Forest sustainability in the state of Texas, USA

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CONTENTS

FIGURES

TABLES

1. Introduction

The combustion of wood for energy purpose is not considered to contribute to the augmentation of greenhouse gases concentration in the atmosphere, as long as the CO2 emissions released during the combustion of wood are balanced by the growth of new trees. It is therefore essential to investigate if the forests in the region where the wood used for energy purpose are managed in a sustainable way, avoiding resources associated with overexploitation of forests, land use change, depletion of carbon stocks, etc...

In this framework, literature research was carried out to produce a summary of forest management in Texas, including general condition, management and sustainability assessment.

2. Texas forests overview

2.1. Location and distribution

Texas is the second largest state in the United States with an area of 696,241 km². The state is located in the South Central region. It is bordered by the U.S. states of Louisiana to the east, Arkansas to the northeast, Oklahoma to the north, New Mexico to the west and the country of Mexico to the south. The southeast of the state borders the Gulf of Mexico.

Figure 1: General map of Texas

Source: http://www.nationsonline.org/oneworld/map/USA/texas_map.htm

As for the other U.S. states, Texas is divided into counties. The state counts 254 counties. It is the most nationwide.

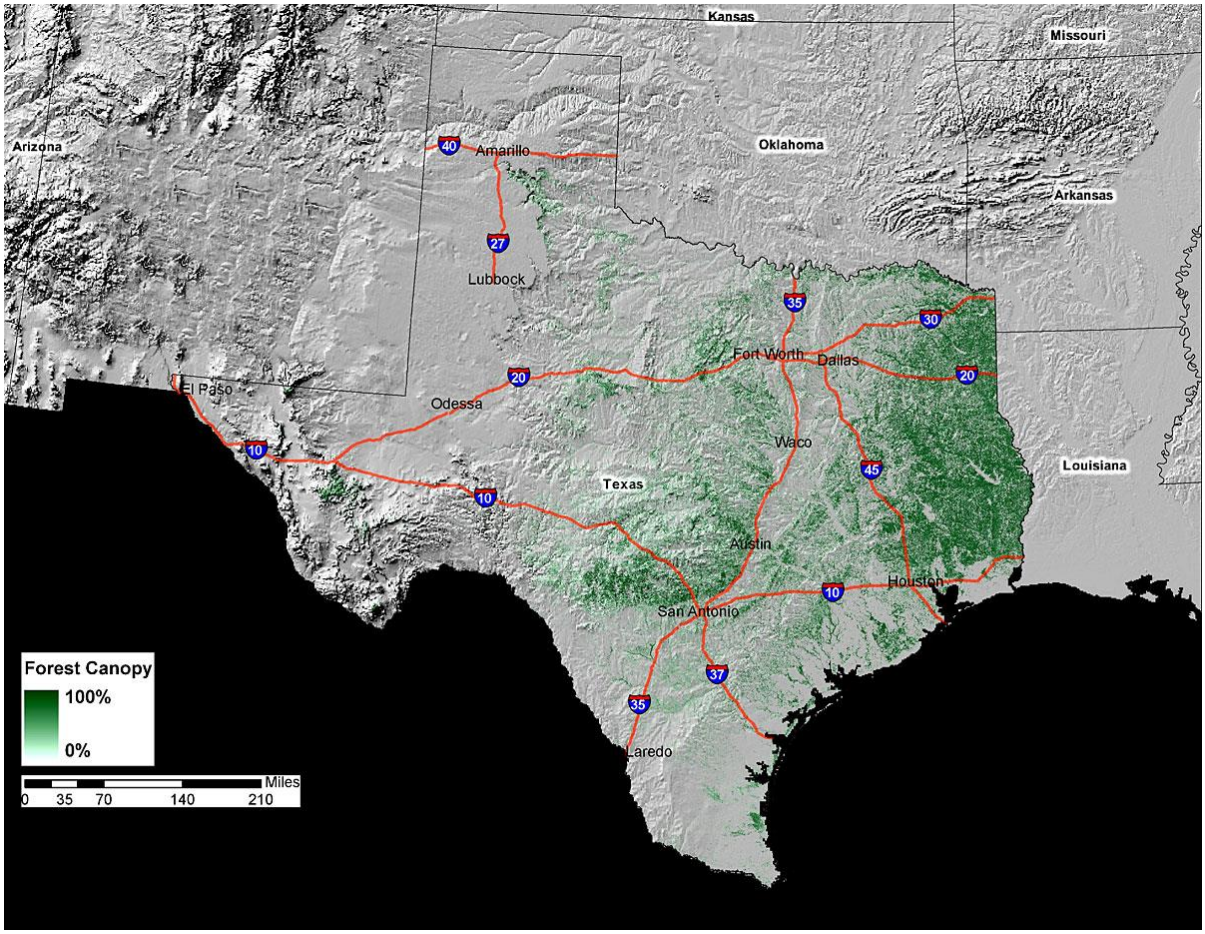
Figure 2: Texas' counties map

Source: https://en.wikipedia.org/wiki/List_of_Texas_county_seat_name_etymologies

Concerning forest area, it covers 25,586,436 ha (255,864.36 km²) or 36.7% of the state's land area in 2014[1]. Forest cover can be seen in Figure 3. Forest is denser in the eastern part of the state. There are forests scattered in the central, northern and southern part of the state.

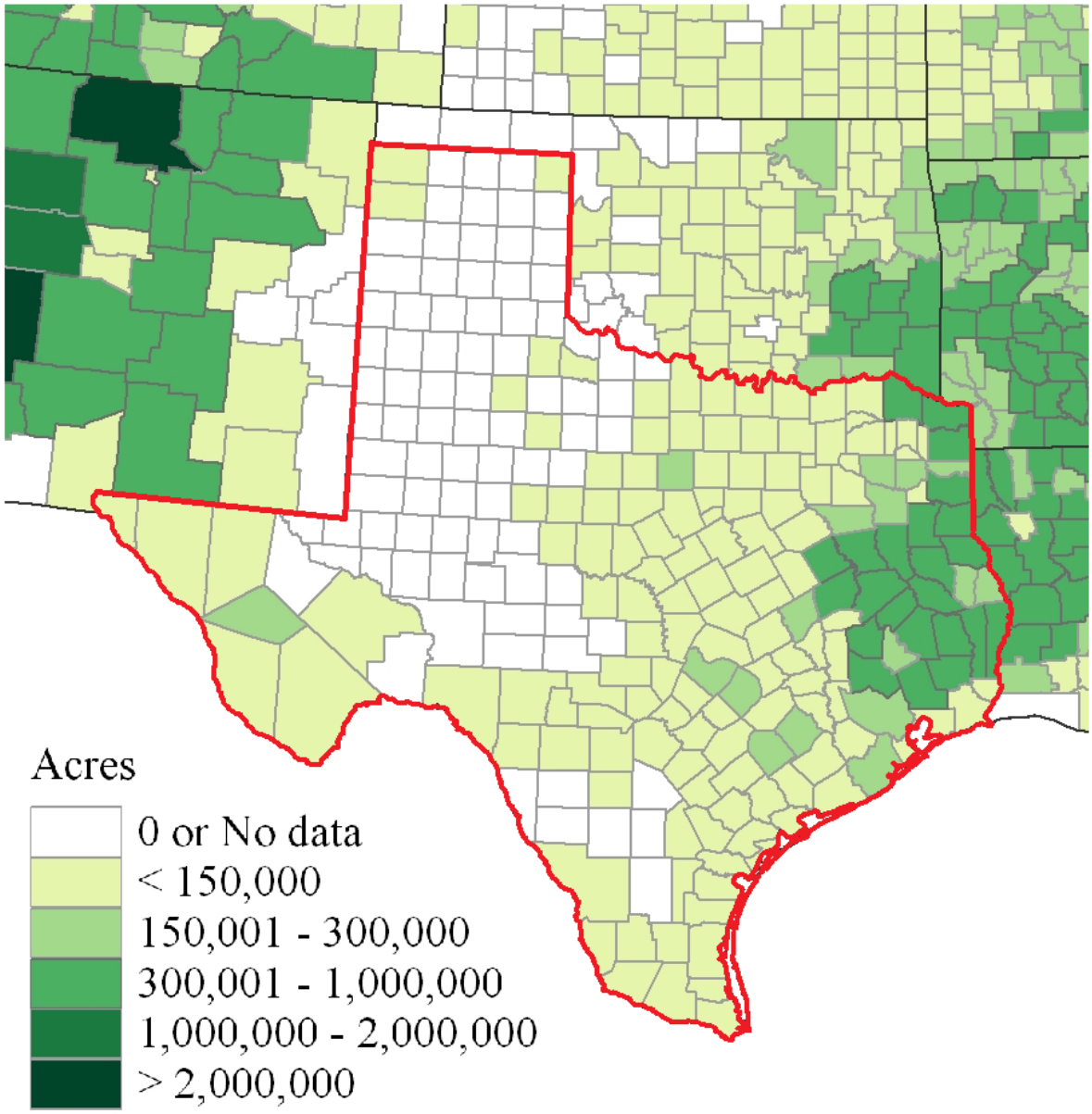
[1] https://apps.fs.usda.gov/fido/standardrpt.html

Figure 3: Forest cover



Source: https://landcover.usgs.gov/texas.php

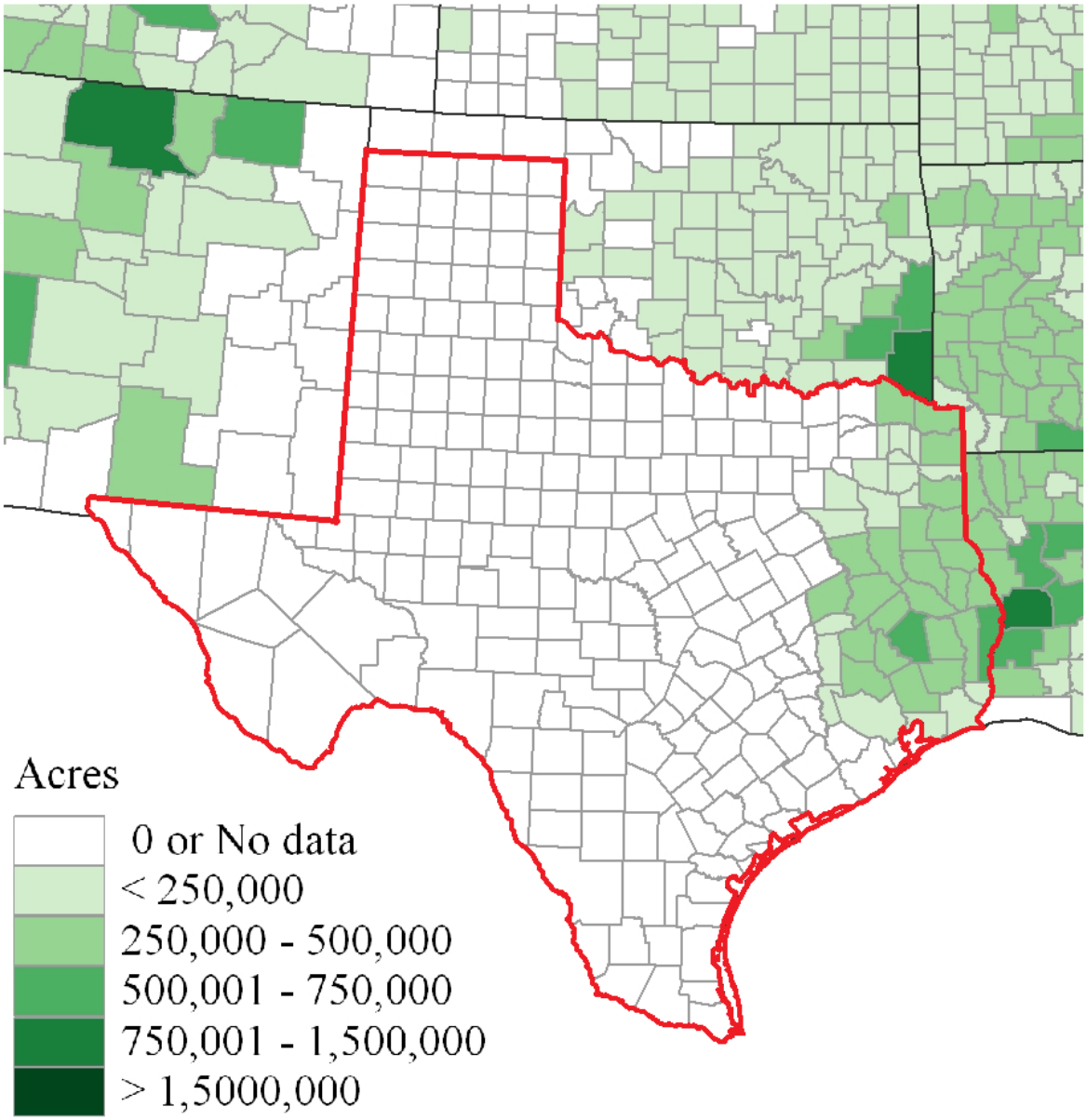
Figure 4: Texas' forest land area (2007)



Source: USDA Forest Services – Forest Inventory & Analysis (modified by SGS)

Part of the forest land is considered as "timberland". It means that in that area, wood is available for timber. In Texas, timberland area was 4,905,871 ha in 2015 or 7% of the state's land area. It represents 19.2% of the total forest land area in the state.

Figure 5: Texas' timberland area (2007)

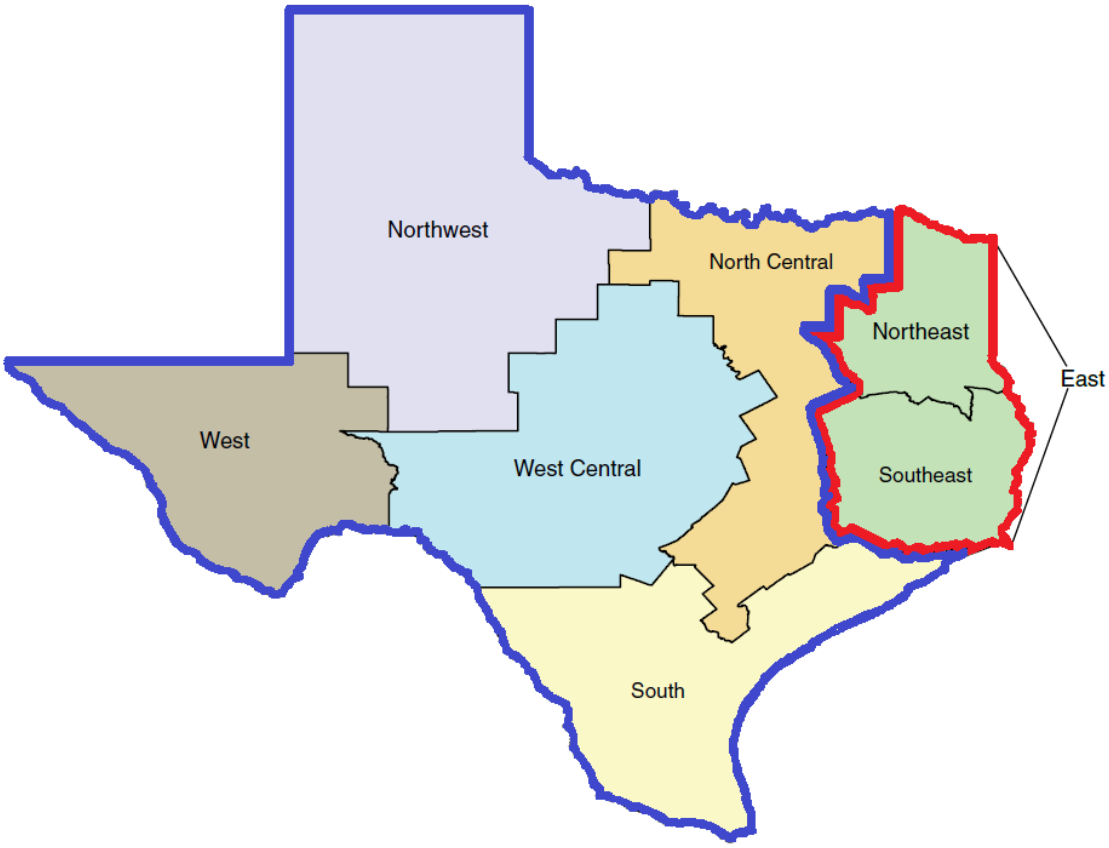


Source: USDA Forest Services – Forest Inventory & Analysis (modified by SGS)

Timberland is almost exclusively present in the eastern part of the state. It is the part of Texas that has the highest density of forest land. For its Forest inventory & analysis, the USDA Forest Services divides the state in seven survey units. Considering that timberland only occurs in the East survey unit (Northeast and Southeast), analyses are carried in the Central & West region (blue line) and in the East of Texas (red line) (Figure 6). The East Texas pine-hardwood region is the main forest region in Texas. The region contains 43 counties and is the western edge of the southern pine region[2].

[2] http://texasalmanac.com/topics/environment/forest-resources

Figure 6: Survey units of East and Central/West Texas (2008)



Source: USDA Forest Services – Forest Inventory & Analysis

2.1. Ecological zones

Texas contains plains, prairies, deserts and mountains.

The State is divided by 12 main ecological zones (level III ecoregions) and most of these continue into ecologically similar parts of adjacent states[3]:

- **Arizona/New Mexico mountains:**
  The Arizona/New Mexico Mountains are distinct from neighboring mountainous ecoregions by their lower elevations and an associated vegetation indicative of drier, warmer environments, which is also due in part to the region's more southerly location. Forests of spruce, fir, and Douglas fir, that are common in the Southern Rockies and the Uinta and Wasatch Mountains, are only found in a few high elevation parts of this region. Chaparral is common on the lower

[3] Source: Primary Distinguishing Characteristics of Level III Ecoregions of the Continental United States (http://www.hort.purdue.edu/newcrop/cropmap/ecoreg/descript.html)

elevations, pinyon-juniper and oak woodlands are found on lower and middle elevations, and the higher elevations are mostly covered with open to dense ponderosa pine forests.

- **Chihuahuan deserts:**
  This desert ecoregion extends from the Madrean Archipelago in southeastern Arizona to the Edwards Plateau in south-central Texas. The region comprises broad basins and valleys bordered by sloping alluvial fans and terraces. Isolated mesas and mountains are located in the central and western parts of the region. Vegetative cover is predominantly arid grass and shrub land, except on the higher mountains where oak-juniper woodlands occur.

- **Western high plains:**
  Higher and drier than the Central Great Plains to the east, and in contrast to the irregular, mostly grassland or grazing land of the Northwestern Great Plains to the north, much of the Western High Plains comprises smooth to slightly irregular plains having a high percentage of cropland. Grama-buffalo grass is the potential natural vegetation in this region as compared to mostly wheatgrass-needle grass to the north, Trans-Pecos shrub savanna to the south, and taller grasses to the east. The northern boundary of this ecological region is also the approximate northern limit of winter wheat and sorghum and the southern limit of spring wheat.

- **Southwestern tablelands:**
  Unlike most adjacent Great Plains ecological regions, little of the Southwestern Tablelands is in cropland. Much of this elevated tableland is in subhumid grassland and semiarid grazing land. The potential natural vegetation in this region is grama-buffalo grass with some mesquite-buffalo grass in the southeast and shinnery (midgrass prairie with open low and shrubs) along the Canadian River.

- **Central great plains:**
  The Central Great Plains are slightly lower, receive more precipitation, and are somewhat more irregular than the Western High Plains to the west. Once a grassland, with scattered low trees and shrubs in the south, much of this ecological region is now cropland, the eastern boundary of the region marking the eastern limits of the major winter wheat growing area of the United States.

- **Cross timbers:**
  The Central Oklahoma/Texas Plains ecoregion is a transition area between the once prairie, now winter wheat growing regions to the west, and the forested low mountains of eastern Oklahoma. The region does not possess the arability and suitability for crops such as corn and soybeans that are common in the Central Irregular Plains to the northeast. Transitional "cross-timbers" (little bluestem grassland with scattered blackjack oak and post oak trees) is the native vegetation, and presently rangeland and pastureland comprise the predominant land cover. Oil extraction has been a major activity in this region for over eighty years.

- **Edwards plateau:**

This ecoregion is largely a dissected plateau that is hillier in the south and east where it is easily distinguished from bordering ecological regions by a sharp fault line. The region contains a sparse network of perennial streams, but they are relatively clear and cool compared to those of surrounding areas. Originally covered by juniper-oak savanna and mesquite-oak savanna, most of the region is used for grazing beef cattle, sheep, goats, and wildlife. Hunting leases are a major source of income.

- **Southern Texas plains:**
  This rolling to moderately dissected plain was once covered with grassland and savanna vegetation. Having been subject to long continued grazing, thorny brush is now the predominant vegetation type. This "brush country", as it is called locally, has its greatest extent in Mexico and contains a greater and more distinct diversity of animal life than that found elsewhere in Texas.

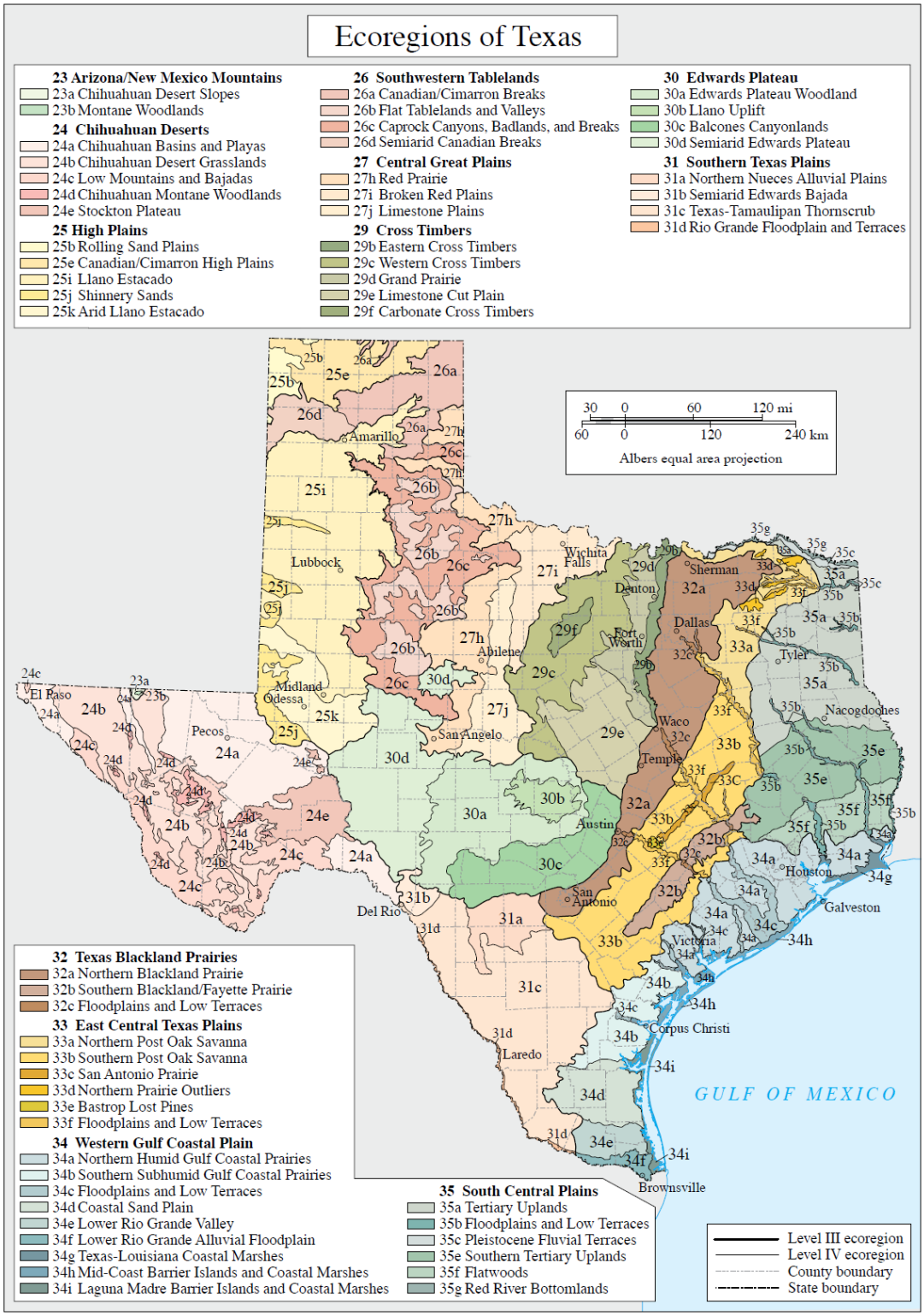
- **Texas blackland prairies:**
  The Texas Blackland Prairies is a distinct ecological region distinguished from surrounding regions by its fine textured clayey soils and predominantly prairie potential natural vegetation. This region now contains a higher percent of cropland than adjacent regions, although much of the land has been recently converted to urban and industrial uses.

- **East central Texas plain:**
  Also called the Claypan Area, this region of irregular plains was originally covered by a post oak savanna vegetation, in contrast to the more open prairie-type regions to the north, south and west and the piney woods to the east. The bulk of this region is now used for pasture and range.

- **Western gulf coastal plain:**
  The principal distinguishing characteristics of the Western Gulf Coastal Plain are its relatively flat coastal plain topography and mainly grassland potential natural vegetation. Inland from this region the plains are more irregular and have mostly forest or savanna-type vegetation potentials. Largely because of these characteristics, a higher percentage of the land is in cropland than in bordering ecological regions. Recent urbanization and industrialization have become concerns in this region.

- **South central plains:**
  Locally termed the "piney woods", this region of mostly irregular plains was once blanketed by oak-hickory-pine forests, but is now predominantly by loblolly and shortleaf pine. Only about one sixth of the region is in cropland, whereas about two thirds is in forests and woodland. Lumber and pulpwood production are major economic activities.

Figure 7: Level III and IV Ecoregions of Texas



Source: Griffith G., Sandy B., Omernik J. and Rogers A., 2007. Ecoregions of Texas

2.2. Forest species

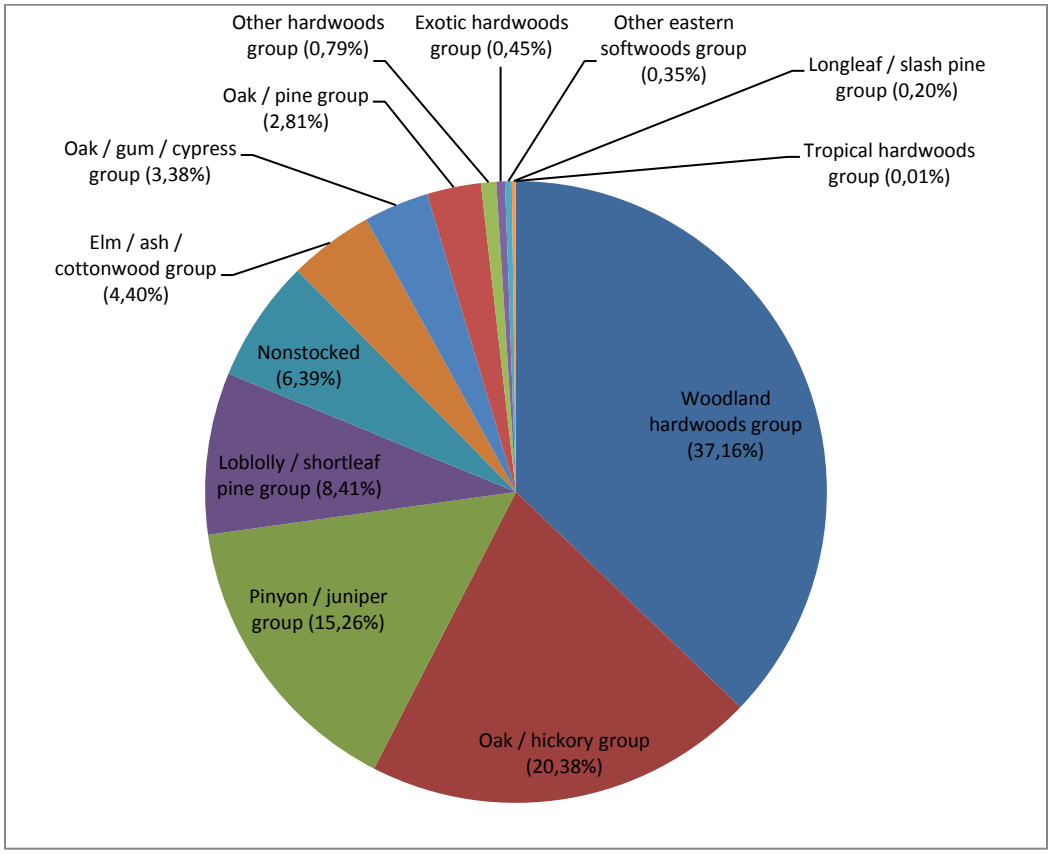
The area of Texas covered by the different forest species can be seen in Table 1. The main group is the woodland hardwoods group with 37.2% of the forest land area, it is followed by the oak / hickory group (20.4%) and the pinyon / juniper group (15.3%). The remaining 27.1% are covered by the other groups that have a proportion of less than 10%.

Table 1 : Forest types in forest land (2014)

Forest-type groups	Stand origin (ha)		Total (ha)	% of total forestland area
	Natural stands	Artificial regeneration		
Longleaf / slash pine group	2,403	28,294	52,324	0.2%
Loblolly / shortleaf pine group	1,042,403	1,109,814	2,152,217	8.4%
Other eastern softwoods group	89,561	-	89,561	0.4%
Pinyon / juniper group	3,903,903	-	3,903,903	15.3%
Oak / pine group	648,672	69,594	718,266	2.8%
Oak / hickory group	5,187,840	26,577	5,214,417	20.4%
Oak / gum / cypress group	854,163	11,764	865,927	3.4%
Elm / ash / cottonwood group	1,124,842	195	1,126,792	4.4%
Other hardwoods group	201,021	1,816	202,836	0.8%
Woodland hardwoods group	9,509,050	-	9,509,050	37.2%
Tropical hardwoods group	2,562	-	2,562	0.0%
Exotic hardwoods group	110,104	4,411	114,515	0.4%
Nonstocked	1,620,465	13,601	1,634,066	6.4%
TOTAL	**24,318,615**	**1,267,821**	**25,586,436**	**100.0%**

Source: adapted from US Forest service, FIA Program (http://apps.fs.fed.us/fido/standardrpt.html)

Figure 8: Forest types in forest land (2014)



Source: adapted from US Forest service, FIA Program (http://apps.fs.fed.us/fido/standardrpt.html)

Concerning timberland in east Texas, forest types are shown in Table 2. The most represented group of forest in the east is loblolly / shortleaf pine group with 44.1% of the timberland area. This group is almost exclusively located in the timberland. It is followed by oak / hickory group (23.5%), oak / pine group (11.7%) and oak / gum / cypress group (11.3%). The last 9.4% are split among the other groups. The forest type dominance is very different than for the whole state of Texas. In the whole state, hardwood is clearly dominant whereas in east Texas, softwood groups take up to approximately 50% of the total timberland area.

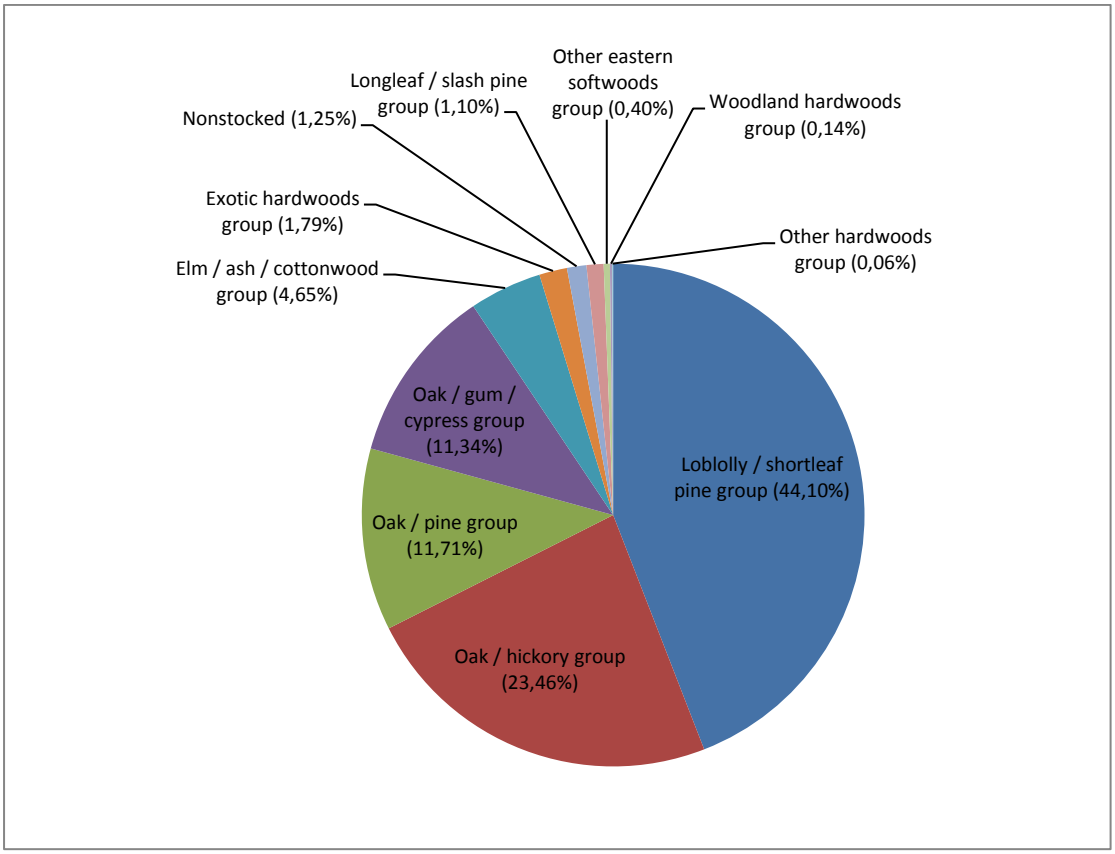
Table 2 : Forest types in timberland (2015)

Forest-type groups	Stand origin (ha)		Total (ha)	% of total timberland area
	Natural stands	Artificial regeneration		
Longleaf / slash pine group	24,265	29,495	53,759	1.1%
Loblolly / shortleaf pine group	1,031,374	1,132,172	2,163,545	44.1%
Other eastern softwoods group	19,531	-	19,531	0.4%
Oak / pine group	509,714	64,881	574,595	11.7%
Oak / hickory group	1,124,316	26,361	1,150,677	23.5%
Oak / gum / cypress group	546,655	9,642	556,297	11.3%

Elm / ash / cottonwood group	226,242	2,012	228,254	4.7%
Other hardwoods group	3,118	-	3,118	0.1%
Woodland hardwoods group	6,983	-	6,983	0.1%
Exotic hardwoods group	83,474	4,387	87,861	1.8%
Nonstocked	45,333	15,918	61,251	1.2%
TOTAL	**3,621,005**	**1,284,868**	**4,905,871**	**100.0%**

Source: adapted from US Forest service, FIA Program (http://apps.fs.fed.us/fido/standardrpt.html)

Figure 9: Forest types in timberland (2015)



Source: adapted from US Forest service, FIA Program (http://apps.fs.fed.us/fido/standardrpt.html)

Considering the type of regeneration for trees in the whole state, except for the loblolly / shortleaf pine group and Longleaf / slash pine group, the main origin is natural stand. Artificial regeneration of loblolly / shortleaf pine trees and longleaf / slash pine trees represents more than 50% of the total area. The other groups have an artificial regeneration smaller than 10% of the total area for each group.

In east Texas, the situation is the same for longleaf / slash pine group and loblolly / shortleaf pine group. Natural regeneration represents 26% of the area and oak / pine group artificial regeneration represents 11%. The other groups have an artificial regeneration smaller than 10%.

2.3. Forest ownership

The clear majority of forest lands are privately-owned: approximately 93.8% of the total area. The rest is publicly-owned and split among the federal, the state and local public owners.

92% of the timberland is privately-owned. The biggest owners are family forest land-owners. It accounts for about 53% of all timberland. Timberland that was owned by corporations that own wood-processing facilities has been transferred to corporations that do not own wood-processing facilities. In the last 30 years and especially in the last 15 years, virtually all large publicly traded forest products companies have either sold most or all of their timberlands, often to institutional investors, or converted themselves to timberland real estate investment trusts[4]. More than 15% of all timberland belongs to other private owners: non-industrial corporate, unincorporated, Native American and nongovernmental organizations.[5]

Texas' forest land and timberland ownership patterns are given in the following table.

Table 3 : Area of forest land and timberland by ownership groups (2014)

Forest land / Ownership groups		**Area (ha)**		**% of total forestland area**
Forest Service	National forest	245,425	245,425	1.0%
Other federal	National grassland	17,525	398,288	1.6%
	National Park Service	69,331		
	Bureau of Land Management	207		
	Fish and Wildlife Service	63,002		
	Department of Defense or Energy	245,638		
	Other federal	2,585		
State and local government	State	676,143	947,898	3.7%
	Local (county, municipal, etc.)	261,549		
	Other non federal lands	10,206		
Private	Undifferentiated private	23,992,962	23,992,962	93.8%
Total			**25,586,436**	100.0%
Timberland / Ownership groups		**Area (ha)**		**% of total timberland area**
Forest Service	National forest	231,835	231,835	4.1%
Other federal	National grassland	5,205	101,422	1.8%
	National Park Service	0		
	Bureau of Land Management	0		
	Fish and Wildlife Service	0		
	Department of Defense or Energy	93,632		
	Other federal	2,585		

[4] Zhang et la., 2012. Institutional Timberland Ownership in the US South: Magnitude, Location, Dynamics, and Management. Journal of Forestry

[5] Forest inventory & analysis report: East Texas 2015.

State and local government	State	67,335	133,580	2.4%
	Local (county, municipal, etc.)	65,458		
	Other non federal lands	787		
Private	Undifferentiated private	5,148,392	5,148,392	91.7%
Total			**5,615,229**	**100.0%**

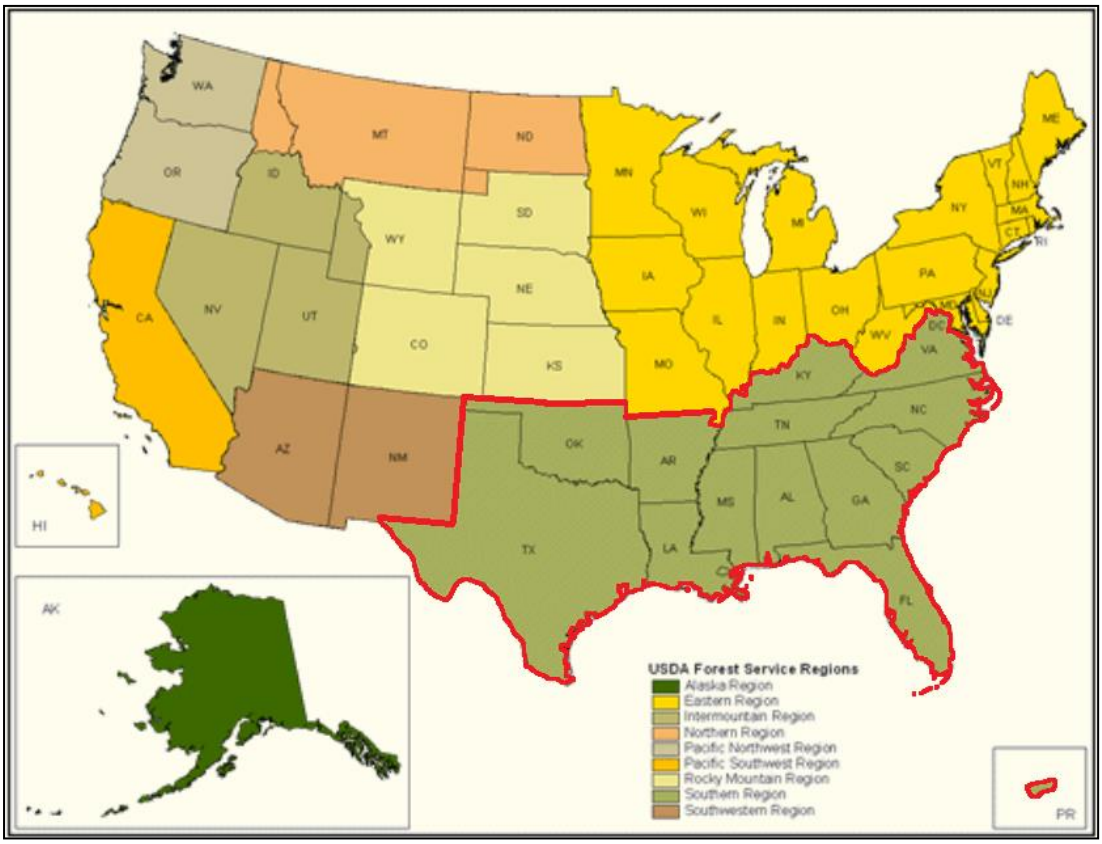
Source: adapted from US Forest service, FIA Program (http://apps.fs.fed.us/fido/standardrpt.html)

2.4. Competent authorities

Forest management in the United States of America, at the federal level is under the authority of the US Department of Agriculture and more specifically it's agency of the US Forest Service whose mission is to: *"Sustain the health, diversity, and productivity of the Nation's forests and grasslands to meet the needs of present and future generation"* [6]

Forest management of the territory of the United States is shared in 10 different parts belonging to regional divisions of the Forest Service. As shown on the figure below, Texas and other States like Louisiana and Florida belongs to the R8 region: Southern Region.

Figure 10 : Regional areas of the Forest Service



[6] Forest Service Agency Financial report- Fiscal Year 2008

Source : http://www.fs.fed.us/

The authority responsible for forest management in Texas is split into two levels: federal and state. The Forest Service – an agency of the Department of Agriculture – is responsible at federal level for the coordination of forest policies and the management of federal forests. At state level, the Texas A&M Forest Service[7] is in charge of forest management. The primary responsibilities of the office are to:

- prevent and manage wildfires,
- assist landowners,
- analyse forest health,
- reforest,
- enforce the law,
- manage water resources,

"The 34th Texas Legislature mandated Texas A&M Forest Service to "assume direction of all forest interests and all matters pertaining to forestry within the jurisdiction of the state." And in 1993, the 73rd Texas Legislature expanded Texas A&M Forest Service responsibility to include "Coordination of the response to each major or potentially major wildland fire in the state." During all-hazard state emergencies, the State Emergency Management Plan calls for Texas A&M Forest Service to work with the Texas Division of Emergency Management to develop regional Incident Management Teams."[8]

2.5. Overview of wood-related industry

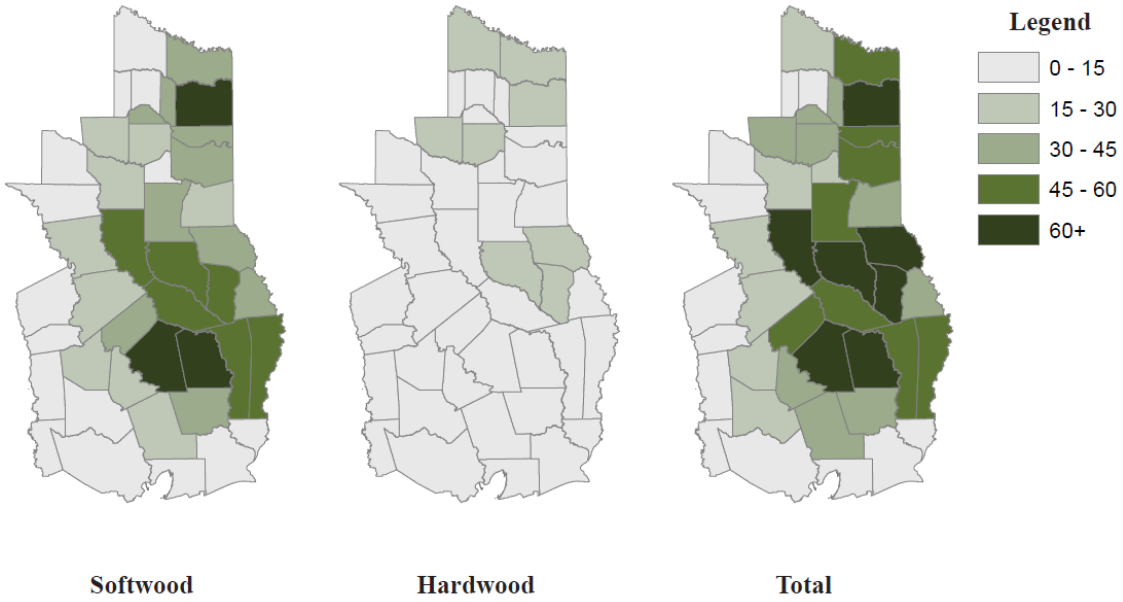
About wood harvesting, East Texas is the most concerned region as it gathers almost all timberland. Outside of that region, only 4% of the total forestland area in Central/West Texas is considered productive timberland, having capacity of producing at least 1.4 m³ per ha per year[9].

Forests are vital economic and environmental assets in East Texas. The Texas forest sector directly contributes 18.3 billion $ of industry output to the Texas economy in 2015. The total economic contribution of the sector is 32.5 billion $ in industry output (direct and non-direct contribution). The forest sector make considerable contributions to local and regional economies as it continued to be one of the top 10 manufacturing sectors in the state.

The intensity of timber harvest in East Texas in 2015 can be seen in Figure 11. Most harvesting concerns softwood. Harvesting of hardwood is minor compared to it. Most of harvesting is carried out in the center and the east of the region.

[7] http://texasforestservice.tamu.edu/default.aspx
[8] http://texasforestservice.tamu.edu/about/
[9] 20 cubic feet per acre per year

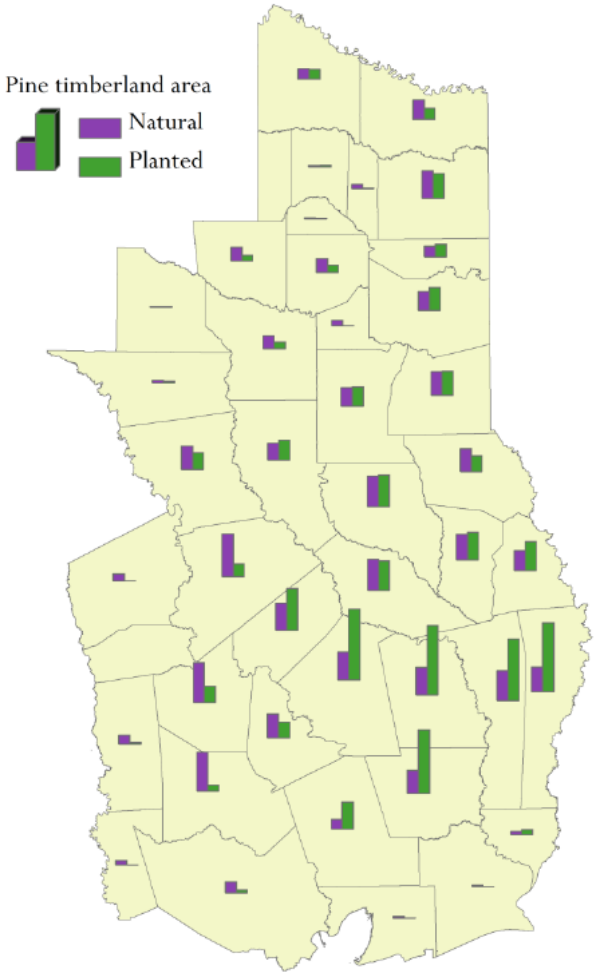
Figure 11 : Intensity of timber harvest by county (2015)



Cubic feet harvested per acre of Timberland
Source : Edgar C. et al., 2017. Harvest Trends 2015. Texas A&M Forest Service

The proportion of industrial plantation of pine compared to natural generation is 52%. The pine timberland area by county in East Texas is shown in Figure 12. Pine timberland area tends to increase as one moves from west to east. The same applies for planting, in the west, pine tends to be more naturally regenerated. The largest amount of plantation occurs in the south central and eastern counties.

Figure 12 : Pine timberland area by county (2015)



Source : Forest Inventory & Analysis – East Texas forestlands, 2015

In terms of production, a total of 3.6 million m³ of lumber, 227.1 million m² of structural panels and 2.1 million tons of pulp and paperboard products were produced in 2015.

Table 4 : Texas Industrial products (2006-2015)

Year	Lumber			Structural Panel	Pulp and paperboard products
	Pine	Hardwood	Total		
	m³			m²	,tons
2006	3,956,012	566,843	4,522,855	272,729,484	2,781,865
2007	3,659,287	426,436	4,085,722	232,623,631	2,788,308
2008	3,318,037	503,075	3,821,113	204,808,751	2,239,347
2009	2,920,889	404,728	3,325,617	181,977,839	2,050,681
2010	2,804,065	328,922	3,132,987	174,821,428	2,089,521

2011	3,087,548	364,799	3,452,347	177,965,451	2,071,404
2012	3,047,788	280,391	3,328,180	190,366,051	2,081,521
2013	3,268,341	331,371	3,599,713	187,423,070	2,168,403
2014	3,407,944	245,623	3,653,567	218,138,381	2,213,026
2015	3,328,347	252,561	3,580,908	227,098,039	2,106,412

Source: adapted from Edgar C. et al., 2017. Harvest Trends 2015. Texas A&M Forest Service

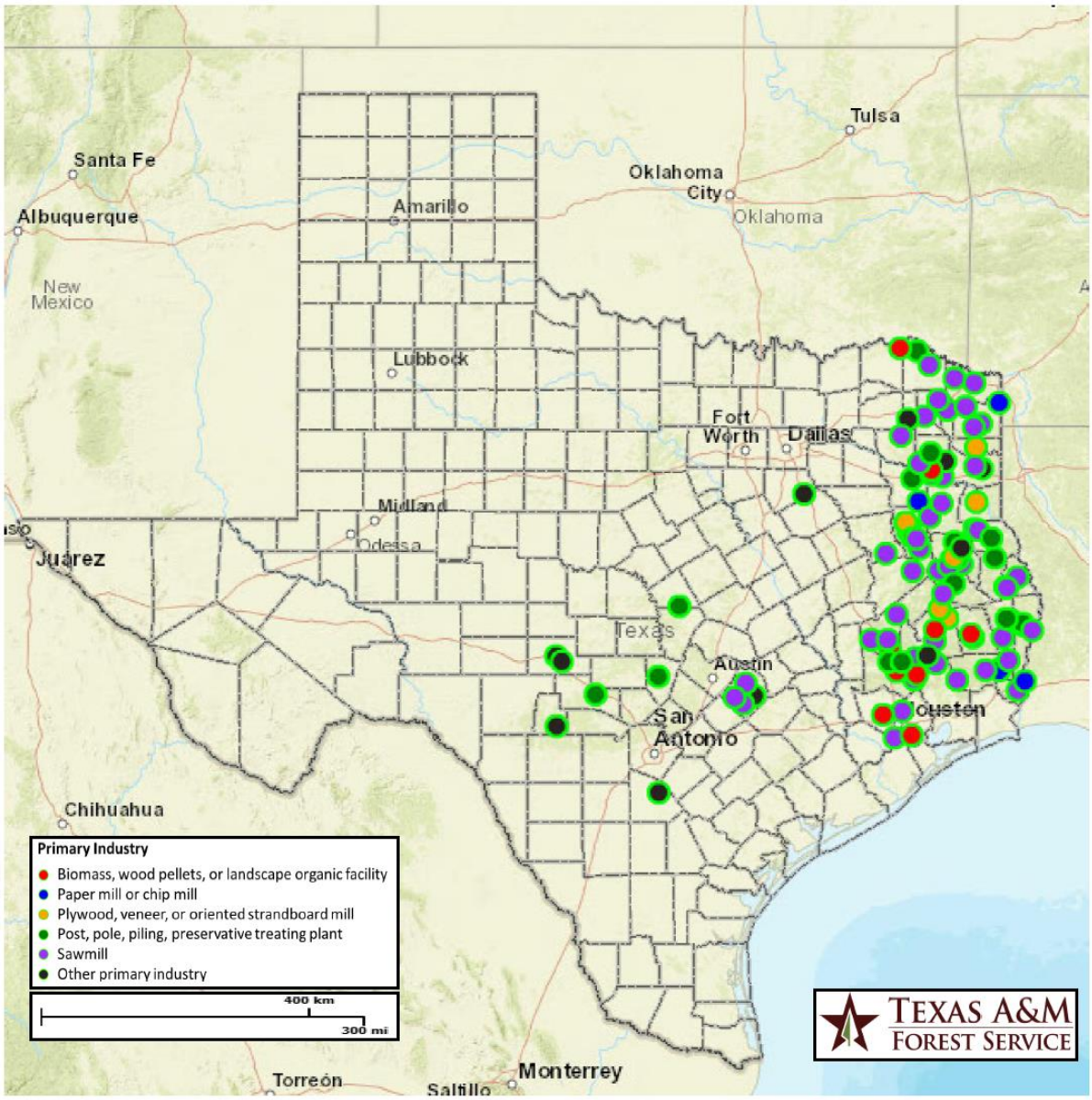
The largest industry outputs were from secondary forest products: wood windows/doors and mill work, wood containers, wood buildings, other wood products, furniture, paperboard containers, coated and treated paper and packaging materials, etc.

In terms of employment, 66,000 people are directly employed by the forest sector. In total, it supports more than 144,500 jobs[10].

Concerning the location of the forest sector industry, primary industry is mainly located in East Texas, where the timberland is located (Figure 13). Secondary industry is more developed in the west but is also mainly concentrated in East Texas (Figure 14).

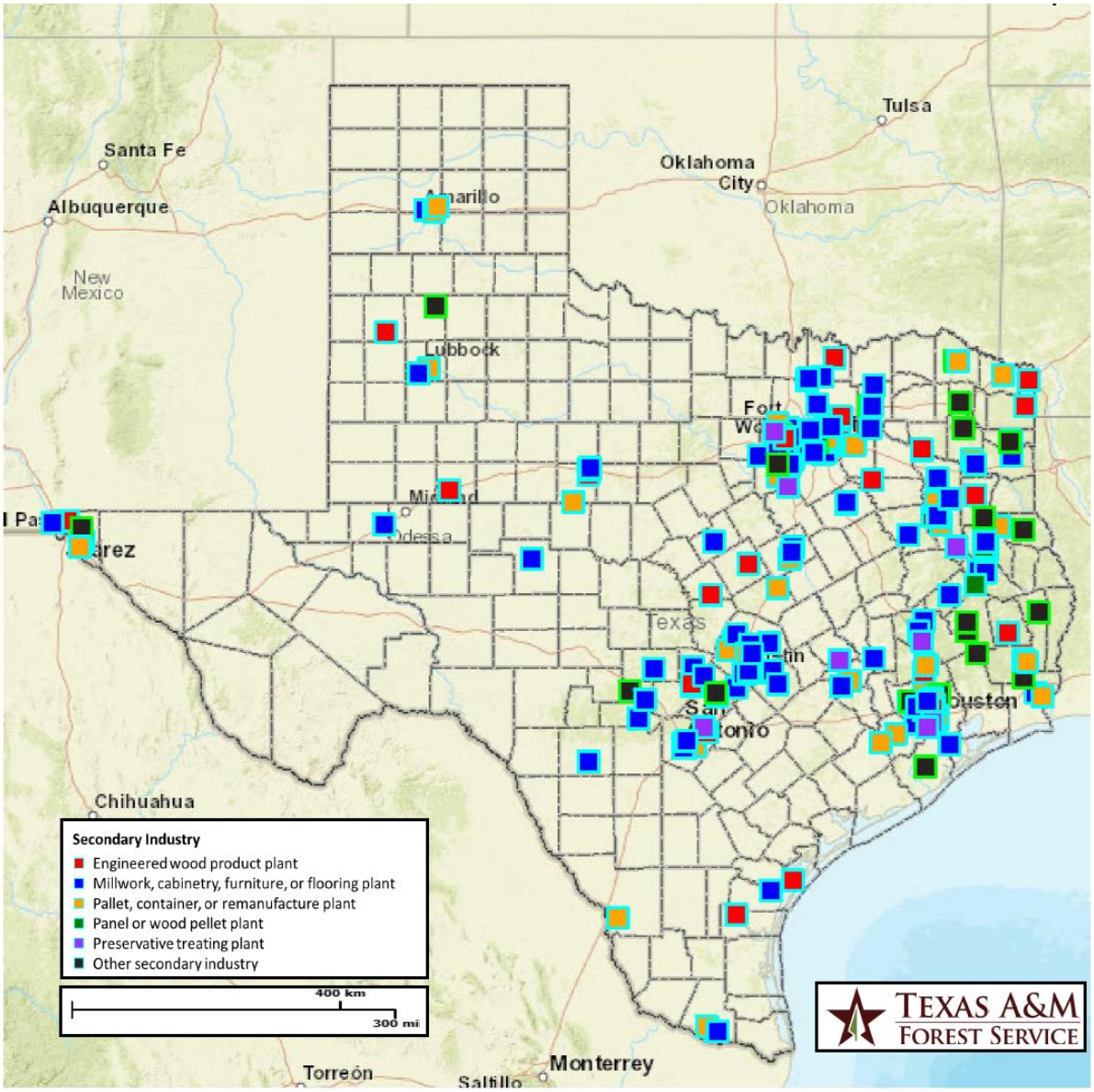
[10] Parajuli R., Zehnder R., A. B. Carraway, 2017. Economic Impact of the Texas Forest Sector, 2015. Texas A&M Forest Service

Figure 13 : Primary industry location



Source : adapted from http://tfsfrd.tamu.edu/ForestProductsDirectory/DirectoryofForest

Figure 14 : Secondary industry location



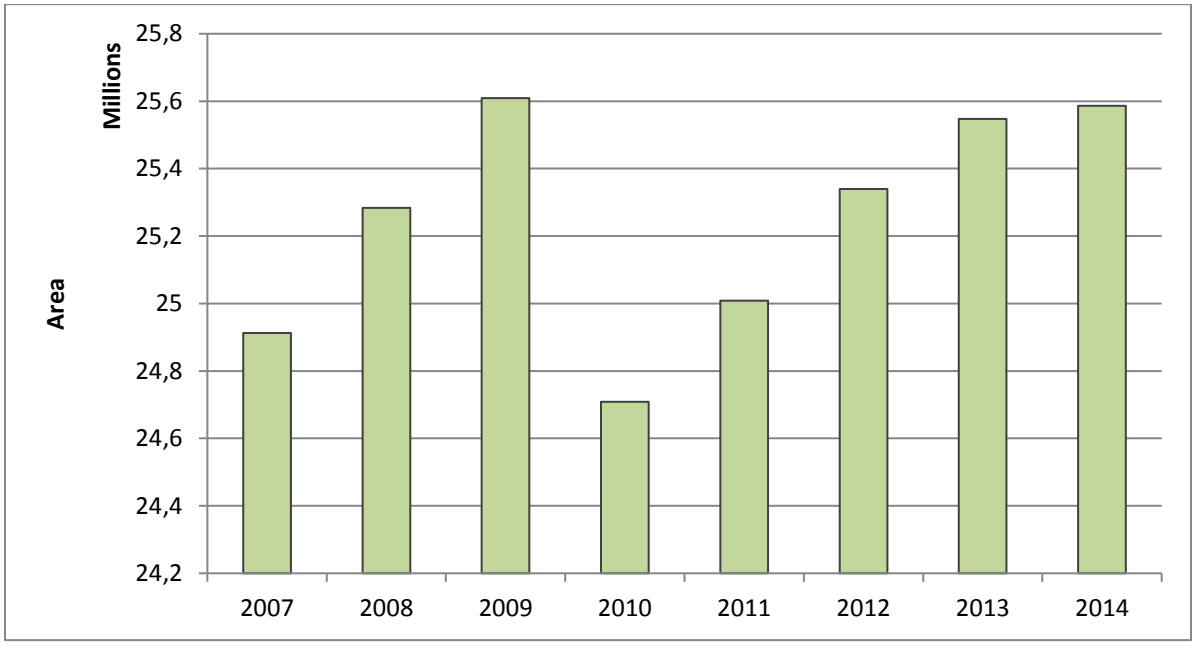
Source : adapted from http://tfsfrd.tamu.edu/ForestProductsDirectory/DirectoryofForest

3. Sustainability of Texas forest

3.1. Evolution of forest area a risk of conversion

According to the inventory, between 2007 and 2014, the area of forest land has been oscillating around 25 million ha (Figure 15). The area was increasing from 2007 until 2009. In 2010, forest land in Texas lost almost 1 million ha in one year. Since that year, it increased and almost reached 25.6 million ha in 2014.

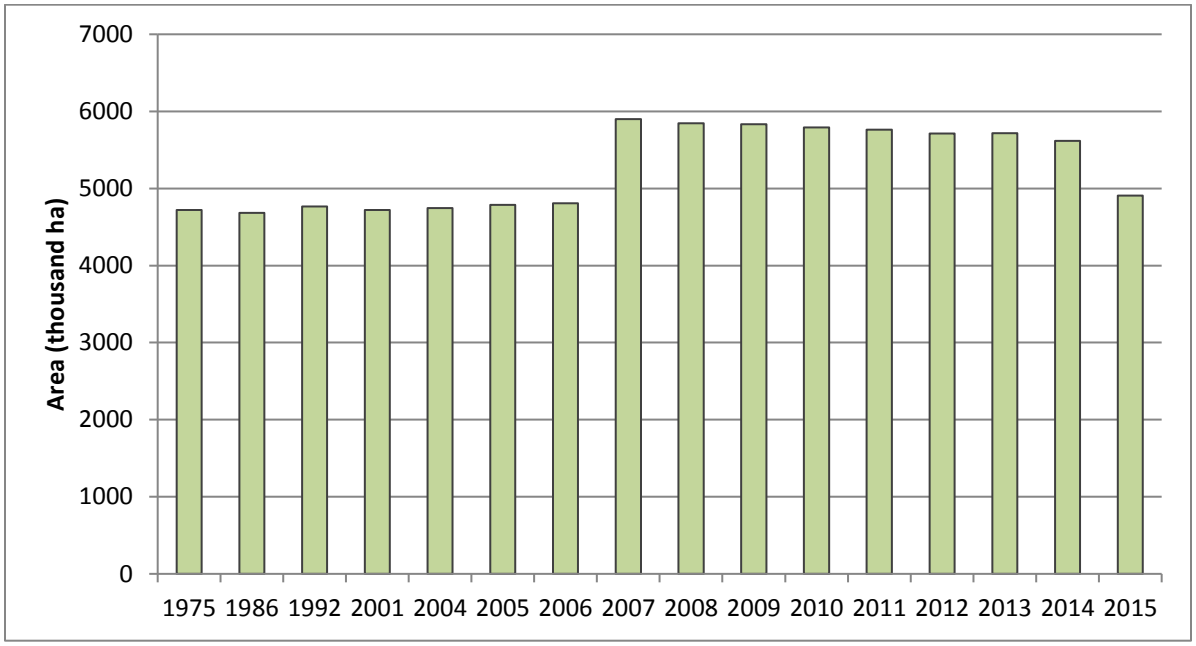
Figure 15 : forest land area over time in Texas (2007-2014)



Source: adapted from US Forest service, FIA Program (http://apps.fs.fed.us/fido/standardrpt.html)

Between 1975 and 2006, timberland area has been stable with 4.7 million ha. In 2007, the area increased by 1.1 million ha. Since that year, it slowly declined until 2014. In 2015, the area was at 4.9 million ha (Figure 16).

Figure 16 : timberland area over time in Texas (2007-2014)



Source: adapted from US Forest service, FIA Program (http://apps.fs.fed.us/fido/standardrpt.html)

Table 5 hereafter considers the most recent information available (2015) in the *US Forest Service* database[11] and summarizes area change.

Table 5: Evolution from forested area (2007-2014) and timberland (1975-2015) in Texas

Forest land	Forest land (ha)	Area change (ha)	Change (%)	Timberland (ha)	Area change (ha)	Change (%)
1975	-	-	-	4,719,445	-	-
1986	-	-	-	4,682,681	-36,764	-0.8%
1992	-	-	-	4,764,701	82,020	1.8%
2001	-	-	-	4,721,522	-43,179	-0.9%
2004	-	-	-	4,745,477	23,955	0.5%
2005	-	-	-	4,787,074	41,597	0.9%
2006	-	-	-	4,808,743	21,669	0.5%
2007	24,912,689	-	-	5,899,188	1,090,445	22.7%
2008	25,283,939	371,250	1.5%	5,844,777	-54,411	-0.9%
2009	25,609,104	325,165	1.3%	5,834,319	-10,458	-0.2%
2010	24,708,891	-900,213	-3.5%	5,790,269	-44,050	-0.8%
2011	25,008,503	299,612	1.2%	5,763,707	-26,562	-0.5%

[11] http://apps.fs.fed.us/fido/standardrpt.html

2012	25,339,396	330,893	1.3%	5,712,530	-51,177	-0.9%
2013	25,547,323	207,927	0.8%	5,716,320	3,790	0.1%
2014	25,586,436	39,113	0.2%	5,615,229	-101,091	-1.8%
2015	-	-	-	4,905,871	-709,358	-12.6%

Source: adapted from US Forest service, FIA Program (http://apps.fs.fed.us/fido/standardrpt.html)

The FSC risk assessment platform www.globalforestregistry.org considers the USA are at unspecified risk in terms of conversion of forest to other land uses, because the following criterion is not verified in the country:

- There is no net loss AND no significant rate of loss (> 0.5% per year) of natural forests and other naturally wooded ecosystems such as savannahs taking place in the eco-region in question.

Indeed, even though at the national level, forested area in the USA increases by 0.1% yearly on average, there are important regional variations and forest extent is known to be decreasing in different parts of the country. Hence the Global Forest Registry recommends performing an analysis at the state level.

3.2. Living wood volumes and removals

Table 6 and Figure 17 show the evolution of net volume, by forest-type groups, of live trees in forest land for the survey years available (2007-2014) in the Forestry Inventory and Analysis (FIA) of the USDA – Forest Service[12].

Since 2007, the net volume of growing stock has decreased by 0.3%. For the same period, forest land area has increased by 2.7%. Table 6 indicates that most of the increase in volume is due to loblolly pine, which is often planted (instead of naturally regenerated) and managed more intensively. While softwood increases mostly via loblolly and shortleaf pines, hardwood decreases. The groups presenting the biggest decreases during that period are oak/hickory group and oak/gum/cypress group.

Table 6: Net volume of live trees in forest land (at least 5 inch d.b.h./d.r.c.), in million m³, by forest-type groups and survey years

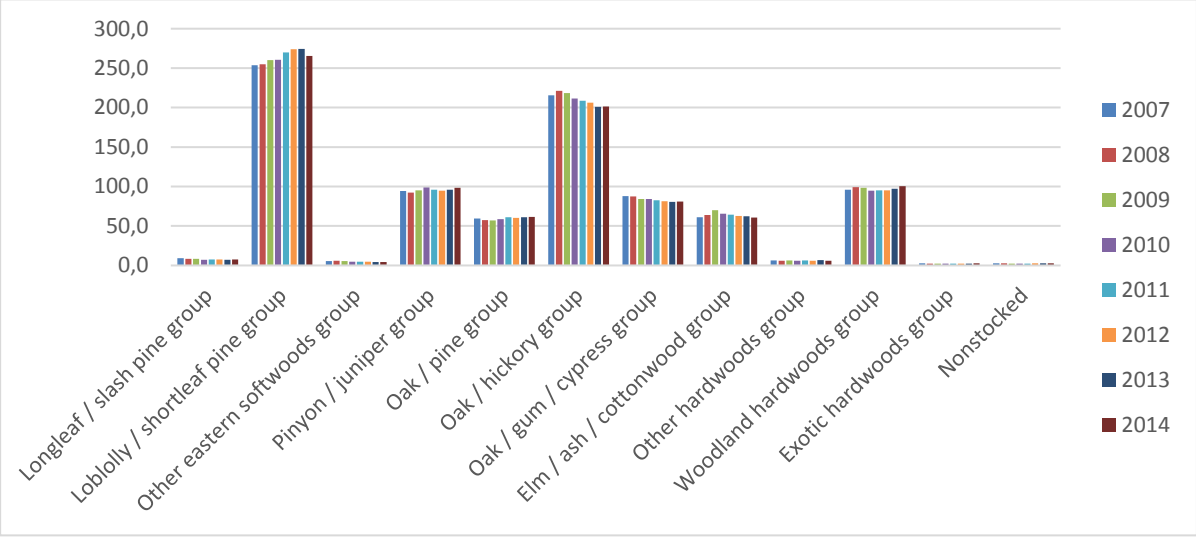
Forest-type groups	2007	2008	2009	2010	2011	2012	2013	2014	Change 2007-2014	
	Mm m³								Mm m³	%
Longleaf / slash pine group	9.3	8.5	8.3	7.0	7.8	7.7	7.0	7.7	-1.5	-16.7%
Loblolly / shortleaf pine group	253.7	254.7	260.3	260.5	270.0	274.0	274.5	265.3	11.6	4.6%
Other eastern softwoods group	5.4	6.0	5.5	4.9	4.6	4.5	4.3	4.4	-1.0	-18.7%
Pinyon / juniper group	94.5	92.4	95.0	98.9	96.1	94.7	96.1	98.3	3.8	4.1%

[12] http://apps.fs.fed.us/fido/standardrpt.html

Oak / pine group	59.6	57.5	57.1	58.7	61.1	60.3	61.3	61.5	2.0	3.3%
Oak / hickory group	215.6	221.4	218.3	211.4	208.6	206.2	201.1	201.4	-14.2	-6.6%
Oak / gum / cypress group	87.8	87.2	84.0	84.4	82.6	81.5	80.4	80.9	-6.9	-7.9%
Elm / ash / cottonwood group	61.2	63.8	70.1	65.5	64.5	62.7	62.5	60.9	-0.4	-0.6%
Other hardwoods group	6.4	5.9	6.5	6.1	6.2	5.8	6.6	5.9	-0.5	-7.7%
Woodland hardwoods group	96.1	99.3	98.3	94.9	95.1	95.2	97.2	100.3	4.2	4.4%
Exotic hardwoods group	2.6	2.2	2.3	2.2	2.4	2.3	2.3	2.8	0.2	7.7%
Nonstocked	2.5	2.5	2.5	2.3	2.4	2.6	2.7	2.8	0.2	9.3%
TOTAL	**894.6**	**901.5**	**908.3**	**896.8**	**901.4**	**897.6**	**895.9**	**892.1**	**-2.5**	**-0.3%**

Source: adapted from USDA – Forest Service (http://apps.fs.fed.us/fido/standardrpt.html)

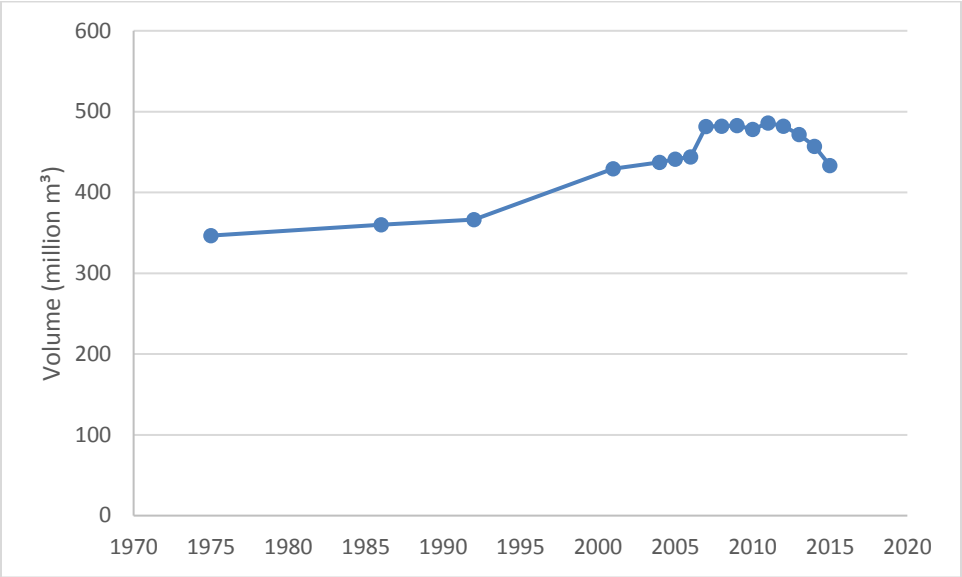
Figure 17 : Evolution (2007-2014) in million m³ of live trees in forest land (at least 5 inch d.b.h./d.r.c.) by forest-type group*



Source: adapted from USDA – Forest Service (http://apps.fs.fed.us/fido/standardrpt.html)

As oldest data are available regarding timberland in the FIA, the figure below shows the evolution of net volume of live trees since 1975. It increased until 2007 (with a sharp rise that year). It was stable for 5 years and began to decrease in 2012.

Figure 18 : Net volume of growing stock in timberland (at least 5 inch d.b.h./d.r.c.), in million m³ since 1975

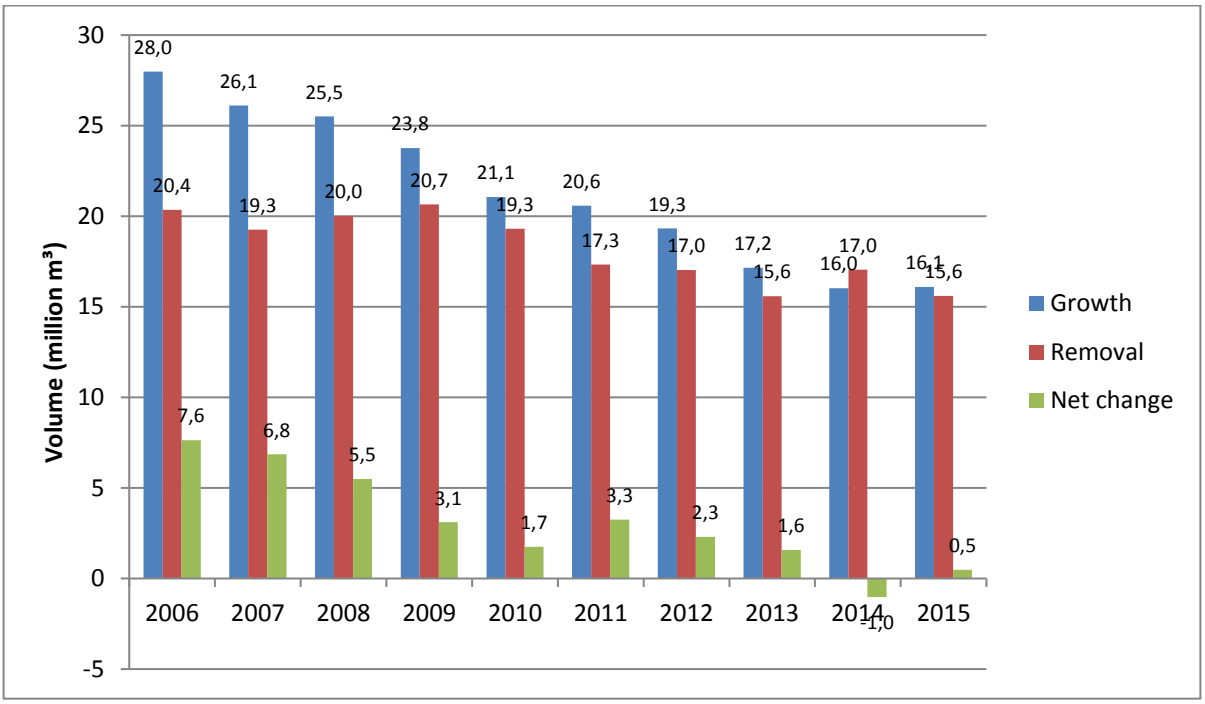


Source: adapted from USDA – Forest Service (http://apps.fs.fed.us/fido/standardrpt.html)

We can see on the Figure 19 that the net growth (for all species combined) exceeds removals every year except for 2014. The annual balance (net change) has almost been consistently positive. Removal of trees is not the cause for the decrease of growing stock in timberland. The negative trend can be explained either by the reclassification of timberland to other land uses such as urban development, agriculture or reserved forest land, or natural disasters such as drought that remove trees from the growing stock.

Whether it is growth or removal, it declines with time, that means the stock is becoming stationary. The decrease of growth for the period is more marked than removals.

Figure 19 : Average net annual growth versus removals (Harvests) of growing stock on timberland (2006-2015)



Net change = net growth - removals

Source: adapted from USDA – Forest Service (http://apps.fs.fed.us/fido/standardrpt.html)

3.3. Protection of ecosystems and biodiversity

The conservation land in Texas covers a small part of the state area. This includes both public and private land, under various conservation statuses. Figure 20 shows an overview of all protected areas in Texas. Those protected areas are either public (federal, state, county or local) and private lands.

There are different statuses for these conservation lands:

Status 1: An area having permanent protection from conversion of natural land cover and a mandated management plan in operation to maintain a natural state within which disturbance events (of natural type, frequency, intensity, and legacy) are allowed to proceed without interference or are mimicked through management.

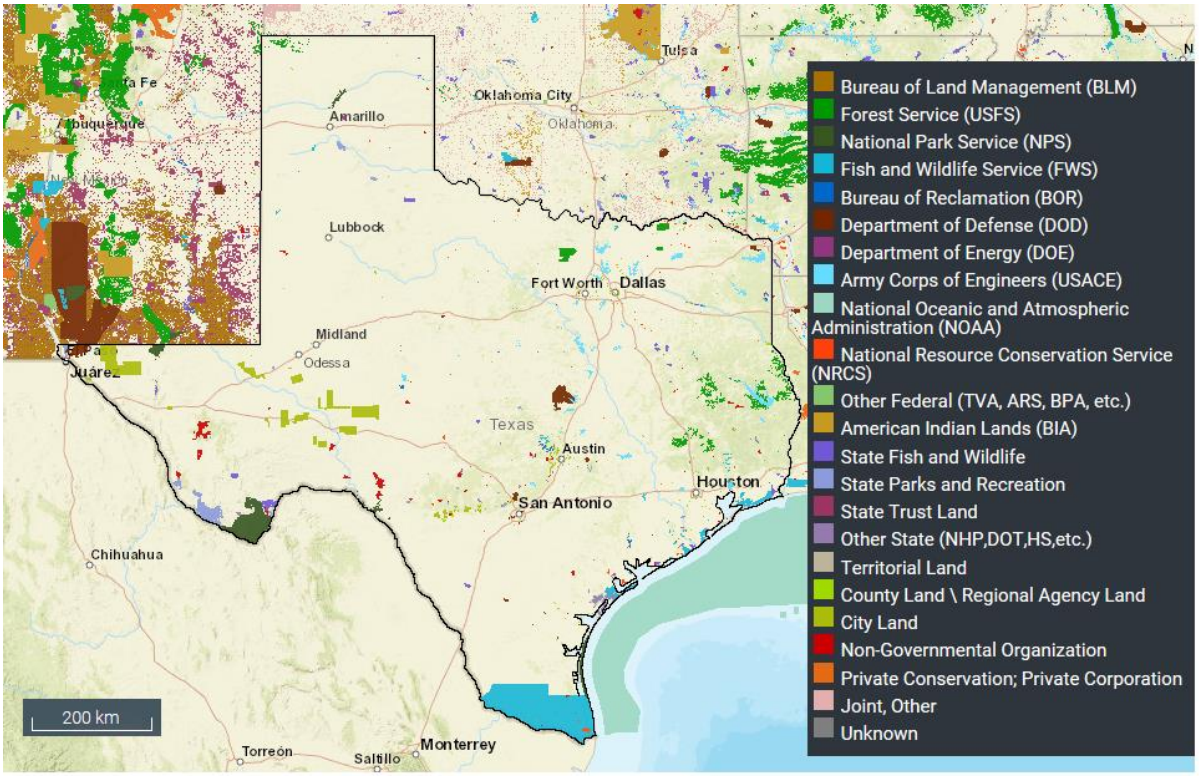
Status 2: An area having permanent protection from conversion of natural land cover and a mandated management plan in operation to maintain a primarily natural state, but which may receive uses or management practices that degrade the quality of existing natural communities, including suppression of natural disturbance.

Status 3: Area having permanent protection from conversion of natural land cover for most area. Subject to extractive uses of either broad, low-intensity type (eg. Logging) or localized intense type (eg. Mining) confers protection to federally listed endangered and threatened species throughout the area.

Note that different figures exist in terms of total conservation area in the State, depending on the categories of protection that are taken into account (particularly in the status 3 as defined above). For example, Figure 20 includes military zones, which are not designated for the purpose of biodiversity and ecosystems protection, even though they might be of considerable interest because the areas are very large and continuous, with most of the time very little human disturbance.

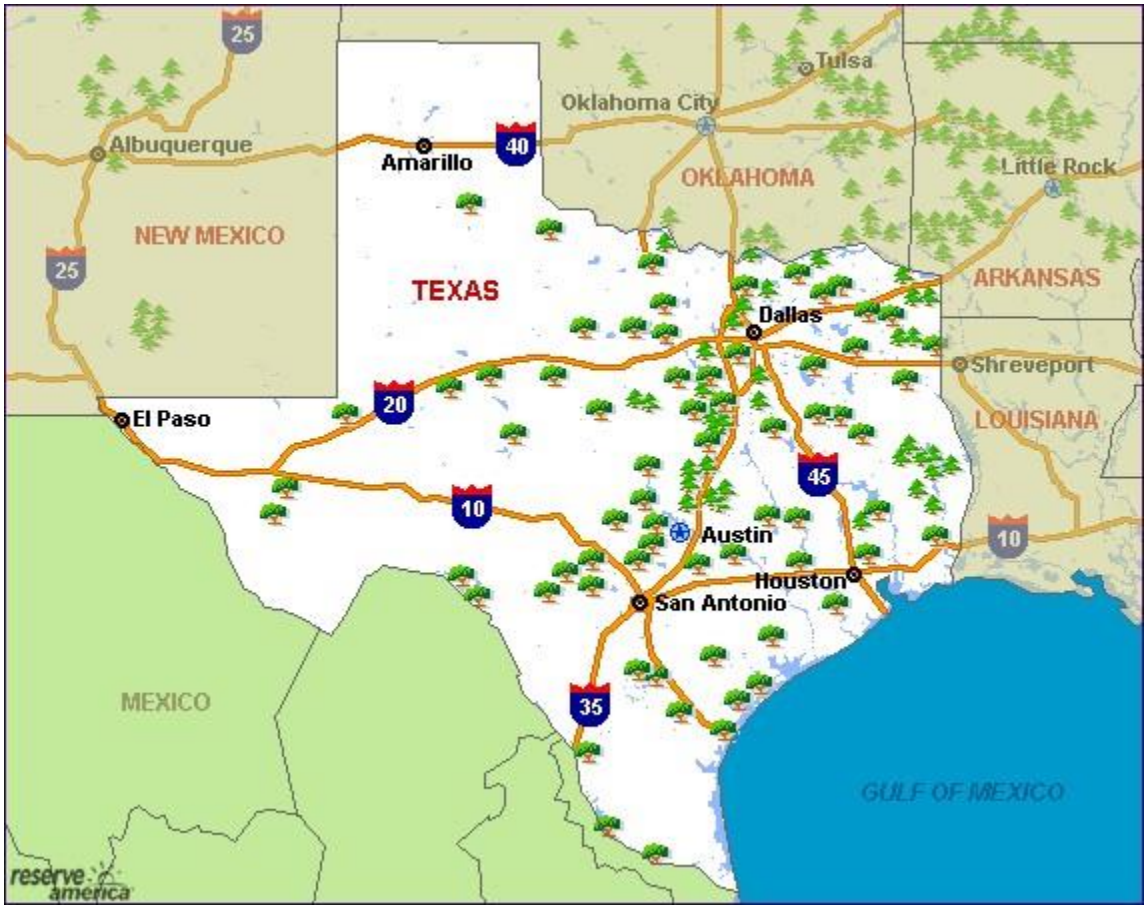
Figure 21 shows the location of State parks in Texas. Figure 22 shows the location of national parks in Texas.

Figure 20 : Protected areas in Texas



Source: National Gap Analysis Program (GAP) – Protected areas data viewer (http://gis1.usgs.gov/csas/gap/viewer/padus/Map.aspx)

Figure 21 : State Parks in Texas



Source: http://www.1830ndaytona.info/map-of-state-parks/map-of-state-parks-15-texas-state-parks-map/

Figure 22 : National parks in Texas

Source: adapted from https://www.nps.gov/index.htm

Table 7 shows the new surfaces put into conservation between 1998 and 2008. Unfortunately, more recent statistics were not available at this time regarding the new land put into conservation.

Table 7: New land under conservation status per year in Texas (1998-2008)

Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Total
Acres	33,532.6	18,711.3	35,385.2	58,291.8	21,771.6	74,850.9	25,922	26,114.5	29,128.7	29,851.3	25,855.3	379,415.2
Ha	13,570.2	7,572.2	14,319.9	23,589.9	8,810.66	30,291.1	10,490.3	10,568.2	11,788	12,080.4	10,463.3	153,544.0

Source : http://www.conservationalmanac.org

The increase of conserved lands shows a very irregular pattern. The total equals 153,544 ha.

Several conservation schemes have been introduced recently to increase the conservation land in Texas.

The most important programs are described hereunder[13]:

- **Texas Parks and Wildlife Department (TPWD)** will receive full funding from the general sales tax attributable to sporting goods. It was estimated that revenues from the sporting goods sales tax for TPWD for the 2014-2015 biennium would be approximately 265 million $. TPWD also uses proceeds from the sale of hunting and fishing licenses as well as the sale of a Horned Toad license plate to fund land acquisition. TPWD also administers the Local Park Grant Programs, which encompass six separate grants. These include: Outdoor Recreation, Indoor Recreation, Urban Outdoor Recreation, Urban Indoor Recreation, Small Community and Regional Outdoor Recreation (this program is currently suspended).

- **Texas Farm and Ranch Lands Conservation Program (TFRLCP)** was established by the legislature in 2005. The goal of the TFRLCP is conservation of working lands with high values for water, fish and wildlife, and agricultural production, especially lands at risk of development. TFRLCP conserves natural resources by protecting working lands from fragmentation and development. TFRLCP maintains and enhances the ecological and agricultural productivity of these lands through Agricultural Conservation Easements. It may be possible to leverage the current $2 million appropriation with other private, state, or federal dollars. The USDA Natural Resources Conservation Service (NRCS) conservation easement programs provide opportunities for leveraging.

- **Enable Local Financing:** The State of Texas authorizes and enables public bodies to acquire land and interests in land for conservation, parks, and agricultural purposes. To do so, public bodies, including municipalities, may appropriate funds, levy taxes, and issue general obligation bonds.

- **The Local Park Grant Program** includes six program categories and assists local units of government with the acquisition and/or development of public recreation areas and facilities throughout the State of Texas. The program provides 50% matching fund to eligible local governments. These are reimbursement grants. Eligible applicants include cities, counties, river authorities, municipal utility districts, and other special districts.

- **The Conservation Reserve Program (CRP)**[14] is a land conservation program administered by the Farm Service Agency. In exchange for a yearly rental payment, farmers enrolled in the program agree to remove environmentally sensitive land from agricultural production and plant species that will improve environmental health and quality. The long-term goal of the program is to re-establish valuable land cover to help improve water quality, prevent soil erosion, and reduce loss of wildlife habitat.

[13] http://www.conservationalmanac.org/secure/almanac/southeast/tx/programs.html
[14] http://www.nrcs.usda.gov/wps/portal/nrcs/main/la/programs/

- **The Environmental Quality Incentives Program (EQIP**)[15] is a voluntary program that provides financial and technical assistance to agricultural producers through contracts up to a maximum term of ten years in length. These contracts provide financial assistance to help plan and implement conservation practices that address natural resource concerns and for opportunities to improve soil, water, plant, animal, air and related resources on agricultural land and non-industrial private forestland.

- **The Farm and Ranch Lands Protection Program (FRPP)**[16]

- **The Wetlands Reserve Program (WRP)**[17]

- **Federal Partnerships:** Federal agencies and programs that have conserved land in Texas include:

  National Oceanic and Atmospheric Administration - Coastal and Estuarine Land Conservation Program (CELCP), Natural Resources Conservation Service - Farm and Ranch Lands Protection Program (FRPP), Natural Resources Conservation Service - Grassland Reserve Program (GRP), Natural Resources Conservation Service - Wetlands Reserve Program (WRP), U.S. Department of Defense - Readiness and Environmental Protection Initiative (REPI), U.S. Fish and Wildlife Service, U.S. Fish and Wildlife Service - Land and Water Conservation Fund (LWCF), U.S. Fish and Wildlife Service - National Coastal Wetlands Conservation Grant Program, U.S. Fish and Wildlife Service - North American Wetlands Conservation Act (NAWCA), U.S. Fish and Wildlife Service - Section 6 Grant, U.S. Forest Service, U.S. National Park Service, U.S. National Park Service - LWCF Stateside

According to Texas Land Conservancy 37352.9 ha of iconic landscape are protected in the state.

Table 8: Area of iconic landscape under protection in Texas

Region	Area (ha)
East Texas	14,139.7
Hill country	5,853.8
West Texas	9,988.9
South Texas	5,667.6
Central Texas	1,702.9
Total	37,352.9

Source: adapted from http://texaslandconservancy.org/protected-lands/

[15] http://www.nrcs.usda.gov/wps/portal/nrcs/main/tx/programs/
[16] http://www.nrcs.usda.gov/wps/portal/nrcs/main/tx/programs/
[17] http://www.nrcs.usda.gov/wps/portal/nrcs/main/tx/programs/

3.4. Protection of water

In the US, the Clean Water Act (CWA) was introduced in 1972 to regulate the discharge of pollutants in water. In this framework, forestry operations are considered as nonpoint sources and, hence, are generally exempted for permit under CWA as long as Best Management Practices (BMP) are developed and implemented. It is the responsibility of states to develop, implement and assess the Best Management Practices, under the control and funding of the federal Environmental Protection Agency (EPA). Even though the impact on water is the core of the BMP, many states have gone further and used the BMP as a tool for other management purpose (soil, landscape, wildlife etc...).

In Texas, forestry BMPs are voluntary conservation practices that protect soil and water resources, two key elements necessary for growing a healthy, sustainable and productive forest. BMPs can include methods such as leaving a buffer zone of trees next to a stream, installing a culvert to cross a waterway or establishing grass on forest roads to prevent erosion.

Texas A&M Forest Service, in cooperation with the forest sector and numerous other partners, develops and periodically updates BMP guidelines, provides education, outreach and training on their application, and monitors their implementation on randomly selected forest operations. Over the years, BMPs have become standard throughout the forest sector.

The guidelines developed by the BMP are[18]:

- Planning for forest operations
- Road construction and Maintenance
- Road Material Sites
- Harvesting
- Site preparation/Planning
- Fire management
- Sylvicultural Chemicals
- Streamside Management Zones (SMZs)
- Forest Wetlands

These Forestry Best Management Practices are a part of the Nonpoint Source Management Program administered by the Texas State Soil and Water Conservation Board. Under the requirements of the Agricultural Code of Texas, the Board is responsible for planning, implementing, and managing programs and practices for abating agricultural and sylvicultural (*forestry*) *nonpoint source pollution*. The specific sylvicultural practices section of the program was modeled with contributions from Texas A&M Forest Service and Texas Forestry Association.

[18] https://tfsweb.tamu.edu/uploadedFiles/TFSMain/Manage_Forest_and_Land/Water_Resources_and_BMPs/Stewardship(1)/Texas%20Forestry%20BMP%20Handbook.pdf

TFS regularly monitors randomly selected forest operations to evaluate the level of BMP implementation in Texas. Since 1991, overall BMP implementation has increased by almost 20 percent to an all-time high of 94 percent in 2011.

TFS also conducted an intensive, highly technological stream monitoring project designed to test the effectiveness of BMPs in protecting water quality. Results showed that Texas BMPs, when applied properly, are effective in protecting water quality.

All the survey across the years are described as follows: *"Overall BMP implementation on forest operations in East Texas has shown tremendous improvement since the first round of monitoring was completed in 1992. Implementation on public and industrial sites has shown steady improvement over the previous eight rounds[19]. Implementation on industry lands dropped slightly in Round 7; however, only 8 industry sites were included in that round as compared to an average of 50 sites in the previous six rounds. This is reflective of the divestiture of industrial forestlands that began prior to 2005, which resulted in a shift in ownership type. Implementation on industry lands in Round 8 rebounded to 97.7%, an all-time high for this landowner type. The corporate category was established in Round 6 in response to these changes in ownership and has demonstrated a high, steady rate of implementation over the last three rounds. Of the four ownership categories, family forest owners have shown the most remarkable progress in BMP implementation, improving from 69.8% in Round 1 to 88.0% or more in the last three rounds."*[20]

The results from the 2015 monitoring survey (round 9) are: *"BMP implementation on public land for Round 9 was 100% with no significant risks to water quality identified. Implementation on corporate land during this period was 94.5% with one significant risk. Family forest owners received an implementation rating of 93.0% with one significant risk. This resulted in an overall BMP implementation rating of 94.0% with a total of 2 significant risks across all ownership categories."*[21]

3.5. Protection of soils

The protection of soil, including soil erosion, soil compaction and soil fertility, is addressed in the Best Management Practice applicable to forestry in Texas. It includes considerations of soil in the following topics:

- Forest roads (location, construction, maintenance, planning and water crossings)
- Road material sites (planning and layout, actives sites, reclamation)
- Harvesting (harvest design, skidding, landings, revegetation)
- Site preparation/planning
- Fire management (prescribed fire, fire line, fire lane maintenance)
- Sylvicultural chemicals (planning, managing spills)

[19] A round corresponds to a monitoring survey accomplished during a certain year between 1992 and 2015.

[20] http://texasforestservice.tamu.edu/uploadedFiles/TFSMain/Manage_Forest_and_Land/Water_Resources_and_BMPs/Stewardship(1)/RD%209%20BMP%20Implementation%20Report%20-%20printers.pdf

[21] http://texasforestservice.tamu.edu/uploadedFiles/TFSMain/Manage_Forest_and_Land/Water_Resources_and_BMPs/Stewardship(1)/RD%209%20BMP%20Implementation%20Report%20-%20printers.pdf

- Streamside management zones (planning design, canopy and vegetation criteria)
- Forest wetlands (mandatory roads, site preparation, fire management)

No evidence of monitoring programme at the State level can be found in order to assess the soils condition (erosion, compaction, fertility) as well as their evolution over time.

3.6. Protection of carbon stocks

In forest land the carbon stocks mainly include:

- living above ground and below ground woody biomass,
- soil organic carbon,
- carbon in litter.

We have seen in section 3.2 that the volume of live trees has been oscillating in Texas over the last three decades. Forest land area is increasing and timberland area is slowly decreasing since 2012. In this context, the total sequestrated carbon stock in living biomass has increased compared to 2007.

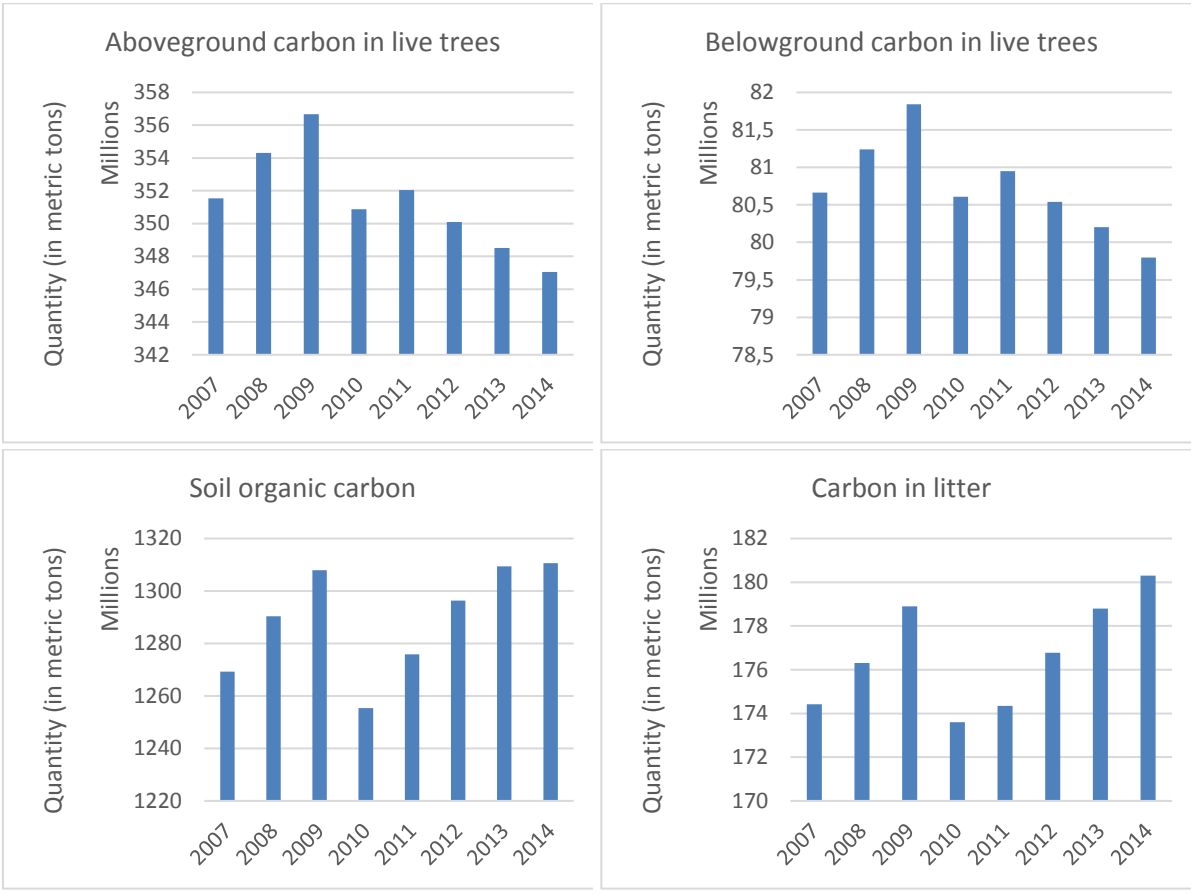
As shown in the Table 9 and related Figure 23 (data from the US Forest service (FIA Program)), above and belowground carbon in live trees follow the evolution pattern of the volume of live trees, a growth followed by a drop in 2010, a small increase and a decrease since 2012. Soil organic carbon and carbon in litter have the same trend. The quantity grows and faces a drop in 2010 and it grows again. The major contributor for the quantity of carbon is soil organic carbon with more than 1.3 billion tons in 2014. It is much bigger than above and belowground carbon in live trees. The area of Texas covered by trees is much smaller than the total area of the state.

Table 9: Carbon stocks evolution in forestland (2007-2014)

Year	In metric tons				
	Aboveground carbon in live trees (at least 1 inch d.b.h./d.r.c.)	Belowground carbon in live trees (at least 1 inch d.b.h./d.r.c.)	Soil organic carbon	Carbon in litter	Total
2007	351,532,985.5	80,664,530.61	1,269,292,671	174,426,054.8	1,875,916,242
2008	354,314,146.2	81,238,584.58	1,290,346,204	176,306,836.2	1,902,205,771
2009	356,673,757	81,840,553.54	1,307,889,250	178,896,206.1	1,925,299,766
2010	350,883,423.8	80,610,034.19	1,255,359,274	173,599,838.8	1,860,452,570
2011	352,045,921.5	80,949,474.7	1,275,811,878	174,347,659.5	1,883,154,934
2012	350,086,284.9	80,539,887.02	1,296,322,355	176,772,580.4	1,903,721,107
2013	348,516,653.4	80,200,962.71	1,309,375,014	178,800,872.8	1,916,893,502
2014	347,059,247.1	79,798,219.74	1,310,566,065	180,301,594.5	1,917,725,126

Source: adapted from US Forest service, FIA Program (http://apps.fs.fed.us/fido/standardrpt.html)

Figure 23 : Carbon stocks evolution in forestland (2007-2014)



Source: adapted from US Forest service, FIA Program (http://apps.fs.fed.us/fido/standardrpt.html)

3.7. Protection of air quality

The main impact of forestry on air quality relates to the use of fire. In Texas, Fire was a natural ecological factor on most Texas rangelands before European settlement, therefore, native vegetation is well adapted to burning. Fire effectively suppresses most woody plants while encouraging grass and forb growth. However, sound range, livestock and wildlife management must accompany the use of fire if benefits are to be realized[22].

Using fire under controlled conditions is a common practice Texas forestry ("prescribed burning"), and can have different objectives:

- Prepare sites before seeding and planting

[22] https://www.landcan.org/pdfs/pwd_bk_w7000_0196.pdf

- Reduce hazardous fuels under tree stands to prevent wildfires
- Improve wildlife habitat
- Manage competing vegetation
- Control insects and disease
- ...

Many states across the United States have a large percentage of public land, making statewide coordinated prescribed burn plans feasible. However, 98 percent of Texas' land is privately held, which makes having a statewide plan more difficult.

The Prescribed Burning Board (PBB) regulates certified and insured prescribed burn managers who work to control vegetative fuels that can contribute to wildfires. Certified and insured prescribed burn managers help to manage, maintain and restore valuable ecosystems in Texas[23].

The BMP describes appropriate use of fire and prevention of wildfires, including appropriate implementation of fire line construction and maintenance.

The basic framework of a BMP consists of four steps that must be followed: planning, safe and effective execution of the burn and sound range, livestock and wildlife management before, during and after the burn.

Occasionally, during periods of relatively stagnant air, the Environmental Protection Agency and/or the Texas Commission on Environmental Quality can forecast or issue an 'Ozone Action Day' or 'Air Pollution Action Day'. When an 'Ozone Action Day' is forecasted, burn managers are asked not to ignite any new fires and to complete any fires burning at the time the 'Ozone Action Day' is declared.

3.8. Illegal logging

The FSC risk assessment platform www.globalforestregistry.org considers the USA are at low risk in terms of illegal logging, because the following criteria are all verified:

1.1 Evidence of enforcement of logging related laws in the district [24]
1.2 There is evidence in the district demonstrating the legality of harvests and wood purchases that includes robust and effective system for granting licenses and harvest permits [25]
1.3 There is little or no evidence or reporting of illegal harvesting in the district of origin[26]
1.4 There is a low perception of corruption related to the granting or issuing of harvesting permits and other areas of law enforcement related to harvesting and wood trade[27]

[23] http://www.texasagriculture.gov/Home/ProductionAgriculture/PrescribedBurnProgram.aspx
[24] www.illegal-logging.info ; www.eia-international.org ; http://www.ahec-europe.org/
[25] www.illegal-logging.info ; www.eia-international.org ; http://www.ahec-europe.org/
[26] www.illegal-logging.info ; www.eia-international.org ; http://www.ahec-europe.org/
[27] http://www.transparency.org/cpi2012/results

3.9. Civil rights and traditional rights

The FSC risk assessment platform www.globalforestregistry.org considers the USA are at low risk in terms of violation of civil and traditional rights, because the following criteria are all verified:

- There is no UN Security Council ban on timber exports from the country concerned
- The country or district is not designated a source of conflict timber (e.g. USAID Type 1 conflict)
- There is no evidence of child labour or violation of ILO Fundamental Principles and Rights at work taking place in forest areas in the district concerned
- There are recognized and equitable processes in place to resolve conflicts of substantial magnitude pertaining to traditional rights including use rights, cultural interests or traditional cultural identity in the district concerned
- There is no evidence of violation of the ILO Convention 169 on Indigenous and Tribal Peoples taking place in the forest areas in the district concerned

3.10. Forest certification

The main forest certification schemes used in Texas are:

- SFI (Sustainable Forestry Initiative[28]), which is endorsed by PEFC (Programme for the Endorsement of Forest Certification)
- ATFS (American Tree Farm System[29]), which is specifically suitable for small private owners
- FSC (Forest Stewardship Council[30]), which is represented in more than 50 countries.

Texas Forestry Association, through its SFI State Implementation Committee, is leading the implementation of SFI in Texas. Other active participants are forest resource companies, Texas Logging Council, Texas Forest Landowners Council, Texas A&M Forest Service and other members of the forestry community.

The certified forest area under each of those schemes as for 2011 is presented in the table hereunder:

Table 10: Certified forest land in Texas (2011)

	SFI	FSC	ATFS	Total certified
Acres certified	2,368,824	26,809	803,083	3,198,716
Ha certified	958,630.0	10,849.2	324,996.4	1,294,475.6
Percentage timberland	16.63 %	0.19 %	5.64%	22.46%

Source : http://www.southernforests.org/resources/publications/SGSF%20Forest%20Certification%20Report%20r1.pdf

[28] http://www.sfiprogram.org
[29] https://www.treefarmsystem.org
[30] https://www.us.fsc.org

4. Conclusions

Texas has a total area of forestlands that covers 36.7% of the state. Timberland, where wood is available for timber, represents 7% of the state. Around 94% of the forests are privately owned.

In forestlands, woodland hardwoods group is dominant with 37.2% of the total area. It is followed by the oak/hickory group (20.4%) and the pinyon/juniper group (15.3%). In timberland, 44.1% of the area is covered by Loblolly/shortleaf pine group (softwood). The next most common forest-type groups are oak/hickory (23.5%), oak/pine (11.7%) and oak/gum/cypress (11.3%).

Forests in Texas are managed at two levels: federal and state. The Forest Service – an agency of the Department of Agriculture – is responsible at federal level for the coordination of forest policies and the management of federal forests. At state level, the Texas A&M Forest Service is in charge of forest management.

Between 2007 and 2014, forest area grew to a maximum over 25.6 million ha, faced a drop in 2010 and grew again until 2014. Timberland is slowly decreasing since 2007, under 5 million ha in 2014. Since 2006, growth exceeds harvest (except for 2014). It means the decreasing volume of growing stockisn't related to timberland decrease.

Carbon stock in Texas' forests has the same trend as its area. It totalled 2.1 billion t in 2014. The biggest contributor to carbon stock is soil organic carbon (68%), followed by aboveground carbon in live trees (18%), carbon in litter (9%) and finally belowground carbon in live trees (4%).

Texas has various types of conservation lands dedicated to the protection of biodiversity and ecosystems, including State parks, National parks, private reserves... Between 1998 and 2008, 153 thousand ha have been put under conservation status. Several conservation programs have been introduced to increase the conservation land in Texas, including initiatives to encourage conservation on private land (which is particularly important given the proportion of private forests in Texas).

Texas has developed Best Management Practices (BMP) for forestry to comply with the Clean Water Act. Those BMP address both water and soil conservation. Texas A&M Forest Service, in cooperation with the forest sector and numerous other partners, develops and periodically updates BMP guidelines, provides education, outreach and training on their application, and monitors their implementation on randomly selected forest operations. From the 2015 monitoring survey, the overall BMP implementation rating was 94% with a total of 2 significant risks across all ownership categories.

Even though controlled fires are often used in forest management practices in Texas, the use of fire is strongly regulated and fire is banned from specific places during periods of relatively stagnant air in order to respect the air quality standards.

The FSC risk assessment platform www.globalforestregistry.org considers the USA are at low risk in terms of violation of illegal logging and in terms of violation of traditional and civil rights.

In 2011, 22.46% of timberland was under a certification scheme. It is either SFI, FSC or ATFS.

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