Land Use Policy xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Land Use Policy

journal homepage: www.elsevier.com/locate/landusepol

Assessing the capacity and flow of ecosystem services in multifunctional landscapes: Evidence of a rural-urban gradient in a Mediterranean small island state

Mario V Balzan*, Julio Caruana, Annrica Zammit

Laboratory of Terrestrial Ecology, Institute of Applied Sciences, Malta College of Arts, Science and Technology (MCAST), Paola, Malta

ARTICLE INFO

Keywords:
Green infrastructure
Island ecosystem services
Malta
Small islands
Spatial analysis

ABSTRACT

Distinguishing between the ecosystems' capacity to generate ecosystem services (ES) and the actual use of these service (ES flow) in ES assessment and mapping is important to develop an understanding of the sustainability of ES use. This study assesses the spatial variation in ES capacity and flow in the Mediterranean small island state of Malta. The services included in this study were crop provisioning, beekeeping and honey production, fodder and livestock production, crop pollination, air quality regulation, and aesthetic ES. This assessment develops different spatial models, which make use of available datasets, causal relationships between datasets, including a generated land use land cover (LULC) map, and statistical models and indicators based on direct measurements. Individual ES indicators were mapped to visualise and compare their spatial patterns across the case study area. Subsequently, an analysis of ES associations and bundles was carried out using Pearson parametric correlation test, for both ES capacity and flow indicators generated from this study, and through Principal Component Analysis. Results demonstrate several significant synergistic interactions between ES capacity and flow in rural landscapes characterised with agricultural and semi-natural LULC categories, indicating high landscape multifunctionality. In contrast, predominantly urban areas tend to be characterised with a low ecosystem capacity and ES flow, suggesting that ES delivery in the landscapes of the study area is determined by land use intensity. These findings support the notion that multifunctional rural landscapes provide multiple ES, making an important contribution to human well-being, and that land use planning that develops green infrastructure in urban areas can significantly contribute to support biodiversity and ES delivery.

1. Introduction

The assessment and mapping of ecosystem services (ES) is increasingly recognised as being important to understand the link between ecosystems and their benefits, and their value to human societies for more informed decision-making (Alkemade et al., 2014; Crossman et al., 2013; Jordan and Russel, 2014) and for the development of nature-based solutions as part of sustainable development strategies (Maes and Jacobs, 2017). ES mapping is also a key objective of the EU Biodiversity Strategy to 2020,[1] which calls on member states to assess the state of ecosystems and their services in their territory.

This study assesses the spatial variation of ES in a multifunctional Mediterranean landscape, supporting cultural, ecological and economic functions. Two distinctive hallmarks of multifunctionality are that landscapes are considered as a matrix, with high spatial heterogeneity, and as an integrative system defined in terms of ecosystem functions and services (Selman, 2009). Given the diversity of the ecosystems and the interactions between these in an integrative system, multiple ecosystem services are provided by multifunctional landscapes, with manifold services occurring in an inter-related manner within the landscape (O'Farrell and Anderson, 2010) whilst supporting human quality of life (Potschin and Haines-Young, 2016). These benefits depend on the needs, choices and values of people and are also place-related depending on the context (Potschin and Haines-Young, 2013). The maintenance of this multifunctionality, by integrating landscape use in an ecological fabric that maintains ecosystem capacities and flow, is seen as being particularly important in order to achieve sustainability (Lovell and Johnston, 2009; O'Farrell and Anderson, 2010), and may serve as an adaptive strategy to address unknown future conditions through increased resilience (Selman, 2009).

Landscapes within the Mediterranean region have been shaped through natural processes and a long history of human activities, which

* Corresponding author.
E-mail address: mario.balzan@mcast.edu.mt (M.V. Balzan).
[1] http://ec.europa.eu/environment/nature/biodiversity/strategy/index_en.htm.

http://dx.doi.org/10.1016/j.landusepol.2017.08.025
Received 31 March 2017; Received in revised form 20 June 2017; Accepted 22 August 2017

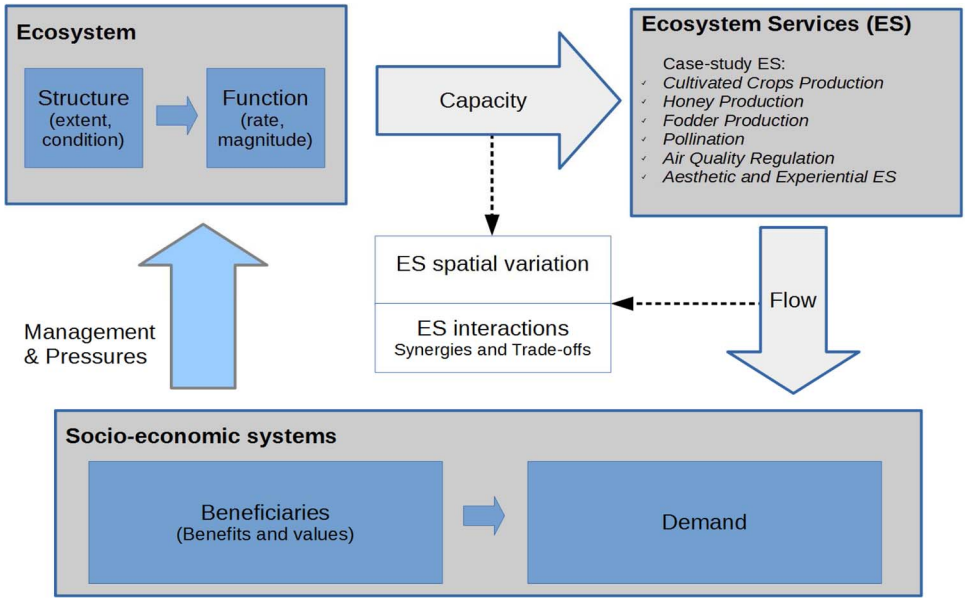

Fig. 1. General conceptual diagram linking ecosystems' capacity and the flow of ES to human well-being. Block arrows indicate the relationship between the ecosystem, ecosystem services and socio-economic systems, while dashed arrows indicate the level of analysis in this study through the identification of interactions, overlap and synergies and trade-offs in ES delivery.

gave rise to mosaic landscapes characterised by a high diversity of ecosystems (Blondel et al., 2010; Naveh, 1994). These multifunctional landscapes result from a co-evolution of social and ecological systems, and are associated with a high endemicity and species richness but are also of socio-cultural significance (Blondel et al., 2010; Martín-López et al., 2016). In these cultural landscapes, high biodiversity and resilience are particularly linked to the cultural values and to social behaviour and perceptions (Oteros-Rozas et al., 2014).

Multiple ES are provided by the cultural landscapes of the Mediterranean basin, and these contribute to an improved human well-being. However, ES are affected by different direct and indirect drivers of change which alter land uses (Ales et al., 1992; Aretano et al., 2013; Rodríguez-Loinaz et al., 2014; Tzanopoulos and Vogiatzakis, 2011). The intensification of land-use management is associated with the loss of traditionally heterogeneous landscapes, as a consequence of population growth, industrialisation, urban development and increasing tourism. These may threaten the natural capital of the region, as multifunctional landscapes, which have traditionally hosted Mediterranean ecosystems and their services, are lost (Plieninger et al., 2014). These changes can have an even more important effect when they occur in small Mediterranean islands, characterised by a mosaic of land-covers and landscapes (Vogiatzakis et al., 2008) and where the socio-economic and environmental insularity often strengthens the linkages between ecosystems and communities (Balzan et al., 2016). In many Mediterranean islands, traditional human activities, which have shaped the islands' landscapes are almost exclusively related to subsistence production such as mining and agriculture (Petrosillo et al., 2013). These activities have declined in recent decades while tourism has increased substantially and today dominates the local economies of many Mediterranean small islands (Aretano et al., 2013; Petrosillo et al., 2013; Tzanopoulos and Vogiatzakis, 2011). Whilst traditional rural landscapes, characterised by a mosaic of arable agriculture, and semi-natural ecosystems, have shown a balance between biodiversity and land use in the past, the recent intensification of land use has also led to severe degradation of ecosystems and natural capital (Makhzoumi and Pungetti, 2008).

The aim of this study is to assess how ES capacity and flow vary spatially in the landscapes of Malta (Central Mediterranean). In order to make ES maps operational for landscape planning various have called for a clearer distinction between the different components linking ecosystems to socio-economic systems (Burkhard et al., 2012; Mouchet et al., 2014; Schröter et al., 2014; Villamagna et al., 2013). Maps of the capacity of ecosystems to deliver an ES, and of the flow of the ES, that is the actual ES use, can be a useful tool for planners and policy-makers, as they can allow for the identification of unsustainably used areas (Geijzendorffer et al., 2015), and hence the redirection of ES flows to areas with a higher ES capacity or the planning and development of green infrastructure to improve the capacity of ecosystems to deliver key ES in areas with ES capacity and flow imbalances (Lovell and Taylor, 2013). Green infrastructure has been defined by the EU Strategy on Green Infrastructure as a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ES for human society (EC, 2013).

The landscapes of the study area have been moulded by the geo-climatic conditions and human exploitation acting over several millennia, and are associated with a mosaic of small-scale and interacting ecosystems of high socio-cultural significance. An understanding of the spatial variation of ES capacity and flow in Malta can be used to provide an indication of spatial imbalance in ES capacity and flow, which results in an unsustainable uptake of the ES when ES flow cannot be met by current capacity. The study also investigates interactions amongst ES, occurring when multiple ES respond to the same driver of change or when interactions between the ES alter the provision of another. ES interactions can lead to synergies, that is situations in which both services either increase or decrease, or trade-offs between ES (Bennett et al., 2009; Mouchet et al., 2014).Through the use of data for six ES, we analyse the contribution of different ecosystems to ES bundles, defined as sets of ES that appear together repeatedly (Raudsepp-Hearne et al., 2010). The development of an understanding of the contribution of different land uses to ES delivery, and the overlap between multiple ES in multifunctional landscapes, is relevant to the design of spatial policies that promote sustainable land use (de Groot et al., 2010).

2. Methods

2.1. Conceptual framework

The distinction between ES capacity and flow builds on the definition of ecosystem services, which considers these as the contributions that ecosystems make to human well-being. The ES Cascade model develops on this definition and links ecosystems to the human society through a chain of components, namely ecosystem structure and processes, functions, services, benefits and values (Potschin and Haines-Young, 2011). Different indicators have been used to assess and map