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Representing composition, spatial structure and management intensity of European agricultural landscapes: A new typology

Emma H. van der Zanden[a,*], Christian Levers[b], Peter H. Verburg[a], Tobias Kuemmerle[b,c]

[a] Environmental Geography group, Department of Earth Sciences, VU University Amsterdam, De Boelelaan 1085, 1081 HV Amsterdam, The Netherlands
[b] Geography Department, Humboldt-University Berlin, Unter den Linden 6, 10099 Berlin, Germany
[c] Integrative Research Institute on Transformations in Human-Environment Systems (IRI THESys), Humboldt-University Berlin, Unter den Linden 6, 10099 Berlin, Germany

HIGHLIGHTS

- We present a spatially-explicit typology of European agricultural landscapes.
- Datasets representing land cover, landscape structure and land management are used.
- An expert-based top-down typology is compared with a data-driven bottom-up approach.
- Inclusion of land management differentiates our results from existing typologies.
- We find clear overlaps in general landscape patterns with existing typologies.

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ABSTRACT

Comprehensive maps that characterize the variation in agricultural landscapes across Europe are lacking. In this paper we present a new Europe-wide, spatially-explicit typology and inventory of the diversity in composition, spatial structure and management intensity of European agricultural landscapes. Agricultural landscape types were characterized at a 1 km^2 resolution based on Europe-wide datasets that represent land cover, landscape structure and land management intensity. Two alternative approaches for typology development were used: an expert-based top-down approach, and a bottom-up approach based on automated clustering using Self Organizing Maps (SOMs). Comparison with available national and European landscape typologies showed that our typology deviates from existing biophysical and anthropocentric typologies relevant to agricultural landscapes as result of the inclusion of land management aspects. Concordance occurred between specific European typology classes, while the comparison with national landscape typologies showed a correspondence in agricultural landscape patterns. Our agricultural landscape typology can provide a basis for landscape assessment at a European-scale to help to identify agricultural landscape types prone to change and landscapes that may require policy response.

1. Introduction

Land use has transformed more than 80% of the global land surface, by conversion of natural ecosystems into agriculture or cities or by using natural ecosystems at varying intensity (Ellis, Klein Goldewijk, Siebert, Lightman, & Ramankutty, 2010). While much research has focused on how land conversions create agricultural and other human-dominated landscapes (Ramankutty et al., 2006; Verburg, van Asselen, van der Zanden, & Stehfest, 2013), much less attention has been paid to characterizing the spatial variation in agricultural landscapes that has developed in relation to the variation in management intensity within these landscapes, even though management intensity is a main driver of rural landscape change in many world regions (Sayer et al., 2013).

Three important dimensions of present-day agricultural landscapes are land cover, land management and landscape structure (Verburg et al., 2013). Land cover types and their arrangement determine the overall agricultural type. Land management refers to the "ways in which humans treat vegetation, soil, and water" for a specific purpose (Lambin, Geist, & Rindfuss, 2006); in other words, the land use practices that people carry out within broad

* Corresponding author.
E-mail addresses: emma.vander.zanden@vu.nl (E.H. van der Zanden), christian.levers@geo.hu-berlin.de (C. Levers), peter.verburg@vu.nl (P.H. Verburg), tobias.kuemmerle@geo.hu-berlin.de (T. Kuemmerle).

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land cover types. Examples of such practices include use of fertilizers or pesticides, irrigation schemes and tillage (e.g., Erb et al., 2013; Follett, 2001). Land management can impact landscape functioning and ecosystem services supply substantially (Tscharntke, Klein, Kruess, Steffan-Dewenter, & Thies, 2005; Zhang, Ricketts, Kremen, Carney, & Swinton, 2007). While such effects have been extensively studied at the local scale (e.g., Shriar 2000; Herzog et al., 2006), the spatial patterns of land management at regional to global scales, and thus their impacts on ecosystem functioning, services and biodiversity, are often ignored (Kuemmerle et al., 2013; Verburg et al., 2013). Landscape structure is scale-dependent and refers to the spatial heterogeneity of the landscape (Turner, 1989), for example the arrangement of land uses or cropland fields, or the prevalence of linear landscape elements (e.g., hedges, ditches, terraces, Paracchini et al., 2012; Kumaraswamy & Kunte, 2013). On a regional scale, landscape structure is closely linked to ecosystem services provisioning, especially for a number of regulating services (e.g. erosion prevention, pollination) and cultural services (e.g. landscape aesthetics and tourism, Pinto-Correia & Breman, 2008; Power, 2010; Syrbe & Walz, 2012; van Zanten et al., 2013), as well as the biodiversity-friendliness of agricultural landscapes (Burel & Baudry, 1995; Dramstad et al., 2001).

Land cover, land management, and landscape structure are also central features differentiating landscapes with exceptional cultural heritage and values (Plieninger, Höchtl, & Spek, 2006). Cultural landscapes – a term adopted in the 1990s by international bodies as a conservation category (Jones, 2003) – often have relatively high structural complexity, traditional, low-intensity landscape practices and historical elements, altogether contributing to the often exceptional value of these landscapes (Antrop, 2005; Fischer, Hartel, & Kuemmerle, 2012; Plieninger & Bieling, 2012). Many cultural landscapes, however, have recently undergone stark transformations as new land-use paradigms based on more intensive agricultural production are adopted (Vos & Meekes, 1999).

Europe is particularly rich in landscapes that are recognized for their natural and cultural heritage (Vos & Meekes, 1999; Plieninger, Höchtl, & Spek, 2006). Many of these cultural landscapes have been shaped by traditional land uses and contain high conservation values that are dependent on continuation of low-intensity agricultural practices (Dieterich & van der Straaten, 2004; Fischer et al., 2012). Historical socioeconomic and institutional events shaped landscape structure and are visible in the landscape today. An example is the high level of fragmentation of ownership and field sizes in post-socialist countries, which is a result of collectivization of land during the socialist time and the re-privatization processes since 1989 (Hartvigsen, 2014; Kuemmerle et al., 2008). Conserving European cultural landscapes, as well as their cultural and natural heritage has received increased attention in European policy making recently, with the introduction of the High Nature Value (HNV) farmland concept as the clearest example (EEA, 2010; Kleijn, Rundlöf, Scheper, Smith, & Tscharntke, 2011; Paracchini et al., 2008; Robinson & Sutherland, 2002; Walz & Syrbe, 2013). Furthermore, specific EU policies, such as the Common Agricultural Policy (CAP), increasingly promote a landscape-based approach (Paracchini & Capitani, 2011), although there is also critique on the dominant environmental focus of landscape management in these policies (Agnoletti, 2014).

To better understand the large spatial heterogeneity of agricultural landscapes across Europe, and to monitor changes in landscape functions and values, it is necessary to reduce the complexity in agricultural landscapes to manageable units that could be an interesting target for policy-making at the European scale. Several initiatives have sought to identify and classify landscapes in Europe since the 1990s (Paleo, 2010), including the Pan-European Biological and Landscape Diversity Strategy (PEBLDS, Council of Europe 1996) and the European Landscape Convention (ELC, Council of Europe 2000). The ELC encouraged member states to identify and assess the national landscapes and their features, but with a focus on member state autonomy and a clear subsidiarity principle (Council of Europe, 2000). Thus, the national landscape maps differ substantially in mapping approaches (see Supplementary material A), data sources, and the underlying landscape-concept (i.e., interpretation of the role of humans in the landscape; see Angelstam et al., 2013 for an overview; Cassatella & Voghera, 2011; Groom, 2005). Substantial progress in developing a Pan-European Landscape map, an important action theme of the PEBLDS (Council of Europe, 1996), was made. Meeus (1995) developed a qualitative classification of traditional European landscapes. Building on this, Mücher et al. (2010) developed a Landscape Map (LANMAP) aimed to give an overall classification of landscape types in Europe, based on quantitative spatial analysis and a consistent classification framework. However, previous research efforts have not incorporated key dimensions that are important for differentiating agricultural landscapes, such as land management and landscape structure.

Our main objective is to focus on this research gap, by developing a typology of the diversity in composition, spatial structure and management intensity of European agricultural landscapes. By focusing on these selected dimensions, we aim to provide a generic basis (i.e., independent from specific locations or geographic contexts) for assessment and comparison of agricultural areas in Europe. Such an approach is highly complementary to existing classifications and typologies which mainly capture biophysical dimensions of landscapes in great detail. A second objective is to compare methods for typology development. As traditional approaches in typology development either take a top-down or a bottom-up approach, we compared an expert-based top-down, and a bottom-up approach based on automated clustering.

Europe is an interesting case for such analysis, as landscape characterization and assessment is a key aspect in European landscape research (Plieninger, Dijks, Oteros-Rozas, & Bieling, 2013). But the typology development also provides a methodological example for the delineation of agricultural typologies for other world regions, moving beyond the standard approach of characterizing differences in landscape and land use by their dominant land cover only (e.g., Busch, 2006; Verburg et al., 2013). The representation of critical aspects of agricultural landscapes is currently lacking on a regional scale, while progress has been made with global scale typologies (see Verburg, van Asselen, van der Zanden, & Stehfest, 2013). Improved representation of agricultural landscapes within sub-global assessments can furthermore clarify landscapes' influence on environmental change (Verburg, van Asselen, van der Zanden, & Stehfest, 2013).

2. Materials and methods

Traditional approaches to develop landscape typologies using geospatial data have applied either a top-down or bottom-up approach. In a top-down approach, the typology is commonly delineated based on a decision tree defined by expert rules and supervised threshold selection (Maxwell & Buddemeier, 2002). A bottom-up approach, in contrast, determines landscape types based on groups of locations that have similar characteristics, usually with the help of statistical clustering methods. We used both of these approaches, specifically a top-down expert-based classification and a bottom-up approach based on automated clustering using self-organizing maps (SOMs) (see Fig. 1), that used the same input data for the land cover, land management and landscape structure dimensions of agricultural landscapes. We then carried out a map comparison to assess the influence of method selection on the resulting maps.