2018

Natural Amenities and Rural Development: A Multilevel Analysis of Regional Trends and Local Patterns

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NATURAL AMENITIES AND RURAL DEVELOPMENT: A MULTILEVEL ANALYSIS OF REGIONAL TRENDS AND LOCAL PATTERNS

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Bachelor of Arts in Economics, University of Montana, Missoula, Montana, 2016

Thesis

Presented in partial fulfillment of the requirements
for the degree of

Master of Arts
in Economics

The University of Montana
Missoula, MT

May 2018

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As rural communities began seeing increased rates of growth following the rural rebound of the 1970’s, many studies have examined the causes and consequences of this shift through the lens of regional amenities and migration trends. Additionally, as development patterns have moved outwards from concentrated growth in urban areas to sprawling development at the rural-urban fringe, many studies have examined the locations of rural development in relation to open space and the amenities it provides. However, examinations of the relationship between these two processes have been severely lacking in the field of land use studies, despite widespread acknowledgement that the scale of analysis influences observed patterns and conclusions reached. Therefore, this analysis implements a multilevel random intercept probit model relating fine-scale development patterns to natural amenities and accessibility characteristics measured at that level, as well as community-wide measures of natural amenities, accessibility, and socioeconomic characteristics. In doing so, this analysis finds a number of natural amenities that significantly influence which communities see development, amenities that influence where that development occurs around communities, as well as some amenities that play significant roles in both processes. Furthermore, the findings presented here suggest that natural amenities have a stronger influence on development in New West communities as well as less remote communities. Combined, these results provide important insights for rural communities trying to capitalize on the benefits of economic growth while conserving the ecological integrity of the landscape that is driving that growth.

Introduction

Going against the grain of most of the 20th Century, throughout which rural America experienced widespread loss of economic opportunity and extensive out-migration, the 1970's witnessed a reversal of the country-wide trend toward urban concentration. Referred to as the 'rural rebound', for the first time in 150 years non-metropolitan growth exceeded that of metropolitan areas, with 80% of rural counties gaining population (Johnson, 1999). This trend continued on in the 1990's, with rural counties seeing an increase in population of about three million people from 1990 – 1996 (Johnson and Beale, 1998), before eventually slowing to an increase of just over two million people between 2000 and 2010 (Johnson, 2012). While some communities undoubtedly benefit from the uptick in economic activity that growth brings, increased development in rural areas also has serious implications for the natural landscapes into which this growth in encroaching.

These rapid-growth rural areas are often characterized by a high level of natural amenities, defined here as environmental features that improve a community's quality of life; such as access to wilderness areas, access to lakes and rivers, and a high degree of landscape variation. With these natural environments often providing crucial support for regional biodiversity, this rural development trend poses significant risk of habitat loss. As housing growth rates in the land immediately surrounding U.S. protected areas were higher than the national average throughout the 1990's (Radeloff et al., 2010), the ecological integrity and connectivity of these vital wildlands is becoming increasingly threatened.

The natural amenity-rich Inter-Mountain West Region of the Rocky, Cascade, and Coastal Mountain Ranges, with scenic landscapes full of abundant recreational opportunities and easily accessible national parks, is emblematic of this shift in development patterns. With the Greater Yellowstone ecosystem experiencing a 350% increase in the area of rural land supporting exurban housing densities during 1970-1999 (Gude et al., 2006), previously isolated communities are dealing with the pressure of balancing the economic benefits of growth with the conservation of the landscape that is spurring this development.

Furthermore, with a 387% increase in population density between 1940 and 2000 in the area around Rocky Mountain National Park (Davis & Hansen, 2011), heightened rural development rates are in part caused by the increasingly important role that location-specific amenities play in influencing regional migration patterns (Graves, 1979; Rappoport, 2007). Referred to as the 'New West', one aspect of this region-wide shift in growth patterns is the in-migration of highly educated out-of-state individuals, large seasonal and tourism-based populations, and increasingly high housing values in amenity rich areas (Winkler et al., 2007); resulting in continued pressure on natural environments despite the decreased employment in resource extraction based industries that traditionally characterized the American Inter-Mountain West.

In addition to changes in regional growth, smaller scale development patterns have also undergone a transformation. Whether driven by a desire to escape from urban disamenities such as congestion or crime, often referred to as a flight from blight (Mieszkowski and Mills, 1993); or attracted to the amenities of open land, development has become increasingly sprawling, with the area of exurban development reaching fifteen times the area of urban development in the U.S. by 2000 (Johnson et al., 2005). Improvements in transportation and infrastructure have decreased the costs of commuting (Glaeser and Kohlhase, 2004), and allowed for more dispersed development that is increasingly spreading into lowly-populated rural areas surrounding urban centers. Open space, and the natural amenities it provides, is often found to be a significant driver of development in exurban areas (Irwin and Bockstael, 2004; Irwin and Bockstael, 2007; Wu et al., 2004), shaping land use in the western U.S.

Although many studies have examined the causes and consequences of large-scale regional growth patterns or the drivers of smaller-scale development decisions, less is known about the relationship between these two processes. Natural amenities, in addition to directly influencing development patterns through a desire to live in close proximity to amenity-rich areas, could also have an indirect effect on development through influencing the regional migration trends that shape development patterns. Single-level models looking at fine-scale development within a single area take population growth into the region to be exogenous, thus failing to explain the larger-scale factors that shape that growth. Likewise, single-level models looking at macro-scale regional trends fail to provide information on the drivers of small-scale development location decisions, and attempts to apply aggregate-based conclusions to lower level processes can result in inference errors (Robinson, 1950). As the scale of analysis in land use studies has been found to influence observed patterns and relationships (Veldkamp et al., 2001; Overmars and Verburg, 2006), single-level analyses are not well equipped for the hierarchical structure of the land use change process. Therefore, in order to more completely understand the role that natural amenities play in land use change, a multilevel framework that explicitly accounts for processes operating at both the local level as well as the regional level should be used. Additionally, by including variables at the local level and aggregated to the regional level, comparisons of the effects at both levels of the process can be made (Snijders and Bosker, 2012). Specifically, how have natural amenities influenced differences in rates of growth between American Inter-Mountain West communities and the locations of development within and around those communities during 1990 – 2010?

Theory of Population Migration and Rural Development

In examining regional migration trends, Roback's (1982) general equilibrium theory provides an important foundational lens through which the drivers of migration can be understood. Positing individual worker utility to be a function of wages, cost of living, and location specific amenities; under free labor mobility, workers would theoretically pursue the highest utility available to them. As location specific amenities are fixed and assumed to provide positive marginal utility, wages and cost of living must adjust across locations to equalize utility and keep workers from migrating to a location that would yield a higher utility. The fact that there are persistent wage differentials across locations then indicates the existence of some unmeasured amenity that is keeping workers from leaving low-wage locations and pursuing the highest wage possible. As preferences for various amenities likely differs by person, those people who more strongly prefer places with abundant natural amenities will choose to accept a lower wage and sort themselves into higher amenity regions.

As workers sort themselves into amenable regions based on preferences, landowners in those locations choose to either develop their land for residential purposes or leave it undeveloped. In choosing to convert land into residential development, landowners at each time period compare the costs of development with the returns to development at each time period, and choose to develop when the expected discounted sum of net benefits are maximized over an infinite horizon (Carrión-Flores and Irwin, 2004). The landowner development decision, in which the returns to development must at least equal the costs of development plus the rent that would be earned by keeping the land undeveloped as given by Carrión-Flores and Irwin (2004) is shown by Eq. (D1):

$$R(x_{it}) = C(w_{it}) + A(z_{it}) \qquad \text{(D1)}$$

Where the development of subplot (i) at time (t) depends on the one-time return from development (R), which is a function of (x) variables influencing the value of development; the costs of development (C), a function of (w) variables influencing the expenses of development; and the rent that would be earned by keeping the subplot as is (A), itself a function (z) variables. As demand drives the returns to development, the vector (x) consists of various characteristics driving the demand for a particular subplot, such as proximity to a particular natural amenity feature. The costs of development are primarily influenced by characteristics such as the terrain and the accessibility of infrastructure necessary for development. Lastly, the rent from keeping the subplot undeveloped, often for agricultural purposes, can depend on factors such as soil quality and proximity to markets. Therefore, analyses that view the relationship between natural amenities and rural residential development at only one level fail to capture the full effect that natural amenities have on develoment.

Thus, natural amenities influence residential development both by increasing the overall population of an area, and by increasing the returns to development of a particular subplot. As those individuals with a higher preference for natural amenities migrate to more amenable locations, the demand for housing will increase, therefore increasing the returns to development for landowners. Additionally, particularly amenable subplots will see a higher probability of development, even if the overall growth of the region is low. Conversely, while a particular region may be growing quickly, those subplots characterized by dis-amenable features will likely refrain from seeing development. Lastly, with more amenable parcels of land initially commanding higher returns to development, an increased demand for housing due to regional growth further increases the returns to development, theoretically causing landowners to develop in an earlier time period than if the returns were strictly a function of parcel-specific characteristics.

Literature Review

Regional Growth

Following the rural rebound that some communities experienced during the 1970's, research began focusing on the reversal of the longstanding trend of population centralization and on analyzing the drivers of migration to previously remote, sparsely populated rural regions in the U.S. In analyzing the relationship between desirable climatic conditions such as moderate temperatures and migration patterns, Graves (1980) highlighted the growing importance of location-specific amenities in shaping migration patterns under the assumption that demand for natural amenities increases as income increases. The idea that rising U.S. incomes has resulted in a greater demand for amenity-rich locations is supported in Rappoport's (2007) study of the relationship between nice weather and migration, finding that climate didn't have a strong effect on migration patterns until the 1920's, which he attributes to incomes rising above a certain level. Additionally, as transportation costs have declined by over 90% during the 20th century (Glaeser and Kohlhase, 2004), once remote areas have become far more accessible, further increasing the attractiveness of living in amenity-rich areas.

In a foundational work on the household location decision, Roback's (1982) general equilibrium theory posited that regional wage differentials are explained by location-specific differences in amenities. As the West was experiencing high population growth rates in the face of relatively low wages, this analysis suggests that choosing to live in the West could reflect a higher demand for some local amenity, such as climate, mountainous and forested landscapes, or access to wilderness areas. This idea is supported by Power and Barrett (2001), who point out that despite a growing wage gap between the Mountain West and the rest of the U.S. during the 1980's and 1990's, approximately three million residents moved into the region, attributing this fact to a compensation through regional amenities. Further work focused on the specific effect of natural amenities on regional growth, such as McGranahan's (1999) study of county-level population growth along a natural amenity based scale, in which it was found the rural West, scoring highest on the amenity scale, experienced a growth rate of 65% from 1970-1996, compared to only 5% in the lowest scoring rural Midwest region. The result of this increased influence of natural amenities on population growth is that while rural areas were experiencing an influx of migration, there were also stark regional differences in rural growth patterns.

Natural Amenity Led Growth

The conclusion that natural amenities are a significant driver of regional growth is mirrored in the work of Deller et al. (2001), who find that all five natural amenity indices of climate, land, water, winter recreation, and developed recreational infrastructure are positively related to measures of economic growth. McGranahan's (2008) finding that migration to rural areas is strongly influenced by preferred landscape qualities characterized by a mix of open land, forest, water, and topographic variation also supports this conclusion. Analyzing migration trends in regions categorized along a rural-urban continuum, Chi and Marcouiller (2013) find that natural amenities have the largest effects on migration for rural communities adjacent to urban areas, with viewsheds, and the presence of water, public lands, and golf courses all significantly affecting in-migration. Furthermore, a more moderate climate has been found to be a significant driver of regional migration (Cragg and Kahn, 1997; Rappaport, 2007). Although other findings suggest climate influences migration within the same county more than influencing migration between counties (Cheshire and Magrini, 2006). As improvements in technology have allowed for growth in previously remote, rural regions, quality of life factors are playing an increasingly strong role in the migration decision and leading to heightened development pressures in those regions endowed with an abundance of natural amenities.

While many findings support the conclusion that the presence of natural amenities is associated with higher levels of growth and development, other studies have yielded contradictory results. Examining the effect of natural amenities on local population change at the MCD-level in Wisconsin from 1970-2000, Chi and Marcouiller (2011) found that economic conditions influenced growth more strongly than natural amenities during the 1980's, although this finding was reversed for the 1990's. Referencing the fact that the 1980's can be characterized as a period of relative population centralization with the 1990's shifting towards more decentralized growth, they conclude that neither economic conditions nor natural amenity levels can be generalized to describe the population distribution process across time periods and stress the importance of both local characteristics and macro-level temporal economic conditions in analyzing migration patterns. Additionally, in examining the relationship between county level population growth in Michigan, Minnesota, and Wisconsin during the 1980's and river, lake, land, warm weather, and cold weather-based amenity indices, it was found that none of the five natural amenity indices exerted a significant influence on population growth (Kim et al., 2005). However, it is not at all clear that these results will extend from the Great Lakes region to the Western Mountain region.

Growth Around National Parks

When examining growth trends of the protected area ecosystems surrounding U.S. National Parks, it has been found that both population density and housing density have increased much faster than the national average (Davis and Hansen, 2011; Radeloff et al., 2010), signifying an increasing demand to live near the amenity-rich landscapes of national parks. Analyzing the rates and drivers of growth in counties within the Greater Yellowstone Ecosystem, Gude et al. (2006) find proximity to national parks as well as other natural amenity measures such as forested areas and warmer climates to be significantly correlated with increases in rural home density. Furthermore, their finding that the five counties that experienced the largest increases in rural homes from 1970-1990 gained 12 times more homes than the five counties with the smallest increases highlights the heterogeneous nature of the rural rebound, as some rural areas experienced high rates of growth not seen in other rural areas. While finding natural amenities such as forest cover or percent of land in nature preserves to be significantly correlated with county level population change, accessibility to larger markets through reliable transportation infrastructure is also found to be a significant factor of growth (Rasker and Hansen, 2000), with travel time to a major airport found to explain 15-25% of the variation in different measures of economic performance among Western counties (Rasker et al., 2009).

Decreasing Transportation Costs

In analyzing the influence of natural amenities on growth and development, most of the current literature focuses on growth patterns within the region closely surrounding the amenity, assuming that the effects of natural amenities only operate through the demand of living in the immediate vicinity of various amenities. However, in light of decreasing transportation costs, this is an increasingly unrealistic assumption to make. Departing from this trend in the literature, Schmidt and Courant (2006) examine whether environmental amenities that are distant from, yet still accessible to urban areas lead to negative compensating wage differentials, finding evidence that individuals are willing to take a 4% drop in earnings in order to be 100 miles closer to a "nice" place. Defining "nice" places as those areas with national parks, shorelines, and recreation areas, their work shows that past studies of the effects of natural amenities on regional growth may be systematically underestimating their true effects by restricting their analysis to the region containing those amenities.

Furthermore, decreasing transportation costs are changing the relationship between urban and rural communities, as increased commutability means urban centers and the rural areas adjacent to them are becoming more interdependent in terms of employment and population growth. Examining the effect of distance to urban areas on surrounding county-level rural population growth, Partridge et al. (2008) find that rural counties adjacent to higher-tiered urban areas experience 2.6% higher population growth per year than rural counties at the average distance from urban areas. Similarly, it has been found that the effects of urban population growth tend to spread to surrounding rural areas rather than absorbing rural growth, signifying a desire for living in the rural landscapes at the urban fringe (Partridge et al., 2007). The increased integration of rural and urban communities means that while the drivers of regional migration such as natural amenities may result in growth in certain urban areas, that growth simultaneously influences the likelihood of rural development. Thus, an analysis of the effect of natural amenities on rural development must account for both regional effects as well as localized effects on the household location decision.

Local Development

As opposed to examining growth and development on a regional level, a large body of literature has instead focused on localized drivers of land use change at a much more detailed and disaggregated scale, investigating the causes and consequences of residential land conversion at the rural-urban fringe. It is well documented that U.S development patterns are becoming more sprawling overall, with development in one-third of U.S. counties becoming less dense over 1960-2000 (Theobald, 2001) and the area of exurban development occupying nearly 15 times the area of higher-density urban settlement by 2000 (Johnson et al., 2005). In analyzing the factors that influence this sprawling pattern of land use change, open space, often characterized by scenic landscapes with an abundance of natural amenities and recreational opportunities, is found to be valued by homeowners (Irwin and Bockstael, 2001; Irwin, 2002; Geoghegan, 2002) and a significant driver of fragmented land use change patterns in exurban areas (Irwin and Bockstael, 2004; Irwin and Bockstael, 2007; Wu et al., 2004). Additionally, a preference for living in low density areas nonetheless accessible to the urban amenities of existing development has been shown to be an important determinant of rural residential development (Carrión-Flores and Irwin, 2004; Carrión-Flores et al., 2010). Along with the observed influence of natural amenities in driving regional growth trends, the findings of this field of literature show that the spatial distribution of amenities also plays a role in determining localized development patterns.

Amenities and Housing Prices

Understanding how individuals value open space provides insight into observed patterns of sprawl in rural residential development and how to enact sensible and efficient growth policies that conserve open space amenities without cutting off potential sources of growth for rural and urban communities. Using an instrumental variable hedonic modeling approach to determine the effect of open space on residential land values while addressing both potential spatial dependence of land use change among neighboring parcels and spatial correlation among explanatory variables, Irwin and Bockstael (2001) find a positive and significant effect of open space on property values and that the prices increases with the proportion of land that is publicly owned. Additionally, individual natural amenity features of open space such as parks, lakes, and scenic views have been found to influence housing prices (Wu et al., 2003) as well as agricultural land prices (Bastian et al., 2002), with the presence of a forest view increasing urban housing values by 4.9% (Tyravinen and Miettinen, 2002). However, it is unclear as to whether the observed effect of open space on housing prices is primarily driven by open space natural amenities or a result of a promised absence of development, as Bockstael (2002) finds a premium associated with permanently preserved open space relative to developable agricultural and forested lands, and Geoghegan (2002) finds permanently preserved open space is three times more valuable than open space that could potentially be developed.

Amenity Led Development

As an alternative to the flight from blight theory in which households choose to locate on the outskirts of highly developed areas in order to escape urban dis-amenities such as crime and congestion, development patterns at the rural-urban fringe are now being analyzed in relation to the relatively higher abundance of natural amenities in rural areas. Using a probit model of parcel-level development in a rural North Carolina county, Cho and Newman (2005) find that proximity to a stream or river is highly correlated with development, and although the probability of development is lower at high elevations, the fact that elevation is positively correlated with housing prices suggests a demand for scenic views constrained by a lack of developable land in mountainous areas. Similarly, while rural residential development tends to be fragmented, proximity to Chesapeake Bay is negatively associated with fragmentation, implying a natural amenity led concentration in development (Irwin and Bockstael, 2007).

Spatial Dependence of Development

Even though rural land use change tends to be characterized by sprawling, low density patterns of development, there has been found to be significant spatial dependence in these patterns, with parcels being influenced by the state of neighboring parcels. In modeling the probability of parcel level land use conversion from agricultural or forested to residential land uses, Carrión-Flores and Irwin (2004) find that the proportion of neighboring residential land is positive and significant, as past development and existing roads increase the probability of new development. Existing infrastructure is commonly found to be significantly associated with rural land conversion (Irwin and Bockstael, 2007; Carrión-Flores et al., 2010), although the direction of the relationship is unclear. A product of the fact that neighboring parcels are more likely to be similar to each other than distant parcels necessitates the use of methods that address spatial error autocorrelation, with a common approach being a sampling method in which noncontiguous plots are selected (Carrión-Flores and Irwin, 2004).

Regional Growth vs Local Development

While studies examining regional growth tend to find the presence of natural amenities to significantly influence migration (McGranahan, 2008; Deller et al., 2001;

Rappaport, 2007), they fail to capture fine-scale development patterns. For instance, those studies examining county-level growth don't provide information on where people are moving to within those counties, and whether natural amenities influence the spatial distribution of development within those counties.

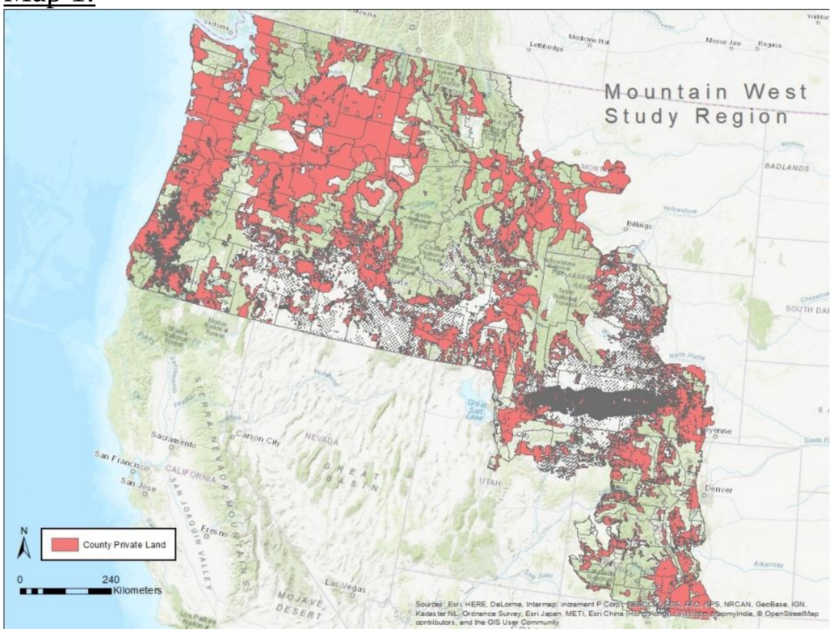
Furthermore, those studies that look at fine-scale development (Cho and Newman, 2005; Carrión-Flores and Irwin, 2004; Irwin and Bockstael, 2007) fail capture regional differences that influence development patterns. By focusing on parcel-level development within a single county or across a few counties, those studies fail to capture regional differences in the effects of natural amenities. While open space and the natural amenities it provides tends to be found to influence development patterns, it is also likely that natural amenities influence migration into the entire region, which increases the likelihood of local development across the whole study area. By modeling this process at only the single level, these studies fail separate the influence of natural amenities into regional and local effects.

In contrast to single-level models, a multilevel framework that combines both regional drivers of development and local drivers of develoment in a single model allows for a direct comparison of effects across the two levels. This allows for an analysis of which factors predominantly operate through influencing regional growth trends and which factors primarily drive local development patterns, providing valuable insight for rural communities trying to conserve the integrity of these natural amenities. Furthermore, if specific natural amenities are found to influence both community-wide variation in development and within-community variation in development, those amenities are at risk for being encroached upon by residential development, which could it turn limit future community-wide growth potential.

Data

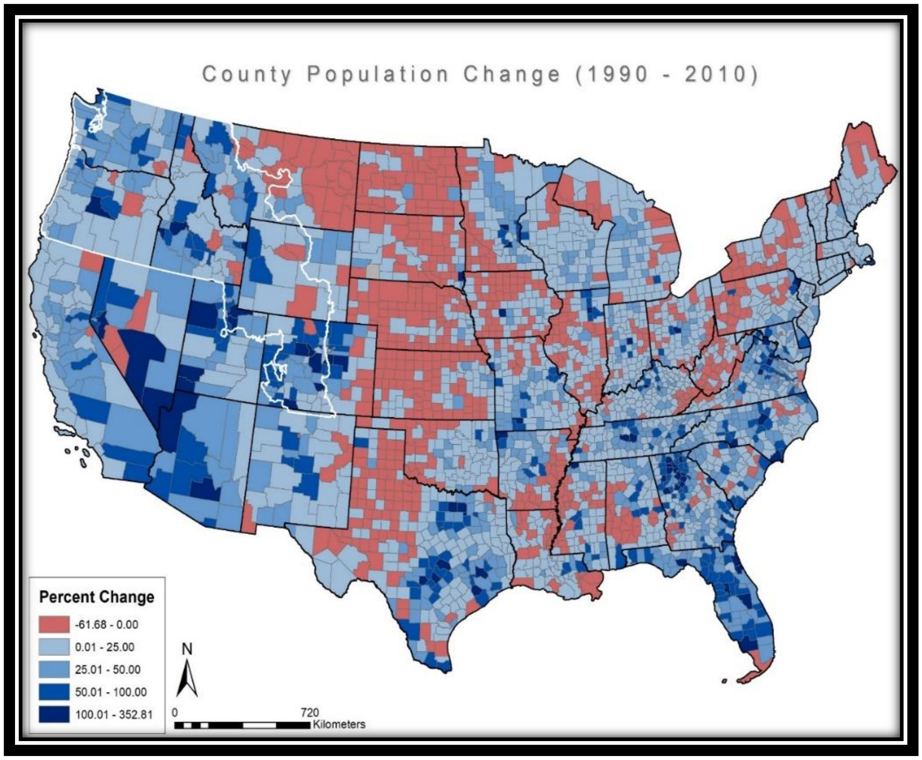
Inter-Mountain West Study Region

Map 1:



Shown above in Map (1) is my ecological boundary-based study area, including the Rocky, Cascade, and Coastal Mountain Ranges. With slightly over 60% of the approximately 1 million km^2 region consisting of public lands, the area is characterized by vast stretches of wilderness areas in addition to numerous National Parks such as Glacier, Yellowstone, and Rocky Mountain National Park. Comprised of the entirety of Idaho, Oregon, and Washington; and parts of Colorado, Montana, Utah, and Wyoming, this region has seen high levels of growth and development over the time period of 1990 – 2010, with population increasing by 40% from 10 million to 14 million and housing density increasing 47% from 4 million units to 6 million units. Shown below in Map (2) is a comparison of nation-wide county population growth and county population growth in my study region, with the average growth rate of my study region being twice that of the national average.

Map 2:



Furthermore, as this growth has been shown to be encroaching on the private lands that surround National Parks and other wilderness areas (Radeloff, et al., 2010; Gude et al., 2006; Davis and Hansen, 2011), sprawling rural development poses a serious risk of ecological isolation and habitat loss for protected areas.

Subplot Development

Despite the potentially severe ecological impacts of sprawling low-density growth, extensive examination of the causes and consequences of residential development in rural areas is constrained by a lack of fine-scale land-cover data. A reliance on coarser units of observation, such as counties or even census tracts, which are based on population and hence tend to be larger in size for lowly populated areas, don't provide detailed information on where low-density development is likely to occur. Furthermore, while techniques have been developed that use satellite imagery to map land cover change, at low land-use intensities the relationship between land cover and land use degrades rapidly (Theobald, 2001). Therefore, this analysis uses development data based on the interpretations of Google Earth satellite imagery done by trained photo interpreters for a stratified random sample of 618 plots approximately 800 m^2 in size.

The stratification process was implemented with the intention of achieving sufficient levels of variation in predictors as well as ensuring a sufficient number of observations where development actually occurred, through oversampling where rural residential development was likely. To that end, the stratification strategy was accomplished through the categorization of counties based on the criteria of climate, whether it is primarily rural or urban, and whether it has primarily New West or Old West characteristics. Then, plots are randomly sampled from private land across all counties in each category, where the within category sample stratification is based on the plot's 1990 nightlight density, which captures the degree of initial development, and distance from those natural amenities hypothesized to be development drivers. Listed below in Table (1) are the county and plot stratification criteria along with subplot counts of each level. While my primary model uses variables that are similar to the stratification variables, they aren't exactly the same. Therefore, included in the appendix are robustness checks in which one model utilizes the subplot covariates of my primary specification, while substituting the county-level stratification variables for my upper level; a second model includes only stratification variables, with the lower level consisting of plot stratification variables and the upper level consisting of county stratification variables.

Table 1:

Measurement Level	**Criterion**	**Categories**	**Subplot Count**
County	Climate	Mild	1,030
		Moderate	1,035
		Harsh	1,025
County	Rural/ Urban	Rural	1,835
		Urban	1,255
County	New West/ Old West	New West	1,825
		Old West	1,265
Plot	NA Index	High NA's	2,040
		Low NA's	1,050
Plot	Nightlight Density	Rural	525
		Rural Transitional	1,350
		Transitional	1,085
		Urban	130

Within each plot are five 100 meter radius subplots, for which one of eight primary land uses is assigned to the 3,090 subplots by examining a series of land use indicators within the subplot and a 227 meter radius buffer zone. Further classifying these eight land use categories as developed or undeveloped for the years of 1990, 2000, and 2010 yields my primary unit of analysis: whether an undeveloped subplot became developed during 1990 – 2010. Shown below in Table (2) are the eight subplot land use categories, of which I classified urban, suburban, developed agriculture, and rural residential development as being developed.

Table 2:

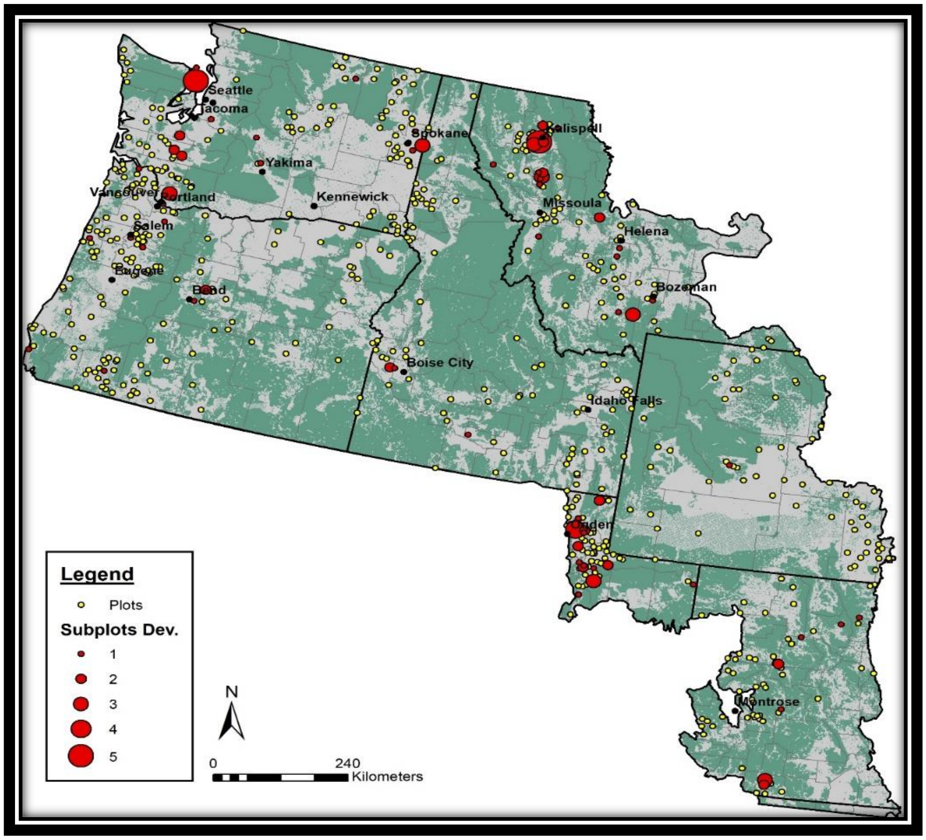
Land Use	**1990**	**2000**	**2010**
Developed			
Urban	50	66	71
Suburban	41	54	62
Developed Ag.	42	58	60
Rural Residential Development	71	93	104
Total Developed Subplots	**204**	**271**	**297**
Undeveloped			
Ag. Cultivated Cropland	655	625	613
Ag. Grazing/Other	635	633	639
Natural Resource Extraction	303	214	227
Natural Cover/Vegetation	1,163	1,217	1,184
Total Undeveloped Subplots	**2,756**	**2,689**	**2,663**
Total	2,960	2,960	2,960

As this analysis is primarily focusing on the drivers of rural development, those 130 subplots that were classified as urban based on nightlight density were removed from the sample. Further restricting the sample by removing the 261 subplots that were already developed in 1990 then leads my primary sample to consist of the 2,756 subplots that were undeveloped in 1990, with counts of subplot development transitions shown below in Table (3), with Map (3) showing the locations of the plots and the number of subplots that became developed in each plot.

Table 3:

Development Transitions	**1990 - 2000**	**2000 - 2010**	**1990 - 2010**
Development Did Not Change	2,689	2,728	2,662
Developed During Time Period	**67**	**28**	**94**
Total	2,756	2,756	2,756

Map 3:



Places

While subplot rural development is likely driven in a large part by the characteristics of the subplots themselves, whether and where rural development occurs is also likely influenced by the characteristics of adjacent communities. Instead of framing those characteristics as unobserved variation and controlling for them through the use of fixed effects models, multilevel random effects models allow for that variation to be conceived as random variation and then explained through the introduction of higher level explanatory variables. By linking each subplot to a nearby census place, the influence of census place characteristics in addition to subplot characteristics is able to be examined.

While census places can be taken to mean a city, town, village, or neighborhood, there are two primary types of census places: Incorporated Places and Census Designated Places. Incorporated Places are legally defined communities residing in a single state established to provide governmental functions to concentrations of people, and Census Designated Places are communities that are primarily delineated for statistical purposes in order to provide data on concentrations of population that are not legally incorporated under state laws but are identifiable by name (Census Bureau), such as Big Sky, Montana. In either case, by linking each plot to the nearest census place that community is assumed to influence the likelihood of rural development on the subplots within that plot through the provision of social, cultural, and economic amenities.

In tying each plot to the nearest census place, care has to be taken in choosing the correct census place population threshold so that each census place is large enough to theoretically have a meaningful impact on development within that plot, the distances between each place and linked plot are small enough to where each census place could reasonably influence development, and a majority of the census places should have multiple subplots linked to them in order to maintain sufficient variation among subplots tied to the same place.

In choosing a population threshold of 10,000 people I believe all three of those considerations are reasonably met, as even if there are census places with lower populations that are closer to each plot, those places are in turn likely influenced by the nearby larger population centers. Secondly, while an average distance of approximately 50 km is a little high, it is likely that most subplots lie within a place's sphere of influence either directly through market relationships or indirectly through the larger census place influencing the characteristics of the more nearby, less populated places. Finally, specifying a population threshold of 10,000 people allows for most of the census places to have more than one subplot tied to it after removing those subplots that were already developed in 1990, as only two census places have only one subplot linked to them. However, an important consideration is that while most census places have multiple subplots linked to them, some of those subplots lie within the same plot, leading to concerns about the amount of variation in explanatory variables among subplots within the same plot.

Thus, Table (4) provides an overview of the linkages and the populations of the 91 census places that are included in my final sample.

Table 4:

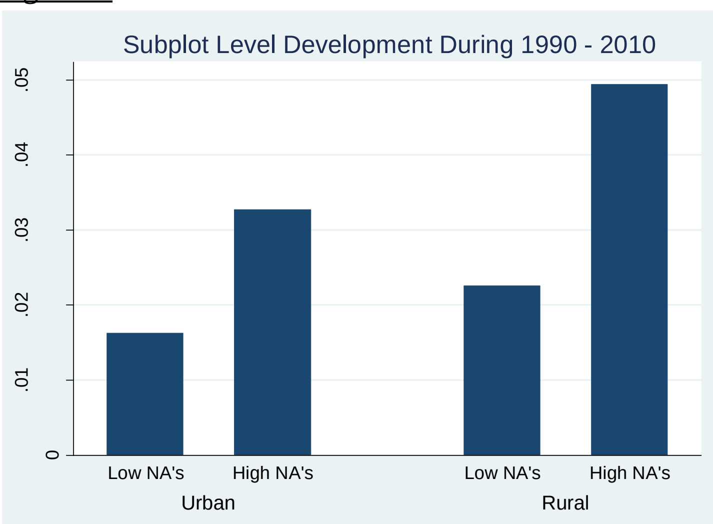
	Count	Mean	SD	Min	Max
Number of Subplots per Place	91	30.29	35.65	1.00	189.00
Subplot to Place Distance	2,756	53.45	40.80	1.59	219.78
1990 Population	91	27281.67	29255.55	10228.00	189925.00
2000 Population	91	33076.40	34757.09	9417.00	211480.00
2010 Population	91	32990.84	35552.74	9270.00	206541.00
1990 Pop. Density (km^2)	91	769.67	343.61	5.35	1650.53
2000 Pop. Density (km^2)	91	936.77	419.02	4.91	2011.73
2010 Pop. Density (km^2)	91	910.16	454.23	4.83	2478.33
1990 - 2010 Pop. % Change	91	21.57	44.37	-27.26	303.42
1990 - 2000 Pop. % Change	91	23.14	23.35	-8.39	170.48
2000 – 2010 Pop. % Change	91	-2.87	17.46	-43.91	52.20

Natural Amenities

For my primary explanatory variables I am focusing on the accessibility of those natural amenities commonly included in the literature, such as wilderness areas (Davis and Hansen, 2011; Radeloff et al., 2010), the presence of water (Chi and Marcouiller, 2013), ski hills (Deller et al., 2001; Rasker, 2006), forest and topographic variation

(McGranahan, 2008), and climate (Graves, 1979; Rappaport, 2007; Deller et al., 2001). For each of the natural amenity distance variables I would expect the sign to be negative, as people theoretically want to live in close proximity to natural amenities. Shown in Figure (1) is a bar graph of the proportion of subplots that transitioned to developed for each combination of the rural/urban and high NA/ low NA stratas, highlighting the fact that although relatively few subplots in the sample transitioned to developed, those subplots in both high NA urban areas and high NA rural areas were much more likely to be developed than their low NA counterparts.

Figure 1:



As the objective of this study is to examine how access to natural amenities influences development, cost distances were used rather than Euclidean distances, allowing for a more accurate representation of accessibility, particularly in the rural and mountainous areas of my study region. These cost distances are calculated by measuring travel time, in minutes, to the nearest feature of interest from every point in the study region. Taking account of features such as the location of roads, highways, and interstates; as well as speed limits and the terrain of the shortest path between the feature and all other points, the cost distance algorithm generates a raster file containing a cost distance value for every point in the study region. Cost distances are then extracted for each subplot in the analysis, and averaged within the extent of every census place.

Additionally, as access to the Pacific Ocean likely only affects development for areas within a traveling distance, and many areas in my study region are outside of that distance, I created a categorical variable of three levels representing level of ocean proximity.

Table 5: Natural Amenity Variables

Variable	Description	Data Source
Distance to National Parks	Cost distance to National Parks (minutes)	USGS Protected Areas Database v1.4
Distance to Public Land	Cost distance to USFWS, BLM land containing national monuments, FS land (minutes)	
Distance to Water Body > .01km^2	Cost distance to water bodies greater than .01 km^2	USGS National Hydrography Dataset
Distance to River	Cost distance to River > 8 meters wide (minutes)	
Distance to Ocean/ Ocean Category	Cost Distance to Pacific Coast (minutes)	
Distance to Ski Area	Cost distance to ski area (minutes)	National Weather Service: NOAA (2007)
Forest Variation	Moving avg. of the standard deviation of forest/non-forest variation in subplot	USGS National Landcover Data
Topographic Complexity	Moving avg. of the standard deviation of elevation in subplot	
Annual Precipitation	- Averages calculated over 1980 - 2015 -Index created through factor analysis to measure effect of climate on development - Index ranges from dry and extreme climates to wet, moderate climates	MACA RCP 85
July Max Temperature		
January Min Temperature		

Shown below in Table (6) are descriptive statistics for natural amenity variables measured at the subplot level as well as the census place level. As opposed to using cost distances, a number of the census place natural amenity variables are measured as the total area (m^2) of the amenity within a 100 km radius around the corresponding census place. The 100 km radius buffer was used to better capture the abundance of the amenity within a reasonable commuting distance from each community, rather than the cost distance to the nearest feature.

Table 6:

	Count	Mean	SD	Min	Max
Subplot Natural Amenities					
Distance to National Parks	2756	295.06	169.09	0.00	1147.00
Distance to Public Lands	2756	48.08	58.94	0.00	512.65
Distance to Waterbody > .01km^2	2756	139.25	158.09	0.00	1184.61
Distance to NHD River	2756	186.42	186.80	0.00	1499.74
Distance to Ski Hill	2756	707.85	808.02	46.26	12112.14
Forest Variation (1992)	2756	31.41	16.03	0.00	49.00
Topographic Complexity	2756	76.72	48.34	2.64	274.30
Ocean Category: Far	2171				
Ocean Category: Near	208				
Ocean Category: Very Near	377				
Census Place Natural Amenities					
Distance to National Parks	91	236.32	130.97	13.61	625.14
Total Public Land (100km)	91	5248.03	4696.31	253.00	20177.00
Total Waterbodies (100km)	91	416.70	232.91	90.00	1232.00
Total NHD Rivers (100km)	91	351.77	234.25	37.00	883.00
Distance to Ski Hill	91	463.76	288.37	41.78	2032.28
Avg. Forest Complexity (100km)	91	31.50	11.28	4.32	45.41
Avg. Topographic Complexity (100km)	91	84.49	27.15	32.64	173.33

Listed in Table (7) are descriptive statistics for the census place climate variables. Data on average annual precipitation, average maximum July temperature, and average minimum January temperature were used to create a climate index through factor analysis (MACA RCP 85). Exploratory factor analysis was used here and in the creation of other indices in order to reduce data dimensions by combining sets of highly correlated variables into a single index that attempts to capture the underlying relationship among the variables.

Table 7:

	Count	Mean	SD	Min	Max
Avg. Max July Temp. (Celsius)	91	28.62	3.29	18.89	34.85
Avg. Min Jan. Temp. (Celsius)	91	-3.64	4.87	-15.95	4.00
Avg. Annual Precipitation	91	61.84	41.28	16.12	184.34
Climate Index	91	-0.00	1.00	-1.76	2.69

Shown in Table (8) are factor scorings from the principal factor analysis used to create the climate index. With average minimum January temperature receiving a negative score, average maximum July temperature receiving positive score, and average annual precipitation receiving a positive score, the index ranges from negative scores being associated with drier, more extreme climates to wetter, more moderate climates.

Table 8:

Climate Index	**Census Place Factor Scoring**
Avg. Min Jan. Temp. (Celsius)	0.196
Avg. Max July Temp. (Celsius)	-0.390
Avg. Annual Precipitation	0. 299
Avg. Min Jan. Temp. ^ 2 (Celsius)	-0.110
Avg. Max July Temp. ^ 2 (Celsius)	-0.019
Avg. Annual Precipitation ^ 2	0.131
Eigenvalue	**4.328**

Market Remoteness

While natural amenities have been found to be major drivers of migration and development trends, market factors such as distance to highways, interstates, railway lines, airports, and urban centers are commonly thought to be necessary for rural growth, (Rasker et al., 2009; Chi and Marcouiller, 2013; Partridge et al., 2008). Thus, I would expect the sign on the individual market distance variables as well as the market remoteness index to be negative, as increasing market remoteness likely decreases the probability of a subplot being developed. Listed below are descriptions of datatypes and data sources for each market remoteness variable.

Table 9: Market Remoteness Variables

Variable	Description	Data Source
Distance to Interstate	- Cost distance (in minutes) from each subplot to interstates, highways, railways, and cities of various population ranges - Factor analysis used to create an index of market remoteness	- USGS Census Bureau Tiger 2010 - National Transportation Atlas Database
Distance to Highway		
Distance to Railway Line		
Distance to City with Pop. of 2,500 - 50,000		USGS Census Bureau USGS TIGER 2010
Distance to City with Pop. of 50,000 - 250,000		
Distance to City with Pop. of 250,000 or 1 million		
Distance to Airport		

Table 10: Subplot Market Remoteness Index

	Count	Mean	SD	Min	Max
Subplot Market Variables					
Distance to Census Place	2,756	53.45	40.80	1.59	219.78
Distance to Pop. > 2,500	2756	257.63	232.17	0.93	1851.58
Distance to Highway	2756	63.54	85.76	0.00	805.82
Distance to Interstate	2756	210.85	166.11	0.00	993.61
Census Place Market Variables					
Distance to Airport	91	20.01	30.17	5.38	265.06
Distance to Highway	91	4.62	10.35	0.32	86.85
Distance to Interstate	91	56.12	105.47	3.82	555.83
Distance to Railway Line	91	3744.00	8324.13	515.20	50293.93
Distance to Pop. >50,000	91	17.43	36.18	3.10	308.16
Distance to Pop. > 250,000	91	433.25	1318.75	9.38	12401.08
Market Remoteness Index	91	0.00	0.937	-1.61	4.02

Listed above in Table (10) are descriptive statistics for market remoteness variables measured at both the subplot and the census place level. Listed below are the factor scorings for the census place market remoteness index.

Table 11:

Market Remoteness Index	**Census Place Factor Scoring**
Log (Distance to Highway)	0.063
Log (Distance to Interstate)	0.238
Log (Distance to Railway Line)	0.108
Log (Distance to Airport)	0.190
Log (Distance to Pop. > 50,000)	0.344
Log (Distance to Pop. > 250,000)	0.258
Eigenvalue	**2.34694**

Socioeconomic Factors

Lastly, to control for differences in socioeconomic and demographic conditions, a New West index was created through factor analysis based on the factors listed below in Table (12), and 1990 population density is included to control for agglomeration effects. I would expect both 1990 population density and the 1990 New West Index to exert a positive influence on the probability of a subplot being developed. As the subplot census data is measured at the census place level, and census place boundaries change over time as communities grow and shrink, using 1990 and 2000 data normalized to 2010 boundaries (Geolytics) allows for a direct comparison across years. This is done by weighting and converting 1990 and 2000 block group data to 2010 boundaries, through the use of census blocks. If a block split or merged between 1990/2000 and 2010, the block that contained more streets is assumed to have a higher population, and thus a higher weight. This weight is then used to determine the distribution of data over the new block boundaries (Geolytics).

Table 12:

Variable	Description	Data Source
1990 Population Density	Census tract pop. density to control for initial conditions	-1990 U.S. Decennial Census - Geolytics data normalization of 1990 census tract boundaries to 2010 census tract boundaries
1990 Socioeconomic Index	Index created through factor analysis to measure degree of "New Westness": - % of population with Bachelor Degree - % of housing value > $200,000 - % employed in FIRE industries (finance, insurance, and real estate) - % employed in natural resource extraction industries - % of seasonal housing - % employed in tourism industries - % of population from out of state	

Table 13:

	Count	Mean	SD	Min	Max
Pct. with Bachelor Degree or Higher	91	18.58	7.93	9.04	48.03
Pct. Born out of State	91	50.22	9.71	26.15	75.08
Pct. with Housing Value > $200,000	91	1.53	1.97	0.00	14.33
Pct. Employed in FIRE Industries	91	4.85	1.40	1.96	8.55
Pct. Employed in Extractive Industries	91	5.60	3.94	0.98	20.87
Pct. Employed in Tourism Industries	91	1.38	0.52	0.16	3.25
Pct. of Seasonal Housing	91	10.01	10.14	0.00	55.11
New West Index	91	0.125	0.355	-0.453	1.073

Listed above in Table (13) are descriptive statistics for the individual census place New West variables, and below are the factor scorings for the census place New West index.

Table 14:

New West Index (1990)	**Factor Scoring**
Pct. with Bachelor Degree or Higher	0.322
Pct. Born out of State	0.129
Pct. with Housing Value > $200,000	0.243
Pct. Employed in FIRE Industries	0.271
Pct. Employed in Extractive Industries	-0.144
Pct. Employed in Tourism Industries	0.114
Pct. With Seasonal Housing	0.066
Eigenvalue	**2.047**

Multilevel Analysis

Land use change is a complex phenomenon that involves drivers operating and interacting at multiple scales, from broad regional factors that influence general migration trends to local characteristics that dictate where development occurs. While this development is essentially the outcome of individual landowner decisions, those decisions are influenced by a multitude of drivers working across various scales, culminating in overarching patterns of growth. Despite the multilevel nature of land use change, modeling techniques that explicitly account for processes operating and interacting across multiple scales are largely underutilized in land use studies (Veldkamp et al., 2001; Irwin et al., 2009). Failing to model the multi-scale structure of land use processes forces data to either be aggregated or disaggregated, leading to generalizations that don't necessarily hold across scales. Attempting to make inferences about micro-level relations from data aggregated beyond that level of observation can result in the ecological fallacy, which states that relationships identified between macro-level variables do not automatically translate to the same micro-level relation (Robinson, 1950). On the other hand, disaggregating data by linking the values of a few higher level observations to lower level units exaggerates the sample size of the upper level data, and leads to a higher probability of Type I errors (Snijders and Bosker, 2012). As the choice of scale can influence the relationship observed in spatial data (Verburg and Chen, 2000), and natural amenities have been found to influence growth and development at both the regional level as well the local level, using a model that explicitly incorporates effects at both scales provides insight into the relationship between the two processes and allows for a direct comparison of effects across the two levels.

Tobler's 1st law of geography states: "Everything is related to everything else, but near things are more related than distant things" (Tobler, 1970). Known as spatial autocorrelation, the fact that observations that are spatially near each other are more likely to be similar violates the independence assumption of standard regression models such as ordinary least squares and probit models, leading to inefficient estimates that can bias tests of significance. In this case, the multiple lower level subplots tied to the same upper level census places are more likely to be similar to each other due to unobserved factors pertaining to developability, government policies, and historical migration patterns, as well as the fact that existing development influences the likelihood of neighboring development (Carrión-Flores and Irwin, 2004). By explicitly specifying that subplots are linked to census places, multilevel models help control for this spatial dependence in which the probability of a subplot being developed depends on the characteristics of the communities to which they are tied, in addition to the characteristics of the subplots themselves.

As natural amenities have been found to influence where local development occurs as well as regional migration patterns, a model that includes measures of natural amenity accessibility for individual subplots as well as community averages provides insight into the relative influence of both processes. Including explanatory variables measured at the individual subplot level as well as the community level can address both aspects of land use change simultaneously and allows for the testing of hypotheses between scales (Overmars and Verburg, 2006; Snijders and Bosker, 2012). This is an important improvement on current studies of the effect of natural amenities on development, as the relationship could conceivably be different between the two scales. For instance, communities with a high abundance of natural amenities could potentially be relatively lacking in amount of developable land, leading natural amenities to appear to be negatively associated with development. However, within those communities one could see a greater demand for developing in places with direct access to natural amenities, leading to the opposite interpretation. A single-level model forces the relationship between natural amenities and development to be the same at both levels, and loses important insights into the nuances of the land use change process.

Random Effects Probit Model

It is common in the multilevel literature to start with a standard model and then proceed by fitting a series of increasingly complex models, incorporating additional levels of variation and then including explanatory variables at that level to explain that source of variation. Eq. (1) then, is a standard probit model relating the probability of a subplot_i in census place_j being developed over 1990 – 2010 to the *q* natural amenity variables measured at the subplot level listed above in Table (x) and a vector of *n* other covariates such as a socioeconomic index, a market accessibility index, and 1990 census tract population density.

$$\Pr(y = 1|x) = \beta_o + \beta_q \textit{Natural Amenity}_q + \beta_n x_n + a_j + R_{ij} \quad (1)$$

However, as stated above, the model in Eq. (1) assumes the influence of natural amenities is the same across the entirety of the study area, an assumption that likely doesn't hold due to potential correlation in the probability of development among subplots tied to the same census places.

In order to test whether there is significant variation in the probability of subplot development between communities an unconditional model is implemented, which is a special type of random intercept model that is 'empty' of explanatory variables. Eq. (2)

consists of the general intercept γ_{00} as well as a random term $U_{0j,}$ which is a group dependent intercept that accounts for the effect of subplots being linked to the same county.

$$Pr(y_j = 1|x) = \gamma_{oo} + U_{oj} + R_{ij} \quad (2)$$

This model then partitions the total variation in the probability of a subplot being developed into its between and within-level components (Polsky and Easterling, 2001; Snijders and Bosker, 2012). In addition to testing the significance of community-level variation, the intraclass correlation coefficient generated from the unconditional model gives the proportion of variance in the dependent variable that is accounted for by the group level (Snijders and Bosker, 2012). Therefore, this model can provide information as to whether more of the variation in the probability of development occurs at the subplot level or the community level, indicating whether regional factors increase the probability of development for all subplots in the area or if local factors drive the development of specific subplots.

Building on the unconditional model in Eq. (2), subplot-level explanatory variables can be added to explain within-community variation in the probability of subplot development as well as potentially explaining some of the between-community variation when values of subplot-level explanatory variables within the same community are consistently higher or lower than the general mean (Overmars and Verburg, 2006). Eq. (3) then, is a random intercept model, which allows the intercept to vary randomly across communities, and relates the probability of development for $subplot_i$ in

community_j to the subplot-level natural amenity variables listed above as well as the vector of other covariates.

$$\Pr(y_{ij} = 1|x) = \gamma_{oo} + \gamma_{qo}\text{Natural Amenity}_{qij} + \gamma_{n0}x_{nij} + U_{oj} + R_{ij} \quad (3)$$

With $\gamma_{oo} + \gamma_{qo}\text{Natural Amenity}_{qij} + \gamma_{n0}x_{nij}$ being the fixed part of the model, which estimates the within community relationship; the random part of the model, U_{oj} accounts for the remaining between-community variation in the probability of subplot development, and is conceived as random variation.

In order to explain the remaining between-community variation in the probability of subplot development, variables measured only at the community level or aggregates of variables measured at the lower level can be included in the model. This allows for a separation of the influence of that variable into its effect at the lower level and the upper level. For the purpose of this study, this allows for the decomposition and comparison of the effect of natural amenities on development at the subplot level and at the community level, providing information on whether an abundance of natural amenities in a community tends to lead to a higher probability of development for all subplots around that community, or if natural amenities have a more significant effect on within community variation in the probability of development. Eq. (4) then, is a random intercept model with *q* natural amenity variables and *n* other covariates measured at the subplot level, in addition to *r* natural amenity variables and *s* other covariates measured at the census place level.

$$\Pr(y_{ij} = 1|x) = \gamma_{oo} + \gamma_{q0}\text{Natural Amenity}_{qij} + \gamma_{n0}x_{nij} + \gamma_{0r}\text{Natural Amenity}_{rj} + \gamma_{0s}x_{sj} + U_{oj} + R_{ij} \quad (4)$$

By including variables measured at the individual level and group averages, differences between within-group and between group regressions can be explicitly modeled (Snijders and Bosker, 2012). This allows for tests of significance at both levels, providing insight into which natural amenities influence between community differences in the probability of development, and which natural amenities primarily influence within community differences in the probability of development. Of particular interest is if a specific natural amenity variable is significant at both the subplot and the census place level, but if the direction of influence is different between the two levels.

The basic concept of the random intercept model can be extended to include additional levels of variability, for instance if the data is structured in a three-level hierarchy such as subplot *i* tied to census place *j*, in turn nested in state *k.*

$$\Pr(y_{ijk} = 1|x) = \gamma_{ooo} + \gamma_{qoo}\text{Natural Amenity}_{qijk} + \gamma_{noo}x_{nijk} + \gamma_{oro}\text{Natural Amenity}_{rjk} + \gamma_{0s}x_{sj} + V_{ook} + U_{oj} + R_{ij} \quad (5)$$

This would allow for the average county intercept to vary between states, accounting for unobserved variation in the probability of subplot development across counties as well as states. Similar to the two-level model, the three-level unconditional model decomposes variation in the probability of development into individual subplot variation, between county but within state variation, and between state variation; and can yield estimates of the intraclass correlation coefficient for subplots within the same county and thus the same state, subplots within the same state, and counties within the same state (Snijders and Bosker, 2012). Including state variability can account for unobserved state effects such as state level development policies, particularly in regards to rural development in vulnerable natural amenity rich ecosystems.

Results

Unconditional Model

Model (1) shown in Table (15) presents the results of the unconditional model, which is described in Eq. (2), estimated using Stata 14. Empty of explanatory variables, this model decomposes the variance in subplot probability of development into variation that occurs between census places and variation that occurs within census places. In partitioning the variation in the probability of development this model shows that variance between census places is significant at the 5% significance level, implying the need for a model that includes factors explaining variation in the likelihood of development both among subplots tied to the same census place and between census places. Furthermore, the intraclass correlation coefficient, which indicates what proportion of the total variation occurs at the group level, is given by ρ_u in Model (1) and suggests approximately 30% of the variation in probability of subplot development occurs between census places. Thus, while subplot characteristics influence where development occurs around a community, community characteristics also play a significant role in development patterns.

Subplot Drivers of Development

Building on the unconditional model, hypothesized drivers of development measured at the subplot level are added to explain both within-community variation as well as potentially some of the between-community variation. Shown in Model (2) are the marginal effects of the hypothesized subplot drivers of development, indicating which factors have a significant effect on the probability of development and the magnitude of that effect. According to Model (2), increasing the distance to water bodies and ski areas decreases the likelihood of development, while increasing the forest complexity of the subplot increases the probability of development. Additionally, a couple individual market access variables have a significant effect on development, as increasing the distance to communities with populations greater than 2,500 people decreases the probability of development, while increasing the distance to interstates increases the probability of development. This likely indicates a desire to live in accessible locations while avoiding the disamenities that come from living in immediate proximity to an interstate. Lastly, while the community level random effect, as given by for $var(U_{oj})$ in Model (2) is still significant, the fact that it is lower than the random effect given by the unconditional model implies that some of the variation in the probability of development that occurs between communities is explained solely by subplot characteristics.

Table (15):

	(1) S.P. Dev. Empty Model		(2) S.P. Dev. Level 1 Model		(3) S.P. Dev. Level 1 with Place Pop. Change		(4) Place % Pop. Change	
Subplot Variables								
Log (Distance to Census Place)			-0.001	(0.005)	-0.001	(0.005)		
Log (Distance to Pop. > 2500)			-0.024***	(0.005)	-0.024***	(0.005)		
Log (Distance to Highways)			-0.004	(0.002)	-0.004	(0.002)		
Log (Distance to Interstates)			0.009**	(0.004)	0.009**	(0.004)		
Log (Distance to National Parks)			0.002	(0.005)	0.002	(0.005)		
Log (Distance to Ski Hill)			-0.012**	(0.006)	-0.011*	(0.006)		
Forest Complexity (1992)			0.001***	(0.000)	0.001***	(0.000)		
Log (Distance to Public Land)			-0.002	(0.002)	-0.002	(0.002)		
Log (Distance to NHD Rivers)			0.003	(0.003)	0.003	(0.003)		
Log (Distance to Waterbodies > .01km^2)			-0.008***	(0.003)	-0.008***	(0.003)		
Topographic Complexity			0.000	(0.000)	0.000	(0.000)		
Ocean Category: Near			-0.006	(0.015)	-0.007	(0.014)		
Ocean Category: Very Near			0.012	(0.017)	0.014	(0.017)		
Census Place Variables								
% Pop. Change (1990 - 2010)					0.606	(0.408)		
Log (Distance to National Parks)							-0.038	(0.040)
Log(Distance to Ski Area)							-0.037	(0.047)
Avg. Forest Complexity (100km)							-0.006	(0.005)
Avg. Topographic Complexity (100km)							0.002	(0.002)
Market Remoteness Index							-0.236***	(0.025)
Climate Index							0.006	(0.042)
Log (Sum NHD (100km)							0.059	(0.075)
Log (Place Sum Waterbody (100km))							0.012	(0.027)
Log (Sum Public Lands (100km))							-0.013	(0.015)
New West Index (1990)							0.121**	(0.034)
Log (1990 Pop. Density)							-0.264***	(0.063)
Constant	-2.198***	(0.142)					2.033**	(0.644)
var(U_{oj})								
Constant	0.473**	(0.199)	0.344*	(0.176)	0.297*	(0.160)		
Observations	2756		2756		2756		94	
Adjusted R^2							0.392	
P_u	0.321		0.256		0.229			

* $p < .10$, ** $p < .05$, *** $p < .01$
Standard errors in parentheses

Subplot Drivers of Development with Census Place Pop. Change

Model (3) includes the same subplot variables as the previous model but with the addition of census place percent change in population as an explanatory variable. As this is only measured at the census place level it provides an indication of how place population growth affects the probability of development for all subplots tied to a community. While census place population growth doesn't exert a significant effect on the probability of development, its addition does decrease the remaining random variation between communities from 0.344 in Model (2) to 0.297 in Model (3). However, the fact that it is estimated as being significantly different from zero implies that not all of the community-level variation in probability of development is captured by the inclusion of community population change as an explanatory variable. A number of subplot-level variables maintain significant marginal effects in this model, indicating a desire to develop in areas with greater forest complexity, near ski areas, waterbodies, and population centers, but away from highways.

Census Place Population Change

Lastly, Model (4) in Table (15) estimates a state-fixed effects regression of percent change in population for the 94 subplot-linked census places on the set of place-level covariates included in my final model. Although none of the included natural amenity variables are found to exert a significant influence on place-level population growth, the market remoteness index, New West index, and initial 1990 population density are all found to be significant at the 1% significance level. These results suggest that a 1 unit increase in the degree of 'New West-ness' is associated with a 12.1

percentage point increase in census place population change, a 1 unit increase in the market remoteness index is associated with a 23.6 percentage point decrease in census place population change, and a 1% increase in 1990 population density is associated with a .264 percentage point decrease in population change. While this model doesn't directly translate to the between community variation as estimated in the final specification of my multilevel probit model, it does provide an indication as to the major drivers of community-wide growth, indicating that migration to census places is influenced more by socioeconomic factors as opposed to natural amenities. However, this model doesn't provide any information on where growth is occurring around the included census places and what drives low-density rural development in the areas surrounding these communities.

Multilevel Random Intercept Probit Model

Shown below in Table (16) are the results of my primary specification: a multilevel random intercept probit model estimating the probability of a subplot becoming developed over 1990 – 2010 as a function of subplot level covariates as well as census place level covariates, including some variables measured at both the subplot level and the census place level.

In comparison to the models solely examining either subplot development or census place growth, this model combines both processes and provides information as to whether the individual natural amenities included at both levels primarily influence variation in community-wide development trends or the specific locations of development around communities. As the relationship between rural development and individual amenities may differ between the two levels, this method of analysis allows for a more nuanced examination of the development process and the scale at which natural amenities influence rural development.

Table 16:

	(1) Standard Coefficients	S.E.	(2) Marginal Effects	S.E.
Subplot Variables				
Log (Distance to Census Place)	-0.089	(0.066)	-0.005	(0.003)
Log (Distance to Pop. > 2,500)	-0.462***	(0.101)	-0.024***	(0.008)
Log (Distance to Highway)	-0.082	(0.052)	-0.004*	(0.003)
Log (Distance to Interstate)	0.216***	(0.066)	0.011**	(0.004)
Log (Distance to National Parks)	0.113	(0.156)	0.006	(0.008)
Log (Distance to Ski Hill)	-0.204*	(0.111)	-0.011*	(0.006)
Forest Variation (1992)	0.021*	(0.011)	0.001**	(0.001)
Log (Distance to Public Land)	-0.056*	(0.030)	-0.003*	(0.002)
Log (Distance to NHD River)	0.030	(0.069)	0.002	(0.004)
Log (Distance to Waterbody > .01km^2)	-0.136**	(0.056)	-0.007***	(0.003)
Topographic Complexity	-0.000	(0.003)	-0.000	(0.000)
Ocean Category: Near	0.575*	(0.343)	0.038	(0.029)
Ocean Category: Very Near	0.920**	(0.468)	0.075	(0.059)
Census Place Variables				
New West Index (1990)	0.463**	(0.222)	0.024**	(0.012)
Market Remoteness Index	-0.330*	(0.187)	-0.017*	(0.009)
Log (1990 Census Place Pop. Density)	-0.332	(0.265)	-0.017	(0.013)
Climate Index	-0.297	(0.285)	-0.016	(0.016)
Avg. Place Forest Complexity (100km)	-0.008	(0.027)	-0.000	(0.001)
Avg. Place Topographic Complexity (100km)	0.095	(5.933)	0.005*	(0.262)
Log (Place Distance to National Parks)	-0.148	(0.196)	-0.008	(0.010)
Log (Place Sum Public Lands (100km)	-0.223*	(0.125)	-0.012**	(0.006)
Log (Place Sum NHD (100km)	-0.426***	(0.099)	-0.022***	(0.004)
Log (Place Sum Waterbody (100km)	0.145*	(0.086)	0.008	(0.005)
Log(Place Distance to Ski Area)	0.022	(0.112)	0.001	(0.006)
Constant	4.971	(3.147)		
var(U_{oj})				
Constant	0.098	(0.139)		
Observations	2756		2756	

Standard errors in parentheses
* $p < .10$, ** $p < .05$, *** $p < .01$

As shown above, a number of subplot level natural amenities significantly influence the probability of development, with increases in subplot distances to ski areas, public land, and water bodies decreasing the probability of development, and increases in subplot forest variation increasing the probability of development. Additionally, subplot market accessibility variables are found to significantly influence the probability of development with increases in the distance to highways and population centers greater than 2,500 people associated with decreases in the probability of development, and increases in the distance to interstates associated with an increased probability of development.

The inclusion of census place level covariates is found to substantially decrease the remaining random variation between census places, as the random part of the full model is far lower than that found in the model with only subplot level variables and is no longer significantly different than zero.

Similar to Model (4), estimating the relationship between census place population change and census place level covariates, increases in a community's degree of 'New West-ness' are found to positively influence the probability of development, while increases in the market remoteness of a community is found to negatively influence the probability of development. Together, these results suggest that development over this time period primarily occurred in communities that are easily accessible and characterized by the social and cultural amenities associated with New West communities.

Furthermore, a number of census place level natural amenity variables are found to significantly influence the probability of development, with place-level topographic complexity and total area of waterbodies within a 100 km radius exerting positive influences. Conversely, higher total areas of rivers and public land within a 100 km radius are associated with a decreased probability of subplot development.

As the inclusion of variables measured at different scales allows for the simultaneous modeling of multiple relationships, the effect on development of drivers measured at the subplot level and at the community level is allowed to differ. Therefore, it is those natural amenities that are found to have opposite effects at the two levels that yield the most interesting insights to the development process. The effect of increasing subplot distance to public land is found to decrease the probability of development in in my primary specification, indicating a desire to develop in close proximity to public land. However, when measured at the census place level, an increase in the total amount of public land surrounding a community is found to decrease the probability of development, potentially due to a lack of developable land. Combined, these results suggest that while a higher amount of public land around a community isn't associated with an increased probability of community-wide development, there is a desire to development near public land within communities.

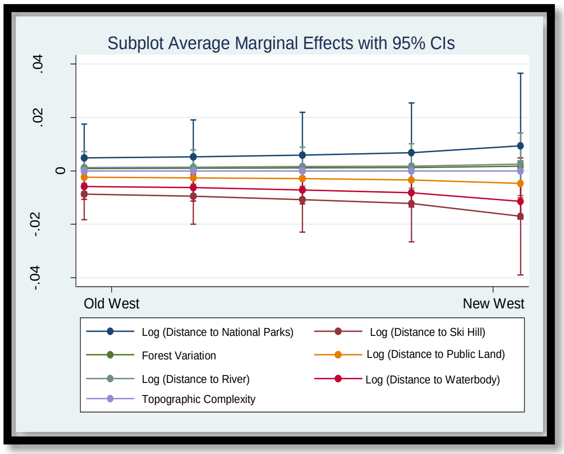
Additionally, those natural amenities that only have a significant impact at one level provide nuanced insight into the development process by revealing whether the amenity is more likely to influence community-wide growth or the specific location of development around that community. Although the effect of subplot topographic complexity not significant, the inclusion of a measure of the average topographic complexity within a 100 km radius of the census places shows a significant and positive effect on the probability of development, indicating a preference for living in more mountainous communities.

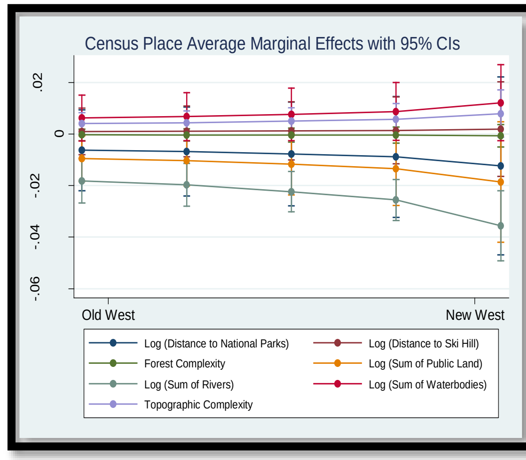
Lastly, while subplot forest variation is found to exert a positive and highly significant effect on the probability of development, the average forest variation around the census places is not found to have a significant effect on development. While the non-significant effect at the community level is surprising, this could indicate that although more heavily forested communities didn't see increased development over this time period, development around each community tended to concentrate in more heavily forested areas.

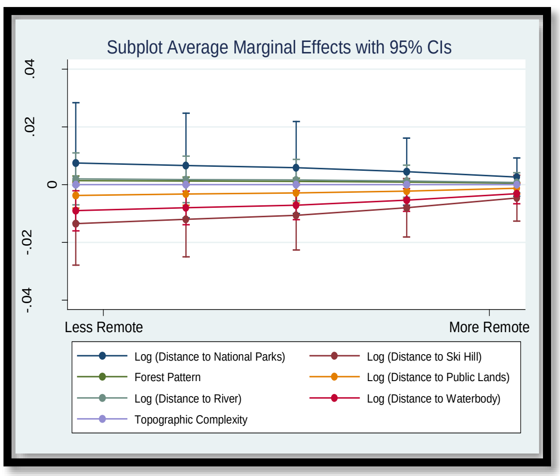
By adopting a multilevel framework that decomposes the variation in the probability of a subplot becoming developed into between-community variation and within-community subplot variation, a more nuanced analysis of the development process is attained that yields insights absent from a single-level model. For instance, in the fixed effects regression of census place population change, it would appear that natural amenities generally do not play a role in driving growth. However, as the multilevel modeling approach allows for a separation of the effect of natural amenities at the subplot level and the census place level, these results suggest a number of natural amenities do in fact have a significant effect on development. In census places with low population growth, a single level model would likely fail to predict development as community-wide growth is slow. Even in slow growing communities, there are likely some highly amenable subplots that have a high probability of development, due to the subplot characteristics themselves. Furthermore, while fast growth in a community may increase the probability of development throughout the community, highly amenable subplots will still have a higher probability of development than less amenable subplots. There are likely even subplots characterized by a high level of disamenities that will not see development despite high rates of community-wide growth.

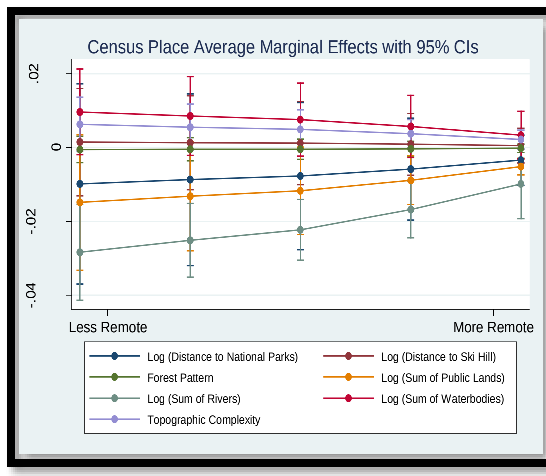
Conversely, a single-level model including only variables measured at the subplot level, doesn't account for regional growth patterns. While a particular subplot may have highly amenable characteristics that would lead to a high predicted probability of development in a single-level model, slow community-wide growth could result in a lack of development, despite the amenities of that particular subplot. On the other hand, results from a single-level model could suggest that a particular subplot will not become developed. However, if a community is seeing high overall rates of growth and development, that particular subplot could actually have a high probability of development regardless of its individual characteristics. Analyzing rates and patterns of development through either of these singular lenses fails to take account of important relationships observed at the other scale and can lead to inaccurate predictions about the occurrence of development.

Plots of Natural Amenity Marginal Effects









Shown in the figures above are plots of the marginal effects at different points along the New West and market remoteness indices for the different natural amenity variables measured at both the subplot level and the census place level. As the Inter-Mountain West study region is relatively rich in natural amenities overall, yet also has uneven rates of growth and development, it is likely that the influence of natural amenities on development is conditional on other factors. These plots highlight the context dependent nature of the relationship between development and natural amenities, as the relationship is strongest for New West communities and less remote communities. Thus while various natural amenities measured at the subplot level, as well as the census place level, are found to have a significant effect on development, that effect is contingent on a community's socioeconomic and demographic characteristics as well as degree of accessibility.

Discussion and Conclusion

In analyzing the causes and consequences of development across a large, relatively natural amenity-rich region, it is imperative to take account of the multiple roles different features may play in driving variations in development both between communities and within communities. While differences in various amenities may influence between community variations in growth and development, if those same amenities are additionally responsible for driving within community patterns of development, they could be at risk for being harmed by encroaching development. In turn, this could potentially lead to community-wide reduced growth rates in the future. In the face of widely varied growth rates among rural communities the Inter-Mountain West Region, a better understanding of the scale at which different natural amenities drive growth can help lead to more informed land use policies that balance attracting growth with the conservation of the natural features that are driving growth.

As highlighted in this analysis, differences in community-wide development trends are driven by a number of natural amenities, in addition to market factors and socioeconomic characteristics. Furthermore, development patterns around those communities are likewise shaped by the locations of different natural amenities and proximity to various measures of market access. In adopting a multilevel framework, a more nuanced examination of various drivers of development is able to be explored by decomposing the relationship into these two, often different processes.

While my results suggest that communities with higher amounts of rivers and public land within a 100 km radius tended to see less development over this time period, communities with more mountainous landscapes and higher amounts of lakes saw more development. Locally, proximity to public land is associated with higher levels of development within and around communities, while landscapes with a higher mix of forest and non-forest cover also saw more development. Lastly, those areas around communities that were closer to lakes and ski areas likewise saw more development.

Some of the differences in effects of natural amenities on development at the census place level and subplot level are readily interpretable. While people generally like the scenic views and abundance of hiking trails that more mountainous communities provide, increasingly complex terrain at the subplot level can hinder development. On the other hand, while people may desire to develop in close proximity to public land, higher amounts of public land around communities may limit the amount of developable land, leading to less overall development at the community level. The finding that community-wide forest variation is not associated with development, but subplot forest variation is positively associated with development is slightly little more puzzling. It is possible that maybe more forested communities saw heavy growth and development over previous time periods, and from 1990 – 2010 development was more heavily concentrated in more mountainous communities, but within those communities people sought out areas that tended to have more forested landscapes.

Lastly, in linking each subplot to the nearest census place, this analysis was able to explore how the effects of natural amenities measured at both the subplot level and the census place level varied by the degree to which a community had 'New West' characteristics and its level of remoteness. My findings suggest that the relationship between development and both subplot level natural amenities and census place level natural amenities is stronger in New West communities as well as less remote communities. This is an important finding in itself, as while the Inter-Mountain West can be characterized by having a comparatively high level of natural amenities overall, it has seen uneven growth rates. My results suggest that even if a community is relatively abundant in natural amenities, it must also be accessible and exhibit New West socioeconomic characteristics in order for development to occur.

Combined, my results suggest that among New West places as well as less remote places, those communities closer to National Parks and with a relatively higher amount of lakes surrounding them will tend to see higher amounts of development. Furthermore, around those communities, development will tend to concentrate near lakes, public land, and towards ski hills. An important implication from these findings is that while people seem to appreciate living in communities surround by lakes, the fact that people also want to develop in the immediate proximity of those lakes suggests a potential for future congestion, leading to less community-wide development in the future. Additionally, concentrated development around lakes could lead to habitat loss in the ecosystems around those lakes.

Lastly, even though communities with higher amounts of public land did not see significantly higher probabilities of development, the finding that subplot proximity to public land is associated with increased development implies that the ecological integrity and connectivity of the wildlands often surrounding public land is being increasingly threatened. Furthermore, the finding that subplot forest variation is associated with increased development implies that sprawling rural development could lead to increased isolation and loss of forested habitats surrounding communities.

While this analysis provided several interesting insights to the role of various natural amenities in the development process, the general lack of development among sampled subplots over this time period means the results are likely fairly noisy. With just under 4% of developable sampled subplots transitioning to developed, these results potentially lack the predictive accuracy obtainable from applying this modeling framework to a different dataset. Furthermore, there are potential issues in the manner by which subplots were linked to census places. As Euclidean distance was used to tie subplots to the nearest census place over 10,000 people, these distances likely lack the representativeness of true travel time that would be provided through the use of cost distances. Additionally, a more sophisticated process of linking that takes into account nearby heavily populated communities with higher tiered economic functions could potentially do a more effective job at tying rural development around communities to the characteristics of the communities themselves. Lastly, with 100 meter radius subplots as the primary unit of observation, there are concerns both in the accuracy of the extracted at that scale as well as concerns about sufficient variation in predictors among subplots within the same plot.

Despite these shortcomings, this analysis presents an application of an underused modeling strategy in land use studies, highlighting the nuanced results and conclusions that can be reached through the multilevel analysis of land use change, and providing meaningful insights into the relationship between natural amenities and rural development in the Inter-Mountain West Region.

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Appendix

Stratification Regressions

Shown below in Table (A1) and Table (A2) are results from a model estimated using subplot covariates and county stratification variables as the upper level, and a model estimated using stratification variables at both the lower and the upper level of my primary specification. With the estimated effects of the subplot covariates shown in Table (A1) being very similar to those estimated in my primary specification and the estimated effect of the New West county strata being significantly positive, these results suggest the census place covariates included in my primary specification were similar enough to my stratification variables to avoid needing probability weights.

The results in Table (A2), in which plot stratification variables were used as the lower level and county stratification variables were used as the upper level are likewise similar to the results of my primary model, suggesting the subplot and census place covariates included in primary model are close enough to the stratification variables so that probability weighting is not necessary.

Table (A1): Subplot Variables and Upper Level Stratification Variables Regression

	(1) Standard Coefficients	S.E.	(2) Marginal Effects	S.E.
Subplot Variables				
Log (Distance to Census Place)	-0.004	(0.104)	-0.000	(0.005)
Log (Distance to Pop. > 2,500)	-0.486***	(0.079)	-0.025***	(0.005)
Log (Distance to Highway)	-0.088*	(0.050)	-0.005*	(0.003)
Log (Distance to Interstate)	0.170**	(0.081)	0.009**	(0.004)
Log (Distance to National Parks)	0.052	(0.099)	0.003	(0.005)
Log (Distance to Ski Hill)	-0.211*	(0.121)	-0.011*	(0.007)
Forest Variation (1992)	0.022***	(0.006)	0.001***	(0.000)
Log (Distance to Public Land)	-0.039	(0.042)	-0.002	(0.002)
Log (Distance to NHD River)	0.052	(0.061)	0.003	(0.003)
Log (Distance to Waterbody > .01km^2)	-0.170***	(0.053)	-0.009***	(0.003)
Topographic Complexity	0.002	(0.002)	0.000	(0.000)
Ocean Near	-0.338	(0.368)	-0.015	(0.014)
Ocean Very Near	0.016	(0.310)	0.001	(0.017)
County Stratification Variables				
County: New West	0.414**	(0.180)	0.020**	(0.009)
County: Moderate Climate	-0.318	(0.225)	-0.014	(0.011)
County: Harsh Climate	0.135	(0.255)	0.008	(0.016)
County: Rural	-0.038	(0.188)	-0.002	(0.010)
Constant	0.102	(0.838)		
var(U_{oj})				
Constant	0.282*	(0.151)		
Observations	2756		2756	

Adjusted R^2	

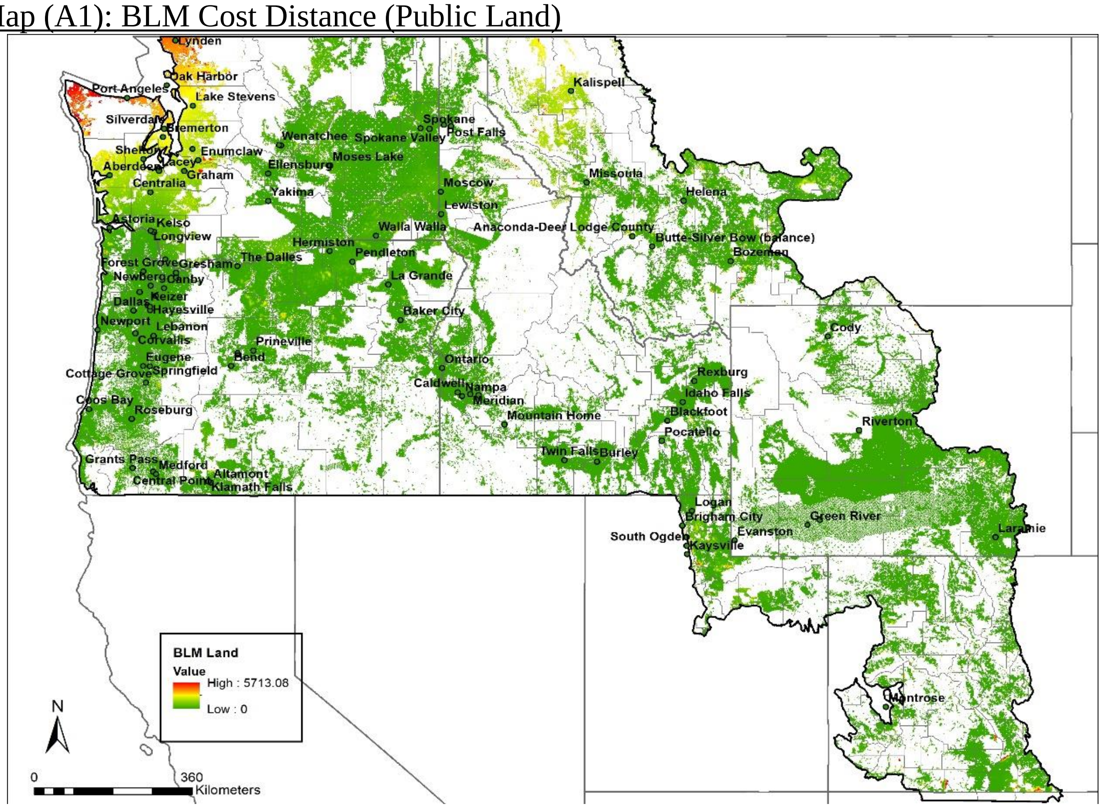
Standard errors in parentheses
* $p < .10$, ** $p < .05$, *** $p < .01$

Table (A2): Stratification Variables Regression

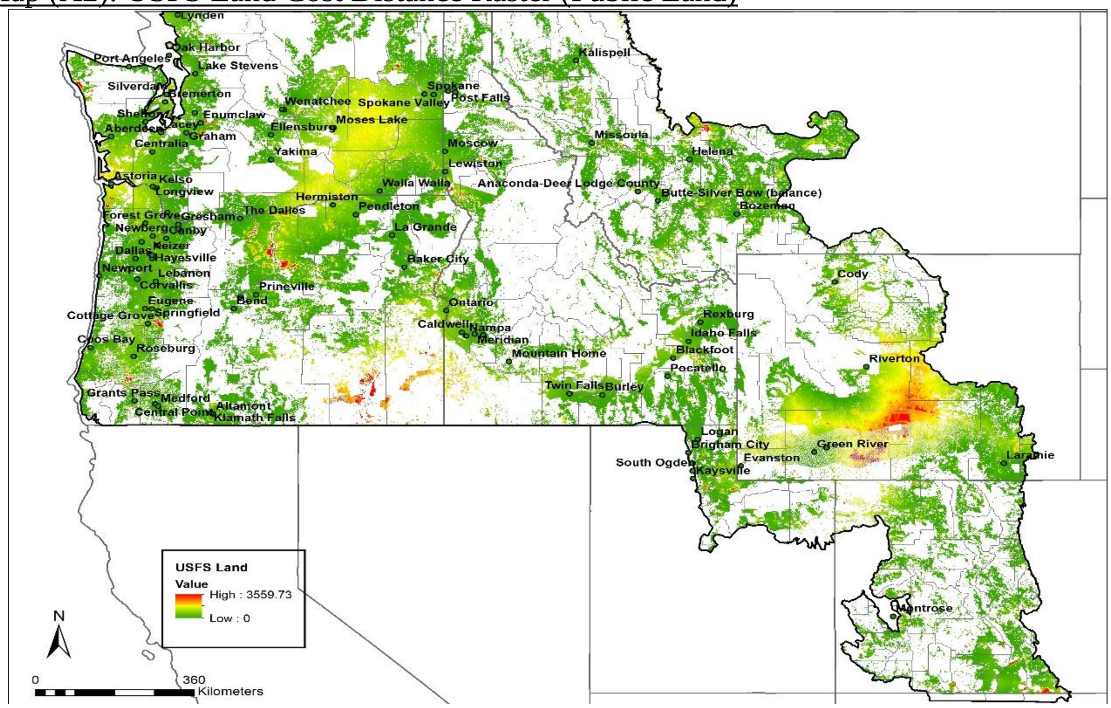
	(1) Standard Coefficients	S.E.	(2) Marginal Effects	S.E.
Plot Stratification Variables				
Plot: High Natural Amenities	0.630***	(0.153)	0.030***	(0.007)
Plot: Rural Transitional	0.570**	(0.280)	0.012**	(0.005)
Plot: Transitional	1.374***	(0.270)	0.068***	(0.011)
County Stratification Variables				
County: New West	0.476***	(0.151)	0.025***	(0.008)
County: Moderate Climate	-0.300	(0.200)	-0.013	(0.009)
County: Harsh Climate	0.262	(0.185)	0.018	(0.012)
County: Rural	0.326**	(0.149)	0.017**	(0.008)
Constant	-3.970***	(0.374)		
var(U_{oj})				
Constant	0.172*	(0.094)		
Observations	2756		2756	
Adjusted R^2				

Standard errors in parentheses
* $p < .10$, ** $p < .05$, *** $p < .01$

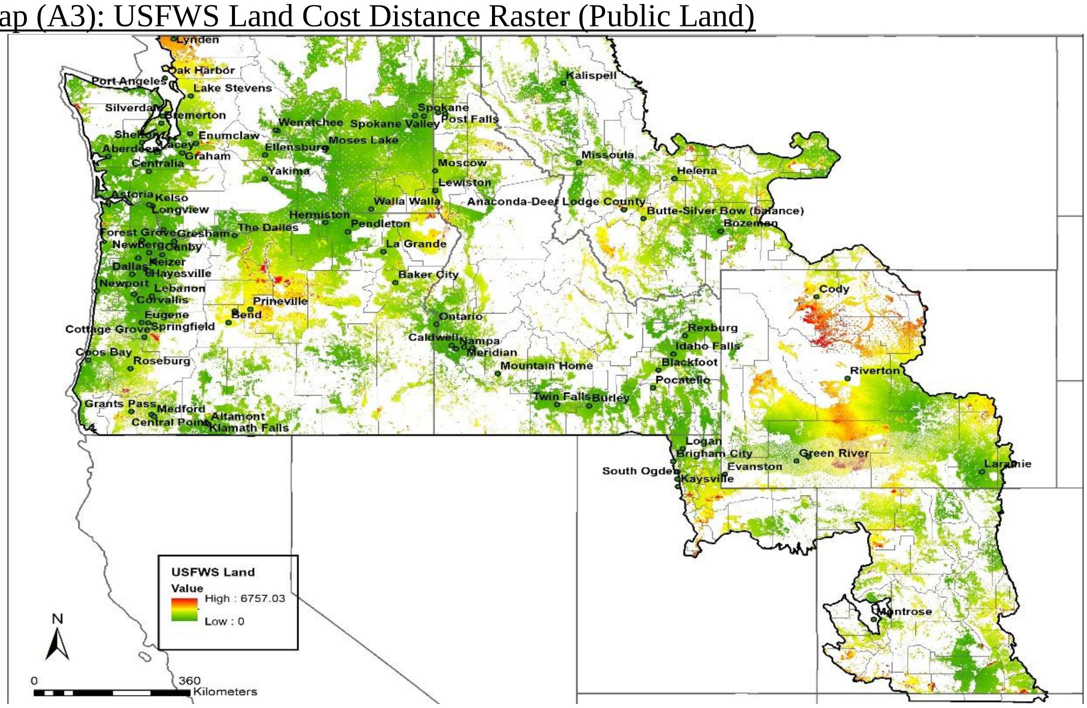
Map (A1): BLM Cost Distance (Public Land)



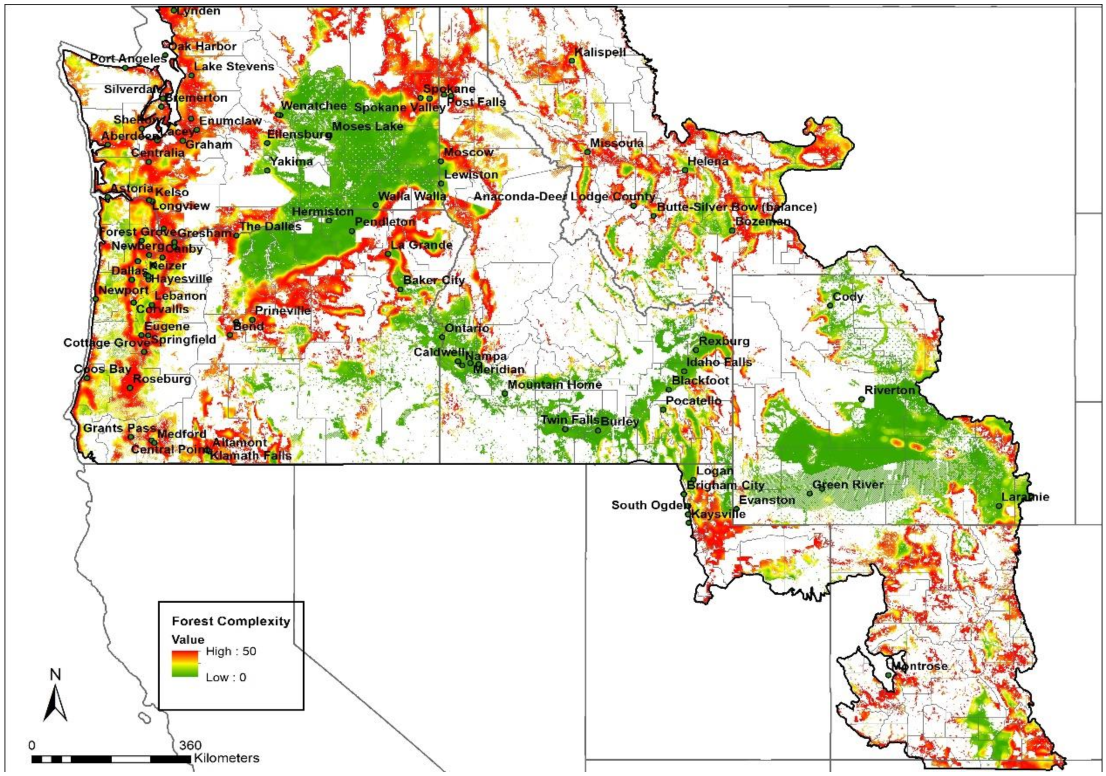
Map (A2): USFS Land Cost Distance Raster (Public Land)



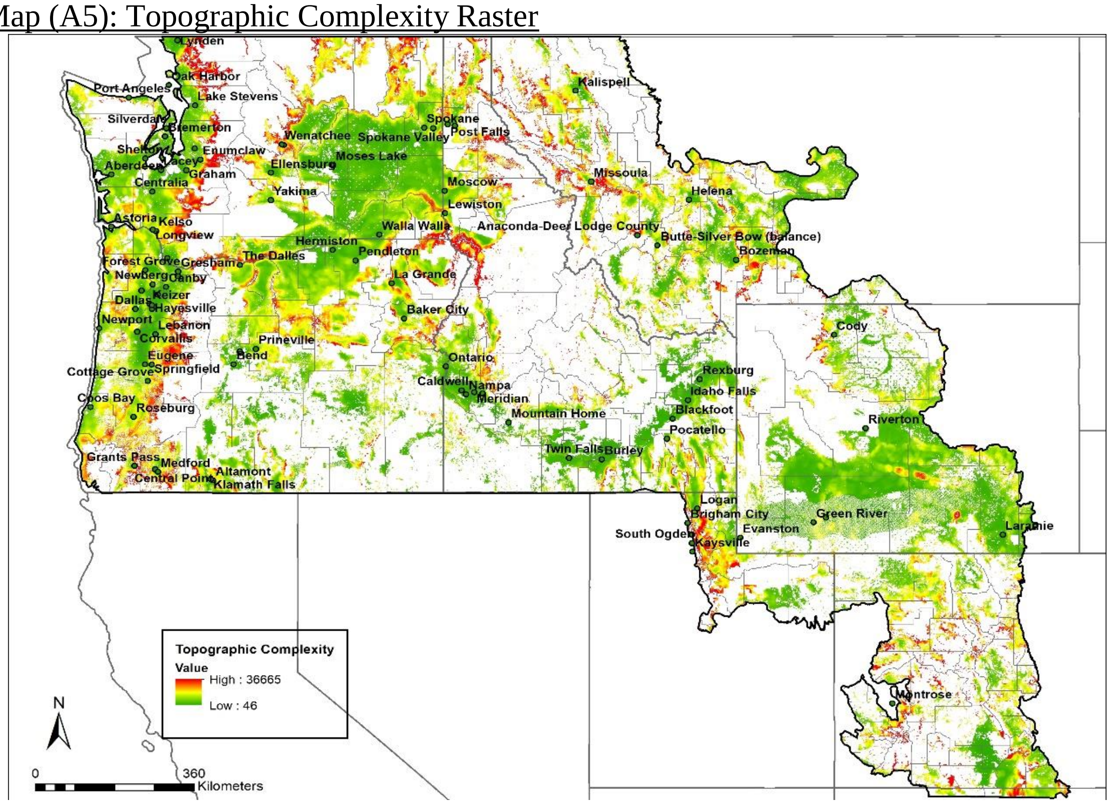
Map (A3): USFWS Land Cost Distance Raster (Public Land)



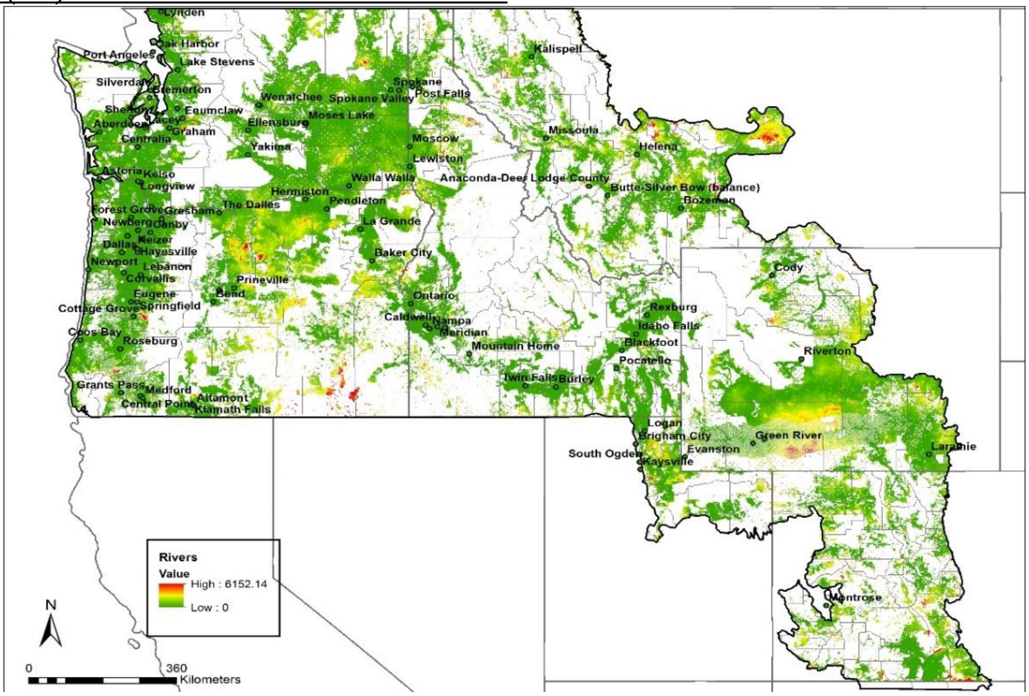
Map (A4): Forest Complexity Raster



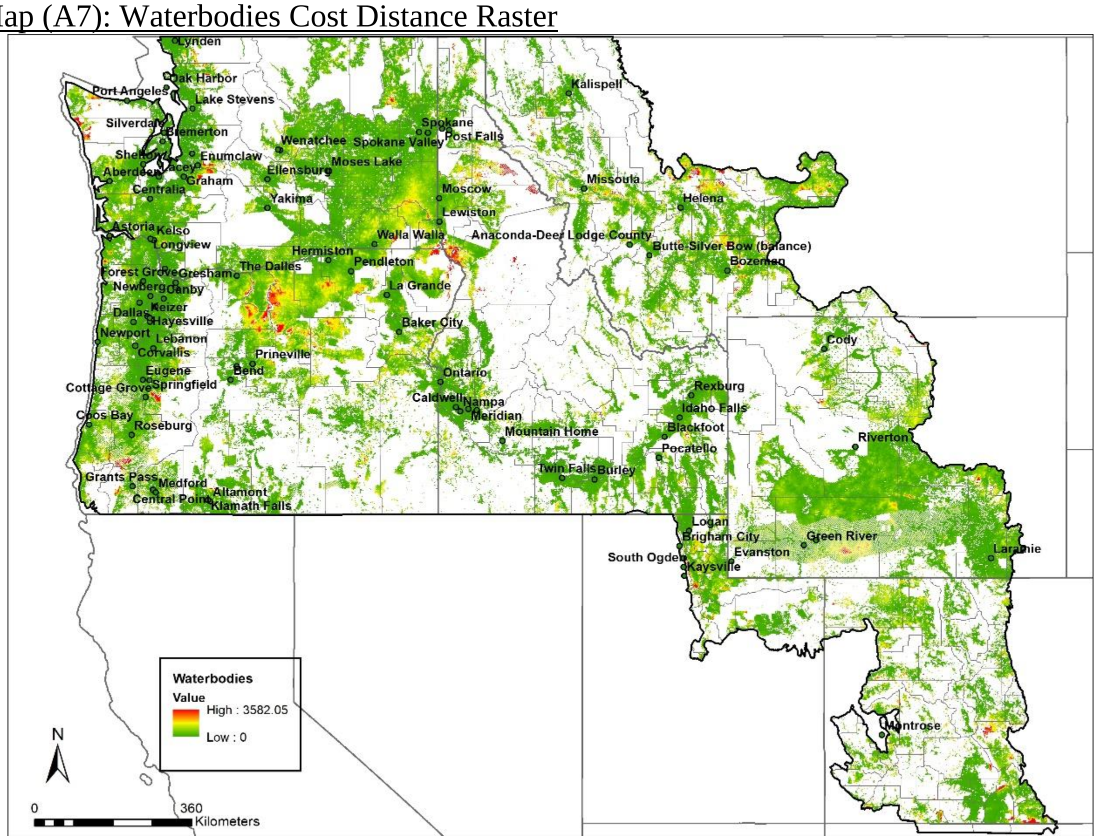
Map (A5): Topographic Complexity Raster



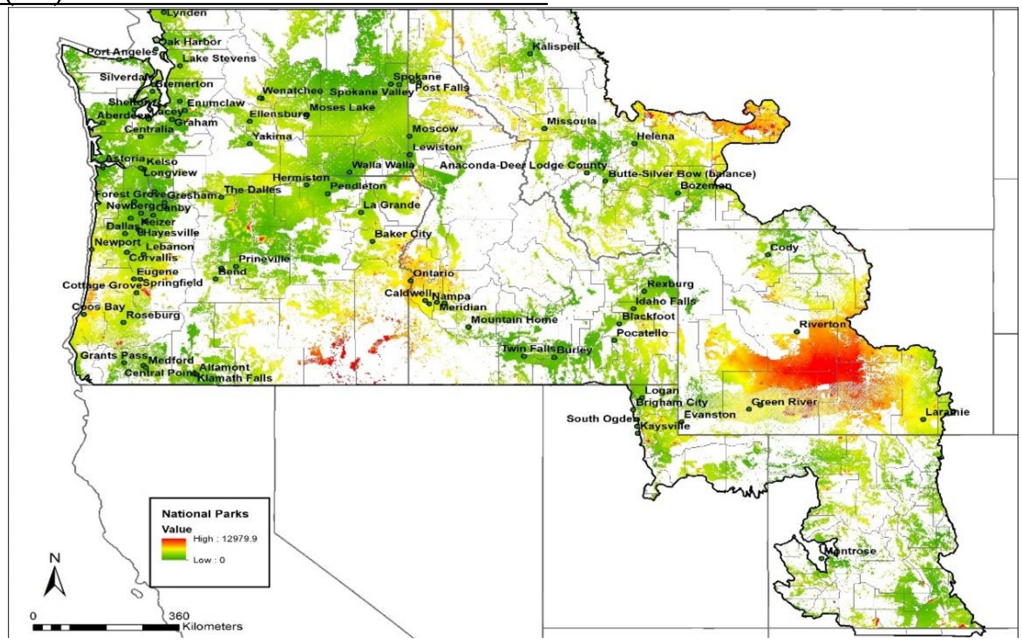
Map (A6): NHD River Cost Distance Raster



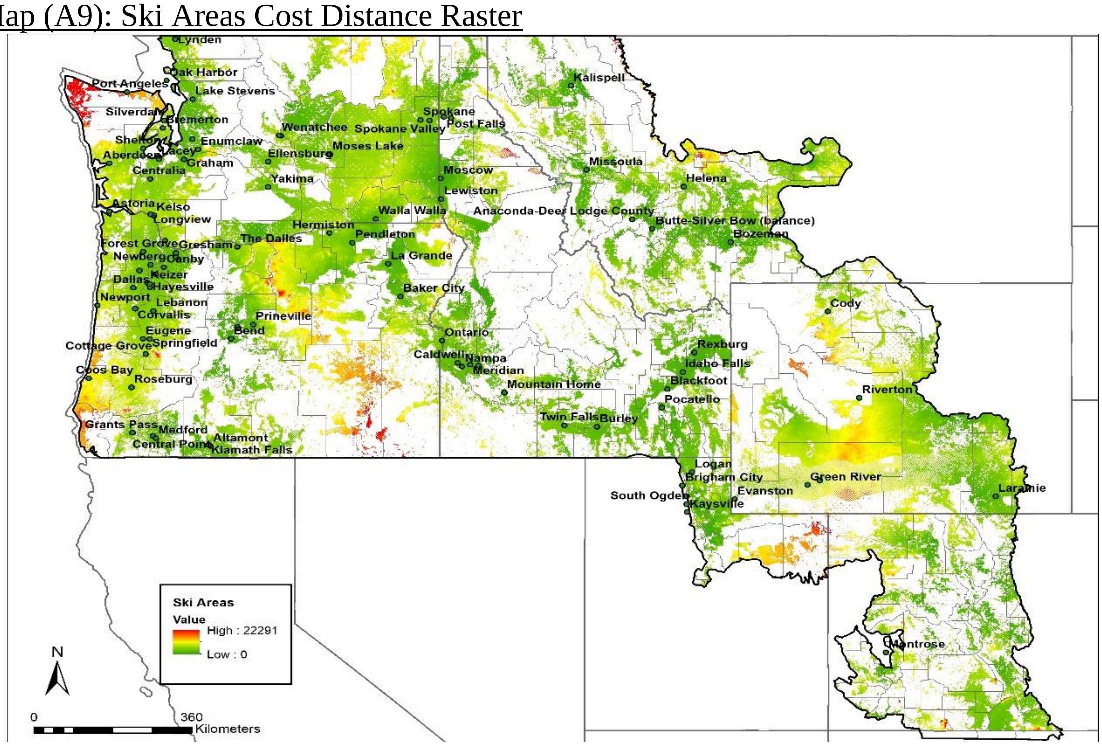
Map (A7): Waterbodies Cost Distance Raster



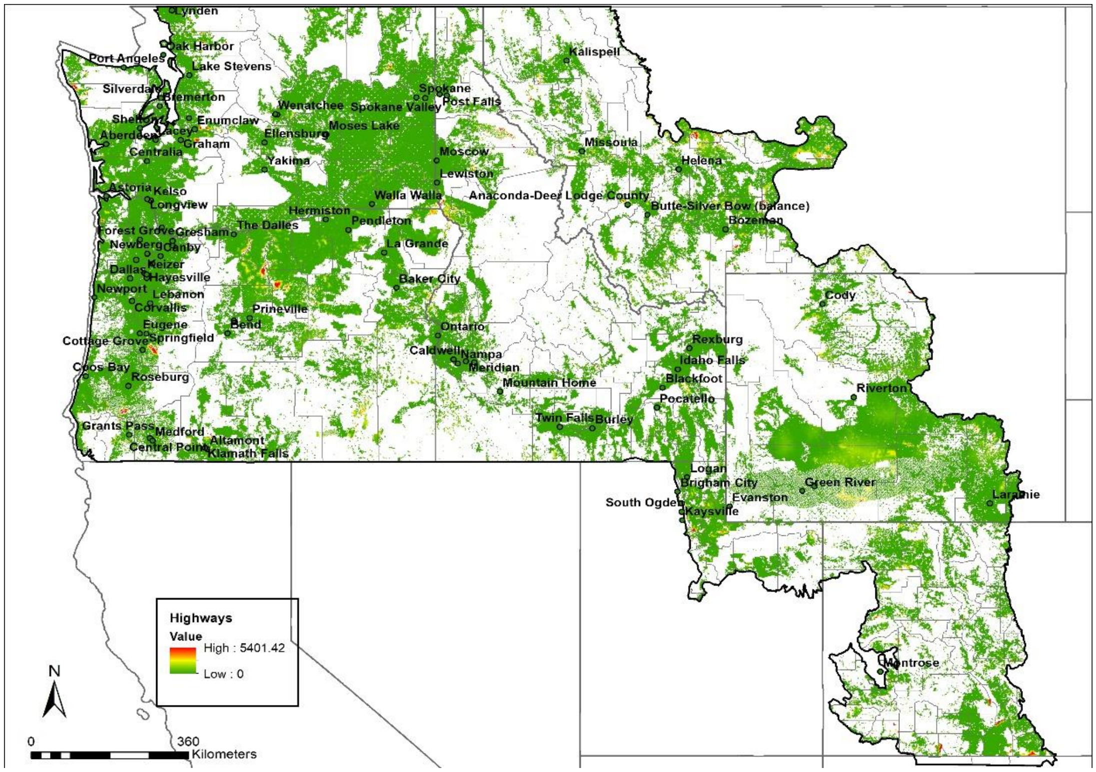
Map (A8): National Parks Cost Distance Raster



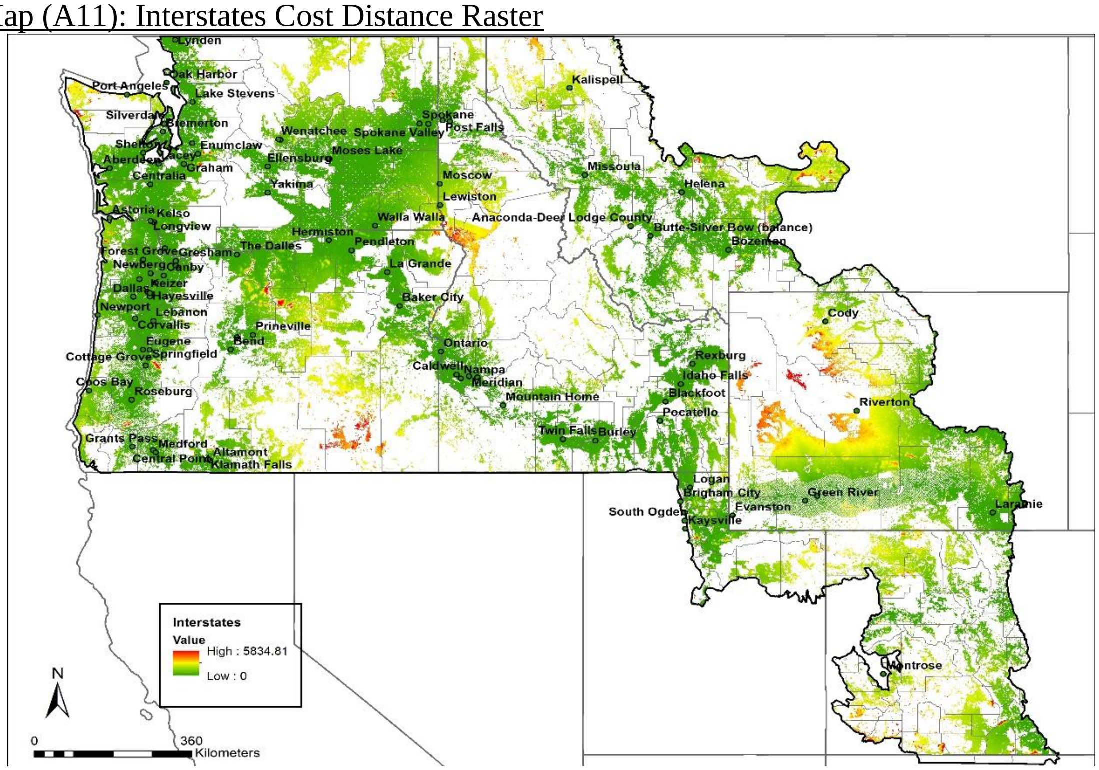
Map (A9): Ski Areas Cost Distance Raster



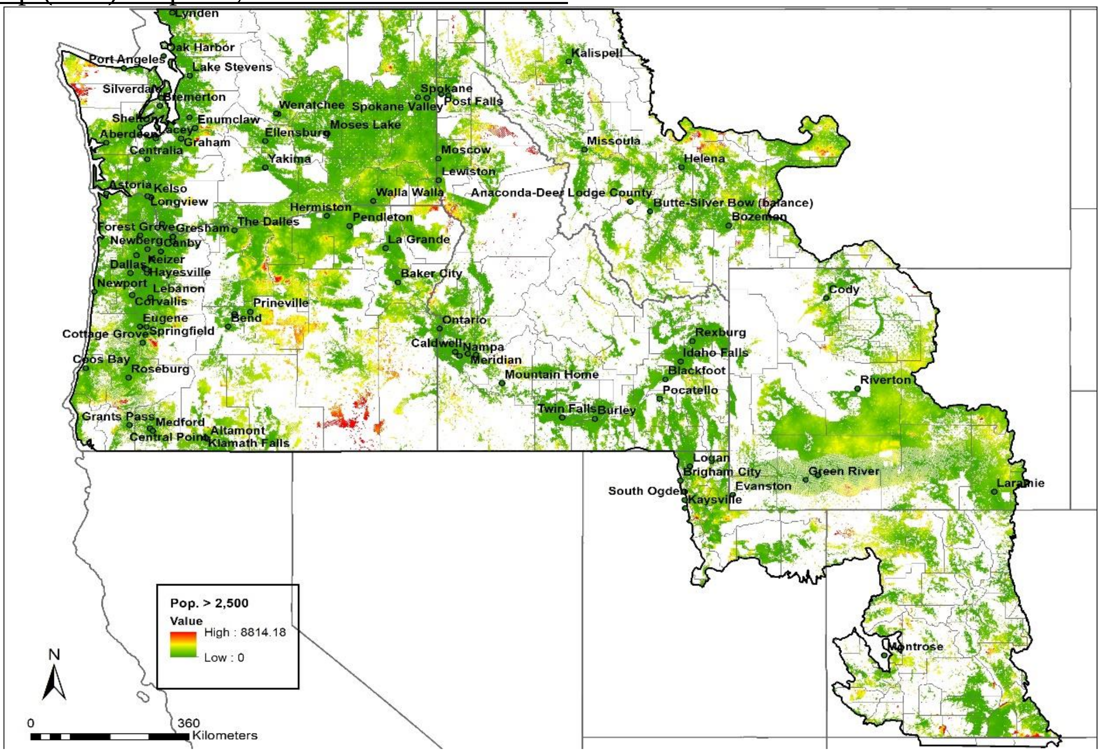
Map (A10): Highways Cost Distance Raster



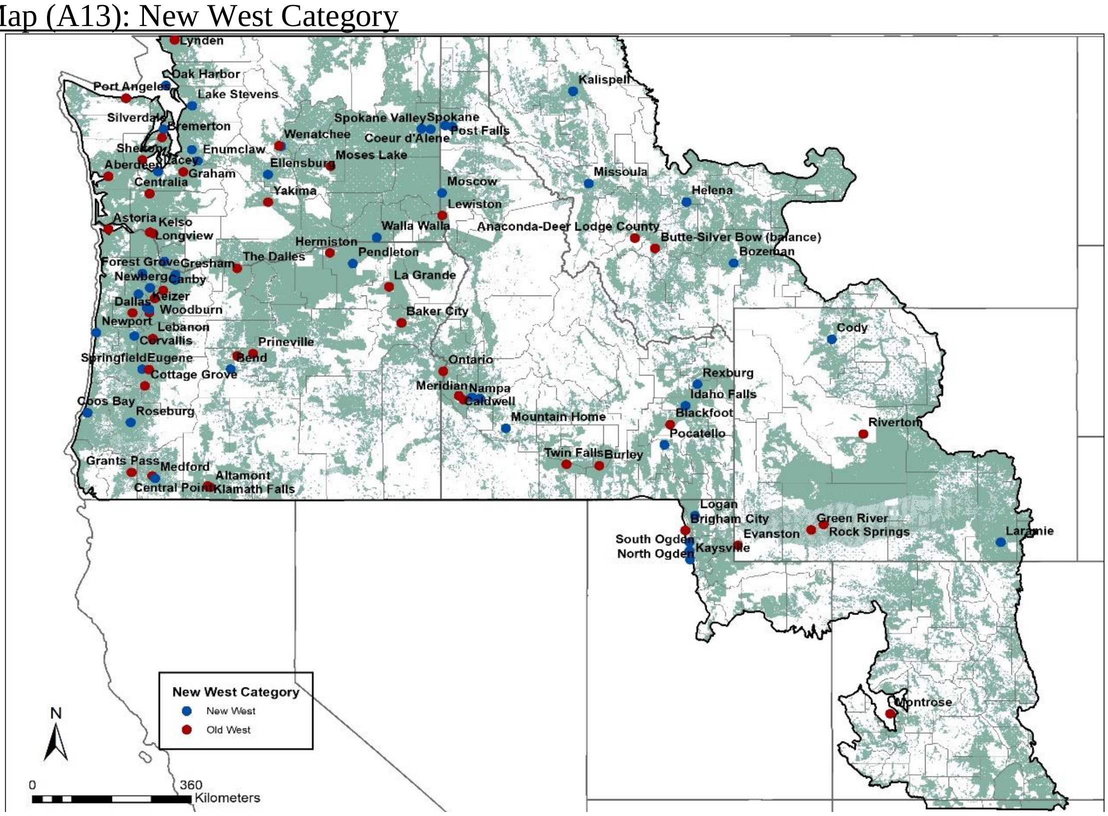
Map (A11): Interstates Cost Distance Raster



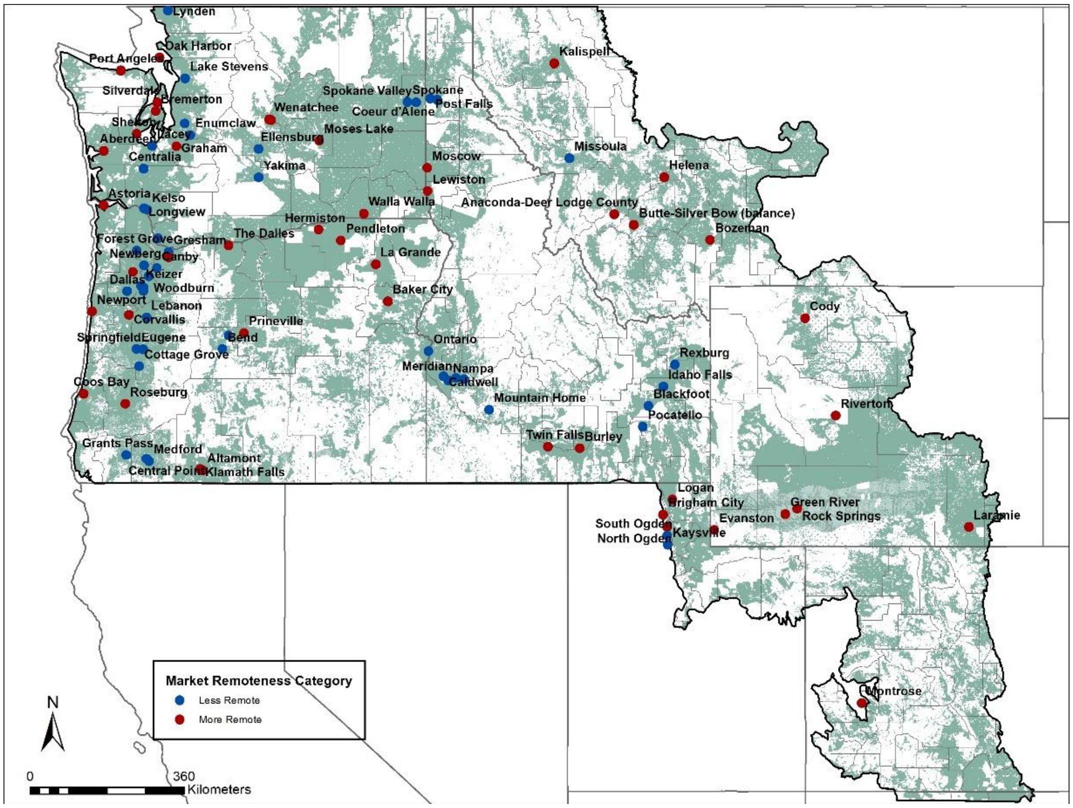
Map (A12): Pop. >2,500 Cost Distance Raster



Map (A13): New West Category



Map (A14): Market Remoteness Category



Lynden
Oak Harbor
Port Angeles
Lake Stevens
Silverdale
Bremerton
Shelton
Lacey
Enumclaw
Aberdeen
Graham
Centralia
Wenatchee
Moses Lake
Ellensburg
Yakima
Spokane Valley
Spokane
Post Falls
Coeur d'Alene
Kalispell
Missoula
Helena
Moscow
Lewiston
Astoria
Kelso
Longview
Walla Walla
Hermiston
Pendleton
The Dalles
Anaconda-Deer Lodge County
Butte-Silver Bow (balance)
Bozeman
Forest Grove
Gresham
Newberg
Canby
Keizer
Dallas
Woodburn
La Grande
Baker City
Newport
Lebanon
Corvallis
Prineville
Bend
Springfield
Eugene
Cottage Grove
Ontario
Meridian
Nampa
Caldwell
Mountain Home
Cody
Rexburg
Idaho Falls
Blackfoot
Pocatello
Riverton
Coos Bay
Roseburg
Twin Falls
Burley
Grants Pass
Medford
Altamont
Central Point
Klamath Falls
Logan
Brigham City
Green River
Rock Springs
South Ogden
North Ogden
Kaysville
Evanston
Laramie
Montrose
Market Remoteness Category
Less Remote
More Remote
N
0
360
Kilometers