESs, which can be succeeded in the Italian territory. At regional and provincial level, the non-market value of AESs was assumed proportional due to lack of data of agricultural GDP at administrative unit level.

The target to achieve the potential value of non-market AESs requires the development of integrated management strategies towards a more sustainable agriculture. One of the first things needed in order to develop such strategies is to set priorities for the implementation of management schemes. The most typical approach used for this purpose is based on the degree of agricultural pollution based on environmental standards such as those provided by EU Member States (e.g. Nitrates Directive - 91/676/EC, Water Framework Directive - 2000/60/EC etc.). This approach requires continuous and extensive monitoring of environmental parameters of high cost and labor.

On the other hand a more simplified approach is proposed in this study, which is based on the extent of agricultural land within an administrative unit in respect to other administrative ones. The approach is based on a simplified priority index, which uses the % coverage of agricultural land and the total coverage in area units of a number of administrative units as follows:

$$P_i = f_{1,i} \times f_{2,i} \quad (1)$$

$$f_{1,i} = \frac{x_i - x_{\min}}{x_{\max} - x_{\min}} + 1 \quad \text{for } x_{\min} \le x_i \le x_{\max} \quad \text{and}$$

$$f_{2,i} = \frac{y_i - y_{\min}}{y_{\max} - y_{\min}} + 1 \quad \text{for } y_{\min} \le y_i \le y_{\max} \quad (2a,b)$$

where x_i: is the % coverage of agricultural land in a province or a region i, and y_i: is the coverage in area units of agricultural land in a province or a region i. The

minimum and the maximum value of x and y parameters correspond to the respective minimum and maximum values observed in the set of administrative units. f_1 and f_2 take always values between 1-2 and thus also P_i is restricted between 1-4. The +1 inside the f_1 and f_2 functions is used to avoid having 0 values in the multiplication.

The concept of using the % coverage x and the total coverage y in area units as two independent parameters is based on the fact that when a region has lower % of agricultural land then it also has greater % of natural land. Natural lands provide a high degree of ESs by themselves but also interact with agro-ecosystems mitigating the impact of agricultural activities. The parameter y of agricultural land coverage in area units is used as a substitute of the non-market AESs because in this study they are considered proportional to agricultural land coverage in both regional and provisional scale. The higher the value of P_i of a region in respect to others, the higher is the priority to implement sustainable agronomic practices in this region.

4. RESULTS

According to CLC2012, the total coverage of agricultural land per province and region is given in Figure **1a,b** while the respective percentage % of agricultural land for the respective administrative units is given in Figure **2a,b**. The mean total economic contribution of agricultural products of the period 2010-2012 in Italian economy at national level was estimated at 38.383 billion USD$2007 according to FAO data.

Table 1: Economic Evaluation of ESs for Agricultural Land According to the Benefit-Transfer Approach of Costanza *et al*. [2]

Agro-Ecosystem Services (AESs)	USD$2007/ ha/Year	%
Food production[1]	2323	41.72%
Raw materials[1]	219	3.93%
Genetic resources[1]	1042	18.71%
Water supply[1]	400	7.18%
Climate regulation[2]	411	7.38%
Erosion control[2]	107	1.92%
Waste treatment[2]	397	7.13%
Biological control[2]	33	0.59%
Soil formation[3]	532	9.55%
Pollination[3]	22	0.40%
Cultural services[4]	82	1.47%
Total sum	5568	100%

[1]Provisioning Services, [2]Regulation services, [3]Supporting services, [4]Cultural services.

The total potential contribution of AESs at national level was estimated at 85.111 billion USD$2007 taking into account the total value of AESs per unit area provided in Table **1** (5568 USD$2007/ha/year) while the respective proportions at regional and provincial level are given in Figure **3a,b**. If we consider that the AESs of food and raw materials production which are directly linked with the market are together the 45.65% of the total AESs (Table **1**), then according to Costanza *et al*. [2] the expected value of these AESs provided by

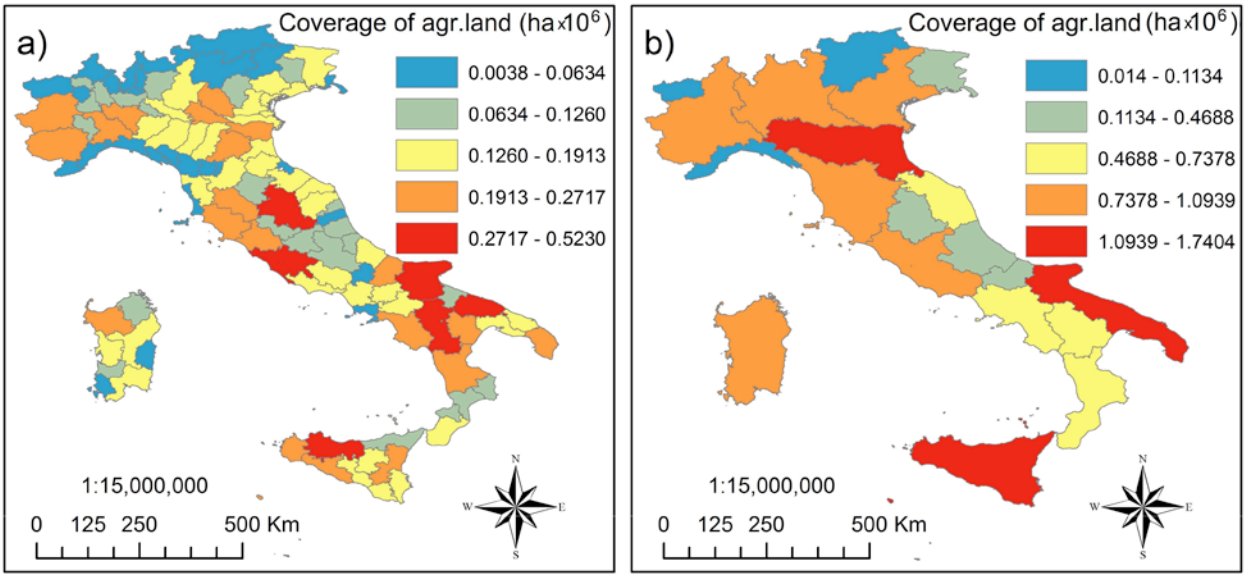

Figure 1: Total coverage of agricultural land **a**) per province and **b**) per region in Italy according to CLC2012.

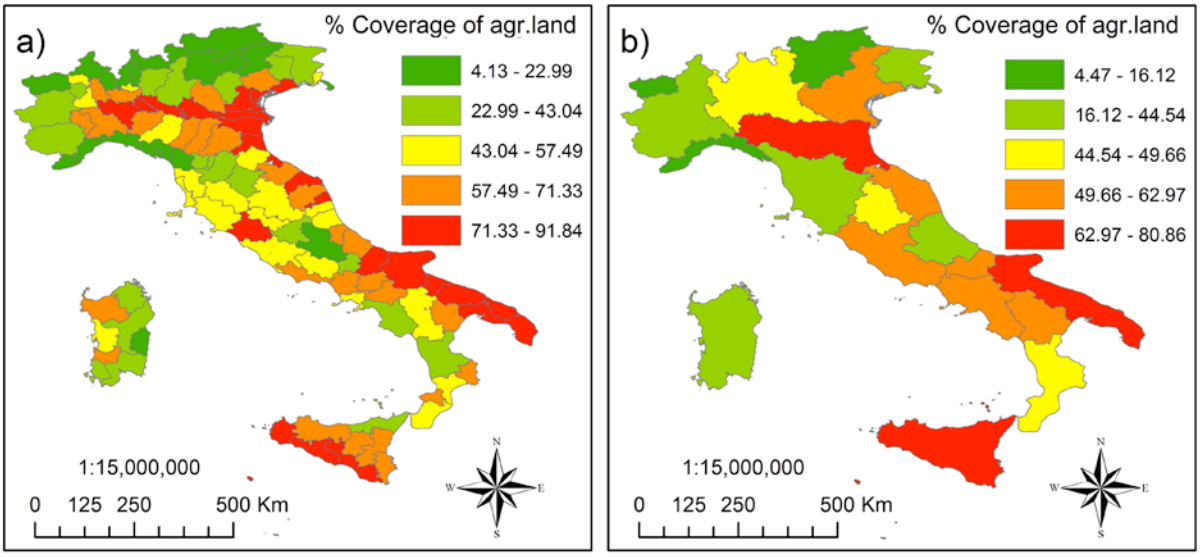

Figure 2: % coverage of agricultural land **a**) per province and **b**) per region in Italy according to CLC2012.

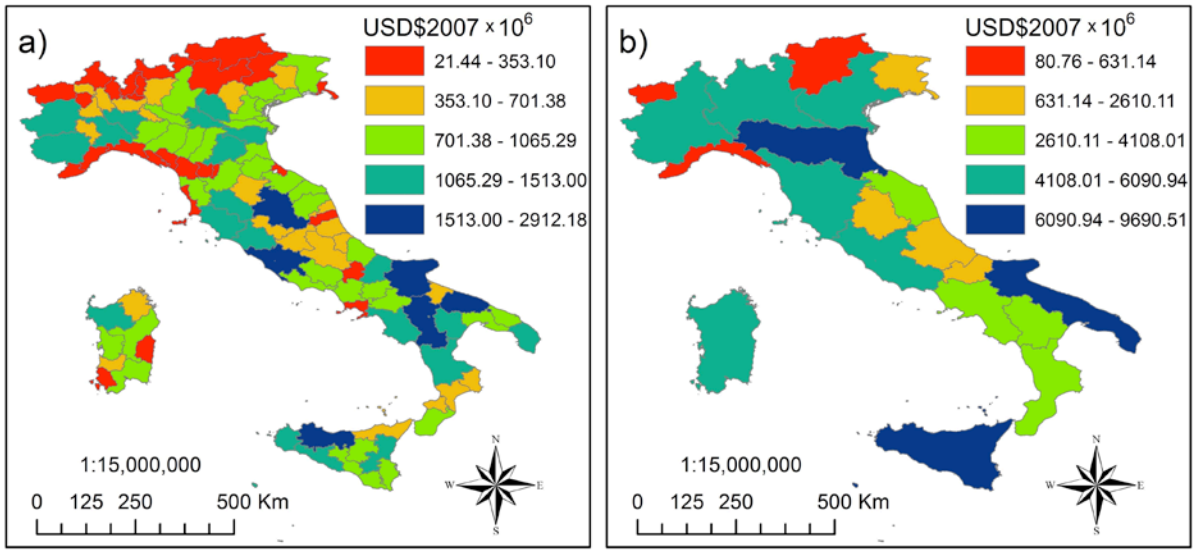

Figure 3: Total contribution of AESs in USD$2007 **a**) at provincial level and **b**) regional level according to Costanza *et al*. [2] (Table **1**).

the Italian agricultural land is estimated at 38.853 billion USD$2007. This value is extremely close to the value provided by FAO verifying the values in Table **1** for AESs linked to the market. If we also assume that the rest values of Table **1** for the non-market AESs are realistic, then a respective 54.35% of the total estimated AESs can provide an estimation of the potential non-market contribution of Italian agricultural land in the national, regional and provincial economy. According to the above, the non-market value of AESs at national scale was estimated at ~46.2 billion USD$2007, while estimations of the total non-market AESs at regional and provincial level are given in Tables **2** and **3**. The multiplication of the total non-market AESs values of each region (Table **2**) or province (Table **3**) with the respective percentages given in Table **1** can provide estimations for each specific non-market AES.

The estimated potential value of non-market AESs at national level is extremely large. It is indicative that for the 15 out of 20 regions the non-market AESs value exceeds the 1 billion USD$2007 while for the 39 out 110 provinces exceeds the 0.5 billion USD$2007. Table **2** and **3** also provides the ranking of regions and provinces based on P_i index. This ranking scheme can be used as tool to set priorities for the implementation of sustainable agronomic practices based on their contribution to non-market AESs.

Table 2: Potential Contribution of Non-Market AESs in USD$2007 in Italy at Regional Level and Priority Ranking for Implementing Sustainable Agricultural Practices at Regional Level Based on the P_i Index

Rank	Region	Non-Market AESs (Million USD$2007)	*Pi*		Rank	Region	Non-Market AESs (Million USD$2007)	*Pi*
1	Apulia	4728.3	3.794		11	Toscana	2964.4	2.337
2	Sicily	5266.8	3.653		12	Basilicata	1699.0	2.209
3	Emilia-Romagna	4507.7	3.383		13	Calabria	2168.7	2.200
4	Veneto	3063.1	2.654		14	Molise	818.1	1.998
5	Lazio	2911.6	2.591		15	Umbria	1270.2	1.965
6	Lombardia	3310.4	2.504		16	Abruzzo	1418.6	1.908
7	Sardegna	3245.8	2.459		17	Friuli Venezia Giulia	907.8	1.684
8	Piemonte	3246.4	2.415		18	Liguria	266.1	1.202
9	Marche	1845.3	2.374		19	Trentino-Alto Adige	343.0	1.111
10	Campania	2232.7	2.341		20	Valle d'Aosta	43.9	~1.000

5. DISCUSSION

The estimated non-market AESs highlight the important economic contribution of agro-ecosystems that can be succeeded beyond food and raw materials production in the Italian agricultural land. Of course, for succeeding these values it is prerequisite to a) move towards more sustainable agricultural practices and b) to increase the awareness and willingness of politics, farmers, scientists, stakeholders and citizens non-related to agriculture to assess and exploit the economic benefits, which can be derived from non-market AESs. Such actions require high-level political interventions in local economies aiming to create a profitable interaction between the farmers and the rest society. The rest society should understand the economic benefits of such interactions and should support economically the farmers to move towards more sustainable practices that usually reduce their net agricultural income.

The last 25 years, the European countries have made a serious effort towards organic agriculture. Italy is one of the leading countries with the largest coverage of organic and in-conversion farming in Europe (http://faostat.fao.org) [46]. Apart from waste treatment, other benefits of this effort have already been identified in many areas of Italy and they are related to increase of biodiveristy [47], carbon sequestration [48] and recreation-agrotourism activities [49]. At the same time, Italy remains one of the top producers in terms of yields at European scale. This suggests that the total recommended ESs value for agricultural land provided by Constanza *et al.* [2] may underestimate the real capacity of Italian croplands for ESs since non-market regulation, supporting and cultural ESs are expected to be much higher. Future studies in Italian territory are necessary in order to assess the non-market economic effect of increased organic agriculture in the local economies in order to be used as a supporting tool for convincing authorities to promote and apply such activities.

As concern the amount of non-market AESs which can be derived by SEPs, the study provides potential estimations and ranking priorities for the implementation of SEPs for three different administrative scales: national, regional and provincial scale. It has to be noted that the smaller the administrative scale is, the larger are the errors of non-market AESs estimations due to more distinct a) differences in the intrinsic properties of agricultural land (e.g. climate, soil, topography), b) differences in the efficiency of SEPs due to crop type differences (e.g. irrigated or non-irrigated crops) c) differences of natural land types which coexist with agricultural land, d) differences in the available capital derived from other sources at administrative scale which can be used for investments and support of SEPs. All the above should be taken into account in order to build a multi-disciplinary approach for setting priorities for SEPs implementation based on criteria which will fairly disseminate both the profit of non-market AESs and the additional cost of SEPs.

6. CONCLUSIONS

The potential economic contribution of the non-market services at national, regional, and provincial level in Italy was assessed in this study. A simplified index-based method for setting priorities at different scales of administration units for the implementation of SAPs was also proposed. The results showed that the potential non-market value of AESs in Italy can reach

Table 3: Potential Contribution of Non-Market AESs in USD$2007 in Italy at Provincial Level and Priority Ranking for Implementing Sustainable Agricultural Practices at Provincial Level Based on the P_i Index

Rank	Province	Non-Market AESs (Million USD$2007)	*Pi*		Rank	Province	Non-Market AESs (Million USD$2007)	*Pi*
1	Foggia	1582.8	3.621		56	Rimini	129.2	2.008
2	Bari	964.5	3.060		57	Pisa	407.3	1.978
3	Lecce	728.3	2.832		58	Salerno	615.8	1.969
4	Ferrara	694.0	2.796		59	Medio Campidano	289.6	1.966
5	Palermo	988.5	2.758		60	Frosinone	478.7	1.958
6	Viterbo	810.8	2.712		61	Novara	257.8	1.940
7	Agrigento	734.3	2.707		62	Reggio Di Calabria	459.1	1.922
8	Pavia	698.9	2.644		63	Teramo	330.3	1.917
9	Mantua	600.3	2.637		64	Milano	281.9	1.914
10	Brindisi	508.5	2.632		65	Nuoro	579.0	1.910
11	Trapani	607.2	2.593		66	Torino	680.2	1.896
12	Campobasso	668.4	2.580		67	Vercelli	337.0	1.886
13	Padua	539.0	2.549		68	Pescara	227.3	1.880
14	Matera	726.2	2.542		69	Brescia	536.8	1.835
15	Sassari	822.3	2.539		70	Catanzaro	350.7	1.831
16	Bologna	756.6	2.539		71	Florence	446.8	1.829
17	Roma	918.4	2.519		72	Vibo Valentia	203.7	1.827
18	Cremona	462.6	2.494		73	Udine	533.4	1.825
19	Caltanissetta	518.7	2.474		74	Terni	313.3	1.797
20	Alessandria	712.8	2.469		75	Cagliari	451.6	1.781
21	Taranto	562.9	2.466		76	Vicenza	357.3	1.766
22	Perugia	956.9	2.439		77	Arezzo	373.8	1.709
23	Potenza	972.8	2.439		78	Ascoli Piceno	188.4	1.706
24	Rovigo	438.9	2.436		79	Pordenone	289.5	1.686
25	Ravenna	459.0	2.424		80	Napoli	179.6	1.685
26	Venezia	497.6	2.422		81	Olbia-Tempio	347.8	1.647
27	Catania	683.0	2.394		82	Gorizia	73.2	1.619
28	Ragusa	409.9	2.385		83	Messina	331.0	1.609
29	Enna	552.8	2.375		84	Livorno	164.6	1.605
30	Treviso	534.8	2.354		85	Rieti	275.1	1.554
31	Barletta-Andria-Trani	381.2	2.341		86	Monza and Brianza	54.9	1.507
32	Modena	553.1	2.324		87	Carbonia-Iglesias	161.6	1.486
33	Verona	597.8	2.307		88	L'Aquila	350.2	1.477
34	Ancona	441.1	2.297		89	Bergamo	241.0	1.471
35	Chieti	510.7	2.237		90	Isernia	149.6	1.438
36	Benevento	435.8	2.217		91	Biella	88.7	1.384
37	Syracuse	441.5	2.217		92	Pistoia	89.8	1.369
38	Avellino	521.4	2.195		93	Lucca	120.4	1.292
39	Piacenza	493.9	2.186		94	Prato	28.7	1.262
40	Lodi	205.6	2.159		95	Imperia	75.9	1.247
41	Grosseto	676.4	2.157		96	Varese	72.0	1.226
42	Reggio Nell'Emilia	446.8	2.155		97	Ogliastra	100.5	1.212
43	Cosenza	822.2	2.151		98	Trento	191.9	1.192
44	Pesaro E Urbino	513.1	2.141		99	La Spezia	49.4	1.189
45	Macerata	497.9	2.133		100	Savona	76.6	1.186
46	Caserta	480.1	2.125		101	Massa Carrara	56.4	1.169
47	Cuneo	819.5	2.125		102	Lecco	41.3	1.165
48	Siena	600.1	2.124		103	Como	59.9	1.165
49	Parma	562.1	2.116		104	Trieste	11.7	1.127
50	Latina	428.6	2.108		105	Bolzano	151.1	1.121
51	Asti	322.4	2.104		106	Genova	64.2	1.120
52	Oristano	493.4	2.100		107	Belluno	97.6	1.111
53	Fermo	204.7	2.081		108	Sondrio	55.2	1.045
54	Crotone	332.9	2.029		109	Aosta	43.9	1.024
55	Forli' - Cesena	413.0	2.019		110	Verbano-Cusio-Ossola	27.9	1.010

~46.2 billion USD$2007. This estimation shows that non-market AESs can play an important role in the national GDP. Finally, a priority ranking for the implementation of SAPs was proposed at regional and provincial level that can be a valuable decision support tool for promoting SAPs. Future studies are necessary in order to develop tools for assessing the variation of ESs within the agricultural ecosystems due to the high differences in environmental conditions, agronomic practices and crops. This would allow to better estimate the non-market ESs and their contribution in the local economies but also to create a more robust basis for developing and improving SAPs based on economical evidences that are more comprehensive to decision makers.

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