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The contribution of plant sociology to the ecosystem service approach in urban and peri-urban areas: evidences from a Mediterranean metropolis case study (Rome, Italy).

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Abstract
In this paper, we promote the use of vegetation and land cover data as biodiversity indicators of pressure, state and impact for ecosystem goods and services in urban and periurban landscapes. In the case study of the Municipality of Rome, a Mediterranean metropolis with a long history of care for biodiversity conservation and sustainable development, recent landscape researches have been addressed towards typification of plant communities, modelling of vegetation series, ecological land classification, design of land ecological network and analysis of land cover change. The results of these investigations have been employed for the identification and ecological evaluation of some locally relevant ecosystem services - such as habitat provision, conservation of species diversity, urban climate regulation, and educational values – and provide experimental evidence of the bioindication potential of plant communities and vegetation series.

Key words: biodiversity indicators, ecosystem services (ES), land cover change, local scale, Municipality of Rome, urban and periurban areas.

Riassunto
Con questo lavoro viene promosso l'utilizzo dei dati di vegetazione e di copertura del suolo come indicatori di pressione, di stato e di impatto su biodiversità e servizi ecosistemici in ambito urbano e periurbano. Nel caso del Comune di Roma, metropoli mediterranea che vanta una lunga tradizione per la conservazione della biodiversità e lo sviluppo sostenibile, le più recenti indagini ecologiche territoriali sono state indirizzate alla tipificazione delle comunità vegetali, alla modellizzazione delle serie di vegetazione, alla classificazione ecologica del territorio, alla progettazione di reti ecologiche e all'analisi del cambiamento di uso del suolo.
I risultati di queste indagini sono stati usati per identificare e valutare, secondo una prospettiva ecologica, alcuni servizi ecosistemici di importanza locale – come la fornitura di habitat, la conservazione della diversità delle specie, la regolazione del clima urbano, il valore educativo – e per evidenziare sperimentalmente il potenziale di bioindicazione delle comunità vegetali e delle serie di vegetazione.

Parole chiave: indicatori di biodiversità, servizi ecosistemici (ES), cambiamento di copertura del suolo, scala locale, Comune di Roma, aree urbane e periurbane.

Introduction

International strategies for biodiversity conservation and sustainable development include the maintenance and improvement of ecosystem integrity and ecosystem goods and services (ES) as focal areas (MA, 2005). At the same time environmental quality and human well-being in urban and periurban areas represent topics of worldwide interest, because of the increasing rate of urban population, which in the Mediterranean-rim countries could reach up to 75% by 2030. Several international and local strategies, such as the Mediterranean Sustainable Regional Strategy Development (MSSD, 2005), consider biodiversity conservation and sustainable development in densely populated areas among their priority actions. These strategies require not only the monetary value estimate but also the ecological identification and evaluation of availability and stability of ecosystem goods and services at local level. Although in urban areas ES are generally more consumed than produced (MA, 2005), varied ecosystems - such as street trees, parks, urban forests, wetlands and agricultural areas – can significantly provide services of local relevance: the relatively few researches on cities, some of these in Northern Europe and in the Mediterranean Basin (Bolund & Hunhammar, 1999; Gulinck *et al*., 2001; Tzoulas *et al.,* 2007), highlighted the importance of local generation and direct availability for the city dwellers of non-transferable services such as micro-climate regulation and noise control, and the significance of residual natural and semi-natural habitats (independently from their structural and functional quality level).

Effective combinations of surrogates for assessing status and trends of ES include vegetation types, as biodiversity indicators, and land cover analysis, in order to assess ES sensitivity to environmental change (Egoh *et al*., 2008; Reyers *et al*., 2009). In most cases vegetation is considered in its structural and/or functional rather than compositional traits, so that forest and grassland structures or plant functional types and primary productivity are commonly adopted for identifying, mapping and monitoring ES at least on coarse scales (Díaz *et al*., 2007; Quétier *et al*., 2007; Feld *et al*., 2009). An alternative approach is to employ the phytosociological dynamic method

(Rivas-Martinez, 2005) to investigate and define plant communities, vegetation series and mosaics, and therefore use sound information about composition, structure, ecology, dynamics, and spatial configuration, rather than dominant life forms or common species, for characterising ecosystems.

In this context, this paper aims to demonstrate that syn- and geosyn-phytosociology, together with ecological land classification and land cover change analysis, can significantly contribute to the recognition and evaluation of goods and services provided by vegetation systems even in highly artificial landscapes. We chose to test the potential contribution of modern phytosociology to the quantification and ecological appraising of ES at local scale in an urban and periurban context as an example of the more challenging areas for reaching sustainability within the Mediterranean basin. The indication potential was explored on multiple levels, from communities to vegetation series and landscape units, according to the synecological, syndynamic and geographic branches of vegetation science.

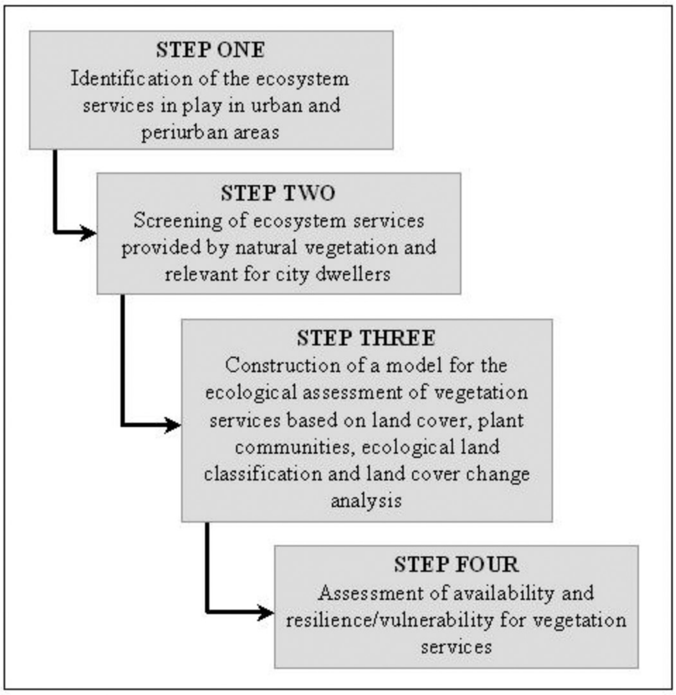

Fig. 1 - Research steps for the ecological valuation of vegetation services in urban and periurban areas.

Material and methods

The research was built following the World Resources Institute recommendations (Ranganathan *et al*., 2008) for effectively applying the ES approach to the decision-making processes. However, we shifted the focus from the economic valuation toward the ecologic assessment of ES and therefore did not take into account the conclusive balance between ecosystem service risks and opportunities (Fig. 1).

Firstly accurate reviews of the rich scientific literature about ES, particularly with regard to services provided by vegetation and to urban contexts, were carried out. References were then selected to better investigate: indication potential of vegetation structure, composition and configuration; accuracy in characterization of vegetation components for the specific account of ES; ecological versus economic valuation of ES; ES approach applied specifically to urban areas; analysis of changes in ES provision. The integration of the scientific literature with "grey literature" on the city of Rome and its metropolitan area (particularly official reports on the state of the environment) supported the selection of vegetation services to be investigated in urban and periurban contexts and according to specific local needs. Afterwards, the concept of the ecological value of the ES in terms of availability, integrity, resilience, and resistance (see de Groot *et al*., 2002) was explored in-depth, taking also into account the indication potential of geobotanical and landscape investigations.

Secondly, an original model for the valuation of selected vegetation services was built. Availability of providers was assessed by taking into account floristic and vegetation data, land cover classes and land units (i), while resilience/vulnerability to human induced changes was estimated through the spatial pattern of change trajectories (ii). This required the integration in a GIS environment of thematic maps of present land cover and land cover change, phytosociological units and ecological land classification.

i) The aim of the ecological land classification is to subdivide territories into homogenous spatial units and the classification process has been applied at various scales, ranging from biomes to ecoregions and sites (Bailey, 1998; Blasi *et al*., 2000; Blasi *et al*., in press). At higher levels ecological land classification usually considers urban areas as undistinguished black spots that are superimposed on the ecoregional pattern and are assigned no ecosystem service value (Costanza *et al*., 1997; Gallant *et al*., 2004) as they acquire a peculiar structure and markedly alter natural functions and ecological processes (Hough, 2004). On medium and finer scales, urban landscapes have more frequently been considered as matrixes that contain natural habitats, which has led to some ecosystem service values being recognized for the "urban green" in general (Troy & Wilson, 2006), or for more specific natural and semi-natural land cover types (Bolund & Hunhammar, 1999). However, a well-defined ecological land classification approach has not yet been adopted to identify ecosystems and assess the services they afford within and around cities. Climate, lithology, morphology and wildlife did, however, impose some constraints on early settlements, at least in Western Europe (Antrop, 2000) and in North America (Grimm *et al*., 2008); such constraints have not been completely eradicated by present urban expansion and may help to rediscover the environmental richness and complexity in and around modern cities. Indeed, within the context of ecosystem services at the local level, we consider the ecological classification of urban and periurban lands as a fundamental tool for the recognition of current ecosystem availability and assessment of the potential extent and distribution of such ecosystems (Blasi *et al*., 2005).

Within land units with homogeneous vegetation potential, phytosociological data represent ancillary information to detail land cover maps and to obtain a proxy of the extent and distribution of actual natural and semi-natural ecosystems. The utility of phytosociological information is particularly relevant to associate the generic grassland classes, generally coarsely classified on land cover maps owing to the resolution of available sources, with different plant communities within each land unit. For example, in the study area of Rome, when pastures occur within the land unit that potentially supports the *Quercus pubescens* Willd. thermophilous woods, they correspond to the herbaceous stages of the *Roso sempervirentis-Quercetum pubescenti* series, such as the "spring therophytic grasslands of *Trifolio scabri-Hypochoeridetum achyrophori*". When pastures occur within the land unit supporting the *Quercus frainetto* Ten. and *Q. suber* L. acidophilous woods, the class may instead host the herbaceous stages of the *Quercetum frainetto-suberis* series, such as the "spring therophytic grasslands of *Moenchio-Tuberarietum guttatae*". Therefore, in-depth vegetation knowledge allows not only to better define ES that occur within urban and peri-urban contexts but also to finely distinguish the providers. The following table compares the indication potential of phytosociological levels with more general land cover types (Burkhard *et al*., 2009) for some ES in the study area (Tab. 1).

ii) Historic or scenario land cover change analysis represents an emerging science for sustainable development that has often been adopted for the spatially explicit estimation of change in the value of ecosystem services over time (Kreuter *et al*., 2001; Diaz *et al*., 2007; Nelson *et al*., 2009). At the landscape level, change analysis can be applied to characterise the ecological configuration and processes that occur within distinct land units (Gallant *et al*, 2004; Haines-Young, 2005; Reger *et al*., 2007; Turner *et al*, 2007). Under an ecological economics perspective, landscape patterns of change represent the context within which ecosystems and their services are currently available, and indicate the major trends to which they will be potentially sensitive in the near future, in line with the panarchical view of the social-ecological systems (Walker *et al*., 2004). In the Municipality of Rome, direction and intensity of change patterns were derived from the classification of the ecological land units according to main change trajectories in two recent time slices (1954-1980 and 1980-2001) (Frondoni, 2009). Land cover change analysis recognized as main change processes the expansion of artificial surfaces on agricultural areas, the stability of the agricultural matrix and the expansion of natural and semi-natural vegetation (Fig. 2). For the purpose of this work, the natural ecosystems and any associated services considered to be locally important for city dwellers were consequently defined as either vulnerable or resilient by assessing their distribution within these different dynamic contexts.

Results

Among the array of ecosystem services recognized worldwide, only those services directly enjoyed, consumed or used by urban people in general, and by Rome city dwellers in particular, were selected to show the indication potential of the integrated method that has been adopted. The choice was based on the existing literature regarding urban areas and on the interdisciplinary knowledge yielded by the Project for the Urban Biosphere Reserve of the Municipality of Rome (Blasi *et al*., 2008a). The availability and vulnerability of some local ecosystem services, related to important social needs in this large, historic Euro-Mediterranean metropolis are assessed below.

Genetic resources provision for cultivated wheat (Figures 3a, 3b and 3c)

a) Ecological, socio-cultural and economic

Phytosoc. level	ES definition		Relevant ES providers	
	FROM	**TO**	**FROM**	**TO**
Plant community (association)	Genetic resources provision	Wild ancestors of the cultivated wheat	Semi-natural grasslands	*Trifolio scabri-Hypochoeridetum achyrophori* therophytic grasslands
	Local climate regulation	Heat island control	Forests	Fragments of broadleaved deciduous and evergreen forests (prevalently *Echinopo siculi-Quercetum frainetto, Cytiso villosi-Quercetum suberis, Carpino orientalis-Quercetum cerridis* and *Cyclamino hederifolii-Quercetum ilicis* woods)
Vegetation series	Invasion resistance	Regulation of plant invasion by *Robinia pseudacacia* and *Ailanthus altissima*	Grasslands, heath-lands/shrublands (and secondarily forests)	*Ulmus minor*. submesophilous pre-woods in the series of *Quercus cerris* woods and of *Quercus pubescens* with *Q. suber* woods (*Carpino orientalis-Querco cerris* and *Roso sempervirentis-Querco pubescentis querco suberis* sigmeta)
Geosigmeta	Science and education	Promotion of environmental knowledge for sustainable urban development	Overall natural and semi-natural areas (secondarily agro-ecosystems and wetlands)	Outstanding combination of geological, hydrogeological and soil elements, threatened species and vegetation types of the EU Habitats Directive, biogeographically distinctive or threatened geosigmeta, historical settlements, traditional agricultural arrangements, and recreational and educational facilities

Tab. 1 - Contribution of phytosociological information to the accurate definition of local ES and of relevant ES providers.

importance at local level: maintaining and recovering typical cultivated varieties, improving resistance toward local pathogens and environmental stresses, and providing opportunities to create new varieties (Evenson & Santaniello, 1999);

b) Service providers: *Triticum ovatum* (L.) Raspail (syn: *Aegilops geniculata* Roth), one of the wild ancestors of the cultivated wheat, often included within the floristic composition of the *Trifolio scabri-Hypochoeridetum achyrophori* therophytic grasslands;

c) Current availability: the sites of the host therophytic grasslands, originally sampled between 1997 and 2004, are found throughout their potential distribution area i.e. throughout land units supporting the series of *Quercus pubescens* Willd. thermophilous woods (coastal gravel terraces, sandy hills and lava flows);

d) Resilience / vulnerability: the service tends to be resilient throughout the countryside (occurrence in land units displaying stable agricultural matrix or expansion of the natural vegetation) and become vulnerable only within part of the eastern urban fringe and of the inner city (occurrence in land units with high artificial trend).

Air filtering and heat island control within the inner city (Figures 3d, 3e, and 3f)

a) Ecological, socio-cultural and economic importance at local level: improved ecosystem and inhabitant health, reduced costs for air conditioning (Gratani & Varone, 2006);

b) Service providers: particularly the residual fragments of broadleaved deciduous and evergreen forests (prevalently *Echinopo siculi-Quercetum frainetto, Cytiso villosi-Quercetum suberis, Carpino orientalis-Quercetum cerridis* and *Cyclamino*

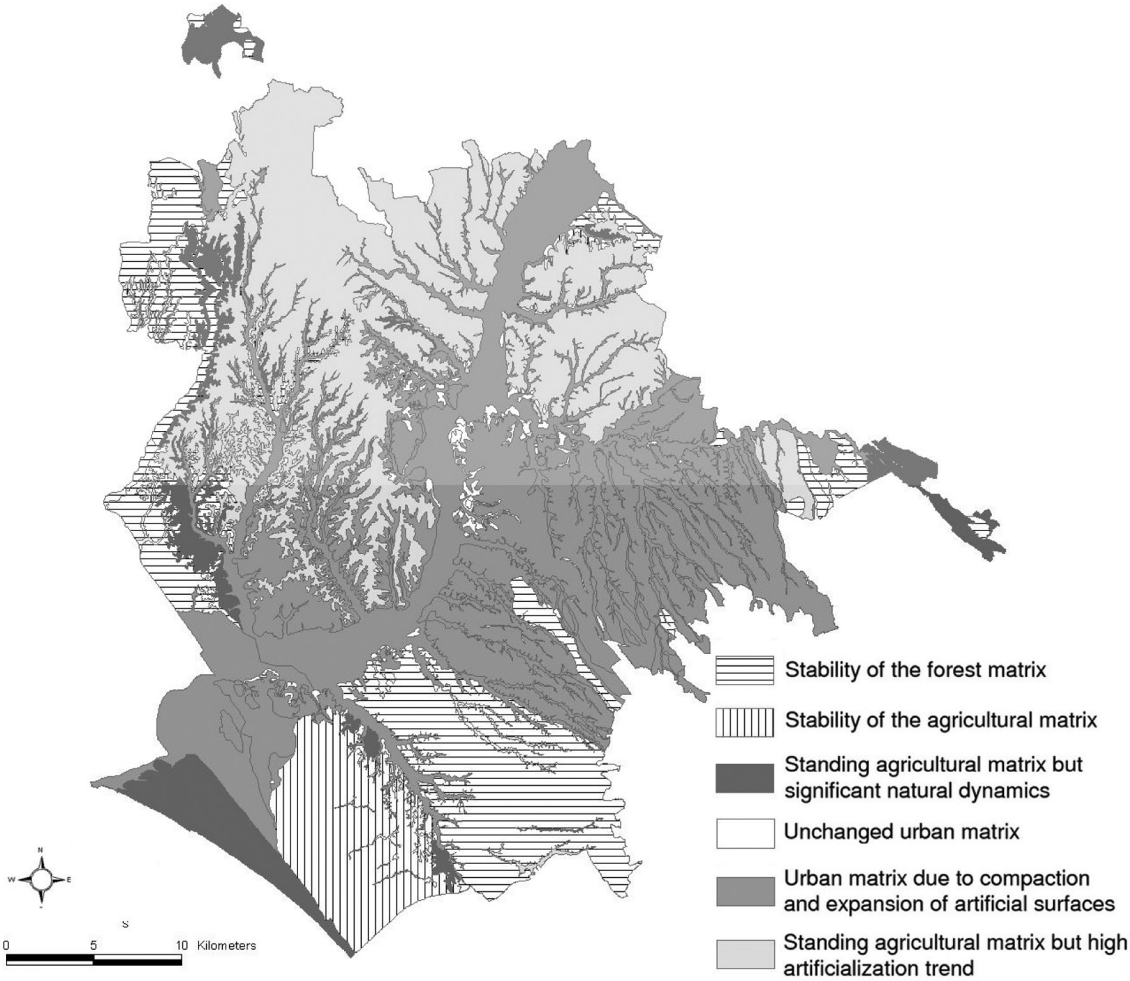

Fig. 2 - Classification of ecological land units based on land-cover change trajectories from 1954 to 2001.

hederifolii-Quercetum ilicis woods);

c) Current availability: 1178 hectares (about 3% of the inner city, conventionally delimited by the main ring road, with an overall potential for forest vegetation) but almost exclusively located in the western areas;

d) Resilience / vulnerability: the service is almost completely lost in the eastern areas, where broadleaved woods were already documented as having disappeared back in 1748 in Nolli's "*Map of Rome*" and were still absent in 1954. In the western areas, the residual service is clearly vulnerable to urbanization, and prevalently occurs within units with a high or very high artificial trend; however, while the ratio between the broadleaved forests and the continuous urban fabric decreased between 1954 and 1980 (from 0.20 to 0.09), it was stable between 1980 and 2001, thereby indicating that recent urbanization processes have been preserving residual woods, which in turn have slightly expanded.

Regulation of plant invasion by *Robinia pseudacacia* L. and *Ailanthus altissima* (Mill.) Swingle (Figures 3g, 3h and 3i)

a) Ecological, socio-cultural and economic importance at local level: mitigation of detriments from alteration of soil composition and nutrient cycling, competition with native plants, damage to buildings and monuments, spread of allergens (Celesti-Grapow *et al*., 2009);

b) Service providers: *Ulmus minor* Mill. submesophilous pre-woods in the series of *Quercus cerris* L. woods and of *Quercus pubescens* Willd. with *Q. suber* L. woods (*Carpino orientalis-Quercetum cerris* and *Roso sempervirentis-Quercetum pubescentis quercetosum suberis*), whose ability to counter the expansion of non-native broadleaved woods with *Robinia pseudacacia* L. and/or *Ailanthus altissima* (Mill.) Swingle emerged from original field observations on vegetation pattern and dynamics;

c) Current availability: about 300 hectares in total, particularly in small patches (2.7 ha on average) scattered over ignimbritic plateaux and slopes and over sandy hills, with the exception of the north-eastern sector of the municipality. Non-native broadleaved woods instead cover about 600 hectares, even in small polygons (3.2 ha on average), and are distributed in the same units but prevalently within the western inner city and in the north-eastern sector of the municipality;

d) Resilience / vulnerability: since the sources of *Ulmus minor* Mill. expansion are fairly widespread and even occur within units subject to the expansion of natural and semi-natural vegetation, this service may be considered as resilient throughout the study area. However, the service is either absent or very vulnerable in the north-eastern sector of the municipality and in the inner city where *Robinia pseudacacia* L. and/or *Ailanthus altissima* (Mill.) Swingle woods currently occur.

Promotion of environmental knowledge for sustainable urban development (Figures 3j, 3k and 3l)

a) Ecological, socio-cultural and economic importance at local level: scientific understanding of local environmental resources and landscape patterns (Blasi *et al*., 2008);

b) Service providers: sites with outstanding combination of physical, biological and cultural values (relevant geological, hydrogeological and soil elements, threatened floristic and faunistic species, habitats of Community interest listed in the EU Habitats Directive, biogeographically distinctive geosigmeta, historical settlements, traditional agricultural arrangements, recreational and educational facilities);

c) Current availability: sites where several values co-occur e.g. the Core Areas identified by the Urban MAB Reserve project;

d) Resilience / vulnerability: the service is particularly vulnerable to artificialisation, not only within the core area "Historical center", which is to be expected on account of its location, but also in the core area "Tiber Delta", which falls prevalently into land units with a high urbanisation trend.

Conclusions

The ecosystem services approach enables to use ecological knowledge to address the sustainability issue (Ruffo and Kareiva, 2009). The experience within the Municipality of Rome confirms the importance of urban arenas and of local dimension within the approach, and adds insights into utility of land ecological classification and vegetation analysis.
Urban landscapes are characterized by high degrees of pressure and impact on an environment in which the majority of people now live: this study shows that residual natural ecosystems, and vegetation communities in particular, can provide services for human society even if fragmented or in suboptimal conservation status, as in the case of air filtering and heat island control. Moreover, examples such as genetic resource provision or the support function for science and education show that some services may even be exported from the cities, thereby partly counterbalancing their ecological footprint.
The ecological classification of land represents a basic source of knowledge on environmental capacities that can be used to identify, contextualize and assess natural ecosystems and their services; the case study we present shows that the approach can also effectively be applied to artificial landscapes, where the natural potential is often hidden by human intervention. The examples demonstrates how this information can be used to recognize both the current and potential ecosystem availability and the vulnerability of ecosystem services to disturbance, such as urbanization.

We fully agree with Bolund and Hunhammar (1999) when they state that "*most of the problems of the urban areas are locally generated*" and that such problems require "*local solutions*". Following our experience in the Municipality of Rome, we wish to stress that the integration among ecological land classification, modern phytosociology and landscape change analysis comprehensively contributes to the identification and promotion of these local solutions, which must in turn be closely associated with the local availability and vulnerability of native natural communities.

In conclusion, the rich floristic, phytosociological, syndynamical and cartographic information provided by vegetation studies, together with the diachronic analysis of biodiversity and plant communities, can help to evaluate the efficiency status of ecosystem services. Vegetation scientists can thus provide important quali-quantitative data on change of ecologically significant indicators at species, community and landscape levels.

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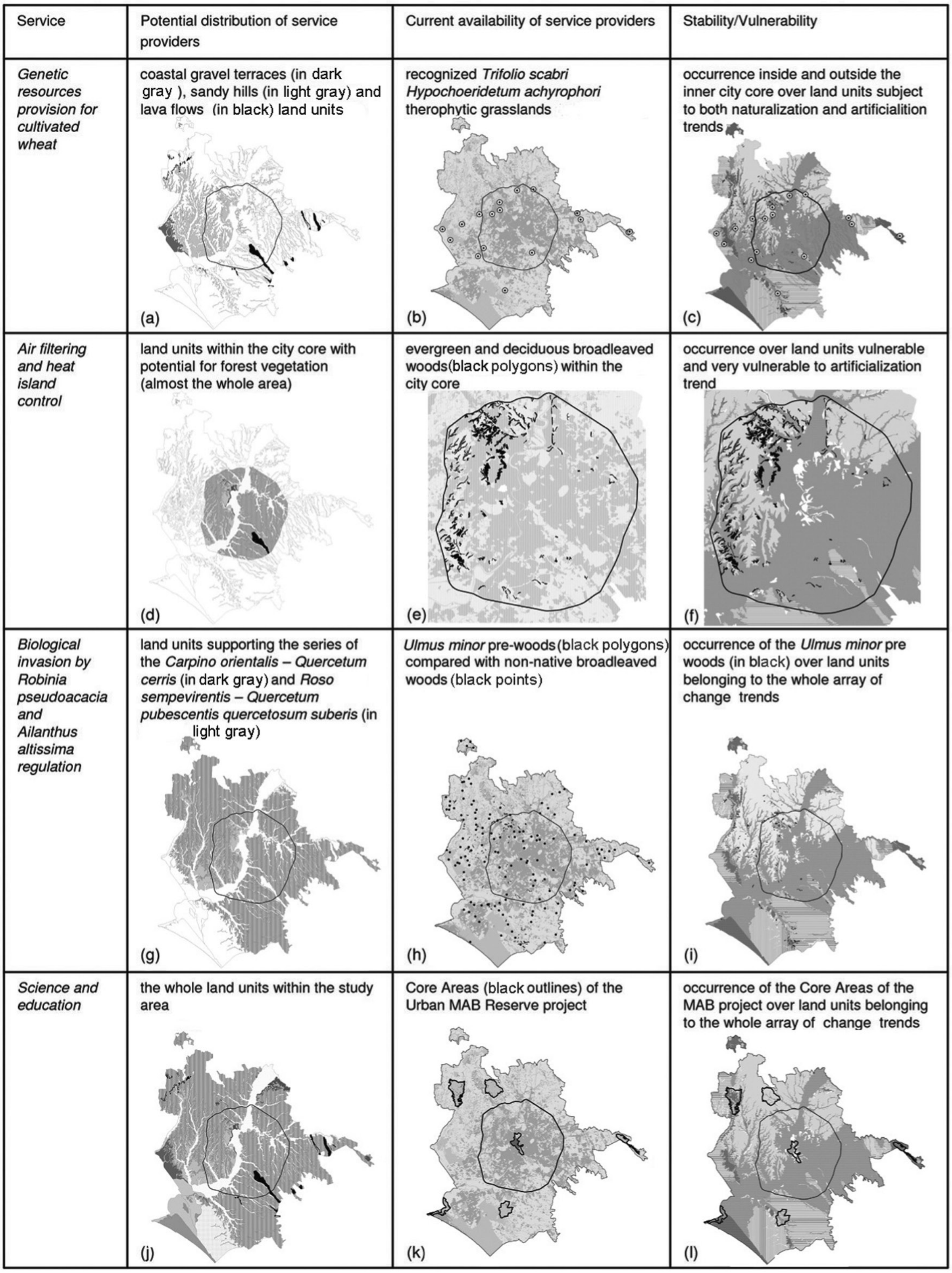

Fig. 3 - Evaluation of ecosystem service providers in terms of potential distribution (a, d, g, j), current distribution (b, e, h, k), and vulnerability to land cover change (c, f, i, l).

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