Journal of the Arkansas Academy of Science

Volume 42 Article 13

1988

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FORESTRY ON THE ISLAND OF TAIWAN, ROC - THE STATE OF THE ART

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ABSTRACT

The forests of Taiwan vary from lush subtropical vegetation to subalpine coniferous associations. Topography is exceedingly rugged, and stands border on the verge of silvicultural inoperability. In the 1950s and 1960s, the wood products industry in the Republic of China was of paramount importance; the production of high-quality sawtimber from old-growth cypress (Cupressaceae) stands provided the financial capital that built one of the most prosperous national economies in the modern world. In the 1980s, forestry in Taiwan is a curious blend of old methods and new technologies, as modern silvicultural practices are used to reforest cutover cypress stands, to harvest and reproduce remaining old-growth stands, and to expand the silvicultural importance of other forest types on the island. Many applied research efforts would be promising in application to the forests of Taiwan, such as long-term studies of silvicultural practices on water quality, methodology of natural regeneration applied to cypress and *Taiwania cryptomerioides* (Taxodiaceae), uneven-aged regulation applied to bamboo, *Phyllostachys pubescens* (Bambusaceae), growth and yield in coniferous plantations, effectiveness of modern herbicides in controlling competition in young plantations, and application of contemporary economic assessments in the evaluation of silvicultural alternatives.

INTRODUCTION

During the past 20 years, a number of forestry scientists and officials from the U.S. and Taiwan have participated in exchange programs to visit and observe forestry programs within the universities, government agencies and industries of the two nations. Among the U.S. representatives, the Department of Forest Resources at the University of Arkansas at Monticello (UAM) has played a significant role. Dr. T.T. Ku was invited to participate in the Sixth National Reconstruction Conference in Taiwan in 1975, and served as a Visiting Professor at the National Taiwan University in 1983 (Ku, 1983) supported by Taiwan's National Science Council. In the late 1970s, and again in the mid-1980s, a number of forest scientists and high-level forest administration officials from Taiwan came to study the operations of the U.S. Forest Service and forest industries in the U.S., including Arkansas.

This decade of cooperation resulted in an international research accord between the University of Arkansas (UA) and the Council of Agriculture (COA) of Taiwan. The agreement was initiated with an international symposium on Forest Productivity and Site Evaluation held in Taipei in the Fall of 1987 (COA, 1987). Over 20 papers, including eight by the authors of this article, were presented to more than 90 scientists representing 15 governments and private agencies from the two countries. However, the symposium was only the centerpiece of a 2-week adventure that included eight days of field tours to observe forest practices and management operations in the southern central and northern sections of Taiwan. This paper reports on those observations.

GEOGRAPHY

Taiwan is located along the fringe of the continental shelf of Asia, on the western border of the Pacific Ocean. It is about 395 kilometers long and 145 kilometers at its broadest width near the central portion of the island. The principal mountain system runs north-south with its highest peak, Mount Jade (Yushan), standing at 3,997 meters near the center of Taiwan. The Tropic of Cancer bisects the island and confers upon it a tropical and subtropical climate. Annual rainfall ranges from 1,000-67,000 millimeters and averages 2,600 millimeters; the average annual temperature is 22 °C. An excellent overview of the physiography and climate can be found elsewhere (Liu, 1976, 1987).

Over 52 percent of its land area is in forests at the present time, with biomes ranging from tropical hardwoods in the coastal low elevations to the humid, montane coniferous forests at the higher elevations. The present population of nearly 20 million people has brought a socio-economic impact to forest policy. The objective in forest resource management over the past years has shifted from timber production in the 1960s to soil and water conservation in the 1970s, and to recreation and environmental preservations in the 1980s.

ECOLOGICAL ZONES

Liu (1976) identified four major ecological zones ont he island of Taiwan based primarily on an elevation gradient; these are the subalpine, cool-temperate, warm-temperate, and tropical zones. The extremely rugged topography, high rainfall accentuated by local orographics,and variability in temperatures result in highly heterogeneous climatic and ecological conditions within each zone. Geologically, soils are quite young with the notable exception of the tropical ultisols and oxisols in the lowlands. Important forest soils on the island include the spodosols at higher elevations (1800 meters and higher), alfisols, inceptisols, and the lithosolic entisols associated with recent landslide activity (Shen, 1987).

Six ecologically-derived forest formations have been recognized (Liu, 1987). These closely correspond with five silvicultural regions, identified by combining the gradients of elevation and temperature with species that are of commercial importance (Kuo, 1987). There are two major distinctions between the ecological and silvicultural classification. First, the division of forestry and agriculture is found at approximately 500 meters (Chen, 1957). Secondly, the lowland littoral ecosystems have little value for commercial timber production.

The subalpine coniferous forest is the uppermost forest of the country, dominated by Taiwan fir (*Abies* spp.) and alpine juniper (*Juniperus chinensis* Linn. var. *kaizuca* Hort. ex. Endl.). It occupies the highest elevations in the country and is characterized by the coldest temperatures. This forest type is not commercially productive, but is extremely important in the stabilization of high slopes.

The cold-montane coniferous forest is a mixed forest dominated by Taiwan hemlock *(Tsuga chinensis* var. *formosana* [Hay.] Li et Keng), Taiwan spruce (*Picea morrisonicola* Hay.), Taiwan red pine (*Pinus taiwanensis* Hay.), and Taiwan armand pine (*Pinus armandii* Fr. var. *mastersiana* (Hay.). This forest type is found between 2000-3000 meters, and is transitional between the types above and below. It is of minor commercial importance.

The warm-temperate montane coniferous forest and warm-temperate montane rain forest are intermingled through altitudes of 700-2500 meters. Generally, the coniferous type occupies the higher elevations, and the hardwood rain forest the lower elevations. Occurrence varies greatly due to local variations in soils, topography, and incidence of precipitation.

The conifers of the warm-temperate montane forest are the backbone of the timber economy in the Republic of China. The species of paramount commercial value are red cypress (*Chamaecyparis formosensis* Matsum.) and yellow cypress (*Chamaecyparis obtusa* var. *formosana* [Hay.] Rehd.). In addition, other conifers of commercial importance in this region are China fir (*Cryptomeria japonica* D. Don.).

Over 200 species of hardwood charcterize the warm-temperate montane rain forest. The most important of these is Zelkova (*Zelkova serrata* [Thunb.] Mak.), a member of the Ulmaceae with utility similar to that of oak. In addition, the bamboo resource reaches its zenith in this type. The island has over 60 species of bamboo, of which the most usable is moso bamboo (*Phyllostachys pubescens* Mazel.). Moso bamboo is valuable both as an ubiquitous construction material and a source of food in bamboo shoots.

The tropical rain forest of Taiwan has been largely cutover and converted to agriculture. The high rainfall, low elevation, moderate topography, and warm year-round temperatures promote activities other than forestry. The second-growth species composition includes general (*Ficus, Trema Macaranga, Mallotus,* and *Bischofia* spp.) common to the second-growth rain forests of Indo-Malaysia (Liu, 1987).

The littoral forest is found at the lowest elevations along the coastline. The mangrove forests of Taiwan are similar in structure and composition to mangroves throughout the tropics. Strand forests are common to seashores in the southern part of the island. In a manner similar to the tropical rain forest, the littoral forest of Taiwan is primarily of ecological significance rather than of value as a raw resource material for manufactured forest products.

DEVELOPMENT OF FORESTRY IN TAIWAN

Forestry has been practiced in Taiwan for over 100 years, beginning with the Japanese occupation of the island in 1895, carrying through the liberation in 1945 with subsequent establishment of the Chinese government, through the present day (Kuo, 1987). Early forest operations were primarily timber mining, as was the case in the United States. In his classic work, Fernow (1913) wrote that the Japanese established an administrative structure for the practice of forestry in the home islands, but exploited the timber resources on the island that was then known as Formosa, a Portuguese word meaning the Island Beautiful or the Fantasy Island. The most valuable species sought in the region were Japanese fir and yellow cypress, with mention of a species of *"Zelkowa"* [sp] (Fernow, 1913).

Modern forestry became prominent after the establishment of the Chinese government in 1945. The major capital assets of the island at that time were its forests, particularly yellow cypress and red cypress. Lumber produced from these species is of exceptional quality and value, and provided much of the financial basis for the government in the 1950s and the early 1960s. With the vigorous growth in the economy due to high-tech industry, and the resulting increase in the standard of living, the demand for non-commodity natural resources has increased to a level that has begun to dictate the current character of resource management. In essence, forestry operations have changed from timber production in the 1950s to the present status of emphasis in research and preservation.

CONTEMPORARY FORESTRY OPERATIONS

Harvest of timber in Taiwan is usually followed by the establishment of plantations. At low elevations (800-1,000 meters), hardwoods such as *Zelkova* and other endemic species, as well as the exotic *Leucaena leucocephala* (Lam.) deWit, are planted at 2 x 2 meter spacings. This dense spacing is important in reducing both competition of weed species and branchiness of the desired species. Underplanting of *Zelkova* with other species such as nitrogen-fixing *Acacia* spp. is done both to promote plantation diversity and to enhance the nutrient status of the site.

At higher elevations (1,500-2,500 meters), harvest is followed by establishment of plantations of the native China fir, Taiwania, the yellow and red cypresses, and the exotic Japanese fir. Seedlings are usually planted at 2 x 2 meter spacing. However the growth and yield that can be expected from these stands are not certain, particularly from recently adopted species.

Planting stock is produced as a two-year-old seedling; after the first year seedlings are transplanted to a polyethylene bag holding about 1,500 cm^3 of soil, and spend a second year in the nursery prior to outplanting. At higher elevations, plantation spacings may vary depending on the topographic severity of the site. On reasonably flat sites (less than 30% slope), spacing within the row and between rows may vary from 2 to 3 meters. On steep slopes, seedlings are planted as a linear clump of three or four trees within a meter; approximately 5 meters separate the clumps within the row, with rows 3 meters apart. This unique practice is easier to implement on steep slopes, promotes desirable form in crop trees, and improves the efficiency of competition control.

Natural regeneration is an increasingly common practice, especially with the more tolerant red and yellow cypress. Two silvicultural systems are frequently employed. Clearcutting is a common practice, with the new stand originating either as advance growth or by means of seed fall from adjacent stands. The uniform seed tree method is also employed, though the sites are frequently inaccessible for seed tree removal. A third alternative that was observed is a classic textbook variation of the seed tree method known as the group seed tree method, where seed trees are left as isolated groups. This practice promotes windfall resistance of the seed trees, and also allows operational harvest of the seed trees associated with early pre-commercial or commercial thinning.

Competition control is a critical aspect of stand establishment in the warm-temperate and subtropical environment. The standard method of weed control is by means of human labor. Woods workers typically use small scythe-like knives to cut swaths amid the competing vegetation within which seedlings can develop. Between 17 and 20 such treatments are applied in the first 10 years of plantation development; three treatments per year are required in the first three growing seasons. Because of such intense labor requirements as well as the logistic support required for these workers at high elevations, the present net value of plantation establishment in the coniferous forest varies from U.S. $2,500-7,500 per hectare (Jen, 1984). Naturally regenerated stands require less competition control — between 10 to 12 treatments in the first 10 years, followed by a pre-commercial pruning/thinning treatment after the tenth growing season.

Herbicides have been considered as a much less expensive form of competition control, but are judged by the Taiwan Forestry Bureau to be impractical for two reasons. First, water (the medium of application) is scarce at high elevations. Secondly, it is thought, though not confirmed by research, that the watershed values of the forest would be compromised by herbicide application.

No discussion of forestry in Taiwan would be complete without a tribute to the commercial and cultural value of the many species of bamboo. Moso bamboo, the major commercial species, is managed on a five-year cycle under an uneven-aged system of density regulation. At the end of each growing season, the oldest age class is harvested. This age class contains about 20% of the culms in the stand, which are randomly distributed and identifiable by the unique color-age relationship of the genus. Culm growth of root-sprout origin occurs in the following spring, reestablishing the youngest 20% of the stand. Research is underway on the nutrient dynamics of bamboo, and on the artificial regeneration of bamboo using coppice plantation silviculture (Kao, 1987). A productive stand of Moso bamboo may produce an annual income of more than U.S. $7,400 per hectare (Kao, 1985).

The forest resource plays a major role as both a watershed and water impoundment landscape for low elevation urban centers. Occurrence of precipitation is highly heterogeneous, varying from dry seasons to storms of typhoon intensity. The government of Taiwan is, of course, aware that its forests directly provide the water for the island economy

and its people. A number of large scale reservoirs and dams have been constructed among the 22 watersheds of Taiwan since the 1950s. Many of these were built in extremely rugged terrain with intense labor forces. Baseline watershed monitoring, initiated in the 1960s, occurs on over a dozen large (100 hectare plus) watershed throughout the island. The effects of silvicultural practices, such as clearcutting and selection cutting, on watershed values are currently being investigated.

At the non-consumable level, the national demand for non-commodity forest resources has increased dramatically with the vigorous national economy and the concomitant increase in the per capita standard of living. Because of increased demand on outdoor recreation, several well known parks, recreational areas, and nature areas have been established for urban dwellers. Among these, the Yangmingshan park, Hsitou and Chihpen recreational areas, and the Kenting and Alishan national parks are most prominent, and operate at full capacity during most weekends and holidays. One component of the surge in popularity of noncommodity forest resources is attributable to an increasingly affluent population learning to enjoy and appreciate the beauty of a natural resource setting. A darker component is attributable to the Malthusian paradox whereby an increasingly large population undertakes the utilization of an increasingly scarce resource. If the enjoyment of these non-commodity resources follows the pattern of western Europe and North America, use will continue to grow at a nearly exponential rate in the next few decades.

CONSTRAINTS ON FORESTRY

Forest practices in Taiwan are constrained by many factors. The high population on a limited land base, about 36,000 square kilometers, dictates an intensive utilization of availble acreage. Intensive agriculture (rice, asparagus and other grain and legume crops), orchards of fruit trees (banana, citrus, pear, apple, vineyard, mango and other scrumptious native species and varieties), and cash crops (vegetables, mushrooms and the highly profitable betelnut) prioritize the rich, level coastal plains and the lower elevation tablelands and rolling hills. The successful agricultural technology literally pushed forestry practices into the higher and agriculturally inaccessible terrains.

Silvicultural operations at high elevations are often impractical due to the lack of water. This limits the upkeep of facilities for woods workers, constrains the application of fertilizer and perhaps herbicides, and leads to an uncertainty in supply of the basic fire fighting tool of the foresters. Conversely, the amount and intensity of rainfall associated with severe storms and typhoons can wash away plantations, access roads, and even entire mountainsides. Taiwan has a high rate of landslide activity due to its relatively youthful geological age. Timber production at high elevations is usually conducted by clearcutting using skyline logging systems, followed by planting and competition control; whether this intensive timber management predisposes slopes to mass-wasting is a concern of the Taiwan forestry officials.

The sheer ruggedness of topography limits operational timber management. Mechanization of forest operations within a forest stand is extremely difficult. Log trucks are modified with water cooled brakes for the steep descent from the logging sites to the mills. Topographic limitations accentuate the disadvantageous aspects of commodity production from the island.

Last and perhaps of greatest significant, sociology comes into play as an operational limitation. As a modern industrialized society, Taiwan is currently experiencing the migration of labor from rural to urban areas. Taiwanese foresters are losing the rural labor pool required to conduct labor-intensive forest operations, particularly those of plantation establishment and competition control in both plantations and natural stands. With respect to balance between commodity and noncommodity resources, the public generally supports efforts by the government to reduce its subsidy of timber management in favor of the watershed and recreational values of the forest.

FORESTY RESEARCH

Forestry research programs have been conducted in universities and the provincial Taiwan Forestry Research Institute (TFRI) during the past four decades with funding provided from Taiwan's National Science Council, the COA, and private organizations and industries. Two of the three universities in Taiwan offer doctorate programs in forestry, with the National Taiwan University at the forefront in both seniority and academic services.

On the forefront of applied ecology, research is underway at TFRI and at the universities on nutrient cycling in plantation forests (Horng, 1987). Production of *Liquidambar formosana* Hance and *Paulownia taiwaniana* Hu and Chang that are resistant to diseases and insects is a major goal of tissue culture research (Yang *et al.*, 1987). Mycorrhizal research focuses on vasicular-arbuscular mycorrhizae in the fast growing hardwood exotic *Leucaena* (Huang, 1987) and on the mycorrhizal symbiosis of high altitude conifers (Hu, 1987).

During the past decades, both native and exotic species trials have been practices in plantations. Today, the use of natural regeneration is becoming more important, especially in remote areas. Research is underway to improve growth and yield forecasting, and to apply modern technology in the field. Thus the evolution from the historical events to the state-of-the-art has occurred in little more than four decades. These trends are noteworthy because modern Taiwan imports over 90% of its timber and fiber needs.

DISCUSSION AND CONCLUSIONS

The divergence between the operational aspects of timber production and the economic and social limitations upon timber production appear to be increasing in Taiwan. Timber production was fundamental to the establishment of the island economy in the 1950s, but is of decreasing importance. The alternative source of timber for Taiwan is primarily of tropical origin in Indo-Malaysia; all indications are that this source is not immediately renewable. From a global perspective, it is unfortunate that managing temperate forest ecosystems in a constrained manner leads directly to an increased reliance upon tropical ecosystems that are even less able to bear sustainable commodity production.

These divergent demands on the forest ecosystems of Taiwan are by no means resolved. As the population becomes more urban and affluent, the recreational aesthetic and watershed amenities of the forest will become more important. In view of the emphasis placed on sound forestry practices and advanced research, the foundation is in place for farsighted stewardship of the forest ecosystems on the island to meet the growing and diverse demands that characterize the Taiwan forests.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the assitance from the Council of Agriculture and the National Science Council of Taiwan, as well as the Taiwan Forestry Bureau, the Taiwan Forestry Research Institute, and the Forestry Development Administration of the Vocational Assistance Commission of Retired Servicemen.

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