



A group-based spatial decision support system for wind farm site selection in Northwest Ohio

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HIGHLIGHTS

- We present a prototype tool that we developed for wind farm site selection.
- Multiple participants rank the factors for promoting group-based decision making.
- The factors are aggregated by WLC technique to generate maps from participants.
- Group-based solution uses Borda method to aggregate the maps from participants.
- Sensitivity analysis is performed on the group solution to examine solution affects.

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ABSTRACT

The purpose of this paper is to demonstrate the benefits of applying a spatial decision support system (SDSS) framework for evaluating the suitability for wind farm siting in Northwest Ohio. The multiple criteria evaluation (MCE) prototype system is intended for regional planning but also for promoting group decision making that could involve participants with different interests in the development of decision alternatives. The framework integrates environmental and economic criteria and builds a hierarchy for wind farm siting using weighted linear combination (WLC) techniques and GIS functionality. The SDSS allows the multiple participants to interact and develop an understanding of the spatial data for assigning importance values to each factor. The WLC technique is used to combine the assigned values with map layers, which are standardized using fuzzy set theory, to produce individual suitability maps. The maps created by personal preferences from the participants are aggregated for producing a group solution using the Borda method. Sensitivity analysis is performed on the group solution to examine how small changes in the factor weights affect the calculated suitability scores. The results from the sensitivity analysis are intended to aid understanding of compromised solutions through changes in the input data from the participant's perspective.

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1. Introduction

A growing number of regional problems driven by social, cultural, economic and environmental forces require assistance of spatial decision support systems (SDSS) for enhancing a variety of management solutions (Gorsevski and Jankowski, 2010; Bone and Dragičević, 2009; Goosen et al. 2007; Barkan et al., 2006; Jankowski et al., 2006; Nyerges et al., 2006; Jankowski, 2000). Specifically, SDSS are explicitly

designed to help planners to solve complex problems by coupling analytical multiple criteria evaluation (MCE) models used for selecting and rating decision criteria and alternatives in combination with geographic information systems (GIS) (Malczewski, 2006, 1999). Such frameworks have been used to resolve complex issues such as siting of municipal solid waste facilities (Gorsevski et al., 2012; Donevska et al., 2012; Wiedemann and Femers, 1993), watershed management (Jankowski et al., 2006; Ramanathan et al., 2004), and land suitability analysis (Boroushaki and Malczewski, 2010a, 2010b, 2010c; Balram and Dragičević, 2005).

A number of SDSS methods and techniques have been also proposed to analyze site suitability for wind farm siting (Aydin et al., 2010; Janke, 2010; Rodman and Meentemeyer, 2006; Baban

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and Parry, 2001). Some of the methods emphasize the role of conflicting objectives such as landscape esthetics (Swofford and Slattery, 2010; Warren et al., 2005), turbine noise (Aydin et al., 2010; Devine-Wright, 2005) avian deaths (Aydin et al., 2010; Farfán et al., 2009), and shadow flicker (Harding et al., 2008; Baban and Parry, 2001). However, complex spatial problems such as wind farm suitability not only face multiple conflicting objectives but also require public–private collaborations for formulating and implementing public policies and decision-making capabilities (Nyerges and Jankowski, 2010; Jankowski, 2000; Jankowski and Nyerges, 2001a, 2001b). Other shortcomings with current SDSS include complex methodological computer applications that are mostly designed for GIS uses, lack of support of multi-user interface, and restricted access for general public participation.

Within this context, the specific processes and key players for a local level policy-making vary by location but interest groups who are directly affected by a decision and its planning consequences are often the primary candidates as stakeholders and participants in public land planning. It is argued that solving public–private problems introduces unreasonable conflicting views, such as public demand for strict environmental regulations, and on the other hand, private interests that may be alleged to be solely aimed at financial prosperity and economic greed. Thus, such antagonistic views involved in the decision process often cannot be structured adequately, quantified and modeled, which halts the planning process. In the literature, those problems are referred as “ill-defined” or “wicked” decision problems, which result in unfeasible solutions that are driven by differences in values, motives, and/or locational perspectives (Jankowski and Nyerges, 2001a, 2001b; Malczewski, 1999).

The way to overcome this weakness is through the development of new tools that allow for synergetic work that integrates computer technologies to facilitate decision-making processes through group collaboration and a flexible problem-solving environment. The empowerment of stakeholders to access those tools allows for the problem to be explored and understood at individual and group levels as well as to understand potential trade-offs between conflicting objectives (Wolsink, 2010, 2007; Devine-Wright, 2009, 2005; Toke et al., 2008; Gomboa and Munda, 2007; Kingston, 2007; Warren et al., 2005). It is expected that the main benefit of such collaborative GIS tools would provide interactive mapping and spatial analysis capabilities for enhancing group decision making in a bottom-up fashion involving all the participants from the very beginning of the planning process. In addition, the planning process is expected to evolve continuously through discussions among the participants and implementations of (1) committed effort on the part of the participants to collectively frame and address tasks that require exploration of spatial attributes and alternatives and visualization of geographical data; (2) a systematic group communication setting for participants to be fully aware of each other and collaboratively act on common goals; and (3) through provided mechanisms for exploring alternatives and building consensus from group preferences.

Some of the new approaches are implemented in a web-based environment that can support an unlimited number of users who are free to participate at their own convenient time and location (i.e., asynchronous distributed interaction model) (Berry et al., 2011; Bishop and Stock, 2010; Boroushaki and Malczewski, 2010a, 2010b, 2010c; Simão et al., 2009; Malczewski, 2006). However, any successful implementation of tools for group decision-making requires a structured theoretical framework that considers issues such as knowledge of involvement and how decisions are being made, values and expectations, including ethical concerns (i.e., justice, equity, and trust), data and information about the problem, understanding of socio-political influence, and data processing and communication tools (Nyerges and

Jankowski, 2010; Gross, 2007; Kingston, 2007; Gomboa and Munda, 2007; Carver et al., 2001; Wiedemann and Femers, 1993; Arnstein, 1969).

The main goal of this paper is to present a prototype tool that we developed and demonstrate its potential for use in the context of a group-based SDSS for wind farm site selection in Northwest Ohio. Although many group-based SDSS have been developed for various spatial decision problems in environmental and economic domains (Gorsevski and Jankowski, 2010; Boroushaki and Malczewski, 2010a, 2010b; Tang and Waters, 2005; Balram and Dragičević, 2005), there are only a few SDSS which have been developed for applications related to wind farm siting (Berry et al., 2011; Bishop and Stock, 2010; Simão et al., 2009). Thus the contribution of the proposed approach is intended to demonstrate a proof-of-concept of prototype software that we presently maintain under development and which we present here, intended for a traditional ‘face-to-face’ and multi-user interaction. Although our short-term goal is to develop a web-based approach, the underlined principles of the group-based and participatory planning process are similar and designed to involve expert and non-expert participants in the decision-making process. However, at this early stage of this project we demonstrate the methodological steps involved in the process through non-expert views, using a study group constituted by both graduate and undergraduate students. To set the context for the envisioned implementation of this flexible methodology, the prototype system is illustrated through an experimental decision scenario. This scenario demonstrates the potential of the proposed tool for assisting decision or policy-makers; the decision tool is discussed in Sections 2 and 3 describe the SDSS tool used in the experiment. Section 4 contains the results and discussion. The conclusion offers discussion ideas for future directions for collaborative SDSS tools for wind farm siting.

2. Wind farm site suitability decision scenario

This section provides an overview of the case study of wind farm site suitability analysis in Northwest Ohio. The following describes the case study design; including the study area, materials, and composition of the study group.

2.1. Study area

The study area is a 27-county region in Northwest Ohio (Fig. 1) with relatively high winds throughout the year. A wind resource assessment conducted at 50 m heights suggests that the region has sufficient annual wind speeds to support large-scale wind farms (NREL, 2004). The glaciated topography of this region has few natural obstacles to wind movement in the area. Prevailing northerly and westerly winds are the most dominant across the region. The coastal areas of Lake Erie are associated with the strongest winds in the area and within Ohio with annual average speeds of 7.0–7.5 m/s while the rest of the area has annual average wind speeds of 5.6–6.4 m/s.

The extensive wetlands in the region provide vital habitats for many birds and other plant and animal species. Bird habitats and migratory bird routes are of special concern in the area. There are 16 locations in the region identified as important bird areas (IBA) including the endangered Indiana Bat (*Myotis sodalis*) (OAS, 2009; USFWS, 2009). The demand for energy in the area comes from the estimated 1.8 million people and mostly by the industrial sector (USEIA, 2010). Ohio’s alternative energy portfolio mandates that by 2025, at least 25% of all electricity sold in the state must come from alternative sources and one-half of this electricity must be produced in the state (USEIA, 2010).

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