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Chapter 2

ECONOMIC EFFECTS OF PROJECTED CLIMATE CHANGE ON OUTDOOR RECREATION IN TENNESSEE

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ABSTRACT

Climate change projections from three General Circulation Models were used to adjust the temperature and precipitation in 2030 and 2080 in each of five ecological provinces in Tennessee to estimate the direct economic effects of the projected changes on recreation using the Tourism Climatic Index. The indirect effects on recreation were evaluated qualitatively, based on current demand for the unique values associated with current conditions. The results of the direct impact evaluation reveal that climate change will have variable effects on recreational activities in Tennessee. The magnitude and direction of the effects vary by the recreational activity involved, patterns of precipitation and temperature regimes, and specific location in Tennessee. Recreational activities such as rock climbing, winter activities independent of snow, and whitewater boating are likely to benefit from projected climate changes due to increased temperatures in the winter months. Summer-based activities such as lake recreation and camping are likely to decline with increasing seasonal temperatures. The indirect effects of climate change on recreation are likely to have a larger effect than the direct impacts of climatic variables.

Keywords: Climate change; Outdoor recreation; Tourism climatic index.

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1. INTRODUCTION

Global climatic change has been a significant scientific and natural resource topic for several decades. During the past ten years, the issue has received increasing attention due to growing evidence of changing temperature and precipitation regimes, and concern about their effects. As evidence for climate change increases, attention has shifted toward projecting the magnitude of potential consequences of climate change and identifying adaptation strategies to address these consequences. This paper presents information on how climate change would affect the forests of Tennessee and identifies the potential economic impacts associated with changes to outdoor recreational activities as a result of global climatic change.

Tennessee was selected for this analysis because its forests are important from recreational, economic, and ecological perspectives. The state offers a wide range of outdoor recreational opportunities and contains a number of key recreational areas such as the Great Smoky Mountains National Park and Big South Fork National River and Recreation Area. The high diversity of tree species in Tennessee's forests supports a large number and variety of plants and animals. Mixed mesophytic forests in Tennessee are among the most diverse in North America, and Tennessee is one of the most diverse inland states in the United States in terms of the number of species found. This high diversity is largely a result of the variation in topography, climate regimes, and by consequence vegetation types across the state.

Tennessee's diverse and unique forests have been affected by land use, land management, non-native species, outbreaks of native insects, and natural disturbances, and climate change is likely to further alter them. There is more forest cover in Tennessee today than there was 50 years ago, as land cut over in the 1940s and 1950s regenerated and is now mature (Wheeler, 1952; Oswalt et al., 2009). The relatively undeveloped, forested regions of the state have become a prime target of retirement and second home developments in the past 10 years, and this trend is expected to exacerbate land-use change in future decades. As a result, Tennessee's forests are being viewed as not only a source of wood products, biodiversity, and other environmental services, but now are also in great demand for development, placing increasing pressure on the lands.

Climate change can have a wide range of potential effects, both localized and global. Responses to these effects vary widely as well, compounding efforts to assess the consequences of change. Local recreational use, for example, can be affected by a changing climate, but forecasting the net effects of climate change is difficult due to the availability of alternative sites or recreational activities which may result in simple shifts in recreational activity. This paper presents the results of an assessment of potential changes in forest cover, recreational use, and the economic implications for Tennessee for two future periods: 2030 and 2080. Based on a range of future climate scenarios, changes in climatic conditions for recreational activities were estimated, as was the effect of these changes on future demand for forest-based recreational use. The same climate scenarios were used to project forest change with the LINKAGES forest ecosystem model (Post and Pastor, 1996). LINKAGES simulates changes in forest composition and structure based on changing biogeochemistry for a 1/12 ha plot. Finally, some of the macroeconomic effects for recreation are reviewed.

2. METHODS

2.1. Climate Change and Tourism Climatic Index

This study was focused on the five ecological provinces in Bailey's ecoregions analysis (Bailey, 1995) that occur in Tennessee (figure 1). Climate change projections from three General Circulation Models (GCMs) were used to adjust the temperature and precipitation in 2030 and 2080 in each ecological province. The temperature and precipitation change projections for 2030 and 2080 for Tennessee were provided by the National Center for Atmospheric Research (NCAR) from three GCMs (selected from 18 possible GCMs) that provide a range of potential climate conditions for Tennessee (personal communication, August 1, 2006, J.B. Smith and C. Wagner, Stratus Consulting Inc., Boulder, CO). The "2030" projections are model simulations of the years 2020-2039, and the "2080" projections are model simulations of the years 2070-2089. The selected GCM outputs represent three conditions:

1. Wet [National Center for Atmospheric Research's Community Climate System Model (ccsm3) (Collins et al., 2006)]
2. Middle [National Center for Atmospheric Research's Parallel Climate Model (PPM) (Washington et al., 2000)]
3. Dry [Center Climate System Research (The University of Tokyo), National Institute for Environmental Studies, and Frontier Research Center for Global Change (JAMSTEC) Model for Interdisciplinary Research on Climate, medium resolution (miroc.medres)].

The GCMs and global climate modeling approaches are described in IPCC (2007). Additional information on the climate projections and forest simulations for Tennessee are described in Dale et al. (2009).

Several recent studies have highlighted the potential impact of climate change on recreational use (Loomis and Crespi, 1999; Richardson and Loomis, 2003; Jones and Scott, 2006; Morris and Walls, 2009). Loomis and Crespi (1999) note that climatic change can have direct effects, including changes in temperature or precipitation regimes, or indirect effects, such as impacts due to changes in the quality or quantity of the natural resources supporting recreation, on recreational use. The direct economic effects of the projected changes on recreation were evaluated using the Tourism Climatic Index (TCI) developed by Mieczkowski (1985). The TCI assesses how changes in several climate variables, including total precipitation, maximum and minimum temperatures, relative humidity, and wind, affect the suitability of a given location for tourism and recreation. The sub-indices used to estimate the TCI are described in table 1.

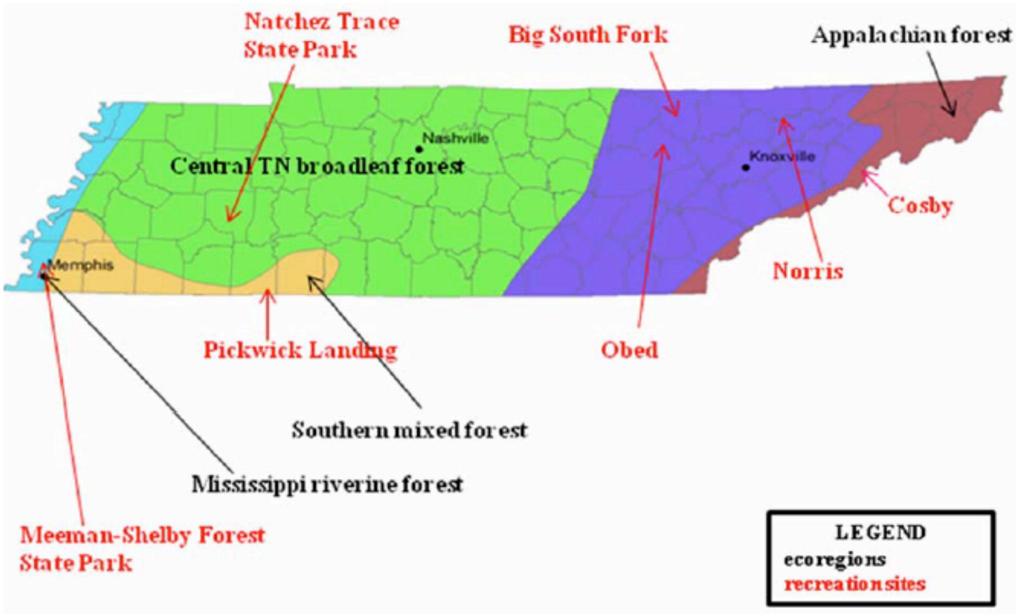


Figure 1. Ecoregions and recreation sites of Tennessee used in analysis.

Table 1. Sub-indices within Tourism Climatic Index[a]

Sub-Index	Monthly Climate Variables	Influence on TCI	Weighting in TCI
Daytime Comfort Index (CID)	Maximum daily temperature & minimum daily relative humidity	Represents thermal comfort when maximum tourist activity occurs minimum daily	40%
Daily Comfort Index(CIA)	Mean daily temperature & mean daily relative humidity	Represents thermal comfort over the full 24 hour period, including activities and holiday enjoyment	10%
Precipitation (P)	Total precipitation	Reflects the negative impact that this element has on outdoor activities and holiday enjoyment	20%
Sunshine (S)	Total hours of sunshine	Rated as positive for tourism, but acknowledged can be negative because of the risk of sunburn and added discomfort on hot days	20%
Wind (W)	Average wind speed	Variable effect depending on temperature (evaporative cooling effect in hot climates rated positively, while 'wind chill' in cold climate rated negatively	10%

[a] Adapted from Scott and McBoyle (1965).

The TCI scores were estimated with the results for the 2030 and 2080 climate projections and applied to visitation numbers for several recreation sites across Tennessee (see figure 1). The sites were selected to assess the potential impacts to recreation in the five ecological regions of Tennessee. In addition, the sites are representative of recreational activities most common in their respective regions. Future recreational use was estimated with a "no" climate change scenario and with the “dry”,” middle”, and” wet” scenarios. The “no” climate change use scenario was determined by multiplying current use estimates by the projected growth multipliers developed by Bowker et al. (1999). Sole reliance on TCI scores could result in summer-based activities being degraded artificially. Therefore, average monthly visitation numbers were utilized to normalize the impact of the TCI scores, while accurately depicting the lower comfort levels in the summer. The “dry”, “middle”, and “wet” use scenarios were developed by applying the Bowker et al. (1999) multipliers to the future use estimates, adjusted by the future climate scenarios. Bowker at al. (1999) projected demand only to 2050. The trends, however, were projected forward to 2080 as a simple linear extension.

2.2. Potential Economic Impacts

The direct economic impact of climate change on future recreational use was estimated by comparing the total consumer surplus associated with the “no” climate change scenario to those of the three change forecasts. The consumer surplus values for all recreation sites except the Obed Wild and Scenic River were calculated by multiplying the projected visits for each site by the average consumer surplus values for recreational activities in the southeastern U.S., as reported by Loomis (2005). The values for the Obed area were calculated similarly but used the consumer surplus estimates reported for the area in Sims et al. (2004). All values reported by Loomis (2005) and Sims et al. (2004) were estimated via stated preference (willingness to pay) surveys. Loomis summarizes net average values for 30 different recreational activities for regions within the U.S., while Sims et al. (2004) reports values for the Obed only. Estimates of economic value were applied to the changes in potential recreational demand for various activities.

The indirect effects of climate change on recreation are likely to be substantial, for they are due primarily to changes in forest composition associated with the potential loss of key species or forest types. The impacts of these changes on recreation were evaluated qualitatively, based on current demand for the unique values associated with current conditions.

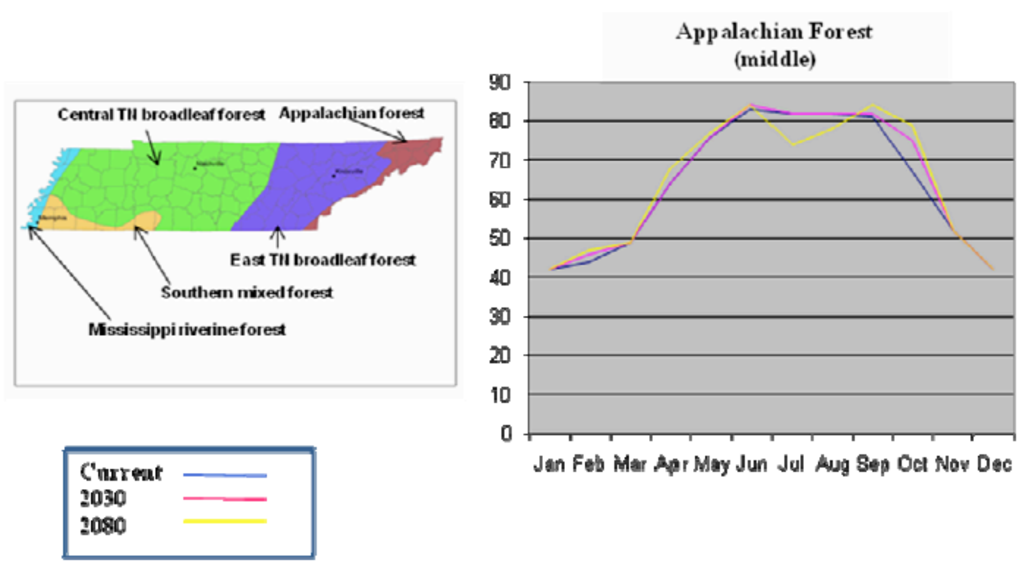
3. RESULTS

3.1. Projected Forest Composition

In all cases, forest species composition shifted. The hickories (*Carya* species) and hackberry (*Celtis laevigata*) became more dominant, basswood (*Tilia heterophylla*) attained greater biomass in some scenarios and declined in others, and both chestnut oak (*Quercus prinus*) and black oak (*Q. velutina*) declined in their biomass contribution to the forest. The contribution of tree species to total biomass changed for all forest provinces in all climate change scenarios as compared to the 1989 equilibrium. The Southern Mixed Forest experienced the greatest alteration in forest composition among the provinces considered. Under the “dry” scenario, the Southern Mixed Forest becomes dominated by four species [loblolly pine (*Pinus taeda*) and three oaks]. The “middle” and “wet” scenarios both resulted in a greater dominance of hackberry and less biomass of basswood. The East TN Broadleaf Forest maintained high diversity under all cases, but with significant shifts in species composition. The “dry” scenario resulted in dramatic changes in forest composition in both 2030 and 2080. Under both the “middle” and the “wet” scenario, biomass increased for basswood and decreased for chestnut oak, black oak, and yellow buckeye. The Appalachian Forest increased in diversity and dominant species shifted. Under all scenarios, chestnut oak increased initially and then declined in terms of its contribution to stand biomass, basswood increased in biomass, and hickory diversity and biomass also increased. For the “middle” and “wet” scenarios, the Central TN Broadleaf Forest stands were dominated by six hickory species, hackberry, and basswood. For the “dry” case, the forest stands consisted mostly of four hickory species, white oak, southern red oak, and American beech. Projected biomass for the MS Riverine Forest declined in chestnut oak, black oak, basswood, and shumard oak (*Q. shumardii*). For the “dry” scenario, red maple (*Acer rubrum*), hickory, southern red oak, loblolly pine, and beech assumed dominance. For the “middle” and “wet” scenarios, hickory species represent about 40% of the stand biomass and hackberry about 30%.

3.2. Recreational Impacts of Climate Changes

The TCI scores for the region were estimated for key recreational sites within each region and by climate scenario (figures 2-6). Generally, the scores for current conditions, 2030, and 2080 were higher than the lowest ‘acceptable’ score of 50. The exception is the “dry” scenario for the 2080 Southeastern Mixed Forest for the summer months, which slightly dropped below 50. The scores, however, provide a measure of how the changing climate may affect future comfort levels relative to current conditions. As would be expected with increasing summer temperatures, the 2030 and 2080 scores for all regions fell below the current scores for the summer months. Conversely, the 2030 and 2080 scores exceeded current comfort levels from late fall to early spring.



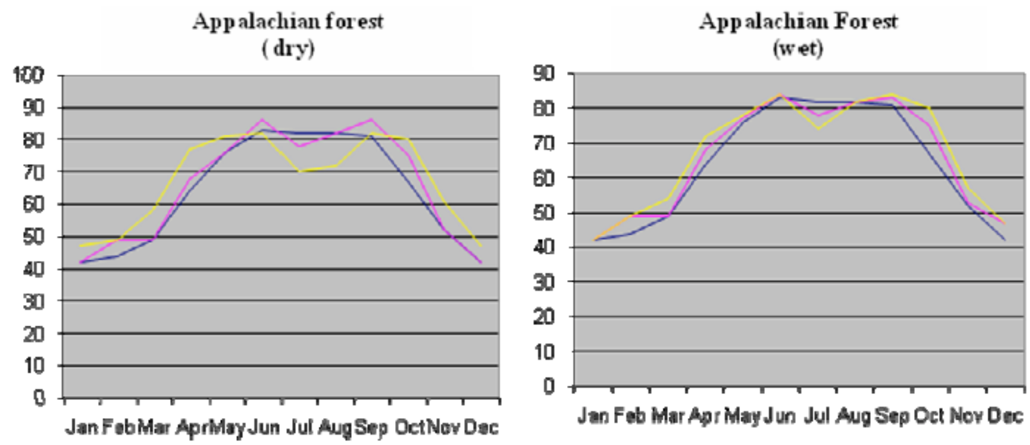


Figure 2. TCI scores for the Appalachian forest.

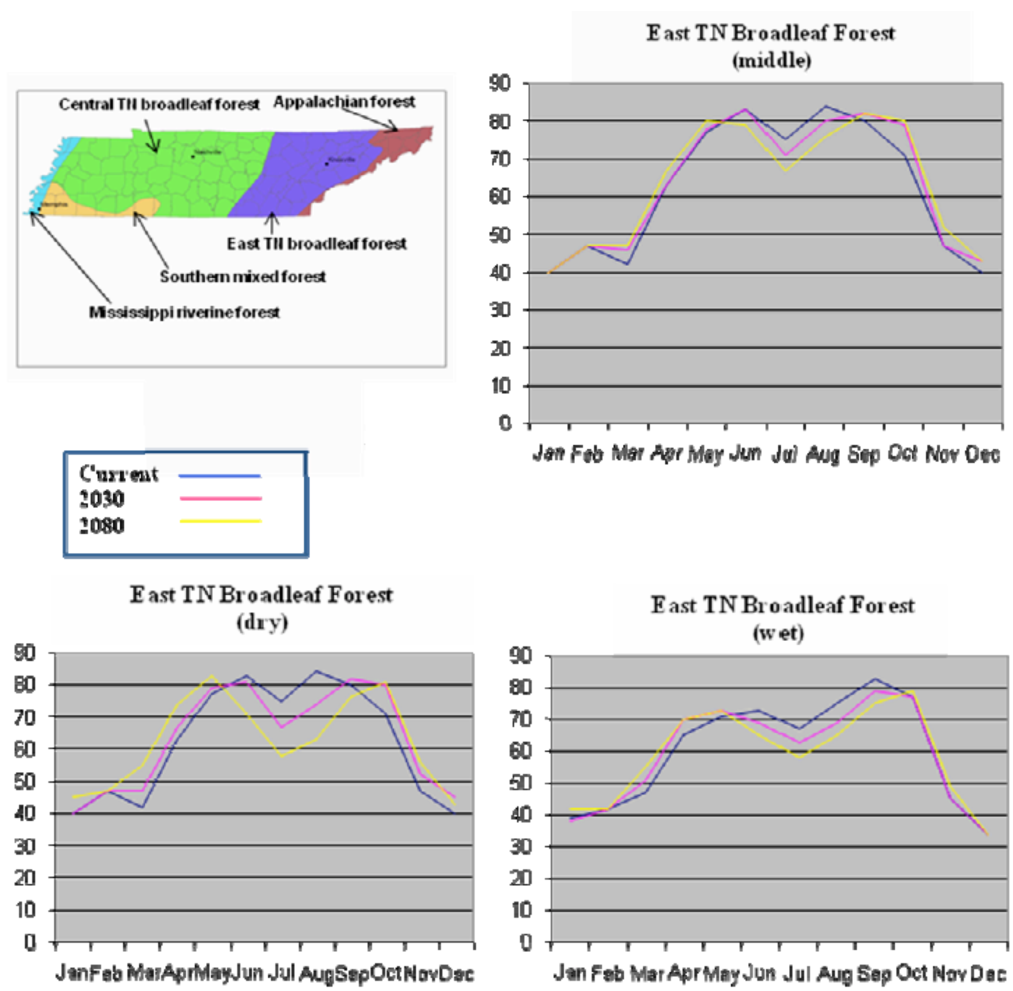


Figure 3. TCI scores for the East Tennessee broadleaf forest.

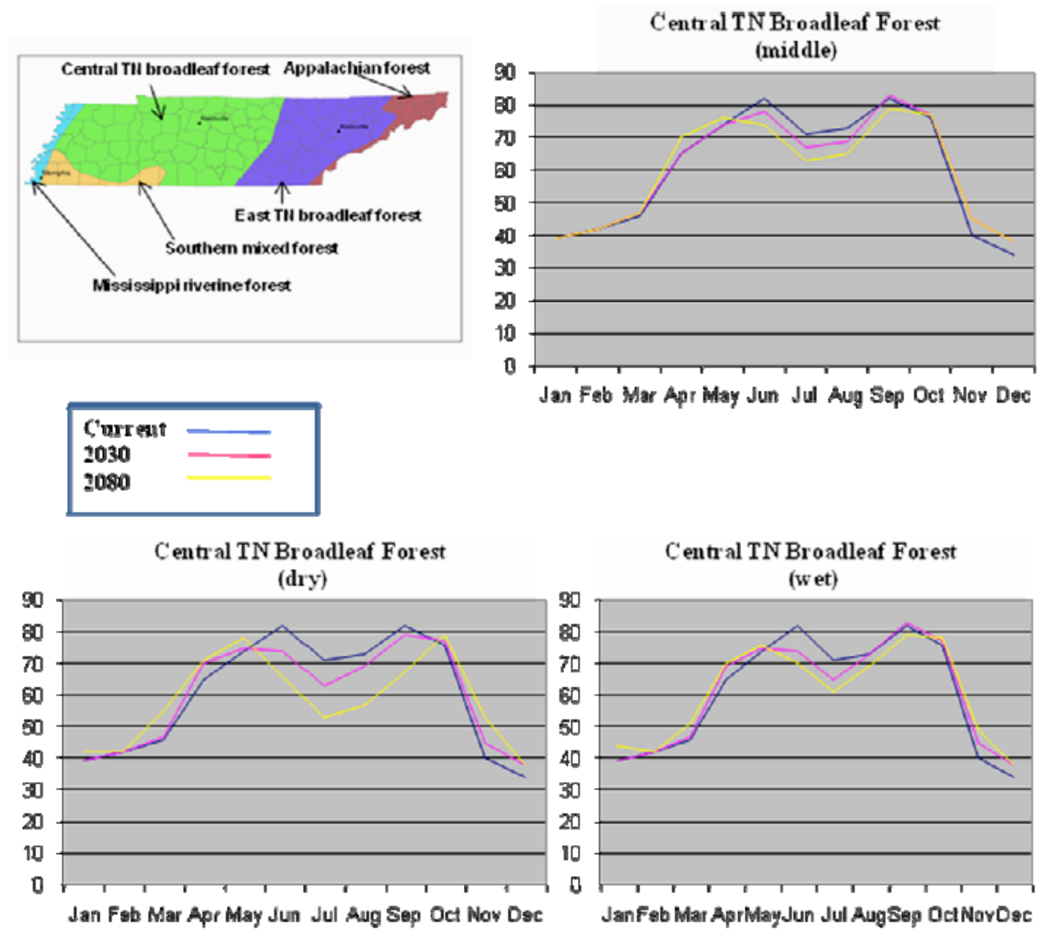
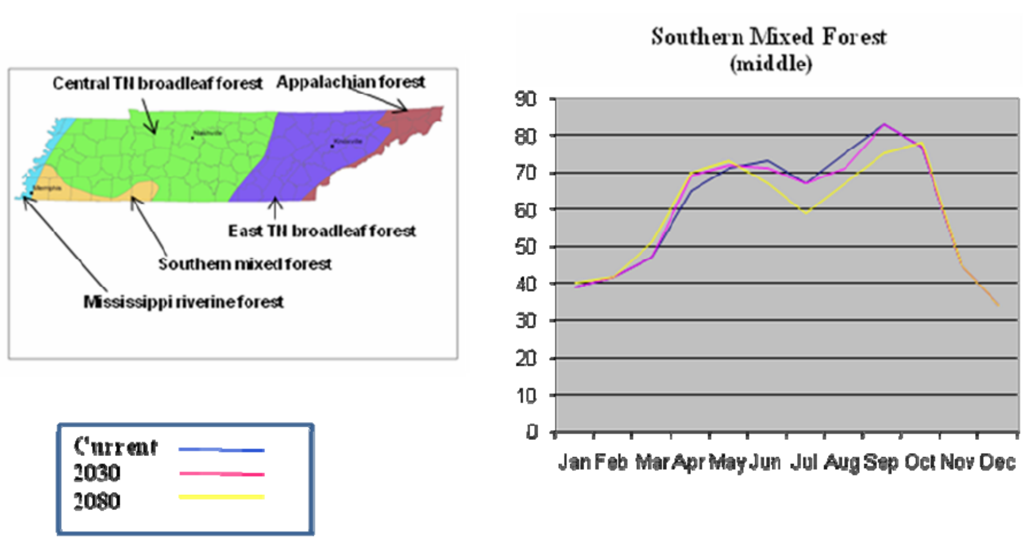


Figure 4. TCI scores for the Central Tennessee broadleaf forest.



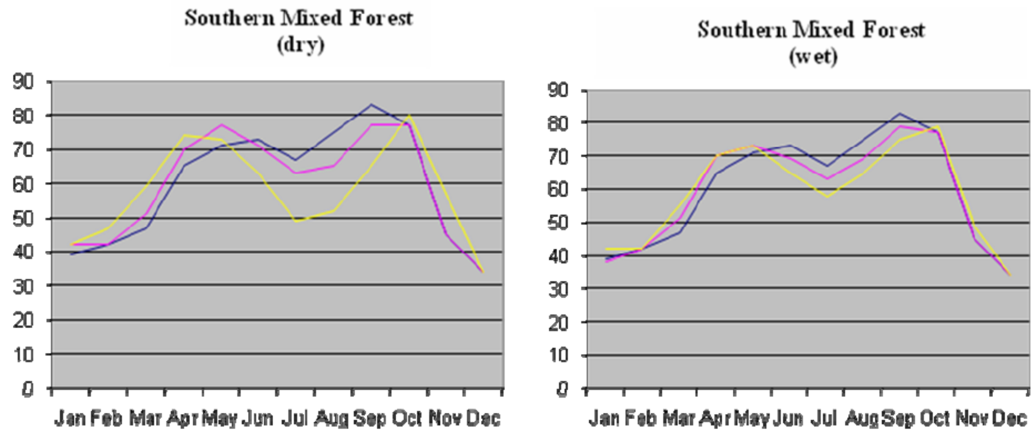


Figure 5. TCI scores for the Southern mixed forest.

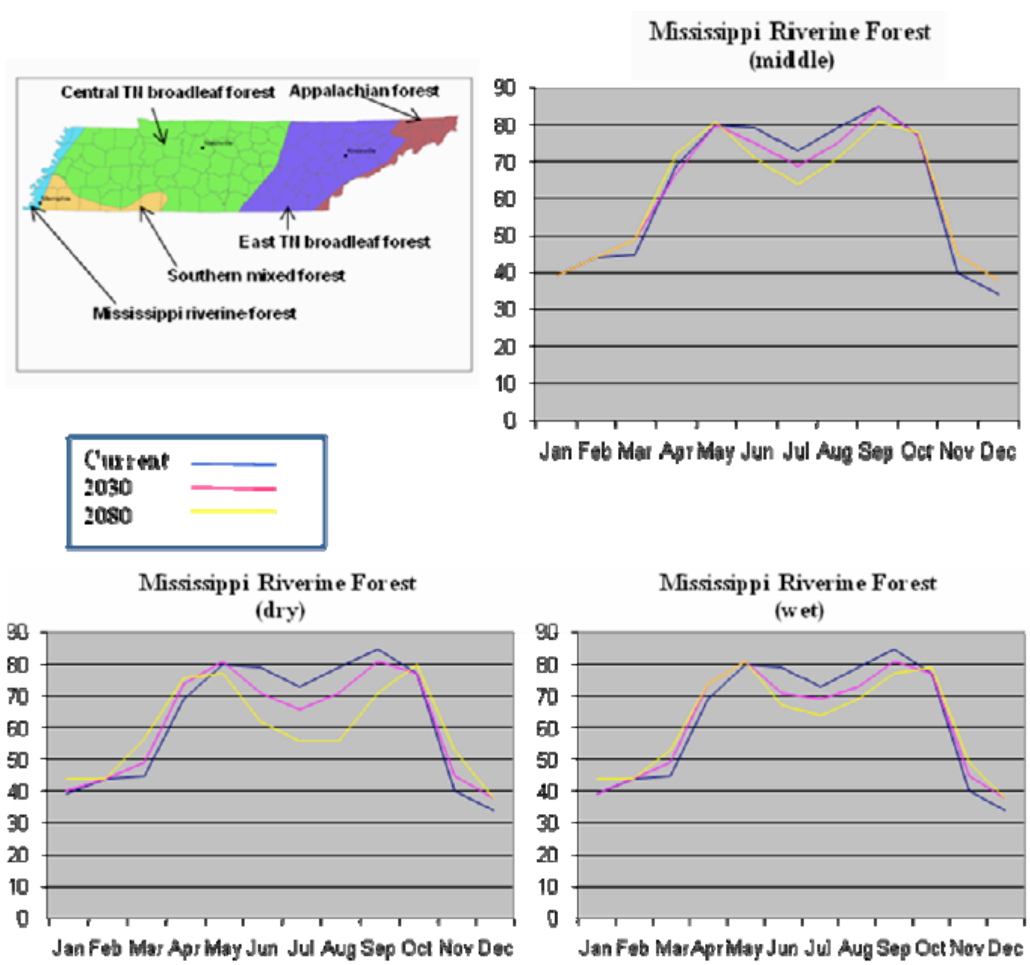


Figure 6. TCI scores for the Mississippi riverine forest.

Using the trends reported by Bowker et al. (1999), future use projections were adjusted by the monthly TCI scores to project how visitation might reflect the changes in climate (both positive and negative) for several recreational sites across Tennessee. As stated previously, the sites were selected based on the availability of average monthly visitation estimates and to provide a representative sample of use across all regions (table 2). The visitation projections for all regions reflect changes in recreational use and associated economic values (as measured by consumer surplus) of less than 10 % (which represents the maximum average deviation in historical annual visitation for the sites examined) for all but one scenario (table 3). The one exception was the "dry" scenario for Cosby. This can be attributed to the fact that the TCI scores for the "dry" scenario equal or exceed the "No Climate Change" scenario for most months, due largely to increased temperatures during the winter months and less precipitation. Such conditions could increase recreational use throughout the Appalachians of Tennessee, which is an extremely important recreational region for the state.

Table 2. Recreational Sites for TCI Assessment

Forest Types	Primary Activities
Appalachian Forest	
Great Smoky Mountains National Park (Cosby)	camping, hiking
East Tennessee Broadleaf Forest	
Norris State Park	boating, general recreational use camping, hiking, horseback riding rock climbing
Big South Fork National River and Recreation Area	
Obed Wild and Scenic River	
Central Tennessee Broadleaf Forest	
Natchez Trace State Park	camping, fishing, horseback riding
Southern Mixed Forest	
Meeman-Shelby Forest State Park	camping, boating, fishing
Mississippi Riverine Forest	
Pickwick Landing State Park	camping, boating, fishing

Total consumer surplus for the Big South Fork National River and Recreation Area, for example, was reduced by 2.1% and 6.1% under the "dry" scenario for 2030 and 2080, respectively. The "wet" scenario for the same area resulted in a slight (< 1%) increase in value for 2030 and a similar decrease by 2080. Two locations, Cosby and Obed, exhibited increased values for both periods and all scenarios. The Cosby site increased primarily because of warmer fall and winter conditions, which would extend the comfortable use season. On the Obed, fall and spring represent the busiest seasons for rock climbing – a period when the TCI scores are greater in future climate scenarios than current scores. The remaining sites exhibit both increases and decreases in consumer surplus, most notably decreases for the "dry" scenario with less precipitation and higher temperatures than current conditions or other scenarios evaluated.

Beyond the direct effects of climate change on recreation, several indirect effects, which are more difficult to assess quantitatively, could impact recreational use. Most notably, the potential decline of species, such as trout and high elevation spruce-fir forests, could have substantial economic impacts on forest-based recreation. More specifically, the trout fishery in the southern Appalachians is a significant component of the regional economy. Increases in stream temperature and the loss of hemlocks as a major component of riparian forests are projected to decrease trout populations throughout the southern Appalachian region (Evans, 2002), which in turn would result in a decline in the fishing economy of the region. Ahn et al. (2000) estimated that the welfare loss per angler is between $5.63 and $53.18 per visit, under future climate scenarios. The economic impact of the loss of the high-elevation spruce-fir forests is more difficult to assess because most visitors visit these areas as part of multi-purpose trips. Visitors to the Great Smoky Mountain National Park, for example, are likely to visit other areas of the park or surrounding natural and human-made attractions. Moreover, no data are available identifying the relative importance of these forests in trip decisions or the values visitors place on such areas. Visitation patterns within the Great Smoky Mountains National Park, however, demonstrate the popularity of the spruce-fir forests, and any changes to this resource could affect recreational uses such as bird watching and backpacking significantly.

4. CONCLUSION

The results of the direct impact evaluation reveal that climate change will have variable effects on recreational activities in Tennessee. The magnitude and direction of the effects vary by the recreational activity involved, patterns of precipitation and temperature regimes, and specific location in Tennessee. Recreational activities such as rock climbing, winter activities independent of snow, and whitewater boating are likely to benefit from increased temperatures in the winter months. Summer-based activities such as lake recreation and camping are likely to decline with increasing seasonal temperatures. These conclusions are based largely on the TCI scores for all regions and climate scenarios, which depict a bimodal distribution of scores, with the lowest scores occurring in the summer. Geographically, recreation in the eastern portion of the state will not experience as much decline in use levels or economic value as the western portion of the state. Some locations may even experience an increase in certain types of recreational pursuits. This difference can be attributed largely to the fact that the higher elevations and recreational pursuits of the east are less affected by heat than recreational activities in the west.

The total consumer surplus for the 7 sites evaluated across Tennessee totaled more than $10.5 million for 2030 and almost $15.0 million for 2080, in the “no climate change” scenario (table 3). The total change in consumer surplus for 2030 was estimated to be 0.01 percent for the “dry” scenario, 0.51 percent for the “middle” scenario, and 0.90 percent for the “wet” scenario. The changes in consumer surplus were considerably different for 2080, where the projected changes were -0.83 percent for the “dry” scenario, -0.81 percent for the “middle” scenario, and 1.26 percent for the “wet” scenario. These differences reflect the effect of the ongoing changes in precipitation and temperature patterns for the 50-year period. By using a recent estimate of the total annual economic impact of outdoor-based tourism in Tennessee as $9.6 billion (Cho et al., 2007), the scenarios could translate into a change in economic activity in the state that ranges from a loss of $80 million for the 2080 “dry” scenario to a net gain of $121 million for the 2080 “wet” scenario. It is important to note that the sites were evaluated by examining the consumer surplus, or net benefit, of the recreation activities. Conversely, the total economic activity estimates from Cho et al. (2007) reflect the direct and indirect impacts of tourism in Tennessee that is based on outdoor activities.

Table 3. Percent Change in Consumer Surplus by Site and Climate Scenario

Forest Type	Dry	Middle	Wet
Appalachian Forest			
Great Smoky Mountains National Park (Cosby)	%Δ	%Δ	%Δ
2030 *($1,271,550)a*	3.22	1.65	4.73
2080 *($1,900,200)*	11.09	2.57	7.59
East Tennessee Broadleaf Forest			
Norris State Park			
2030 *($183,375)*	-1.04	0.18	-0.46
2080 *($242,050)*	-5.70	-1.16	-2.33
Big South Fork National River and Rec. Area			
2030 *($959,275)*	-2.13	-0.98	0.64
2080 *($1,710,600)*	-6.06	-2.67	-0.29
Obed Wild and Scenic River			
2030 *($823,650)*	1.60	1.23	4.12
2080 *($1,294,500)*	4.45	1.67	5.27
Central Tennessee Broadleaf Forest			
Natchez Trace State Park			
2030 *($2,073,660)*	-0.24	0.87	1.25
2080 *($2,879,900)*	-0.35	-0.08	2.14
Mississippi Riverine Forest			
Meeman-Shelby Forest State Park			
2030 *($2,243,750)*	0.06	0.73	0.50
2080 *($3,067,450)*	-1.50	-0.50	0.95
Southern Mixed Forest			
Pickwick Landing State Park			
2030 *($2,911,500)*	-0.94	-0.11	-1.47
2080 *($3,850,250)*	-5.69	-3.26	-2.69
TOTAL CONSUMER SURPLUS			
2030 *($10,466,760)*	0.01	0.51	0.90
2080 ($14,944,950)	-0.83	-0.81	1.26

[a] Figures represent estimated consumer surplus by year with "no" climate change scenario.

The indirect effects of climate change on recreation are likely to have a larger effect than the direct impacts of climatic variables. Changes in the environments where many recreational pursuits occur may limit such activities. The loss of hemlocks in riparian forests due to the hemlock wooly adelgid, coupled with projected increases in water temperature, could have a substantial detrimental effect on streams in the southern Appalachians (Evans, 2002). The result could be a loss of one of the more popular recreational pursuits in the region, trout fishing, with significant economic implications as described by Ahn et al. (2002). In addition to trout populations, climate change will change forest species composition and potentially alter the attractiveness of some areas for recreation. As mentioned previously, the potential loss or reduction of the high-elevation spruce-fir forests in the eastern border of the state could eliminate a unique environment that attracts a significant portion of the visitors to the Great Smoky Mountains and other public lands for a number of recreational activities dependent on or enhanced by forests.

Not all factors were considered in the analysis of recreational impacts. The analysis was confined to considering changes only within the state boundaries. Recreationists may substitute alternative sites for their activities to locations in other states in search of more favorable climatic conditions or environments, in most cases to more northerly environs. While this substitution can occur for some activities, other recreational pursuits are often site-specific and substitutes may not exist. Tennessee offers a wide range of outdoor recreational experiences unique to the state or small regions of bordering states. Rock climbing, whitewater boating, and backpacking opportunities, for example, are available throughout the eastern one-third of the state and in the states and regions bordering Tennessee. Therefore, changes to these sites and unique areas such as high-elevation forests could eliminate recreational opportunities from the region. Moreover, individuals who historically have recreated in areas south of Tennessee are likely to seek opportunities in the state, negating a portion of the lost activities and the accompanying economic value. Another consideration in evaluating climate change impacts that was not addressed is the influence of changes in climate-dependent insects and diseases threatening human health. A number of threats such as Lyme disease, Rocky Mountain spotted fever, encephalitis, and hantavirus are likely to be affected by climate change (NRC, 2001; WHO, 2003) and could discourage recreational activities.

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