

Agent-based modelling of the spatial pattern of leisure visitation in forests: A case study in Wallonia, south Belgium



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ABSTRACT

The leisure use of forests is a fast growing sector in European tourism. The difficulties in monitoring real usage pattern have hindered communications in tourism, conservation and public health in forested areas. In this study, we present an agent-based model to approximate forest visit patterns at the regional level, based on the visitor, residential and forest attributes. The model was then adapted locally for Wallonia, south Belgium, to predict the daily distribution of forest visits and visitor flows. The results suggest high visit rates in urban forests. In highly attractive forests that are distant from major cities, the visit rates may greatly respond to the visitor-level and environmental changes. Future empirical investigations are encouraged to build a cross-contextual understanding on visitors' decision-making mechanisms and to identify how these mechanisms may be influenced by environmental factors operating at different spatio-temporal levels.

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1. Introduction

The leisure use of forests is a fast growing economic sector in tourism (Young et al., 2005; Zandersen and Tol, 2009). Outdoor leisure activities are diverse and include camping, hiking, nature-observation, cycling, etc. Resulting problems relate to biodiversity conservation and exposure to forest associated vector-borne diseases. Negative impacts of leisure use may include ground vegetation loss, wildlife behaviour change and the spread of parasites and diseases, such as ticks and Lyme disease (Li et al., 2012b; Marzano and Dandy, 2012; Brearley et al., 2013; Claerebout et al., 2013). There is a need to better understand and approximate the pattern of forest leisure visitation, i.e., the distribution and number of visitors at both origins and destinations, and visitor flow, from

which further research and practices in tourism, conservation and public health can benefit.

Spatial patterns of forest leisure visits are inherently complex and heterogeneous, as individual motivations and preferences differ and can be influenced by individual and environmental factors. Empirical investigations on forest tourism is increasing, e.g., articles collected in special issues (Bell, 2010) and (Stein et al., 2011), while spatial modelling studies on understanding or predicting forest leisure visitation patterns remain rare. Existing regional-level models have mainly been focusing on the influence of travel distance (or time) (Brainard et al., 2001; de Vries and Goossen, 2002; Ode and Fry, 2006), in particular, using distance-decay functions. The visitor-level information, that may determine the travel behaviour and distance, has largely been ignored. Forest attractiveness has been considered as another key component affecting visit rates. Due to a general difficulty in data collection, forest attractiveness has been assessed using either coarse regional-level information or site-specific data on a single aspect, i.e., natural features or the land use status. The integration of cross-scale and cross-disciplinary information in the assessment of forest

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attractiveness, however, has not been achieved. These shortcomings, in many cases, can lead to a great loss in model predictive power (An et al., 2005).

Agent-based models (ABMs) can be useful to address these shortcomings. An ABM can be defined as a loosely coupled network of entities, which are autonomous and heterogeneous in nature, that have a set of behaviours and work either independently or collaboratively to solve problems, or make decisions (Durfee and Lesser, 1989). This bottom-up approach may allow predicting and explaining the emergence of system-level phenomena by tracking the behaviours and interactions of multiple individuals (the agents) constituting the system. In natural or social modelling applications, an agent can be a representation of an individual, a population segment, an organization or any other entities. Agents are autonomous and can engage in flexible interactions: (i) they are able to decide for themselves when and which actions they should perform, and (ii) they can make decisions at run time rather than design time, hence they can respond to changes in their environment. As a result, ABMs are ideally suited to address problems that have multiple perspectives and sub-objectives. They have been used widely to deal with complexity and spatial heterogeneity in the modelling of human–ecosystem interactions, especially with the assistance of GIS for the management of spatially-explicit data from multiple sources (Fontaine and Rounsevell, 2009; An, 2012; Murray-Rust et al., 2014). In human mobility studies, it has been found that humans may follow simple reproducible travel patterns (Gonzalez et al., 2008) which can suitably be integrated in ABMs.

In this study, we present a predictive modelling approach to quantify regional forest leisure visits. The term forest is used as the collective term for an area of trees, including woodland which usually indicates a relative smaller wooded area with a more open canopy. The main objective was to provide an estimation and understanding of the numbers, origins and destinations of visitors conducting day trips to forest for recreational activities, based on cross-scale data and cross-disciplinary survey results. The secondary objective was to develop an agent-based modelling framework for decision support in forestry and tourism management, by which

the effects of future environmental changes on spatial pattern of forest leisure visit could be predicted.

2. Study area

Wallonia (south Belgium) has long been attractive for outdoor pursuits. This region has an overall population density of about 200 inhabitants/km², with large differences at the local level. The population is concentrated in the northern areas mainly (Fig. 1), following the industrial axis, running from east (Liège) to west (Mons) in the 19th century (Thomas et al., 2008). Forests (5400 km²) occupy approximately 30% of the Walloon territory. These forests are mainly located in the central and southern parts of the region and are mostly far from major cities. More specifically, about 75% of the forest patches larger than 5 ha are located farther than 15 km from the centres of towns of more than 20,000 inhabitants (Colson et al., 2010). Provided more than 51% of the forest visitors have reported a travel distance greater than 10 km (Colson, 2007), trips outside of the municipality of residence may highly contribute to the regional spatial patterns of forest visitation.

The Walloon region is an excellent study area because of the availability of cross-scale and cross-disciplinary data for modelling forest visit rates. Extensive data on forest tourism have become available through three recent surveys. The first survey was a phone interview among 1005 Walloon inhabitants, on their general participation rate and preference of forest activities (Colson, 2006). The second survey was a face-to-face interview with 4046 visitors in 40 forests throughout Wallonia, on their profiles, travel behaviours and satisfaction (Colson, 2007). The third survey was a face-to-face interview with forest managers from each of the 37 local administrative districts (“cantonnements”) in the Walloon region, for their experiences of visit patterns at 1201 local forest estates (Colson et al., 2010). The first two surveys provided the best available information to characterise visitor-level behaviours during leisure trips to Walloon forests. The latter survey, from which expert knowledge had been gained, can be used to quantify the attractiveness of the Walloon forests. Along with these surveys,

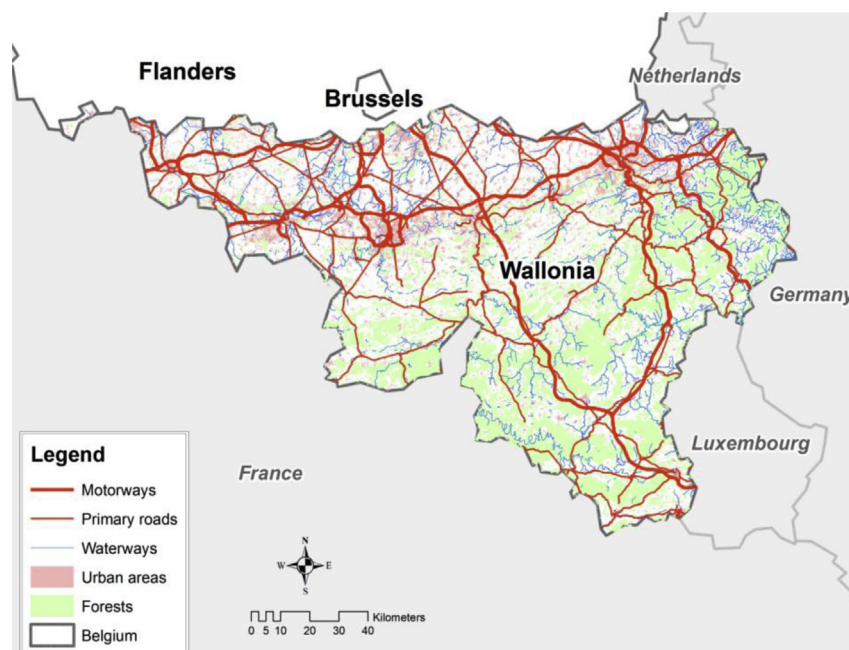


Fig. 1. Study area: the Walloon region (Wallonia) of Belgium.

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