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A comparison of techniques for generating forest ownership spatial products

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A B S T R A C T

To fully understand forest resources, it is imperative to understand the social context in which the forests exist. A pivotal part of that context is the forest ownership. It is the owners, operating within biophysical and social constraints, who ultimately decide if the land will remain forested, how the resources will be used, and by whom. Forest ownership patterns vary substantially across the United States. These distributions are traditionally represented with tabular statistics that fail to capture the spatial patterns of ownership. Existing spatial products are not sufficient for many strategic-level planning needs because they are not electronically available for large areas (e.g., parcels maps) or do not provide detailed ownership categories (e.g., only depict private versus public ownership). Thiessen polygon, multinomial logit, and classification tree methods were tested for producing a forest ownership spatial dataset across four states with divergent ownership patterns: Alabama, Arizona, Michigan, and Oregon. Over 17,000 sample points with classified forest ownership, collected as part of the USDA Forest Service, Forest Inventory and Analysis (FIA) program, were divided into two datasets, one used as the dependent variable across all of the models and 10 percent of the points were retained for validation across the models. Additional model inputs included a polygon coverage of public lands from the Conservation Biology Institute's Protected Areas Database (PAD) and data representing human population pressures, road densities, forest characteristics, land cover, and other attributes. The Thiessen polygon approach predicted ownership patterns based on proximity to the sample points in the model dataset and subsequent combining with the PAD ownership data layer. The multinomial logit and classification tree approaches predicted the ownership at the validation points based on the PAD ownership information and data representing human population, road, forest, land cover, and other attributes. The percentage of validation points across the four states correctly predicted ranged from 76.3 to 78.9 among the methods with corresponding weighted kappa values ranging from 0.73 to 0.76. Different methods performed slightly, but statistically significantly, better in different states Overall, the Thiessen polygon method was deemed preferable because: it has a lower bias towards dominant ownership categories; requires fewer inputs; and is simpler to implement.

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Introduction

The United States is endowed with an estimated 304 million ha (751 million ac) of forest land covering 33 percent of the nation's land area (Smith, Miles, Perry, & Pugh, 2009). These forests provide a plethora of goods and services, including wood products, wildlife habitat, recreational opportunities, water purification, and carbon storage (Chopra & Dasgupta, 2008). Ownership has been shown to be an important determinant and factor in numerous natural resource issues (Jaimes, Sendra, Delgado, & Plata, 2010; Paudel & Thapa, 2004; Serra, Pons, & Saurí, 2008). The use and disposition

Abbreviations: FIA, Forest inventory and analysis program of the United States Department of Agriculture Forest Service; NLCD, National Land Cover Database; PAD, Protected Areas Database; USDA-FS, United States Department of Agriculture Forest Service.

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of forest resources is dependent upon those who control it – the forest owners – operating within the biophysical constraints of the land and the economic, regulatory, and normative constraints of society. The forests of the United States are owned by a diversity of entities including: federal, state, and local governments; private corporations; families; individuals; Native American tribes; and other groups. Ownership goals, management practices, and applicable regulations can vary widely among these entities (Bengston, Asah, & Butler, 2011; U.S. Department of Agriculture Forest Service, 2011). Many of the private lands are under growing pressure due to parcellation, fragmentation, and development (Jin & Sader, 2006; White, Alig, & Stein, 2010).

Forest ownership patterns vary substantially across the U.S., at both coarse and fine scales. For example, at the coarsest spatial and thematic scales (i.e., broad ownership categories), the forests of the eastern U.S. are 81 percent *privately* owned versus the forests of the western U.S. which are 70 percent *publicly* owned (Smith et al., 2009). At finer scales, these patterns can still be highly variable with intermingling of ownership types and resulting implications for forest policy, industry, conservation, and society. From a policy perspective, it is important to understand which tools to use where and how these tools will interact (Harper et al., 2006) – for example, different policy tools are used to mitigate wildland fire depending on the ownership patterns. From a forest industry perspective, it is important to accurately predict the supply of raw materials, be it for lumber, biomass, or other end uses, and this depends, in part, on landowners' objectives and constraints (Butler, Ma, Kittredge, & Catanzaro, 2010; Polyakov, Wear, & Huggett, 2010). From a conservation perspective, it is important to know which lands are already protected, which are most threatened, and where the greatest opportunities for land conservation exist (Stein et al., 2005). For many private citizens, outdoor recreation is important (Cordell, Betz, & Green, 2008) and the accessibility of lands depends, to a large extent, on who owns it (Snyder & Butler, 2012; Snyder, Kilgore, Taff, & Schertz, 2008). All of these issues are strongly tied to forest ownership patterns and therefore, understanding and mapping forest ownership patterns can facilitate more informed decisions to help maintain forests and the social benefits they provide. Previous studies have focused on mapping of some social dimensions related to forests (Brown & Raymond, 2007; Sherrouse, Clement, & Semmens, 2011), but not ownership.

Like all land use patterns, land ownership patterns are not random. The specific use of a given piece of ground is a function of social, economic, political, historical, and environmental factors (van Kooten, 1993). It has been posited that land ownership patterns are the results of similar factors and a modified land rent theory can be applied (Hardie, Parks, Gottleib, & Wear, 2000; Wear, 2011). Land rent theory states that a given piece of land is allotted to its highest and best use based upon the demands from society (e.g., distance from population centers) and the characteristics of the land (e.g., suitability of the land for development) (van Kooten, 1993). Using analogous logic, forest land ownership patterns can also be thought of as being a function of the demands of society and the inherent characteristics of the land (Wear, 2012).

Land rent theory, while a useful construct, is, as with all theories, a simplification of the underlying processes. There are countless other factors that also impact the ultimate land use and ownership patterns, including historical factors. Banner (2011) provides an overview of the historical ownership patterns of the U.S. and discusses the country's adaptation of the British ownership system. As the Euro-Americans progressed across the U.S., they brought with them their ownership systems. From the meets and bounds measurements of the eastern U.S., a more systematic land division system, the Public Land Survey System, was authorized by the Land Ordinance of 1785 and first implemented in Ohio. This system resulted in the very ordered, checkerboard patterns of land ownership that exist across many parts of the country.

Homesteading acts, such as the Homestead Act of 1862, have played an important role in the legitimization and distribution of lands across much of the U.S. Individuals meeting certain requirements were able to claim lands, but if they were unable to "prove their claims" or became delinquent on taxes, the land, by default, reverted to public ownership. These lands were then sold or retained by the government, many of which became the basis for the federal holdings in the western U.S. The government, at federal-, state-, and local-levels, has also actively procured land. For example, the Weeks Act of 1911 and the Organic Act of 1916 set out to place large swaths of undeveloped land into the hands of the federal government, and as a result, millions of hectares of forest land were put into federal ownership. Land grants were used as a way to encourage the western expansion of railroads and funding for school systems. Many of these allotments were made over 100 years ago, but many still persist and the effects of others, e.g., the checkerboard ownership pattern, are still very apparent.

Private companies and individuals have acquired forest land through other mechanisms besides just land grants and homesteading; namely purchases and, for some individuals, inheritances. For forest lands, it was initially companies operating sawmills, pulp mills, and other wood consuming factories that acquired large acreages. These lands tended to be in more rural areas. In more recent times, there has been large-scale divestiture of forest lands by traditional, vertically-integrated forest companies with many of these acreages now being owned by timber investment management organizations and real estate investment trusts (Zhang, Butler, & Nagubadi, 2012). Although many large parcels of forest land are owned by these corporations and their investors, private citizens make up the vast majority of forest land owners in the U.S. Ownership of land by individuals has long been an American ideal and millions of Americans now own forest land, predominately for privacy, esthetic, and family legacy reasons (Butler, 2008).

Currently, forest ownership data is available in aspatial or coarse spatial formats, with fine-scale spatial data having limited availability. Tabular data are available from the USDA-FS (e.g., Smith et al., 2009), but lack spatial detail beyond state- or county-level summaries. The current spatial datasets are incomplete in extent and/or thematic detail (i.e., only report broad ownership categories, such as public versus private). Detailed, parcel-level maps in electronic formats, while available in some areas of the country, are not available for many locales. Moreover, the available datasets are often in different and/or inconsistent formats, are not in a centralized location, can cost substantial amounts of money to acquire, and can be difficult to work with. Some commercial sources have aggregated these data, but these sources can be expensive and still exclude large swaths of the U.S. The Protected Areas Database (PAD; Conservation Biology Institute (CBI), 2010) is a national geospatial database established to document the locations of protected lands across the U.S. and includes information on ownership of protected lands. PAD is freely available for public use, and some elements of PAD are included in this study. Ongoing efforts provide periodic updates to PAD, and references here pertain to PAD-US (CBI Edition) v1.1. PAD is built by assembling spatial data from public agencies from across the country; the accuracy of PAD varies among states depending on the quality of these input data. Private ownership categories are included only for private protected areas, which comprise a small minority of all private forest holdings in the U.S. A national database of conservation easements (www.conservationeasement.us) has been created, but this source focuses only on the small segment of the private land that is under easements and is not useful for mapping broad ownership patterns. A national database of land ownership parcels is not yet available,