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A pan-European model of landscape potential to support natural pest control services

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ABSTRACT

Pest control by natural enemies (natural pest control) is an important regulating ecosystem service with significant implications for the sustainability of agro-ecosystems. The presence of semi-natural habitats and landscape heterogeneity are key determinants of the delivery of this service. However, to date, synthetic and consistent indicators at large scales are lacking. We developed a pan-European, spatially-explicit model to map and assess the landscape potential to sustain natural pest control. The model considers landscape composition in terms of semi-natural habitats types, abundance, spatial configuration and distance from the focal field. It combines recent high-resolution geospatial layers with empirical results from extensive field surveys measuring the specific contribution of different semi-natural habitats to support insects flying enemies providing natural pest control. The resulting maps facilitate a comparison of the relative biological control potential of different areas and show that currently a large proportion of high-productive agricultural areas in Europe has low potential. The obtained indicator can inform the formulation of policies and planning strategies aimed at increasing biodiversity and ecosystem services and can be used to assess trade-offs between different services. Potential fields of application include the Common Agricultural Policy and the EU Biodiversity Strategy, in particular the implementation of Green Infrastructure.

1. Introduction

Mapping and assessment of Ecosystem Services (ES) stands out as a major research domain that has now moved to the science-policy interface (Maes et al., 2016). The availability of spatially explicit, synthetic information is considered pivotal to mainstream the ES concept into policy-making and planning across different scales and sectors (Maes et al., 2012), and to inform decision-making on key issues such as where a mismatch between ES demand and supply is occurring or the identification of priority areas to target policies (*ibid*).

The EU Biodiversity Strategy to 2020 (EC, 2011) requires Member States to map and assess the state of ecosystems and their services in their national territory. The Strategy also requires the implementation of a Green Infrastructure, defined in a subsequent specific document as a 'strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services' (EC, 2013). The emphasis on Green Infrastructure and associated services provides an important rationale for the conceptualisation of the role of natural and semi-natural vegetation, highlighting the need for the analysis at landscape level and the distinction of different habitat typologies.

Recent advancements in ES mapping do not equally concern all ES, though. Natural pest control, also referred to as 'pest control', 'pest regulation', 'biocontrol' or 'biological (pest) control' is an important regulating service supporting crop production that has been extensively studied, but still harbours considerable knowledge gaps (Holland et al., 2017). In intensively managed agricultural landscapes, plant protection is largely based on chemical inputs, which increases production costs and environmental pollution, resulting in, among others, a negative impact on biodiversity, (agro)ecosystem functions and the provision of

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other ES (Chaplin-Kramer et al., 2011; Tschumi et al., 2015). Enhancing natural pest control has thus a high potential to contribute to ecological intensification (*sensu* Bommarco et al., 2013) and food security while reducing pressures on biodiversity and the environment. Despite the acknowledged importance of natural pest control as an ES, very few studies have attempted to develop spatially explicit models to map and assess it. In a recent systematic review, Englund et al. (2017) identified 347 cases of ES mapping, among which natural pest control turned out to be the least covered ES with only four studies.

A growing body of research has collected empirical evidence on natural pest control and its relationship with landscape structure over the last years (Chaplin-Kramer et al., 2011; Rusch et al., 2016; Holland et al., 2017). Despite the complexity of the underlying ecology, the literature points to some recurrent findings that can be generalized. Firstly, the presence of semi-natural habitats (SNH) in agroecosystems is crucial to support natural enemies by providing overwintering habitat, shelter, and alternative food; and different types of SNH have different potential to provide such resources (Holland et al., 2016 and references therein). Secondly, the capacity of local SNH to support natural enemies is dependent on landscape complexity, i.e. the amount and configuration of SNH at the landscape scale (Chaplin-Kramer et al., 2011; Jonsson et al., 2014; Rusch et al., 2016). Landscape complexity is commonly measured as the share of SNH or non-cropped habitat in a landscape sector surrounding the focal crop field within a certain radius, usually 500–1000 m (Rusch et al., 2016). Accordingly, landscape simplification proved to be correlated with increased pest abundance, (Landis et al., 2008; Meehan et al., 2011; Veres et al., 2013; Meehan and Gratton, 2015), though exceptions have been documented (see studies reported in Veres et al., 2013). Thirdly, the effect of SNH on natural pest control in the field decreases with distance (Lavandero et al., 2016; Tylianakis et al., 2006; Johnsonn et al., 2014; Holland et al., 2016). Fourthly, findings converge to support the 'intermediate landscape-complexity hypothesis' proposed by Tscharntke et al., (2012) according to which landscape-moderated effectiveness of local conservation management is highest in structurally moderate landscapes (intermediate amount of SNH), rather than in extremely simplified landscapes (due to lacking species pools) or highly complex ones (already high resource availability by existing SNH).

In this paper, we present concepts and modelling methods to build a spatially-explicit, fine-resolution, pan-European model to measure and map the potential capability of the landscape to support flying natural enemies that provide pest control services across Europe. The ES conceptual framework adopted here is the well-known ecosystem service cascade originally proposed by Haines-Young and Potschin (2010) and recently refined by Maes et al. (2016) and La Notte et al. (2017) This schematization links biodiversity and ecosystems stepwise to human wellbeing through the flow of ES (Fig. 1) and is considered particularly suitable for mapping and assessing ES (Maes et al., 2012). In this framework, 'ecosystems' are a complex network of interplaying physical structures and ecological processes, entailing flows of energy and matter through different trophic levels. A subset of the ecosystems' characteristics and properties – termed ecosystem *functions* – are potentially useful for human beings as they underpin the capacity of the ecosystem to supply the final service. This in turn generates a direct or indirect benefit to people, to which an economic value may be assigned.

The work presented in this paper aimed at: (1) developing an ecosystem service map for natural control at the European level taking into account landscape complexity and the role of SNH based on available data sources (2) determine the indications that can be derived from this map to inform policy-making and planning and (3) assessing the challenges and bottlenecks when developing such a map in order to define data that need to be collected in the future to improve it.

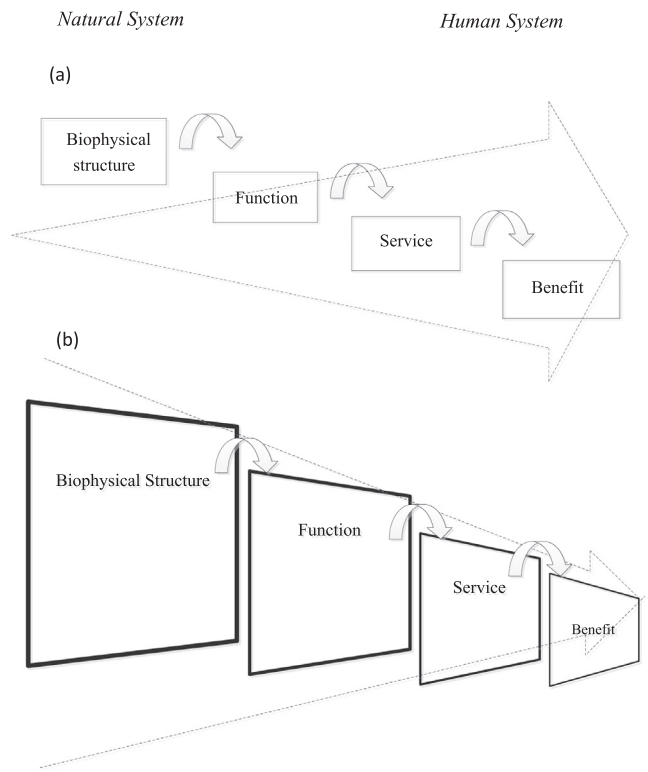

Fig. 1. (a) The traditional cascade framework with emphasis on end-use benefits; (b) re-interpretation of the cascade framework, with emphasis on the underpinning complexity of the ecological system. Source: La Notte et al. (2017).

2. Materials and methods

2.1. Model design

The model aims to quantify, in a spatially explicit way at European scale, the potential of the landscape to support insect flying predators able to control crop pests in agricultural landscapes. The abundance of these natural enemies is likely — but not necessarily — positively correlated with natural pest control services (Chaplin-Kramer et al., 2011). Therefore, the model quantifies the potential service supply for a given landscape rather than the final service delivery (reduction in pest density, higher crop yield) or related benefits, which are highly context-dependent.

Europe is schematized as a regular flat grid of square cells (resolution 100 m). The natural pest control potential in a given target cell depends on landscape complexity up to a certain distance from each cell centre. For the present study we selected 500 m as this is reported in literature as the distance at which flying natural enemies such as parasitoid species respond most strongly to landscape composition (Thies et al., 2005; Bianchi and Wäckers, 2008; Jonsson et al., 2014), but the model structure allows to set a different value. We classified SNH into four types according to the predominant vegetation type, either woody or herbaceous, and their shape, areal or linear. SNH patches extending over 25 m in all directions were defined as areal elements, whereas any element with width ≤ 25 m and length ≥ 100 m is defined as a woody linear element. Therefore, each SNH pixel was classified as either Woody Areal (WA), Woody Linear (WL), Herbaceous Areal (HA) or Herbaceous Linear (HL). Each SNH type was assigned a specific score according to its potential to support flying natural enemies, using empirical results from extensive field surveys presented in Moonen et al. (2016) (see Section 2.2). The weight of the contribution of surrounding source cells to the target cell decreases with distance between the source and the target; we used a rotationally symmetrical 2Dt-

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