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Research paper

Exploring the relationship between parcelization metrics and natural resource managers' perceptions of forest land parcelization intensity

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HIGHLIGHTS

- Parcelization can adversely impact many forest-derived goods and services.
- Resource managers ranked forest ownership patterns for their impacts.
- Certain ownership patterns are seen as having greater adverse impacts than others.
- Some metrics are strongly correlated with rankings of parcelization impact.

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ABSTRACT

A major challenge associated with forest land parcelization, defined as the subdivision of forest land holdings into smaller ownership parcels, is that little information exists on how to measure its severity and judge its impacts across forest landscapes. To address this information gap, an on-line survey presented field-based public natural resource managers in the Lake States of Minnesota, Wisconsin, and Michigan with four private forest ownership patterns, each containing the same total forest area, number of parcels and average parcel size. Survey respondents ranked each landscape from most to least parcelized based on the degree to which each ownership pattern was perceived to adversely impact three forest-based goods and services: timber production, recreational access, and wildlife habitat. Using an exploded logit model, respondents' rankings of parcelization impact were found to be consistent, regardless of the forest good or service evaluated. Rankings were also not influenced by the respondent's professional discipline, location, length of professional experience, or employer. Of the four parcelization metrics evaluated, the Gini Coefficient and Adjusted Mean metrics appear to best capture the forest land ownership patterns that natural resource professionals are most concerned about, suggesting those metrics may be useful indicators by which to assess parcelization impact.

1. Introduction

Forest land parcelization is the subdivision of forest land holdings into smaller parcels. A major challenge associated with understanding the effects of forest land parcelization is that little information exists on when and to what degree forest land ownership patterns diminish the production of forest-based goods and services. Specifically, the relationship between ownership patterns and forest resource outputs is not well understood, and likely depends on the forest-based good or service in question as well as the actions and management behaviors of the landowners. Forest land parcelization has been linked to the loss of wildlife habitat (e.g., forest land subdivision has been found to be a forerunner to forest habitat fragmentation, land development, and road building), reduced timber availability (e.g., smaller parcel size has been found to be less economical to harvest and associated with a decreased landowner interest in management and investment), and greater restrictions on recreational access (e.g., smaller tracts of forest land have been found to have a greater likelihood of being posted against public access) (Dennis, 1993; Theobald, Miller, & Hobbs, 1997;

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Mehmood & Zhang, 2001; Rickenbach & Gobster, 2003; Brooks, 2003; Gobster & Rickenbach, 2004; LaPierre & Germain, 2005; King & Butler, 2005; Richenbach & Steele, 2006; Mundell, Taff, Kilgore, & Snyder, 2010). In sum, the parcelization literature makes linkages between smaller parcel size and diminished ecosystem function or output. Yet, related literature in the social sciences also suggests that different forest land ownership *patterns* may impact forest-based goods and services as well (e.g., Vokoun, Amacher, Sullivan, & Wear, 2010).

There is also no agreed-upon measure or metric for judging and comparing the extent to which a landscape has been parcelized, which creates difficulties when determining where and how to prioritize efforts to minimize the effects of parcelization. In a previous study reported in this journal, Kilgore, Snyder, Block-Torgerson, and Taff (2013) evaluated four parcelization metrics with respect to their similarity in quantifying the degree to which a forested landscape is parcelized. Their work illustrated that each metric often describes a different intensity of parcelization for a given pattern of forest ownership, attributed in large part to each metric capturing unique aspects of land tenure arrangements within a landscape. They concluded that the choice of metric used to quantify forest land parcelization within a landscape is a critical choice, but were unable to recommend a universal metric due to the context-specific nature by which ownership patterns need to be evaluated. This finding is in-line with efforts in the field of landscape ecology to identify multiple metrics that can capture various spatial characteristics of landscape composition and pattern (e.g., McGarigal & Marks, 1995).

Additional research that relates forest ownership patterns with their associated impacts on forest-based goods and services is needed. As a step toward addressing this need, we draw on the perspectives and experiences of field-based natural resource managers in relating different forest ownership patterns to their perceived impacts on different forest goods and services. Our research examines the question of whether natural resource professionals perceive differences in parcelization impact among select forest ownership patterns that vary by parcel size and pattern, and whether their perceptions are influenced by their background and experience? Specifically, we report on the findings of a study we conducted that examined rankings of forest land parcelization impact by public natural resource managers. We also examine the relationship between these rankings and several parcelization metrics that have been cited in the literature to examine the metrics' ability (or usefulness) to capture changes in ecosystem goods and services that are associated with changing forest ownership patterns.

2. Data and methods

A questionnaire was developed to solicit rankings from public natural resource managers of select forest land ownership patterns based on the degree to which they believed each pattern adversely impacts several forest resource goods and services. The questionnaire was part of a broader survey that obtained resource manager perspectives and insights on various aspects of forest land parcelization. Using modified Likert scale response items, public natural resource managers provided parcelization-related information such as their familiarity with and degree of parcelization activity in their work area, and important drivers and potential outcomes of parcelization. The questionnaire also collected background information on the respondent (e.g., years of experience, state the respondent worked in, employer, professional discipline).

The questionnaire presented natural resource managers with four different private forest ownership patterns (Fig. 1). The basis for selecting these four patterns and the forest goods and services evaluated was feedback we received at an interactive scoping session with public natural resource field professionals in MN in 2012. In that session, participants evaluated a number of different stylized and actual land ownership patterns, as well as a range of potential impacts associated with forest land parcelization. With respect to characterizing the impacts of parcelization, participants indicated that stylized ownership patterns were easier to judge than actual patterns, and that the patterns needed to reflect a wide range in individual parcel sizes.

The four patterns depicted include: 13 parcels representing considerable size heterogeneity (Landscape A), 13 parcels of nearly equal size (Landscape B), one very large parcel covering over 90% of the area and 12 equally-sized smaller parcels (Landscape C), and one large parcel covering half of the area and 12 equally-sized smaller parcels (Landscape D). This heterogeneity, particularly with respect to the size of the largest parcel in the landscape, tested whether the degree of impact is associated with the size of the landscape's largest parcel (both the literature and the feedback we received at the scoping session suggests this larger parcels play an important role in mitigating impacts).

To facilitate data analysis and the ability to compare rankings to average parcel size (the most widely-cited parcelization metric), participants were informed that each of the four ownership patterns contains the same total forest area (one section or 640 acres), number of parcels (13) and average parcel size (49 acres) (similar to the average in the region), and that the landscape is completely forested. The questionnaire instructed respondents to rank each landscape in terms of the degree to which its land ownership pattern is perceived to adversely impact each of three forest-based goods and services: timber production, recreational access, and wildlife habitat. These three were selected because they were identified during the interactive scoping session as those goods and services perceived to be most adversely impacted by forest land parcelization.

An on-line version of the questionnaire was developed using SurveyMonkey's Wufoo on-line Form Creator (www.wufoo.com). The questionnaire was tested for functionality and comprehension with three public natural resource professionals. A final version of the questionnaire was prepared based on the feedback provided from the test.

The survey's target population was field-based public natural resource managers in the Lake States, USA (Michigan, Wisconsin, Minnesota). This consisted of forestry, wildlife, recreation, planning, and conservation professionals working for federal (i.e., USDA Forest Service and Natural Resource Conservation Service, USDI Fish and Wildlife Service), state (i.e., state departments of natural resources), and county/local (i.e., county land departments, soil and water conservation districts) agencies. The region was selected due to the importance of its forests as a source of raw materials for a diverse forest products industry and an important land cover in amenity-rich areas (e.g., lakes and rivers) that are attractive for recreation and second-home development. The region also has been documented as an area where forest land parcelization has been occurring (e.g., Gobster & Rickenbach, 2004; Mundell et al., 2010; Kilgore et al., 2013).

Forest cover maps of each state were used to identify those areas in the region that are predominantly forested. Government e-mail addresses for individuals working in the forested regions of each state were obtained by searching agency websites and contacting agency information officers. The final survey mailing list consisted of 773 e-mail addresses and represented, to the best of our knowledge, a census of field-based public land natural resource professionals working in the forested landscapes of the Lake States that met our selection criteria.

The internet survey was administered in fall 2014. Survey administration generally followed the protocols suggested by

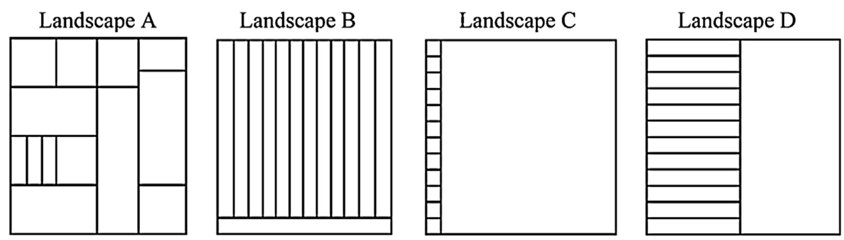

Fig. 1. Forest ownership patterns ranked by public natural resource managers for their perceived adverse impact on timber production, recreational access, and wildlife habitat. The managers were informed that each landscape has the same area (640 acres), number of parcels (13) and average parcel size (49 acres) and is completely forested.

Table 1
Usable survey responses by professional discipline and unit of government.

	Federal	State	County/local	Total
Forest management	11	99	44	154
Wildlife management	4	39	1	44
Soil & water conservation	32	0	2	34
Natural resource planning	14	2	2	18
Other[a]	3	2	1	6
Total	64	142	50	256

[a] Includes forest ecology and forest recreation disciplines.

Dillman (2000). It consisted of a pre-survey e-mail to public agency administrators (e.g., division directors) describing the study and informing them a questionnaire would be sent to their field-based employees within the next week; a pre-survey e-mail to survey recipients describing the study and indicating they would be receiving an on-line questionnaire within the next few days; an email to survey recipients with a link to the on-line questionnaire; and two follow-up reminder e-mails sent one and two weeks after the initial survey invitation, respectively. For the questions on parcelization impact rankings, the survey produced 325 total and 256 usable responses for a 42% total and 33% response rate, respectively. Only the usable responses (Table 1) were used in the modeling analyses. Due to the anonymity of the responses, opportunities to perform an analysis of nonresponse bias were limited. We compared usable responses to survey recipients for each level of government and found no significant ($X^2 = 4.2$, $p = 0.157$) over or under representation (i.e., federal, state, and county/local employees constituted 31%, 52%, and 17% of the survey and 25%, 55%, and 20% of the usable responses, respectively).

2.1. Exploded logit model

An exploded logit model (Allison & Christakis, 1994; Allison, 1999) was used to analyze the ownership pattern rankings. The model, which is anchored in random utility theory, is derived from a generalization of the conditional logit model and is used to analyze rank-ordered preference data (Luce, 1959; McFadden, 1974). The exploded logit has been applied in marketing research (e.g., Kamakura & Mazzon, 1991), health and medical studies (e.g., Hsieh, 2005; Diederich, Swait, & Wirsik, 2012), invasive species control (e.g., Paudel, Dunn, Bhandari, Vlosky, & Guidry, 2007; Touza, Pérez-Alonso, Chas-Amil, & Dehnen-Schmutz, 2014), and the environmental economics literature (e.g., Montgomery, 2002; Kumar & Kant, 2007; Scarpa, Notaro, Louviere, & Raffaelli, 2011).

In our survey, respondents were asked to rank the four ownership patterns based on how they perceive each impacting three different forest-based goods and services. All respondents ranked the landscapes for their impact on timber production first, followed by impact rankings for recreational access and then for wildlife habitat. While we did not specifically offer (or prevent) the option of tied rankings in the instructions, none of the respondents specified tied rankings. Ten respondents provided incomplete ranks. Due to the computational challenge in handling incomplete rankings and the small number in our dataset, these responses were removed.

Invoking the random utility theory framework, it is assumed that an individual, i, has preferences over the set of landscapes, J, such that the utility derived from a choice j, U_{ij}, can be specified as:

$$U_{ij} = u_{ij} + \varepsilon_{ij} \quad (1)$$

where U_{ij} is the sum of a systematic component u_{ij} and a random component ε_{ij}. While the U_{ij}'s are unobserved, it is assumed that an individual will give landscape j a 'higher' rank than landscape k whenever $U_{ij} > U_{ik}$.

The systematic component can be expressed as a linear function of explanatory variables:

$$u_{ij} = \beta_j x_i \quad (2)$$

where x_i is a vector of attributes associated with the individual i and β_j is a vector of coefficients associated with landscape j. The value of the u_{ij}'s indicates the degree to which the respondent i 'prefers' landscape j (i.e., deems it to be more adversely impacting) over all of the other landscape choices. Thus, in comparing landscapes 1 and 2, the odds of ranking landscape 1 over landscape 2 is calculated by $\exp\{u_{i1} - u_{i2}\}$.

Where the exploded logit model specification deviates from the traditional multinomial logit model is in the expansion or 'explosion' of a single observation of J-ranked alternatives into J-1 independent decisions, each based on a decreasing set of alternatives such that ($U_{ij} > U_{ik}$) can be interpreted as ($U_{i1} > U_{ij}$, $j = 2$ to J), ($U_{i2} > U_{ij}$, $j = 3$ to J), and ($U_{i3} > U_{ij}$, $j = 4$ to J). The ranking decisions are treated as a sequence of choices in which the landscape with the greatest parcelization impact is chosen over all the other landscapes, then the landscape with the next greatest parcelization impact is chosen over the remaining landscapes, and so on. Thus the respondents' ordering of the landscapes reflects the rank order of the utilities of the choices.

The likelihood function (L_i) for a single respondent is specified as follows following the random utility model:

$$L_i = \prod_{j=1}^{J} \left[\frac{\exp\left\{u_{ij}\right\}}{\sum_{k=1}^{J} \delta_{ijk} \exp\left\{u_{ik}\right\}} \right] \quad (3)$$

where $\delta_{ijk} = 1$ if $Y_{ik} > Y_{ij}$ and 0 otherwise, where Y_{ik} and Y_{ij} are the ranks given to landscapes k and j by respondent i, respectively.

For a sample of n independent respondents, the following log likelihood function is implied from Eq. (3):

$$\log L = \sum_{i=1}^{n} \sum_{j=1}^{J_i} u_{ij} - \sum_{i=1}^{n} \sum_{j=1}^{J_i} \log \left[\sum_{k=1}^{J_i} \delta_{ijk} \exp\left(u_{ik}\right) \right] \quad (4)$$

The model was estimated using the partial likelihood procedure Proc PHREG in SAS 9.4 for estimating proportional hazards models following Allison and Christakis (1994).

To allow ranked data, such as ours, to be analyzed with the exploded logit model, a dataset stratified by the respondent needed to be prepared. That is, from our ranked landscape data, an expanded dataset was developed in which a separate record was created for each respondent for each of the four landscapes, for a total of 1024 records. Each record consisted of a unique identifier for each respondent, the ranking of the landscape, a dummy variable associated with each landscape, and covariates associated with the respondents such as professional discipline and years of experience.

Several exploded logit models were estimated. First, a model was run to test whether natural resource professionals perceive any differences in the degree of parcelization impact among the four landscapes. This test was accomplished by modeling three of the four dummy variables for the landscapes as the independent variables with landscape C (Fig. 1) as the reference category; i.e., the $u_{ij} = \beta_j$ for all i and j, with one of the β_j's set to 0 as the selected reference landscape. Additional models were run to evaluate whether the rankings were influenced by attributes associated with the respondents rather than just random variation. Thus, separate models were estimated to test the null hypotheses that the rankings do not vary by the respondent's years of experience, state the respondent worked in, and/or professional discipline. These models also included interaction terms (e.g., discipline × landscape, years of experience × landscape) to test whether combinations of the covariates have a non-additive effect on parcelization rankings.

In an attempt to better understand the relationship between the rankings of parcelization impact and several parcelization metrics that have been cited in the literature, the following four metrics were examined: mean parcel size, Shannon entropy index, Gini coefficient, and Adjusted Mean. The Shannon entropy index and Gini coefficient are also used in the landscape ecology literature to quantify landscape structure (McGarigal & Marks, 1995). Mean parcel size is the average size of all private forest land parcels in the landscape. The Shannon entropy index measures the heterogeneity of forest parcels within landscape. The Gini coefficient also measures parcel size distribution within a landscape. Adjusted Mean takes into account the number and spatial extent of small parcels in a landscape. See Kilgore et al. (2013) for additional information on these metrics. Ordinary least squares regression was used to examine the relationship between exploded logit models' odds ratios and Gini, Shannon, and Adjusted Mean parcelization metrics.

3. Results

Natural resource managers' rankings of the four landscapes with respect to how each ownership pattern was perceived to impact timber production, wildlife habitat, and recreational access are shown in Table 2. An initial set of models was developed that allow for differences in rankings across the four forest ownership patterns (landscapes), but not for differences across public natural resource managers (Table 3). Global model tests for the null hypothesis that there are no perceived differences in the impacts associated with the four landscape ownership patterns produced a likelihood ratio chi-square statistic of 279 for the timber production model, 287 for the wildlife habitat model, and 322 for the recreational access model, all with 3 degrees of freedom. The p-values associated with these chi-square statistics are all less than 0.0001, so we reject the null hypothesis in all three instances. That is, natural resource managers perceive the four ownership patterns to have differential effects on each of the three forest resource goods or services evaluated: timber production, wildlife habitat, and recreational access.

Estimates of the β_j model parameters for these three models are presented in Table 3 in the order they were ranked by natural resource managers for each of the three forest resource goods and services we evaluated. Note that all parameter estimates are in reference to Landscape C. The parameter estimates tell us that natural resource managers perceive the ownership pattern associated with Landscape B has the greatest adverse impact on all three forest goods and services evaluated (timber production, wildlife habitat, recreational access), with the ownership pattern represented in Landscape C having the least adverse effects on these forest resources. The β_j values represent the difference in log odds relative to Landscape C. For example, the odds that natural resource managers perceived Landscape B to have greater adverse impact on timber production is 4.62 times the odds of perceiving Landscape C as having greater adverse impacts ($e^{1.53} = 4.62$). Similarly, the odds that natural resource managers perceived Landscape A to have greater adverse impact on wildlife habitat is 2.72 times the odds of them perceiving Landscape C as having greater adverse impacts. Note that comparisons between any two land ownership patterns can be made by exponentiating the differences in the parameter estimates.

The rankings for all but three pairwise landscape comparisons are significantly different (p-values less than 0.0001) (Table 3). Rankings of parcelization impact are not significantly different ($\alpha \leq 0.05$) between Landscapes A and D with respect to their impacts on timber production, wildlife habitat and recreational access. The parameter estimates for the three models also tell us that public natural resource managers consistently ranked the four landscapes from most to least adverse impactful, regardless of the forest good or service they evaluated. In other words, the ownership pattern associated with Landscape B was always considered to have the greatest adverse impacts, while the ownership pattern associated with Landscape C was consistently perceived to be least adverse with respect to its impact on timber production, wildlife habitat, and recreational access.

Additional models were developed to test the null hypothesis that natural resource professionals' perceptions of forest parcelization impact are not influenced by their background and experience. Specifically, the models tested whether rankings of parcelization impacts are associated with the respondent's employer (e.g., federal natural resource agency), discipline focus (e.g., forest management), or geographic location (e.g., Minnesota), as well as interactions among these variables. None of the models provide additional information on how or whether these variables influence the respondents' perceptions of the different ownership patterns impact on timber production, wildlife habitat, and recreational access, so we cannot reject the null hypothesis. Stated differently, the respondents' state of residence, employer, and professional discipline has no statistically significant effect ($\alpha \leq 0.05$) on their ranking preferences.

Table 3 also contains the values of each of the four parcelization metrics examined by Kilgore et al. (2013) for the four ownership patterns evaluated by public natural resource managers. The Adjusted Mean and Shannon indices are both positively correlated with the respondents' perceptions of parcelization impacts, while the Gini coefficient is inversely related to their rankings (by definition in how the Gini is specified). Mean parcel size is constant across the four landscapes.

Fig. 2 depicts the relationship between the odds ratios associated with the parameter estimates for the three models described in Table 3 and the Gini, Shannon, and Adjusted Mean values for the four land ownership patterns evaluated. While all three metrics are strongly associated with the ranking preferences of natural resource professionals, Gini and Adjusted Mean have the strongest linear correlation with the model-derived odds ratios across the three forest goods and services evaluated. In other words, these two metrics best capture the rankings of how our respondents viewed the four forest ownership patterns presented to them with respect to their impacts to timber production, wildlife habitat, and recreational access.

Table 2
Natural resource managers' rankings of ownership patterns according to perceived degree of adverse impacts on timber production, wildlife habitat, and recreational access. Perceived greatest adverse impacts are assigned a rank of 1; perceived least adverse impacts are assigned a rank of 4. Values represent percent of time rank was assigned. Percentages may not always total 100 due to rounding.

Rank	Landscape A			Landscape B			Landscape C			Landscape D		
	Timber	Wildlife	Rec access	Timber	Wildlife	Rec access	Timber	Wildlife	Rec access	Timber	Wildlife	Rec access
1	13	13	13	76	77	79	11	9	8	0	1	1
2	46	41	40	13	13	12	2	2	1	39	45	47
3	36	39	40	1	2	2	4	6	7	59	52	50
4	5	6	6	9	9	7	83	83	85	2	2	2

Table 3
Exploded logit model results describing natural resource managers' rankings of ownership patterns according to perceived degree of adverse impacts on timber production, wildlife habitat, and recreational access.

Private forest ownership pattern	Timber production β_j	Wildlife Habitat β_j	Recreational Access β_j	Parcelization metrics			
				Gini	Adjusted mean	Shannon	Mean
Landscape B	1.53	1.58	1.70	0.01	11.92	2.56	49.00
Landscape A	1.04	1.00	1.05	0.38	5.42	2.36	49.00
Landscape D	0.91	0.98	1.03	0.46	6.50	1.94	49.00
Landscape C	0.00	0.00	0.00	0.91	0.49	0.49	49.00
Global model statistics	$\chi^2 = 279$ $p < 0.001$ $-2LL = 12867$	$\chi^2 = 287$ $p < 0.001$ $-2LL = 12691$	$\chi^2 = 322$ $p < 0.001$ $-2LL = 12778$				

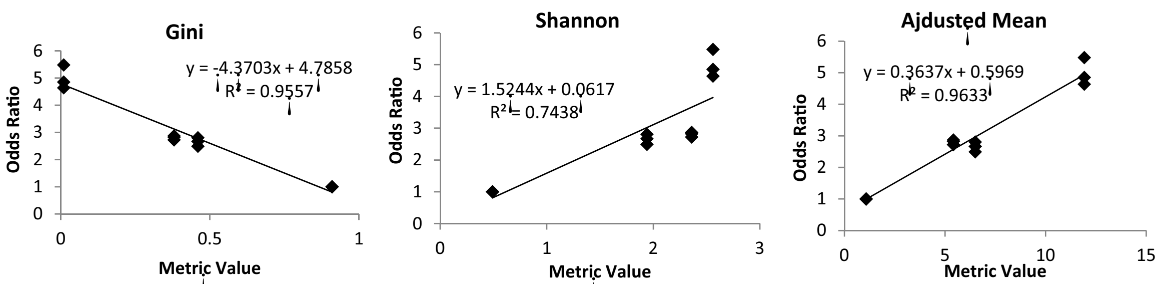

Fig. 2. Relationship between exploded logit models' odds ratios and Gini, Shannon, and Adjusted Mean parcelization metrics.

4. Discussion and conclusions

Our research sought to improve our understanding of how different private forest land ownership patterns are perceived to impact the ability of forests to provide different goods and services. By evaluating public natural resource professionals' perceptions of parcelization impact associated with different patterns of land ownership, we were able to characterize which of the four ownership patterns are perceived to have the most deleterious effects on three forest-based goods and services: timber production, wildlife habitat, and recreational access. We were also able to examine how several parcelization metrics explored in earlier research (and in the landscape ecology literature) relate to perceptions of impact that are associated with different forest land ownership patterns. To our knowledge, neither analysis has previously been reported in the literature.

We found that rankings of parcelization impact do not change, regardless of whether the impacts are in reference to timber production, wildlife habitat, or recreational access. We further found that these rankings are not influenced by several factors that vary across the population of public natural resource managers in the Lake States such their professional training, location, professional experience, or employer.

We determined that several parcelization metrics align with the rankings of parcelization impact provided by our survey respondents. In particular, the values associated with the Gini and Adjusted Mean metrics are very highly correlated with the log odds associated with each of our model's parameter estimates. This suggests that, of the metrics we evaluated, these two best capture the forest land ownership patterns that public natural resource professionals are most concerned about with respect to their impact on timber production, wildlife habitat, and recreational access. As such, they may be useful indicators of the effects of parcelization.

Judging by the rankings, the landscape containing the largest intact holding is viewed to be least impactful, irrespective of the amount of ownership fragmentation or the size of ownerships that surround this parcel. For example, public natural resource professionals regarded Landscape C, with a single 587 acre parcel as having the least adverse impact on timber production, wildlife habitat, and recreational access, even though it has more extremely small parcels than the other three landscapes.

Yet, the size of the largest patch is a not always a good indicator of parcelization impacts. For example, Landscape D (with half of the surface area in a single parcel) and Landscape A (the largest parcel captures less than 19% of the total surface area) were ranked equally in terms of the impacts on timber production, wildlife habitat, and recreational access. This suggests there may be a threshold size for the dominant parcel (percent of surface area within a landscape) below which its ability to mitigate the impacts of parcelization is limited. It also may suggest there may be other factors at play other than the size of the dominant parcel. For example, Vokoun et al. (2010) found that incremental increases in the number of private individuals bordering a parcel increased landowner willingness to consider jointly planning forest management with neighbors (e.g., conduct a timber harvest, improve habitat). This could help explain why Landscape A, with a larger number of adjacent owners to individual parcels, is perceived to have the same level of impact as Landscape D, even though the latter contains a much larger single, contiguous parcel.

The strong correlation between the parcelization impact rankings and Gini and Adjusted Mean values suggests these metrics may have important practical use to natural resource managers. To the extent this relationship exists, the metrics can help identify those areas within a landscape whose ownership patterns are most/least likely to impair forest function. Knowing where these areas are can assist managers in prioritizing efforts aimed at reducing parcelization impacts. Such efforts might include fee acquisition or conservation easements to protect large, contiguous holdings from subdivision, land use zoning that establishes minimum parcel and development standards, and property tax programs that provide financial relief to landowners who meet certain ownership and/or land management requirements. Additional research is needed to examine how well these metrics relate to perceptions of impact across a wider range of ownership configurations than the four patterns evaluated in this study. Likewise, further research might test the applicability of other indices used to describe habitat fragmentation as a measure of parcelization impacts.

Our findings need to be interpreted with some caution. We assumed survey participants were presented with a sufficient number and types of ownership patterns that would enable them to identify differential impacts for each forest-based good or service in question. We also assumed the ownership patterns we presented were realistic, and that respondents knew enough about parcelization impacts to provide meaningful, differentiated responses, both according to the ownership patterns they evalauted and the goods and services impacted by parcelization. We are doubtful all of these assumptions were fully met. Follow-up research is needed to evaluate the validity of these assumptions. Additionally, our study only surveyed public natural resource professionals in a three-state area. Research that examines the relationship between ownership patterns and their impacts in other parts of the country and includes perspectives beyond public natural resource managers (e.g., private landowners) is needed to determine the extent to which our findings have broader applicability.

We view our research as an initial attempt to correlate natural resource professionals' rankings of parcelization impacts for a specific forest output or use such as timber to different parcelization metrics assigned to the same landscapes. While we view this work as exploratory, the results are informative in that they describe how landscapes containing certain ownership features (e.g., one large parcel among several small ones) are viewed relative to their impact on various forest goods and services. We believe this research could be a precursor to a more in-depth study where, with the help of a multi-disciplinary team of scientists, forest ownership patterns and the associated parcelization metrics can be more precisely linked to specific landowner actions and their economic or ecological effects (e.g., inability to sustain commercial timber harvesting, water quality degradation). Such research would advance our understanding of how to more precisely measure the impact land ownership patterns have on a specific forest good or service.

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