Habitat International xxx (2016) 1–15

Contents lists available at ScienceDirect

Habitat International

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

Examining sustainable landscape function across the Republic of Moldova

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ARTICLE INFO

Article history:
Received 8 August 2016
Received in revised form
29 October 2016
Accepted 9 November 2016
Available online xxx

Keywords:
Indicator-based assessment
Landscape science
Regional development
Spatial autoregressive modeling
Sustainable development planning
Sustainable urbanization

ABSTRACT

Sustainability remains an undeniable, yet obscure, destination for humanity to reach. Although progress has been made, there remains no agreed upon method for spatial scientists, nor landscape and regional planners to use during sustainable development assessments. Furthermore, limited examples exist that investigate relationships between-landscape form (e.g. urban configuration) and population dynamics (e.g. number of settlements)- and a local measure of sustainable development. Using a recently published local sustainable development index (LSDI) for Moldova, a regional spatial analysis was created to further elucidate strengths and weaknesses of index-based assessments of sustainable landscape function. Using a one-to-many relationship, sixty-six landscapes were joined to 399 mean LSDI sample locations for the quantitative spatial assessment ($n = 399$). A rarity of this study was that it employed the Eastern School of Geography's “landscape units” for Moldova during geospatial data aggregation and spatially enabled regression. Moran's I scatterplot and spatial correlogram were used to visualize spatial autocorrelation dynamics of LSDI. Three local conditional autoregressive (CAR) models were made, with all explaining over 70% of LSDI variation. The two strongest positive predictors of LSDI were city population density and road intersection density, while the two most consistent negative were settlement density and distance between urban land cover patches (ENN_AM). Findings suggest index-based landscape valuations could suffer from spurious inferential correlations when landscape-calculated sub-metrics (i.e., proportion agricultural land) are included within evaluation indices. This phenomenon complicates the interpretation of results during regional analyses, thus potentially hindering sustainable development planning and policy responses across spatial scales.

1. Introduction

Humanity's understanding on how to live sustainably is as open as ever. As we progress through the early stages of the Anthropocene, not one of the original eight Millennium Development Goals (MDGs) were reached by 2015, nor has the rate of global warming or sea level rise slowed (Dutton et al., 2015), nor has the eradication rate of our life-supporting ecosystems decreased (Butchart et al., 2010). The world's richest countries have seen improvements in socioeconomic and material well-being (Weinzettel, Hertwich, Peters, Steen-Olsen, & Galli, 2013); albeit at the cost of metabolizing natural habitats within their own borders through land cover change, and devastating entire ecosystems across the developing world through globalization (Rands et al., 2010; Shaker, 2015a). More than 40% of Threatened or Endangered species are at risk of extinction due to human propagated invasive species (Grime, 2006). Lastly, marine resources continue to be overharvested (Worm et al., 2006), their waters are becoming more acidic due to pollution deposition from the continual burning of fossil fuels (Hoegh-Guldberg et al., 2007), and terrestrial garbage continues to collect in natural oceanic gyres (Jambeck et al., 2015). These direct and indirect sustainability stressors are driven primarily by population growth, which was recently projected to continue into the next century and surpass 12 billion globally (Gerland et al., 2014). Despite the current condition of humanity's life-supporting ecosystems, Griggs et al. (2013) reiterated that inequalities between groups, high-levels of poverty, and human well-being need to be addressed while restoring biophysical stability.

According to Hales and Prescott-Allen (2002), “Making progress

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http://dx.doi.org/10.1016/j.habitatint.2016.11.002
0197-3975/

towards sustainability is like going to a destination we have never visited before, equipped with a sense of geography and the principles of navigation, but without a map or compass" (6). With over 300 working definitions of sustainability and sustainable development (Dobson, 1996), and some definitions contradicting each other (Goodland & Daly, 1996), some feel that achieving a sustainable destination is more remote than ever (Jickling, 2000). In example, a paradox is present within the term "sustainable development" – development has been used synonymously with growth, and sustainable implies increase endlessly, which is not possible on a planet with finite natural resources (Bartlett, 2006). Despite its deficiencies, sustainable development remains an appropriate guide for creating a long-term, positive relationship between humankind and life-supporting ecosystems; albeit, bombastic and inconsistent goals hamper humanity's ability to determine if this relationship has been or will be achieved (Mayer, Thurston, & Pawlowski, 2004). Slow evolution of sustainable development has been linked to progress being mostly conceptual and methodological (Hezri & Dovers, 2006). For this study, the applied definitions for "sustainability" and "sustainable development" are adopted from Shaker (2015b: 305) as: "'sustainability' should be viewed as humanity's target goal of human-ecosystem equilibrium (homeostasis), while 'sustainable development' is the holistic approach and temporal processes that lead humanity to its end goal of sustainability."

Policy and decision makers have encouraged researchers to improve existing models and develop new techniques for managing coupled human-natural systems associated with local and regional sustainable development planning (Grosskurth, 2007). In response, the planning community sees a need for sustainable development initiatives that goes beyond lip-service and puts concepts into action. "Along with the questions 'should we?' or 'can we implement sustainable development?' more the question of 'how can we apply this concept?' dominates the literature" (Chifos, 2007). Despite uncertainty about operationalization, the field of planning acknowledges that sustainable development is an influential concept and should shape future methodology and practice (Godschalk, 2004; Jepson, 2004). That said, there remains no 'ideal' instrument for attaining sustainability on neither regional nor local planning scales (Keiner, 2006). As suggested by Wu (2008), landscape ecology appears to be the most relevant solution-driven and place-based discipline for moving humanity towards sustainability across geographical scales. Landscape ecology is the study of: i) spatial relationship among landscape elements and/or ecosystems; ii) the flow of energy, minerals, nutrients, and species (including *Homo sapiens*) among the elements; and iii) the ecological dynamics of the landscape mosaic through time (Forman, 1995). Despite numerous urban planning, environmental management, conservation, and restoration projects completed, Naveh (2007) stated that landscape ecology has had limited impact on sustainable landscape management.

Evaluation of landscapes can be accomplished through use of existing sustainable development indices, which allows for assessing connections between landscape patterns and development processes (Mander & Uuemaa, 2010). At the global level, the need for indicators was expressed in Chapter 40.4 of Agenda 21: "indicators of sustainable development need to be developed to provide solid bases for decision making at all levels and to contribute to a self-regulatory sustainability of integrated environment and development systems" (UN, 1992). At local and regional scales, indicator-based assessment of landscape function provides a fundamental tool for evaluating relationships during sustainable landscape planning (Leitão & Ahern, 2002; Mander & Uuemaa, 2010). Regional planning studies of coupled human-natural systems have been further elucidated using landscape measures and various spatial analysis tools (e.g. FRAGSTATS) (i.e., Shaker et al., 2010; Shaker & Ehlinger, 2014). Recently, for sustainable development planning purposes, Shaker (2015a) recorded significant relationships between-landscape and population variables- and development indices when investigating sustainable urbanization at the macroscale. That said, sustainable landscape function research at regional and local scales using evaluation indices of sustainability conditions remain virtually nonexistent.

While studies have employed evaluation indices to understand landscape pattern on process, few have specifically used a local sustainable development measure to assess sustainable landscape function across a country. Furthermore, although likely the most appropriate areal unit for understanding sustainable development at the landscape scale, no studies have incorporated "landscape units" into explorations of landscape patterns on sustainable development process. To address these issues and guide this study, the following two null hypotheses are tested: (1) no significant relationship exists between-landscape form and population dynamics- and the local sustainable development index (LSDI) created for Moldova; and (2) local spatial autoregressive modeling does not corroborate global ordinary least squares (OLS) regression methodology. This study also aims to deliver regional sustainability planners and landscape scientists an applied example for systematically assessing, describing, and monitoring sustainable landscape function across space.

2. A landscape unit approach

The landscape scale, "geographical landscape," or specifically the "landscape unit," may be the best management scale for assessing and monitoring sustainable landscape function across a region. A landscape unit is an areal unit that is created from a collection of *in situ* (disaggregated) spatial data, and is methodologically rooted to Russian soil science (Shaw & Oldfield, 2007). The first landscape units were published within Lev Semenovich Berg's (1947) seminal work *Geographical Zones of the Soviet Union*. It was in this research that Berg spelled out the pioneering definitions of geographical landscape and the foundational principles of the Russian landscape unit. According to Berg (1947), "A geographical landscape is that combination or grouping of objects and phenomena in which the particularities of relief, climate, water, soil, vegetation, fauna, and to a certain degree human activity, is blended into a single harmonious whole." Other physiographic land management systems have been created throughout the world, but the inclusion of human aspects makes the Russian-influenced physiographic planning system unique. Using this Eastern School of Geography's conception of landscape science, landscape units were created from the culmination of over ten years of field surveys in the Republic of Moldova (Proka, 1978, pp. 69–72, 1983). The Moldavian multi-hierarchical land management system was organized into four nested spatial scales: two zones, five regions, 74 landscape units, and 120 elementary landscape features (Fig. 1).

Increasingly, sustainability planners, scientists, and policy-makers have focused on understanding coupled human-environmental systems and there remains a need for international integration between the various landscape traditions. Neither in Russia nor the West have scientists succeeded in specifying an agreed and unproblematic understanding of landscape, or more broadly promoted a common geographical conception of human-environmental relationships (Shaw & Oldfield, 2007). The Moldavian multi-hierarchical land management system was designed to provide a useful basis for decision-making about integrated human and natural systems. For multidisciplinary projects with applied geographical and ecological aims (i.e., sustainable development), the employment of landscape units has been