Draft (08/25/2007)

Conference on the Science and Education of Land Use:
A transatlantic, multidisciplinary and comparative approach
The Westin Washington, DC City Center
September 24-26, 2007

Change of Forest Ecosystem in the Long Sweep of History: An Economic Perspective

Yaoqi Zhang
School of Forestry & Wildlife Sciences
Auburn University, AL 36849-5418, USA
Phone: (334) 844 1041; Fax: (334) 844 1084; Email: yaoqi.zhang@auburn.edu

Abstract: Forest ecosystem is one of the most important ecosystems on the earth. The change in forest ecosystem has been shaped by the forces of nature, but also by the human forces in response to the changes in relative scarcity of the products and services to the human beings. For a long history worldwide, food has been relatively scarcer than wood, so forests have been largely changed into agricultural uses. However, modern agricultural technological advances and dramatic shrinking in forests during the last century make wood products as well as forest ecological services become relatively scarcer than food. Consequently, a large scale of agricultural lands have been converted back into forestlands. Meanwhile, plantations have replaced natural forests as a major timber supply in most countries. This paper first briefly explains the evolution of forest land use/cover from an economics perspective, then uses land use changes in China, US South and New Zealand as examples to support our argument. Finally some general conclusion and a perspective of the future forestland change are presented.

Keywords: forest transition, relative scarcity, land use change, the United States, New Zealand, China

Introduction

Forest ecosystem is one of the most important ecosystems on the earth. Forests can be either natural endowment, or man-influenced and man-made. For example, longleaf pine ecosystem is one of the evidence of the influence of fire by nature as well as by native American, while loblolly pine is largely man-made. For a long history worldwide, food has been relatively scarcer than wood, so forest lands had been largely changed into agricultural uses. The same trend will continue in most developing countries. But in some developing countries and many developed countries forests have ceased to shrink in area and have even begun to expand either by plantation or simply natural restoration– a reversal which in literature is called forest transition (e.g., FAO 2006).

Land use by human beings is largely in response to the relative scarcity and economize the land and other resources. When forests are abundant, they are converted to agricultural land, when food is more abundant due to technological advancement, agricultural land is converted to forestland. For example, rise in timber price would result in more logging on natural forests to make remote forest resources more accessible and drive the rainforest disappear, but promote forest plantation (especially the eucalyptus and some southern pines) that would shift other land use in to forests in Hainan Island in China (Zhang et al 2000). The establishment of longleaf and planting loblolly in Southern U.S. are caused by different reasons even though both are pines. In New Zealand, two kinds of forests (natural forests and plantation) are fundamentally different in ecological function, motivation and in response to socio-economic circumstances.

This paper is made to attempt to formulate an integrated economic framework of the deforestation and forest transition and to provide empirical evidence from China, New Zealand and the US South from a long sweet of history.

Simple Economic Model of Land Use/Cover

When abundant frontier land available

Most studies on land use/cover are in the duration of short period of time, and for permanent settled society. But if we divide the human history into four ecological phases, (1) hunting and gathering, (2) the early farming phase, (3) early urban phase, and (4) current high-energy phase, the first phase is far more longer than the later phases (Steiner 1993).

During the hunting and gathering and the early farming phase, population density was very low, transportation and farming was very primitive and land was very abundant, it was more economic to live nomadically since moving "home" to close resource costs less than traveling long distance to get foods. Therefore, land tends to be used intermittently, with heavy reliance on fire to clear fields and fallowing to restore fertility (often called shifting cultivation or slash and burn farming) (Boserup 1965). Under this farming system, the change of land from forestland to agricultural land is usually not permanent. The decision of the settlers is not between agriculture and forestry (no forestry at that time), but between farming and fallowing and between settlement in one place and moving to a new place. The mosaics of the landscape depends on the population density. Only when population density rises to some level, would some land adopt annual cultivation using field preparation, weed control, and irrigation.

Under abundant land available, populations are always seeking for cheap resources, including land and forest resources. The past 3 centuries of the North American is the best example. Population growth changes the land-labor ratio. Consequently, changes in the relative value of land and labor lead to an increase in the value of inferior land. With respect to forest resources (or land), the decline in the forest-labor ratio increases the relative value of forests and decreases the value of labor. Thus increasingly remote forest (or land) becomes valuable and labor spreads out to seek its higher value. In other words, when population migration is less costly than transporting the resources, population will move to locations close to the resources. The population movement can occur either as a slow spread of population, or as big new settlement projects which are rapidly established. This process will continue as long as any virgin land and frontier forests remain. Historically, population migration plays a much more important role in forest change than the local growth of population. Even in modern time (e.g., in the 19^{th} and early part of 20^{th} century in the US), logging was typically cut and run since that is most economic way of using forest resources when resource is abundant.

Land Use for Agriculture versus Forestry

The biggest conflict among land uses in modern history is between agriculture and forestry (Clawson 1981). When permanent agriculture develops, the land use/cover change can be very much used model developed by von Thunen (1875). It was illustrated by Figure 1 in the context of forestland and agriculture (Zhang 2000). Land is used for the option which creates the highest land rent in a competitive land market. Therefore, the land use option and forest management method are determined by the land quality and socio-economic environment. Land quality is a broad concept here, referring not only to soil, steepness, incidence of rocks, sources of water and exposure to wind and sun, but also to distance and types of roads to market and habitation, etc. The socio-economic environment refers to the output and input prices, and institutions. The input and output prices can be measured on-site and in a market. Prices may vary greatly when transportation costs are significant.

The land rent for forestry or any other land use is determined by the output prices, the input costs and the land quality. For simplicity, agriculture is considered as the only other land use option. If we use (p_a, w_a) and (p_f, w_f) to represent the set of output price and input cost by agriculture and forestry respectively, the land rent (μ) for agriculture and forestry with land quality *q* will be $\mu_a(p_a,w_a,q)$ and $\mu_f(p_f,w_f,q)$. If $\mu_a(p_a,w_a,q) > \mu_f(p_f,w_f,q)$, the land will be allocated to agricultural use. Otherwise, the land will be used for forestry. For instance, the land to the left of A in Figure 1 should be allocated to agricultural use, and the land to the right of A should be used for forestry. On the boundary, the rents for agriculture and forestry are equal (if not equal, the land use will be changed).

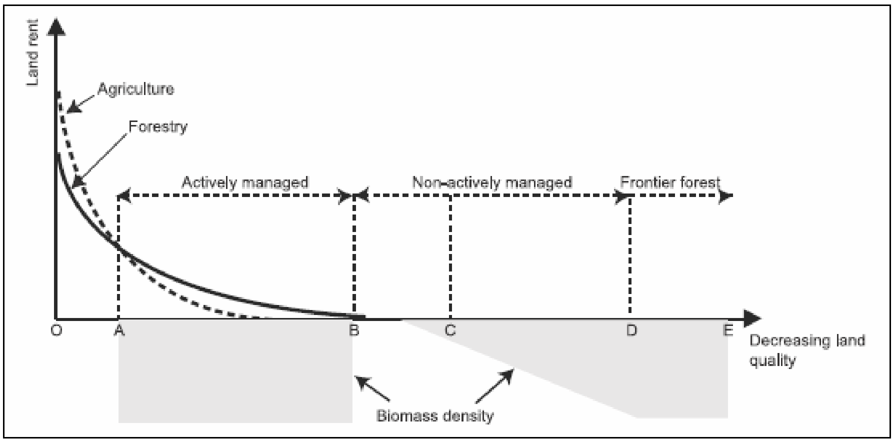


Figure1: Shift between forest land and agricultural land.
(Source: Zhang 2000)

Forest Cover and Forest Land Use

Since a large amount of land is covered by forests by natural endowment (either old forest or second growth) rather than intently or actively managed/planted. It is important to distinguish between forest cover and forest land use. Forest land use refers to "forest land under active management" that is "according to a professionally prepared plan or is otherwise under a recognized form of management applied regularly over a long period (five years or more)" (FAO 1995a).

The earth might be largely covered by forests but cannot called as "forest land use" prior to presence of human beings. When population was low, land was never intended used for tree growth. The abundant forests do not justify any forest management and intended management. In Figure 1, only the land to the left of B is under active forest management. The inaccessible forests, which are located to the right of D in Figure 1, means that the costs to get it is more than the value. Since the forests already exist, their value is not related to soil productivity, but is closely related to the status of the forests, depicting species, the growing stock of the forests, the distance and the accessibility to the market, and harvesting and transport technology. If everything equal, harvesting cost is very much proportional to the distance between the market, so the density of biomass that is economically accessible to harvest is like the area between B and E in Figure 1.

Causes for Shifts in Land Use and Management

Increasing timber prices or decreasing extraction costs – due to road construction or improved logging or transportation technology – will make more remote forests increasingly exploitable, shifting the forest frontier (Point D in Figure 1) and probably some secondary forests (Point C) to the right. Frontier forests on a large scale are located in remote and less populated regions. Since most of these forests are owned by the state or are in open access, any change in the frontier will greatly depend on public policies in road expansion, population settlement and logging regulations.

Point A in Figure 1 shifts when on-site output or input prices for agriculture and forestry and land quality change. For simplification, we just consider the changes in input and output prices and do not consider land quality change that may derive from road expansion, soil degradation, etc. Graphically, if prices for agricultural goods rise (or input price decreases), the curve of the agricultural rent will shift to the right, and some of the forestry land will be devoted to agriculture, moving A rightward. Alternatively, if the prices of forest products rise (or its input price decreases), some of agricultural land will be devoted to forestry, moving point A leftward. Forest land conversion to agriculture and other uses might be significant during the early stage of economic development as wood price is unlikely rising as fast as food simple because of low demand for wood and more available both from natural re-growth and larger distance.

In the short term, it is assumed that population settlement remains static. Point A in Figure 1 could be very sensitive to the change of the relative market price of timber and other goods that are largely based on land. During the early stage of economic development of a country with substantial natural forest growing stock, the elasticity of timber price to population growth is likely to be less than the elasticity of food price to population growth. Consequently, agricultural expansion is likely, and Point A in Figure 1 usually shifts to the right.

The land use change is generally associated with population migration. The migration might be from settled area to frontier area, but can also from high density area to lower density area. The general path on forest change in the context of population change is, therefore, as follows: First, as the population grows and the economy develops, the speed with which A in Figure 1 shifts to the right for agricultural expansion, and the speed with which D shifts to the right for timber extraction from frontier forest is faster than the movement of B to the right. The area between B and D is largely bareland, open forest and shrubs, and non-actively managed forest land. Whenever a large forest area or other land resources are not inhabited and used, population migrations into these areas are likely to occur. Therefore, deforestation could occur for a quite long period of time. When Point D approaches E, pushing D to the right is difficult because of increasing marginal costs. The speed with which B moves to the right increases as price increases. Finally, forest expansion becomes dominant. At this time, large population movements are mostly characterized by urbanization. Forest cover would cease to decrease, remain stable, or perhaps even begin to increase.

In the following sections, I would like to use China, US South and New Zealand as examples to demonstrate the long sweep of history of land use/cover change from an economic perspective.

China

If the current territory of China (see Figure 2) is divided by a diagonal line from the northeast to the southwest, the original vegetation cover can be classified into three categories: Forest land dominated the area with a extensive and dense forest cover of over 70–90% to the right of the diagonal; grassland and forest with 20–30% forest cover dominated in the transition zone, along the diagonal line; and as the third category desert and bareland dominated with less than 5% scattered forest to the left of the diagonal. The types of forests varied from boreal forest in the northeast, temperate deciduous broadleaf in the north, and mixed deciduous and evergreen broadleaf forest in the south, with tropical forests in the southernmost region of China. Thus, about half of the land was originally covered by forest. Liu and Wang (1989) estimated that in 2700 BC there were six provinces with more than 90% forest cover and 14 provinces with more than 50%.

In general, the demand for agricultural land and timber following human settlement and growth are clearly the primary causes of forest loss. However, the rate of agricultural land expansion is much lower than that of the population, and deforestation is much faster than the agricultural land expansion. As early as the Tang and Yao era (about 2500 BC), shifting cultivation was extensively carried out and continued for one thousand years during the Xia and Shan Dynasties (2100 BC–1100 BC). During the early Han Dynasty (206 BC–220 AD), the Chinese began a systematic land reclamation and irrigation schemes.

To summarize, China's deforestation started in the Loess Plateau Area in the central China, moving eastward along the Yellow River to the current Shanxi, Henan and Shandong Provinces, then spread northward to the current Hebei and Beijing regions, and finally moved beyond the Great Wall to northeast China. Meanwhile, the population moved southward to southern China, even across the sea to Hainan Island. In general, the plains and locations along major rivers were usually occupied and cultivated first, then progressed to low hilly regions and finally to mountainous ranges.

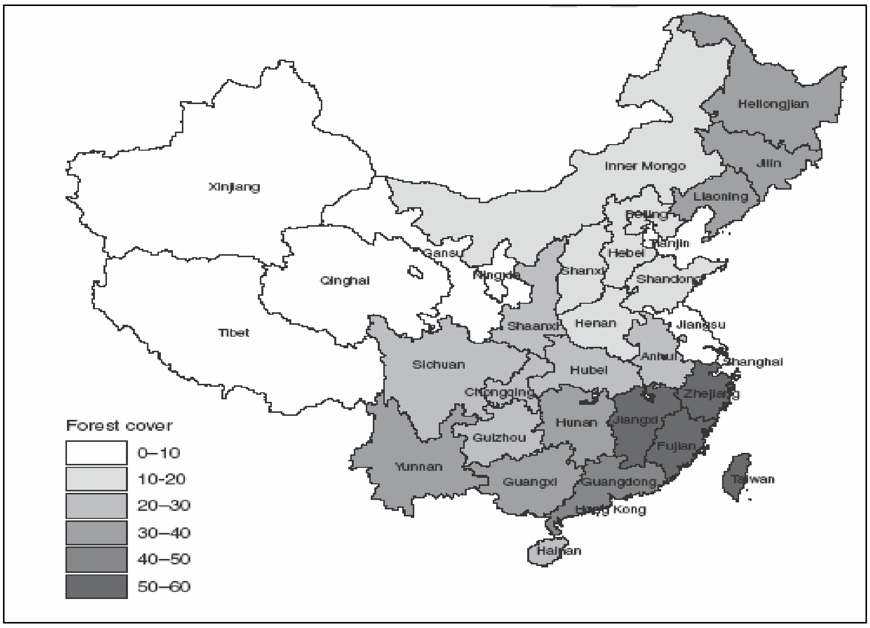


Figure 2 : China Forest Coverage

Prior to the 1940s, there was no national-wide data regarding forest cover in China. Data concerning China's forest resources was published in the China Yearbook in 1943 and on at least ten other occasions before the first national forest inventory (1973–1976). All the data, basically relying on the data of 1943, stated that the forest cover rate ranged from 5% to 8%; the 8% is more often cited. These figures, however, are misleading. The mistakes resulted from both incorrect estimates and varying definitions, such as definition of forest, the territory of China, etc. Unfortunately, many public officials and academics, both domestic and international, have used this data as a point of reference (Chu 1988). Thus, this 1943 forest area became the most widely recognized benchmark when the People's Republic of China was founded in 1949. In fact, it is reasonable to believe that the 1949 forest area proportion was about 15% assuming the same definition of forests.

Since the 1970s, China has conducted six national forest inventories (see Table 1). FAO (1995b) assumes that the reliability class is 1 for the state estimates and 2 for the change assessment (range from best = 1 to worst = 3).

If we analyze the forest land use/cover change in the past 50 years, in the first 20 years (1950-1970), some significant frontier forests in the Northwest and Southwest had been logged (moving point D to right); from 1960-1970, a large of forestry land had been converted into agricultural use (Moving point A to right); from the 1970 to current time, the most significant change has been from the non-actively managed forestry land into active forest management land by primarily plantation (moving the point B rightward); from the 1980s to current time the remaining virgin forests, together with some secondary natural forests, have been protected to fulfill environmental services. The biggest contribution to change the non-active management to active management is the improved the socio-economic conditions and institutions, including laws and property rights security, will reduce the protection costs and the risks that investors must bear. The development of institutions has already played a role in the forest transition and will continue to be important in the sustainable expansion of forests.

Table 1: China's forest resources, 1973–2003.

Years of inventory	Forestry land*		Forest		Forest cover
	Area mill. ha	Stock bill. M^3	Area mill. Ha	Stock bill. m^3	%
1973–1976	257.6	10.3	121.9	9.4	12.7
1977–1981	267.1	10.3	115.3	9.0	12.0
1984–1988	267.4	10.6	124.7	9.1	12.3
1989–1993	262.9	11.8	133.7	10.1	13.9
1994-1998	263.3	12.5	158.9	11.3	16.55
1999-2003	284.9	NA	174.9	12.5	18.21

Source: China's National Forest Resources Inventories (1973–2003)

Note *The concept of *forestry land*, frequently used in China means all the land with a present or potential future forest cover, or the land that is allocated for forestry purposes. So not all forestry land are forested, but may be with some trees.

Hainan Island

Hainan is a good example of showing the forest land use change in China. Hainan is a tropical island of 3.4 million hectares in the South China Sea. Hainan was originally covered by tropical rain forest. The forestland had been gradually replaced by agricultural uses gradually from the seashore moving into the central mountainous area. Initially it was mostly by shifting cultivation, then permanent agriculture.

Rainforests still covered 50% of the island in the early 1930s. During World War II, a huge amount of timber was removed for road construction and war preparation, and more was destroyed by forest fire. By the early 1950s forest cover had declined to about thirty percent of Hainan's land area and the remaining forest was mostly located in central mountain ranges (HAZC 1980). Forest cover continued to decline is response to expanding demands for wood, both within and outside the island. About 40,000 to 60,000 m^3 of tropical logs annually flowed off the island from the late 1950s to the early 1970s. Forty thousand hectares of rainforest had been logged by the end of the 1980s with very little silvicultural reinvestment. After repeated logging, many harvested sites shifted to degraded shrubs or even bareland. Hainan went from being a net exporter of timber in the 1950s to an importer in the 1980s.

Tropical tree crops (rubber, tea, fruit) were introduced at the beginning of the 20th century but the area in these crops did not expand significantly until the 1950s, when it expanded dramatically. Agricultural land use did not expand significantly since the 1950s. By the late 1970s Hainan's forests had shrunk to their minimum—fifteen percent of total land area. Degraded lands had become the largest category of all forestland, accounting for one-fourth of Hainan's land area by the mid-1970s (HAZC 1980).

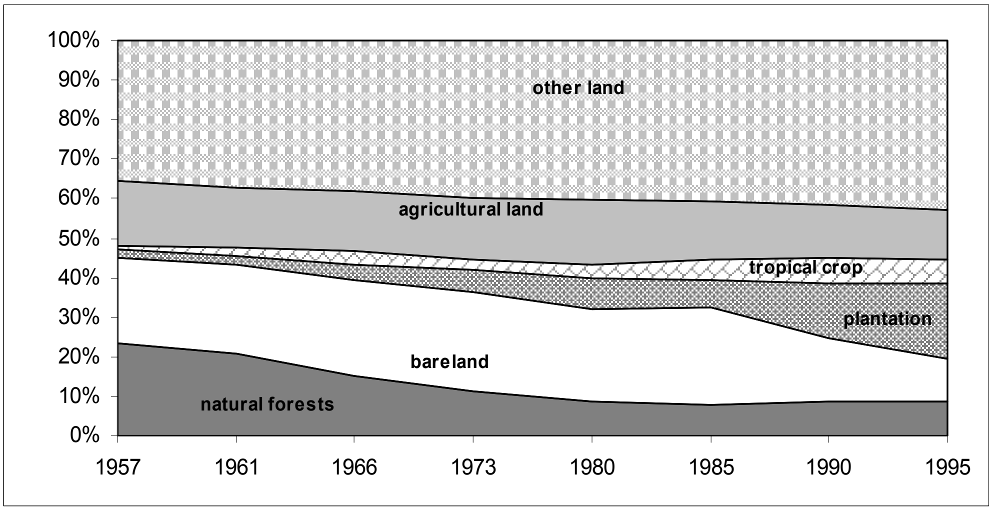


Figure 3: Land use/cover change in Hainan (1950s to 2000s)

The declining trend in forest cover reversed in the late 1970s, and the land area in forest is expanding at present (see Figures 3). Such change is fundamentally in response to the rise in timber price (eucalyptus woodchips) and appreciating of the remained natural forests. Currently plantation forest is much larger than the natural forests. Therefore, Hainan provides empirical support for the “forest transition” hypothesis that suggests that, with economic growth, forest cover first declines with initial economic growth, and then eventually begins to increase with further growth (Mather 1990, Hyde et al. 1996, Rudel 1998, and Zhang 2000).

US South: From Longleaf to Loblolly

There is growing evidence that the United States’ roots are not in a state of "pristine" nature but rather in a "human-modified landscape" over which native peoples have since long exerted vast control (for its original range see Figure 4A). American Indians had been manipulating the environment, primarily with fire for a minimum of 12,000 years (Carroll et al. 2002). Fire, Native Peoples, and the natural landscape seeks a middle ground between those conflicting paradigms, offering a critical, research-based assessment of the role of Native Americans in modifying the landscapes of pre-European America (Vale 2002). For thousands of years the Indians employed a pattern of land use that influenced the landscape.

Longleaf pine ecosystem to some degree was the result of the agriculture, hunting and Indian lifestyle and economy. The longleaf is a hardy species, relatively wind firm and resistant to many insects and tolerant of fire and even requires fire for its survival. Fire was the most effective tool for the Native American, who first settled primarily along floodplains and largely depending on fishing then spreading out with larger areas and increasingly dependent on hunting and finally on cultivation. The extensive use of fire was supported by biological evidence for native burning and witness of the early European (Landers et al. 1995, Cowdrey 1983, Byrd 1928).

Disappearing Longleaf Ecosystem

When the white man moved in and dispossessed the Indian of the better lands, land management practices changed. Although Native Americans frequently modified the forest for agriculture, large-scale exploitation of Southern forestlands for timber and agriculture began with the immigration of European settlers to this area in the early 1800s. Longleaf pine, which once covered more than 60% of the uplands of the region and 40% of the entire region, has declined by more than 98% (Noss 1989, Ware et al. 1993).

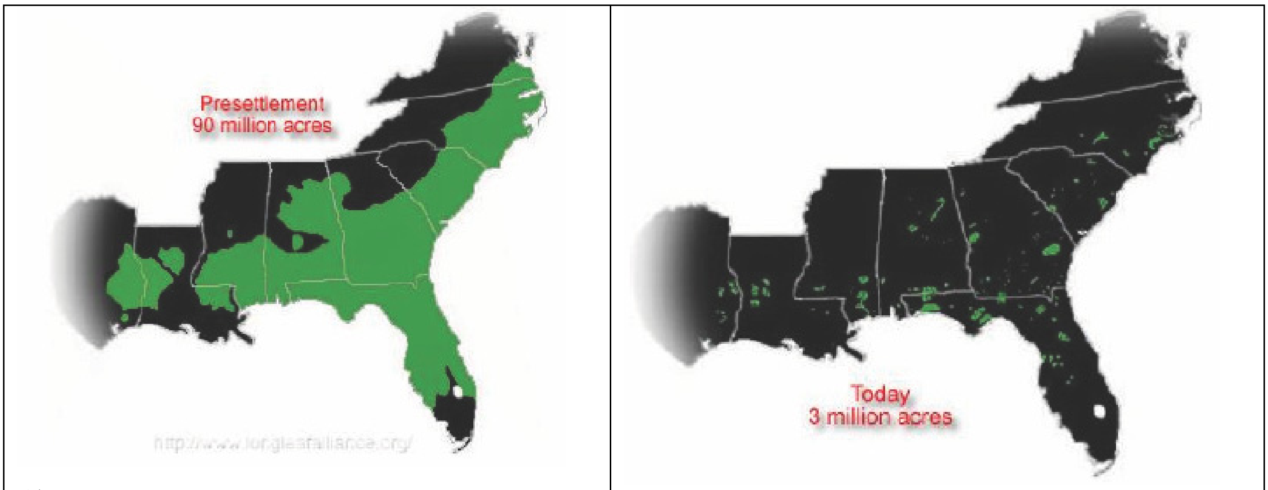
Many factors contribute to the demise of this ecosystem include, clearing for agriculture and development, aggressive logging at the turn of the last century, fire suppression efforts, and conversion to other pine types for faster growth and profits. Fundamentally all the changes are in response to the change in relative scarcity of the resources.

Cotton was very valuable crop and its cultivation was very profitable. Cotton flourished in the South as was the fur trade and more and more white settlers started pouring in from the neighboring areas especially Georgia, Tennessee, Alabama and Mississippi. The fertile soil on level or rolling land, cheap labor from slaves especially promote the crops (tobacco, sugar, rice, indigo, cotton). Blacks were brought to work as forced labor in what was primarily an agrarian society, firstly as salves, and later becoming sharecroppers or tenants after Civil war. By 1900, 30.7 million acres (or 12 million hectare) or about 27% of the longleaf pine upland was listed as "improved" farmland, a category that included pasture, roads and building as well as cropland (Frost 1993, data source from U.S. Census of Agriculture 1902). "With the advent of agriculture, cleared land was often worth more than forested land, and by the early 1900s, much of the original forest had been cleared of forest" (Boyce 2002).

Timber was minor through the early Colonial Period to the mid-1730s.Commercial logging remained a constant but minor industry from 1730 to around 1850, and mostly along streams (Frost 1993). Only after railroad's expanding in the deep South since the 1820s, vast quantities of wood was used for ties, cars, fuel, bridges, and trestles and railroad, and long distance transportation of timber became possible and economical. In other words, timber became valuable, and vast stand of centuries-old longleaf pine were gradually logged. For example, the first railroad in Alabama under construction started in 1832 and by 1890 3,422 miles were covered (Ivey 1954). Each mile of track required over 2,500 crossties that had to be replaced every five to seven years (Burdette 1995).

Much of the timber produced in the South before the Civil War was milled into lumber for only local use. After the war, reconstruction of damaged and destroyed buildings and infrastructure increased the demand for lumber and the number of sawmills multiplied. Depleted forests in the Northeast also created markets for southern timber. The rich, vast stands of centuries-old longleaf pine drew the nation's lumber industry to the Southeast. As the nation grew and flourished, so did the railroads, stretching across the country's vast plains and mountains and up and down its coasts. By the 1880s, sawmills were the dominant industry in the South. Narrow gauge tram lines, improvements in steam-powered sawmill machinery, and other technological advances hastened the liquidation of the South standing timber (Burdette 1995).

The agriculture (including the pasture land use) could not allow tree grow, but timbering is only extracting the wood and still leave the land to re-grow. Fire exclusion policy is another important factor that make longleaf regeneration fair after the logging. The fire exclusion policy was a long process since the early of 20th century (Pyne 1997). Longleaf cannot regenerate because it cannot compete with other species without the support of fires that kill other species. Therefore it was largely replaced by short leave pine and southern mixed hardwood (Mohr 1896, Ware et al. 1993).



A) B)

Figure 4: A) Longleaf in the pre-settlement time; B) Longleaf today
Source: Longleaf Alliance website
http://www.longleafalliance.org/ecosystem/ecosystem.htm

Today, longleaf ecosystems are considered among the most threatened in North America (see Figure 4B). A recent study found only 5,095 hectares of remaining old-growth longleaf pine acreage, and these forests were divided among 15 stands (Vaner and Kush 2004). The special value for wildlife help to maintain some longleaf pines. During the early 20th century, affluent landowners recognized the value of longleaf pine forests as habitat for bobwhite quail *(Colinus virginianus)* and white-tailed deer *(Odocoilem virginianus)* and acquired large tracts for private hunting reserves. Many large areas of longleaf pine exist today primarily for hunting . Current remaining longleaf are managed mostly by non-industrial private forest landowners. They serve as preferred habitat for many game species like white-tailed deer, turkey, bob-white quail and rabbit such that they are in high demand by hunters (Landers et al. 1995).

The Growing Loblolly

In contrast, the loblolly pine was fundamentally driven by the growing demand for modern pulp and paper industry. A few decades of intense pine harvesting since the later 1800s destroyed 90% of the original 48.6 million ha of longleaf pine systems and left 25% of the entire region without natural reproduction or seed trees. Artificial regeneration, by either planting or direct seeding, was the only means to get this land back into pine production (Mann 1969). A few small loblolly pine plantations can be traced back to as early as 1873. By 1931 there were 29,565 ha of southern pine plantations, many of which were loblolly pine (Schultz 1999).

During the early part of the 20^{th} century, large areas of the loblolly pine, primarily in the Piedmont, but also on well-drained Coastal Plain soils, were developed on degraded farmlands. Most of these lands had been cropped for extensive periods without the benefit of chemical amendments or water and erosion control (Trimble 1974), and were "worn out" – highly eroded and depleted of nutrients. This land was no longer profitable for agricultural use. Loblolly pine was ideal species for the land.

By the late 1920s the old-growth forests were virtually gone, and millions of acres were cleared or degraded. Beginning in the 1920s, there was a large migration of African Americans out of the state to northern manufacturing centers. During the Great Depression of the 1930s, the Civilian Conservation Corps planted over 200,000 ha to pines during a 7-year period. These early nursery operations and plantings proved that loblolly pine could be artificially regenerated on a large scale and that it would grow rapidly on many diverse sites.

After the Second World War, the pulp and paper industry grew rapidly in the South, taking advantage of the under-utilized native pines and low-grade hardwoods. But the raw materials were very limited if without plantations. The favorable markets for softwood products and state and federal incentive programs, as well as industry's commitment to short rotation, high fiber yield forestry, and tree improvement programs, resulted in an exponential increase in loblolly pine seedling production during the mid- to late-1900s (Schultz 1999).

Since the 1930s. forest industry had purchased large tracts of forestland to intensively manage for wood fiber to satisfy future raw material demand. During this same period, agricultural areas were abandoned and fire control was improved, resulting in many old fields reverting back to loblolly. It now predominates on 13.4 million ha (45 percent) of the commercial forest land in the southern United States (see Figure 5), and directly or indirectly provides 110,000 jobs and $30 billion to the economy of the region (Schultz 1999). National-wide current loblolly pine area is approximately equal to longleaf two centuries ago.

The longleaf not only cannot compete with loblolly pine by natural regeneration if without fires but also in economic return. Associated with such trend is the private timberland consolidation. The dominance of longleaf in the early colonial and settlement era followed by its replacement with agriculture (cotton) and finally by loblolly pine (mainly plantations) in the recent past follows a distinct economic rationale as discussed in this paper.

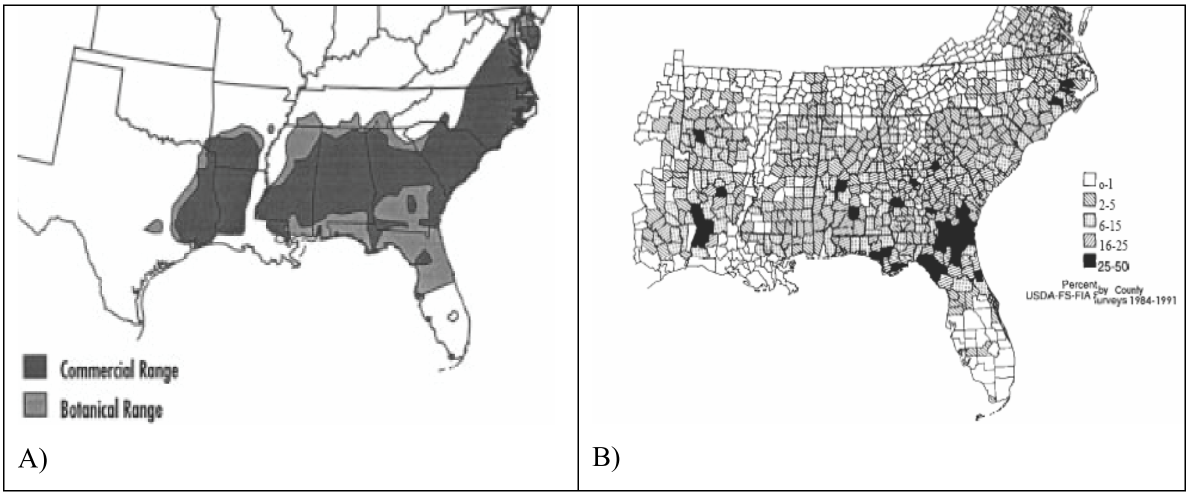


Figure 5: A)Range of Loblolly pine (Source: Goebel 1974, cited from Schultz 1999);
B) Pine Plantation in the South (based on 1984-1989 US Forest Service, map provided by V. Rudis, Southern Forest Experiment Station, Starkville, MS; cited Allen et al. 1996).

The change is often not unidirectional. Recent developments provide hope that these negative trends may be reversed and longleaf pine ecosystems that once dominated US South’s landscape could be restored. Conversion of longleaf pine to other tree species has slowed, as numerous federal and state agencies have begun regenerating longleaf pine on their lands following harvest, and they rehabilitate degraded longleaf pine forests with fire and other appropriate techniques (McMahon et al. 1998). Interest in longleaf pine reforestation and afforestation has increased on private lands because of incentives provided by the federal government; from 1998 to 2000, longleaf pine was planted on 68,240 ha across the region. The southern forestry community has also gained an improved understanding of longleaf pine ecosystems and has come to appreciate the natural heritage that could be lost. No single entity dominates landownership in longleaf pine ecosystems but numerous groups share a sense of urgency, and partnerships have developed (Brockway et al. 2005).

New Zealand

The deforestation to pastoral land during the 19th century and the large scale plantation on the previous pastoral land largely reflect the economic change in New Zealand in the past 2 centuries. New Zealand's islands were once covered with trees. But as much as four fifths of these forests were denuded, first by the Maoris millennium ago, then by English settlers in the 1800s. The southern North Island was firstly opened up for sheep farming in the late 1840s, then moving to South Island in the early 1850s. Gold production peaked around 1865. Sheep farms went where trees once stood, as wool and meat exports became New Zealand's main sources of wealth.

Except for some ecological reasons by grazing (Brooking 2006), the decades of tumbling wool and mutton prices eventually led to abandoned ranchland in the early 20th century. Needing jobs for soldiers returning from World War I, New Zealand in the 1920s set them to planting trees on the more marginal sheep spreads. Initially planting trees was not for fiber production or economic return, but hoping the planting program would reduce erosion on denuded slopes, tried dozens of species. They found that radiata pine that often grow bent and scraggly in their native California coast thrived more than other trees in the rich soil and moist and moderate climate.

It wasn't until the 1980s that it was realized that it was profitable to harvest those farm-grown pines, as well as a smaller number of North American Douglas firs, both originally planted largely to stem erosion. The pragmatic approach taken by New Zealand's environmentalists stems largely from economic necessity. New Zealand was suffering a downturn in its mainstay industry of meat and dairy exports in the late 1980s. It is also driven by profitability of the plantation (see, Wilson and Arthur 1999). Carlton (2003) vividly described how the landowners changed from pastoral land into higher returned forest plantation in the past decades.

New Zealand is another great example of land use specialization that it is becoming well-known as the “New Zealand solution” (see Maclaren, 2001). During the 20th century, New Zealand had planted 1.80 million ha of forests (MoAF, 2001). The area in plantation currently amounts to 6% of New Zealand’s total land. They are dominated by one particular conifer, radiata pine, which accounts for 90 percent of the total planted resource. Around 33% of the planted forests are situated on the Central North Island. Having a large planted forest resource enables New Zealand to manage its Crown and privately owned indigenous forests in a sustainable way.

New Zealand's forest resources, covering 29% of the total land area, can be divided into two distinct forest types in almost mutually exclusive zones. There are still about 6.4 million ha of natural forests (accounting for about 23% of the total land), containing species indigenous to New Zealand, consisting of either virgin or regenerating forests. They are located mainly in the mountains, particularly on the West Coast of the South Island. Indigenous forests harbour large numbers of unique wildlife, some of which are classed as endangered or threatened. The indigenous forests are a key part of New Zealand's environment and help protect the natural ecosystem. Associated cultural values include recreational, scientific, historic, and scenic dimensions. However, less than 0.1 percent of New Zealand's total forest production is now harvested from indigenous forests.

Conclusions and Discussion

The three empirical examples above can be summarized into Table 2. Based on the three examples, some general conclusion from economic perspectives can be made.

Table 2: Economic rationale of the change in forestland

	Hainan Island	US South	New Zealand
Deforestation	1) Agricultural and tropical crops (rubber trees); 2) logging rain forests;	1) Agricultural expansion; 2) logging of the longleaf pine	1) Pastoral land expansion
Reforestation	1) Eucalyptus plantation for export of wood chip; 2) Natural forest protection for environmental services;	1) Loblolly pine plantation for soil conservation 2) Loblolly pine for pulp and paper industry	1) Radian pine plantation for exports 2) Natural forest protection

First, when frontier land and forests are still abundant in any region or in the world, migration to frontier area will be important, and deforestation in that area would be unlikely avoidable, and timber prices would not rise fast as food, and forest plantation would not occur either. More forestland is likely converted inyo other uses, especially agricultural land. The Northeast and South Western China prior to 1950s, The US South prior to the 1800s, New Zealand prior to the 1850s were in this stage. Such situation is gone worldwide. Population migration to frontier has hit the wall, so timber supply has to be dependent on plantation forests, and rise of timber price is very likely and even more than food. So the conflict between forestry and agriculture arise. Which one prevail will be dependent on the relative price change.

Secondly, the remaining virgin and even some secondary natural forests (such as the natural forests in the Southwest China, in New Zealand and the US west) are very limited and become more valuable in providing environmental services. Marginal timber extraction from natural forests might be unavoidable but only selective cutting is allowed. In this sense, these forests are neither frontier forests nor non-actively managed forests, but managed forests and their value is reflected in their environmental functions. Therefore, neither a small rise in timber price nor a decrease in extraction cost should be a threat to them. In fact, the increase in environmental value caused by the growing demand and decreasing supply of environmental services will help their protection, management and expansion. Increasing large-scale protection forests and nature reserves are good examples of this process.

Thirdly, it is likely that in some distinct areas, timber production has a comparative advantage, while in others providing environmental outputs has comparative advantages. Along with global market liberalization and the reduction of transportation costs, land use specialization should not be limited to specific countries and regions. This trend has already been predicted by Sedjo (1983) among others. Sedjo (2001) argued that by 2050, most of the world's industrial wood will be produced from planted forests covering a remarkably small land area, perhaps only 5 to 10% of the extent of today's global forests. While some of this area will be in the temperate world, much of it will be in subtropical and tropical developing countries. Most of the current global forest will be retained, to be devoted to non-forest outputs such as the maintenance of wilderness, wildlife and watershed protection and recreation. This situation is likely to occur not only through technological but also through market development.

Fourthly, like green evolution in agriculture, technological advance in forestry is likely very important. Technological advances usually occurs when the products become scarce. The increasing scarcity of timber and environmental service justified the technological investment in silviculture. With new technologies, through tree growing, commercial wood can become a crop, as in agriculture, to be planted, tended and harvested. As Sedjo (2001) argued, "by the middle of the twenty-first century, the transition to tree cropping will be largely completed, and the greatest part of human wood consumption will come from planted forests, most of them intensively managed."

In sum, the change of forest ecosystem is fundamentally driven by the human action in response to the change in relative scarcity. Currently most of the world's frontier forest is protected by economic factors-remote locations and unfavorable terrain keep farmers and lumberjack at a distance (Victor and Ausubel 2000). Technological advancement in logging is in response of the increasing difficulties in accessing resources and increasing cost of labor; technological advancement in silviculture is in response of shrinking natural forests and increasing scarcity of land resources. Converting agricultural land to forest land is in response to the change in profitability of land use options that affected by population and technology. Land use/cover will be always dynamic to the changes in our society. Forestry once was primarily logging that promoted timberland into non-timber land is changing into more like tree farming that plants trees.

References

Allen, A.W., Bernal, Y. K. & Moulton, R. J. (1996). Pine Plantations and Wildlife in the Southeastern USL as Assessment of Impacts and Opportunities. Information and Technology Report 3, US Department of Interior.

Boserup, E. (1965) [2005]. The Conditions of Agricultural Growth: the Economics of Agrarian Change under Population Pressure. London: AldineTransaction.

Boyce, T.C., Dumont, D. & Bailey, M. (2002). Alabama Forest Legacy Program Assessment of Need Document. Alabama Forest Resources Center Mobile AL.

Brockway, D. G., Outcalt, K. W., Tomczak, D. J. & Johnson, E. E. (2005). Restoring longleaf pine ecosystems in the southern U.S. In J.A. Stanturf, P. Madsen (Eds), Restoration of Boreal and Temperate Forests (pp. 501-519). Boca Raton: CRC Press.

Brooking, T. (2006). Pasture, present and future –A brief history of pastoralism in New Zealand. RM Update Issue, 18, 1-3.

Burdette, D. (1995). The Southern Forests: 1800-1850. Alabama TREASURED Forests, 3(1), 22-23.

Byrd, W. (1928). A journey to the land of Eden. New York: Macy-Massius. 367 p.

Carlton, J. (2003). New Zealanders Shear Trees Instead of Sheep. Wall Street Journal (A1) May 29, 2003.

Carroll, W. D., Kapeluck, P. R., Harper. R. A. & Van Lear, D. H. (2002). Chapter 24: Background paper: Historical Overview of the Southern Forest Landscape and Associated Resources. In Wear, D. N. and J. G. Greis (Eds), Southern Forest Resource Assessment. General Tec. Report. SRS-53. Southern Research Station, Asheville, NC.

Chu, C. (1988). History on calculation of the forest cover rate. Forest Resources Management, 1988 (3), 5–10.

Clawson, M. (1981). Competitive land use in American Forestry and Agriculture. Journal of Forest history, 25, 222-227.

Cowdrey, A. E. (1983). This land this south, and environmental history. Louisville, KY: University of Kentucky Press. 236 p.

Cronon, W. (2003). Changes in the Land: Indians, Colonists, and the Ecology of New England. New York: Hill and Wang,.

FAO. (1995a). Forest resources assessment 1990 - Global synthesis. FAO Forestry Paper 124. Rome.

FAO. (1995b). Forest resources assessment 1990 - Non-tropical Developing Countries. Technical Report FO: GCP/INT/474/FRA. FAO, Rome.

FAO. 2006. Global Forest Resource Assessment 2005. FAO Forestry Paper 147，FAOSTATS

Frost, C. C. (1993). Four centuries of changing landscape patterns in the longleaf pine ecosystem. Proceedings of Tall Timbers Fire Ecology Conference, 18, Tallahassee, FL: Tall Timbers.

HAZC (Hainan Agricultural Zoning Commission). (1980). Collection of Hainan Agricultural Zoning Reports. Haikou, China.

Hyde, W., Amacher, G.S. and Magrath, W. (1996). Deforestation, Scarce Forest Resource, and Forest Land Use: Theory, Empirical Evidence, and Policy Implications. World Bank Research Observer 11: 223–248.

Ivey, B. D. (1954). From river to rail in Pickens county. Alabama Review 7(1): 53-65.

Landers, J.L., Van, L., David, H. & Boyer, W.D. (1995). The longleaf pine forest of the southeast: requiem or renaissance?. Journal of Forestry **93**, pp. 39–43.

Liu, C., Wang, Z. (1989). China's Forest Change Process, Structure and Patterns. Beijing Forestry Science and Technology 1989(1): 41–48. (in Chinese).

Maclaren, P. 2001. Forestry in New Zealand: the Opposite of Multiple Use? In Palo, M, Uusuvuori, J. & Mery, G. (Eds), World Forests, Markets and Policies. The Netherlands: .Kluwer Academic Publishers.

Mather, A. 1990. Global Forest Resources. Timber Press. Portland, Oregon.

McMahon, C.K., Tomczak, D.J., & Jeffers, R.M. (1998). Longleaf pine ecosystem restoration: the role of the USDA Forest Service, in Ecological Restoration and Regional Conservation Strategies, Kush, J.S., Comp., Longleaf Alliance Report No. 3, Soion Dixon Forestry Education Center, Andalusia, AL, 20, 1998.

Ministry of Agriculture and Forestry. (2001). A National Exotic Forest Description (as at 1 April 2000). Wellington, New Zealand.

Mohr, C. (1896). The timber pines of the southern United States. ISDA Division of Forestry, Bulletin No. 13. Washington DC, 176 p.

Noss, R. F. (1989). Longleaf pine and wiregrass: Keystone components of an endangered ecosystem. Natural Areas Journal, 9, 211-213.

Pyne, S. (1997). Fire in America: a cultural history of Wildland and Rural fire, 2nd edition. Seattle, WA: University of Washington Press. 680pp.

Raup, H. (1966). The View From John Sanderson's Farm: A Perspective for the Use of the Land. Forest History 10 (April, 1966): 2 – 11.

Rudel T. (1998). Is there a forest transition? Deforestation, reforestation,and development. Rural Sociology, 63：533–552.

Schultz, R. P. (1999). Loblolly -- the pine for the twenty-first century, New Forests, 17: 71-88.

Sedjo, R. A. (2001). From foraging to cropping: the transition to plantation forestry, and implications for wood supply and demand. Unasylva, 204: 24-32.

Smith, W. B, Miles, P. D & Vissage, J. S. (2004). Forest resources of the United States. USDA Forest Service North Central Research Station General Technical Report NC-241.

Steiner, D. 1993. Human Ecology: Fragments of Anti-Fragmentary Views of the World. Routledge, New York

U.S. Census Office. (1902). Twelfth census of the U.S. Vol. 5 Agriculture. Part 1. US Government Printing Office, Washington DC. 767 p.

Varner, J.M. & Kush. J. S. (2004). Remnant Old-Growth Longleaf Pine Savannas and Forests of the Southeastern USA: Status and Threats. Natural Areas Journal 24:141-9.

Victor, D. G. & Ausubel, J. H. (2000). Restoring the forests. Foreign Affairs, 79 (6), 127-144.

von Thunen, J.H. (1875). The Isolated State in Relation to Land Use and National Economy. Schmaucher Zarchlin, Berlin.

Ware, S., Frost, C.C. & Doerr, P. (1993). Southern mixed hardwood forest: The former longleaf pine forest. Pages 447-493. in W. H. Martin, S. G. Boyce, and A. C. Echternacht, editors. Biodiversity of the Southeastern United States: Lowland Terrestrial Communities. Wiley, N.Y.

Wilson, B. & Arthur, L. (1999). New Zealand. In Wilson B., van Kooten, G C, Vertinsky I, Arthur L. (Eds.), Forest Policy: International Case Studies. UK: CABI Publishing.

Zhang, Y, Uusivuori J & Kuuluvainen J. (2000). Econometric analysis of the causes of forestland use/cover change in Hainan, China. Canadian Journal of Forest Research, 30: 1913-1921

Zhang, Y. (2000).Deforestation and Forest Transition: Theory and Evidence from China. In Vanhanen M, Palo, M (eds): Global Prospects on Deforestation & Forest Transition. Dordrecht：Kluwer Academic Publishers.