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EVALUATION OF ECOSYSTEM SERVICES ALONG URBAN-RURAL TRANSECTS IN SOUTHERN ITALY

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Abstract

The concept of Ecosystem Services (ES) has gained relevance on the scientific agenda and has found its way into research on urban environments. Cities and towns, like any other ecosystem, provide specific services to their inhabitants and communities and they are benefited by surrounding ecosystems as well. At the same time, processes of urban development threaten contemporary metropolitan contexts and lead to an overall decreasing of environmental quality and general fragmentation of agricultural and (semi) natural landscapes. As a result of these processes the number of Non Urbanized Areas present in urban contexts is dramatically decreasing. These areas include cultivated land, abandoned farmlands, grassland, woods and shrubs that are often located at the peri-urban cities' fringes. Among these areas, farmlands and other forms of urban and peri-urban agriculture provide all three major categories of Ecosystem Services: provisioning, regulating and cultural services.
This paper presents an evaluation of the provision of Ecosystem Services along three urban-rural transects of a high density urban context, namely the metropolitan area of Catania (south Italy). Land-use categories are evaluated with GIS spatial analysis in terms of their potential provision of the Ecosystem Services. Results show that agricultural lands are the most important landscape features in providing ES, both in terms of their spatial extension and numbers of provided services. The study also revealed as cultural services are under-estimated in urban contexts when only land-use/land cover data are used in the evaluation.

Keywords: *Ecosystem Services, Metropolitan Areas, urban-rural, GIS, Land-use;*

INTRODUCTION

Non-Urbanized Areas (NUAs) are part of contemporary urban contexts that produce ecosystem services [1], [2]. They are outdoor places with significant amounts of vegetation, mainly seminatural areas that represent the last remnants of nature in urban areas and that provide important functions such as biodiversity in urban areas, production of O_2, reduction of air pollutants and noise, regulation of microclimates, reduction of heat island effect, supply of recreational value and play a fundamental role in health, well-being, and social safety [2].

NUAs can include different urban ecosystems, including street trees, lawns/parks, urban forests, agricultural land, abandoned farmlands, wetlands, lakes/sea, and streams [3]. NUAs provide different types of ecosystem services (ES). ES contribute to human wellbeing, since they are end products of various ecosystem functions such as climate amelioration and recreation and because they are enjoyed, consumed or used by humans. Ecosystem goods can be defined as tangible products derived by ES, such as wood, fuel, or food as results of ecosystem processes [4].

Within the network of NUAs, agricultural land supplies all three major categories of ecosystem services, provisioning, regulating and cultural services [5]. Even if the most tangible services provided by agriculture are food, fuel and fibre, a number of other services are also provided, such as maintenance of soil fertility, regulation of pollinators, pests, pathogens and wildlife, water quality and supply, greenhouse gas emissions and carbon sequestration [6]. Other cultural services include the benefits coming from open space, rural viewscapes, and cultural heritage related to rural lifestyles.

However, in the contexts of contemporary metropolitan areas NUAs suffer from a wide range of pressures by urbanization process. The process of gradual erosion of peri-urban farmlands by urban development land has been usually accompanied by a low consideration of the importance of these areas, often just considered as simple reservoirs of space for new urban settlements. For example in Italy, this process is not limited to particular geographic areas of the country, but it can be observed in different geographical contexts of different size, from northern more developed regions to southern metropolitan areas [7]. The impact and externalities of these processes encompass physical, environmental, socio-economical, and political issues.

Particularly, in some geographical contexts of Italy—such as the Catania metropolitan area, NUAs have always been targeted by urban plans as generic farmlands or undefined greenspaces without any consideration of natural resources (e.g. soil, water, species, landscape) and related ES. This is one of the reasons why agricultural and greenspaces have been constantly eroded by urban sprawl. Weak environmental policies have been one of the results of the lack of attention to NUAs. Furthermore, urban planning (strongly driven by the real estate market) has not been able to evaluate agricultural areas in a proper way so to recognize roles, functions, and services they provide to humans.

This paper presents an assessment of the Ecosystem Services provision along three urban-rural transects of a high density urban context, namely the metropolitan area of Catania, south Italy (fig. 1). Land-use categories are evaluated with GIS spatial analysis in terms of their potential provision of the Ecosystem Services.

STUDY AREA AND MATERIALS

As anticipated in the previous section, the study area for ES assessment is the Catania Metropolitan area in south Italy. The city is the centre of the largest metropolitan area in Sicily, a settlement system characterised by extensive urban sprawl [1]. Many NUAs are located at the fringe of the city and include farmlands (citrus and olive groves and vegetable groves), abandoned farmlands, woods, shrubs and lava fields.

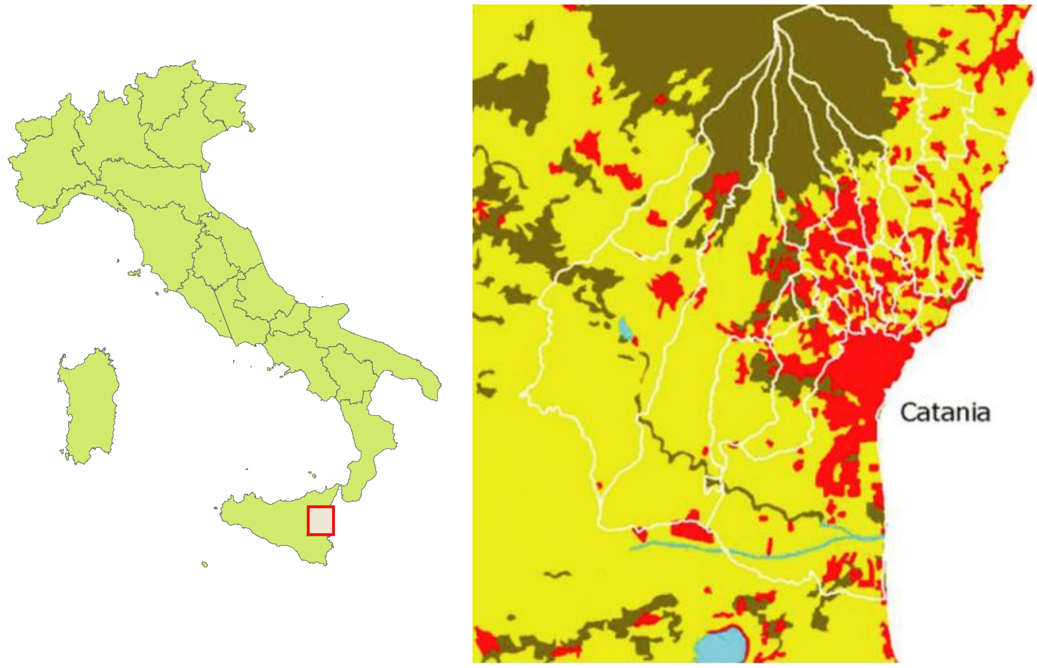

Figure 1. The study area of Catania Metropolitan area (south Italy)

In this paper, all GIS elaborations were based on a layer of NUAs, obtained by Urban Atlas land-use layer [8]. For the metropolitan area of Catania, this layer had an average scale of detail of 1: 12,000. Urban Atlas layers are based on the land-use classification of a high resolution SPOT 5 images (2.5 m). However, to update and check the Urban Atlas land-use layer, a visual inspection of high-resolution (0.25 cm) regional orthophotos and recent Google Maps images was performed. In order to make possible its updating, Urban Atlas land-use layer also required a spatial adjustment to match the Italian national geo-referencing system of the regional orthophotos.

METHODS

Three transects have been chosen as the geographical units where to assess and map the ES. They have been designed according to main criterion of being geographically representative of the entire study area. This required to place three transects of 9 km x 1 km in order to have a balanced geographically sampling of the study area and the different land uses types, from high density urban areas to agricultural contexts (fig. 2).

Within these transects, a set of ES have been quantified and mapped. There are three main approaches for mapping ES [9]: valuations of ES through benefit transfer applies a monetary value to different land cover types; community value methods based on spatial measures of social values preference surveys; social–ecological assessments of the ES supply integrating different types of physical/ecological data (e.g., field samples of services, climate, land-cover, hydrological, remote-sensed data) and social variables (e.g. census data and other ancillary layers).

Figure 2. Urban-rural transects in the Catania metropolitan area

In this paper, the first approach was chosen and the mapping of ES was based on the assessment model by [10], that developed a multicriteria assessment framework for the qualitative estimation of regional landscape to provide ES. These authors used a benefit transfer and an expert driven approach to assess contribution of the land cover classes for the provision of ES. Basically, this assessment applied relative coefficients to different land-use categories of 2006 Corine Land Cover as scores of their potential of ES provision. Coefficients were chosen according a literature review or previous studies and an expert-based assessment. The categories of assessed ES included Provisioning, Regulating, Supporting and Cultural services [5]. Furthermore, the category of Regional Economy was added to account for the potential economy outputs that the different land-use categories can generate. Categories and relative services are reported in table 1.

ES Category	**Service**
Provisioning services	S1: Provision of fresh water and air S2: Timber S3: Food and fibers
Regulating services	S4: Local Climate regulation S5: Global Climate regulation S6: Water (balance) regulation S7: Clean water provision S8: Soil erosion protection
Cultural services	S9: Recreation and tourism S10: Aesthetics
Supporting services (Ecological integrity)	S11: Biodiversity
Regional economy	S12: Income/returns from land-based production S13: Contribution to overall value added

Table 1 – ES Categories considered

However, since we used the Urban Atlas land-use dataset instead of Corine Land Cover, we had to slightly modify the categories of land cover used in the assessment and the relative ES coefficients. Table 2 reports the modified land-use categories and the standardized coefficients that have been used. This coefficients must be read as relative values for the potential provision of ES, scoring from 0 (no contribution to ES) to 100 (maximum contribution). From an operational side, they have been linked to attributes of the polygons of the Urban Atlas layer and thus summarized within each of the rural-urban transect to get a single overall value of ES. The following formula was used to derive a single value of ES within each of the 3 transects:

$$\sum_{LUi}^{n} A_i \, ES_{ij}$$ (formula 1),

where Ai is the Area of the single patch of land-use; ESij is the coefficient according to table 2, LUi is the patch with land-use category i and n are the number of patches within each transect.

Each transect was further divided into 5 sub-transects of 1.8 km x 1 km, and the overall value of ES was calculated for each of these sub-transects. This allowed to get a more differentiated picture of variation of ES values within the entire study area and gradually along an urban-rural transect.

Land-use categorie	CODE	SE1	SE2	SE3	SE4	SE5	SE6	SE7	SE8	SE9	SE10	SE11	SE12	SE13
Continuous Urban Fabric (S.L. > 80%)	11100	0	0	0	0	0	0	0	0	0	26	6	0	89
Discontinuous Dense Urban Fabric (S.L. : 50% - 80%)	11210	10	10	10	11	0	10	5	15	5	37	22	5	78
Discontinuous Low Density Urban Fabric (S.L. : 10% - 30%)	11220	20	20	20	22	0	20	10	30	10	48	38	10	67
Isolated Structures	11300	30	30	30	33	0	30	15	45	15	59	54	15	56
Industrial, commercial, public, military and private units	12100	0	0	0	0	0	0	0	0	0	0	0	0	100
Port areas	12210	0	0	0	0	0	0	0	0	0	0	0	0	100
Other roads and associated land	12220	0	0	0	0	0	0	0	0	0	0	0	0	50
Railways and associated land	12230	0	0	0	0	0	0	0	0	0	0	0	0	50
Mineral extraction and dump sites	13100	0	0	0	0	0	3	0	5	0	0	3	23	28
Cantieri	13300	0	0	0	0	0	0	0	0	0	0	0	0	50
Green urban areas	14100	5	15	45	53	21	30	30	35	53	53	33	10	6
Sports and leisure facilities	14100	5	15	45	53	21	30	30	35	53	53	33	10	6
Agricultural, semi-natural and wetland areas	20000	67	18	50	59	52	58	50	60	65	68	62	64	27
Forests	30000	10	55	77	82	86	80	89	95	93	92	92	42	28

Table 2 – ES coefficients’ values for the used land-use categories

RESULTS AND DISCUSSIONS

Figure 3 (left) shows a map of the ES values in the three transects for all patches of land-use categories and according to adjusted coefficients reported in table 2. Following the aggregation in formula 1, ES total values were higher in Transect 1 (43105/Km^2), followed by Transect 3 (26679/Km^2) and then Transect 2 (40703/Km^2) (fig. 4). This relevant difference in ES values between Transect 1 and Transect 2 is mainly related to the presence of a wide industrial area in the west part of the city of Catania. Higher values are present in more rural areas on the west and, on the contrary, lower values characterize more urban contexts. This result is also reflected by fig. 3 (right), showing how values of ES within the 15 sub-transects generally decrease when moving from urban to rural parts of the study area.

This work is based on the assumed relationship between land-use categories and supply of ES; this approach, although very common, have been mostly untested in most of the performed assessment in many regions of the world [9]. It has to be reminded that this approach may lead to strong errors that are mainly related to the quality of spatial information about land cover available [11]. Furthermore, working with land-use data requires data with a sufficient number of categories, in order to highlight and map relevant variation of ES provision. For example, the category of “Agricultural, semi-natural and wetland areas” included in Urban Atlas land-use data encompasses very different land-uses, and thus provide an unique value of ES. In this case it would be necessary to re-classify this category and sub-diving it into the different agricultural and (semi)natural land-use categories present in the area.

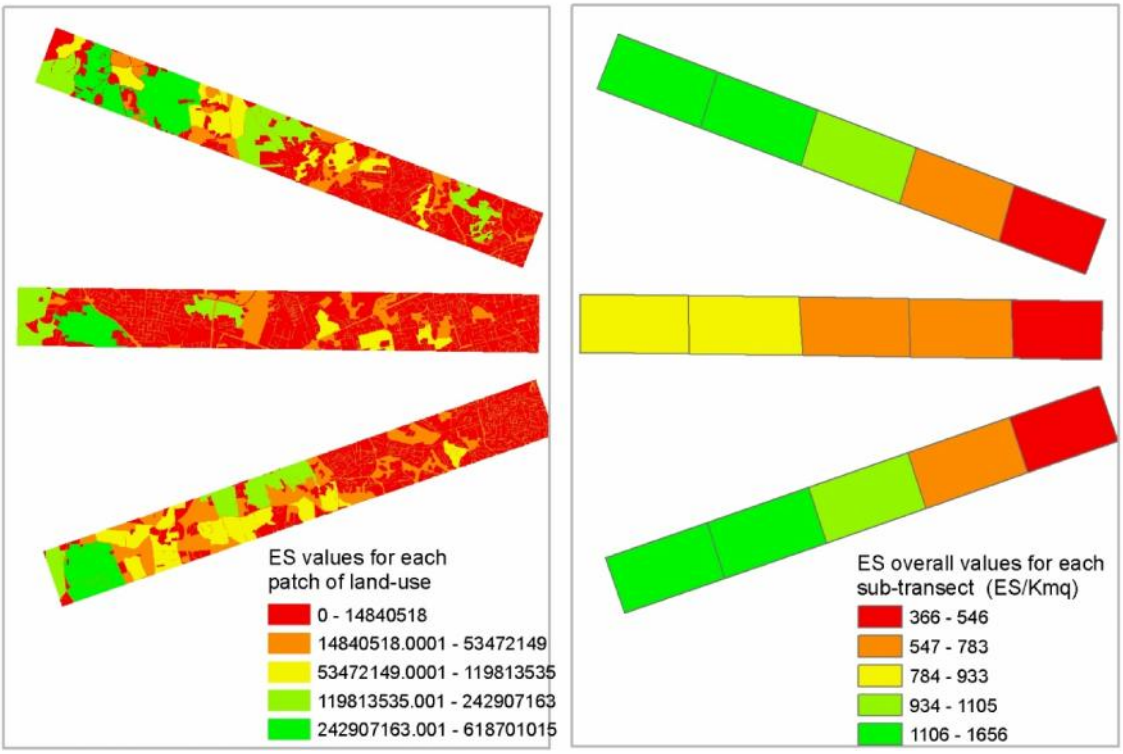

Figure 3. Map of ES values within the 3 transects and values of ES within the 15 sub-transects

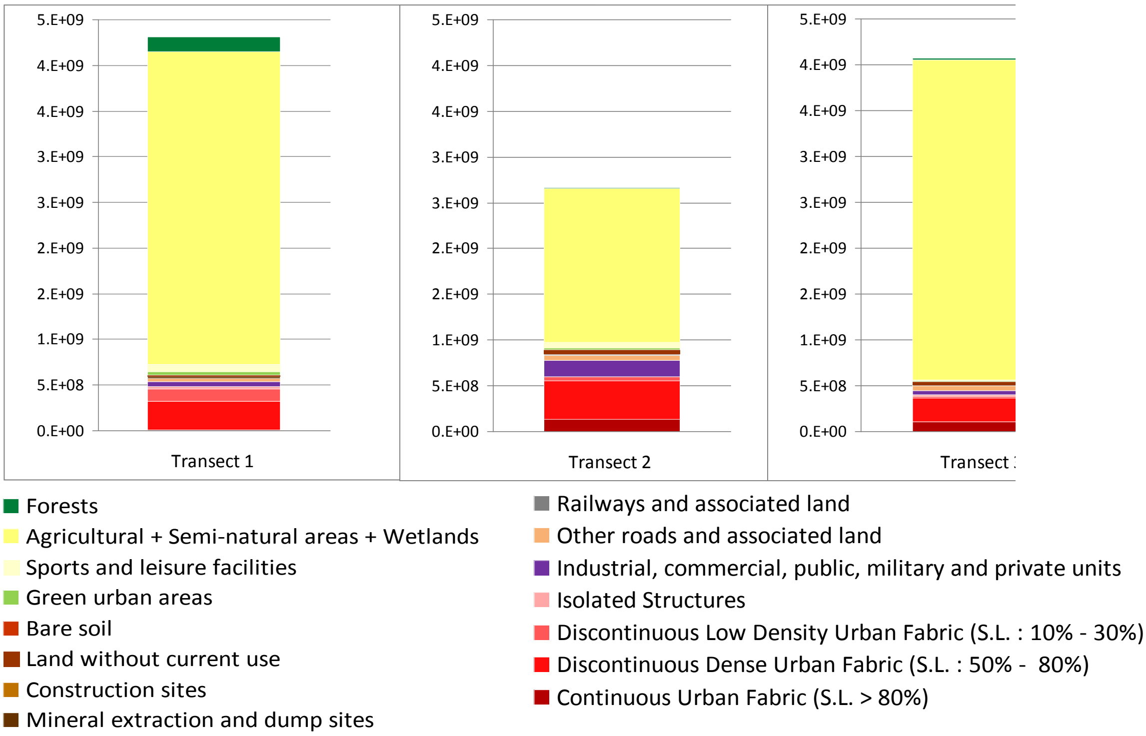

Figure 4. Total ES values for each land-use category in the three transects

This work also demonstrated the need for indicators specifically addressing Cultural ES in urban contexts, especially when considering that urban landscapes are places with the higher density of cultural ES [12]. Mapping of ES by land-use datasets only are unable to capture particular urban items like cultural objects, architectures, monuments, particular configurations of land uses. Such features, as elements of the urban ecosystem, significantly influence the ability of such urban ecosystems to provide cultural ES and thus should be considered in ES evaluations and mapping.

Despite the above mentioned limitations, the work highlighted the importance of agricultural areas as the ones that provided the highest values of ES. This is mainly due to their extent but also requires planning policies and choices that integrate urban agriculture in the metropolitan contexts, aiming at reaching a multifunctional and sustainable land-use for current NUAs and to protect existing productive farmlands from urban development pressures.

CONCLUSIONS

Mapping of ES is a consolidated approach for planning purposes and allows decision makers and all actors involved in planning processes to spatially identify areas that should be maintained due to their high supply of ES. Maps are also important to assess trade-offs and/or synergies among multiple ES, as well as to identify prior areas needing multiple conservation goals.

Results from the proposed mapping work showed the importance of farmlands, within the network of NUAs, in providing ES. Regarding existing farmlands and abandoned farmlands, the proposed method offers a quick and easily reproducible spatial tool for urban planners to understand new forms of agriculture that can act as a buffer against urban development and uncontrolled sprawl processes. This might be achieved by proposing new land uses for these areas that might enhance the overall quality of the urban landscape, support climate change adaptation policies and increase the economic value of the land as contributions toward a more livable and healthy urban environment.

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