Sustainability of Forest Resources

Urbanization

Urbanization is classically defined as migration of rural populations to cities and towns. In the context of forests and forestry, urbanization refers to the spread of urban land uses (residential, commercial or industrial) into forested areas. The fringes of expanding urban areas, where forest and agricultural uses are interacting with increasing urban development, identify the wildland urban interface (WUI). The WUI is a zone of dynamic land use change activity that brings on complex challenges for residents, natural resource professionals and local governments. These challenges include increased risk of damage to buildings and threat of loss of life from wildland fires; introduction of exotic pests through urban ports and urban residence travel into rural communities for outdoor recreation; fragmentation of forested landscapes as new buildings, roads and other infrastructure are constructed in forested areas; increase in unmanaged recreational use; and decreased probability of timber harvesting practices (Nowak et al. 2005).

Oswalt et al. (2009) used the 2001 national land cover database to classify and map Tennessee's landscape based on seven land use categories: interior forest, edge forest, patch forest, agriculture, developed, open water, and other (refer to Oswalt et al. 2009 and Ritters et al. 2002 for details). Interior forests (32.8%) followed by agriculture (30.0%) land use covered the majority of Tennessee's landscape. Developed space is concentrated around major cities and along road corridors, occupying an estimated 8.6 percent (Figure 24).

Nowak et al. (2005) studied urban expansion over multiple decades and discussed its influence. In 1990 Tennessee's urban area, as defined by the 2000 U.S. Census, was estimated to cover 1.2 million acres, occupying 4.4 percent of the landscape (Figure 25). By 2000 urban area expanded to more than 1.5 million acres, occupying 5.8 percent of the landscape. Urban area grew by 360,000 acres, an increase of 1.3 percent urban land cover. The urban area growth during this period displaced an estimated 178,000 acres of forestland, 135,000 acres of agricultural lands and 2,500 acres of other lands (Figure 26). Based on this information, Tennessee ranked as the 19th most urban state in 2000.

Figure 24. Landscape classification of land use in Tennessee according to seven land use categories (2001)

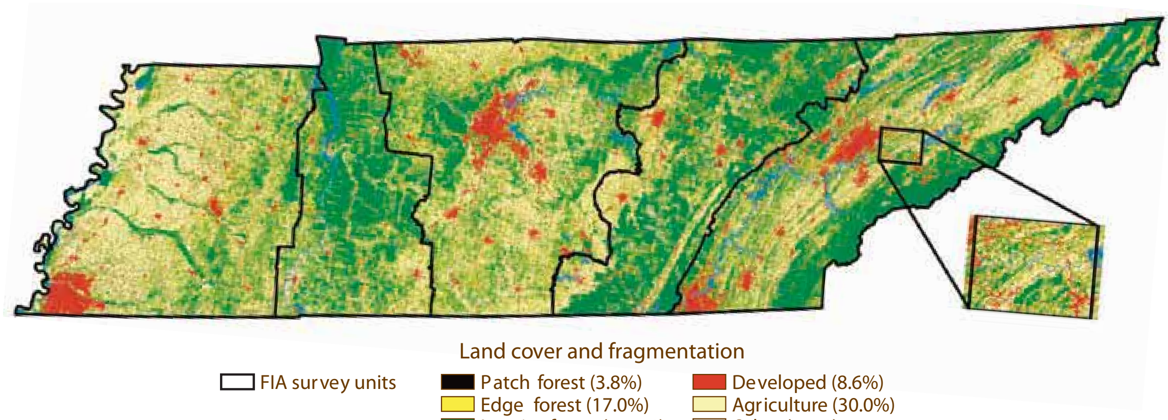


Figure 25. Growth of urban land in Tennessee between 1990 and 2000

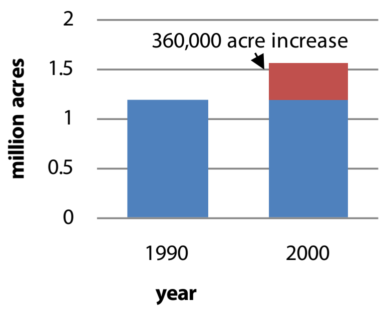
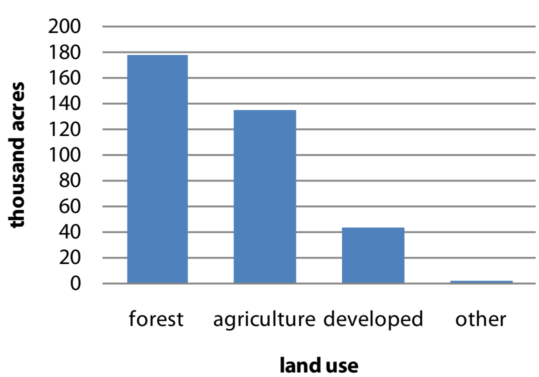


Figure 26. Land uses displaced by urban land growth in Tennessee between 1990 and 2000

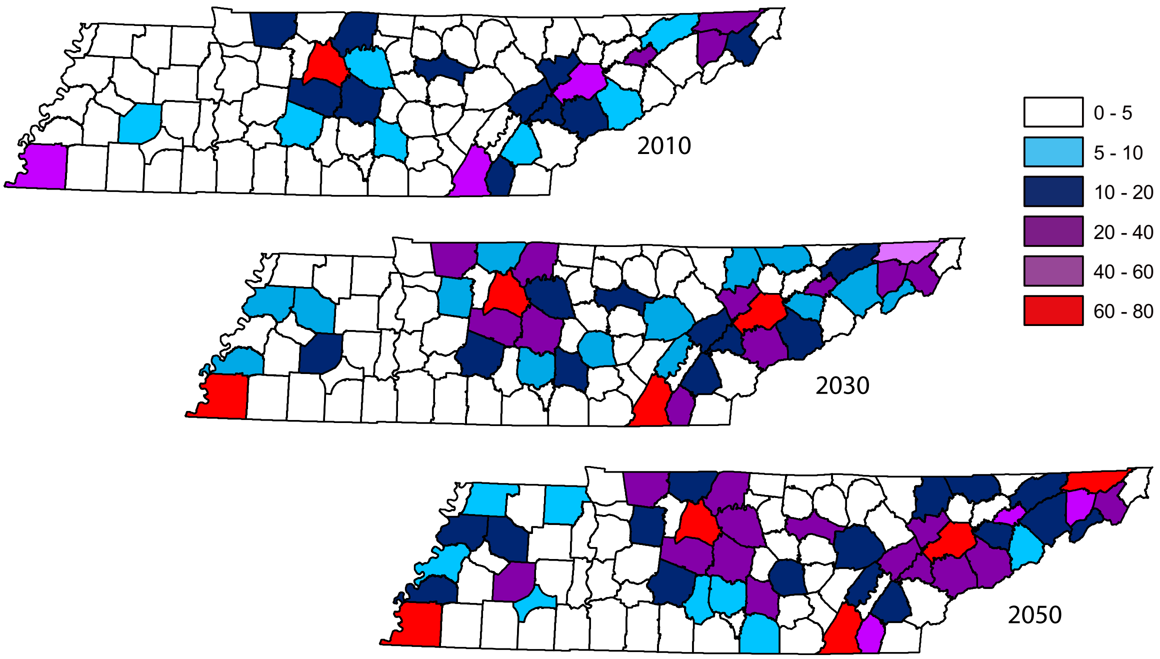


Projected increases in urbanization through 2050 have been estimated using national average growth rates and assuming similar growth trends as experienced in the 1990's (Nowak and Walton 2005). Tennessee specific estimates from this study indicate an additional 1.2 million acres of forestland, representing 7.8 percent of forestland present in 1992, could be urbanized before 2050. This future urban growth is projected to be focused in the central basin adjacent to Nashville and along an eastern corridor between Chattanooga and the Tri-cities area of the state (Figure 27). Assumptions do come to play in making a prediction 50 years into the future but it is hard to envision a scenario that does not reflect an increase in urban land use. Urban expansion, regardless of rate, will replace previous land uses, and it is all but certain that some forestland will be lost.

Even though significant amounts of forestland will be replaced by urban uses, this change does not necessarily mean all the previous forest will disappear. Varying amounts of forests can be retained in urban areas depending on development patterns and natural vegetation (Nowak and Walton 2005). These "urban forests" provide many benefits, including improved air quality, reduction of storm water runoff and erosion, tempering local climate, conservation of energy, increased property values, habitat for plants and animals, improved health of residents, and a stronger sense of community (USDA Forest Service 2003). Knowing how to maintain and manage urban forests for these benefits becomes increasingly important as the urban land base expands and human populations increase.

Agencies, professionals, and businesses that either

Figure 27. Percent of Tennessee projected to be urban for 2010, 2020 and 2030



help manage forests or derive their livelihood from forests will face new and complex challenges with continuing urbanization. Natural resource professionals should become more integrated with local, regional, state, and federal land use planning efforts. Natural resource professionals have a vested interest in developing strategies to slow increasing trends in urbanization, to mitigate the negative impacts of urbanization, and to manage additional urban forest resources resulting from urbanization.

References:

Nowak, D.J.; Walton, J.T.; 2005. Projected Urban Growth (2000-2050) and Its Estimated Impact on the US Forest Resource. Journal of Forestry 103 (9): 383-389.

Nowak, D.J.; Walton, J.T.; Dwyer, J.F.; Kaya, L.G.; Myeong, S. 2005. The Increasing Influence of Urban Environments on US Forest Management. Journal of Forestry 103 (9): 377-382.

Oswalt, C. M.; Oswalt, S. N.; Johnson, T.G.; Chamberlain. J.L; Randolph, K.D.; and Coulston, J.W. 2009. Tennessee's Forests, 2004. Resource. Bull. SRS-144. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 96 p.

Riitters. K.H.; Wickham, J.D.; O'Neill, R.V.; Jones, K.B.; Smith, E. R.; Coulston, J. W.; Wade, T. G. and Smith, J .H. 2002. Fragmentation of Continental United States Forests. Ecosystems (2002) 5: 815-822.

USDA Forest Service. 2003. Benefits of Urban Trees. Forestry Report RS-FR 71. Atlanta, GA: U.S. Department of Agriculture Forest Service, Southern Region. 16p.

SUSTAINABILITY

Forest Parcelization and Fragmentation

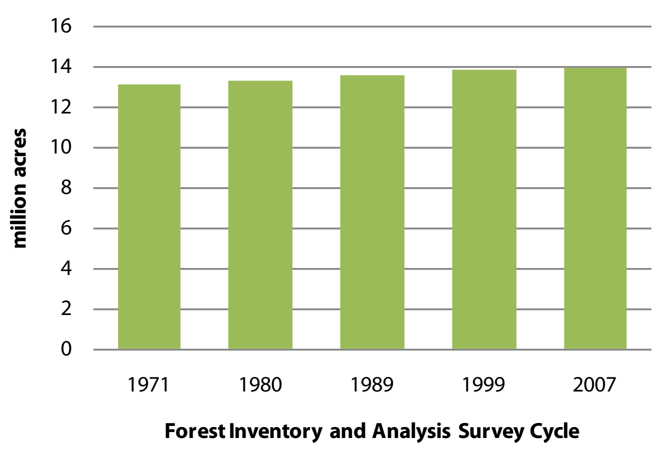
Parcelization and fragmentation have been identified as processes that significantly change the spatial arrangement and condition of forested landscapes. These two terms are not synonymous. In the context of forest land use change, parcelization generally refers to the division of ownerships that result in smaller holdings while fragmentation refers to isolation of forest tracts from one another (Southern Group of State Foresters 2007). How these processes interact to impact forested landscapes is not straight forward. One process is not a prerequisite for the other to occur and each process brings a different set of impacts to the forest. A general relationship does seem to exist between forest parcelization and fragmentation in that a parcelized landscape is at greater risk of fragmentation.

Concern should be raised when parcelization and fragmentation severely compromise the benefits derived from a forested landscape. These benefits include timber products (lumber, furniture, paper, etc.), clean water, recreation opportunities (camping, hiking, hunting, etc.), aesthetics (scenic vistas, colorful fall foliage, etc.) and habitat for plants and animals. A forest's capacity to provide these benefits is significantly altered or completely lost with increased parcelization and fragmentation. Highly parcelized and fragmented forests are more vulnerable to the introduction of exotic and invasive plants, insects and diseases. These areas also pose greater risks for property to be damaged by wildfire if residential and commercial land uses become intermingled with forestland.

Forestland

Current forest inventory data indicates that past forestland acreage increases appear to have plateaued (Oswalt et al. 2004, Miles 2009) (Figure 28). More recent observations indicate that forestland acreage may be declining given the high percentage of new development and land use change. It remains to be seen if a trend toward a net loss in

Figure 28. Total forestland in Tennessee

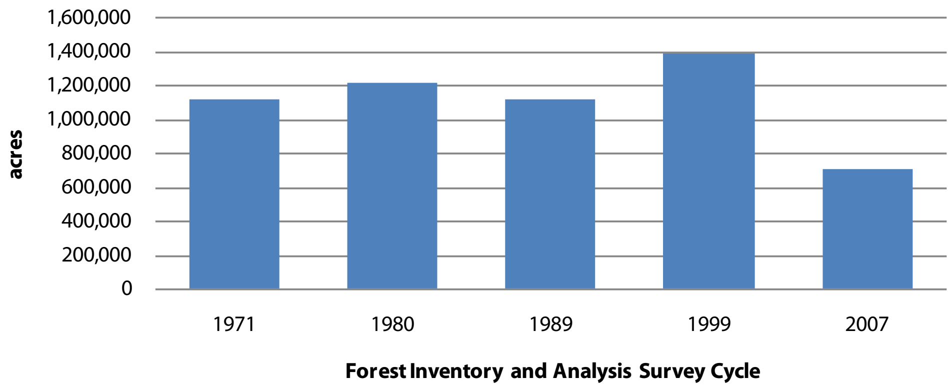


forested acres will occur in the near future. A net loss of forested acres may indicate an accelerating trend in parcelization and fragmentation.

Forest Industry Ownership

Recent changes in Tennessee's forest industry forestland ownership provide a case study of how parcelization and fragmentation can impact a forested landscape. Beginning in the mid 1990s, forest industry initiated large scale liquidation of their timberland holdings. An estimated 681,000 acres of timberland (5% of the 1999 private timberlands) previously owned by forest industry was subdivided and placed under new ownership with portions going to timber investment management companies (TIMOs), private investors, private individuals, and state government (Murphy 1972, Staff 1982, Vissage and Duncan 1990, Schweitzer 2000, Miles 2009) (Figure 29). Some of these acres were converted to non-forest uses; some acres will be maintained as forests for an unknown period of time; and some acres were protected as forests for perpetuity. Change in forestland ownership has continued since the 2007 data was collected. It is anticipated almost all of the 1.4 million acres owned by forest industry in 1999 will be under new ownership in the near future.

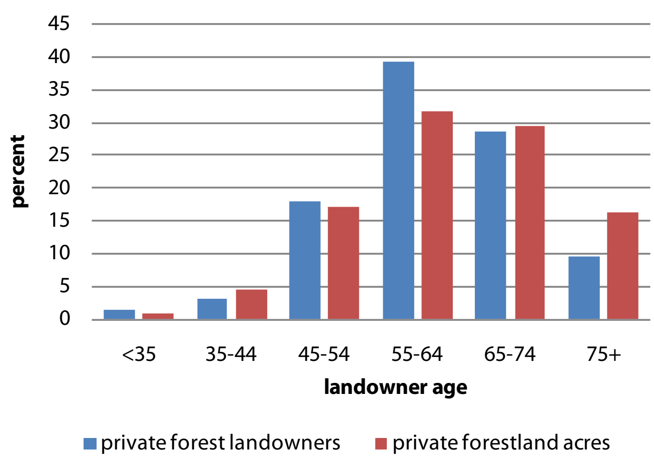
Figure 29. Forest industry ownership in Tennessee



Forest Landowner Age

Tennessee is in the early stages of a "changing of the guard" in forestland ownership. The most recent woodland owners survey (Butler 2008) estimates 45 percent of family owned forestlands are owned by landowners 65 years old or older (Butler 2008) (Figure 30). The fate of these forests is uncertain as ownership is passed to heirs or sold to new landowners. The future management and retention of these forests will depend on how the new generation of landowners value forestland. While the consequences resulting from this change cannot be determined, inevitably some new landowners will further subdivide properties, some will convert to non-forest land uses, and some will do both, potentially yielding a more parcelized and fragmented forest landscape.

Figure 30. Percent of family forest landowners and acreage by landowner age class in Tennessee (2006)



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Average Forested Parcel Size

Tennessee has an estimated 530,000 non-industrial private forest (NIPF) landowners with an average parcel size of just over 18 acres (Butler 2008). Sixty-five percent of the NIPF landowners (344,000) own a total of 960,000 acres (10% of total NIPF acres) in tracts of less than 10 acres of forestland (Figure 31). This information indicates a portion of Tennessee's landscape has already experienced a significant degree of parcelization and fragmentation.

Conversely, an estimated five percent (24, 000) of NIPF landowners own 44 percent of the NIPF acres (4.4 million) in tracts 100 acres or larger in size. While the average forested ownership is relatively small (18 acres), a large portion of Tennessee's NIPF lands are still owned in large tracts by relatively few people.

Interior Forests

Tennessee's Forest Inventory and Analysis (FIA) survey classified the state's landscape into the following land use classifications: interior forest, edge forest, patch forest, agriculture, developed, open water and other (Oswalt et al. 2009). Interior forests are the least impacted by parcelization and fragmentation followed by edge forests and then patch forests. The interior forest land use classification was the most prevalent land use occurring on Tennessee's landscape. (Figure 32).

Further more, interior forests are concentrated in the East, Plateau, and West Central forest inventory and analysis survey units (Figure 33). This concentration is due to the rugged topography, soils less suitable for agriculture, and remoteness from the state's larger urban centers.

Figure 31. Percentage of acres and ownership units by ownership size class for family owned forest in Tennessee (2006)

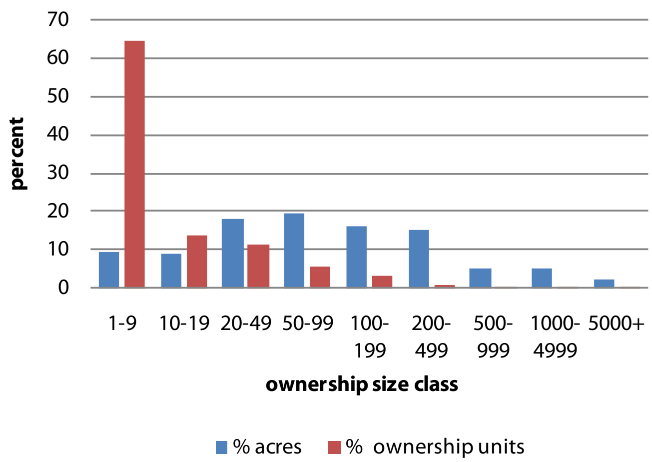

Figure 32. Percentage of Tennessee landscape classified according to seven land use categories (2001)

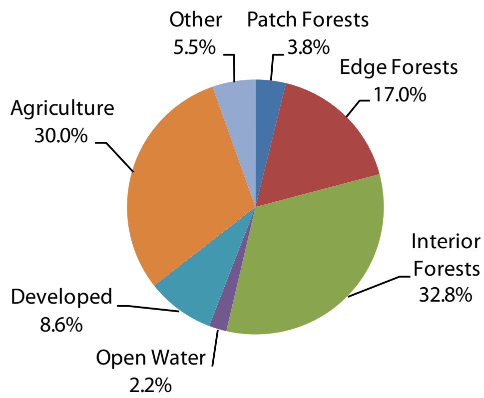

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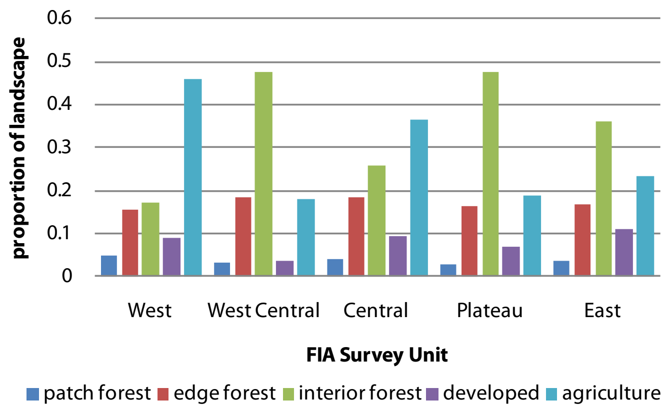
Figure 33. Proportional allocation of land use by FIA survey unit according to five land use categories in Tennessee (2001)



The trend of increasing forestland acres over the last three decades appears to have plateaued, forest industry has liquidated a significant portion of its forestland holdings, and a large percentage of NIPF lands are poised for ownership change as current landowners continue to age. Collectively, these events suggest a period of accelerated parcelization and fragmentation for Tennessee's forests is possible, if not inevitable. Conversely, a large percentage of Tennessee's forests is contained in tracts 100 acres or larger in size and interior forests comprise the most prevalent land use, indicating opportunity still exists to maintain landscapes dominated by intact forests in regions of the state.

Research has identified several factors that drive parcelization and fragmentation (Mehmood and Zhang 2001). Death, taxes and regulatory uncertainty can result in landowners selling forestland; increasing income and urbanization can result in forestlands being bought for residential or commercial development; and financial assistance for landowners can encourage forestland ownership. Understanding these relationships can provide guidance when developing strategies intended to address increasing rates of forest parcelization.

References:

Butler, B.J. 2008. Family Forest owners of the United States, 2006. Gen. Tech. Rep. NRS-27. Newton Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 72 p.

Mehmood, S.R., and Zhang, D. 2001. Forest Parcelization in the United States: A Study of Contributing Factors. Journal of Forestry 99 (4): 30-34.

Miles, P. D. Jul-30-2009. Forest Inventory EVALIDator web-application version 4.01 beta. St. Paul, MN: USDA Forest Service, Northern Research Station [Available only on internet: http://fiatools.fs.fed.us/Evalidator4/tmattribute.jsp].

Murphy, P.A. 1972. Forest Resources of Tennessee. Resource Bull. SO-35. New Orleans, LA: U.S. Department of Agriculture Forest Service, Southern Research Station. 33p.

Oswalt, C. M.; Oswalt, S. N.; Johnson, T.G.; Chamberlain. J.L; Randolph, K.D.; and Coulston, J.W. 2009. Tennessee's Forests, 2004. Resource Bull. SRS-144. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 96 p.

Schweitzer, C.J. 2000. Forest Statistics for Tennessee – 1999. Resource. Bull. SRS-52. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 78 p.

Southern Group of State Foresters – Issue Paper. Forest Parcelization and Fragmentation (or Fractured Forests). June 2007.

Staff of Renewable Resources Evaluation Work Unit. 1982. Forest Statistics for Tennessee. Resource. Bull. SO-89. New Orleans, LA: U.S. Department of Agriculture Forest Service, Southern Research Station. 64p.

Vissage, J.S.; Duncan, K.L.; 1990. Forest Statistics for Tennessee Counties-1989. Resource. Bull. SO-148. New Orleans, LA: U.S. Department of Agriculture Forest Service, Southern Research Station. 72p.

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Bio-energy/Biofuels

Bioenergy use in Tennessee has the potential to be a contributor in reducing the amount of fossil fuel used in the United States each year. Forest industry within the state already uses much of its woody by-products for conversion to energy through use in boilers to produce electricity, provide process steam and to dry lumber. Table 15 summarizes the statewide biomass volumes consumed for various uses (Miles 2009).

Forest biomass can be derived from a number of sources including processing by-products from the manufacture of primary or secondary wood products, logging residue and standing inventory of woody plants (SGSF 2008). Other sources including urban tree trimmings or other waste materials that normally find their way into the landfill may also be available, and are discussed later in this section.

Table 15. Weight of Bark and Wood Residuals in Tennessee (2007)

Source	Species	Fiber by-product	Fuelwood by-product	Misc. by-product	Not used	Total by-products
		thousand dry tons				
Bark	Softwood	0	203	6	1	**210**
	Hardwood	0	188	169	26	**383**
Coarse Wood	Softwood	16	3	6	3	**28**
	Hardwood	595	71	92	80	**838**
Fine Wood	Softwood	0	8	8	1	**17**
	Hardwood	11	340	121	27	**499**
All Residues	Softwood	16	214	20	5	**255**
	Hardwood	606	599	382	133	**1720**
Total		**622**	**813**	**402**	**138**	**1975**

Wood processing facilities within the state produce approximately 2 million dry tons of material on a yearly basis. Most (93%) of this material is being utilized currently in the making of pulp and paper or being burned for boiler fuel.

Biomass from yearly logging residue is estimated to be 1.85 million dry tons of material on a yearly basis (Miles 2009). This is unused material that is being left behind on the logging site (Table 16).

The largest volume of biomass is contained in the standing inventory on timberland. The portion of this standing inventory that would not be utilized for other forest products (eg. lumber, panel products, pulp, etc.) represents a potential inventory available for bio-energy/biofuel needs. Table 17 utilizes Tennessee's most current FIA data (Miles 2009) to estimate potential bio-energy/biofuel inventory by subtracting the merchantable biomass available (sawlogs and pulpwood primarily) from the total biomass. The volume of biomass contained in the stump is also subtracted from the total because of the very high cost to capture the stump volume currently. The approximate inventory is 146 million dry tons (or 11 tons per acre) on the 13.45 million acres of timberland in the state. This information suggests there is sufficient biomass available for new bioenergy facilities across the state. This could also mean there would be some increased cost and adjustments in supply for the existing wood by-product and chip using facilities in some parts of the state.

Urban Waste

It is unknown how much urban wood waste is generated in Tennessee cities and towns that is trucked to landfills. Unsubstantiated reports indicate that up to 50 percent of a city's landfill may be wood waste, so it is projected that a significant resource is being lost. Some urban wood is used for firewood for supplemental home heating, but the amount used is also unknown.

Wood from suburban areas is similar to urban areas in that tree services generate wood waste, while some wood is also burned for firewood. The amount of this resource is also unknown. Suburban areas may also contain remnant forests or small acreage woodlots that do not generate traditional forest products, so logging residues and forest management improvements are typically not measured as part of the overall resource for energy use and savings.

References:

Miles, P. D. Jul-30-2009. Forest Inventory EVALIDator web-application version 4.01 beta. St. Paul, MN: USDA Forest Service, Northern Research Station [Available only on internet: http://fiatools.fs.fed.us/Evalidator4/tmattribute.jsp].

Southern Group of State Foresters (SGSF). 2008. Recommended Methodology for Assessing Forestry Biomass for Bio-energy Utilization. Services, Utilization, and marketing Task Force (prepared by Nathan McClure). http://www.southernforests.org/publications/Methodology%20for%20Assessing%20Forest%20Biomass.pdf/view.

Table 16. Annual Logging Residue in Tennessee (1995 to 2007)

	Growing Stock	Nongrowing Stock - Stump	GS Conv glbs/cf	NGS Conv glbs/cf	Growing Stock	Nongrowing Stock - Stump	Total
	Million Cubic Feet				Oven Dry Tons*		
Softwood	7.3	14.0	69	69	125,925	241,500	**367,425**
Hardwood	29.5	49.5	72	77	531,000	952,875	**1,483,875**
Total	**36.8**	**63.5**			**656,925**	**1,194,375**	**1,851,300**

**Oven Dry Tons = green lbs/4000 lbs*

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Table 17. Potential energy biomass (ODTons) from timberland in Tennessee (2007)

		Species group - Major Group				
Current d.b.h.	**Total**	**Pines**	**Other softwds**	**Soft hardwds**	**Hard hardwds**	**Other hardwds**
	oven dry tons					
1.0-2.9	19,539,080	1,010,306	884,913	8,230,527	9,411,002	2,331
3.0-4.9	34,521,687	2,475,390	2,049,375	12,691,118	17,297,900	7,903
5.0-6.9	14,288,017	1,249,924	980,019	4,321,557	7,735,663	856
7.0-8.9	13,947,594	1,201,022	771,268	3,741,367	8,232,530	1,406
9.0-10.9	14,849,086	1,023,776	588,703	3,461,966	9,774,641	0
11.0-12.9	16,806,688	1,029,066	414,910	3,768,581	11,594,131	0
13.0-14.9	16,881,647	938,890	296,441	3,508,178	12,138,137	0
15.0-16.9	15,108,241	571,371	179,182	2,945,369	11,412,317	0
17.0-18.9	11,564,655	344,315	142,257	2,484,134	8,593,948	0
19.0-20.9	9,073,690	237,447	152,734	1,918,122	6,757,561	7,826
21.0-22.9	7,393,387	177,017	147,567	1,486,612	5,582,192	0
23.0-24.9	4,613,258	77,553	221,506	817,022	3,497,177	0
25.0-26.9	2,771,477	32,729	104,703	519,047	2,114,997	0
27.0-28.9	1,404,077	74,908	69,781	114,885	1,144,503	0
29.0-30.9	1,829,436	65,357	143,465	261,668	1,358,947	0
31.0-32.9	786,550	19,859	24,014	186,757	555,919	0
33.0-34.9	744,085	36,088	40,137	184,643	483,216	0
35.0-36.9	262,496	0	0	42,386	220,109	0
37.0-38.9	279,193	0	0	0	279,193	0
39.0-40.9	140,507	0	0	140,507	0	0
41.0+	140,778	0	0	0	140,778	0
Total	**186,945,622**	**10,565,018**	**7,210,975**	**50,824,446**	**118,324,861**	**20,322**
Total-Stump	**146,350,865**	**8,557,665**	**5,840,890**	**39,643,068**	**92,293,392**	**15,851**
Acres	13,450,284					
oven dry Tons/ Acre	10.88					

Forest Certification

In Tennessee, forest interests are becoming increasingly involved in forest certification. Forest certification means that forests are managed in a sustainable manner and that trees are harvested with environmentally sound practices. These management practices are certified by objective third parties. Wood that originates from certified forests is labeled and merchandised separately. Landowner participation is voluntary.

During the 1990s, many of the larger forest products companies with facilities in the state initiated and completed third-party certification. The Tennessee Department of Agriculture Division of Forestry completed the process of certifying all 158,000 acres of state forests in 2002. State Forests now contain 166,679 acres. Many of the major retail outlets of wood and paper manufacturers have announced policies that recognize and give preference to certified wood products. These policies are in turn changing the wood procurement policies of the solidwood and pulpwood processing facilities in Tennessee to ensure that their products can be certified. As a result of these concerns, some stakeholders are beginning to debate the necessity of implementing forest certification on family forests.

Family forests are particularly important in Tennessee, where they comprise 83 percent of the state's forest land. Moreover, these forests contribute 80 percent of the State's annual hardwood removal volume (Bentley and Schnabel 2007). These forests are also vital for the protection of soil, water, and wildlife resources and for the production of non-timber goods and services. In time, market forces could require large-scale certification, and the needs and preferences of family forest owners in Tennessee must be considered to ensure their participation.

Not all family forest owners will certify their forest land, but in a study of West Tennessee landowners, a vast majority (81 percent) indicated they would at least consider it (Mercker 2006). Five sociodemographic variables were identified as significantly related to landowner's willingness to certify, including landowners that: 1) were well educated 2) were new at land ownership, 3) were professionals, 4) have received forestry advice or information, and 5) desired to stay up to date with new forestry practices and programs.

Forest certification may continue to gain in popularity and become the primary way of doing business for the wood products industry. This ownership class is vital to a strong and sustained wood products industry. Currently only a small percentage of the total privately owned forest acreage is certified. More is needed to assure a competitive industry.

References:

Bentley, J.W., and D. Schnabel. 2007. Tennessee's timber industry – an assessment of the timber product output and use, 2005. USDA Forest Service, Resource Bulletin SRS-126

Mercker, D. 2006. Forest Certification and Nonindustrial Private Forest Landowners: assessing awareness, acceptance, and educational preferences. The University of Tennessee.

SUSTAINABILITY

Forest Health

Since at least the early 1990's, forest health has been a term used to describe the relative condition of forests and forested landscapes, particularly in regard to the presence of insects, diseases, and other biological agents that may affect forested ecosystems. Abiotic influences such as drought, heat and cold damage, mechanical damage, air pollution, etc. are also factors that can greatly influence forest health.

The term "forest health" is a nebulous term for many, however, there are certain concepts that must be considered in any definition of forest health:

- The forest as a whole must be considered, not just individual trees
- The forest can be a natural forest or a plantation (excluding Christmas trees, nursery plantations, etc.)
- The presence of native insects or diseases may or may not denote a healthy forest, depending upon their extent and effect upon the forestland
- The presence of non-native insects, diseases, or plants may or may not denote a healthy forest, depending upon their extent and effect upon the forestland
- Human needs are as important as ecological needs

In the publication *Forest Health in the United States*, R. Neil Sampson and Lester A. DeCoster define forest health as "a condition of forest ecosystems that sustains their complexity while providing for human needs." A similar definition for a healthy forest as given in Tennessee's Rapid Forest Health Assessment Program may be: "the ability of the forest to sustain itself ecologically and provide what society wants and needs" (TDF 2009).

Tennessee's physiological conditions and location in the southern U.S. determines forest types and land uses within the state. It also helps determine patterns of commerce from outside the state which may provide potential pathways for pests. With increasing populations and economic activity Tennessee has become a literal crossroads of these potential pathways. Highways and waterways are potential pathways for pest introduction and are cause for concern for several pests currently found in other regions of the continent, many of which are exotic pests. This includes gypsy moth, emerald ash borer* and Asian longhorned beetle from the north; southern pine beetle from the south; hemlock woolly adelgid from the east; and thousand cankers disease* from the west.

* At the time of printing, emerald ash borer and thousand cankers disease were discovered in east Tennessee for the first time. State response plans were being implemented for each pest.

Impacts of pests on forest health in Tennessee

The impact of pests on Tennessee's forestland can vary greatly from year to year. For example, the southern pine beetle outbreak from 1999 to 2004 was greater in intensity than anytime before in recorded history. It drastically reduced pine acreage in East and Middle Tennessee. Since then southern pine beetle populations have been very low across the state with very little pine mortality (Oswalt et al. 2009).

Other pest examples where there has been state or region-wide impact include eastern tent caterpillar, jumping oak gall, periodical cicadas and beavers. Pests that have a history of more local impact include red oak borer, variable oak leaf caterpillar, cankerworms, oak wilt, and deer. Secondary pests such as hypoxylon canker which invade weakened trees take a heavy toll as well.

On the other hand some non-native pests have had and will continue to have devastating impacts on Tennessee's forest. The chestnut blight and Dutch elm disease are classic cases in point. Currently the hemlock woolly adelgid is significantly reducing the hemlock resource in the state, which could greatly impact cold water ecosystems. Butternut canker has caused butternut to be put on the Federal "species of concern" list and is currently state listed as "threatened" in Tennessee. Dogwood anthracnose has devastated flowering dogwood in many Eastern and Middle Tennessee counties. Tennessee has experienced several significant gypsy moth infestations in East and Middle Tennessee amounting to, in some cases, thousands of acres being sprayed at costs of hundreds of thousands of dollars.

Future non-native pests that may have devastating impacts on the state's forests include emerald ash borer[*], cogongrass, sudden oak death, beech bark disease, laurel wilt, Sirex woodwasp, and pine shoot beetle. Undoubtedly other pests yet detected or described in the U.S. are possible.

Invasive pest plants should be viewed differently as a threat than non-native insects and diseases because of the different ecological interactions with the forested environment. Whereas non-native forest insects and diseases impact forests by killing their host, non-native invasive pest plants tend to displace native plants, reducing ecosystem diversity within a given area. This problem is most acute in the Wildland Urban Interface and Urban areas.

Native/non-native forest pests

Native forest pests can negatively and even severely affect Tennessee's forests, but non-native pests pose the greater threat to the sustainability of Tennessee's forests.

Native pests have evolved with the forest and generally are accompanied by a group of predators, diseases, parasites, parasitoids, and other agents to control populations, keeping ecological impacts minimal. In addition, many host plants have developed resistance to the negative impacts of a pest. When a native pest such as southern pine beetle, red oak borer, or hypoxylon canker presents a problem, environmental or host conditions usually provide the explanations for the outbreak. Extreme drought, warm winters, stressed hosts with low vigor, low productive sites, etc. generally provide the reasons behind the problem.

Non-native pests generally are introduced into this country (and state) with no accompanying control agents. Native trees and other vegetation become hosts of these pests and have little or no resistance and generally succumb, resulting in reduced or even extinct populations of what may have been a rather common species. If the hosts are stressed, decline and mortality can become accelerated. There is a ripple effect to the natural environment with the introduction of non-native pests. For instance, hemlock mortality due to hemlock woolly adelgid is expected to impact the cold water ecosystem.

[*] At the time of printing, emerald ash borer was discovered in east Tennessee for the first time. A State response plan was being implemented for this pest.

Detection/Monitoring

Current and future non-native forest pests pose serious threats to Tennessee's forests. No one agency can handle the demands of planning, funding, detection, delimiting, eradication, suppression, or other management activities to eliminate or slow their spread. Public and landowner education, state and federal regulations and/or quarantines, research, and other measures are important initiatives to fend off these threats and help to maintain the integrity of forest heath.

Tennessee has a list of native and non-native forest pests that are of current concern to professional resource managers. Forest Inventory Analysis (FIA) personnel are trained to identify the damage they create and enter such information into the FIA database (Table 18). The list is by no means complete. However it does indicate the diversity of the kinds of pests one may expect to encounter, now or in the future.

There are several state and federal agencies that conduct surveys for certain forest pests, including the Tennessee Department of Agriculture's Division of Forestry and Division of Regulatory Services, the USDA Forest Service and the USDA Animal and Plant Health Inspection Service. Many state and federal land management agencies also cooperate in conducting surveys including the Tennessee Department of Environment and Conservation, Tennessee Wildlife Resources Agency, National Park Service, the Corps of Engineers, the Department of Defense, Tennessee Valley Authority, and others. Most comprehensive surveys are for non-native forest pests and recently have included the gypsy moth, emerald ash borer, exotic bark beetles, sudden oak death, hemlock woolly adelgid, Sirex woodwasp, and others.

Table 18. List of forest insect and disease damages to be tracked by Forest Inventory Analysis surveys.

Common Name	Scientific Name
Southern pine beetle	*Dentroctonus frontalis*
Tent caterpillars	*Malacosoma, spp.*
Cicadas	*Cicadidae*
Red oak borer	*Enaphalodes rufulus*
Armillaria root disease	*Armillaria spp.*
Annosus root disease	*Heterobasidion annosum*
Hypoxylon canker of oak	*Hypoxylon atropunctatum*
Fusiform rust	*Cronatium quercumm*
Oak wilt	*Ceratocystis fagacearum*
Oak decline	*NA*
Other declines	*NA*
Gypsy moth	*Lymantria dispar*
Hemlock woolly adelgid	*Adelges tsuga*
Emerald ash borer	*Agrilus planipennis*
Sudden oak death	*Phytophthora ramorum*
Beech bark disease	*Nectria coccinea*

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Non-native Invasive Plants

Non-native plants are those living outside their normal range. When non-native plants begin to displace native vegetation they are termed non-native invasive. Not all non-native plants are invasive.

Introduction of non-native invasive plants into Tennessee has occurred since the state's inception. In some cases, the introduction has been intentional through plantings. Other introductions have been accidental, such as a by-product of commerce. Distribution occurs via wildlife, wind and water, and from vehicular transport. The invasion of non-native plants mostly goes unmonitored in Tennessee, with gradual spread into forests, often accelerated along forest edges, forest openings, and in areas where soils are disturbed.

Intentional and natural spread of exotic plant species is also a statewide concern. As an example, Tree of Heaven is considered a serious threat to native vegetation (TEPPC 2004). Twenty-three counties are known to support stands of Tree of Heaven in middle and east Tennessee (USDA 2009). Also, the use of exotic cool season grasses as cover to re-seed logging roads and decks is concerning.

Oak decline

Oak decline is discussed in this chapter separately as a forest health issue because:

- It is caused by a combination of factors, including abiotic stresses, insects, and/or diseases
- It is currently the most pervasive problem we have with our forests in the state

Nationwide, oak decline for red oak species was the second-highest contributor to the 2006 National Insect and Disease Risk Map and encompasses a large portion of the central and eastern United States (USDA 2007). While southern states including Arkansas, West Virginia, Missouri, and North Carolina contain large portions of their states with the potential to lose significant numbers of red oaks to decline, at least two sections of Tennessee, the Western Highland Rim and the Cumberland Plateau, have the highest risk for oak decline, though all other portions of the state support an oak resource at risk from oak decline.

The US Forest Service identifies many plants that in various magnitudes are invasive to Tennessee forests. Table 19 summarizes the list, which is divided into non-native invasive plant problems and emerging concerns. A coherent, multi-disciplined strategy on how to address the problems associated with non-native invasive plants is needed and should be developed.

Table 19. Non-native Invasive Plants (NIP) of Tennessee

Non-native Invasive Plant Threat	Plant Type	Common Name
Problem	Trees	Tree-of-Heaven, mimosa, princesstree
	Shrubs	bush honeysuckle, privet, non-native roses, sacred bamboo
	Vines	climbing yams, Japanese honeysuckle, kudzu
	Forbes	Lespedeza
	Grasses	tall fescue, Nepalese browntop
Emerging	Trees	Chinaberry, tallowtree
	Shrubs	autumn olive, barberry, Spirea, burningbush, Nandina, Japanese knotweed
	Vines	Oriental bittersweet, English ivy, periwinkle, non-native wisteria, crown vetch, winter creeper
	Forbs	garlic mustard, thistles, purple loosestrife
	Grasses	Johnsongrass, congongrass

Future forest health challenges in Tennessee

Sound silvicultural practices, such as appropriate harvesting, help keep forest stands vigorous and at relative low risk from native and a few non-native pests. Also, biological control efforts, regulations, quarantines, and pesticides offer alternatives in minimizing damages to Tennessee's forests. Several federal grants, cost-share programs, and educational activities are being used to inform citizens of the challenges and threats to Tennessee's forests. As of this writing, more new and foreign insects and diseases are threatening our nation's forests, many of which will eventually threaten Tennessee's forests. Transferring technology, enforcing laws, leveraging partnerships, and educating our citizens, among other activities, will be critical to ensure that the functions and benefits of Tennessee's forested landscapes will remain important contributors to Tennessee's well being.

References:

Oswalt, C.M., S.N. Oswalt, T.G. Johnson, J.L. Chamberlain, K.C. Randolph, and J.W. Coulston. 2009. Tennessee's forests, 2004. USDA Forest Service, Resource Bulletin SRS-144. Asheville, NC: USDA Forest Service, Southern Research Station. 96 p.

Sampson, R. N. and L.A. DeCoster. 1998 *Forest Health in the United States*. American Forests,Washington, DC.

Tennessee Department of Agriculture Division of Forestry (TDF). 2009. Rapid Forest Health Assessment Program [dataset].

Tennessee Exotic Pest Plant Council (TEPPC). 2004. Invasive Exotic Pest Plants in Tennessee. http://www.tneppc.org/TNEPPC2004PlantList-8x11.pdf

United States Department of Agriculture (USDA). 2009. PLANTS Database. Natural Resource Conservation Service. http://plants.usda.gov/java/county?state_name=Tennessee&statefips=47

United States Department of Agriculture (USDA) Forest Service. 2007. Forest Health Technology Enterprise Team (FHTET). Mapping risks from forest insects and diseases.

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Wildfire and Fire Suppression

Wildfire History

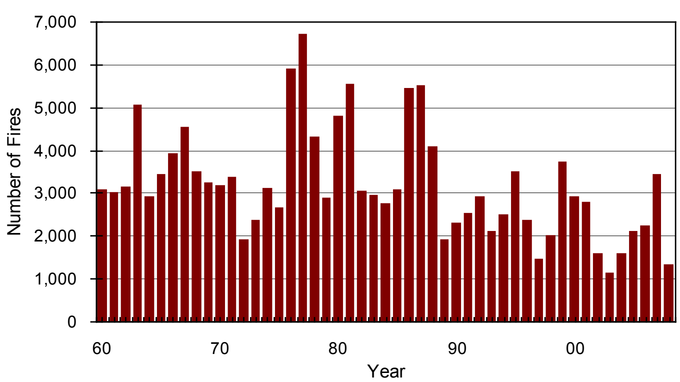
Fire has always been part of Tennessee's landscape. As demographics and societal standards changed, the losses to uncontrolled fire became unacceptable.

An average of 2,500 wildfires occur annually in Tennessee that burn approximately 30,000 acres (Figure 34). The primary causes of these wildfires are burning of debris that escapes control, and woods arsonists who intentionally ignite wildfires. There is a small percentage of wildfires resulting from assorted causes such as power lines, smoking, electric fences, fireworks, lightning and campfires (TDF 2009).

Wildfire Suppression and Prevention

Available wildfire suppression resources can quickly be overwhelmed by numbers and size of wildfires. This fact underscores the importance of cooperation among partners. Each of these partners have resources which can be added to fire suppression efforts. The major partners involved in wildfire collaboration are the Tennessee Department of Agriculture Division of Forestry (TDF), United State Department of Agriculture Forest Service including the Cherokee National Forest, National Park Service Great Smoky Mountains Park, Tennessee Emergency Management Agency, Tennessee Department of Environment and Conservation (TDEC) Division of Parks, TDEC Division of Water Pollution Control, TDEC Division of Air Pollution Control, Tennessee Wildlife Resources Agency, various other state and federal agencies, Volunteer Fire Departments, various communities, county mayors, and other local officials. These cooperative efforts have resulted in more efficient use of resources for fire suppression, wildfire prevention and public education.

Figure 34. Annual number of wildfires in Tennessee



The precarious balance of fire fighting resources with the occurrence of wildfires also highlights the important role of fire prevention to keep the numbers of wildfire starts to a minimum. TDF regulates outdoor burning during the traditional "fire season" months from October 15 to May 15. This process, along with aggressive enforcement of wildfire laws by the Tennessee Department of Agriculture, Agricultural Crime Unit (ACU), have proven to be valuable in limiting the numbers of wildfires during times of high danger. The burning permit program addresses the debris burner while the ACU addresses the arsonist (TDF 2009).

Wildfire Impact on Forests

The forest resources impacted by wildfire are generally considered to be the forest products of wood and fiber, forest flora and fauna. Wildfire is often a destructive force upon each of these resources. In its worst case wildfire clears a forest to ashes and heats the soil to sterilization. This situation occurs during dry and windy conditions when forests become volatile fuels. These fires quite often result in forest stand replacement where the former forest conditions are destroyed and eventually replaced. The replacement of vegetation, soil organisms, insects and animals may take years. In most situations only a portion of a particular wildfire will reach this level of intensity.

Fortunately the majority of Tennessee's wildfires are of low to moderate intensity. While the non-timber resources (animals, soil, water, etc.) are able to recover quickly, the trees are often damaged by scarring. The loss of timber value to scarring may not be recognized immediately but the eventual decay reduces the commercial value of the trees dramatically.

Since wildfire is part of the history of Tennessee's environment, there are ecosystems and species that are adapted to fire, and some that are dependent on fire for their existence. Controlled burning, also called prescribed fire, is being used to maintain these species and for various other land management benefits. Each year in Tennessee approximately 45,000 acres are burned for land management. The land on which controlled burning is conducted includes federal, state and private ownerships (TDF 2009).

Wildland-Urban Interface

An emerging issue is the recent trend of building residences in or near the edge of the forest or other undeveloped land. This condition is referred to as the Wildland-Urban Interface (WUI). WUI has become problematic throughout the nation as more people choose to live in rural locations. This situation puts these residences in close proximity to wildfires in areas where the local community may lack the fire protection capability needed to fully protect all homes (Figure 35). This in turn leads to losses of these residences when wildfires occur and these structures become fuels to spread wildfire.

Issues related to fire and the WUI trend include:

- public pressure to reduce debris burning in suburban and rural settings
- increasing values of residences and other improvements resulting in higher expectations for fire protection services
- increasing need to include FIREWISE principles in the planning and development phase of communities

Figure 35. Structures in the WUI threatened by fire in March, 2009

- better collaboration among groups and agencies to resolve issues of common concern
- growing need for fire prevention education of citizens
- continuous monitoring of fire ordinances and laws for effectiveness
- pressure from interest groups to expand or restrict the use of controlled burning, and
- a shift of cause of wildfire percentage numbers to arson as the number of debris burning caused fires declines.

The response to this trend of high value property being interspersed in the wildland is to educate homeowners on how to reduce their risk to wildfire. Communities are being led by wildfire officials to develop Community Wildfire Protection Plans (CWPP). CWPPs provide an analysis of the community's WUI wildfire issues. It then enumerates steps to mitigate these issues.

An integral part of the CWPP is to incorporate the principles of FIREWISE. FIREWISE is a program that educates homeowners in simple and practical ways they can reduce their risk to wildfire (Figure 36). Tennessee currently has six nationally recognized FIREWISE communities. These communities are Cumberland Cove, Cumberland Lakes, Bluff Mountain, Sprucy Ridge, Norris Shores and FenceRail Gap (TDF 2009) (Figure 37).

Using the tools available, and in concert with cooperators, TDF places emphasis on wildfire prevention, wildland fire fighter training, fitness and personal protection equipment, and assisting WUI communities to reduce wildfire risks.

References:

Tennessee Department of Agriculture Division of Forestry (TDF). 2009. Wildland Fire Protection Program [dataset].

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Figure 37. Community group organizing to address wildfire risk to their homes

Figure 36. Community residents participating in wildfire fuel reduction near their homes

Climate Change

There is increasing concern that climate change will adversely impact people and the ecosystems on which they depend (The National Academies 2008). Future effects of climate change are estimated by computer modeling. Today's climate models simulate the interactions of the atmosphere, oceans, land, and sea ice, with different models producing different results. Results from global climate modeling conducted over the last two decades indicate the average global surface temperature is increasing or warming (Hansen and Lebedeff 1987; Vinnikov et al. 1990; Hansen et al. 1999; Jones and Moberg 2003; Brohan 2006; Lugina 2006). Observations of natural phenomena supporting an increasing average global temperature such as melting sea ice (NSIDC 2009, NASA 2009), melting land ice (Steffen et al. 2004), longer growing seasons (Menzel and Fabian 1999, Compton et al. 2004) earlier leafout (Chmielewski and Roter 2001, Wolfe et al. 2005), earlier flowering (Cayan et al. 2001), changes in plant distributions (Kelly and Goulden 2008), animal distributions (Allison et al. 2005) and phenology of life history events in animals (Bradley et al. 1999, Inouye et al. 2000, Gibbs and Breisch 2001, Both et al. 2004) have also been observed.

Regardless of the models used, the climate of the southeastern U.S. and Tennessee is expected to change and impacts to forests and forested habitats may occur for decades and centuries to come. The cumulative impacts of a changing climate in concert with other sources of stress could produce significant impacts to Tennessee's incredible diversity of forests, forested habitats and wildlife (TWRA 2009).

Climate Trends in the Southeastern U.S. and Tennessee

Several climate models predict varied outcomes for the southeastern U.S. (NAST 2000). These models are in agreement that the Southeast's, including Tennessee's, climate will warm over the remainder of the 21st century, although the degree of warming varies and depending on the model, precipitation may increase or decrease (TWRA 2009).

Potential Effects of Climate Change on Tennessee Forests

In general, tree species are predicted to move northward in latitude and upward in elevation (Woodall et al. 2009) due to increased warming. Tree species less suited to their environment will begin to decline and eventually die, sometimes in large numbers. There will likely be disassembly of existing forest communities with eventual reassembly into new communities (Hobbs et al. 2006). An important challenge will be whether, by forest management, we can help forest systems adapt to new environmental conditions caused by climate change, without having had experience managing these new forming ecosystems (Malmsheimer et al. 2008).

The Tennessee Wildlife Resources Agency (TWRA) released a report in 2009, "Climate Change and Potential Impacts to Wildlife in Tennessee, An Update to Tennessee's State Wildlife Action Plan." (see full report at www.tnwildlife.org/wildlife.html). All six Tennessee terrestrial ecoregions described in the TWRA report are predicted to exhibit significant decreases in forest biomass primarily through tree decline and mortality, which will bottom out by the year 2100. At this time, for most scenarios, forest biomass is predicted to increase until around the year 2200, when it will approach year 2000 levels and begin to level off (Hodges et al. 2008 forthcoming). The following is a summary of projected forest cover type changes in the six ecoregions described in the TWRA report:

Mississippi Alluvial Valley

Compared to the current forest composition, future climate models predict a significant decrease in the dominant elm-ash-cottonwood forest type, with a significant increase in the oak-hickory forest type through the year 2100 (Iverson et al. 2008, TWRA 2009).

Upper Gulf Coastal Plain

Compared to the current forest composition, future climate models predict a small increase in the dominant oak-hickory forest type as well as in the less common oak-pine type, with a small decline in the elm-ash-cottonwood forest type, through the year 2100 (Iverson et al. 2008, TWRA 2009).

Interior Low Plateau

Compared to the current forest composition, future climate models using high carbon emissions predict a significant increase in the dominant oak-hickory forest type, no change in the less common oak-pine forest type, and the disappearance of the elm-ash-cottonwood and loblolly-shortleaf pine types, through the year 2100 (Iverson et al. 2008, TWRA 2009). Future climate models using low carbon emissions predict a significant decrease in the dominant oak-hickory forest type, a significant increase in the oak-pine type, and the disappearance of the elm-ash-cottonwood and loblolly-shortleaf pine types, through the year 2100 (Iverson et al. 2008, TWRA 2009).

Cumberland Plateau and Mountains

Compared to the current forest composition, future climate models predict significant decreases in the dominant oak-hickory forest type and significant increases in the oak-pine forest type through the year 2100 (Iverson et al. 2008, TWRA 2009).

Ridge and Valley

Compared to the current forest composition, future climate models predict very significant decreases in the dominant oak-hickory forest type and very significant increases in the oak-pine forest type through the year 2100 (Iverson et al. 2008, TWRA 2009).

Southern Blue Ridge

Compared to the current forest composition, future climate models predict significant decreases in the dominant oak-hickory forest type, very significant increases in the oak-pine forest type, and the disappearance of the maple-beech-birch forest type, through the year 2100 (Iverson et al. 2008, TWRA 2009). Future climate models also predict the disappearance of the red spruce-Fraser fir forest type (Iverson and Prasad 2001).

Effect of Climate Change on Wildlife Habitat

The changes in forest types and forest biomass described above will manifest themselves through die-off of less adaptable tree species in the forest canopy, followed by increases in forest biomass as dead trees are replaced by other trees and vegetation. It is difficult to predict how this will impact wildlife habitat; however several general conclusions can be drawn. With widespread decline of the less adapted tree species that currently comprise the overstory, there will be an increase in canopy gaps of varying sizes. This will result in more understory vegetation and more early-successional wildlife habitat, especially where overstory decline is greatest (e.g., in current elm-ash-cottonwood forest of Mississippi Alluvial Valley ecoregion), until better-adapted tree species establish their place in the overstory. Where tree mortality is greatest, the disappearance of areas of later-successional forest will negatively affect forest interior wildlife species. In these same areas, the increase of early-successional forest will benefit early-successional wildlife species. Where tree mortality is less extreme, gaps in the older forest canopy will benefit some forest interior wildlife species that need some openings, will prove detrimental to wildlife species requiring more of a closed canopy (TWRA 2009). For a more detailed analysis of predicted effects of climate change on Tennessee's wildlife, including individual chapters on birds, amphibians and reptiles, cave and karst wildlife, mammals, and aquatic species, see the full report at www.tnwildife.org/wildlife.html.

Effect of Climate Change on Forest Industry

Hodges et al. (2008 forthcoming) project a decline in oaks and other commercially important tree species and an increase in hickories and other less valuable woods, which will require the forest industry to change the type and mix of products they provide. Manufacturers who utilize low-quality wood (e.g., pallets, ties, flooring, paperboard, and upholstered furniture) are expected to adapt more quickly than those who require high-value wood (e.g., sawtimber, veneer and plywood, millwork, higher quality paper products, and wood furniture), therefore the high-value wood sectors of the industry are more likely to be negatively affected by climate change.

The pine-dependent sectors (e.g., pulp mills, wood preservation, mobile homes, and paper products other than paperboard) and the logging sector are also likely to be affected by climate change, but the types of effects are not easily determined (Hodges et al. 2008 forthcoming). On the one hand, although projections do not show increase in natural occurrence of loblolly pine in Tennessee, conditions could increase the potential for managed stands due to increased demand by the pine-dependent sectors to the south. On the other hand, increasing temperatures with drier, warmer summers will increase the potential for pests, including southern pine beetle, and mortality of pine. Pine stand establishment costs could increase by 50 percent or more in some areas due to pest issues as well as the need for more intensive site preparation and intermediate treatments in the changing climate (Hodges et al. 2008 forthcoming).

Effect of Climate Change on Urban Forests

Climate changes are expected to compound the stresses urban forests already endure. Increased warming added to the already elevated temperatures from the heat island effect that urban areas experience will increase stress on trees, making them more susceptible to insects, diseases, and abiotic impacts. This increases the potential for shortened life spans and increased maintenance costs. Changes in rainfall may result in similar additional stresses for urban trees that have the same effect.

Effect of Climate Change on Forest Insects and Diseases

Insect development is generally temperature-dependent, with at least some non-indigenous insect forest pests likely to have greatly increased populations due to faster development with rising temperatures due to climate change (Simberloff 2000). According to many researchers, increasing temperatures will result in more winter survival and greater numbers of insect generations per year, therefore greatly increasing pest pressures on forest vegetation (Mooney 1996, Simberloff 2000).

Global climate change could intensify infestations of the native southern pine beetle by a factor of 2.5 to 5, and could result in 4 to 7.5 times the current annual mortality of pines (Gan 2004, Dale et al. 2009).

Just as the northern spread of hemlock woolly adelgid may be slowed or prevented by cold temperature, warmer temperatures may enhance its spread (Skinner et al. 2003, Dale et al. 2009).

With the potential for more planting and managing of loblolly pine in Tennessee due to predicted increased demand for this species, the changing precipitation and temperatures patterns will increase the likelihood of pests and mortality associated with this species (Hodges et al. 2009).

Effect of Climate Change on Invasive Plants

Invasive plants are plants that are able to reproduce and spread over a landscape because the niche constraints of the species have been reduced. As atmospheric CO_2 levels increase, there is a risk that plants currently not invasive will become so.

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Effect of Climate Change on Fire

Climate change may result in the increase of forest fire intensity, extent, and frequency (Flannigan et al. 2000, Dale et al. 2001). Drought effects due to climate change will continue to result in greater probability of longer and bigger fire seasons, in more regions in the nation, with the Southeast (along with the Southwest) especially vulnerable to fire risk (IAFC 2009).

References:

Allison, Perry L., Paula J. Low, Jim R. Ellis and John D. Reynolds. 2005. Climate Change and Distribution Shifts in Marine Fishes. Sci. 308:1912-1915.

Both, Christiaan, Aleksandr V. Artemyev, Bert Blaaw, Richard J. Crowie, Aarnoud J. Dekhuijzen,Tapio Eeva, Anders Enemar, Lars Gustafsson, Elena V. Ivankina, Antero Jarvinen, Neil B. Metcalf, N. Erik I. Nyholm, Jaime Potti, Pierre-Alain Ravussin, Jaun Jose Sanz, Bengt Silverin, Fred M. Slater, Leonid V. Sokolov, Janos Torok, Wolfgang Winkel, Jonathon Wright, Herwig Zang and Marcel E. Vissel. 2004. Large-scale geographical variation confirms that climate change causes birds to lay earlier. Proc. R. Soc. Lond. 2004. 271:1657-1662.

Bradley, Nina L., A. Carl Leopold, John Ross and Wellington Huffaker. 1999. Phenological changes reflect climate change in Wisconsin. PNAS 96:9701-9704.

Brohan, P., J. J. Kennedy, I. Harris, S. F. B. Tett and P. D. Jones. 2006: Uncertainty estimates in regional and global observed temperature changes: A new dataset from 1850. J. Geophys. Res., 111, D12106, doi:10.1029/2005JD006548.

Cayan, D. R., Kammerdiener SA, Dettinger MD, Caprio JM, Peterson DH. 2001. Changes in the onset of spring in the western United States. Bull. Am. Meteorol. Soc. 82:399-415.

Chmielewski, Frank and Thomas Rötzer. 2001. Response of tree phenology to climate change across Europe. Ag. and For. Meteorol.108: 101-112.

Compton J. Tucker, Daniel A. Slayback, Jorge E. Pinzon, Sietse O. Los, Ranga B. Myneni Malinda G. Taylor. 2004. Higher northern latitude normalized difference vegetation index and growing season trends from 1982 to 1999. Int J Biometeorol 45:184–190.

Dale, V. H., L. A. Joyce, S. McNulty, R. P. Neilson, M. P. Ayres, M. D. Flannigan, P. J. Hanson, L. C. Irland, A. E. Lugo, C. J. Peterson, D. Simberloff , F. J. Swanson, B. J. Stocks, and B. M. Wotton. 2001. Forest disturbances and climate change. BioScience 51:723-734.

Dale, Virginia H., Karen O. Lannom, M. Lynn Tharp, Donald G. Hodges, and Jonah Fogel. 2009. Effects of climate change, land-use change, and invasive species on the ecology of the Cumberland Forests. Canadian Journal of Forest Research 39: 467-480.

Flannigan, M. D., B. J. Stocks, and B. N. Wotton. 2000. Climate change and forest fi rest. Science of the Total Environment 262:221-229.

Gan, J. B. 2004. Risk and damage of southern pine beetle outbreaks under global climate change. Forest Ecology and Management 191:61-71.

Gibbs, James P. and Alvin R. Breisch,II. 2001. Climate warming and the phenology of frogs near Ithaca, New York, 1990-1999. Conser. Bio. 15:1175-1178.

Hansen, J.E. and S. Lebedeff. 1987. Global trends of measured surface air temperature. J. Geophy. Res. 92:13345-72.

Hansen, J., R. Ruedy, J. Glascoe, and Mki. Sato, 1999: GISS analysis of surface temperature change. J. Geophys. Res., 104, 30997-31022, doi:10.1029/1999JD900835.

Hobbs, R.J., S. Arico, J. Aronson, J.S. Baron, P. Bridgewater, A.A. Cramer, P.R. Epstein, J.J. Ewel, C.A. Klink, A.E. Lugo, D. Norton, D. Ojima, D.M. Richardson, E.W. Sanderson, R. Valladares, M. Vila, R. Zamora, and M. Zobel. 2006. Novel ecosystems: Theoretical and management aspects of the new ecological world order. Global Ecology and Biogeography 15(1):1–7.

Hodges, Donald G., Jonah Fogel, Virginia H. Dale, Karen O. Lannom, and M. Lynn Tharp. 2009. Economic effects of projected climate change on Tennessee forests. Chapter submitted to: Gan, J., S. Grado, and I. Munn (Editors). Global Change and Forestry: Economic and Policy Impacts and Responses. Nova Science, NY. Forthcoming.

Inouye, David W., Billy Barr, Kenneth Armitage and Brian D. Inouye. 2000. Climate Change is affecting migrants and hibernating species. PNAS 97:1630-1633.

International Association of Fire Chiefs (IAFC), 2009 Quadrennial Fire Review Draft Report. Available online at http://www.iafc.org/associations/4685/files/wild_QFR2009ReportCommentDraft.pdf; last accessed July 29, 2009.

Iverson, L. R., and A. M. Prasad. 2001. Potential changes in tree species richness and forest community types following climate change. Ecosystems 4:186-199.

Iverson, L. R., A. M. Prasad, S. N. Matthews, and M. Peters. 2008. Estimating potential habitat for 134 eastern US tree species under six climate scenarios. Forest Ecology and Management 254:390-406.

Jones, P.D., and A. Moberg. 2003. Hemispheric and large-scale surface air temperature variations: An extended revision and update to 2001. J. Climate 16:206-223.

Kelly, Anne E. and Michael L. Goulden. 2008. Rapid shifts in plant distribution with recent climate change. PNAS 105: 11823-11826.

Lugina, K. M., P.Ya. Groisman, K.Ya. Vinnikov, V.V. Koknaeva, and N.A. Speranskaya, 2006. Monthly surface air temperature time series area-averaged over the 30-degree latitudinal belts of the globe, 1881-2005. In Trends: A Compendium of Data on Global Change. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn., U.S.A. doi: 10.3334/CDIAC/cli.003.

Malmsheimer, R.W., P. Heffernan, S. Brink, D. Crandall, F. Deneke, C. Galik, E. Gee, J. Helms, N. McClure, M. Mortimer, S. Ruddell, M. Smith, and J. Stewart. 2008. Forest Management Solutions for Mitigating Climate Change in the United States. Journal of Forestry Volume 106, Number 3:115-171.

Menzel, Annette and Peter Fabian. 1999. Growing Season extended in Europe. Nature 397:659.

Mooney HA. 1996. Biological invasions and global change. In: Sandlund OT, Schei PJ, Viken A, editors. Proceedings of the Norway/UN Conference on Alien Species. Directorate for Nature Management and Norwegian Institute for Nature Research, Trondheim, Norway, 1996:123]126.

National Aeronautics and Space Administration. 2009. Satellites Show Arctic Literally on Thin Ice: Briefing Material. Available at www.nasa.gov/topics/earth/features/seaice_status09.html. Last accessed 10/01/09.

National Assessment Synthesis Team (NAST). 2000. Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change. U.S. Global Change Research Program, Washington D.C.

National Snow and Ice Data Center. 2009. Northern hemisphere extent anomalies, September 2009. Available at nsidc.org/data/seaice_index/images/n_plot_hires.png. Last accessed 10/1/09.

Simberloff, D. 2000. Global climate change and introduced species in United States forests. Science of the Total Environment 262:253-261.

Skinner, M., B. L. Parker, S. Gouli, and T. Ashikaga. 2003. Regional responses of hemlock woolly adelgid (Homoptera: Adelgidae) to low temperatures. Environmental Entomology 32:523-528.

Steffen, K., S.V. Nghiem, R. Huff, and G. Neumann. 2004. The melt anomaly of 2002 on the Greenland Ice Sheet from active and passive microwave satellite observations, Geophys. Res. Lett., 31:20.

Tennessee Wildlife Resources Agency. 2009. Climate Change and Potential Impacts to Wildlife in Tennessee: An Update to Tennessee's State Wildlife Action Plan.

The National Academies. 2008. Understanding and responding to climate change: highlights of National Academies Reports 2008 edition. http://dels.nas.edu/dels/rpt_briefs/climate_change_2008_final.pdf.

Vinnikov, K.Ya., P.Ya. Groisman, and K.M. Lugina. 1990. Empirical data on contemporary global climate changes (temperature and precipitation). J Climate 3:662-77.

Wolfe, D.W., M.D., Schwartz, A.N. Lakso, Y. Otsuki, R.M. Pool, N. Shaulis, 2005. Climate change and shifts in spring phenology of three horticultural woody perennials in northeastern USA. Inter. J. Biometeorol, 49: 303-309.

Woodall, C.W., C.M. Oswalt, J.A. Westfall, C.H. Perry, M.D. Nelson, and A.O. Finley. 2009. An indicator of tree migration in forests of the eastern United States. Forest Ecology and Management 257: 1434–1444.

SUSTAINABILITY

Urban Forestry

The sustainability of urban forests in Tennessee is dependent on two broad factors. One is the technical and biological challenges that arise in growing trees in the urban environment. Two is the human component of individuals, governments, private enterprise and non-profit organizations.

Five technical and biological challenges must be addressed in order to achieve sustainable urban forests.

Space

For a tree to produce its maximum benefits it must have growing space. Unfortunately, many trees have to compete with buildings, streets, sidewalks and utilities and other uses for space to grow, with the result being stunted growth and limited potential to provide benefits. Space below ground for root growth is especially severe and is often a major factor in stunted growth potential and pre-mature decline and death of the tree.

Soil

Urban soils within the built environment are a major challenge for successfully growing trees. Compaction, soil chemical changes, destruction of soil profile layers, additions of brick and concrete and removed top soil are some of the problems that inhibit sustainability of trees in cities and towns.

Microenvironments

Reflected heat, wind tunnels caused by buildings, building shade and artificial lighting can have a major impact on trees in cities. These effects, along with soils mentioned above, can change abruptly and contribute to success or cause failure within the same block.

Species

Based on the Urban Forest Inventory and Analysis (FIA) study for Tennessee, it appears Tennessee's urban forest resources are comprised of less desirable species that in turn reduces sustainability (see Table 2, page 12). To increase sustainability, greater emphasis on tree selection for urban tree planting projects is needed (planning before planting).

Pests

The challenges to the urban forest listed above tend to exacerbate pest problems that trees experience, particularly invasive pests. Insects and Diseases that may otherwise be at a non-epidemic level can become a major problem when trees are stressed. In addition, urban trees are threatened by a number of exotic pests imported to North America from other parts of the world. A list of some of these pest problems and their potential devastation are listed in table 20 (TDF 2009).

Table 20. Risk and Potential Value Loss of Tennessee's Urban Trees From Exotic Pests

Pest	Potential Trees at Risk	Dollar loss ($)
Asian Long Horn Beetle	74,300,000	18,700,000,000
Gypsy Moth	30,300,000	21,600,000,000
Emerald Ash Borer on ash	5,100,000	2,200,000,000
Dutch elm disease	18,800,000	3,100,000,000

Actions by individuals, private enterprise, non-profits, and governments have a significant impact on urban forestry sustainability.

Individuals are often not recognized for their efforts to sustain the urban forest. However, they hire the designer, buy the trees and pay the planting service. They water the newly planted trees and complete other establishment maintenance. They also hire the arborist to accomplish mature tree pruning, maintenance, and removal when the tree dies or becomes hazardous.

Private enterprise supports the urban forests by nurseries that grow trees, landscape architects that design the green component of buildings, and arborists that maintain and remove trees. Grounds keepers for commercial properties also plant, maintain and remove trees on the properties that they are responsible for managing.

Local and state non-profits play a role in sustaining the urban forests primarily through fund raising for projects, but may also provide volunteers for planting projects, marshalling support for government programs, and sponsoring educational conferences and workshops.

National non-profits, in addition to financially supporting projects and providing support for programs at the national level, can sponsor programs that provide a framework for helping local programs maintain their tree resource. Tree City USA, Tree Line USA, and Tree Campus USA by the Arbor Day Foundation are examples. By setting standards for a local city or town to meet (tree board, ordinance, $2.00 per capita, and celebrate arbor day), they are encouraging communities across Tennessee (and the nation) to work toward maintaining and improving their tree resource. Currently, Tennessee has 39 Tree City USA's, 12 Tree Line USA's, and 1 Tree Campus USA that recognize the importance of trees in their community.

Local governments are key to establishing and maintaining programs that sustain the resource. Tree Ordinances help protect trees. City foresters and tree boards work to keep trees planted and healthy. They also advocate for trees to local community leaders. Most of the funds that are vital to sustaining the urban forest come from the local level.

State government programs provide a variety of assistance that helps sustain the urban forest. In Tennessee, one of the key components is to provide cost-sharing tree planting grants to cities and towns. The state supports local programs by providing expertise, particularly to smaller cities and towns that can not afford their own urban forester. They also act as a conduit for information and the exchange of ideas between cities and towns.

The federal government also contributes to the sustainability of urban forests by providing grants that support both state and local programs, and by establishing a set of standards that are the foundation of a sound local urban and community forestry program. These standards, called the Community Assessment and Rating System (CARS) include:

1. establishing a tree board or tree advocacy group,
2. passing a tree ordinance,
3. completing a tree inventory and compiling an assessment and plan for managing trees, and
4. having professional urban forestry expertise on staff or on retainer.

References:

Tennessee Department of Agriculture Division of Forestry (TDF) and USDA Forest Service. 2009. Urban Forest Inventory Analysis Pilot Study [dataset].

SUSTAINABILITY