THESIS

THE INFLUENCE OF CLIMATE, AMENITIES AND SOCIO-ECONOMIC FACTORS ON POPULATION GROWTH IN AREAS AROUND WESTERN NATIONAL FOREST LAND

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ABSTRACT

THE INFLUENCE OF CLIMATE, AMENITIES AND SOCIO-ECONOMIC FACTORS ON POPULATION GROWTH IN AREAS AROUND WESTERN NATIONAL FOREST LAND

Understanding factors that do and do not affect population change helps public land managers anticipate future population changes around national forests and informs future land management planning decisions. This study examines the effects of climate, natural and manmade amenities and socio-economic factors on population growth in rural counties in the West that contain national forest land. Further, it employs a series of forecasting models to estimate population change through 2060 under multiple climate change scenarios and a baseline climate scenario, with particular focus on the five Wyoming counties that contain the Shoshone National Forest. Cross-sectional analysis of population growth from 2000 to 2010 indicates that a wide range of variables are significant in predicting population change. Within the class of climate variables, average low winter temperature exhibits a highly significant negative correlation with population change (i.e. as winter temperatures rise, population growth slows). Average high summer temperature also has a significant negative correlation with population growth, though only when analyzed independently of average low winter temperature. Estimated population growth rates through 2060 tended to be higher among sampled counties with larger base populations. For the most part, forecasting models predicted increases in population for the five Shoshone counties. Among these counties, projected percent change in population from 2010 to 2060 varied considerably less across models for the three counties with relatively larger base populations. Across forecasting models, aggregated predicted population

increases for the Shoshone region varied from 65.4% to 154.2%. A relatively small portion of this anticipated population growth was attributable to forecasted increases in summer and winter temperatures, compared to the underlying trend of higher predicted growth rates among counties with higher base year populations.

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CHAPTER 1: INTRODUCTION

In recent years, substantial analysis has been conducted on the influence of climatic factors on both economic growth and human migration (Deller et al., 2001; Poston Jr. et al., 2008; Cordell, 2011). This analysis has provided a foundation for research on the effects of predicted climate change on population growth and amenity-rich public lands. Indeed, the combination of evolving economies, increasing commoditization of natural amenities and changing climates likely will determine, to a large extent, population growth patterns in rural western counties over the next several decades.

Study Objective

The objective of this study is to estimate whether, and to what extent, climatic conditions of 199 counties, each of which contains at least a portion of one of 40 national forests located in 12 western U.S. states, influence population growth in the counties containing these forests. Other variables capturing ecological characteristics and manmade amenities of the forests, as well as infrastructure and socio-economic conditions in those counties in which the forests are contained, also will be analyzed for their influence on population growth. Model results will be compared to those from previous studies.

Further, this study's population growth estimates will focus on the five Wyoming counties that contain the Shoshone National Forest by applying climate change projections to population growth forecasting models. Located in northwest Wyoming, the Shoshone covers 2.4 million acres of varied terrain ranging from sagebrush to mountains. Abutting the forest to the west is Yellowstone National Park and, to the north, Montana (U.S. Department of Agriculture, 2013). Among the changes predicted to take place in the Shoshone are increased average summer and winter temperatures, elevated overall peak water flows countered by decreased peak summer flows, and increased overall precipitation concurrent with decreased summer precipitation (Rice et al., 2012).

Given climate projections for each of the counties comprising the study sample, population forecasts may help inform county and state governments how climatic changes will affect human migration to population centers surrounding the Shoshone and other national forests over the next several decades. To the extent that model results suggest that other factors, including manmade and natural amenities, as well as select socio-economic conditions, also influence population growth, public land managers' and governments' planning for population growth may consider these as well. Further, this study will add value to the growing body of literature studying the drivers of population growth in the rural West through its regional focus and breadth of analysis of climatic, ecological, manmade and socio-economic factors.

CHAPTER 2: LITERATURE REVIEW

Human migration in the western United States increasingly is being examined in the context of the confluence of several phenomena: the economic impact of the preservation of federal lands; the appeal of natural and manmade amenities; the changing landscape of the economies of the rural west; and climate change. Studies in the late 1990's began to dispel the argument that land and species preservation slows economic development in the West (Duffy-Deno, 1997; Duffy-Deno, 1998). To the contrary, an expanding body of literature demonstrates that the presence of wilderness areas and natural amenities positively impacts local economies and population growth (Rudzitis and Johnson, 2000; Deller et al., 2001; Hill et al., 2009; Cordell et al., 2011). Further, economies of the West increasingly rely on outdoor recreation, as well as sectors such as finance, technology, real estate and business services, and less on traditional sectors such as mining, wood products, farming and ranching (Murphy, 2007).

The scope of literature reviewed in this chapter reflects the interplay of the factors that are considered in this study as potential drivers of future population growth. The review begins with a survey of literature that examines the role that amenities play in spurring economic and population growth in rural areas, with an initial focus on the particular effects of federal land and species preservation. The focus of the review then shifts to the specific role that climate has played in influencing historical migration, as well as the anticipated effects of climatic factors on future migration trends. Finally, this section provides a summary of U.S. Forest Service climate changes for the Shoshone National Forest.

There has been disagreement historically regarding the economic impact of laws preserving land and species in non-metropolitan counties of the West. In analyzing the effects of the listing of threatened and endangered species by the Endangered Species Act on employment growth rates for 333 non-metropolitan counties in the eleven-state West between 1980 and 1990, Duffy-Deno (1997) rejected the hypothesis that endangered species listing had a negative effect on. Duffy-Deno (1998) subsequently evaluated the hypothesis that employment in resource-based industries in the intermountain West was negatively impacted by the existence of federal wilderness land. Sampling from 250 nonurban counties in the eight states of the intermountain West, he used a disequilibrium model of population and employment growth to reject the hypothesis.

Rudzitis and Johnson (2000) provided additional clarity regarding the economic impacts, both positive and negative, of federal wilderness designation. The authors surveyed existing studies to explain the dichotomous economic effects of federal wilderness designation: while commodity extraction on federal lands may create more jobs than wilderness designation in the short-term, wilderness designation plays a significant role in attracting new migrants to a place or region. The authors specifically pointed to rapid population increases through the 1990s in areas where timber harvests and resource extraction experienced significant declines, including states of the intermountain West and Pacific Northwest.

Rasker et al. (2003) examined the importance that wilderness, national parks, national monuments and other protected public lands can play in driving economic growth, but also considered are other economic development variables, including access to metropolitan areas, via both road and airport, as well as the level of education of the workforce. The authors first documented the transition of western rural economic development from a reliance on extraction industries, including farming, ranching, mining, energy development and the wood products industry, to non-labor sources of income, such as money earned from investments and retirement benefits, as well as service-related industries. Employing a variety of statistical techniques, the authors argued that counties that contain or are located close to protected lands grow fastest. In order of importance, drivers of income growth in the west were: producer services; education; proximity to a major airport; the presence of a ski resort; arts, entertainment and food; proximity to protected lands; and mountains.

Booth (1999) examined the spatial determinants of population, employment and income densities in 86 rural mountain counties of California, Colorado and Montana. Common to each of the counties included in the study was the inclusion of a large amount of federal lands in federal ownership within their boundaries. Booth's analysis covered the years 1985-1994 and revealed that high population densities were correlated with proximity to large metropolitan centers, a concentration of natural amenities and the presence of manmade amenities such as ski areas, National Parks and universities and colleges. Booth contrasted the importance of these factors in driving population growth with the relatively lesser importance of employment in locationally dependent industries; by extension, he concluded that some migrants must have relatively "footloose" forms of income.

Additional pre-Internet age studies revealed the importance of natural amenities in driving in-migration and spurring economic development. Johnson and Rasker (1995) surveyed 500 businesses located in the Greater Yellowstone Ecosystem to test the assertion that environmental amenities, in addition to traditional economic measures, attract new businesses and increase retention of existing businesses. Among the authors' findings were that the quality of the environment factored heavily in rural business owners' location decisions and that quality of life values, associated strongly with natural amenities, were particularly important to business owners who had lived in the region for more than five years.

Rasker and Hansen (2000) tested the relative influence of a broad range of ecological, amenity, social and economic variables on rural population growth, with a specific focus on the Greater Yellowstone Region. The authors employed a two-tiered approach, first determining whether a relationship existed between population growth and ecological characteristics of rural land, and then testing ecological, economic and social variables against one another to determine which held the highest relative power for explaining population growth. Among the strongest drivers of population growth in rural counties were forest cover, high variation in topography, maximum annual precipitation over the timer period 1961-1990, and the degree to which the land is in some form of protected status. Also strongly correlated with population growth were education of the population and the percentage of people employed in the business and producer services. Looking ahead, the authors suggested the validity of testing whether the Internet plays a role in facilitating rural population growth.

The particular influence of climate on migration patterns has garnered greater attention in recent years. The role of climate, in the context of both historical migration and future population shifts, increasingly has been incorporated into studies analyzing the primary drivers of migration patterns in the U.S. Poston Jr. et al. (2009) examined the effect of climate on in-migration, out-migration and net migration across the 50 U.S. states over the time period 1995-2000. The authors analyzed the significance of three dimensions of climate – temperature, humidity and wind – on migration, both in isolation and together with variables drawn from human ecology. Study results showed conclusively that each of the three climate dimensions was strongly associated with one or more of the migration rates, even when modeled with the other independent variables. In many instances, the authors found that climate had the strongest effect on migration. Overall, the study showed that population gains through migration were correlated with climates characterized by winters with less extreme low temperatures and summers with less extreme high temperatures and humidity.

Cordell et al. (2011) analyzed population migration patterns in the United States from 1990 to 2007 to determine the influence of natural amenities, including climate and landscape. Among the authors' findings were that people prefer rural areas with mild winters and cooler summers, as well as varied landscapes. The authors then applied their findings on the effects of these amenities to forecast rural migration through 2060, projecting for which regions predicted changes to natural amenities would have a positive or negative effect. A brief comparison of findings of Cordell et al. (2011) and this study is presented in Chapter 4.3.

Specifically relevant to this study are predicted climatic changes to the Shoshone National Forest. Rice et al. (2012) analyze the historic climate of the Shoshone to estimate the forest's future climate and its effects on natural resources. Among the authors' key projections are: annual temperatures will increase 3°F by 2050; seasonal increases in temperature will range from 2° to 10°F by 2100; winter temperatures will increase 4°F relative to temperatures observed from 1950 to 1999; summer temperatures will increase 5°F relative to temperatures observed from 1950 to 1999; annual precipitation will increase by 10%, with a winter increase in precipitation of 10% and a summer decrease of 10%. Further, the authors' analysis yielded the following projections: peak water flows will increase over the 21st century 40 to 154%; summer flows will decrease 30 to 62% as summer temperatures increase; aggregate annual flows will decrease 5 to 24% with a net temperature increase; and annual flows will begin 4 to 5 weeks earlier than present as temperatures increase. While climate change is considered in this study only in terms of changes in temperature and precipitation, the associated effects on amenities such as miles of river and lake area may be incorporated into future analysis.

CHAPTER 3: METHODOLOGY

3.1 Forecasting Model Framework

Sample selection was determined largely by the study's focus on how climate change, specifically, affects population growth. An underlying premise of the study is that both winter and summer temperatures are predicted to increase across most of the west over the next several decades (Joyce et al. in press, Coulson et al. 2010b, Coulson et al. 2010c)**.** For example, Forest Service climate projections indicate that the Shoshone National Forest will experience temperatures in future decades currently present in areas further south. Put differently, the climates of states such as New Mexico and Arizona are projected to gradually migrate northward. It was therefore important to include national forests encompassing a range of latitudes. The inclusion of forests in the three coastal states – California, Oregon and Washington – further increased the climatic heterogeneity across sampled counties.

As explained in greater detail below, all climate variables were included in final models, regardless of level of significance. This was done to identify the particular impact of climatic changes on population growth projections, keeping other independent variables constant. Other independent variables under analysis reflect existing literature examining drivers of amenity migration and population growth in rural western counties. While in- and out-migration implicitly are examined, as migration is a key contributor to population change, more readily accessible and reliable data for population growth were available at the county level. Therefore, net population change (in percentage terms), and not in- and/or out-migration, is the dependent variable under analysis.

3.2 Data

Initial modeling considered population change from 2000 to 2010 only. However, subsequent modeling was performed for three time periods - 2000-2005, 2005-2010 and 2000-2010 - as it was hypothesized the downturn in the economy in the latter part of the decade altered migration patterns. For all sets of models, the dependent variable is percent change in population from the base year to the end year. Change in population, in numeric terms, is equivalent to the following:

$$\Delta\ Population = Population_{2000} + Births_{2000\text{-}10} - Deaths_{2000\text{-}10}$$
$$+\ In\text{-}Migration_{2000\text{-}10} - Out\text{-}migration_{2000\text{-}10}$$

County populations for 2000 and 2010 were taken from the 2000 and 2010 Censuses, respectively, while 2005 population figures represent intercensal Census Bureau estimates. Analysis was limited to 2000 and after, as it was hypothesized that a structural change in the socio-demographic composition of rural areas was facilitated by the advent of the Internet.

Independent Variables

Four classes of independent variables – climate, built features, natural amenities and socio-economic measures – were hypothesized for their significance in influencing population change. Table 3.2.1 defines all independent variables that are included in final model results, while Table 3.2.2 defines variables from each category that lacked significance across models. Data for many of the independent variables, as well as population, were measured at the county level. Data capturing natural and built amenities of national forests, however, were available only at the forest level. It therefore was necessary to determine how to reconcile these forest-level data with county-level analysis. A county-level weighted calculation of forest amenity values based on the percentage of the total area of a forest lying within a county was rejected, as the distribution of amenities – both natural and manmade – across different sections of forests is uneven. Instead, county-level amenity data under analysis reflects the sum of amenity levels across all sampled national forests lying even partially within a county. The justification for this approach is that residents of a county containing part of a national forest have access to all of that forest's amenities, even if they lie outside county borders.

Data Limitations and Variations in Socio-Economic Variables across Models

Intercensal data capturing socio-economic measures included in prior analysis were not available in certain cases. Specifically, percentage breakdown of employment by industry was incomplete for many of the sampled counties. However, intercensal percent of employment considered farm jobs was complete for all sampled counties and, therefore, has been incorporated into the models capturing migration over the two five-year periods. In addition, housing affordability within the models covering 2000-2005 and 2005-2010 is measured as median selected owner costs as a percentage of household income for houses with a mortgage, but for 2000-2010 is measured as the percentage of county households with a mortgage for which selected owner costs (including the mortgage) is greater than 30 percent of household income. Further, this study does not break down population change into in-migration and out-migration, as statistically reliable county-level migration data was not available at this level of detail.

Sample Selection

A total of 202 counties contain some portion of at least one of the 40 national forests that comprise the full sample. However, as county population (and population-squared) is an independent variable in all models, a data plot of percent change in population against population

Table 3.2.1. Definition of Variables Included in Final Models

Climatic	
High Summer Temp	Average annual high temperature (° Fahrenheit)*
High Summer Temp SQ	Square of average annual high temperature
Low Winter Temp	Average annual low temperature (° Fahrenheit)*
Low Winter Temp SQ	Square of average annual low temperature
Temperature Difference	Difference of average high summer and average low winter temperatures
Precipitation	Average annual precipitation (mm)
Precipitation SQ	Square of average annual precipitation
Built Features	
Picnic Tables	Number of picnic tables in all NFs contained at least in part within county
Campgrounds	Number of campgrounds in all NFs contained at least in part within county
Hiking Trails	Miles of hiking trails in all NFs contained at least in part within county
Campsites	Number of campsites in all NFs contained at least in part within a county
Natural Features	
Lake Area	Total area (sq. miles) of lakes in all NFs contained at least in part within county
Wilderness Lake Area	Total area (sq. miles) of wilderness lakes in all NFs contained at least in part within county
Wilderness River Miles	Total miles of wilderness river in all NFs contained at least in part within county
Max. Elevation	Highest elevation (feet) in county
Mountainous Topography	Dummy variable designating topography of county mountainous (Natural Amenities Scale)
Socio-Economic	
Population	County population in year t. For Models 1a-1c and Models 3a-3c, county population in the year 2000 is used; population in 2005 is used in Models 2a-2c.
Population SQ	Square of county population in year t
Housing Cost	Model 1a-1c and Models 2a-2c: Median selected owner costs as percentage of household income for houses with a mortgage. Example costs include mortgage, electricity, gas, fuel, water and condo fees. Models 3a-3c: Percentage of county households with a mortgage for which selected owner costs (same as above) constitute at least 30 percent of household income.
Non-labor Income	Non-labor income as a percentage of total income. Non-labor income includes dividends, interest and rent collected, as well as government payments to individuals, payments to nonprofit institutions, and business payments to individuals.
Farm Jobs	Number of farming jobs as percentage of all jobs in county (Models 1a-1c and Models 2a-2c only).

*Average low winter temperature and average high summer temperature values were converted from Centigrade to Fahrenheit to avoid negative winter temperature values.

Table 3.2.2. List of Variables, by Category, that Lack Significance Across Models

Climatic
All climate variables, regardless of level of significance, were included in final models.
Built Features
Driving time to closest metropolitan center
Interaction term of dummy variable for presence of a ski area within county with average low winter temperature
Dummy variable for presence of National Park within county
Dummy variable for presence of an interstate within county
Miles of wilderness hiking trails in all NFs in county
Percent of total area of county that is constituted by national forest land
Miles of dirt and paved roads in all NFs contained at least in part within county
Natural Features
Number of lakes in all NFs in county
Miles of river in all NFs in county
Dummy variable for topographical designation of county as Plains and Tablelands (Natural Amenities Scale)
Dummy variable for topographical designation of county as Plains
Dummy variable for topographical designation of county as Open Hills or Mountains
Socio-Economic
Percentage of county workforce employed in travel/tourism sectors (Models 3a-3c only)

revealed that the three counties with much greater populations (> 900,000) than the other 199 biased the results for the population variable. The biasing effect of these three counties was confirmed by comparing regression results for the full sample with results for the smaller sample of 199 counties. Therefore, these three outlier counties, each of which contains a large metropolitan center, were excluded from the final sample.

Chow tests were performed with regard to the percentage of total county land area constituted by national forest land, as it was hypothesized that parameter instability may occur for a sub-sample of counties containing relatively little NF land. However, no parameter instability was detected, and no further sample reduction was deemed necessary. Chow tests also revealed no parameter instability with regard to the percentage of total national forest land in a county accounted for by the in-sample 40 forests, as opposed to non-sampled national forests that lie, at least in part, within sampled counties.

3.3 Model Specification and Development

Three sets of models were run for each of the three time periods considered: models 1a, 1b and 1c for 2000-05; 2a, 2b and 2c for 2005-10; and 3a, 3b and 3c for 2000-2010. Distinguishing characteristics for the three types of models are:

- Model a. All continuous, non-percentage variables are in non-logarithmic form. Climate variables are analyzed in both linear and quadratic forms.
- Model b. Climate and population variables are in non-logarithmic form, with all other continuous, non-percentage variables in natural log form. Climate variables are analyzed in both linear and quadratic forms.
- Model c. All continuous, non-percentage variables, including climate and population, are in logarithmic form.

The model specification is summarized as follows:

$$\% \, \Delta \, Population = b_0 + b_{1\text{-}6}(Climate\ Variables) + b_{7\text{-}17}(Built\ Features)$$
$$+ \, b_{18\text{-}27}(Natural\ Features) + b_{28\text{-}35}(Socio\text{-}Economic\ Measures)$$

Temperature Variable Analysis

Regardless of level of significance, all climate variables were included in a first set of models (denoted "FC"), while non-climate variables lacking high significance were excluded. This was done to allow for population change projections that incorporate average high summer temperature, average low winter temperature and average annual precipitation variables, as well as to facilitate cross-model comparison of the estimated effects of each climate variable on population growth. However, it was hypothesized that average high summer temperature and average low winter temperature may help explain one another and, consequently, yield incorrect significance tests for temperature variables. This hypothesis of the presence of multicollinearity between temperature variables was supported by correlation matrices generated for all independent variables present in each of the final nine FC models (three for each of the three time periods) and VIF testing. Table B.4 is a correlation matrix for independent variables included in Model $3b_{FC}$.

To control for the potential confounding or suppressing effects of either or both temperature variables on the other, additional regressions were run and population projections generated in which a variable calculated as the difference between average annual high and low temperatures was substituted for average annual low temperature. These "temperature difference" models are denoted "TD." It was believed that replacing the linear and quadratic low winter temperature variables with the temperature difference variable – rather than just excluding them – would eliminate the potential for omitted variable bias. Since the winter temperature variables were highly significant across FC models, and the summer temperature variables were not, the latter were selected for inclusion in the TD models to allow for additional explicit analysis of the effect of summer temperatures on population change. As indicated in Table B.4, a correlation matrix for independent variables included in Model $3a_{TD}$, multicollinearity between temperature variables is much lower in the TD models than the FC models. Graphical representation of the relative correlations of average low winter temperature and temperature difference values, respectively, to average high summer temperature is provided in Figures 3.3.1 and 3.3.2. Additional explanation of the interpretation of the temperature difference variable models is provided in Chapter 4.

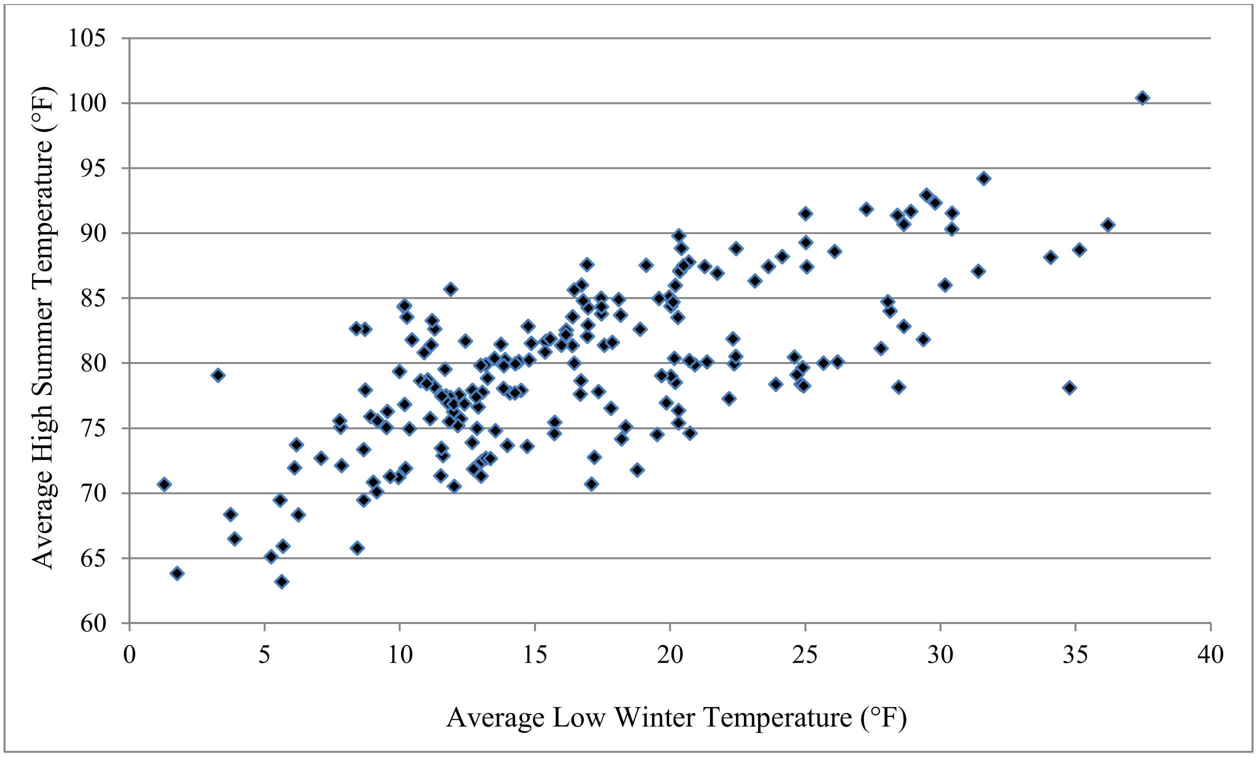

Figure 3.3.1. Average Low Winter Temperature against Average High Summer Temperature for 199 Counties (Base Climate Temperature Values)

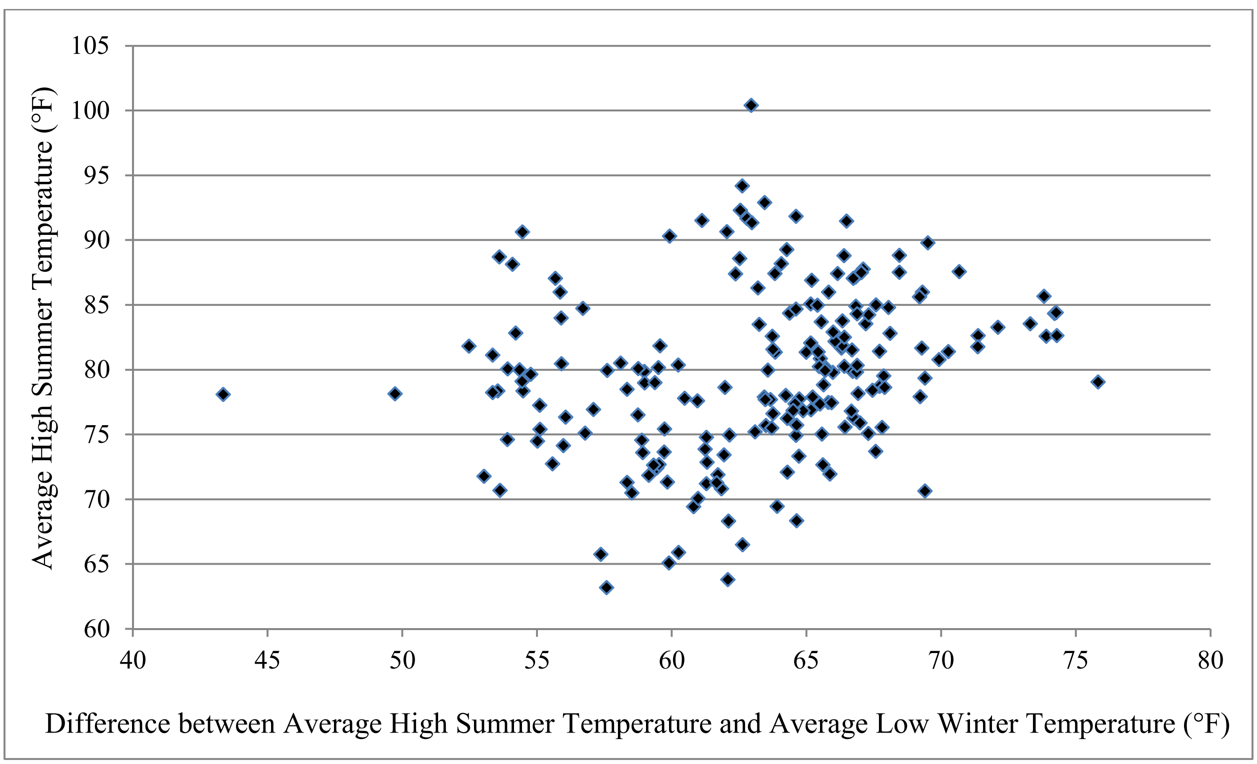

Figure 3.3.2. Difference between Average High and Average Low Annual Temperatures against Average High Summer Temperature for 199 Counties (Base Climate Temperature Values)

CHAPTER 4: MODEL RESULTS

4.1 Full Climate Variable Models

Only those non-climatic variables with p-values of 0.10 or lower were included, as one "best" model from each time period was to be selected for application to population projections. F-statistics for each of the nine FC models indicated high overall model significance across all models. As indicated by adjusted R-squared values, the models capturing percent change in population across 2000-05 (Models $1a_{FC}$-c_{FC}) and 2000-10 (Models $3a_{FC}$-c_{FC}) fit the data better than do the three models for 2005-10 (Models $2a_{FC}$-c_{FC}). Further, the "b" model for each time period exhibited the greatest explanatory power and consistency of sign and significance of independent variables. As a result, Models $1b_{FC}$, $2b_{FC}$ and $3b_{FC}$ were used to generate county population projections. Results for these three models are presented in Table 4.1.1 and analyzed below. Full results for all nine FC models are presented in Table B.1 and summarized in Appendix B.

Overall, Model $3b_{FC}$ held the highest predictive power with an adjusted R-squared of 0.4031, followed by Model $1b_{FC}$ (0.3747) and Model $2b_{FC}$ (0.3522). At least one variable from each of the four classes of independent variables was significant in all three models, and all variables had the same sign when highly significant in multiple models. While all but one non-climatic variable that was highly significant in Model $3b_{FC}$ were also significant in Model $2b_{FC}$, Model $1b_{FC}$ exhibited dissimilarity to the other two models with regard to which variables were highly significant. Results for the three models are explained by class below.

Climate

Neither the linear nor quadratic form of average high summer temperature or average annual precipitation was significant in any of the three best FC models. Average high summer temperature and high summer temperature-squared had negative and positive signs, respectively, in Models $2b_{FC}$ and $3b_{FC}$, but signs were reversed in Model $1b_{FC}$. Precipitation was positively correlated with population change in all three models, while precipitation-squared was negatively correlated.

Both linear and quadratic forms of average low winter temperature were highly significant in all three best FC models. The negative sign for the linear form and positive sign for the quadratic form indicate that the rate of population change will decline in counties where average low winter temperature increases, but only up to a point. A test of the joint significance of average high summer temperature and average low winter temperature in Model $3b_{FC}$ yielded the rejection of the null hypothesis that the variables were not significantly different from zero (Prob > F = 0.0001).

Built Features

Two variables – number of campgrounds and miles of non-wilderness hiking trails in all national forests lying at least in part within a county – were highly significant in all three best FC models. Number of campgrounds was negatively correlated with population growth, while miles of non-wilderness hiking trails had a positive correlation. Number of picnic tables in all national forests lying at least in part within a county was highly significant and positively correlated with population growth in Models $2b_{FC}$ and $3b_{FC}$ but was not significant in Model $1b_{FC}$.

The results for the built features variable category seem to suggest that national forests with a greater number of manmade amenities that are easily accessible to day visitors (picnic tables and hiking trails) attract people to reside in the areas around those forests, whereas a higher number of campgrounds may be a sign that a national forest is less accessible to day visitors.

Among the manmade amenities that were not highly significant across all FC models were driving time to the closest metropolitan center, presence of national park land within county borders, presence of a ski area in the county and an interaction term of the presence of a ski area with average low winter temperature. The lack of significance of these variables represents a departure from previous studies examining the key drivers of rural migration (Rasker et al., 2003; Booth, 1999) and likely is attributable to differences in the geographic compositions of the three study samples, variation in the time periods and range of independent variables under analysis and, possibly, disparities in the definition of what constitutes a ski area.

Natural Features

Only one variable – total area of non-wilderness lakes in all national forests contained at least in part within a county – was highly significant in all three best FC models and exhibited a positive correlation with population growth across the three models. Three other natural amenity variables – total area of wilderness lakes and total miles of wilderness rivers in all national forests lying at least in part within a county, as well as a dummy variable designating the county's topography as mountainous – were significant only in Models $2b_{FC}$ and $3b_{FC}$. Wilderness lake area and wilderness river miles were negatively and positively correlate with population growth, respectively, while mountainous topography was positively correlated with population growth.

Socio-Economics

Population was highly significant and positively correlated with percent population change in all three best FC models, while population-squared also was significant across models and was negatively correlated with population change. Thus, model results suggest that people are attracted to counties with sizeable population centers, but that population growth rates tend to decline at the upper end of the population distribution of the 199 sampled counties.

As noted in Table 3.1.1, and due to asymmetrical data availability for the different time periods analyzed, housing costs were measured somewhat differently between the five-year and ten-year models. However, while housing costs were measured identically (though for different years) in Models $1b_{FC}$ and $2b_{FC}$, the variable was significant only in Models $1b_{FC}$ and $3b_{FC}$. This likely is attributable to the recession that began in late 2007 and impacted employment rates, incomes and housing costs. In fact, across sampled counties, housing costs for households with mortgages constituted an average of 22.0 percent of household income in 2000 (used in Model $1b_{FC}$) and 24.3 percent in 2010 (used in Model $2b_{FC}$). The positive correlation between housing costs and population change in Models $1b_{FC}$ and $3b_{FC}$ over the time periods 2000-05 and 2000-10 may be an indication of people's willingness to pay higher housing costs in areas that afford them a higher level of amenities or improved quality of life.

Non-labor income, measured as a percentage of total household income, was highly significant and negatively correlated with population change in Models $2b_{FC}$ and $3b_{FC}$ but was not significant in Model $1b_{FC}$. That non-labor income – including dividends, interest and rent collected, as well as government payments to individuals, payments to nonprofit institutions, and business payments to individuals – was negatively correlated with population change over 2005-

10 and 2000-10 suggests that people were more likely over these time periods to move to areas with higher employment rates.

Farm employment, measured as the number of farming jobs as a percentage of all jobs in the county, was considered for inclusion only in Models $1b_{FC}$ and $2b_{FC}$. This variable was significant only in Model $1b_{FC}$ and was negatively correlated with population change.

4.2 "Temperature Difference" Models

As mentioned above, auxiliary forecasting models, in which a temperature difference variable was substituted for the linear and quadratic average low winter temperature variables, were generated for each of the three time periods. Across time periods, adjusted R-squared values were lower for each best TD model than for its respective best FC model; however, as exhibited in Table B.4, levels of correlation between the temperature difference and summer temperature variables were lower in the TD models than those between high summer and low winter temperature variables in the FC models. For the 2005-2010 and 2000-2010 time periods, the models with all non-percentage, non-dummy variables in continuous form (Models $2a_{TD}$ and $3a_{TD}$) were selected as the best models. For 2000-2005, Model $1b_{TD}$, in which all non-percentage, non-dummy variables were expressed in logarithmic form, was identified as the best model. Adjusted R-squared values for the three best models also indicate that Model $3a_{TD}$ (0.3926) held the highest predictive power, followed by Model $1b_{TD}$ (0.3745) and Model $2a_{TD}$ (0.3448). The superior predictive power of the best 2000-2010 and 2000-2005 TD models, relative to the best 2005-2010 TD model, mirrored the relative predictive strength of the three FC models to one another.

Table 4.1.1. Population Forecasting Model Results for Three "Best" Full Climate Variable Models

	$1b_{FC}$ (2000-05)	$2b_{FC}$ (2005-10)	$3b_{FC}$ (2000-10)
Adj. R-squared	0.3747	0.3522	0.4031
Independent Variables			
Climate[1]			
High Summer Temp	0.0149 (0.0179)	-0.0179 (0.0169)	-0.0250 (0.0324)
High Summer Temp SQ	-0.0001 (0.0001)	0.0001 (0.0001)	0.0002 (0.0002)
Low Winter Temp	-0.0084** (0.0036)	-0.0088** (0.0037)	-0.0206*** (0.0070)
Low Winter Temp SQ	0.0002** (0.0001)	0.0002** (0.0001)	0.0004** (0.0002)
Precipitation	9.88e-05 (8.94e-05)	4.85e-05 (0.0001)	0.0001 (0.0002)
Precipitation SQ	-9.39e-08 (5.39e-08)	-6.68e-08 (5.25e-08)	-1.32e-07 (1.02e-07)
Built Features[2]			
Picnic Tables		0.0183*** (0.0065)	0.0345*** (0.0124)
Campgrounds	-0.0530*** (0.0154)	-0.08621*** (0.0161)	-0.1576*** (0.0311)
Hiking Trails	0.0187** (0.0094)	0.0380*** (0.0092)	0.0647*** (0.0177)

Natural Features[2]			
Lake Area	0.0153*** (0.0054)	0.0178*** (0.0055)	0.0319*** (0.0109)
Wilderness Lake Area		-0.0084** (0.0039)	-0.0157** (0.0075)
Wilderness River Miles		0.0095** (0.0045)	0.0175** (0.0087)
Mountainous Topography		0.0273** (0.0112)	0.0471** (0.0219)
Socio-Economics			
Population[1]	8.70e-07*** (1.92e-07)	3.55e-07** (1.48e-07)	1.37e-06*** (3.39e-07)
Population SQ	-1.49e-12*** (3.86e-13)	-5.45e-13* (3.07e-13)	-2.35e-12*** (6.91e-13)
Housing Costs[3]	0.0099*** (0.0022)		0.4194*** (0.1215)
Non-Labor Income[4]		-0.2440*** (0.0592)	-0.4092*** (0.1172)
Farm Employment[5]	-0.2679*** (0.0755)		
Constant	-0.7393 (0.7145)	0.7704 (0.6754)	0.9610 (1.2964)

* Indicates p-value of 0.10 or lower

**Indicates p-value of 0.05 or lower

***Indicates p-value of 0.01 or lower

[1] Models “a” and “b” for each time period include linear and quadratic climate and population variables in non-logarithmic form; “c” models include climate and population variables only in natural log form. Models 1a-1c and 3a-3c use 2000 population; Models 2a-2c use 2005 population.
[2] Built and natural features variables for “a” models for each time period are in non-logarithmic form and are in natural log form in “b” and “c” models.
[3] Housing affordability for Models 1a-c and 2a-c is measured as median selected owner costs as a percentage of household income for houses with a mortgage for 2000 and 2010, respectively; it is measured in Models 3a-c as the percentage of households with a mortgage for which selected owner costs (including the mortgage) is greater than 30 percent of household income.
[4] 2005 data is used for Models 1a-c; 2010 data is used for Models 2a-c and Models 3a-c.
[5] 2005 data is used for Models 1a-c; 2010 data is used for Models 2a-c; a farm employment variable is not included in analysis for Models 3a-c.

Both linear and quadratic average summer temperature variables were highly significant in Models $2a_{TD}$ and $3a_{TD}$ but not in Model $1b_{TD}$. In all three models, linear average high summer temperature was negatively correlated with population change, while its quadratic term exhibited a positive correlation. The temperature difference variable was highly significant only in Model $3a_{TD}$ but was positively correlated with population growth across models. Additional interpretation of temperature difference variable results is provided below. Neither the linear nor quadratic average annual precipitation variable was significant in any of the three best TD models. A test of the joint significance of average high summer temperature and temperature difference in Model $3a_{TD}$ yielded the rejection of the null hypothesis that the variables were not significantly different from zero (Prob > F = 0.0001).

Directions of influence were the same for all variables that were highly significant in multiple TD models. Signs also were the same for all variables that were highly significant in both FC and TD models. Number of campsites, and not campgrounds, in all national forests contained at least in part within a county was significant in Models $2a_{TD}$ and $3a_{TD}$ and was negatively correlated with population change. Not surprisingly, the level of correlation between number of campsites and number of campgrounds (0.8607) was high, and only one of these variables was included in any one particular model.

Across the three best TD models, population was positively correlated and population-squared negatively correlated with population change. As with the FC models, the variable capturing housing costs was positively correlated with population growth but significant only in the 2000-05 and 2000-2010 models (Models $1b_{TD}$ and $3a_{TD}$). Non-labor income was negatively correlated with population growth and significant in all three TD models. Results of the three best TD models are presented in Table 4.2.1, while Table B.2 provides results for all nine TD models.

Interpreting the Temperature Difference Variable Results

As noted above, the primary objective in substituting the average low winter temperature variables with the temperature difference variable was to control for the potential confounding or suppressing effects of low winter temperature and high summer temperature on one another. Indeed, a comparison of average high summer temperature variable results for the FC and TD models reveals changes in coefficient magnitudes and p-values across respective time period models. That the temperature difference variable had a positive sign (though highly significant only in Model $3a_{TD}$) and the high summer temperature variable a negative sign in all three TD models (highly significant in Models $2a_{TD}$ and $3a_{TD}$) suggests that people are attracted to areas with large seasonal differences in temperature and/or areas with colder winter temperatures.

Considering simultaneously the negative correlations between population change and both low winter temperature (across "best" FC models) and high summer temperature (wherever highly significant), it appears that the temperature difference variable results affirm that it is, in fact, average low winter temperature that is a particularly strong predictor of population growth. However, given the relatively low correlation between high summer temperature and temperature difference, the statistically significant negative association of high summer temperature with population growth is an important result of the TD analysis and one not evident from the FC models. Thus, the temperature difference variable analysis achieves the goal of adding statistical clarity to the effects of summer and winter temperatures, independent of one another, on population growth.

Table 4.2.1. Population Forecasting Model Results for Three "Best" Temperature Difference Models

	$1b_{TD}$ (2000-05)	**$2a_{TD}$ (2005-10)**	**$3a_{TD}$ (2000-10)**
Adj. R-squared	0.3745	0.3448	0.3926
Independent Variables			
Climate			
High Summer Temp	-0.0123 (0.0135)	-0.0513*** (0.0128)	-0.1006*** (0.0244)
High Summer Temp SQ	0.0001 (0.0001)	0.0003*** (0.0001)	0.0006*** (0.0002)
Precipitation	1.074e-04 (8.95e-05)	2.26e-06 (9.17e-05)	-0.0001 (0.0002)
Precipitation SQ	-8.35e-08 (5.33e-08)	-1.78e-08 (5.28e-08)	-5.32e-09 (1.01e-07)
Temperature Difference	0.0015 (0.0013)	0.0010 (0.0012)	0.0057** (0.0002)
Built Features			
Picnic Tables		0.0011*** (0.0003)	0.0018*** (0.0005)
Campgrounds	-0.0488*** (0.0151)		
Hiking Trails	0.0165* (0.0092)		
Campsites		-4.51e-05*** (8.56e-06)	-7.28e-5*** (1.54e-05)

Natural Features			
Lake Area	0.0148*** (0.0054)		
Mountainous Topography		0.0323*** (0.0113)	0.0609*** (0.0216)
Max Elevation		4.55e-06* (2.31e-06)	
Socio-Economics			
Population	9.02e-07*** (1.88e-07)	4.37e-07*** (1.58e-07)	1.51e-06*** (3.35e-07)
Population SQ	-1.60e-12*** (3.75e-13)	-6.93e-13** (3.02e-13)	-2.60e-12*** (6.81e-13)
Housing Costs	0.0105*** (0.0022)		0.5611*** (0.1202)
Non-Labor Income	-0.1335* (0.0700)	-0.2320*** (0.0588)	-0.4147*** (0.1158)
Farm Employment	-0.2029*** (0.0746)		
Constant	0.2475 (0.5678)	2.0023*** (0.5301)	3.6921*** (0.9963)

4.3 Comparison with Cordell et al. (2011)

This section compares findings of Cordell et al. (2011) with the current study, as both focus on the influence of natural amenities and, in particular, climatic factors, on population change. It is important to conduct this comparison in the context of the differences in study frameworks. For example, Cordell et al. analyzed migration, rather than net population growth, and included a sample of 2,014 rural counties encompassing all regions of the U.S. Cordell et al. omitted socio-economic factors from their analysis but included a more comprehensive range of amenity variables. Another difference is the current study's incorporation of national forest-level natural amenity data, rather than county-level data. While these and other differences render imperfect a direct comparison of results, they also provide insight into what aspects of the current study may explain results that differ from existing literature.

As shown in Table 4.3.1, differences exist between the two studies with regard to measures, signs and significance of natural amenity variables. Where discrepancies in variable measurement exist, however, the variables are proxies for one another. There is agreement between the studies with regard to the signs of all variables except for winter temperature, which is positively correlated with migration in Cordell et al., as well as other studies (Poston Jr. et al., 2009), but negatively correlated with population growth in Model $3b_{FC}$. Each of the five variables was highly significant in Cordell et al., while average high summer temperature and average annual precipitation were not in Model $3b_{FC}$. Magnitudes are excluded, primarily because this study is estimating the effects of changes to natural amenities on percent change in population, while magnitudes in Cordell et al. signify that unit changes in natural amenities will result in a numeric change in net migration that is equal across sampled counties.

Table 4.3.1. Comparison of Selected Results for Model $3b_{FC}$ with Cordell et al. (2011)

Variable	Study	Definition	Sign	Statistically Significant?
Summer temp	Current	Average high summer temperature	—	No
	Cordell	Average summer temperature	—	Yes
Winter temp	Current	Average low winter temperature	—	Yes
	Cordell	Average winter temperature	+	Yes
Precipitation	Current	Average annual precipitation	+	No
	Cordell	Average monthly precipitation	+	Yes
Water area	Current	Total area of lakes in all NFs in county	+	Yes
	Cordell	% of county covered by water	+	Yes
Mountainous	Current	County considered mountainous (Natural Amenities Scale)	+	Yes
	Cordell	% of county area that is mountainous	+	Yes

CHAPTER 5: POPULATION PROJECTIONS

5.1 Projection Methods

U.S. Forest Service county-level climate change projection data for the years 2005 to 2060 were used to estimate population growth through 2060 for all 199 counties in the sample. The USFS provided nine sets of climate projections (Joyce et al. in press, Coulson et al. 2010b, Coulson et al. 2010c), data from each of which was plugged into Models $1b_{FC}$, $2b_{FC}$ and $3b_{FC}$, as well as Models $1b_{TD}$, $2a_{TD}$ and $3a_{TD}$, to generate growth estimates. For Models $1b_{FC}$, $1b_{TD}$, $2b_{FC}$ and $2a_{TD}$, which forecast population change over five-year periods, values for predicted percent change in population (and new population level) were generated in five-year increments. Predicted change in population was calculated over 10-year increments for Models $3b_{FC}$ and $3a_{TD}$. In Tables 5.2.1-5.2.6, population in the year 2010 for Models $1b_{FC}$ and $1b_{TD}$ represents predicted population, while it represents actual 2010 population in the remaining four best models. This is because population growth was measured through 2010 for Models $2b_{FC}$, $2a_{TD}$, $b3_{FC}$ and $3a_{TD}$, but only through 2005 for Models $1b_{FC}$ and $1b_{TD.}$ As climate variables lacking high significance were included in all best six models, confidence intervals ($\alpha = 0.10$) were calculated for each 2060 population projection and are included in Tables 5.2.1-6.

All variation in population estimates is attributable to adjustments to climate and population levels across time period models; data for all natural and built features, as well as socio-demographic variables other than population and population-squared, are held constant from the base year (alternately 2005 or 2010) through 2060.

The Population Inertia Effect

Across model population projections, there was a pronounced tendency for percentage growth estimates to be much higher among those counties within the sample with higher base year populations, with the exception of counties at the highest end of the 2010 population distribution. This "population inertia" effect was most pronounced in Model $3a_{TD,CC}$: the mean estimated 2010 population for counties for which Model $3a_{TD,CC}$ predicted a net decline in population from 2010 to 2060 was 8,794, compared to a mean population of 71,498 for those counties for which the model predicted a population increase. For Model $3b_{FC,CC}$, the mean 2010 population of counties with predicted population losses through 2060 was 9,557; for those counties for which the model predicted population increases, the mean 2010 population was 60,306. Median 2010 populations for the population decline and growth sub-samples for Model $3b_{FC,CC}$ were 6,153 and 20,092, respectively. In total, 52 counties witnessed population declines from 2000 to 2010. Of the 33 counties forecasted to experience population losses from 2010 to 2060, 19 were among those with net declines in population from 2000 to 2010.

While population growth predictions for counties with higher base year populations generally were higher than for less-populated counties, this trend was reversed for the counties with the largest 2010 populations. For Model $3b_{FC,CC}$, the mean predicted growth rate from 2010 to 2060 among counties with base year populations between 100,000 and 400,000 was 201.2%, compared with 13.2% for the four sampled counties with base year populations greater than 500,000. The positive sign of the linear population term and negative sign of the quadratic population term (both across all models) explain the concave distribution of predicted growth rates, when plotted against base year population. The respective positive and negative effects of the linear and quadratic population terms are illustrated in Figures 5.1.1 and 5.1.2.

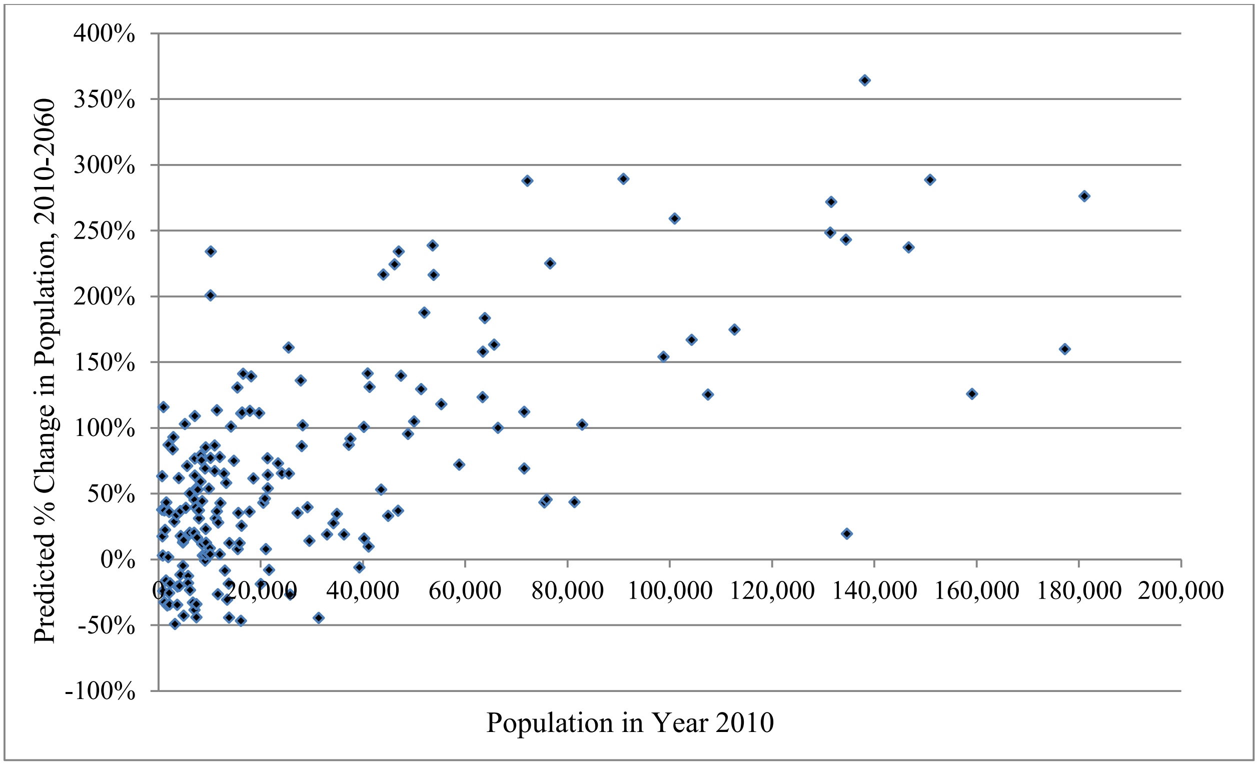

Figure 5.1.1. Estimated Population Growth Rate against 2010 Population for Counties with Base Populations < 200,000 (Model 3b$_{FC,CC}$)

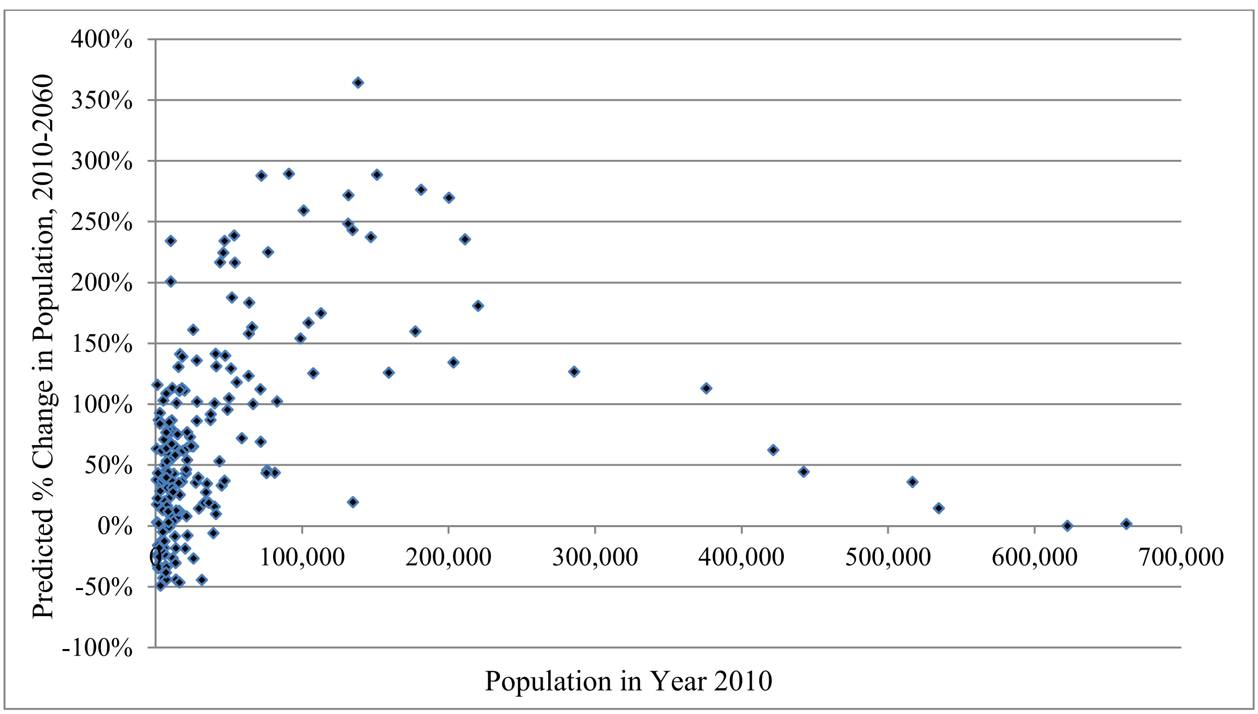

Figure 5.1.2. Estimated Population Growth Rate against 2010 Population for 199 Sampled Counties (Model 3b$_{FC,CC}$)

5.2 Predicted Population Growth of Shoshone NF Counties

Aggregate population growth estimates across the five-county Shoshone region ranged from 65.4% (Model1b$_{TD,BC}$) to 154.2% (Model 2b$_{FC,BC}$). All aggregate growth estimates were higher under the baseline climate scenario than the climate change scenario (represented as the mean of the nine climate change scenario population estimates). Numerically, aggregated regional 2060 population estimates ranged from 163,854 to 266,053, an increase from the 2010 population of 104,681. Further, all six FC model population projections were higher than those of respective TD models. On a county level, this also was the case for Fremont, Hot Springs, Park and Sublette Counties. For Teton County, projections for Models 2a$_{TD,BC}$, 2a$_{TD,CC}$ and 3a$_{TD,BC}$ were higher than Models 2b$_{FC,BC}$, 2b$_{FC,CC}$ and 3b$_{FC,BC}$, respectively. In general, there was less variation in predicted percentage population growth across all models for the three counties with the highest 2010 populations: Fremont, Park and Teton.

Table 5.2.1. Projected Population Growth for Five Shoshone Counties, 2010-2060

Model 1bFC	2010 Population	2060 Population	% Change	C.I. ($\alpha = 0.10$)	
Baseline Climate	101,400	216,705	113.7%		
9 Climate Change Model Average	101,262	202,772	100.2%	196,619	208,925
Model 2bFC					
Baseline Climate	104,681	266,053	154.2%		
9 Climate Change Model Average	104,681	239,030	128.3%	232,315	245,745
Model 3bFC					
Baseline Climate	104,681	231,943	121.6%		
9 Climate Change Model Average	104,681	214,738	105.1%	209,839	219,637
Model 1bTD					
Baseline Climate	101,618	174,078	71.3%		
9 Climate Change Model Average	99,050	163,854	65.4%	161,476	166,232
Model 2aTD					
Baseline Climate	104,681	241,610	130.8%		
9 Climate Change Model Average	104,681	229,647	119.4%	223,569	235,725
Model 3aTD					
Baseline Climate	104,681	193,216	84.6%		
9 Climate Change Model Average	104,681	175,826	68.0%	169,778	181,874

Significance of Difference between BC and CC Projections

This study focuses primarily on population projections for the five Wyoming counties that contain the Shoshone National Forest. Figures C.1-C.15 compare population projections under climate change and baseline climate scenarios for all six best FC and TD models, with population expressed as the mean of the nine climate forecast model projections in the climate change (denoted CC) models. Figures C.16-C.30 compare 2060 population estimates by county and forecasting time period for each of the nine climate forecast models, as well as for a baseline climate (denoted BC), or no-climate change, model. For example, Figure C.16 displays 2060 population projections for Fremont County for Models $1b_{FC}$ and $1b_{TD}$, and for all nine climate change scenarios and the baseline climate scenario. Predicted percent change in population for each county under both baseline climate and climate change (calculated as the mean of predicted percent change across the nine climate forecasting models) scenarios for each forecasting time period model, and for both FC and TD models, is displayed in Tables 5.2.2-5.2.6. Table 5.2.1 shows predicted percent change in population, aggregated across the five Shoshone counties, under both baseline climate and climate change scenarios for each forecasting time period.

For each county and model, BC and CC projections were compared to determine if the former fell within the 90 percent confidence intervals of the CC projections. This was the case for Fremont County projections for Model $3a_{TD}$, as well as for Hot Springs County for Models $2b_{FC}$ and $1b_{TD}$. Therefore, these three sets of population projections were determined not to be statistically different from the baseline climate population change estimates. All other BC projections fell outside the 90 percent intervals of their respective CC projections. It is uncertain whether these estimates are significantly different, as confidence bands were not generated for BC projections.

Fremont

Population growth estimates for Fremont County ranged from 54.5% (Model $1b_{TD,CC}$) to 151.2% (Model $2b_{FC,BC}$). From a 2010 figure of 40,123, Fremont County's population was predicted to rise to between 58,834 and 100,808 residents. Among FC models, Models $2b_{FC,CC}$ and $2b_{FC,BC}$ predicted greater population growth than the 2000-2005 and 2000-2010 models. Similarly, the two 2005-2010 TD models forecasted greater population growth than Models $1b_{TD,BC}$, $1b_{TD,CC}$, $3a_{TD,BC}$ and $3a_{TD,CC}$. The Model $3a_{TD,BC}$ estimate for 2060 population was the only one that fell within the 90% confidence bands of the Model $3a_{TD,CC}$ estimate.

Table 5.2.2. Projected Population Growth, Fremont County, 2010-2060

	Model 1bFC	**2010 Population**	**2060 Population**	**% Change**	**C.I. (α = 0.10)**	
FC	Baseline Climate	38,974	76,301	95.8%		
	9 Climate Change Model Average	38,907	70,460	81.1%	68,842	72,078
	Model 2bFC					
	Baseline Climate	40,123	100,808	151.2%		
	9 Climate Change Model Average	40,123	96,142	139.6%	93,472	98,812
	Model 3bFC					
	Baseline Climate	40,123	84,527	110.7%		
	9 Climate Change Model Average	40,123	80,296	100.1%	78,575	82,017
TD	**Model 1bTD**					
	Baseline Climate	39,337	61,707	56.9%		
	9 Climate Change Model Average	38,078	58,834	54.5%	57,840	59,829
	Model 2aTD					
	Baseline Climate	40,123	87,854	119.0%		
	9 Climate Change Model Average	40,123	92,444	130.4%	88,940	95,948
	Model 3aTD					
	Baseline Climate	40,123	64,826	61.6%		
	9 Climate Change Model Average	40,123	65,199	62.5%	62,203	67,936

Hot Springs

Population growth estimates for Hot Springs County ranged from -15.8% (Model $3a_{TD,BC}$) to 114.2% (Model $2b_{FC,CC}$), or a change from 4,812 people (2010 population) to between 4,052 and 10,305. Across all models and counties, Models $3a_{TD,CC}$ and $3a_{TD,BC}$ for Hot Springs County were the only models that predicted a decline in population. This is likely attributable to the population inertia effect of the linear population variable, which was most pronounced across Shoshone counties in Model $3a_{TD}$. Population forecast estimates for Hot Springs County varied with regard to whether anticipated population growth was higher under a baseline climate or climate change scenario. BC population projections fell within 90% confidence intervals for Models $2b_{FC}$ and $1b_{TD}$.

Table 5.2.3. Projected Population Growth, Hot Springs County, 2010-2060

	Model 1bFC	**2010 Population**	**2060 Population**	**% Change**	**C.I. (α = 0.10)**	
FC	Baseline Climate	4,800	7,357	53.3%		
	9 Climate Change Model Average	4,790	6,811	42.2%	6,695	6,927
	Model 2bFC					
	Baseline Climate	4,812	9,630	100.1%		
	9 Climate Change Model Average	4,812	10,305	114.2%	9,374	9,928
	Model 3bFC					
	Baseline Climate	4,812	5,594	16.3%		
	9 Climate Change Model Average	4,812	5,443	13.1%	5,325	5,561
TD	**Model 1bTD**					
	Baseline Climate	4,800	5,819	21.2%		
	9 Climate Change Model Average	4,672	5,851	25.2%	5,752	5,949
	Model 2aTD					
	Baseline Climate	4,812	8,290	72.3%		
	9 Climate Change Model Average	4,812	9,421	95.8%	8,926	9,916
	Model 3aTD					
	Baseline Climate	4,812	4,052	-15.8%		
	9 Climate Change Model Average	4,812	4,412	-8.3%	4,146	4,678

Park

Population growth estimates for Park County ranged from 67.4% (Model $3a_{TD,CC}$) to 126.8% (Model $2b_{FC,BC}$), or an increase from a 2010 population of 28,205 to a 2060 population ranging from 47,226 to 63,974. Percentage variation in population growth estimates across models for Park County were relatively low, compared to other Shoshone counties. For none of the six models did BC 2060 population estimates fall within 90% confidence intervals of respective CC estimates, and all baseline climate estimates were higher than their respective climate change estimates.

Table 5.2.4. Projected Population Growth, Park County, 2010-2060

	Model 1bFC	**2010 Population**	**2060 Population**	**% Change**	**C.I. (α = 0.10)**	
FC	Baseline Climate	27,943	54,098	93.6%		
	9 Climate Change Model Average	27,925	52,625	88.5%	51,231	54,020
	Model 2bFC					
	Baseline Climate	28,205	63,974	126.8%		
	9 Climate Change Model Average	28,205	57,335	103.3%	56,105	58,565
	Model 3bFC					
	Baseline Climate	28,205	61,168	116.9%		
	9 Climate Change Model Average	28,205	57,033	102.2%	55,861	58,206
TD	**Model 1bTD**					
	Baseline Climate	28,358	51,576	81.9%		
	9 Climate Change Model Average	27,664	48,213	74.3%	47,635	48,792
	Model 2aTD					
	Baseline Climate	28,205	60,097	113.1%		
	9 Climate Change Model Average	28,205	53,428	89.4%	52,667	54,188
	Model 3aTD					
	Baseline Climate	28,205	54,804	94.3%		
	9 Climate Change Model Average	28,205	47,226	67.4%	45,930	48,522

Sublette

With a 2010 population of 10,247, Sublette County was predicted to grow between 85.6% and 385.2% by 2060. Numerically, 2060 population projections for Sublette ranged from 14,774 and 49,714. Together with Hot Springs County, Sublette exhibited the greatest variation in predicted percent change in population from 2010 to 2060. Predicted population growth for Sublette was much higher for all FC models than for respective TD models. In percentage terms, 2010 population estimates for Models $1b_{FC}$ and $1b_{TD}$ were substantially lower than actual 2010 population levels. All baseline climate projections fell outside the 90% confidence interval of their respective climate change projections.

Table 5.2.5. Projected Population Growth, Sublette County, 2010-2060

	Model 1bFC	**2010 Population**	**2060 Population**	**% Change**	**C.I. (α = 0.10)**	
FC	Baseline Climate	8,255	22,040	167.0%		
	9 Climate Change Model Average	8,243	19,474	136.2%	18,671	20,276
	Model 2bFC					
	Baseline Climate	10,247	49,714	385.2%		
	9 Climate Change Model Average	10,247	41,279	302.8%	39,858	42,701
	Model 3bFC					
	Baseline Climate	10,247	38,234	273.1%		
	9 Climate Change Model Average	10,247	34,253	234.3%	33,344	35,161
TD	**Model 1bTD**					
	Baseline Climate	8,037	15,391	91.5%		
	9 Climate Change Model Average	7,961	14,774	85.6%	14,580	14,968
	Model 2aTD					
	Baseline Climate	10,247	32,448	216.7%		
	9 Climate Change Model Average	10,247	29,710	189.9%	29,366	30,055
	Model 3aTD					
	Baseline Climate	10,247	24,239	136.5%		
	9 Climate Change Model Average	10,247	21,522	110.0%	21,084	21,959

Teton

Population growth estimates for Teton County ranged from 59.5% (Model $2b_{FC,CC}$) to 165.6% (Model $1b_{FC,BC}$), or an increase from a 2010 population of 21,294 to a 2060 population ranging from 33,969 to 56,909. Teton is only one of the five Shoshone counties for which predicted population increase was not higher for all FC models than for respective TD models. For none of the six models did BC 2060 population estimates fall within 90% confidence intervals of respective CC estimates, and all baseline climate forecasts are higher than their respective climate change forecasts.

Table 5.2.6. Projected Population Growth, Teton County, 2010-2060

	Model 1bFC	**2010 Population**	**2060 Population**	**% Change**	**C.I. (α = 0.10)**	
FC	Baseline Climate	21,428	56,909	165.6%		
	9 Climate Change Model Average	21,397	51,600	141.2%	49,378	53,822
	Model 2bFC					
	Baseline Climate	21,294	41,927	96.9%		
	9 Climate Change Model Average	21,294	33,969	59.5%	32,852	35,086
	Model 3bFC					
	Baseline Climate	21,294	42,420	99.2%		
	9 Climate Change Model Average	21,294	37,713	77.1%	36,734	38,692
TD	**Model 1bTD**					
	Baseline Climate	21,086	39,585	87.7%		
	9 Climate Change Model Average	20,675	36,182	75.0%	35,670	36,695
	Model 2aTD					
	Baseline Climate	21,294	52,921	148.5%		
	9 Climate Change Model Average	21,294	44,644	109.7%	43,670	45,618
	Model 3aTD					
	Baseline Climate	21,294	45,295	112.7%		
	9 Climate Change Model Average	21,294	37,467	76.0%	36,286	38,648

5.3 Selection of One "Best" Model

Selection of a single best model from the six highlighted above primarily entailed a comparison of the forecasting model and population projection results of each relative to the others. A first approach was to identify which forecasting model was the most consistent, relative to all six models, with regard to sign and significance of independent variables. Next, the model generating the fewest population projections that were at either the far lower or upper end of each set of six was identified, relative to the entire body of projections. In applying both criteria, Model $3b_{FC}$ emerged as the best model. That Model $3b_{FC}$'s adjusted R-squared of 0.4031 is the highest among the six "best" models supported this determination. Model $3b_{FC}$ population projections for the five Shoshone NF counties are summarized in Table 5.3.1.

In observing model and projection results, broader results also emerge: analysis of the full sample time period, 2000-2010, increased predictive strength across FC and TD models; among climate variables, the winter temperature variables added the greatest predictive strength; and functional form contributed to model strength, mostly insofar as climate and population variables were included in both linear and quadratic forms, and not exclusively in natural log form (as evidenced in Tables B.1 and B.2). The inclusion of both linear and quadratic climate and population variables allowed for the potential reversal of population growth rates at higher levels of the these variables.

Table 5.3.1. Model 3bFC Population Projections for Five Shoshone NF Counties, 2010-2060

County	Model	2010 Population	2060 Population	% Change	C.I. (α = 0.10)	
Fremont	BC	40,123	84,527	110.7%		
	CC		80,296	100.1%	78,575	82,017
Hot Springs	BC	4,812	5,594	16.3%		
	CC		5,443	13.1%	5,325	5,561
Park	BC	28,205	61,168	116.9%		
	CC		57,033	102.2%	55,861	58,206
Sublette	BC	10,247	38,234	273.1%		
	CC		34,253	234.3%	33,344	35,161
Teton	BC	21,294	42,420	99.2%		
	CC		37,713	77.1%	36,734	38,692
Shoshone Region	BC	104,681	231,943	121.6%		
	CC		214,738	105.1%	209,839	219,637

CHAPTER 6: CONCLUSIONS

Identifying the historical determinants of migration can assist land managers and governments in anticipating future migratory patterns and population growth. Migration patterns of rural counties of the intermountain West, in particular, have proven susceptible to an amalgam of forces. No longer are purely economic considerations – specifically, the presence of industries based on the extraction of natural resources – considered preponderant in influencing population change in these areas. To the contrary, numerous studies have demonstrated that the presence and preservation of natural amenities both attracts migrants and spurs economic development of non-resource based sectors. The growing body of literature linking climatic factors to migration decisions is particularly important in the context of anticipated shifts in temperature and precipitation patterns and the consequences that these changes hold for natural amenities.

The results of this study indicate that, within sampled counties, a variety of factors are significant in predicting population growth. The negative correlations of average low winter temperature and (when significant) average high summer temperature suggest that, as temperatures climb over the next several decades, population growth will be higher in areas with cooler climates. As anticipated climate change is a key premise of this study's population projections, the TD models prove valuable in demonstrating the strength of correlation between high summer temperature and population growth – a finding absent across FC models. The lack of significance of precipitation represents a departure from previous studies and may be a result that is specific to the sample under analysis. Indeed, the focus of this study on rural counties located primarily in the intermountain West and that contain national forest land proves dually insightful and, in the case of some variables, potentially limiting.

The strong linkages between population change and built features of national forests – such as number of picnic tables and campgrounds, as well as miles of hiking trails – likely represent a more general positive correlation between national forest day-use accessibility and population increase, rather than causal relationships between those amenities and population change. Somewhat surprising was the lack of significance of driving time from the largest county population center to a major metropolitan center, a result that directly contradicts previous findings (Booth, 1999).

Among natural amenity variables, the significant positive correlation between national forest lake area and population growth in the majority of the "best" forecasting models is important in the context of anticipated changes in precipitation and water flows (Rice et al., 2012). Though lacking significance across TD models, the high significance of wilderness lake area and wilderness river miles in two out of the three best FC models also takes on added importance in this light. The positive correlation between mountainous topography and population growth confirms earlier findings (Rasker and Johnson, 2000) and underscores the appeal of a diversity of natural amenities to migrants.

In the class of socioeconomic measures, the strong positive correlation of a variable representing housing costs and population growth likely reflects a hedonic effect of the presence higher levels of amenities in areas with higher housing costs. Non-labor income was significant and negatively correlated with population change in five of the six best models. The magnitudes and respective positive and negative signs of the linear and quadratic population variables had a profound effect on the distribution of population projections. Counties with higher base year populations tended to have higher predicted growth rates, but predicted growth declined substantially among counties at the high end of the base year population distribution.

Temperature and precipitation data from nine U.S. Forest Service climate change projection models were applied to the final six FC and TD models to generate population growth estimates through 2060. Depending on the forecasting model, these estimates were generated in five or ten-year increments. Additional estimates that were generated by holding climate variables constant at base levels allowed for isolation of the effects of the climate variables on future population projections. For all six models, baseline climate projections of percent change in population were higher than percent change in population projections under climate change scenarios for the aggregated five-county Shoshone National Forest region. It is important to point out, however, that the lower predicted increases in percent growth in population under the climate change scenario are based on the assumption, implicit in the forecasting model, that the climates of other counties in the sample will remain constant. While temperatures in the Shoshone region are forecasted to increase, so too are those of areas with currently warmer temperatures. Thus, a drawback of this study's projection method is that it does not account for increases in in-migration that are likely to occur, per model results, as other sampled areas also experience warming.

Predicted increases in population across the region varied from a low of 65.4% to 154.2%. All three FC models predicted at least a doubling of the Shoshone region population by 2060 under both the baseline climate and climate change scenarios. Variation in predicted percent change in population from 2010 to 2060 was lowest among the three Shoshone counties with the highest base year populations.

All variation in population projections across incremental time periods was due to changes in climate and population levels, making relatively transparent the specific effects of these variables on predicted population growth. However, as natural amenities such as lake area and miles of wilderness rivers were significant in explaining population growth, future projection analysis may be strengthened by incorporating estimated changes to these amenities as they are quantified. Alternately expanding or contracting the sample size will allow for analysis of the significance of various factors in different regional contexts. Further, adjustments to the functional form of the forecasting models may help dissipate the powerful influence of the linear and quadratic population variables on growth rate predictions for counties at either end of the base year population spectrum and inspire greater confidence across all projections. Finally, as statistically reliable estimates of county population and socioeconomic measures are published over the next several years, time series analysis may help increase the strength of population predictions.

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APPENDIX A: Sampled Counties and National Forests

Table A.1. List of Sampled National Forests

National Forest	State	National Forest	State
Apache-Sitgreaves	AZ, NM	Lewis and Clark	MT
Beaverhead/Deerlodge	MT	Lincoln	NM
Bighorn	WY	Malheur	OR
Blackhills	SD, WY	Manti-LaSal	CO, UT
Caribou-Targhee	ID, WY, UT	Medicine Bow	WY
Carson	NM	Modoc	CA
Cibola	NM	Ochoco	OR
Colville	WA	Okanogan	WA
Coronado	AZ, NM	Payette	ID
Custer	MT, SD	Pike-San Isabel	CO
Dixie	UT	Plumas	CA
Fremont-Winema	OR	Prescott	AZ
Gila	NM	Rio Grande	CO
Helena	MT	Salmon-Challis	ID
Humboldt-Toiyabe	CA, NV	San Juan	CO
Inyo	CA, NV	Shasta-Trinity	CA
Kaibab	AZ	Shoshone	WY
Klamath	CA, OR	Tonto	AZ
Kootenai	ID, MT	Umatilla	OR, WA
Lassen	CA	Wallowa-Whitman	ID, OR

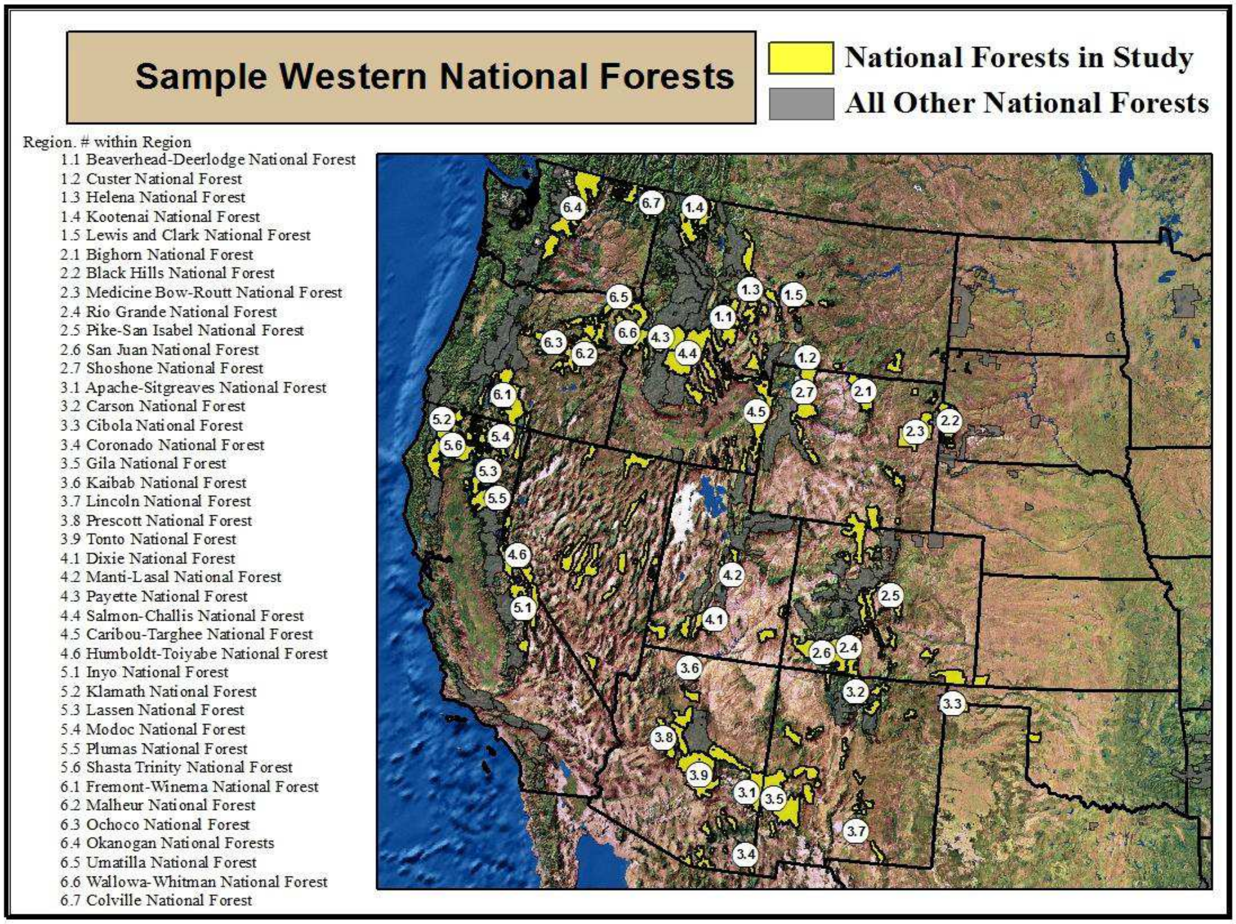

Figure A.1. Map of Sampled National Forests; Kasberg, K., 2012.

Table A.2. Sampled Counties

Arizona	Clear Creek	Fremont	Teton	**Oregon**	**Washington**
Apache	Conejos	Idaho	Wheatland	Baker	Asotin
Cochise	Costilla	Lemhi		Crook	Columbia
Cococino	Custer	Madison	**Nevada**	Grant	Ferry
Gila	Dolores	Nez Perce	Carson City	Harney	Garfield
Graham	Douglas	Oneida	Clark	Jackson	Okanogan
Greenlee	El Paso	Power	Douglas	Klammath	Pend Oreille
Maricopa	Fremont	Teton	Elko	Lake	Stevens
Mohave	Hinsdale	Valley	Esmerelda	Malheur	Walla Walla
Navajo	Huerfano	Washington	Eureka	Morrow	
Pima	Jefferson		Humboldt	Umatilla	**Wyoming**
Pinal	La Plata	**Montana**	Lander	Union	Albany
Santa Cruz	Lake	Beaverhead	Lincoln	Wallowa	Big Horn
Yavapai	Las Animas	Broadwater	Lyon	Wheeler	Carbon
	Mesa	Carbon	Mineral		Converse
California	Mineral	Carter	Nye	**S. Dakota**	Crook
Alpine	Montezuma	Cascade	Washoe	Custer	Fremont
Butte	Montrose	Chouteau		Fall River	Hot Springs
El Dorado	Park	Deer Lodge	**New Mexico**	Harding	Johnson
Humboldt	Pueblo	Fergus	Bernalillo	Lawrence	Lincoln
Inyo	Rio Grande	Flathead	Catron	Meade	Natrona
Lassen	Saguache	Glacier	Chaves	Pennington	Park
Madera	San Juan	Golden Valley	Cibola		Platte
Modoc	Summit	Granite	Colfax	**Utah**	Sheridan
Mono	Teller	Jefferson	Eddy	Box Elder	Sublette
Nevada		Judith Basin	Grant	Cache	Teton
Plumas	**Idaho**	Lewis and Clark	Hidalgo	Carbon	Washakie
Shasta	Adams	Lincoln	Lincoln	Emery	Weston
Sierra	Bannock	Madison	McKinley	Garfield	
Siskiyou	Bear Lake	Meagher	Mora	Grand	
Tehama	Blaine	Park	Otero	Iron	
Trinity	Bonner	Pondera	Rio Arriba	Kane	
Tulare	Bonneville	Powder River	Sandoval	Piute	
Yuba	Boundary	Powell	Sierra	San Juan	
	Butte	Rosebud	Socorro	Sanpete	
Colorado	Caribou	Sanders	Taos	Sevier	
Alamosa	Clark	Silver Bow	Torrance	Utah	
Archuleta	Custer	Stillwater	Valencia	Washington	
Chaffee	Franklin	Sweet Grass		Wayne	

APPENDIX B: Complete Forecasting Model Results

Results for FC models a, b, and c from each sample time period are presented in Table B1. As with Models $1b_{FC}$, $2b_{FC}$ and $3b_{FC}$, only those non-climatic variables with p-values of 0.10 or lower were included in the remaining six models. F-statistics for each of the nine models indicated high overall model significance. As with the three best FC models, directions of influence are the same across models for all highly significant variables, and variables from all four categories are included in each of the nine models. Full model results are detailed below by class of variable.

Climatic

Both linear and quadratic forms of the three temperature variables – average high summer temperature, average low winter temperature, and average annual precipitation – were included in "a" and "b" models for each time period; these three variables, however, were included only in natural log form in the three "c" models. Average high summer temperature was highly significant in Models $2a_{FC}$, $2c_{FC}$, $3a_{FC}$ and $3c_{FC}$. However, it was negatively correlated with population growth in both "a" models and positively correlated in both "c" models. High summer temperature was significant in none of the models analyzing population growth over the 2000-05 time period (Models $1a_{FC}$-$1c_{FC}$). High summer temperature-squared was significant only in Models $2a_{FC}$ and $3a_{FC}$ and was positively correlated with population growth. Thus, summer temperature results for Models $2a_{FC}$ and $3a_{FC}$ indicate that an increase in high summer temperature is associated with a decline in population, but the decline decreases in rate as high summer temperature continues to rise.

Average low winter temperature, whether in non-logarithmic or logarithmic form, was highly significant in all models except Model $2a_{FC}$, and was negatively correlated with population growth in all models. Average low winter temperature-squared was highly significant in all three "b" models, as well as in Model $1a_{FC}$, and was positively correlated with population growth in all "a" and "b" models. These results indicate that an increase in average low winter temperature is associated with a decline in population, but that the rate of decline decreases as average low winter temperature continues to increase.

Neither precipitation nor precipitation-squared was highly significant in any of the nine FC models; however, precipitation was positively correlated with population growth in all models except Model $1c_{FC}$, and precipitation-squared was negatively correlated in all six models in which it was present (all "a" and "b" models).

Built Features

Three built feature variables – number of picnic tables, campgrounds and hiking trails in all national forests contained at least in part within a county – were highly significant in a minimum of six of the nine FC models. Number of picnic tables was highly significant in all models except Model $1b_{FC}$ and was positively correlated with population growth in all other models. Number of campgrounds was highly significant in all models except Model $2a_{FC}$ and had a negative sign in all other models. Miles of non-wilderness hiking trails was significant in all "b" and "c" models but not in any of the three "a" models, and was positively correlated with population growth in all models in which it was significant. Finally, number of campsites in all national forests located at least in part within a county was significant only in Model $2a_{FC}$ and was negatively correlated with population growth.

Natural Features

There was a great deal of variation, by both time period and functional form of model, in natural features variables that were highly significant in predicting population change. Total area of non-wilderness lakes in all national forests contained at least in part within a county was highly significant and positively correlated with population growth in all "b" and "c" models but lacked significance in all three "a" models. Non-wilderness lake area was the only natural features variable that was highly significant in any of the models for the time period 2000-05. Conversely, several natural features variables were significant in predicting population change over 2005-10 and 2000-10.

Two natural features variables – total area of wilderness lakes and miles of wilderness rivers in all national forests in a county – were significant in Models $2b_{FC}$, $2c_{FC}$ and $3b_{FC}$, but neither was significant in any "a" models. A dummy variable designating a county's topography mountainous was significant and positively correlated with population change in all 2005-10 models (Models $2a_{FC}$-2cFC), as well as Models $3a_{FC}$ and 3bFC (2000-10). Maximum elevation within a county was significant and positively correlated with population only in Model $2a_{FC}$.

Socio-Economic Measures

Population was highly significant and positively correlated with percent population change in all nine models, while population-squared was significant and negatively associated with population change in all "a" and "b" models. While housing costs were measured identically (though in different years) in both sets of five-year models, the variable was significant only in Models $1a_{FC}$-c_{FC} but in none of Models $2a_{FC}$-c_{FC}.

Non-labor income was highly significant and negatively correlated with population change in Model $1a_{FC}$, as well as Models $2a_{FC}$-c_{FC} and $3a_{FC}$-c_{FC}, but was not significant in

Models $2a_{FC}$ or $2b_{FC}$. Farm employment – the number of farming jobs as a percentage of all jobs in the county – was considered for inclusion only in Models $1a_{FC}$-c_{FC} and $2a_{FC}$-c_{FC}. This variable was significant and negatively correlated with population change in Models $1a_{FC}$ and $1b_{FC}$.

Table B.1. Complete Population Forecasting Model Results for Full Climate Variable Models

	2000-05			2005-10			2000-10		
	$1a_{FC}$	$1b_{FC}$	$1c_{FC}$	$2a_{FC}$	$2b_{FC}$	$2c_{FC}$	$3a_{FC}$	$3b_{FC}$	$3c_{FC}$
Adj. R-squared	0.3742	0.3747	0.3389	0.3465	0.3522	0.2880	0.3823	0.4031	0.3553
Independent Variables	Coefficient (Std. Err.)								
Climate[1]									
High Summer Temp	0.0095 (0.0176)	0.0149 (0.0179)	0.1152 (0.1175)	-0.0379** (0.0161)	-0.0179 (0.0169)	0.3011** (0.1162)	-0.0647** (0.0310)	-0.0250 (0.0324)	0.6764*** (0.2191)
High Summer Temp SQ	-5.9e-05 (0.0001)	-0.0001 (0.0001)		0.0002** (0.0001)	0.0001 (0.0001)		0.0004** (0.0002)	0.0002 (0.0002)	
Low Winter Temp	-0.0088** (0.0036)	-0.0084** (0.0036)	-0.0331** (0.0155)	-0.0049 (0.0034)	-0.0088** (0.0037)	-0.0409** (0.0158)	-0.0143** (0.0067)	-0.0206*** (0.0070)	-0.1105*** (0.0298)
Low Winter Temp SQ	0.0002* (0.0001)	0.0002** (0.0001)		0.0001 (0.0001)	0.0002** (0.0001)		0.0003 (0.0002)	0.0004** (0.0002)	
Precipitation	5.48e-05 (9.07e-05)	9.88e-05 (8.94e-05)	-0.0015 (0.0166)	2.53e-06 0.0001	4.85e-05 (0.0001)	0.0014 (0.0170)	1.3e-05 (0.0002)	0.0001 (0.0002)	0.0022 (0.0321)
Precipitation SQ	-6.06e-08 (5.44e-08)	-9.39e-08 5.39e-08		-2.49e-08 (5.31e-08)	-6.68e-08 (5.25e-08)		-5.90e-08 (1.01e-07)	-1.32e-07 (1.02e-07)	
Built Features[2]									
Picnic Tables	0.0008*** (0.0003)		0.0108* (0.0063)	0.0011*** (0.0003)	0.0183*** (0.0065)	0.0178*** (0.0065)	0.002*** (0.0005)	0.0345*** (0.0124)	0.0275** (0.0119)
Campgrounds	-0.0007*** (0.0002)	-0.0530*** (0.0154)	-0.0610*** (0.0163)		-0.08621*** (0.0161)	-0.0778*** (0.0163)	-0.0018** (0.0004)	-0.1576*** (0.0311)	-0.1491*** (0.0304)
Hiking Trails		0.0187** (0.0094)	0.0244** (0.0096)		0.0380*** (0.0092)	0.0398*** (0.0095)		0.0647*** (0.0177)	0.0737*** (0.0180)

Campsites				-4.68e-05*** (8.65e-06)					
Natural Features[2]									
Lake Area		0.0153*** (0.0054)	0.0131** (0.0052)		0.0178*** (0.0055)	0.0135** (0.0056)		0.0319*** (0.0109)	0.0172* (0.0103)
Wilderness Lake Area					-0.0084** (0.0039)	-0.0071* (0.0039)		-0.0157** (0.0075)	
Wilderness River Miles					0.0095** (0.0045)	0.0089*** (0.0045)		0.0175** (0.0087)	
Mountainous Topography				0.0313*** (0.0114)	0.0273** (0.0112)	0.0261** (0.0115)	0.0425** (0.0215)	0.0471** (0.0219)	
Max Elevation				4.84e-06** (2.32e-06)					
Socio-Economics									
Population[1]	8.45e-07*** (1.92e-07)	8.70e-07*** (1.92e-07)	0.0233*** (0.0041)	4.03e-07** (1.61e-07)	3.55e-07** (1.48e-07)	0.0081*** (0.0039)	1.33e-06*** (3.45e-07)	1.37e-06*** (3.39e-07)	0.0312*** (0.0075)
Population SQ	-1.41e-12*** (3.88e-13)	-1.49e-12*** 3.86e-13		-6.25e-13** (3.07e-13)	-5.45e-13* (3.07e-13)		-2.20e-12*** (7.03e-13)	-2.35e-12*** (6.91e-13)	
Housing Costs[3]	0.0111*** (0.0022)	0.0099*** (0.0022)	0.0111*** (0.0023)				0.5088*** (0.1192)	0.4194*** (0.1215)	0.5365*** (0.1202)
Non-Labor Income[4]			-0.1277* (0.0704)	-0.2263*** (0.0589)	-0.2440*** (0.0592)	-0.2441*** (0.0615)	-0.3608*** (0.1174)	-0.4092*** (0.1172)	-0.4130*** (0.1160)
Farm Employment[5]	-0.2566*** (0.0758)	-0.2679*** (0.0755)							
Constant	-0.5194 (0.6907)	-0.7393 (0.7145)	-0.8076 (0.5028)	1.544* (0.6494)	0.7704 (0.6754)	-1.2496** (0.5515)	2.6312** (1.2190)	0.9610 (1.2964)	-2.9771 (0.9698)

* Indicates p-value of 0.10 or lower
**Indicates p-value of 0.05 or lower
***Indicates p-value of 0.01 or lower

[1] Models "a" and "b" for each time period include linear and quadratic climate and population variables in non-logarithmic form; "c" models include climate and population variables only in natural log form. Models 1a-1c and 3a-3c use 2000 population; Models 2a-2c use 2005 population.

[2] Built and natural features variables for "a" models for each time period are in non-logarithmic form and are in natural log form in "b" and "c" models.

[3] Housing affordability for Models 1a-c and 2a-c is measured as median selected owner costs as a percentage of household income for houses with a mortgage for 2000 and 2010, respectively; it is measured in Models 3a-c as the percentage of households with a mortgage for which selected owner costs (including the mortgage) is greater than 30 percent of household income.

[4] 2005 data is used for Models 1a-c; 2010 data is used for Models 2a-c and Models 3a-c.

[5] 2005 data is used for Models 1a-c; 2010 data is used for Models 2a-c; a farm employment variable is not included in analysis for Models 3a-c.

Table B.2. Complete Population Forecasting Model Results for Temperature Difference Variable Models

	2000-05			2005-10			2000-10		
	$1a_{TD}$	$1b_{TD}$	$1c_{TD}$	$2a_{TD}$	$2b_{TD}$	$2c_{TD}$	$3a_{TD}$	$3b_{TD}$	$3c_{TD}$
Adj. R-squared	0.3710	0.3745	0.3345	0.3448	0.3367	0.2680	0.3926	0.3876	0.3234
Independent Variables	Coefficient (Std. Err.)								
Climate									
High Summer Temp	-0.0133 (0.0135)	-0.0123 (0.0135)	-0.0253 (0.0785)	-0.0513*** (0.0128)	-0.0454*** (0.0127)	0.0938 (0.0858)	-0.1006*** (0.0244)	-0.0835*** (0.0245)	0.0988 (0.1557)
High Summer Temp SQ	7.63e-05 (0.0001)	0.0001 (0.0001)		0.0003*** (0.0001)	0.0003*** (7.86e-05)		0.0006*** (0.0002)	0.0005*** (0.0002)	
Precipitation	2.88e-05 (9.21e-05)	1.074e-04 (8.95e-05)	-0.0012 (0.0180)	2.26e-06 (9.17e-05)	3.98e-05 (8.91e-05)	-0.0050 (0.0189)	-0.0001 (0.0002)	8.63e-05 (0.0002)	-0.0091 (0.0357)
Precipitation SQ	-4.23e-08 (5.41e-08)	-8.35e-08 (5.33e-08)		-1.78e-08 (5.28e-08)	-4.73e-08 (5.25e-08)		-5.32e-09 (1.01e-07)	-9.12e-08) (1.02e-07)	
Temperature Difference	0.0018 (0.0012)	0.0015 (0.0013)	0.0859 (0.0779)	0.0010 (0.0012)	0.0010 (0.0012)	0.0945 (0.0788)	0.0057** (0.0002)	0.0049** (0.0024)	0.3370** (0.1529)
Built Features									
Picnic Tables	0.0008*** (0.0003)			0.0011*** (0.0003)	0.0125** (0.0062)	0.0165** (0.0066)	0.0018*** (0.0005)	0.0235** (0.0119)	0.0251** (0.0122)
Campgrounds	-0.0006*** (0.0002)	-0.0488*** (0.0151)	-0.0485*** (0.0155)		-0.0814*** (0.0156)	-0.0760*** (0.0166)		-0.1477*** (0.0301)	-0.1426*** (0.0313)
Hiking Trails		0.0165* (0.0092)	0.0197** (0.0096)		0.0367*** (0.0090)	0.0379*** (0.0096)		0.0617*** (0.0174)	0.0692*** (0.0183)
Campsites				-4.51e-05*** (8.56e-06)			-7.28e-5*** (1.54e-05)		

Natural Features									
Lake Area		0.0148*** (0.0054)	0.0137** (0.0055)		0.0138** (0.0053)	0.0138** (0.0057)		0.0242** (0.0104)	0.0181* (0.0107)
Wilderness Lake Area						-0.0066* (0.0039)			
Wilderness River Miles						0.0081* (0.0045)			
Mountainous Topography	0.0195* (0.0115)			0.0323*** (0.0113)	0.0275** (0.0111)	0.0289** (0.0116)	0.0609*** (0.0216)	0.0476** (0.0214)	0.0454** (0.0220)
Max Elevation				4.55e-06* (2.31e-06)					
Socio-Economics									
Population	9.55e-07*** (1.84e-07)	9.02e-07*** (1.88e-07)	0.0180*** (0.0048)	4.37e-07*** (1.58e-07)	3.88e-07** (1.59e-07)	0.0075* (0.0039)	1.51e-06*** (3.35e-07)	1.47e-06*** (3.37e-07)	0.0312*** (0.0078)
Population SQ	-1.64e-12*** (3.75e-13)	-1.60e-12*** (3.75e-13)		-6.93e-13** (3.02e-13)	-6.04e-13** (3.04e-13)		-2.60e-12*** (6.81e-13)	-2.54e-12*** (6.86e-13)	
Housing Costs	0.0108*** (0.0022)	0.0105*** (0.0022)	0.0110*** (0.0023)				0.5611*** (0.1202)	0.4278*** (0.1207)	0.5178*** (0.1241)
Non-Labor Income		-0.1335* (0.0700)	-0.1301* (0.0709)	-0.2320*** (0.0588)	-0.2605*** (0.0585)	-0.2619*** (0.0622)	-0.4147*** (0.1158)	-0.4334*** (0.1146)	-0.4300*** (0.1186)
Farm Employment	-0.1985*** (0.0752)	-0.2029*** (0.0746)							
Constant	0.2418 (0.5563)	0.2475 (0.5678)	-0.5537 (0.5822)	2.0023*** (0.5301)	1.7793*** (0.5341)	-0.7801 (0.5838)	3.6921*** (0.9963)	2.9877*** (1.0339)	-2.0781* (1.1136)

Table B.3. Correlation Matrix for Significant Independent Variables Included in Model $3b_{FC}$

	High Summer Temp	High Summer Temp SQ	Low Winter Temp	Low Winter Temp SQ	Precipitation	Precipitation SQ	Picnic Tables	Campgrounds	Hiking Trails	Lake Area	Wilderness Lake Area	Wilderness River Miles	Mountainous Topography	Population	Population SQ	Housing Costs	Non-Labor Income
High Summer Temp	1																
High Summer Temp SQ	1.00	1															
Low Winter Temp	0.71	0.71	1														
Low Winter Temp SQ	0.67	0.68	0.97	1													
Precipitation	-0.34	-0.34	0.18	0.25	1												
Precipitation SQ	-0.21	-0.21	0.27	0.34	0.96	1											
Picnic Tables	-0.06	-0.05	0.10	0.11	0.22	0.19	1										
Campgrounds	-0.32	-0.32	-0.06	-0.01	0.30	0.27	0.55	1									
Hiking Trails	-0.36	-0.35	-0.10	-0.09	0.21	0.16	0.28	0.67	1								
Lake Area	-0.28	-0.28	-0.12	-0.07	0.37	0.36	0.48	0.67	0.36	1							
Wilderness Lake Area	-0.31	-0.31	-0.17	-0.14	0.10	0.05	0.28	0.50	0.36	0.42	1						
Wilderness River Miles	-0.06	-0.06	0.02	0.02	-0.05	-0.06	0.02	0.27	0.27	0.10	0.81	1					
Mountainous Topography	-0.40	-0.40	-0.20	-0.13	0.47	0.42	0.06	0.21	0.07	0.28	0.26	0.11	1				
Population	0.26	0.26	0.29	0.30	0.04	0.06	0.03	0.05	-0.06	0.04	-0.10	-0.05	0.07	1			
Population SQ	0.14	0.13	0.12	0.11	-0.03	-0.02	-0.02	0.06	-0.03	0.03	-0.06	-0.01	0.08	0.93	1		
Housing Costs	-0.11	-0.10	0.23	0.27	0.42	0.38	0.14	0.30	0.24	0.32	0.06	-0.02	0.26	0.16	0.07	1	
Non-Labor Income	-0.12	-0.12	0.07	0.07	0.24	0.21	-0.13	0.02	0.08	0.01	0.19	0.21	0.04	-0.26	-0.22	0.24	1

Table B.4. Correlation Matrix for Significant Independent Variables Included in Model 3a$_{TD}$

	High Summer Temp	High Summer Temp SQ	Precipitation	Precipitation SQ	Temp Difference	Picnic Tables	Campsites	Mountainous Topography	Population	Population SQ	Housing Costs	Non-Labor Income
High Summer Temp	1											
High Summer Temp SQ	0.9984	1										
Precipitation	-0.3441	-0.3413	1									
Precipitation SQ	-0.2068	-0.2053	0.9645	1								
Temp Difference	0.2365	0.2298	-0.6673	-0.6259	1							
Picnic Tables	-0.034	-0.0338	0.1771	0.1568	-0.1527	1						
Campsites	-0.1257	-0.1166	0.1745	0.183	-0.1714	0.4504	1					
Mountainous Topography	-0.4026	-0.3967	0.469	0.4188	-0.2069	-0.0169	0.2413	1				
Population	0.2581	0.2593	0.0396	0.063	-0.085	0.0037	0.1261	0.0679	1			
Population SQ	0.1356	0.1339	-0.027	-0.0167	0.0059	-0.0349	0.1017	0.078	0.9277	1		
Housing Costs	-0.1081	-0.101	0.4219	0.3838	-0.4522	0.1507	0.3294	0.2552	0.1595	0.0713	1	
Non-Labor Income	-0.1248	-0.1208	0.2435	0.2096	-0.2405	-0.1802	-0.0734	0.0365	-0.2628	-0.2231	0.2422	1

APPENDIX C: Population Projection Figures for Shoshone Counties

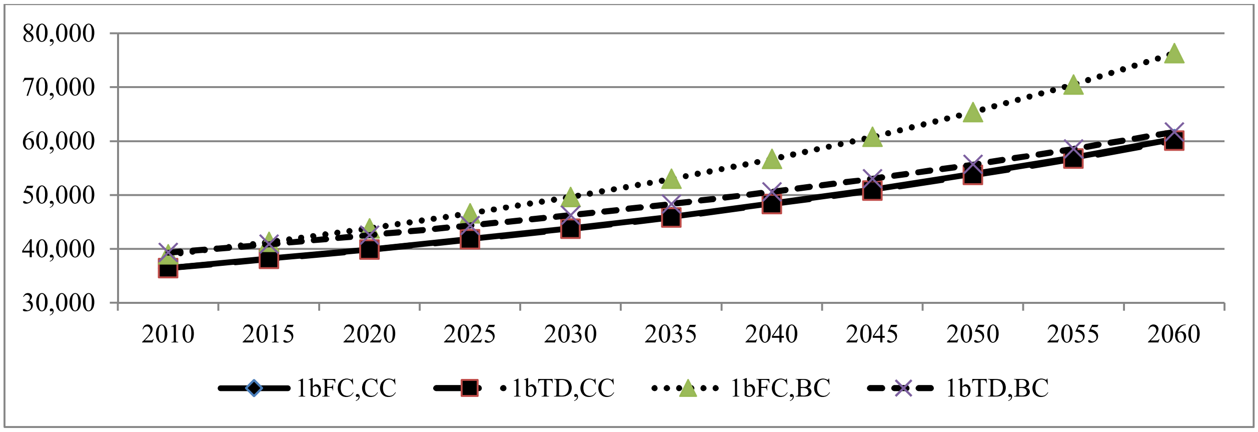

Figure C.1. Projected Population Growth for Fremont County under Climate Change Scenarios* (CC) and a Baseline Climate Scenario (BC) for Model 1bFC and Model 1bTD

*For Figures C.1-15, climate change estimates for each time period model represent the mean of predicted population change across all nine climate change forecasts.

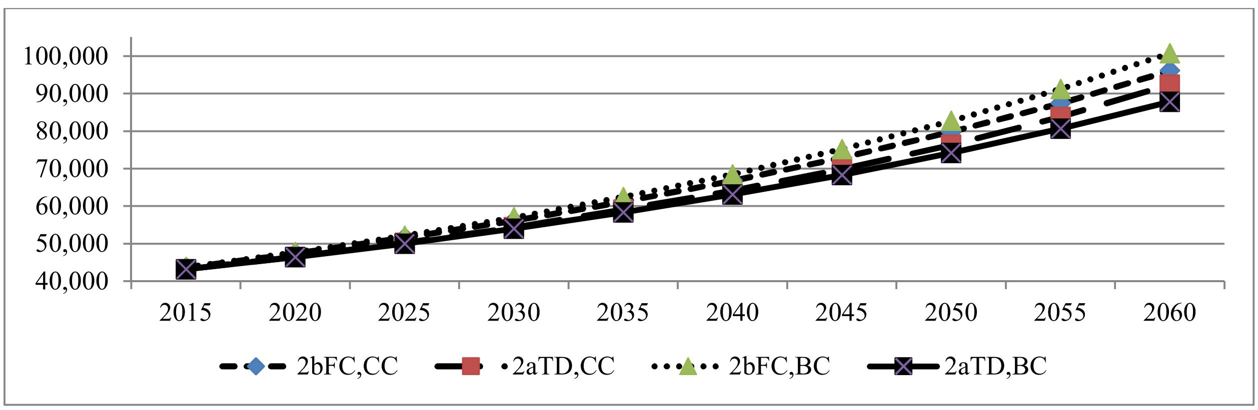

Figure C.2. Projected Population Growth for Fremont County under Climate Change Scenarios (CC) and a Baseline Climate Scenario (BC) for Model 2bFC and Model 2aTD

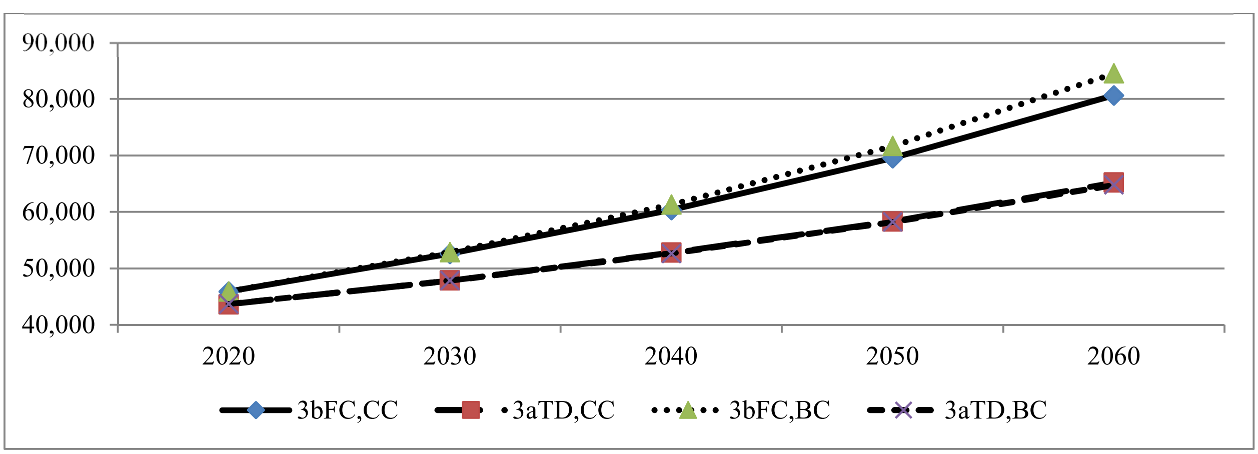

Figure C.3. Projected Population Growth for Fremont County under Climate Change Scenarios (CC) and a Baseline Climate Scenario (BC) for Model 3bFC and Model 3aTD

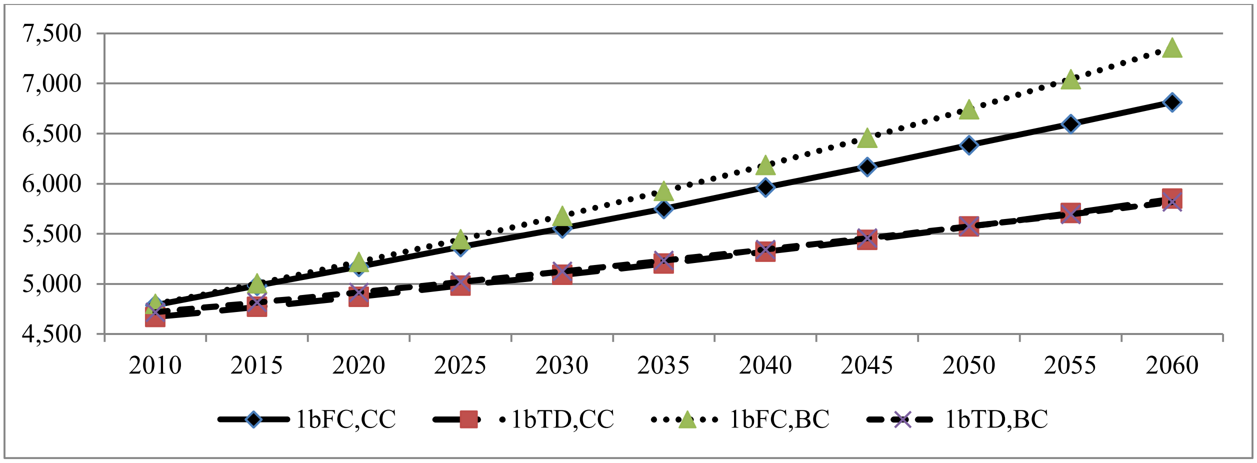

Figure C.4. Projected Population Growth for Hot Springs County under Climate Change Scenarios (CC) and a Baseline Climate Scenario (BC) for Model 1bFC and Model 1bTD

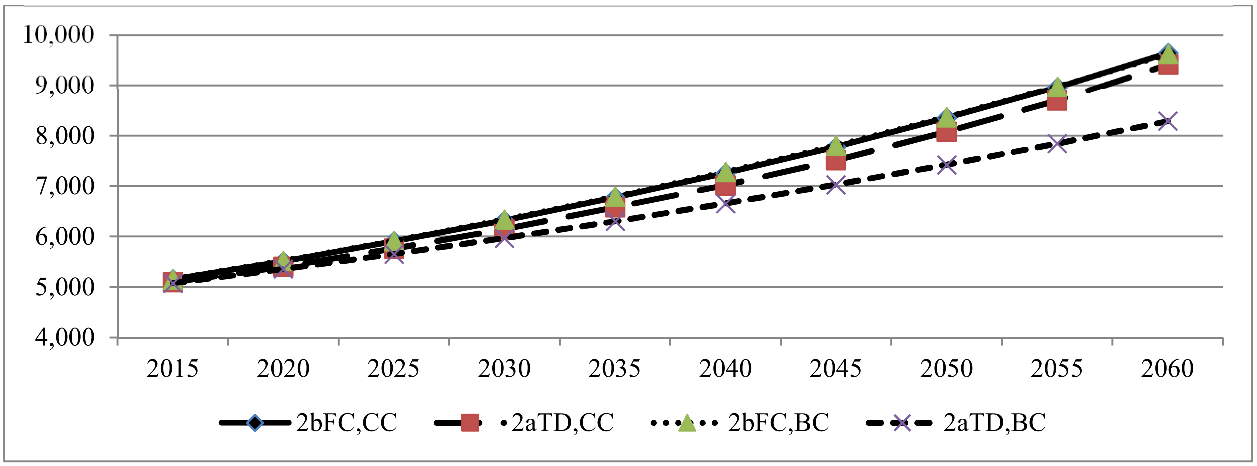

Figure C.5. Projected Population Growth for Hot Springs County under Climate Change Scenarios (CC) and a Baseline Climate Scenario (BC) for Model 2bFC and Model 2aTD

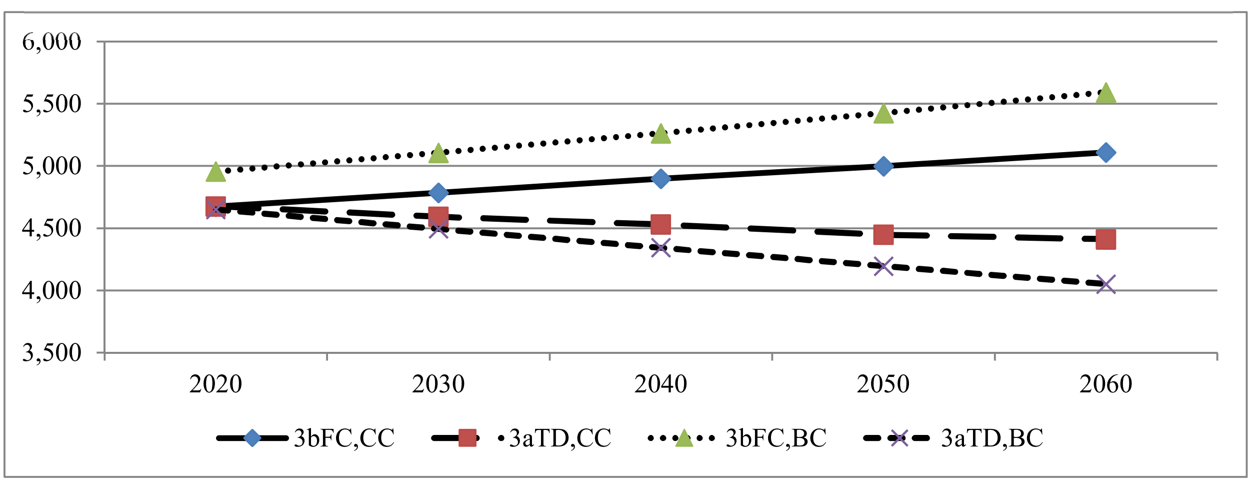

Figure C.6. Projected Population Growth for Hot Springs County under Climate Change Scenarios (CC) and a Baseline Climate Scenario (BC) for Model 3bFC and Model 3aTD

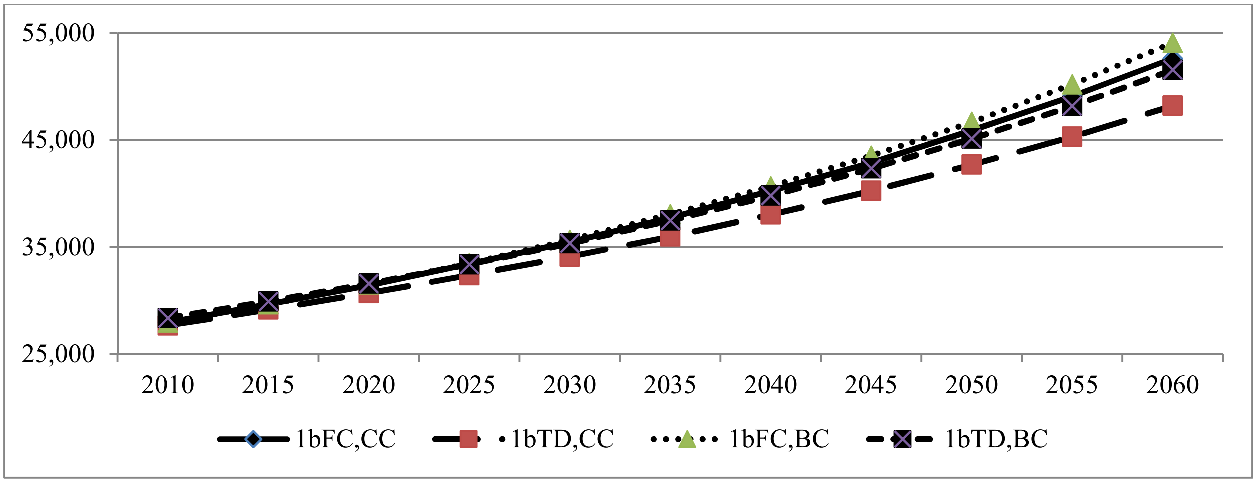

Figure C.7. Projected Population Growth for Park County under Climate Change Scenarios (CC) and a Baseline Climate Scenario (BC) for Model 1bFC and Model 1bTD

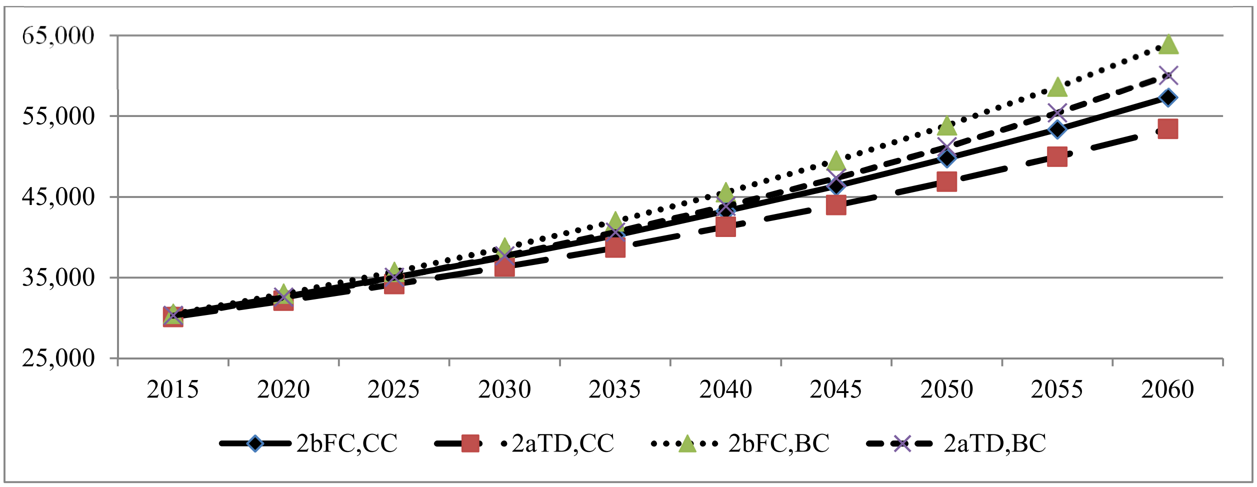

Figure C.8. Projected Population Growth for Park County under Climate Change Scenarios (CC) and a Baseline Climate Scenario (BC) for Model 2bFC and Model 2aTD

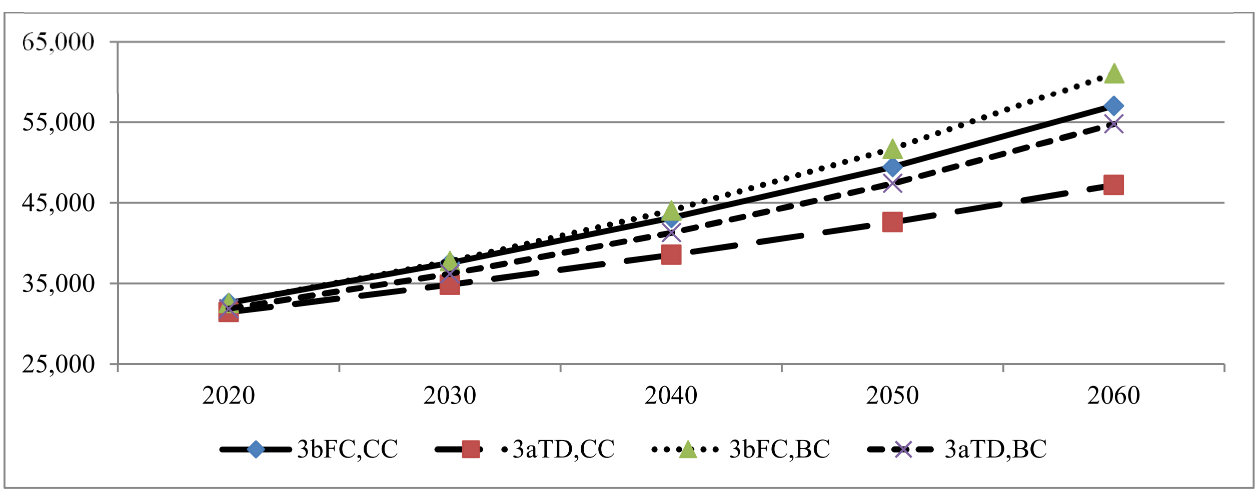

Figure C.9. Projected Population Growth for Park County under Climate Change Scenarios (CC) and a Baseline Climate Scenario (BC) for Model 3bFC and Model 3aTD

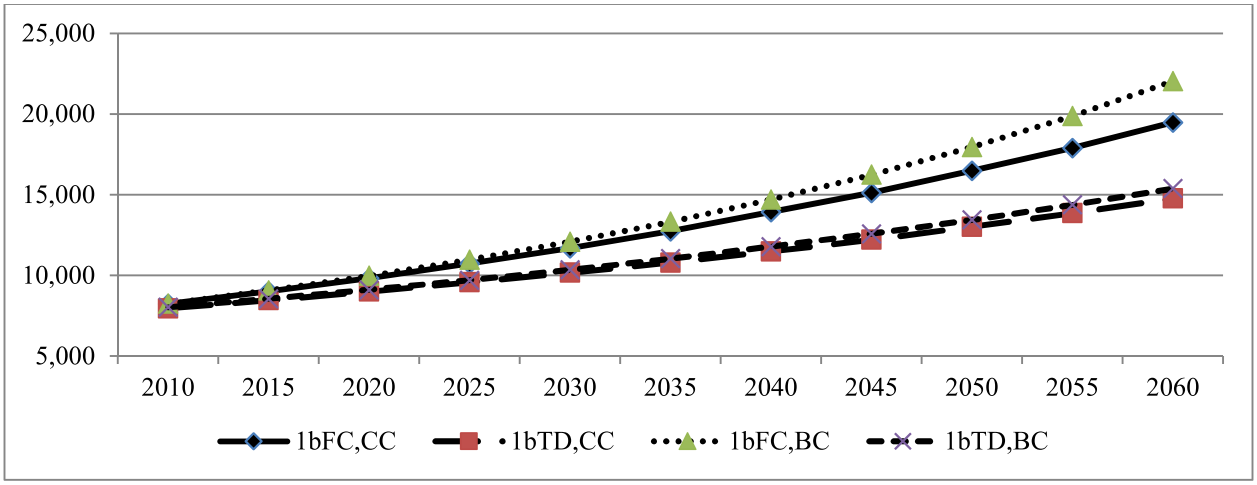

Figure C.10. Projected Population Growth for Sublette County under Climate Change Scenarios (CC) and a Baseline Climate Scenario (BC) for Model 1bFC and Model 1bTD

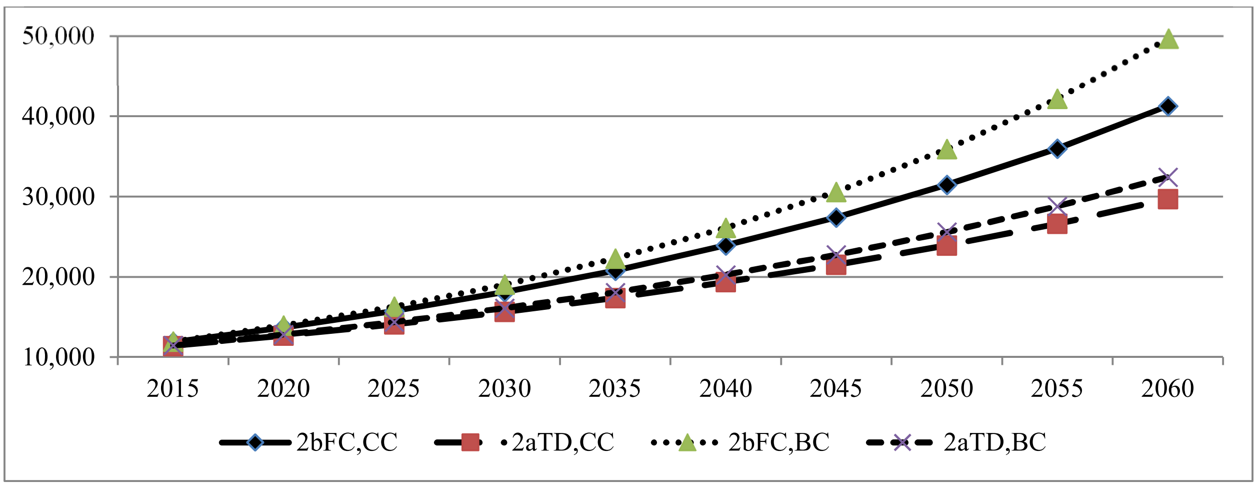

Figure C.11. Projected Population Growth for Sublette County under Climate Change Scenarios (CC) and a Baseline Climate Scenario (BC) for Model 2bFC and Model 2aTD

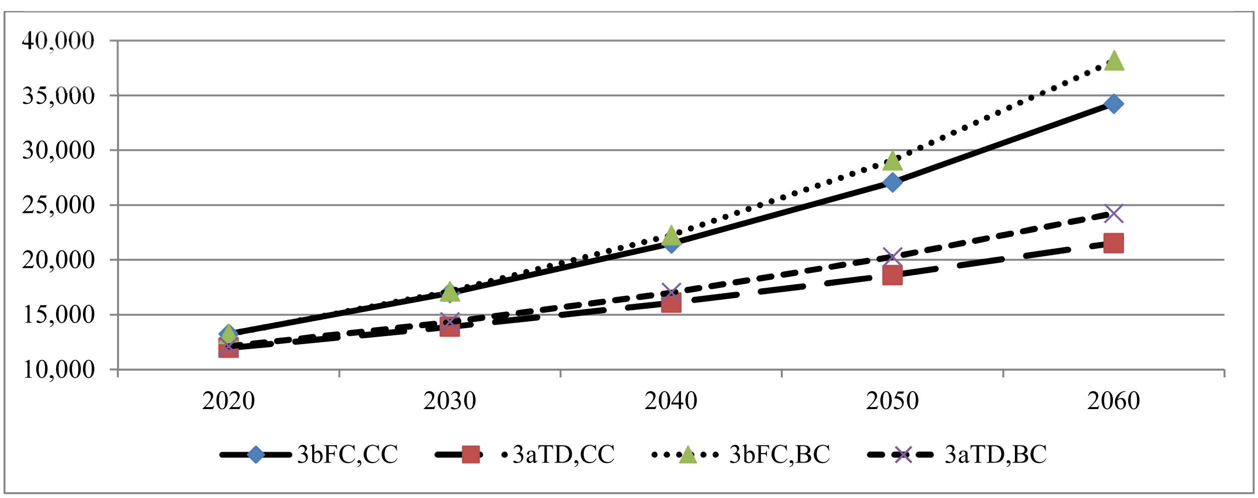

Figure C.12. Projected Population Growth for Sublette County under Climate Change Scenarios (CC) and a Baseline Climate Scenario (BC) for Model 3bFC and Model 3aTD

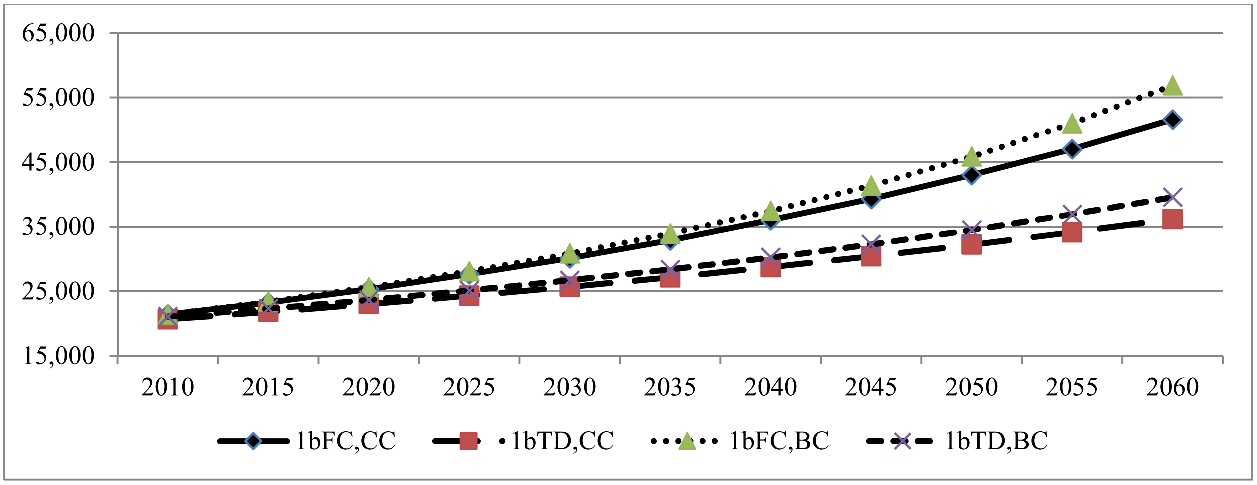

Figure C.13. Projected Population Growth for Teton County under Climate Change Scenarios (CC) and a Baseline Climate Scenario (BC) for Model 1bFC and Model 2bTD

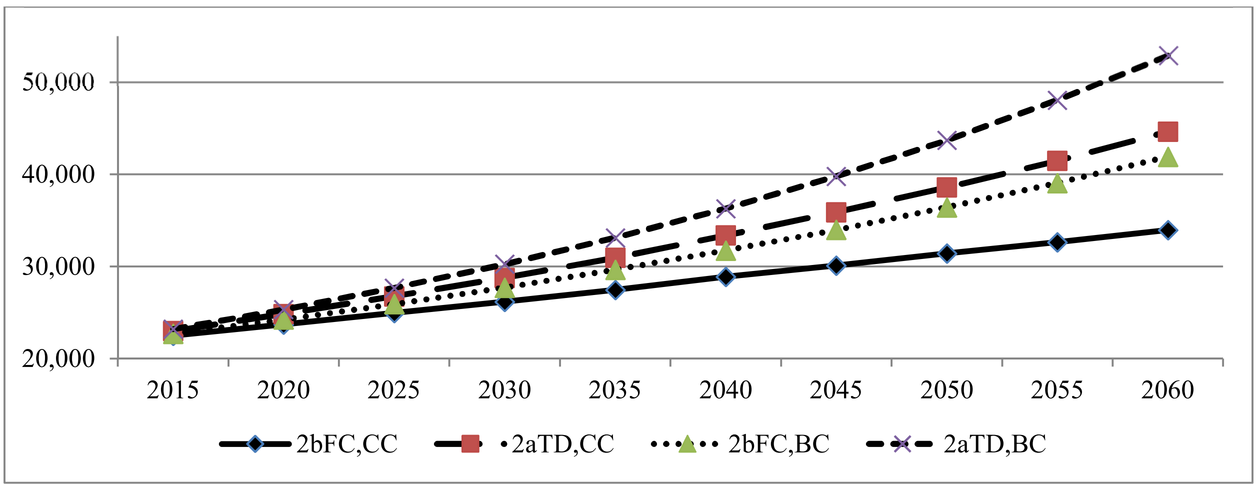

Figure C.14. Projected Population Growth for Teton County under Climate Change Scenarios (CC) and a Baseline Climate Scenario (BC) for Model 2bFC and Model 2aTD

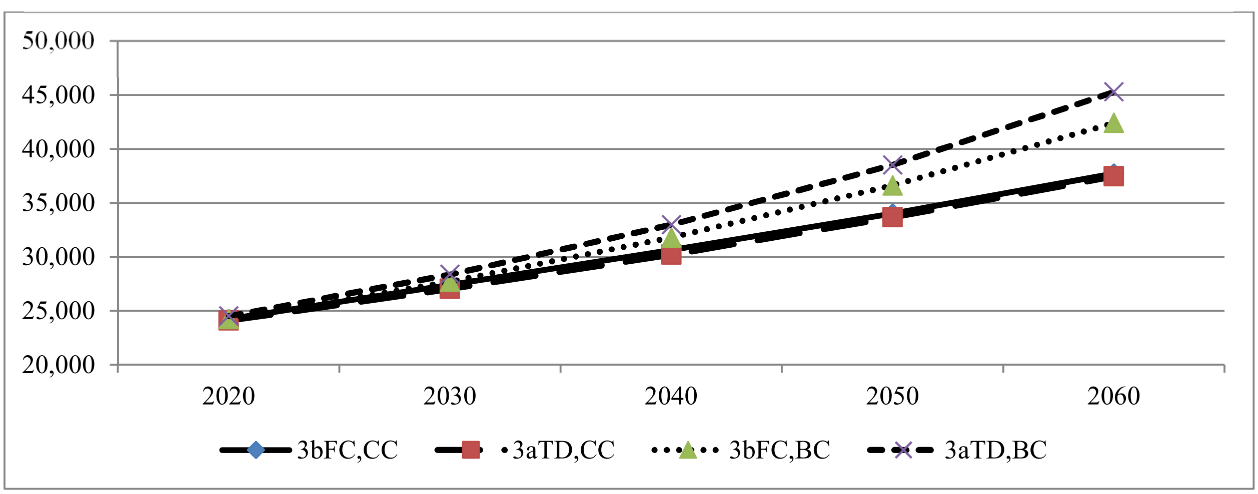

Figure C.15. Projected Population Growth for Teton County under Climate Change Scenarios (CC) and a Baseline Climate Scenario (BC) for Model 3bFC and Model 3aTD

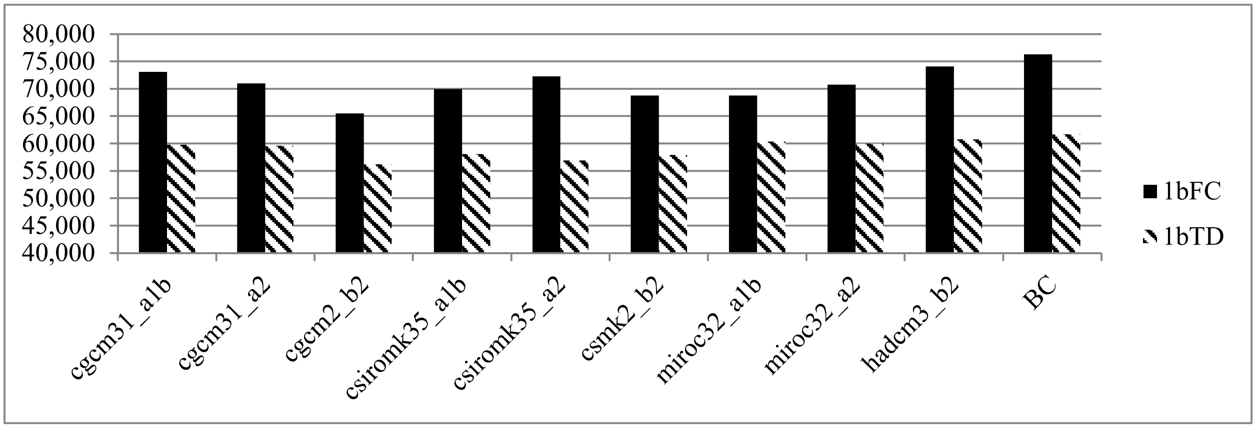

Figure C.16. Estimated 2060 Population for Fremont County, WY under a Baseline Climate (BC) and Nine Climate Change Scenarios (Model 1bFC and Model 1bTD)

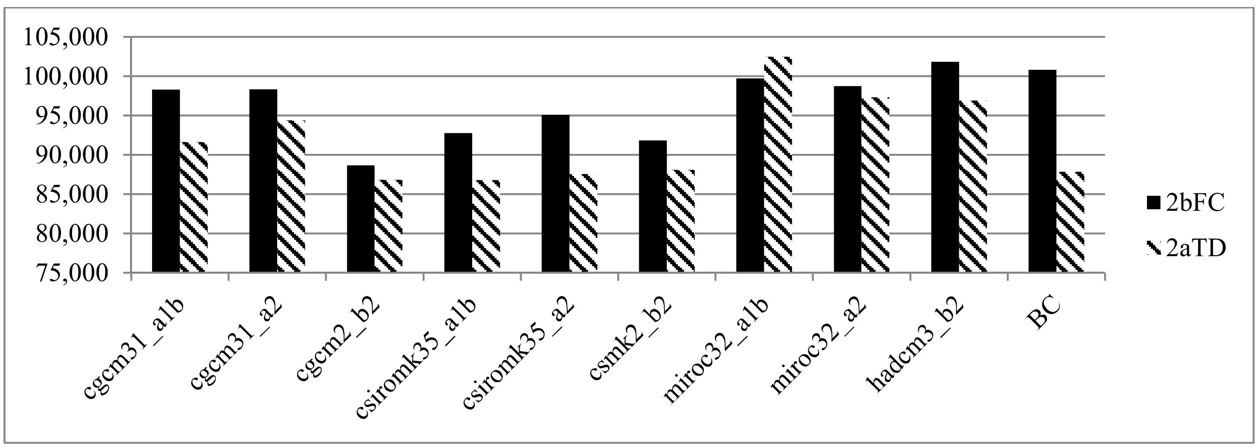

Figure C.17. Estimated 2060 Population for Fremont County, WY under a Baseline Climate (BC) and Nine Climate Change (CC) Scenarios (Model 2bFC and Model 2aTD)

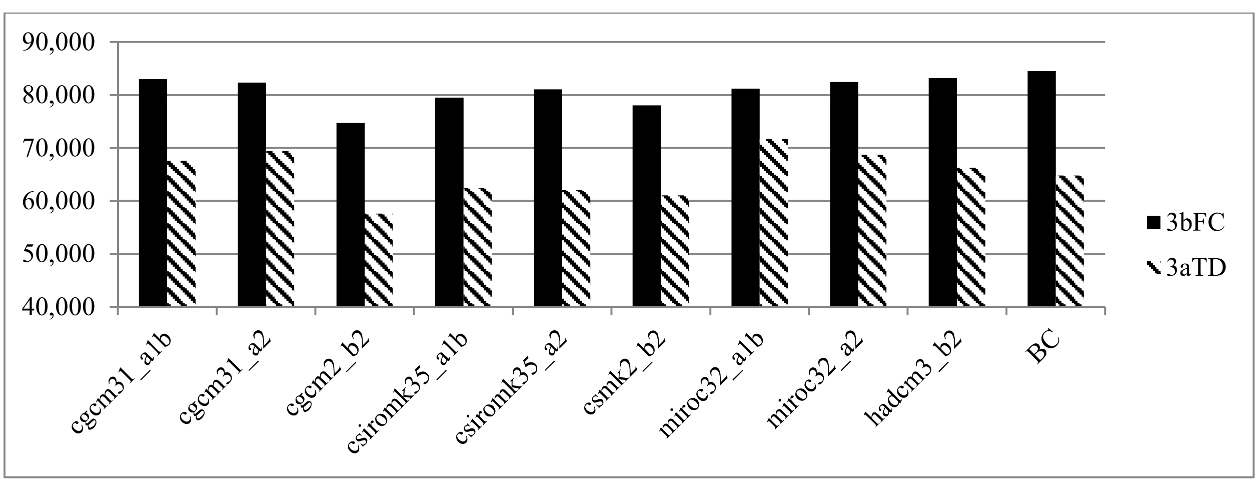

Figure C.18. Estimated 2060 Population for Fremont County, WY under a Baseline Climate (BC) and Nine Climate Change (CC) Scenarios (Model 3bFC and Model 3aTD)

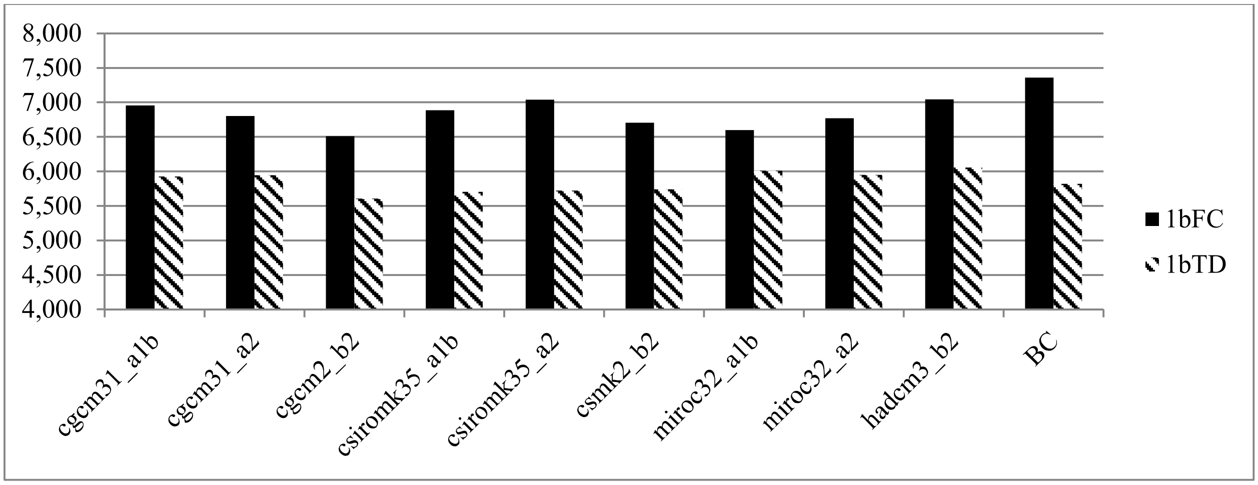

Figure C.19. Estimated 2060 Population for Hot Springs County, WY under a Baseline Climate (BC) and Nine Climate Change (CC) Scenarios (Model 1bFC and Model 2bTD)

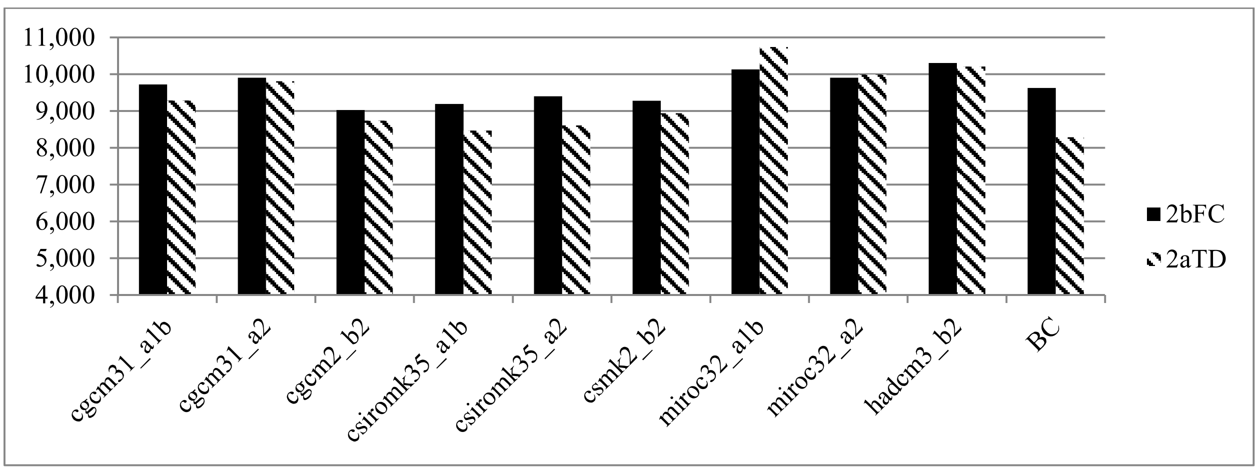

Figure C.20. Estimated 2060 Population for Hot Springs County, WY under a Baseline Climate (BC) and Nine Climate Change (CC) Scenarios (Model 2bFC and Model 2aTD)

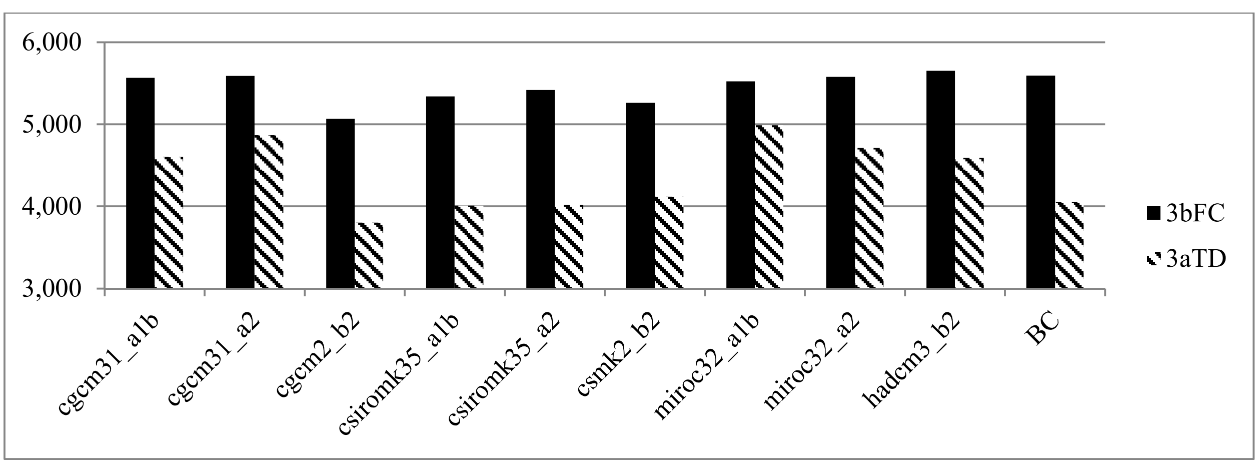

Figure C.21. Estimated 2060 Population for Hot Springs County, WY under a Baseline Climate (BC) and Nine Climate Change (CC) Scenarios (Model 3bFC and Model 3aTD)

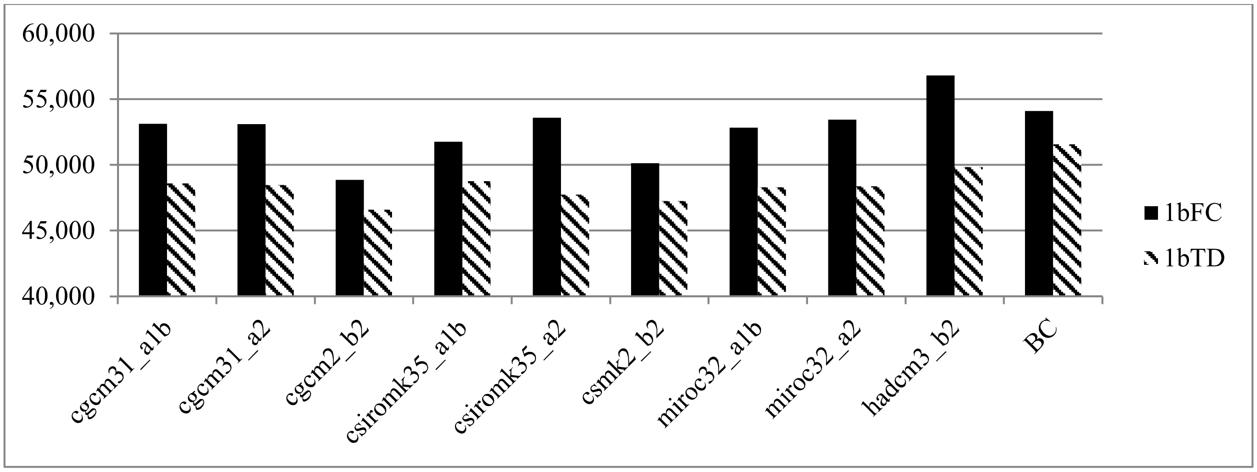

Figure C.22. Estimated 2060 Population for Park County, WY under a Baseline Climate (BC) and Nine Climate Change (CC) Scenarios (Model 1bFC and Model 1bTD)

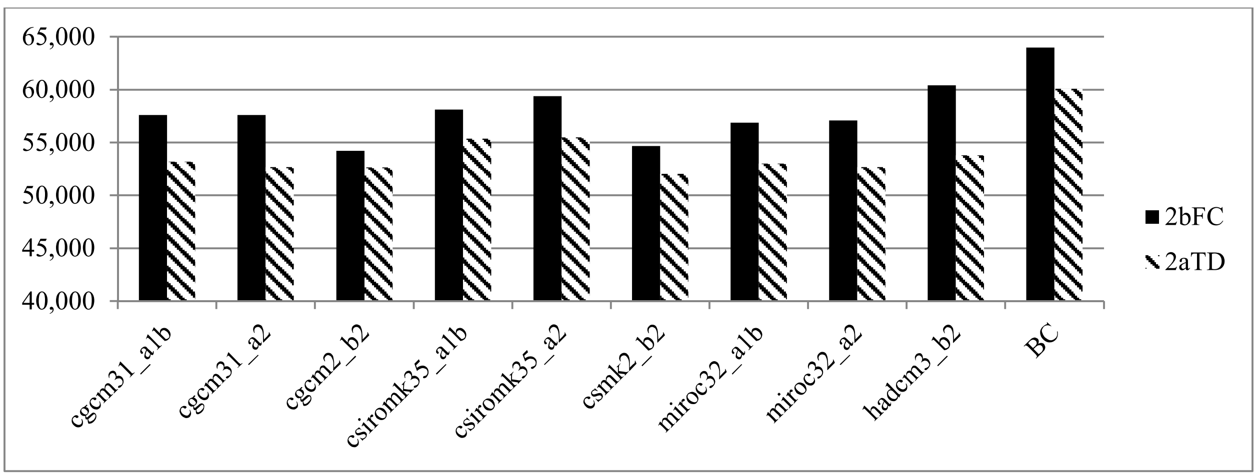

Figure C.23. Estimated 2060 Population for Park County, WY under a Baseline Climate (BC) and Nine Climate Change (CC) Scenarios (Model 2bFC and Model 2bTD)

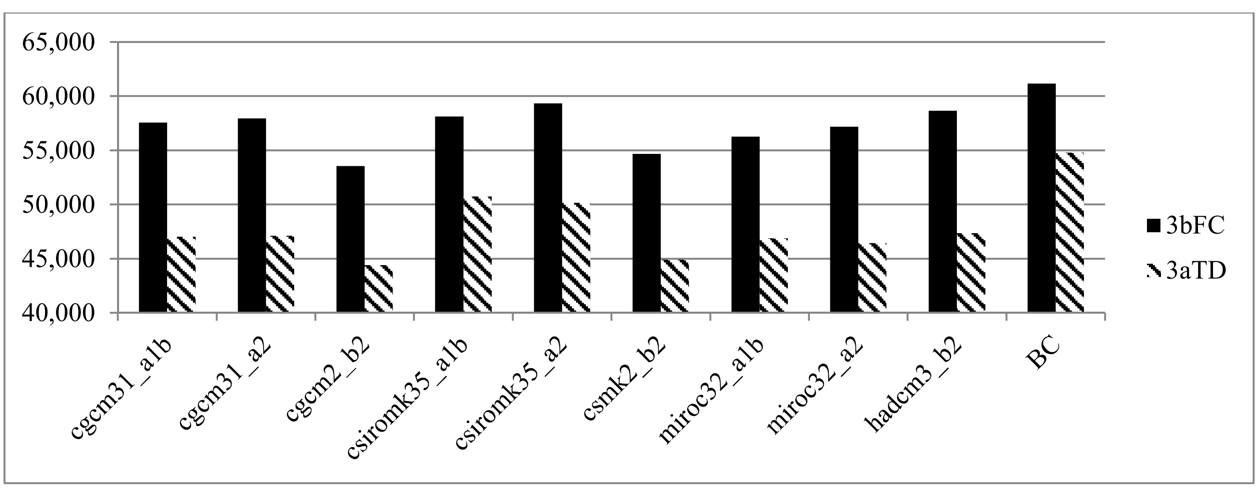

Figure C.24. Estimated 2060 Population for Park County, WY under a Baseline Climate (BC) and Nine Climate Change (CC) Scenarios (Model 3bFC and Model 3aTD)

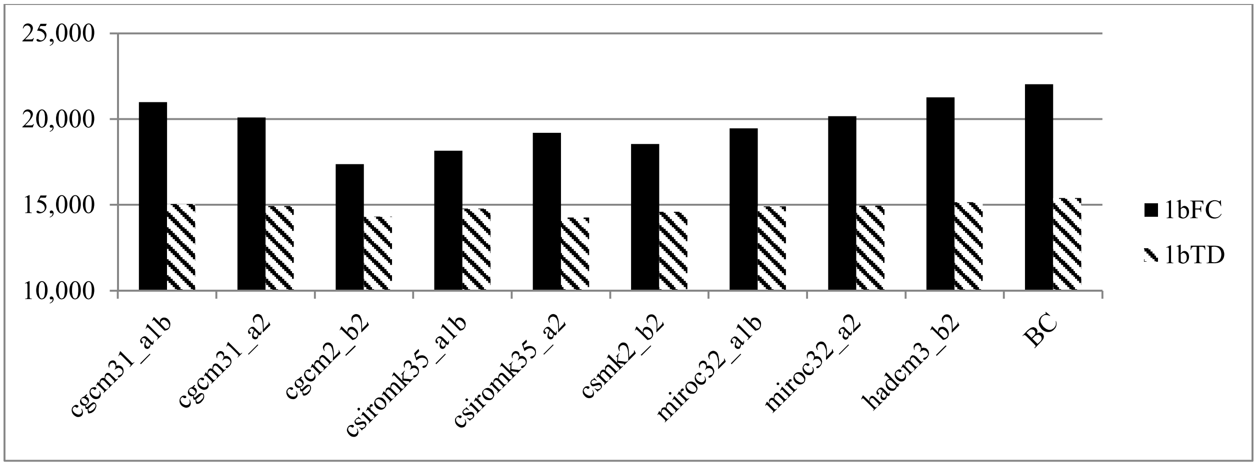

Figure C.25. Estimated 2060 Population for Sublette County, WY under a Baseline Climate (BC) and Nine Climate Change (CC) Scenarios (Model 1bFC and Model 1bTD)

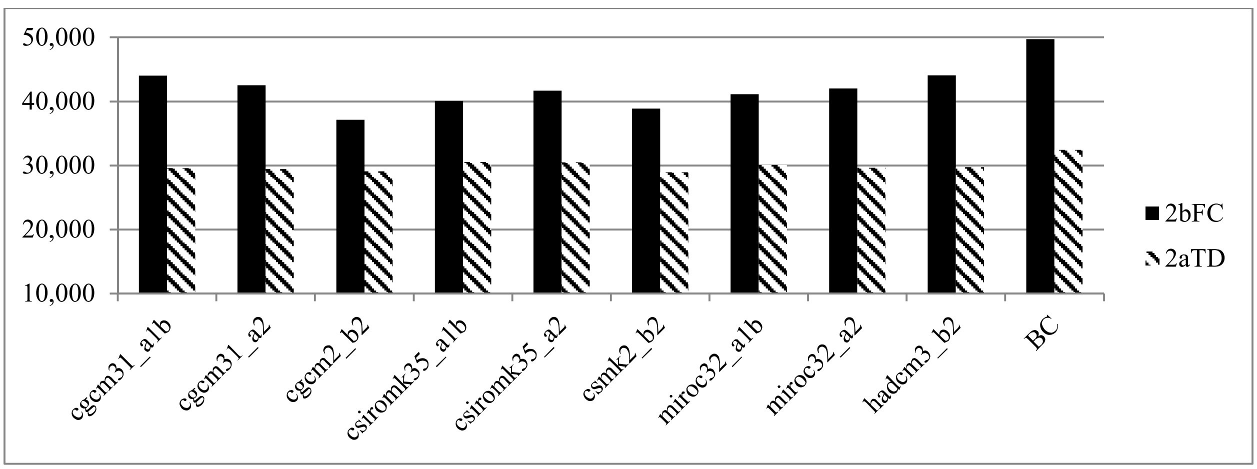

Figure C.26. Estimated 2060 Population for Sublette County, WY under a Baseline Climate and Nine Climate Change (CC) Scenarios (Model 2bFC and Model 2aTD)

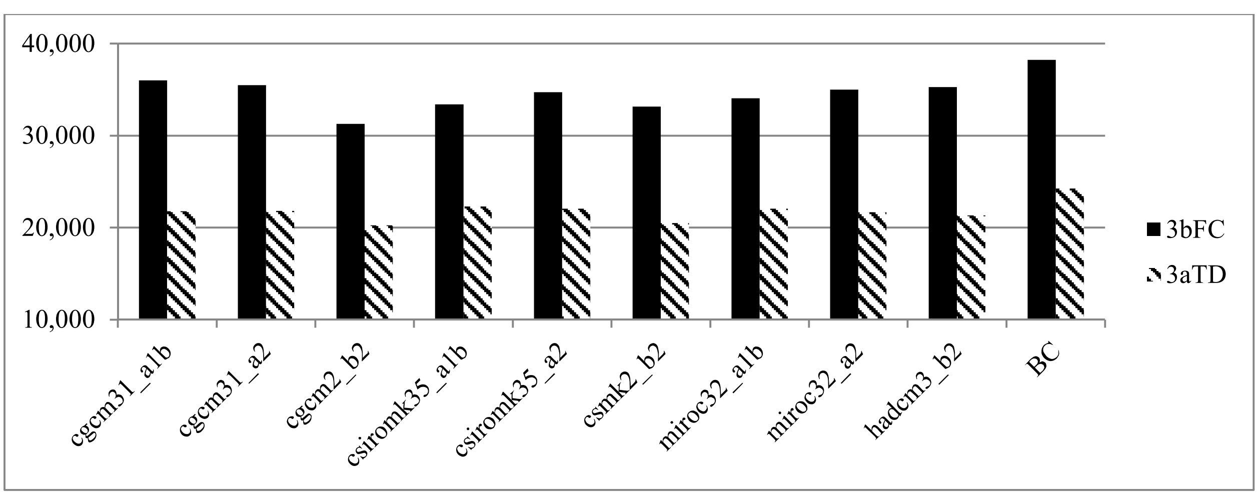

Figure C.27. Estimated 2060 Population for Sublette County, WY under a Baseline Climate (BC) and Nine Climate Change (CC) Scenarios (Model 3bFC and Model 3aTD)

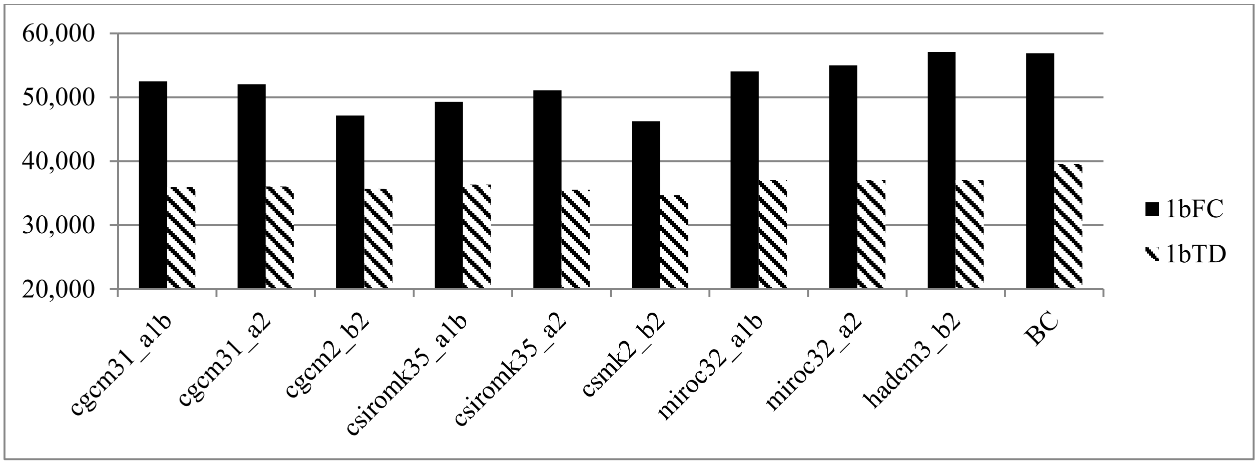

Figure C.28. Estimated 2060 Population for Teton County, WY under a Baseline Climate (BC) and Nine Climate Change (CC) Scenarios (Model 1bFC and Model 1bTD)

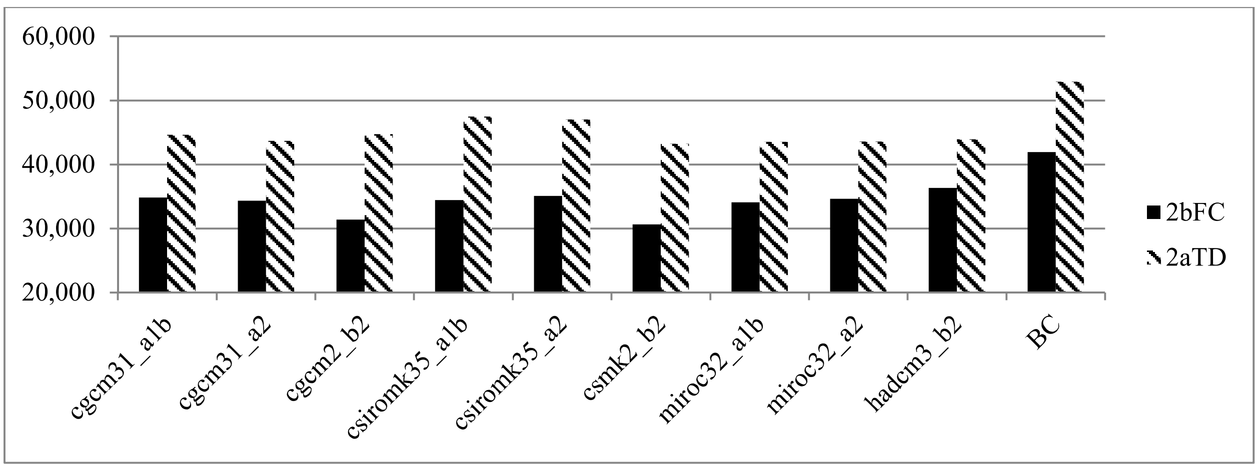

Figure C.29. Estimated 2060 Population for Teton County, WY under a Baseline Climate (BC) and Nine Climate Change (CC) Scenarios (Model 2bFC and Model 2aTD)

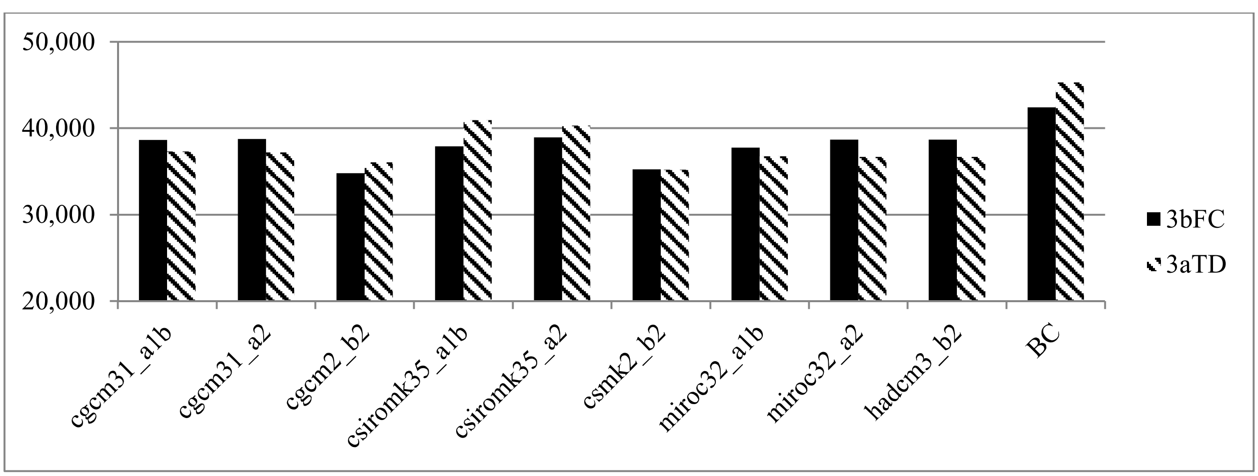

Figure C.30. Estimated 2060 Population for Teton County, WY under a Baseline Climate (BC) and Nine Climate Change (CC) Scenarios (Model 3bFC and Model 3aTD)

APPENDIX D: Data Sources for Variables

Table D.1. Data Sources

Variable	Source
High summer temp	USFS historical climate data and climate projection data
High summer temp SQ	
Low winter temp	
Low winter temp SQ	
Temperature difference	
Precipitation	
Precipitation SQ	
Picnic tables	Kasberg, K., 2012.
Campgrounds	
Hiking trails	
Campsites	
Miles of dirt and paved roads	
Number of lakes	
Miles of river	
Lake area	
Wilderness lake area	
Wilderness river miles	
Max. elevation	County Highpointers, 2012.
Mountainous (topographic dummy)	USDA ERS Natural Amenities Scale
Plains and Tablelands (topographic dummy)	
Plains (topographic dummy)	
Open Hills or Mountains (topographic dummy)	
Population & Population SQ	2000 and 2010 US Census
Average age	
Housing cost	
Non-labor income	
Farm jobs	
Percentage employed in travel/tourism	
Percent Hispanic	
Number of county jobs/County population	

Driving time to metropolitan center	Google Maps
Dummy variable for presence of an interstate within county	
Dummy for presence of National Park within county	County websites
Percent of county that is national forest land	USFS Land Areas of the National Forest System 2013

APPENDIX E: Regional Model Results

This Appendix summarizes results of population change analysis conducted for each of three regions:

- Region 1: Colorado, New Mexico, Utah, Arizona, Nevada ($n_1 = 86$)
- Region 2: California, Oregon, Washington ($n_2 = 39$)
- Region 3: Wyoming, Montana, South Dakota, Idaho ($n_3 = 74$)

The full sample of 199 counties was divided into these three regions to estimate whether climatic factors, as well as factors encompassing the three other classes of independent variables, influenced population growth differently from one region to another. As it was hypothesized that the population variable was capturing the influence of other potentially significant socio-demographic factors in the six FC and TD models presented in the body of this study, three additional socio-economic variables were incorporated into the regional analysis:

- Percentage of the county population self-identifying as Hispanic in 2000
- Median age of the county population in 2000
- Number of jobs divided by total county population in 2000

Two additional full sample regressions were run, the first to isolate the regionally specific effects of climate variables on population growth, and the second with the same specification as Model $3b_{FC}$, but with the addition of the three new socio-economic variables. The specification for the first model included interaction terms for each climate variable and region, as follows:

$$\% \Delta \ Population_i = b_0 + b_1 HighSummerTemp_i \bullet Region1 + b_{2\text{-}17}(Climate\ Variables) + b_{18} Precip_i^2 \bullet Region3 + b_{19\text{-}29}(Built\ Features) + b_{30\text{-}39}(Natural\ Features) + b_{40\text{-}50}(Socio\text{-}Economic\ Measures)$$

Forecasting model results yielded negative population growth projections for all counties in Region 2 and Region 3 and, therefore, are not presented in this analysis. Forecasting model results for the revised full sample model were similar to those of Model $3b_{FC}$ but are included to allow for comparison of both model results and population forecasts with Model $3b_{FC}$, as well as with those of the regional models. Table E.3 compares forecasting model results of the revised full sample model and Model $3b_{FC}$, and Figure E.1-E.4 compare 2060 population growth forecasts by state and region for the regional models (RM1, RM2 and RM3), the revised full sample model and Model $3b_{FC}$.

Regional Model Results

Regional model results are presented in Table E.1, and descriptive statistics for climate variables and an independent variable for percent of county population that was Hispanic in 2000 are presented in Table E.2. In Table E.1, standard errors for each climate variable are included in parentheses below coefficients. All climate variables were included, regardless of level of significance, while all other variables had p-values less than 0.10. Highly significant climate variables are designated with asterisks.

Adjusted R-squared values for each of the three regional models are higher than that of the revised full sample model and Model $3b_{FC}$. Linear summer temperature is positively correlated with population growth for Region 1, which has the highest mean high summer temperature among the three regions, but is negatively correlated in RM2 and RM3. Linear winter temperature is negatively correlated with population growth across regions and highly significant in RM1 and RM3. Linear precipitation, which was not significant in any of the full sample models, has a positive sign in all three models and is highly significant in RM1 and RM2.

Population in 2000 was significant only for Region 1, which had the highest mean 2000 population and highest mean population growth rate (2000-2010) among the three regions. The percent of county population self-identifying as Hispanic in 2000 was highly significant and negatively correlated with population growth in RM1 and RM3. Median age in 2000 was highly significant for Region 2 and Region 3 and negatively correlated with population growth, as well as the only socio-economic measure exhibiting high significance in RM2.

There was substantial variation across regions with regard to which built features and natural amenities were significant in explaining population growth. Miles of river in all national forests contained at least in part within a county was the only variable from these two classes that was significant for multiple regions (RM1 and RM3). Total area of lakes in all national forests located at least in part within a county was significant and positively correlated with population growth for Region 2, while number of lakes exhibited a negative correlation in RM1.

Table E.1. Regional Model Results

	RM1	RM2	RM3
Adj. R-sq.	0.4989	0.7112	0.5358
Sample size	86	39	74
Independent Variables			
Climate			
Summer Temp	-0.1093 (0.0693)	0.0866* (0.0490)	0.1606 (0.1150)
Summer Temp SQ	0.0009* (0.0004)	-0.0005* (0.0003)	-0.0010 (0.0007)
Winter Temp	-0.0318** (-0.0149)	-0.0157 (0.0157)	-0.0639*** (0.0137)
Winter Temp SQ	0.0001 (0.0004)	0.0004 (0.0003)	0.0019*** (0.0005)
Precip	0.0014** (0.0006)	0.0003*** (8.65e-05)	0.0004 (0.0006)
Precip SQ	-1.05e-06 (6.52e-07)	-1.66e-07*** (4.80e-08)	-3.97e-07 (4.13e-07)
Socio-Economics			
Pop 2000	1.31e-06** (5.23E-07)		
Pop 2000 SQ	-2.21e-12** (9.92e-13)		
Non-Labor Income	-0.5636*** (0.1842)		-0.5684*** (0.1885)
Housing Costs	0.8402*** (0.2119)		0.6114*** (0.0.1684)
Percent Hispanic 2000	-0.0019** (0.0009)		-0.0073*** (0.0027)
Median Age 2000		-0.0085*** (0.0020)	-0.0085** (0.0034)

Built Features			
Dirt Road Miles	0.0788*** (0.0293)		
Campsites			-0.2568*** (0.0682)
Campgrounds		-0.1164*** (0.0225)	
Picnic Tables			0.0979*** (0.0227)
Wilderness Hike		-0.0372*** (0.0097)	
Natural Amenities			
Number of Lakes	-0.2258*** (0.0705)		
Lake Area		0.0272*** (0.0062)	
River Miles	0.1746*** (0.0633)		0.0660** (0.0327)
Wilderness River		0.0403*** (0.0103)	
Mountainous			0.1029*** (0.0279)
Cons	2.6649	-2.8368	-4.6323

*p-value of 0.10 or lower
**p-value of 0.05 or lower
***p-value of 0.01 or lower

Table E.2. Descriptive Statistics for Population, Population Growth and Climate Variables, by Region

Region 1

Variable	**Mean**	**Min**	**Max**
Population in 2000	62,492	562	557,601
% Pop Growth$_{2000\text{-}2010}$	12	-20	107
Summer Temp	81.9	63.2	100.4
Winter Temp	17.1	1.8	37.5
Precip	395.1	143.6	889.3
% Hispanic Pop	21.7	1.5	81.6

Region 2

Variable	**Mean**	**Min**	**Max**
Population in 2000	54,901	1209	368,627
% Pop Growth$_{2000\text{-}2010}$	5	-9	22
Summer Temp	80.2	70.7	92.3
Winter Temp	24.3	15.7	36.2
Precip	736.8	167.9	1,709.9
% Hispanic Pop	10.5	1.7	50.8

Region 3

Variable	**Mean**	**Min**	**Max**
Population in 2000	17,294	1,019	88,872
% Pop Growth$_{2000\text{-}2010}$	8	-13	72
Summer Temp	76.9	68.4	85.7
Winter Temp	12.1	1.3	24.6
Precip	521.6	314.0	1,007.5
% Hispanic Pop	3.9	0.6	34.2

Table E.3. Population Forecasting Model Results Revised Full Sample Model (FSM) and Model $3b_{FC}$

	FSM	$3b_{FC}$
Adj. R-squared	0.4208	0.4031
Independent Variables		
Climate		
High Summer Temp	-0.0262 (0.0319)	-0.0250 (0.0324)
High Summer Temp SQ	0.0002 (0.0002)	0.0002 (0.0002)
Low Winter Temp	-0.0228*** (0.0070)	-0.0206*** (0.0070)
Low Winter Temp SQ	0.0005*** (0.0002)	0.0004** (0.0002)
Precipitation	0.0001 (0.0002)	0.0001 (0.0002)
Precipitation SQ	-1.47e-07 (1.00e-07)	-1.32e-07 (1.02e-07)
Built Features		
Picnic Tables	0.0331*** (0.0123)	0.0345*** (0.0124)
Campgrounds	-0.1375*** (0.0316)	-0.1576*** (0.0311)
Hiking Trails	0.0568*** (0.0177)	0.0647*** (0.0177)

Natural Features		
Lake Area	0.0288*** (0.0108)	0.0319*** (0.0109)
Wilderness Lake Area	-0.0182** (0.0075)	-0.0157** (0.0075)
Wilderness River Miles	0.0200** (0.0086)	0.0175** (0.0087)
Mountainous Topography	0.0467** (0.0216)	0.0471** (0.0219)
Socio-Economics		
Population	1.36e-06*** (3.34e-07)	1.37e-06*** (3.39e-07)
Population SQ	-2.29e-12*** (6.81e-13)	-2.35e-12*** (6.91e-13)
Housing Costs	0.4469*** (0.1202)	0.4194*** (0.1215)
Non-Labor Income	-0.4042*** (0.1155)	-0.4092*** (0.1172)
% Hispanic	-0.0015** (0.0006)	
Constant	0.9912 (1.2771)	0.9610 (1.2964)

*p-value of 0.10 or lower
**p-value of 0.05 or lower
***p-value of 0.01 or lower

Population Projections

Positive population growth from 2010 to 2060 was projected across regional models for all 12 states. These results are consistent with the regional population growth projections of Cordell et al. (2011), who predicted increases in population through 2060 for most areas of the Intermountain West and Pacific Northwest. RM1 predicted much higher regional population growth than did RM2 and RM3 (138.5% compared to 56.0% and 58.6%, respectively). Predicted percent increases in population varied considerably more across the three regional models than they did for FSM or Model $3b_{FC}$. This is not a surprising result, as both significance and magnitude of all independent variables varied across regional models. The FSM predicted that Region 2 would experience the greatest growth (131.9%), followed by Region 1 (110.1%) and Region 3 (94.0%). Model $3b_{FC}$ exhibited a much smaller range in projected percentage growth across regions, from a low of 90.9% (Region 2) to a high of 96.4% (Region 1).

There was relatively little variation across models in predicted percent increases in population for Nevada, New Mexico, Oregon, Idaho and Wyoming, while California and South Dakota exhibited the greatest variation in predicted population growth. Two out of the three models (grouping the regional models together) projected the greatest percent increase in population for Arizona. Utah was the only other state for which all three models predicted an increase in population greater than 100%. As shown in Table E.5, the states comprising Region 1 had five of the six highest base year populations.

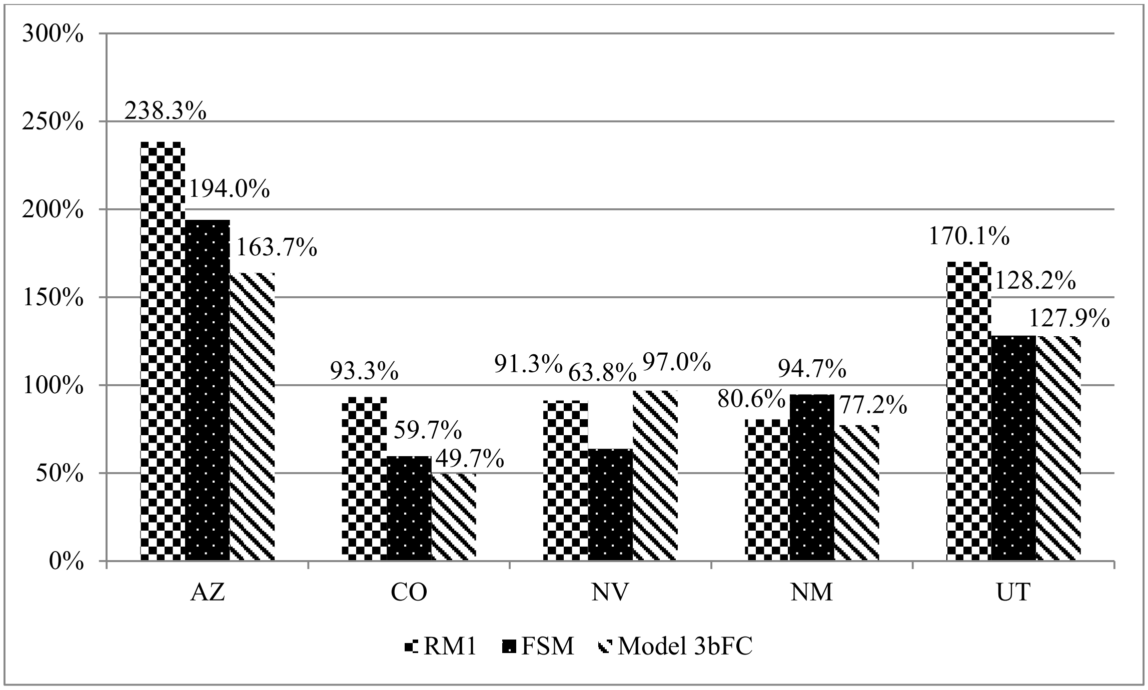

Figure E.1. Projected Increases in Populations for Region 1 States, 2010-2060

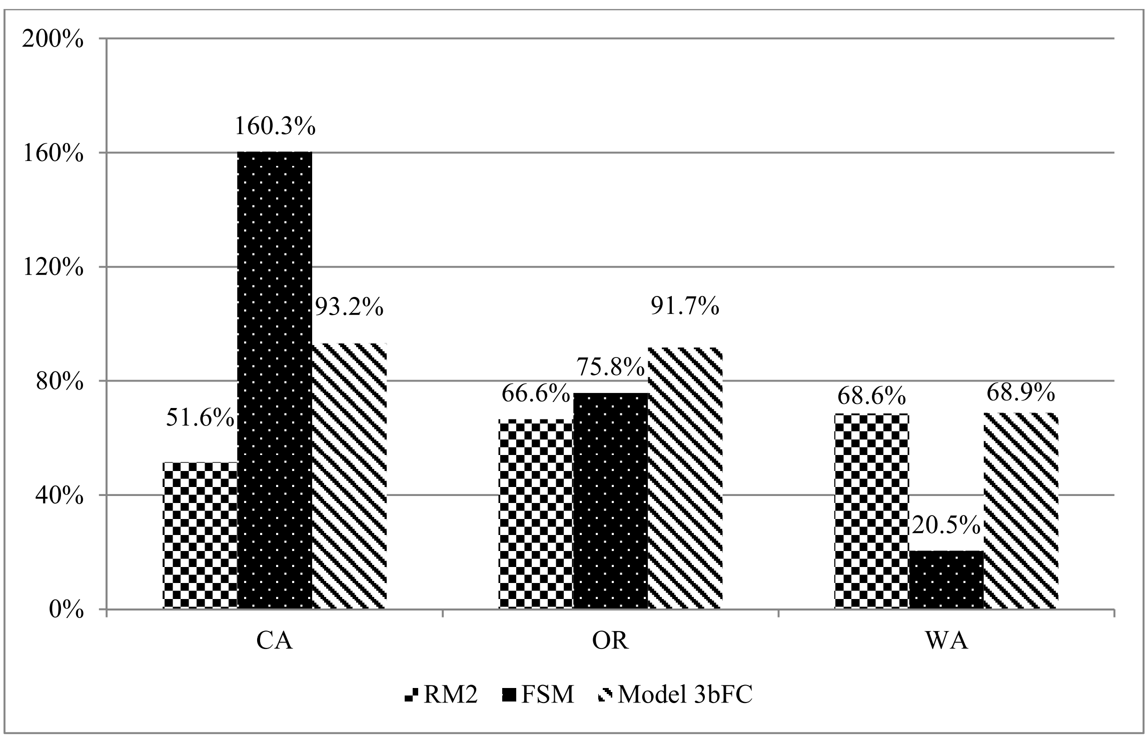

Figure E.2. Projected Increases in Populations for Region 2 States, 2010-2060

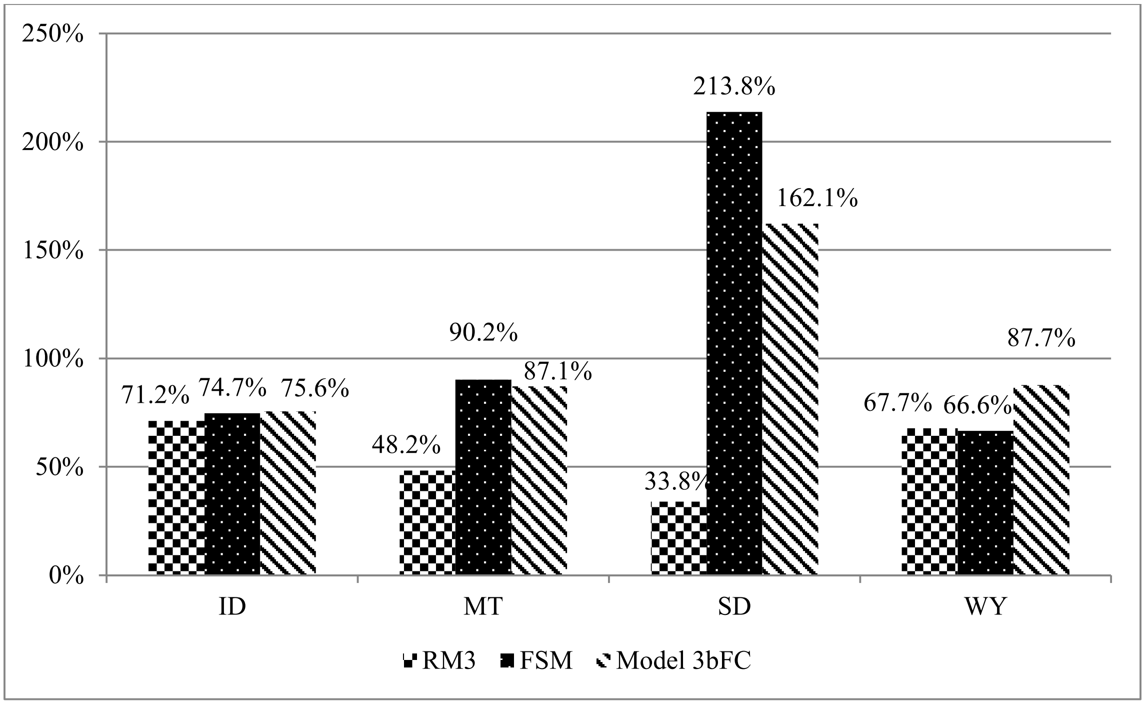

Figure E.3. Projected Increases in Populations for Region 3 States, 2010-2060

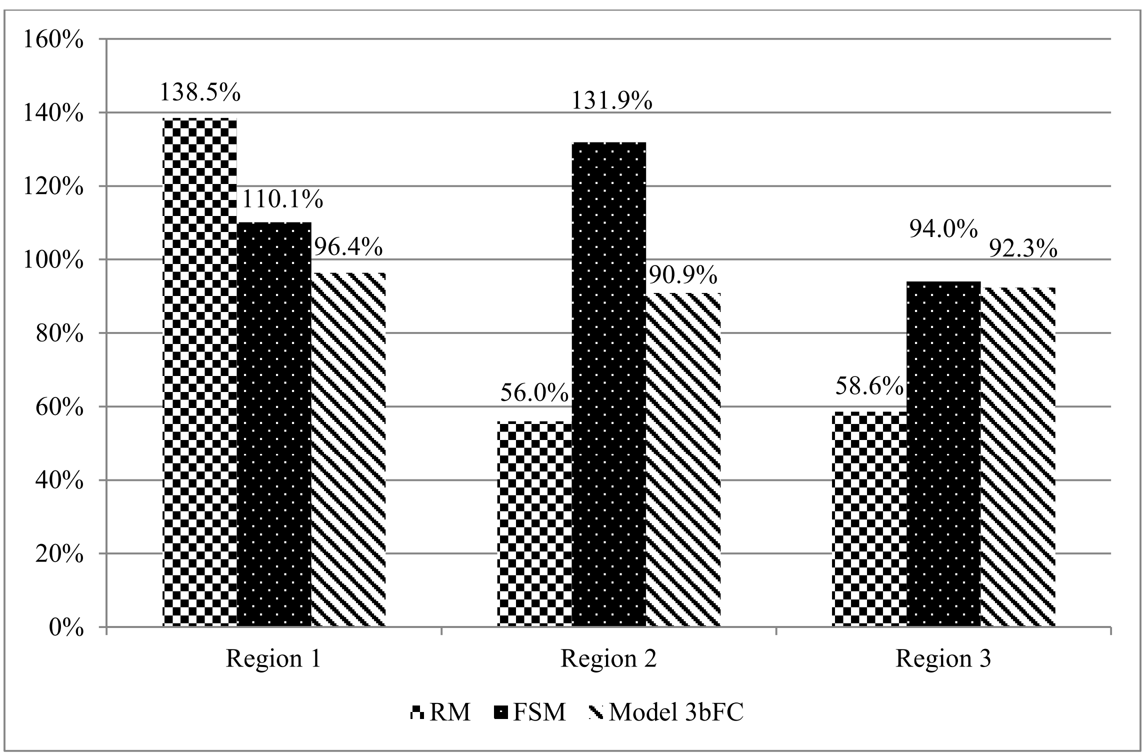

Figure E.4. Projected Increases in Regional Populations, 2010-2060

Regional Model Baseline Climate and Climate Change Population Projections

As shown in Table E.4, Regional models predicted positive population growth for each of the 12 states over 2010-2060. RM1 predicted greater than 100% population growth for sampled areas of Arizona, Nevada and Utah under both baseline climate and climate change scenarios. These were the only states for which population was projected to increase by at least 100% under both climate scenarios. California and Idaho were the only states for which baseline climate and climate change population growth projections were not statistically different.

Population projections for 2060 were higher under the climate change scenario than the baseline climate scenario for all states in Region 1 and Region 2. For Region 3, however, this result was reversed, as all four states' baseline climate population growth projections were higher than their respective climate change projections. These results seem to contradict the hypothesis that people will tend to migrate to climates with cooler temperatures as summer and winter temperatures continue to increase in the warmer states of Region 1. It appears, therefore, that forecasted increases in annual precipitation over the time periods 2010-2020 and 2010-2060 among nearly all sampled counties in Region 1 likely are responsible for higher population growth projections under the climate change scenario.

Table E.5 compares population growth projections for each of the three regions under baseline climate and climate change scenarios. The baseline population for Region 1 was nearly three times greater than that of Region 2 and more than four times greater than that of Region 3. Projected percentage increases in population under both baseline climate and climate change scenarios also were much higher for Region 1 than for Region 2 or Region 3. Predicted population growth rates for Region 3 under both climate scenarios were higher than those for Region 2. Thus, aggregated regional population growth in sampled rural areas was predicted to be higher over 2010-2060 in the intermountain west than in California and the Pacific Northwest.

Table E.4. RM1, RM2 & RM3 State Population Growth Projections under Baseline Climate and Climate Change Scenarios, 2010-2060

State	Model	2010 Population	2060 Population	Change	C.I. (α = 0.10) (Two-sided)	
AZ	$RM1_{BC}$	1,378,397	4,053,876	194.1%		
	$RM1_{CC}$		4,663,695	238.3%	4,364,428	4,962,963
CO	$RM1_{BC}$	2,102,973	3,596,934	71.0%		
	$RM1_{CC}$		4,064,693	93.3%	3,753,476	4,375,910
NV	$RM1_{BC}$	713,642	1,522,924	113.4%		
	$RM1_{CC}$		1,745,695	144.6%	1,631,575	1,859,816
NM	$RM1_{BC}$	1,349,351	1,909,782	41.5%		
	$RM1_{CC}$		2,436,460	80.6%	2,200,183	2,672,736
UT	$RM1_{BC}$	985,078	2,384,919	142.1%		
	$RM1_{CC}$		2,660,832	170.1%	2,504,882	2,816,781
CA	$RM2_{BC}$	1,700,767	2,521,352	48.2%		
	$RM2_{CC}$		2,578,277	51.6%	2,503,088	2,653,466
OR	$RM2_{BC}$	482,032	746,300	54.8%		
	$RM2_{CC}$		803,141	66.6%	789,911	816,370
WA	$RM2_{BC}$	191,951	316,615	64.9%		
	$RM2_{CC}$		323,614	68.6%	318,708	328,520
ID	$RM3_{BC}$	454,829	808,751	77.8%		
	$RM3_{CC}$		778,653	71.2%	735,223	822,082
MT	$RM3_{BC}$	454,966	709,320	55.9%		
	$RM3_{CC}$		674,156	48.2%	656,473	691,840
SD	$RM3_{BC}$	167,044	313,786	87.8%		
	$RM3_{CC}$		223,581	33.8%	207,662	239,501
WY	$RM3_{BC}$	345,098	703,698	103.9%		
	$RM3_{CC}$		578,666	67.7%	549,839	607,492

Table E.5. RM1, RM2 & RM3 Regional Population Growth Projections under Baseline Climate and Climate Change Scenarios, 2010-2060

Region	Model	2010 Population	2060 Population	Change	C.I. (α = 0.10) (Two-sided)	
1	$RM1_{BC}$	6,529,441	13,468,434	106.3%		
	$RM1_{CC}$		15,571,375	138.5%	14,454,544	16,688,206
2	$RM2_{BC}$	2,374,750	3,584,267	50.9%		
	$RM2_{CC}$		3,705,031	56.0%	3,611,707	3,798,356
3	$RM3_{BC}$	1,421,937	2,535,555	78.3%		
	$RM3_{CC}$		2,255,056	58.6%	2,149,197	2,360,915