Annual Report of Taiwan Forestry Research Institute 2001

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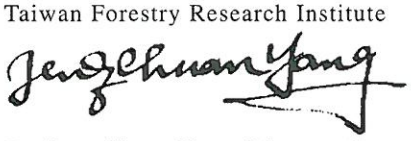
FOREWORD

In the first year of the twenty-first century, Taiwan again faced several major natural disasters induced by the after-effects of the catastrophic Chi-Chi earthquake of 1999. Mudflows and flooding caused by a number of typhoons have raised serious concerns in the government and the public. A movement proposed to "grasp our earth with tree-roots" has hence been initiated by the Executive Yuan. This phenomenon buttresses the importance of a sustainable forest management policy. The approaches to sustainable forest management are based on knowledge of forest ecosystem at all facets, which has been the research focus of our institute for many years. Programs of the institute emphasis on the organization of different multidisciplinary teamwork that provide a wealth of long-term data sets and conclusions on the dynamics of forest ecosystems of Taiwan. The data sets should be able to provide a scientific knowledge base to help land-use strategic decision-making and nature conservation of the island.

Working at laboratories, research stations, and national forests throughout Taiwan, our scientific workforce is divided into 10 divisions and 6 research stations. This annual report presents the results of the year 2001, and gives updates on several of our long-term studies. Also, through interpretative activities, conservation workshops, and educational extension programs, we are trying to rouse the public awareness of the importance of forest protection and sustainable forest management. These tasks closely meshes with the public welfare, social, and economic well-being of the nation. Our research findings reach far beyond benefiting the citizens of Taiwan; they have valuable applications throughout the world as well.

In the past year, we received funding support from the Council of Agriculture, the National Science Council, and some other agencies. We would like to express our sincere thanks to all of them. Strategic planning effort on research will continue to be integrated into our future work that needs to be addressed on a national basis. Research on sustainable forest ecosystem management, watershed health and restoration, forest production, botanical garden system and conservation are some of the work delineated. We shall endeavor to reach these goals in the coming years.

Taiwan Forestry Research Institute



Dr. Jenq-Chuan Yang, Director-General,

October, 2002

I HISTORY

In the 21st year of the reign of Emperor Kuanghsu, Ching Dynasty, (or the 28th year of the reign of Emperor Meiji, Japan, A.D. 1895), during the early years of the Japanese occupation of Taiwan, the Regenerative and Products Bureau of the Japanese Governor General's office planned to establish a nursery, and on January 6 of that year, selected an 8750-ping lot near Nanmen (South gate) in Taipei City for this purpose. This was the forerunner of the Taiwan Forestry Research Institute. In the 25th year of Kuanghsu (1899), the nursery was relocated to the Talongtung and Yuanshan areas to the north due to construction of an army garrison hospital on the original site. In October of the following year, 1900, a new lot was purchased at the present location of the Taipei Botanical Garden to reestablish the so-named Taipei Nursery. The nursery's goals were to nurture seedlings and cultivate saplings. By the 3rd year of Emperor Shuantung, Ching Dynasty (44th year of Meiji, 1911), on the foundation of the Taipei Nursery, a Forestry Experimental Station under the aegis of the Regenerative and Products Bureau of the Governor General's Office was set up to shoulder responsibility of forest management in Taiwan and to undertake surveys of forest resources. In the 10th year after the founding of the Republic of China (10th year of the reign of Emperor Daisho, 1921), the Japanese unified all research institutions and established the Central Research Institute.

The Forestry Experimental Station was included and was named the Forestry Division of the Central Research Institute. On the site of the Institute's original Taipei Nursery, the Taipei Botanical Garden was established. In the 28th year of the Republic of China (14th year of Emperor

Showa, Japan; 1939), after restructuring of the Central Research Institute, the Forestry Division was recast as the independent Forestry Research Institute.

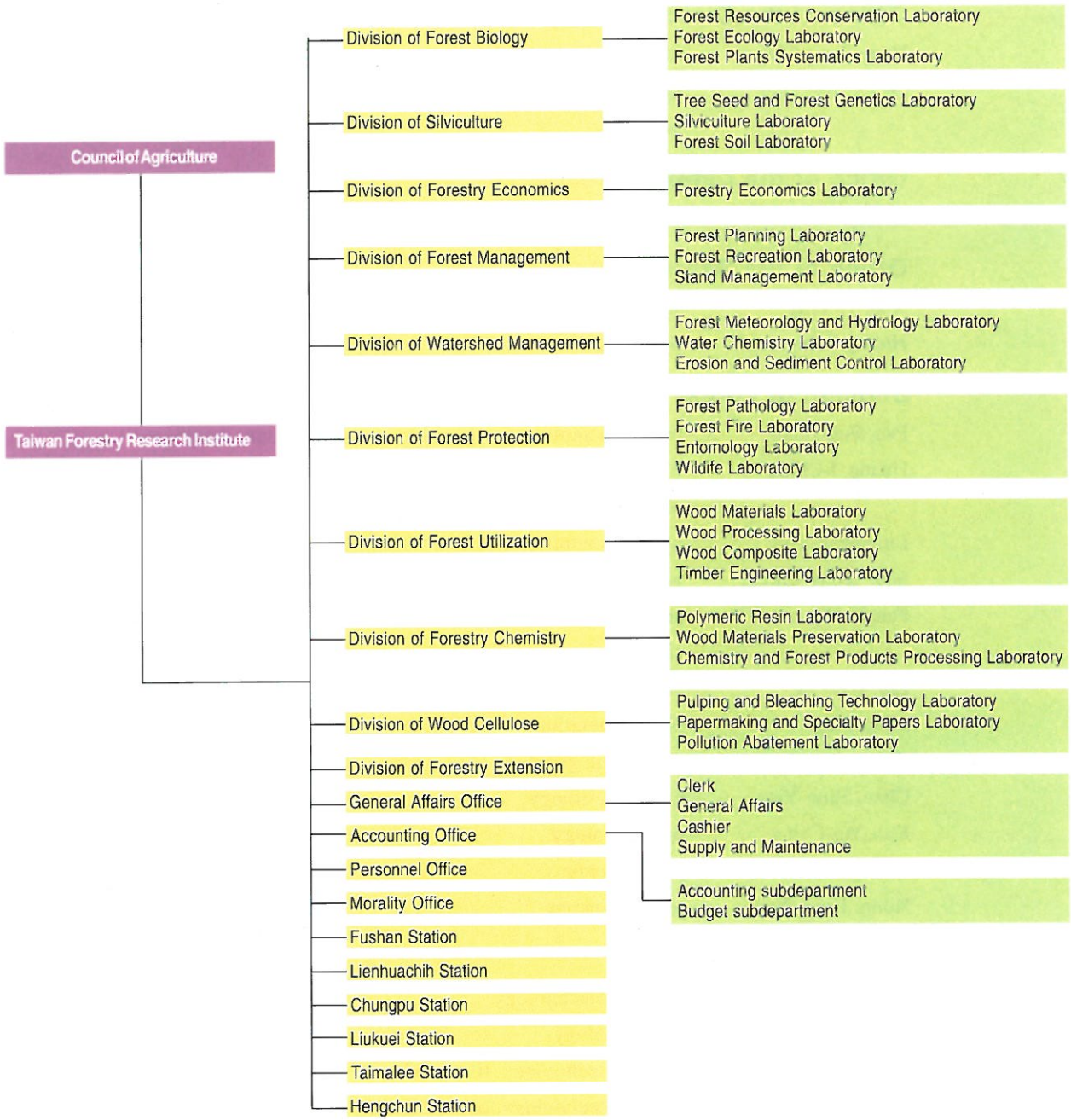
The 34th year of the Republic of China (1945) saw the retrocession of Taiwan after the defeat of Japan in World War II. The Taiwan Administrative Offices formally took over the Institute on November 1 of that year. It was then renamed the Taiwan Forestry Research Institute. In September 1949, the Institute was transferred from directly under the Taiwan Provincial Government to a subordinate Administration of Agriculture and Forestry. Upon taking over from Japan, there were 6 divisions, namely, forest biology, silviculture, management, utilization, chemistry, and wood pulp; 4 branch stations at Lienhuachih, Chungpu, Hengchun, and Taimalee, as well as a resin experimental post at Pashienshan. After subsequent restructuring and shifts in research needs, there are currently 10 divisions, i.e., forest biology, silviculture, forestry economics, forest management, watershed management, forest protection, forest utilization, forestry chemistry, wood cellulose, and forestry extension; there are also 4 offices, i.e., general affairs, accounting, personnel, and ethics ; as well as 6 branch stations at Fushan, Lienhuachih, Chungpu, Liukuei, Taimalee, and Hengchun.

II ORGANIZATION

The Institute currently has a staff of 175 people (with 136 people at the Taipei headquarters, 5 at Lienhuachih, 4 at Chungpu, 11 at Liukuei, 7 at Hengchun, 5 at Taimalee, and 7 at Fushan). Among the staff, 30 are administrative and 145 are technical personnel. The Institute is supervised by a director general, a deputy director general, and a secretary general, followed by 10 heads of divisions and 4 heads of administrative offices. Among the technical staff, there are 21 scientists, 26 associate scientists, 48 assistant scientists, and 49 assistants. The positions of deputy director general, secretary general, heads of divisions, and chiefs of branch stations are filled by scientists or associate scientists. In addition to the 4 administrative heads, there are section heads, clerks, office assistants, and scribes totalling 26 people. There are also 201 technicians, helpers, and drivers who are assigned to various units of the headquarters, divisions, offices, and branch stations based on their job specifications. They assist in conducting research experiments and managing forests.

The running of the Institute is internally stratified, based on the establishment of divisions, offices, and branch stations. In order to integrate research manpower and resources, to foster team spirit, and to strive for maximal efficiency in carrying out research subjects, a laboratory system was instituted. Based on various research items, objectives, and manpower requirements, 27 laboratories were established under various divisions. These support the conducting of inter-divisional research and permit easy adjustments to meet research needs. Organization of the Institute is delineated in the following diagram:

ORGANIZATION SYSTEM DIAGRAM



Scientists on Staff

Office of the Director

Yang, Jenq-Chuan	forest genetics, silviculture	jcyang@serv.tfri.gov.tw
Hsu, Chia-Chun	epiphyte ecology plant taxonomy	ecogarden@serv.tfri.gov.tw

Office of the Deputy Director

Horng, Fu-Wen	forest soils, forest ecology	horng@serv.tfri.gov.tw

Office of the Secretariat

Kao, Yu-Ping	silviculture	kao@serv.tfri.gov.tw
Huang, Ming-Jen	Secretary	secr@serv.tfri.gov.tw

Division of Forest Biology

Pan, Fuh-Jiunn	botanical garden management	fjpan@serv.tfri.gov.tw
Huang, I-Ching	tissue culture, plant breeding, plant propagation	ching@serv.tfri.gov.tw
Lu, Sheng-You	plant taxonomy	sylu@serv.tfri.gov.tw
Sen, Yeong-Chium	moths, plant vegetation	ycsen@serv.tfri.gov.tw
Fan, Yi-Pin	pollination, environmental education	ybfan@serv.tfri.gov.tw
Liu, Wen-Yu	botanical garden management	wyliu@serv.tfri.gov.tw
Ju, Li-Ping	plant vegetation, systematics	lpju@serv.tfri.gov.tw
Cheng, Yu-Pin	population genetics	ypcheng@serv.tfri.gov.tw
Chen, Shun-Ying	plant physiology	sychen@serv.tfri.gov.tw
Kao, Yui-Ching	forest ecology	rich@serv.tfru.gov.tw
Chung, Shih-Wen	plant taxonomy	wenwen.9@kimo.tw
Hong, Kung-Yuang	plant taxonomy	tfrihc@serv.tfri.gov.tw

Division of Silviculture

Chen, Zenn-Zong	forest biotechnology	zzchen@serv.tfri.gov.tw
Lin, Kuo-Chuan	forest ecology	kuolin@serv.tfri.gov.tw
Ho, Cheng-Kuen	orest biotechnology, tissue culture	ckho@serv.tfri.gov.tw
Chang, Shu-Hwa	orest biotechnology, tissue culture	shchang@serv.tfri.gov.tw

Wang, Chiao-Ping	biogeochemistry, pedoecology, stable isotopes, soil microbiology	cpwang@serv.tfri.gov.tw
Yu, Han-Ming	silviculture	yhm@serv.tfri.gov.tw
Chang, Nan-Hang	soil seed banks and seedling regeneration, seed technology	nh@serv.tfri.gov.tw
Chen, Cheng-Fong	clonal forestry, tree physiology	ccf@serv.tfri.gov.tw
Hsui, Yen-Ray	silviculture, seedling physiology	syr@serv.tfri.gov.tw
Ma, Fu-Ching	silviculture, forest regeneration	ma@tfri.domino.tfri.gov.tw
Chung, Jeng-Der	floral biology, anatomy	chung@serv.tfri.gov.tw
Tsay, Jeen-Yin	tissue culture	tsay@serv.tfri.gov.tw
Duh, Ching-Tzer	forestry GIS, photogrammetry	gisdu@serv.tfri.gov.tw
Lin, Kung-Chin	soil survey, soil fertility	kcling@serv.tfri.gov.tw
Huang, Chu-Mei	soil chemistry	tfrisil@tfri.domino.tfri.gov.tw
Chen, Yi-Chiann	biotechnology, horticulture	chiann@serv.tfri.gov.tw
Chien, Ching-Te	silviculture management, tree and seed physiology	chien@serv.tfri.gov.tw

Division of Forest Management

Cheng, Chi-Chuan	remote sensing and GIS, forest management	cccheng@serv.tfri.gow.tw
Chiu, Chih-Ming	forest tending and management, wood properties	cmchiu@serv.tfri.gov.tw
Wang, Dar-Hsiung	forest management and modeling	dhwang@serv.tfri.gov.tw
Hsieh, Han-Ching	forest management, GIS	mickeymail@kimo.com.tw
Lo-Cho, Chen-Nan	forest management	
Tang, Sheng-Lin	silviculture, forest management	daisy@serv.tfri.gov.tw
Wang, Pei-Jung	social forestry, forest policy, forest management, forestry ethics	pjwang@serv.tfri.gov.tw
Chang, Che-Chang	GIS, vegetation ecology	jeremy@serv.tfri.gov.tw
Wang, Su-Fen	GIS	sfwang@serv.tfri.gov.tw
Tang, Shyh-Chian	forest operations	stantang@serv.tfir.gov.tw
Hsieh, Han-Ching	forest management, GIS	mickeymail@kimo.com.tw

Division of Watershed Management

Lu, Hui-Sheng	forest hydrology	lusteve@serv.tfri.gov.tw
Huang, Chiung-Piau	watershed management	tfrihcp@serv.tfri.gov.tw
King, Hen-Biau	ecology, biogeochemistry	hbking@serv.tfri.gov.tw
Hu, Su-Cherng	soil erosion	schu@serv.tfri.gov.tw
Lin, Juang-Pey	soil and water conservation	jplin@serv.tfri.gov.tw
Hwong, Jeen-Liang	forest hydrology	jlhwong@serv.tfri.gov.tw
Hwong, Liang-Shin	forest hydrology	lshwang@serv.tfri.gov.tw
Liu, Chiung-Pin	water chemistry and biogeochemistry	sbliu@serv.tfri.gov.tw
Tang, Kai-Jung	botany	kjtang@serv.tfri.gov.tw
Chou, Yu-Chi	watershed management, landslide control	ycchou@serv.tfri.gov.tw

Division of Forestry Economics

Wu, Chin-Shien	forestry economics	johnwu@serv.tfri.gov.tw
Jen, I-An	forestry economics	ian@serv.tfri.gov.tw
Chen, Lih-Chin	forestry economics	cherry@serv.tfri.gov.tw
Wu, Wann-Yih	forestry economics	tfrieco@domino.tfri.gov.tw
Lin, Jiunn-Cheng	forestry economics	ljc@serv.tfri.gov.tw
Jeng, Meei-Ru	forest economics	beer@serv.tfri.gov.tw
Chen, I-Shang	silviculture	ishang@serv.tfri.gov.tw

Division of Forest Protection

Chang, Tun-Tschu	forest pathology	ttchang@serv.tfri.gov.tw
Chao, Jung-Tai	animal behavior, forest insects, wildlife conservation	jtchao@serv.tfri.gov.tw
Lin, Chau-Chin	forest fires	chin@serv.tfri.gov.tw
Wu, Meng-Ling	forest pathology	mlw@serv.tfri.gov.tw
Koh, Chao-Nien	avian ecology	nien@serv.tfri.gov.tw
Lu, Sheng-Shan	insect conservation	sslu@serv.tfri.gov.tw
Chen, Yi-Ming	wildlife biology, forestry	ymchen@serv.tfri.gov.tw
Jaung, Ling-Mu	entomology	lmjaung@serv.tfri.gov.tw
Fu, Chuen-Hsu	forest pathology	fch@serv.tfri.gov.tw

Division of Forest Utilization

Wang, Ying-Shen	wood identification	yswang@serv.tfri.gov.tw
Chou, Chun	timber engineering	chunchou@serv.tfri.gov.tw
Tang, Jung-Lei	wood composites	jltang@serv.tfri.gov.tw
Huang, Yan-San	wood cutting	yshuang@serv.tfri.gov.tw
Hwang, Gwo-Shyong	wood gluing	gshwang@serv.tfri.gov.tw
Hwang, Chin-Yin	wood processing	chinyin@serv.tfri.gov.tw
Chen, Shin-Shin	wood properties	sschen@serv.tfri.gov.tw
Lee, Ming-Chung	wood machining	mclee@serv.tfri.gov.tw
Chen, Yuh-Shiow	wood anatomy	yschen@serv.tfri.gov.tw
Lin, Yu-Jen	physical and mechanical properties	yujen@serv.tfri.gov.tw
Hsu, Fu-Lan	physical and mechanical properties	fulan521@yahoo.com.tw
Lin, Cheng-Jung	forest utilization	zzlin@serv.tfri.gov.tw

Division of Forestry Chemistry

Tsou, Che-Tsung	wood chemistry adhesives and finishes	cttsou@serv.tfri.gov.tw
Shieh, Jui-Chung	wood chemistry	jcshieh@serv.tfri.gov.tw
Wang, Chen-Lan	forest chemistry	clwang@serv.tfri.gov.tw
Lee, Hong-Lin	wood preservation and chemistry	honglin@serv.tfri.gov.tw
Lin, Shung-Jei	wood deterioration and preservation, wood chemistry	che-sjl@serv.tfri.gov.tw
Yin, Hwa-Wen	forest chemistry	hwyin@serv.tfri.gov.tw
Shiah, Tsang-Chyi	wood chemistry, pulp and paper making	ccshiah@serv.tfri.gov.tw
Lin, Ping-Fei	forest utilization, forestry technique extension	chanel@serv.tfri.gov.tw

Division of Wood Cellulose

Su, Yu-Chang	pulp and paper science, wood science and technology, natural organic chemistry	ycsu@serv.tfri.gov.tw
Wang, Eugene I-Chen	effluent treatment, pulp and paper science	iwang@serv.tfri.gov.tw

Chiou,Chun-Hsiung	pulp and paper science, conversion and screening	chchiou@serv.tfri.gov.tw
Wang, Kuo-Tsai	pulp and paper science	ktwang@serv.tfri.gov.tw
Yeh, Ruoh-Yun	pulp and paper science	zoeyeh@serv.tfri.gov.tw
Chang, Ming-Ji	Pulp and Paper making	tfricel@serv.tfri.gov.tw
Ho, Chen-Lung	Forest Products, Pulp and Paper making	chenlung@serv.tfri.gov.tw

Division of Forestry Extension

Liu, I-Hsin	wildlife management, conservation ecology, applied silviculture	ihsinliu@serv.tfri.gov.tw
Wang, Ping-Tsung	forest management	ycchen@serv.tfri.gov.tw
Chang, Tien-Yung	silviculture	tfriext@serv.tfri.gov.tw
Chen, Yen-Chang	silviculture, forest management	ycchen@serv.tfri.gov.tw
Tu, San-Hsien	forest utilization and marketing	asan@serv.tfri.gov.tw
Lai, Chih-Ming	silviculture	lai@serv.tfri.gov.tw
Chang, Sun-Young	forest conservation	csy@serv.tfri.gov.tw

Fushan Station

Chiou, Wen-Liang	plant community ecology	chiou@serv.tfri.gov.tw
Lin, Tzer-Tong	plant community ecology	tfritlin@ms1.hinet.net
Chen, Chun-Hsiun	management of natural reserves	tfritlin@ms1.hinet.net
Hwang-Wu, Ching-Biau	improvement of silvicultural techniques	hwcb0719@ms46.hinet.net
Huang, Chin-Mu	forest management	chinmu.huang@msa.hinet.net
Chao, Hui-Te	silviculture	jht@serv.tfri.gov.tw
Tung, Gene-Sheng	Cecidology, gall insect	gall@serv.tfri.gov.tw
Chou, Min-Hsiung	forest ecology	tfrifs@serv.tfri.gov.tw
Su, Sheng-Hsin	forest ecology, phytosociology, plant taxonomy	sush@serv.tfri.gov.tw

Lienhuachih Station

Chen, Tsai-Huei	silviculture, windbreak forests	thchen@serv.tfri.gov.tw

Sun, Cheng-Chun	silviculture, watershed management	pdaf0103@ms17.hinet.net
Fuh, Chao-Hsien	silviculture, forest pathology	pdaf0103@ms17.hinet.net
Chang, Hua-Chou	silviculture, nutrient cycling	tfrilhc@serv.tfri.gov.tw
Liu, Ching-Kuo	taxonomy, silviculture	tfrilhc@serv.tfri.gov.tw

Chungpu Station

Ho, Kuen-Yih	taxonomy, ecology	chungpu@ms19.hinet.net
Deng, Shu-Lin	silviculture, forest protection	chungpu@ms19.hinet.net
Chang, Yi-Hsuan	silviculture, forest protection	chungpu@ms19.hinet.net
Tsai, Ching-Chu	silviculture	pdaf0103@ms17.hinet.net
Wang, chiou shyan	Silviculture, tree physiology	chungpu@ms19.hinet.net

Liukuei Station

Lu, Shiang-Yue	hydrology	shiang@serv.tfri.gov.tw
Yang, Chi-Shong	silviculture	luk1234@ms26.hinet.net
Chiou, Chong-Chi	silviculture	luk1234@ms26.hinet.net
Lin, Chao-Sung	forest management, forest road engineering	luk1234@ms26.hinet.net
Suen, Ming-Yuan	silviculture	luk1234@ms26.hinet.net
Tsai, Jia-Bin	tree physiology	tjb@serv.tfri.gov.tw
Lin, Wen-Chih	forest ecology	lwenc@serv.tfri.gov.tw
Ju, Rong-San	forest ecology	shanluk@ms39.hinet.net
Lu, I-Chu	silviculture	chun@serv.tfri.gov.tw

Taimalee Station

Chen, Yung-Hsiu	forest ecology	cyh@serv.tfri.gov.tw
Chou, Ming-Shun	tree breeding, nursery practices, silviculture	tml12345@ms14.hinet.net
Lai, I-Min	nursery practices, silviculture	tml12345@ms14.hinet.net
Lin, Chieh-Lung	nursery practices, silviculture	dragon@serv.tfri.gov.tw
Yang, Jeng-Chuann	seed technology	yjc@serv.tfri.gov.tw
Lee, Hung-Te	nursery practices, silviculture	pp@serv.tfri.gov.tw

Hengchun Station

Wang, Hsiang-Hua	plant ecology, ethnobotany	hhwang@serv.tfri.gov.tw

Chen, Hsuan-Wu	population biology	chw@serv.tfri.gov.tw
Kuo, Chi-Fan	plant taxonomy	tfrihc@serv.tfri.gov.tw
Wu, Shu-Hui	vegetation ecology	gentiana40@hotmail.com
Tzeng, Hsy-Yu	taxonomy, fig biology	9283@kimo.com.tw
Hung, Sheng-Feng	population genetics	hsf@serv.tfri.gov.tw
Chang, Li-Wan	silviculture	tfrihc@serv.tfri.gov.tw

IV Celebrating the Year's Successes

Forest Biology

In terms of research characteristics, the Department of Forestry Biology has labs which include the Plant Systematics Lab, Plant Cultivation Lab, Environmental Education Lab, Ethnobotany Lab, and Botanical Garden Management Research Lab. Their primary research objectives and achievements include the following.

(I)The Plant Systematics Lab

Originally, Taiwan had abundant plant resources. However, the native plants have been threatened by over exploitation throughout their natural ranges. To preserve the diversity of plant resources, the primary research objectives of this lab include taxonomic research, plant resources surveys, and plant resources preservation.

The herbarium is the center of plant taxonomy research. The TAIF was the earliest established herbarium in Taiwan, originally located inside the Taipei Botanical Garden, but it was moved to the Preservation Building's 2nd and 3rd floors in March 2000. Currently, specimens are the primary collection of this herbarium, and are stored inside transportable specimen shelves. There were 30,000 domestic and foreign plant specimens produced and categorized in the last year. So far the total number of stored specimens is 153,000. And exchanges of plant specimens with foreign and domestic herbaria include 2,770 specimens. Scholars visiting to observe specimens numbered 64 persons; and 98 specimens were borrowed by foreign and domestic researchers.

The work on plant resources surveys, in the northern Taiwan area has been completed. The survey coverage includes mid- and lower-elevation forests of Ilan County. In this area, there were 9,376 species recorded, including 624 specimens. This program, which began in 2000, now has produced 2 newly recorded species, and 79 rare plants have been recognized, including 25 ferns, 7 gymnosperms, 35 dicotyledons , and 12 monocotyledons.

Research projects on the preservation of plant resources, this year included source collection and preservation of ferns, research on the sperm-inspiring agents of the spinulose tree fern, preservation research of rare and endangered plants, and research on the Arhat pine genetic abnormalities in Taiwan and neighboring areas. As to the research of ferns, fern spores from 45 species have been collected, and the Taiwanese golden dog fern survey has also been completed. For the rare plant preservation study, the species focused on for surveys and studies were the rare and endangered plants of Taiwan. To facilitate these studies, the lab also published "*the color illustration of Taiwanese rare and endangered plants VI.* For "the heregenetic abnormality research on the Arhat pine" the taxonomic studies this year focused on 5 categories and 9 groups. The survey showed that the differences included: Nanzhen Mt. (large leaf Arhat pine) 0.161, Anma Mt. (group flower evergreen) 0.093, Dawu (small leaf Arhat pine) 0.165, Hsingon (small leaf Arhat Pine) 0.179, Leihwa Pond (Taoshi evergreen) 0.246, and Lanwu (Lanwu Arhat pine) 0.148.

(II) Plant Cultivation Lab

Modern integrated botanical gardens have the responsibilities of utilizing studying natural botanical resources, preserving rare and endangered plants, and exchanging and introducing economic and ornamental plants through international exchanges, so as to enrich the categories and species for planting and exhibition. For these very reasons, exhibition areas combined with the functions of collecting and assessing original botanical ecological systems and hereditary genetic resources as well as research on growth, propagation, and development of plants have not only been established for preservation, but also to provide knowledge resources for the public and study material for students and scholars. Thus, the preservation, educational, and research functions of botanical gardens are fully evident. Based on this understanding, the Plant Cultivation Lab primarily focused on the exploitation and uses of native plants, the propagation and preservation of rare and endangered plants, and research on and preservation of new species and newly recorded botanical groups. Projects carried out last year included the survey and propagation of native hedge plants, the establishment of new species and newly recorded botanical exhibition areas in the Botanical Garden, the genetic material collection and preservation research on Fagaceae plants, and the propagation of rare plants and their ex situ preservation.

As for research on hedge plants, 8 candidate plants were surveyed, and their growth conditions assessed. Among them, better results were obtained with *Distylium racsmosum* (蚊母樹), *Taxus mairei* (紅豆杉), and *Scolopia oldhamii* (魯花樹). As to new species and newly recorded

plants, ecological surveys and branching tests of *Symplocos shilanensis* (希蘭灰木) and *Prunus buergeriana* (高山小白櫻) have been completed. Surveys of the rare plants, *Pinus morrisonicola* (臺灣五葉松) and *Taiwania cryptomerioides*(臺灣杉)have been completed. As to research on the Fagaceae, a cutting test on *Pasania dodonaeifolia*(柳葉石櫟)while was done. Cutting specimens from wild natural trees failed, on the contrary, specimens from the Fushan Specimens Garden, achieved 30% survivability. Another experiment with an in vitro regeneration system for immature seeds is still underway.

(III) Environmental Education Lab

The most direct approach to study the composition, growth, replenishment, and evolution of any botanical system is to establish a permanent botanical ecosystem for sampling. This botanical ecosystem not only can provide detailed survey material for regional researchers, but also offer necessary information for resource preservation managers to understand the resource composition, any abnormal configurations, and exotic plant invasion. Based on this reality, this lab especially focused on establishing permanent sample areas with specific ecological management and planting surveys, to investigate genetic abnormalities, discuss genetic relations, and monitor and prevent the invasion by exotic species. The programs carried out last year included the establishment of a permanent sample area in the Liuquan area, and research on 4 species of Lauraceae, genetic abnormalities of *Cinnamomum kanehirae*, *Cinnamomum micranthum*, and the Lauraceae, along with the study of the genetic relations of these three plants, as well as monitoring and prevention of invasion by

Leucaena leucocephala（銀合歡）and *Eupatorium sp.*（香澤蘭） in southern Taiwan.

Research results on the Lauraceae showed that *Cinnamomum camphora*（樟樹） and *Litsea cubeba*（山胡椒） were visited by insects during both day and night, by flies and *Cantharidae*（菊虎）during the day, and by *Geometridae*（尺蛾）, *Noctuidae*（夜蛾）, *Pyralidae*（螟蛾）at night. Lauraceae flowers lasted an average 5.4 ± 0.2 days, while the male and female flowers of *Litsea cubeba*（山胡椒） lasted 12.82 ± 2.2 days and 15.44 ± 2.8 days , respectively. As to the study of exotic plant species, a survey of the damage by *Eupatorium sp.*（香澤蘭）and *Leucaena leucocephala*（銀合歡）has been completed. Further monitoring and research on their prevention are needed in the future.

(IV)The Ethnobotany Lab

Ethnobotanical research is an emerging science which examines the exploitation of plants by our ancestors. Its objectives, in addition to preserving the cultural heritage of our ancestors, are to scientifically test and analyze certain types of plants to learn about their valuable uses. In Taiwan's rapidly changing society, not only have the aboriginal people lost their original culture, knowledge, wisdom, and experiences in a rapid manner, but the botanical culture of the Han race has also suffered. To preserve our ancestors' precious cultural heritage, this lab used field surveys to study folklore botanical knowledge and the exploitation of botanicals of the cultures of Lanyu (Orchid Island) aborigines and the Han people in Taiwan proper, and scientifically tested and analyzed certain types of plants.

The program of this lab last year was to analyze botanical resources management and their uses by the Dawu people on Lanyu, and the impacts on the forest composition and structure.

(V) Botanical Management Research Lab

The differences between botanical gardens and ordinary parks consist of the former's attention to the preservation of plant species and studies on various plant species along with their contribution to providing the public with knowledge of plants. In fact, the Taipei Botanical Garden has become an important location for urban citizens' botanical learning and entertainment. Therefore, the garden management has faced increasing demands of tourists and pressures of the misuse of resources. It has become very urgent to study botanical garden management and tourist behavior so that the garden can demonstrate its best functions and avoid damage from overuse. Based on this philosophy, this lab focused on the analysis of botanical management and tourist behavior. The program of the Botanical Management Research Lab this year was to assess and promote the introduction of educational systems of the Taiwan Forestry Research Institute and assess tourist behavior inside the gardens and its impact on garden ecological systems.

Silviculture

(I) Research mission and orientation

The Division of Silviculture consists of 3 research laboratories for silviculture technology, forest soils, and tree seed and forest genetics. Research missions differ for the 3 laboratories. In recent years, research on natural regeneration in hardwood stands, and diverse silviculture operations in man-made forests and in natural forests has been carried at by the Laboratory of Silviculture Technology. There were 3 primary projects conducted by the soil research group in 2001. First, the field soil survey in high-elevation areas was completed. The data will be used to establish a system for the classification, management, and utilization of forest soils. Second, the biomass and carbon storage of the understory and forest floor in Taiwania plantations of the Liukuei area were investigated and estimated for carbon dioxide sequestration research of forest stocks. Third, wood debris from the Fushan Experimental Forest was investigated to understand the importance of the debris to nutrient accumulation. In the future, major research work will be to analyze the field soil survey data, in order to produce a detailed soil map of all forests in Taiwan, and to build up a soil system as described above. To investigate the carbon dioxide problem, a better monitoring method will be tested for estimating forest carbon dioxide sequestration. Research on the influences of land use changes on soil carbon storage is also one of the key projects. To preserve the germplasm of woody trees in Taiwan and to commercially exploit economically important trees, we established a seed storage room, and are dedicated to improving *Calocedrus formosana*, *Cinnamomum kanehirae*, and *Taxus mairei*. To

improve the pulp quality of fiber trees, transgenic trees of *Eucalyptus camaldulensis* transfected with lignin- related genes were obtained. Some achievements have attracted private companies to join in these projects to commercialize economic products.

(II) Important research results

1. Silviculture Technology Laboratory

(1) Study of the regeneration of natural hardwood forests

Seedling survival capacity and growth potential of woody species under various forest canopy statuses vastly contribute to the dynamic processes of forest regeneration. The relatively important influence of forest composition and structure may vary from species to species; however, through intensive surveys of natural regeneration patterns and active management in plantations, we can build up a ideal forest stand to meet the goal of not only increasing biodiversity but also of maintaining productivity within plantations.

In the Fushan Experimental Forest, 3 years of monitoring data revealed that the tree mortality rate (3.9%) was slightly higher than the sapling recruitment rate (3.5%). Seedlings of primary species could grow normally in understory light conditions, except for *Machilus zuihoensis* seedlings. In the Liukuei Experimental Forest, the analysis of vegetation structure showed that the recruitment ability of *Pseudotsuga wilsoniana* was low and showed a non-reversed J shape, while that of the primary hardwood trees species was high. Plenty of seedlings and saplings of hardwood species

already exist there and are just waiting for canopy openings for their subsequent growth. The seed density in the soil seed bank was estimated to be 6,762 individuals/m^2, and the species composition was quite different from the canopy species. Site preparations of the forest floor of the plantation benefited the recruitment of primary species. Partial thinning of pioneer trees and underplanting local primary trees species could promote the evolution of a pure plantation into a diverse mixed forest.

(2) Study of multi-silviculture operations of plantations

In the past, most forestlands in Taiwan were shifted to pure man-made plantations. Deterioration of forest soils, and simplification of forest species and structure caused by monoculture planting led to an inappropriate balance between organisms and the environment. Therefore, creating multistory, mixed plantations with diverse species by active management is needed, which meshes with the goal of "sustained ecological forest management".

In accordance with the culture experiment using different containers and 22- month plantation growth performance, the plastic bag system was determined to be best for raising *Machilus thunbergii* and *Litsea acuminata* seedlings, and the dibbling tube system was the ideal choice for raising *Michelia compressa* and *Elaeocarpus japonicus* seedlings. Among various shade treatments, 7.6% relative light was fundamental for the survival and growth of *Zelkova serrata*, *Liquidambar formosana*, and *Engelhardtia rouxberghiana* seedlings. Fourteen species of insects were investigated as plantation insect pests. The main injuries were to newly sprouting shoots

and leaves and occurred mainly in summer (June-August). Rust disease was the main disease affecting *Machilus thunbergii* seedling growth.

The mean tree height of 7-year-old seedlings planted at the Tamalee experiment site reached 717 and 636 cm for *Elaeocarpus sylvestris* and *Cinnamomum camphora*, respectively, and the survival rate was about 60%. Although the heights of other planted tree species, such as *Lithocarpus castanopsisifolius*, *Schima superba*, *Schefflera octophylla*, *Pasania ternaticupula*, *Machilus Zuihoensis*, and *Cinnamomum kanehirai*, were lower than those of *Zelkova serrata* and *Machilus zuihoensis*, which are traditional plantation species, the average tree height could reach 5 m. It was concluded that with intensive management during the early planting period native broadleaf tree species are potential species for reforestation at low and middle elevations.

To accomplish the 2 stage, gap regeneration planting practice, most of the primary hardwood species can be used to establish a multistory plantation through different silviculture practices, e.g., under-planting, gap planting, and enrichment planting.Using those plantation management experiments should produce multifunctional, uneven aged, multistory, mixed forests coniferous-hardwood.

(3) Research on environmental protection forests

Following the development of modern society and urbanization in Taiwan, functions of forests for public welfare, i.e., land protection, resource conservation, and environment greening, are more concerned with social

policies. Under the threat of exploitation of coastal industrial areas and urbanization of society, research on environmental protection forests is needed in order to improve the living environment quality inland from the coastline and to increase the green cover in urban areas in order to build a "green island of silicon", an island with high- tech development and a high percentage of green areas.

Some groundcover species, including *Ipomoea pescaprae*, *Vitex rotundifolia*, *Spinifex littoreus*, and *Wedelia chinensis*, were planted on shifting sand dunes behind sand fences on the Taoyuan seacoast, northwestern Taiwan. In summer, these plants could completely cover the sand surfaces where they were planted, and *I. pescaprae* grew the fastest among them, while *V. rotundifolia* could withtand being buried in sand, but only *S. littoreus* could endure the thick sea salt in winter time. It is recommended that a mixed planting with *I. pescaprae*, *V. rotundifolia*, and *S. littoreus* on shifting sand dunes can achieve the best effects of sand stabilization.

The growth performance was evaluated of 28 seed lots of *Casuarina equisetifolia* at Shihu, Yuenglin and Chiangmei of Penghu County. Highly significant differences in seedling growth characteristics were found in 8-yr-old trees among provenances. At the Shihu experiment site, seed lot 23 showed the optimal survival percentage (69%), and tree height growth reached 9.9 m at 8 years old, while number 12 had the highest tree height of 10.5 m. There were differences between site conditions for selecting suitable seed lots. In Penghu County, number 3 of the Egyptian provenance

had the highest survival rate of 96%, and tree height reached 6.1 m, which was only lower than number 12 seedlot where tree heights reached 7.2m but with a survival rate of only 79%. It was concluded that tree performance showed differences among provenances and sites, the same as results found at the Liukuei and Taimalee highland experiment sites for the provenance study of *Casuarina junghuhniana*, introduced from CSIRO.

An assessment of the genetic diversity of *Casuarina* in Taiwan, based on cluster analysis and principal coordinates analysis of 15 coastal locations, supported the hypothesis of hybridization of *Casuarina* in Taiwan. A dendrogram based on RAPD data showed that most sampling sites in Taiwan formed a subgroup that was linked with the native provenance of *C. equisetifolia*, suggesting that most plants in Taiwan are close to but not typical of *C. equisetifolia*. Two sampling sites in Taiwan were linked with provenances of *C. glauca*, indicating that some plants in Taiwan are close to this species.

2. Forest Soils Laboratory

(1) Studies on the identification and classification of forestland soils

The identification and classification of forestland soils is the basis of forest practices in forest management; in particular, forestland classification is a standard to evaluate the suitability of practices for forestlands. A soil classification system of forestland suited to the Taiwanese environment should be developed. With some other factors such as site topography, this system will be used to run cross-analyses and evaluations, in order to

determine the principle and standard values of forestland ranks. Under guidance of the concept of forest ecosystem management, the forestland rank indicates various forest practices, which follow ecological principles, to reach the goal of sustainable forest resource management.

The field soil survey was completed, and the data files of soil attributes were established for the Taan, Tachia, and Pahsienshan working circles managed by the Dongshih Forest District of the Taiwan Forest Bureau. In this study, 633 soil samples were collected, and 26 soil legends were identified. For each soil sample, 31 attributes were described using a PC ARC/INFO system. For soil legends, chemical and physical properties were analyzed, which included soil pH, texture, organic carbon, total nitrogen, CEC, aggregate stability, clay minerals and free Fe, Mn, and Al. Based on these data, 82 soil mapping units were developed, and a soil phase map at a scale of 1/25,000 was produced. These results will be used to determine standard values of forestland classification for forest districts using an established model.

(2) Studies on CO_2 sequestration of forests

To evaluate CO_2 sequestration, Taiwania plantations in the Liukuei area were selected to estimate the carbon storage of many components such as understory plants, the litter layer, litterfall, and soils of man-made forests. Plantations included 2 stands which were not thinned and which were of 2 different ages. Three 5 x 5-m plots in each selected stand were established for species investigation and biomass estimation. The sampled plants were cut and weighed in the field. The samples of plant components

were brought back to the lab to obtain oven dry weights and to analyze carbon content. The litter layer and soil were also sampled in the same plantations. The results showed only a few plant species under the Taiwania canopy. The understory biomass in 22- and 29-year-old stands were 4215 and 1418 kg/ha, respectively, and carbon storage of the understory in both stands was 2178 and 852 kg/ha, respectively. While the amount of litterfall was higher in the 22-year-old stand than in the 29-year-old stand, carbon contents in the litter layer and soil were larger in the 29-year-old stand than in the 22-year-old stand.

In order to learn the theory and methods of CO_2 sequestration in forests for use as references for relative research in Taiwan, 1 scientist visited the WINROCK research station and attended field activities in McConnelsville, OH from May 6-13, 2001. With the cooperation of Winrock and American Electric Power, the project focused on the impact of forest harvesting on carbon sequestration. The method estimates carbon storage by examining satellite images, and results are revised by field inventories to build relationships between the images and field data. The purpose of the project is to collect data from a small area to validate the image method for future application to a larger area.

After the trip, it was suggested that the Council of Agriculture and Forest Bureau pay more attention to the carbon sequestration functions of forests and to encourage activities to estimate forest carbon storage and to promote selective cutting. The research institute should help the government agencies monitor the impact of forest practices on carbon sequestration,

stimulate selective cutting practices in forest management, and organize an international workshop on forest carbon sequestration, in order to raise the research quality and to collect more-precise data on forest carbon sequestration in Taiwan.

(3) Studies on accumulation and distribution of woody debris

In order to estimate the accumulation and distribution of woody debris of the warm temperate broadleaf forest in the Fushan Experimental Forest, three 20 x 20- m plots in the Fushan forest representing 2 topographies, hillside and valley, were established. The woody debris was classified into 5 classes by several factors, such as size, decay condition, and situation, following the wood debris classification system of US Northwest forests. But to fit the local situation, the size classification of wood debris here is smaller than that in the US, since the sizes of trees at Fushan are much smaller than those in the US Northwest forests. The results showed that average amounts (mean ± standard deviation) of wood debris with diameters larger than 5 cm were 121.28 ± 93.10 and 27.45 ± 16.40 m^3/ha for the hillside forest and valley forest, respectively. The average amounts of wood debris with diameters 1-2 and 2-5 cm were 361.1± 56.0 and 335.1±156.0 kg/ha for the hillside, and were 220.5 ± 82.2 and 310.6 ± 203.3 kg/ha for the valley forest, respectively. The amount of wood debris for the hillside forest was larger than that for the valley forest, probably because the hillside forest had more trees than the valley forest did. Meanwhile, the wood debris amount in the Fushan forest was much lower than that in forests of the US Northwest.

3. Tree Seed and Forest Genetics Laboratory

(1) Seed storage study

We have established 3 cool rooms in which temperatures are precisely controlled at -20 ± 1℃, 4 ± 1℃, and 15 ± 1℃, and moisture content is controlled below 60% R.H. Orthodox seeds are dried to within 6-10% moisture content and stored at -20℃ for long-term storage. There are 121 species and 578 seed lots presently being stored. Both recalcitrant and intermediate type seeds are stored at 4℃ for short-term storage, and include 31 species and 53 seed lots. These storage seed lots can achieve the goal of ex situ conservation and provide for domestic and international research.

(2) Breeding and propagation of economic tree species

Investigating fruit production of seed orchards containing 35 clones of *Calocedrus formosana* at 3 locations, only 8 and 4 clones located at Lienhuachih and Taimalee stations, respectively, produced fruits. The failure to produce fruit may have been because of abortion of the male pollen. To preserve pollen viability, we tried to establish a frozen storage method. Investigating the growth of 4-year-old *Taxus mairei* trees in the field, the average height of trees grown at Liukuei was 119 cm, 28 cm taller than those grown at Chiayan. Concentrations of taxol and 10-deacetylbaccatin III (10-DBC) in needles of 40 clones derived from different provenances varied at different sites. The rank of 10-DBC concentrations in 3 sites were Wulai > Liukuei > Taipei, while the rank of taxol concentrations were Liukuei > Wulai > Taipei. Branches of 3- and 4-year-old trees harvested above 1 m weighed 2.1 and 2.8 kg, respectively.

(3) Production of healthy propagules using tissue cultures

From international seed exchanges, we introduced 15 seed lots of *Taxus* species from 10 countries. The species introduced were *T. baccata*, *T. canadaensis*, *T. cuspidata*, *T. media*, and *T. brevifolia*. Using embryo cultures, all germinated in vitro. To propagate juvenile propagules of *Cinnamomun kanehirai*, buds collected at Liukuei and Taimalee in different seasons were cultured in vitro. Survival rates of bud cultures collected from spring were the greatest. Browning of cultures occurred. Adding anti-browning agents into the medium could control it. Shoot tip cultures could induce 5.5 times as many shoots. The plantlets which were planted out last year grew strong and remained erect.

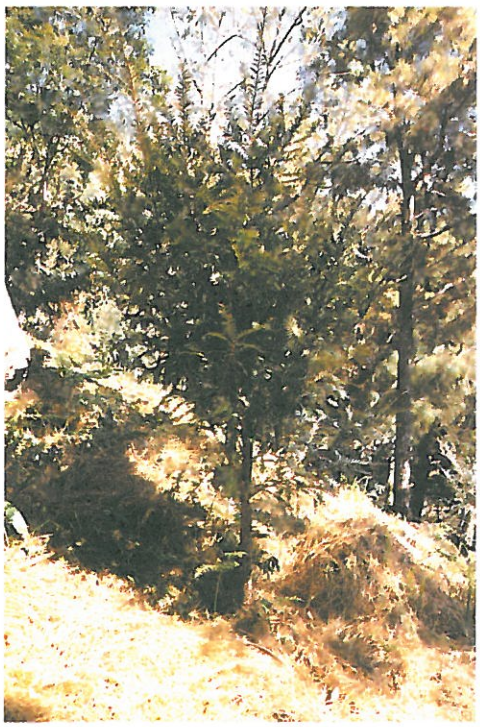
(4) Taxol production from cell cultures

In *Taxus* cell cultures, both monitored parameters of changes of culture conditions and elicitor addition were very important factors. The relationships among pH, pO_2, electric conductivity, cell growth, and taxol yield were investigated. To improve taxol yields, we found that modifying the carbohydrates in the medium to a high concentration of sucrose, sucrose plus fructose, or using glucose alone were very effective. Another effective method was adding methyl jasmonate or jasmonica acid to the medium. A good cell line cultured in flasks could produce 8.5 mg/l/day, and the yield of baccatin III could reach 6.5 mg/l/day in modified culture medium.

(5) Genetic transformation of *Eucalyptus* species

In the study of gene transformation for hybrid eucalypt, calli transformed with the GUS gene were obtained and identified. Shoots

induced from these calli were found, however, they survived with difficulty. In the study of genetic engineering in *Eucalyptus camaldulensis*, we obtained plantlets transformed with the 4CL (4-coumaric acid: coenzyme A ligase) gene. Plants transformed with sense and antisense C4H genes duplicated last year were planted at Liukuei. We cloned 1101 bp of the OMT (O-methyltransferase) gene from RNA isolated from primary lignin tissues of *E. camaldulensis* using an RT PCR technique. DNA sequencing of this OMT gene revealed it should be a caffeic acid 3-O-methyltransferase gene.



▲ Four-year-old trees of *Taxus mairei* at the Liukuei Station.



▲ One-year-old plantlets in vitro planted out in a greenhouse for 1 year.



▲ Experiment of branch harvesting for 3- and 4-year-old *Taxus maireia* at Wulai.



◀ One-year-old transgenic *Eucalyptus camadulensis* carrying the C4H transgene established in a test plantation.



▲ A man-made coniferous plantation naturally invaded by broadleaf seedlings.



▲ "SssE" soil profile (Chilan mt.area).



▲ *Ipomoea pescaprae, Vitex rotundifolia,* and *Spinifex littoreus* mixed-planted behind sand fences.



▲ Mixed hardwood plantations with diversified tree species.



▲ Wood debris in the Fushan forest.



▲ Investigation on carbon sequestration of understory plants in a *Taiwania* plantation of the LiuKuei Experimental Forest.

Forestry Economics

(I)Evaluation of economic benefits of water conservation from experimental watersheds of the Taiwan Forestry Research Institute

Forest ecosystems provide multiple benefits for human beings, which can be considered to be a type of perpetual natural resource. Evaluating forest resources is a key step toward their sustainable use. Water and soil conservation and flow regulation is 1 of the major functions of forest ecosystems in Taiwan. However, it is a kind of indirect use value. Estimating these values is intricate and takes time. The focus of this study was to estimate the economic value of water conservation from 2 experimental branch stations of TFRI, i.e., the Lienhuachih forest, and the Liukuei forest. From this study, the preliminary result of economic value from the function of the Lienhuachih Experimental Forests is estimated to range from NT$ 6.9 million to NT$27 million annually.

(II) Assessing the feasibility of planting forest energy crops in Taiwan

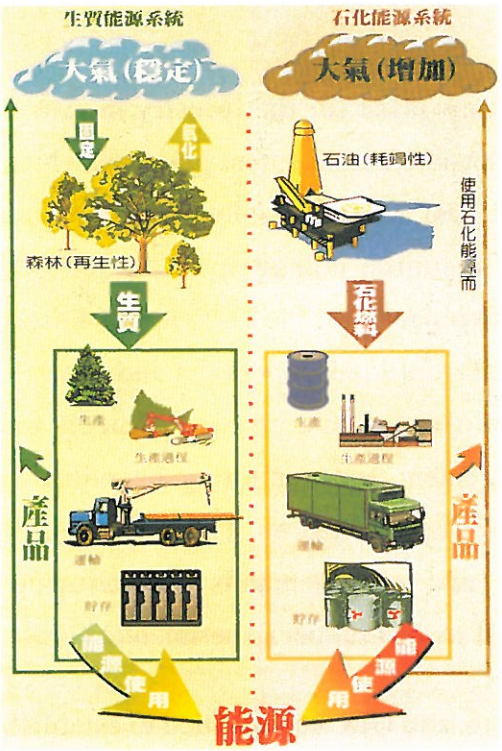
Energy crops refer to plants whose usage is for bio-fuels (like ethanol) or for burning to produce electricity. The purpose of the project was to study the production efficiency, growth, and feasibility of bioenergy crops, assessing the prospective benefits of energy crops in Taiwan, and the potential of current wood and bamboo resource serves as bioenergy in Taiwan.

The project will run for 2 years. In the first year, by reviewing the literature, related papers of forest resource bioenergy and energy crops in the world, and the forest growth situation and biomass production in Taiwan will be collected, analyzed, and discussed. In addition, potential markets and demand and supply of planting energy crops and selecting appropriate species of energy crops will be studied.

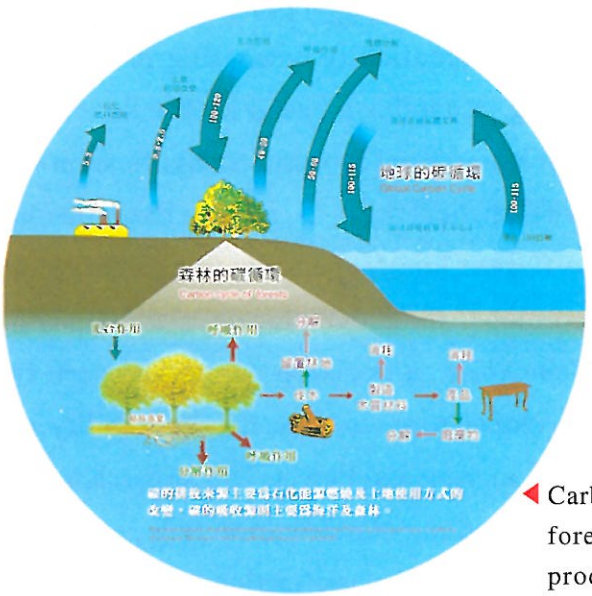
Prospective contributions of this project will be to determine the carbon sequestration, energy production potential, and efficiency of timber energy crops in order to demonstrate the importance of forests for greenhouse gas mitigation and green energy supply. The forest management model for promoting utilization efficiency of bioenergy can be a scientifically based reference when the government sector draws up its green policy.

(III) Analysis of the atmospheric carbon flow and storage effects from forest resources and wood products in Taiwan

Climate change is considered to be one of the most important environmental policy issues in the world. Concern about emissions of CO_2 led to worldwide attention. The Kyoto Protocol allows countries to claim a credit of C sequestered as a result of afforestation and reforestation, while C lost due to deforestation is a debit. Carbon is stored in trees, understory, forest litter, and forest soils. In addition the account of C sequestration in wood products is also important. This study attempts to calculate carbon flows and storage both in forests and wood products in Taiwan.



Demonstration of the forest for greenhouse gas mitigation and green energy supply.



Carbon is stored in trees, understory, forest litter, forest soils, and wood products.

Forest Management

Sustainable management is a new issue for the forestry industry. Ecosystem management, which emphasizes management practices which are ecologically sound, economically feasible, and socially acceptable, is a new research direction for forest resource management to achieve sustainable forests. To achieve these objectives, the Division of Forest Management not only will apply different landscape units and spatial-temporal information concerning biological and physical aspects for forestland classification, forest management, and monitoring, but will also add a research project concerning public participation. This arrangement coincides with ecological, economic, and social demands. The following are the research results of the year 2001 in the Liukuei Experimental Forest.

Photogrammetry, remote sensing, and GIS were applied to establish a scheme of forestland classification. The research processes included the development of an approach of automatically extracting multi-scale ecological units and establishing a database based on the developed landscape units. Then a scheme of hierarchical ecosystem classification was developed based on multivariate statistical analysis, and the Experimental Forest was classified into 3 different landscape units (e.g., ecoregion, landscape mosaic, and site) according to the geographical variations among different landscape units. Meanwhile, a decision support system for forestland classification was developed to assess forestland suitability and site selection for Taiwania in the Experimental Forest. The research results can be extended to island-wide forestland classification (e.g., questions about multi-scale landscape units, forestland classification approaches, and

hierarchical ecosystem classification) and forestland administration through the developed decision support system.

On the aspect of sustainable management of artificial plantations, since its objective will emphasize the productivity of forestland and the diversity of forest stands in order to avoid impacts on the ecological environment, man-made forests should be managed as timber management areas after forestland classification. Therefore, the research aims are the establishment of multistory mixed-species forests of damaged Konishi fir Cunninghamia konishi in order to match the prevailing issues of concern for the protection of the ecological environment and conservation of natural sources. Prelimary results show that the average density in stands is 786 trees/ha before treatment which are mostly composed of Konishi fir and Taiwania. The damage investigation indicates the most 90% injured trees are Konishi fir. Split plots were designed, and tree densities of the residual number of trees of 200, 300, and 400 trees/ha of Konishi fir were used in the main plots, while 6 endemic hardwood species were underplanted in the subplots. Five blocks including a control treatment were set up. The total area is about 5 ha. There is a tendency showing that the ground diameter of seedling is increasing while the residual Konishi fir is decreasing. However, with respect to underplanted seedling height, no significant differences between 200 and 300 trees/ha exist, but the survival ratio of underplanted seedlings became smaller greater when with residual upper trees increased. In general, differences in ground diameter, tree height, and survival ratio among seedlings of 6 underplanted species were very significant.

For the attempt to promote public participation in ecosystem management, the study focused on 2 townships of Liukuei and Moulin near the forest, from the aspects of local social and economic development. Data were collected in 2 ways. First, information on the inhabitants' quality of life and industrial structure was obtained from records of secondhand statistical materials. Second, local key persons were identified by analyzing hundreds of questionnaires designed for this project. The result showed that the development of these 2 townships was categorized as 'rural style'. This is because most of the people have been engaged in farming for a long time, and the main local products are rice, fruits, and vegetables. On the other hand, the study encouraged TFRI because we made a good impression on the local people for our long-term efforts and performance. It was also discovered that most of the residents intend to support the townships moving towards the development of integrating diversified ecotourism and recreation. Although there were some discrepancies between Liukuei and Moulin in terms of the formation mechanisms of public opinion, a common conclusion revealed that some special figures such as the heads of the townships, the representatives of the townships, and the commissioners of the villages still play very important roles in the evolution of local public opinion. This is of significance especially for those who are in charge of forest management planning and research.



▲Establishment of a decision support system for forestland classification.



▲ Multistory forests consisting of residual upper trees of Konishi fir and Taiwania, and an underplanted species, Incense machilus (Machilus zuihoensis).



▲ Man-made Konishi fir damaged by squirrels.

Watershed Management

The watershed management research program includes 2 integrated research projects.

(I). Effects of watershed land use on soils and hydrology in forest ecosystems

At present, 11 gauged watersheds and 12 meteorological stations in TFRI experimental forests are managed and maintained in good condition by the Watershed Management Division. Historical records of some stations (such as Lienhuachih, Liukuei, Pilichi, and Fushan) have been processed and published in the TFRI Extension Series. Compilations of meteorological data of the Hengchun and Kangkao stations were completed this year.

Analyses of throughfall data for betel nut plantations and natural hardwood forests indicate that the average coefficients of variation for betel nut plantations, natural hardwoods, and open area are 0.65-1.16, 0.23-0.28, and 0.005-0.034, respectively. Standard deviations of throughfalls in betel nut plantations and natural hardwoods show proportional effects with their means. Due to larger proportional effects of betel nut plantations, it is very difficult to measure throughfall accurately. The mean of spatial distribution for throughfall of betel nut plantations and natural hardwoods can be estimated from rainfall of open areas with regression equations.

Makino and thorny bamboo woodlands were selected in order to investigate their interception, infiltration, evapotranspiration, and subsurface runoff characteristics because of the large areas they occupy and the less

interference by humans. The percentage of interception losses to gross rainfall for Makino and thorny bamboo woodlands are 14.7% and 18.2%, respectively. In comparison to natural hardwood forests, the interception losses for bamboo woodlands are higher. In addition, the average daily evapotranspiration was estimated to be about 4.53 mm/day using a simplified lysimeter.

Six treatmentse of bahia grass cover, bahia grass cover with a hillside ditch, weed cover, weed cover with a hillside ditch, China fir planting, and bare ground as a control were selected to evaluate the effects on soil losses and runoff. The preliminary results indicate that runoff and soil losses from grass cover plots (bahia grass or weeds) are on average 0.75 and 0.33 times those from the bare plot. Bahia grass cover with a hillside ditch had the best effect in reducing runoff and soil losses. Runoff and soil losses were 0.70 and 0.30 times those from the bare plot, respectively.

Hydrological monitoring was established at the Herkenshi watershed (856 ha) and its tributary watersheds of Jalongshi (370 ha) and Houpeikenshi (357 ha) in the Lienhuachih area of central Taiwan. The percentage of forest land is 88.4% for the Jalongshi watershed, 68.4% for the Houpeikenshi watershed, and 77.6% for the Herkenshi watershed. Annual streamflow was 1811.9 mm (72.6%) at Herkenshi, 1832.1 mm (73.4%) at Jalongshi and 1828.0 mm (73.2%) at Houpeikenshi in 1999. Annual streamflow was 1594.9 mm (82.8%) at Herkenshi, 1630.8 mm (84.6%) at Jalongshi and 1671.1 mm (86.7%) at Houpeikenshi in 2000. Annual streamflow was 1649.5 mm (75.6%) at Herkenshi, 1640.4 mm (75.2%) at Jalongshi and 1708.2 mm (78.3%) at Houpeikenshi in 2001. Monthly rainfall and

streamflows varied with seasons. Streamflows varied directly with rainfall. Streamflows and suspended load in the main stream and tributary watersheds fluctuated contemporaneously simultaneously.

Understanding the nutrient dynamics of soil water and the buffering capacity of forest soils to acid precipitation is an important focus in forested watersheds in Taiwan. The base cation concentrations (Na, K, Ca, and Mg) of soil solution decreased with depth of soils, as did anion concentrations (NO_3, Cl, and SO_4), especially SO_4 in Fushan soils. High soil organic matter content inhibits sulfate sorption. On the other hand, removal of free iron and aluminum oxides by dithionite-citrate-bicarbonate solutions caused low sulfate sorption. Thus, free iron and aluminum oxides contents were the major factors affecting the sulfate sorption capacity in Fushan soils.

(II). Changes in soil and water resources in the Chiufenershan area after the Chichi earthquake (Sept. 21, 1999)

Two hydrologic stations were established near the Fulu and Wanlung bridges for monitoring the hydrologic effects of both landslides and landslide-dammed lakes in the Chiufenershan area after the Chichi earthquake which measured 7.3 on the Richter scale on September 21, 1999. The hydrologic station at Fulu bridge measures streamflow from the Chiutsaihu upstream watershed that includes almost no landslide areas. The hydrologic station at Wanlung bridge measures streamflow from the Chiutsaihu mainstream watershed that includes a large area of landslides. Based on analyses of the

preliminarily hydrologic data, the stormflow of the mainstream watershed including the great landslide area was larger than that of the upstream watershed with almost no landslide area.

Investigating potential landslide mechanisms is an important topic. Four boring holes (BH-1, BH-2, BH-3, and BH-4) were made for geological investigation and interpretation. Rainfall gauges, groundwater level recorders, and underground inclinometers were installed in the landslide area and adjacent areas. Based on the investigation of the borings, the main stratum is gray and brown sandstone. The shear strength test of rock samples revealed 6.5 kg/cm^2 of peak cohesion force and 35.6° of peak frictional angle. The relative mineral ratio of slip soil in decreasing order was as follows: quartz (57%), feldspar (15%), mica (10%), kaolinite (8%), chlorite (7%), and smectite (3%). The groundwater levels in BH-1, BH-3, and BH-4 were between GL-20.85 and GL-22.85 m. A small distance movement was only 2.56 mm at depth of 5 m.

After the Chichi earthquake of September 21, 1999, large-scale landslides occurred in central Taiwan. Satellite images and a digital elevation model were used to process the vegetation index analysis for identifying landslide sites and to extract topographic information of the areas. A complicated system combined with GIS was effectively used to monitor and assess the recovery rates of vegetation in landslide areas. The functions of site analysis, dynamic watershed query, automated coding, rank of priority management, and revegetation monitoring and evaluation for the landslides in the Chiufenershan area were all integrated with this system.



Hydrological monitoring at the Houpeikenshi watershed.



Measuring runoff and soil losses with runoff plots for a sloping betel nut plantation.



One of 11 gauged stations in the TFRI experimental forests.

Forest Protection

(I) Forest Protection Consultation and Information

This project is to provide service and information on forest diseases and pests. The information poster of the Diagnosis Center of Forest Diseases and books about forest diseases published by Taiwan Forest Research Institute (TFRI) have been sent to several county governments, the Taiwan Forest Bureau, and its subordinate units. The website "Diagnosis Center of Forest Diseases" has been established for service and information on forest diseases and pests from the website that is included in the net of TFRI. A telephone number (02-23078733) is provided for the identification and diagnosis of forest diseases. In total, 106 cases of forest diseases or pests were identified during this year: 54 cases of diseases, 39 of insects, 9 of physiological agents, 1 of animal damage, 1 of an undetermined agent, and 2 of diagnostic service.

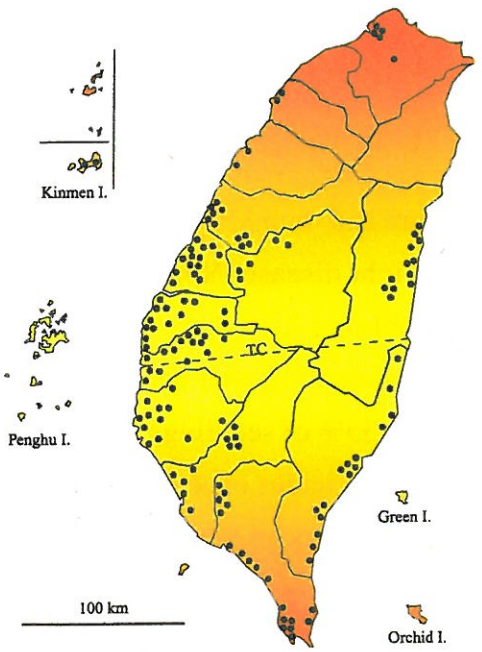
(II)Forest Pathology Research: Forest Diseases and Their Management

A declining disease is characterized by brown root rot, wilting of foliage, leaf discoloration, a brown mycelial mat growing on roots and stem bases of affected trees, and ultimate death of trees. Seedlings of various host plants found naturally infected in the field were inoculated with *Phellinus noxius* grown on camphor twig medium. Seedings of all inoculated species were infected, and the fungus was reisolated from the diseased tissues. Although *Phellinus noxius* did not favor particular soils from pH 4 to 9, it was most frequently found in soils from pH 5 to 8.

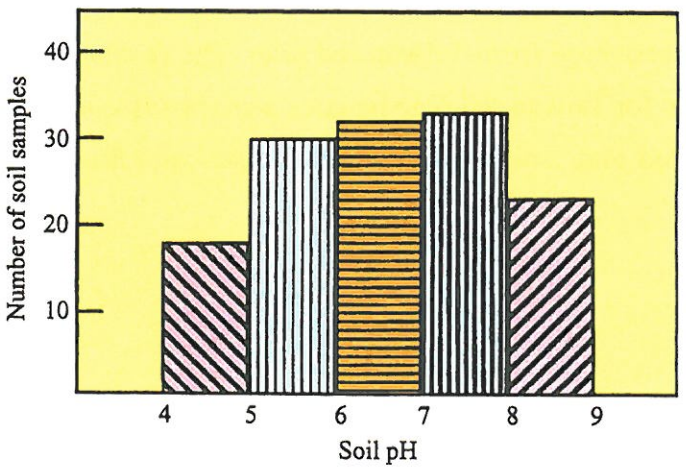
Phellinus noxius occurred mostly in soils with sand, loamy sand, and sandy loam textures. Urea, $CuSO_4$, Quinolate + $Cu(OH)_2$, Quinolate and Nustar were significantly effective for disease protection in the field.

In high-temperature and -humidity climate, hardwood seedlings were attacked by southern blight disease. Now these newly recorded diseases have been proven by applying Koch's rules. At the Da-Peing Nursery in northern Taiwan, severe seedling root rot of *Taiwania cryptomerioides* Hay occurred, and nearly 35% of seedlings were lost. For controlling root rot disease, we screened fungicides on the market and found that Terrazole and Metalaxyl had better effects on inhibiting the growth of *Pythium* spp.

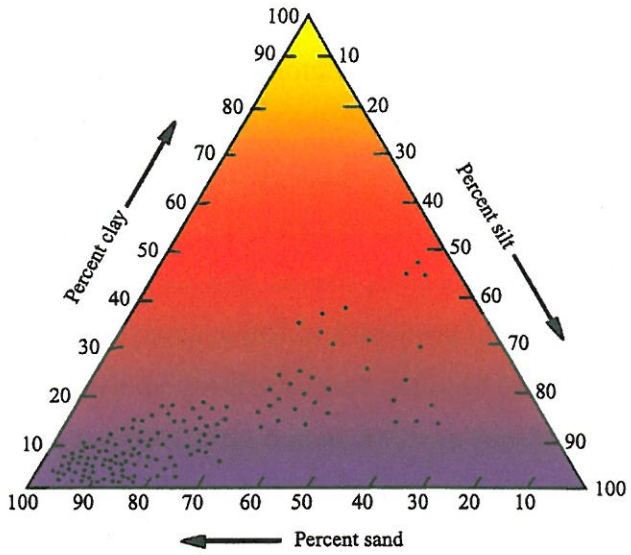
Highly sensitive and specific molecular diagnostic probes for detecting *Phellinus noxius*, *Heterobasidion insulare*, and *Bursaphelenchus xylophilus* were developed. The diagnostic techniques are useful for the establishment of a pathogen-free nursery. A species-specific PCR technique with primer pairs derived from satellite DNA was used to analyze pine wood nematodes recovered from Taiwan red pine. The results showed that the PCR reaction for Taiwan red pine isolates were positive and indicated that the Taiwan red pine isolates were *B. xylophilus*, not *B. mucronatus*.



▲ Geographic distribution of *Phellinus noxium* in Taiwan. Each point represents a combination of host and locality. TC: Tropic of Cancer.



▲ pH of rhizosphere soils of plants infected with *Phellinus noxius*.



▲ Texture of rhizosphere soils of plants infected with *Phellinus noxius*. Each point represents a combination of host and locality.

(III)Forest Entomology Research

The major tasks of the Forest Entomology Laboratory in 2001 included the monitoring and assessment of disturbances to forest arthropod diversity, and evaluation of the effects of field treatments on the mortality of pine sawyers. Arthropods constitute the dominant animal group in forests, of which insects are the major components, and they play an important role in functions and ecological processes of forest ecosystems. The aims of this study were to establish baseline data on arthropod diversity, and to monitor and evaluate the effect of disturbance on arthropod diversity in forest ecosystems. In addition, we attempted to identify the biological and environmental significance of different biodiversity indices, in order to use them properly as references in future research and ecosystem management. We used 8 different collecting methods and devices to monitor different kinds of forest-dwelling insects, which also occupy different ecological niches, in a 1-ha experimental plot. They included malaise traps, window traps, light traps, pitfall traps, canopy knockdown, bark spraying, litter extraction, and soil extraction. During 2001, three collecting trips were made, 31,128 specimens were identified to order level, and preliminary data analyses have been initiated. Light traps alone collected over 20,000 specimens, mostly lepidopterans (moths, ca. 52.6%). Arthropods collected from bark spraying and soil samples ranked the second in terms of numbers, with each contributing 2500-2700 specimens, with springtails (50.2%) and Acari (mites, 43.1%) dominating. Malaise traps collected 1428 specimens, with dipterans (71.4%) the most abundant. From litter samples we obtained 1261 arthropod specimens, with Acari (61%) dominating. Canopy knockdown, window traps, and pitfall traps only collected small numbers

of arthropods. Lepidopterans (31.0%), dipterans (40.1%), and springtails (21.1%) each constituted the most abundant group for the respective collecting methods.

In another study, we sawed and collected 20 pieces of 1-m pine logs from a Ryukyu pine (*Pinus luchunesis* Mayr) forest in Taipei County, and implanted five 2nd instar larvae of the pine sawyer, *Monodhamus alternatus* Hope,into each log. The 20 logs were then divided into 5 groups (4 logs in each group). Three of them were placed in a secondary forest in Erhtzuping, Yangmingshan National Park, and were treated as follows: (1) uncovered as a field control group, (2) covered with grass, and (3) covered with a plastic canvas. The 4th group was placed in an open area exposed to sunlight, and the 5th group, an indoor control group, was set in a growth chamber, where constant temperature and humidity were maintained. We collected all logs 7 months later; and mortality, developmental conditions, and morphological character values of pine sawyers implanted were measured. There was a significant difference in larval mortality among the 5 groups ($F = 3.199$, $p = 0.044$): the mortality of the field control group was the highest (50%), and that in the group exposed to sunlight ranked the second (30%). The number of pine sawyers increased in the sun-exposed group (41%) and was significantly higher than those in other groups ($f < 0.001$). However, the numbers of larvae increasing in the logs did not correlate with the mortality of implanted larvae ($r = 0.154$, $n = 20$, $p = 0.516$). In addition to pine sawyers, we also found 6 other species of insects in the pine logs, including *Cryptorrhynchus insidiosus* Roelofs, *Sipalus formasanus*, 2 unidentified scolytids, 1 unidentified long-horned

beetle, 1 unidentified species of Corrodentia, and 1 unidentified click beetle. We found no correlation between the mortality of pine sawyers and individual numbers of each of these 6 species.



▲ The method of canopy knockdown used for the first time in Taiwan. Twenty hoops were suspended below the canopy for collecting fallen arthropods.



▲ A Malaise trap hanging underneath a tree crown for catching flying insects.



▲ The rearing of pine sawyers in captivity to collect their eggs for life history studies.



▲ Pine log damaged by rodents.

(IV) Forest Fires: Fire and Diversity

Due to the close relationship between fire regimes which are defined by fire cycles, intensity, damaged areas, and species life cycles, wildfires affect the functioning of ecosystems in both positive and negative ways. Therefore, understanding postfire responses of ecosystems is a fundamental basis of ecosystem management. Jialo Lake is located on the wide ridge between Nanhu Mt. and Sanshin Mt. terraces. Plantations including cypress (*Chamaecyparis formosensis* and *Chamaecyparis obtusa*) and Japanese fir (*Cryptomeria japonica*) around these lakes were established in the 1960s. A fire occurred in April 1999 destroying the area. In order to understand postfire processes of this area, a research team conducted a survey in 2001. Twenty-eight sample plots were set up in the fire area. In total, 152 species in 52 families of plants were recorded. Eleven types of plant communities were analyzed. Primary results show that fire more strongly influenced herbs than woody plants. However, the á and â diversity of herbs after the fire is higher. Recovery methods differed between herbs and woody plants. In terms of woody plants, sprouting from either root collars or stolons was the major response to the fire. However, herbs used seeds stored in the seed bank to generate seedlings in response to the fire. The next step of the study will attempt to understand the composition and structure of the recovering plant communities in this area.



◀Research team surveying the vegetation at the study site.



◀Recovery of woody plants after the fire.



◀Recovery of herbs after the fire.

Forest Utilization

(I) Application and development of a stress wave measuring technique

The basic properties of wood such as moisture content, density, grain direction, and modulus of elasticity can be measured. Nondestructive test methods are able to assess wood properties using technigues which do not destroy the sample. In this project, a resistance strain gauges were used to measure the time difference of stress waves and the main frequencies of timber. The output of the strain gauge signal was connected to an oscilloscope and a Fast Fourier Transformation (FFT) spectrum analyzer. The measured resonant frequency was compared with that simultaneously obtained by the tap tone method. Results showed that the sound speed in wood measured with a strain gauge was exactly the same as that measured with the tap tone method. The advantage of the strain gauge method is that it is free of environmental noise effects experienced with tap tone testing. The sound speed measured by the stress wave time difference between the 2 gauges was slightly greater than that from the resonant frequency. A semi-conductive strain gauge was used to increase the signal output voltage of the Wheastone bridge circuit. A reusable strain gauge was made with flexible epoxy resin laminae by an embedding method.

(II) Research and development of techniques for wood compression and finger-joints

It is important to help increase the degree of self-sufficiency and also help improve lumber quality of plantation trees (softwoods) in Taiwan.

Therefore, the purpose of this study was to investigate the effect of 2 treatments (heat and steam) on the properties of compressed wood. China fir (*Cunninghamia lanceolata*) wood cut from a plantation forest was compressed in the radial direction under different compression loads and then heat or steam-treated. The weight loss, recovery of set, and bending strength of the compressed wood were examined afterwards.

The weight loss of compressed wood increased with increases in treatment temperature and time. The recovery of set of compressed wood decreased with increases in treatment temperature and time. The MOR and MOE of compressed wood increased with the increasing compression set. However, heat or steam-treated compressed wood had lower bending strength properties than untreated compressed wood.

(III) Effect of site quality and management practices on wood strength variation and design stress value of Japanese cedar grown in Taiwan

The domestic wood of Japanese cedar trees varies in properties with growth locality and management practices. Accordingly, a survey and testing of wood materials are conducted to study variations in strength properties. The project focuses on mature wood from Japanese cedar in Taiwan, i.e., wood from trees near or over 30 years old. The factors being investigated include growth locality or site, management practices, and possible seedling origins. Material preparation is in accordance with grading rules published by the Chinese National Standard of the Central Standard Bureau for material classification. By doing so, the information obtained from the study

can easily be adopted by users. Therefore, the aforementioned objectives of the project will be fulfilled.

(IV) Studies on the improvement in interfacial adhesion testing technique for wood and plastics

Wood flour and fibers are excellent fillers for thermoplastics, due to their low density, high specific strength, desirable aspect ratio, and biodegradability. Strength properties of composites mostly rely on the compatibility of their constituent ingredients, therefore the key factor in the performance of wood-plastic composites is the interfacial properties between the wood and plastic. The measurement of strength properties only indirectly reveals the overall performance of the composites, and the single-fiber pullout test is a commonly used method to directly measure the interfacial shear strength of model composites. However, the fragility of the wood fibers and vast variations among fibers make the application of the traditional single-fiber pullout test difficult as well as impractical. Another problem encountered in the development wood-plastic composites is that when subjected to humidity changes, the repeated adsorption and desorption phenomena of the wood ingredients induce deterioration of the composites. The purposes of this study were to modify the traditional single-fiber pull-out test and to evaluate the effects of wood species, dowel diameter, moisture content, plastic type, and cyclic humidity changes on the interfacial shear strength of wood and plastics.

Birch and rubber wood dowels with 2 moisture content levels and 5 diameters were used to make model composites with 6 types of commercial

plastics. The resultant average interfacial shear strength of the treatments ranged between 6 and 76 kgf/cm^2. Analysis of variance showed significant main effects of wood species, moisture content, dowel diameter, and plastic type, and 2-way interactions between plastic type and moisture content as well as plastic type and wood species at á = 0.05. The main effect of dowel diameter was that the interfacial shear strength of model composites increased with increasing dowel diameter and then gradually decreased. The interaction between plastic type and wood species revealed the selectivity of plastic to wood species: birch is more compatible with PP/PE, whereas rubber wood is more compatible with polymers in the PS family. Interactions between plastic type and moisture content showed that HDPE and PS are the most sensitive to dowel moisture content, while styrene-acrylonitrile copolymer is the least.

(V) Study on the material properties and structural strength of wood-based floors

The object of this study was to investigate the material properties and structural strength of wood flooring of various species. Concentrated loading according to ASTM standards was used to test the strength of flooring from different construction methods. Four types of flooring were chosen based on results from a previous study over the past 2 years. Factors investigated were the space between joists, types of subfloor (plywood of different thicknesses and differently oriented strained board), and flooring species of wood.

Results showed that failure of floor specimens occurred mostly on

specimens with a 6-mm plywood subfloor. The most common failure type was surface splitting of the flooring under load. The deflection increased with increasing space between the joists and with decreasing thickness of the plywood. Specimens with Ipe flooring were the strongest under load, followed by Kempass, Teak, and Fukien cypress. In general, the space between joists affected the specimen deflection most significantly, followed by the thickness of the plywood and the species of wood.

(VI) Studies on a laser-cutting technique applied to domestic lumber as a value-added product

To improve process quality and commercial value, the purpose of this research was to investigate the optimal cutting conditions with the laser-cutting technique for the main native timbers in Taiwan. The results using different laser powers and cutting speeds indicated the following. 1. The processing time of a laser-cut direction in the vertical axis was 15-17 times than in the horizontal axis. 2. The weight reduction of the timber during processing had a positive relationship with laser power, 3. and a negative relationship with cutting speed. 4. The black tar formed on the timber during processing can be cleaned up by washing with water.

(VII) Management of the wood specimens gallery

Research is being conducted on anatomical and basic material properties of domestic and imported commercial lumber. A data bank was established to provide information on lumber properties. The following studies were completed during the past year. The wood specimens gallery contains a collection of 20 species from South America and 20 species

from other areas. The wood identification and material properties analyses services processed about 115 cases. One of the 20 species was used as a sample for exhibition.

Forestry Chemistry

(I)The Project for strengthening cooperation in wood science technology between the R.O.C. and France

The purposes of this project are to strengthen the cooperation in wood science and forestry technology between the ROC and France, and to raise the level of wood industry and forestry technology of ROC. The project is planed to be conducted as follows:

1. Dr. X. Deglise, Director of INRA UMR 1093 Unite Mixte de Rechrche, between INRA and University of Nancy I, will be invited to come to Taiwan to discuss future cooperation items of agriculture between the ROC and France, to instruct us on wood science technology ,and visit the TFRI.

2. It is expected that our knowledge of wood science and forestry technology will be enhanced by strengthening the cooperation with this developed country.

3. It is proposed Dr. C.T. Tsou from TFRI will visit the INRA UMR 1093 laboratory on a wood science research project.

(II) Thermal analysis of phenol-formaldehyde adhesive and its applications

The Arrhenius and Kissinger formulas were used to determine the kinetics parameters of the adhesive. The phenol-formaldehyde (PF) glue for manufacturing container plywood was synthesized as the raw material.

Examination indicated that the solid content is 46.75%, viscosity is 229 cps at 25℃, and pH is 13.14. The thermo-kinetic reaction following the ASTM E 698 method indicated the linear relation of ln(k) vs. 1000/k, which obeys the Arrhenius equation. It revealed that the activation energy of this kind of PF glue is 145.2 kJ/mole, its half-life is at 101.2℃, and the pre-exponential factor is 18.33/min. At different pressure-plate temperatures and pressure times, it takes 21 min to reach 100% conversion at 135℃; 7 min to reach it at 140℃; 5.2 min to reach it at 145℃; 2.6 min to reach it at 150℃; and 1.5 min to reach it at 160℃. In different heating environments and conversion rates, it takes 2.65-h to reach a 95% conversion rate at 90℃; 1.53-h to reach that rate at 95℃; 28.2 min to reach that rate at 100℃; 9.6 min to reach that rate at 110℃; and 4.2 min to reach that rate at 120℃.

(III) Study of volatile organic compounds in forests and ambient air

When one is inside the forest environment, the phytoncides diffusing in the air of the forest contribute to mental and physical health. In spite of this, the air in the vicinity of forests, affected by exhaust emitted form motorized vehicles contains benzene types of aromatic hydrocarbons which are toxic air pollutants and may cause cancer, such as xylene, 1,3,5-trimethylbenzene, 1,2,4-trimethylbenzene, etc.

We attempted to determine differences and similarities between volatile organic compounds from natural diffusion in forests and man-made emissions, and the influence of their development extent on air quality. An air sampling pump together with a sorbent tube and a tedlar bag were

respectively used to carry out the collection work. Following that, the heat detaching-air phase layer analysis method was used to detect the formation of volatile compounds.

Through the establishment of the optimal process and detection skill, it is now possible to learn more about the volatile organic compounds in the forest environment and its perimeter as well as the influence of air pollution caused by urbanization and development. This method can help determine the positive effects of forests on the environment and the public benefit and can serve as a reference for further forestry operations.

(IV) Synthesis of boron compounds and evaluation of their effects on thermal and fungal resistance of wood

The purpose of this research was to evaluate the thermal-, decay-, and termite- resistance properties of chemically modified wood treated with different chemical functional groups of aliphatic amines (propylamine, butulamine, hexylamine, or octylamine) or aromatic amines (aniline, p-toludine, p-anisidine, or 4-nitroanoline) and boric acid. The results revealed that smaller changes in surface brightness and color difference values were observed when wood was treated with aliphatic amine and boric acid, especially with the formulation of propylamine and boric acid. Among the 4 aliphatic amines and boric acid treatment methods, the best fire retardancy was demonstrated in wood treated with propylamine and boric acid. Meanwhile, wood treated with p-anisidine and boric acid showed the best thermal properties among the 4 applied aromatic amines and boric acid

treatments. The effectiveness of treated wood against fungi and termite attack was proportional to the chemical retention in the wood. Among the 4 aliphatic amines and boric acid- treated woods, wood treated with octylamine and boric acid had the best decay- and termite-resistance properties. Also, the same results were observed in wood treated with 4-nitroaniline and boric acid among the 4 aromatic amine and boric acid treatments. Wood treated with aromatic amine and boric acid showed better hydrophobic properties than did wood treated with aliphatic amine and boric acid, resulting in better properties of decay and termite resistance.

(V) Studies of reproduction of agro-forest residues

Due to the frequent occurrence of fire hazards in recent years, accidents have caused major damage to human lives and properties, and this is the reason for the high demand for fire-resistant construction materials. This study focused on the production of fiber cement boards with thinned China fir and rice straw used as material. Chipped and ground woody particles and rice straw were mixed with Portland cement under the control of a carbon dioxide injection pressurization method to make the fiber-cement boards. Treatments with different proportions of cement, injection times, and ratios of materials could be prepared in as little time as 4-6 min. The strength properties were proven to be proportional to the amounts of cement blended, the 24-h water absorption rate (40.59-57.87%), and thickness swelling rate (2.15-4.62%), and boards met the class 3 CNS 6532 incombustibility test. Therefore the fiber cement boards were not only dimensionally stable but also qualified as fire retardant products.

(VI) Extraction of tannins from tree bark

Fresh bark powder of *Cunninghamia lanceolata* was extracted using 3 different solvents (acetone, benzene, and chloroform) individually. The extracts were chromatographed over celite to remove nonpolar chemical components. Crude tannins were obtained from the alcohol-soluble portion and concentrated under reduced pressure. The extracts extracted with acetone, benzene, and chloroform yielded tannins from the bark of 1.7~3.1%, 2.1~2.9%, and 2.3~3.4% (w/w), respectively, with the largest yield from chloroform.

Each 10 g of crude tannins extracted with acetone, benzene, and chloroform was refined using the salt analysis method. Crude tannins were dissolved in a NaCl solution, then filtered, and tannin was precipitated by continually adding NaCl. A fine tannin was obtained after drying the filtered precipitate. Results showed that yields of fine tannins were 9.0, 8.5, and 8.3 g when using acetone, benzene, and chloroform, respectively. Obviously, chloroform has the lowest yield with the highest amounts of impurities, while acetone could extract the best tannin with fewer impurities.

(VII) Cyclitols from carbohydrate metabolism in tree seed cells

Seeds of *Leucaena leucocephala* were collected at the prematuring stage. Soluble carbohydrates and cyclitols were extracted from seeds with 75% ethanol. An ion-exchange column was used to preliminarily purify the extractive. The neutral carbohydrate solutions were analyzed and detected by GC, LC-MS, ESI-MS, and NMR. The major components in the seed

extractives were determined to be inositol, glucose, galactose, sucrose, raffinose, and stachyose.

Wood Cellulose

With regards to the forest products sector, pulping and papermaking are components with larger economic scales thus they often show greater environmental impacts as well. In recent decades, the pulp and paper industry has achieved tremendous progress in effluent treatment, coupled with the extensive use of renewable fiber resources, and hence the industry is regarded in economically advanced countries as a paradigm of a green industry. There are still residual environmental problems associated with the sector though. In the aspect of water use, the treated effluents of the industry often retain color and inorganic salts that affect the appearance and hinder its reuse. In the aspect of wastepaper recycling, for lack of an ideal sorting system, recovered wastepaper is often poor in quality and difficult to provide a good quality paper stock. There are several paper products that are difficult to recycle as well, and their presence often causes trouble and idle time in mills. This study focused on the above problems and proceeded with studies on effluent decolorization, recycling techniques for highly converted paper grades and laminated papers, and methods for turning wastepaper into panel raw materials. The purposes were to create new aspects of utilization so that the pulp and paper industry can be even more environmentally friendly and at the same time put the fiber resource-poor domestic industry on a path to more fully utilize available secondary resources.

(I) Decolorization study of paper industry effluents

Treated effluents from the pulp and paper industry often retain residual synthetic dyestuff or chromophores from degraded lignin fragments. These

entities are not easily removed through conventional biological treatments. Despite their low concentration and not being a biohazard, they can be an eyesore and often cause environmental confrontations. In this study, several colored effluent streams, viz., bleaching effluent, pulp mill effluent, industrial paper mill effluent, and effluents from mills making colored paper, were collected and subjected to membrane ultrafiltration, adsorption, and chemical coagulation and precipitation treatments. Ultrafiltration was found to be effective in removing SS, COD, and color from the effluents, while concentrates from the treatment were suitably returned to the biological treatment cycle. Due to significant developments in membrane technology, ultrafiltration and reverse osmosis have gained a greater acceptance among various industrial sectors. Paper industry effluents that comply with the current effluent standard appear to be suitable cadidates for membrane treatment. Adding coagulants and flocculants to wastewater facilitates the aggregation and removal of suspended and colloidal particles. But ligneous chromophores are typically smaller particles and are not conducive to such treatment. Also adding chemicals to water inevitably increase its pollution loading, thus this line of study showed unfavorable results. Our experiments did show that flyash from steam and electricity cogeneration systems often installed in larger mills can serve as an effective absorbent. Although it is not as effective as activated carbon, it is, however, much cheaper. One concern when utilizing an absorbent in color removal is the potential of salt leaching from it and causing an increase in conductivity, thus hindering the reuse of the water. This study shows, however, that activated carbon and flyash do not have a negative influence on conductivity, therefore their application for decolorization is recommended.

(II) Recycling techniques for highly converted paper grades and laminated papers

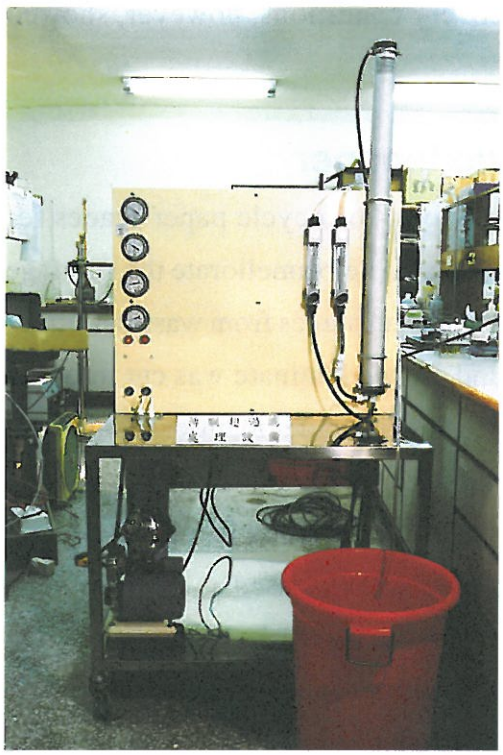
A survey of domestic consumption of laminated papers suggests that based on purposes, laminated papers are used for packaging liquid and solid food as well as for other uses. Liquid packs including aseptic packaging, such as liquid-pak, reached an annual consumption of ca. 50,000 tonnes; double layer PE-laminated milk cartons with an annual consumption of ca. 20,000 tonnes; and PE laminated paper cups reached ca. 15,000-20,000 tonnes. Food packaging consists mostly of box-lunch packages of single or double PE-laminated paper boxes having an annual consumption of ca. 60,000-70,000 tonnes. There are also an unspecified volume of foil-laminated papers such as cigarette packs, etc. All these highly converted paper grades need suitable recycling techniques, otherwise they are liable to become disposal problems. Studies on box-lunch paper indicate that the products are made of hardwood pulp covered with PE films. The pulp has moderate wet strengths and can be dispersed after the shredded paper pieces are soaked in water or an alkaline solution. As there is printing on the outside of the PE films, deinking treatment was deemed unnecessary. Pulp recovery rates of about 90% were obtained, and plastics made up 8. 5% of the dry weight. Due to a lack of adequate screening facilities, the pulp still retained contraries. Perhaps even milder soaking and disintegrating processes can help minimize this problem. As for high-wet-strength liquid-pak wastepaper, its difficulty with recycling has led to wasteful disposal. This study indicated that when using a high soaking temperature and alkali swelling, about 70% of the wastepaper can be recovered as kraft pulp. The higher treatment temperature entailed higher pulp yields, but temperature

had no apparent influence on disintegration and flotation deinking yields. Applying a 2.5% sodium hydroxide swelling agent and a high treatment temperature (100℃) for a duration of 1 h achieved the best fiber yield. Handsheets made using different recovery conditions, however, showed little variations among treatments.

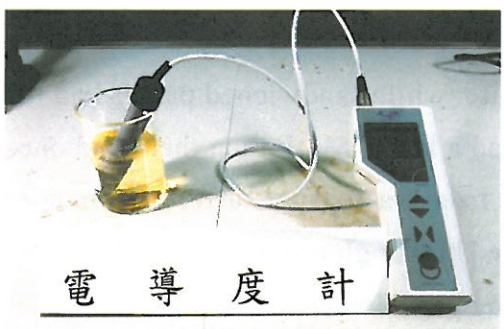
(III) Panel making from wastepaper

In this study, we used certain difficult-to-recycle paper grades for making composite panels. The purpose was to help ameliorate the shortage of forest resources and maximize the reuse of resources from wastes. Liquid-pak wastepaper with aluminum foil and plastic laminate was cut into thin strips and blended with urea formaldehyde glue under identical conditions as those for making wood particleboard. Three varieties of panels were obtained: wastepaper panels, wood-paper-wood sandwiched panels, and wood-paper mixed panels, wood particleboard was used as a control. The results show that wastepaper of high intrinsic strengths can be made into composite panels having adequate strength properties. Panel specimen soaking tests indicated that the high wet-strength paper imparts low swelling to the panels which showed better dimensional stability than their wood counterparts. There were, however, poorer internal bonding strengths among the paper layers, and delamination problems could occur. Wastepaper panels had the best modulus of rupture, while sandwiched panels had the poorest MOR. Wastepaper panels had a lower MOE than the wood ones though. Overall, particleboard made from wastepaper suffered from poor internal bonding, therefore it may need higher glue application. This study demonstrates the feasibility of making particleboard from suitable grades

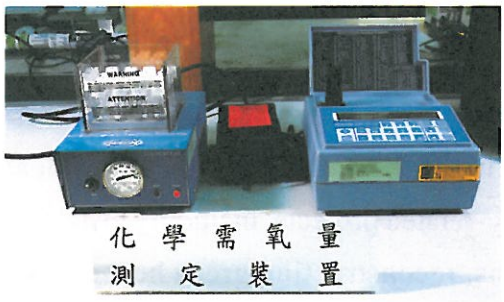
of wastepaper. In view of the greater energy and chemical demand in repulping high wet-strength grades, they may be better put to use as raw materials for making structural panel materials.



◀Ultrafiltration unit for decolorizing papermaking effluents.



◀Using a conductimeter to check for changes in salt concentrations after addition of a decolorizing absorbent.



◀ Multiple-sensor water quality meter used to measure effluent parameters.



◀ Determination of chemical oxygen demend (COD) in effluents.



◀ Screw press used for crampling and crushing laminated paper and paperboard.

V COMMUNICATING WITH NATURE : BOTANICAL GARDENS AND STATIONS

(I) Taipei Botanical Garden

To reinforce the internal security of the park, the Taipei Botanical Garden has completed several security-related projects, including installing broadcasting and monitoring systems, reconstructing green houses, and performing subsurface engineering (including electricity, internet, telephone, water supply, and water circulation). The beautification of the garden has continued, such as the improving the pavement on partial routes and open spaces, replacement of some steel fencing with new fencing plants, and the clearing of some PC pavement by for use as a pedestrian roadway.

To help citizens actively learn botanical knowledge as they appreciate the scenes of this garden, and further gain some enlightenment and experiences, the garden authority has established 9 principle descriptions and 770 plant tags along with its original literature on a botanical description wall in the exhibition area. At the same time, there are also 30 blind-help descriptive stones and 25 famous botanical personnel introduction stones in the sensing plants area. As for tour-guiding facilities, 15 entrance area introduction boards, maps, and location tags have been erected , and description plates with the Chinese 12 calendar animal symbols were also completed in 2001.

In addition to the physical improvements, there have also been some new contributions to introduction, education, and research. For example, the holiday introduction, from 09:00 to 14:00 every Sunday, prepares an activity each month. This program used 450 person-times of introducers, and attracted 2700 participants in 2001. The weekday prearranged

introduction programs, primarily used by schools and institutions for outdoor education, was stuffed by 805 introducers and 183 applied units and attracted 14,195 people. In addition in the same year, various parent-children activities attracted 3000 participants; activities included coconut palm plants, the Chinese 12 animal symbol plants, gymnosperm plants, bamboo and grass plants, ration plants, aquatic plants, plump plants, extra-experience of plants, ethno-plants, and a plants of the *Book of Songs* and Chinese idioms.

The parent-children activity, the "Lotus Extra Experiencing Tour of Lotus Pond Anthology," jointly held with the Education Radio Station and designed specifically for the vision-impaired, attracted 70 participants. And the "Nan-yuan Summer Lotus" activity, jointly held with Chung-cheng District administrative department and the National History Museum, had 300 participants. In 2001, there were 24 volunteer training courses with 1359 trainees, including these for coconut palm plants, the Chinese 12 animal symbol plants, gymnosperm plants, bamboo and grass plants, ration plants, aquatic plants, plump plants, extra-experience of plants, ethno-plants, and the plants of the *Book of Songs* and Chinese idioms, the introduction of education and volunteer organization, biodiversity and long-term biological research, the germination and storage of plant seeds, the life of the fireworm, the ecological index of river monitoring by aquatic insects, the introduction of Taiwanese blue-spotted butterfly, the diversity of Taiwan beetles, the biodiversity of mangroves, the diversity of Taiwanese fungus,etc. In July and August of 2001, there were 2 outdoor study activities in the Extra-biological Center and Se-hu Workstation each with 25 participants.

(II) Fushan Botanical Garden and station

The Fushan Botanical Garden, located in northeastern Taiwan, covers an area of 409 ha at elevations ranging between 400 and 850 m. According to surveys, 538 native vascular species, or about 1/7 of the total native vascular plants of Taiwan, have been recorded in this area. This botanical garden was set up in 1990. Its main purposes are to display both the structure and composition of natural forests and native vascular plants of Taiwan's low and middle elevations.

More than 700 species of vascular plants have been added to the display areas. Three perimeter fences were erected to prevent wildlife browsing in the divisions of rhododendron, shade-tolerant plants, and ferns, because the wildlife populations have increased yearly under the careful protection of the garden staff. For improving guest services, more than 50 volunteer-interpreters have been trained since January 1999 to provide tourist services.

In addition to managing the Fushan Botanical Garden, research of the Fushan Branch Station has concentrated on the natural resources of the Fushan Experimental Forest. These studies aim to understand the composition and functions of this ecosystem. Disturbance factors, such as typhoon and pollution, are being empathized in order to recognize their impacts on the ecosystem. The subjects include climate, hydrology, nutrient cycling, production, succession, zoology, botany, microbiology, and so on. The research team includes researchers from the headquarters of TFRI, as well as several universities and research institutes.

In "The impact of visitors on the ecosystem" project, the ecological capacity of the botanical garden is being studied. Fushan Botanical Garden has limited visitor numbers since its opening. However, visitor impacts are still unclear. In this study, the influence of visitors on animals and the environment was investigated. The psychological feeling of visitors was explored through questionnaires. The data will be used to estimate a reasonable capacity. The results will hopefully be able to suggest a practical strategy so that a sustainable management with high educational quality and low environment impacts can be achieved.

To understand the growth characters and adaptability of the plants cultivated in the botanical garden, the height and DBH are measured every year. In addition, the characters of phenology, i.e., bud germination, leaf development, flowering, fruiting, and senescence, are investigated every month. The data provide basic information for seed collection, seedling culture, planting, and landscape design.

In an ethanobotany study, 54 species used by aboriginal people have been recorded during this year. Among these, 18 species are used for food, 16 species for tools, 12 species for medicine, 5 species for housing, 3 species for festivals, 3 species for spices, 3 species for clothing, 1 species for hunting, and 1 species for other usage. Among these 8 species (14.8%) are used for more that 2 purposes. The species of the Asteraceae are mostly common used.

To monitor the Hapen Nature Reserve, a weather station has been built in the Hapen Reserve, and climate factors have been collected since

June 2001. Also, water is sampled from the Hapen River 2 times every month. The results show no significant differences in pH, conductivity, cations, and anions among the 7 sampling stations.

(III)Lienhuachih Station

Lienhuachih station is located in low elevation of subtropical forest zones of central part of Taiwan. It is the fifth watershed experimental station from 1966. The primary purpose of establishing this station focuses on research of watershed management and flood control. Today, the station is not only doing the research to address the missions on this purpose but also has been a outdoor educational place of water and soil conservation.

The past year, our staffs worked with scientists of headquarters in several projects including forest meteorology, watershed erosion and stream water quality, technique of forest road construction, environmental protection forest sivilculture. Some results are as follows.

1. To cope with ecosystem principle, we executed 185 ha Chinese fur thinning and management.

2. Bred plants that are suitable for local environment and forestation such as *Formosa michelia,* Taiwan incense-cedar, and gums.

3. Worked on outdoor educational facility such interpretive signs, trails, and programs.

4. Organized nature education programs and conducted 6 programs in 2001.

5. Surveyed and collected ethanobotany including species used by aboriginal people living around.

6. After earthquake in September 21, 1999, to help reestablishment of damaged communities around Nantou county, we joined the reconstruction committee to prompt the concept of community forest including water and soil conservation and reforestation to work with the local communities.

(IV) Chungpu Station

Chungpu Station is located in low-elevation hills of the subtropical zone. Due to the ideal climate, it has been devoted to the promotion and breeding of foreign economic crops since its founding. The Taiwanese government now has been working on the economic development of the East Coast, but in terms of the balance between industrial development and environment quality, forest conservation should come first. Because of the above-mentioned background, and coordination of future national forestry management and development, and the need for forestry research, we now are undertaking an overall review and adjustment for the future development direction of national forestry technology in compliance with governmental reengineering plans. Research on forest conservation is our first priority. Consequently, we are working with great efforts to promote a study system on windbreak forests, industrial greens, and urban forests. We are concerned about the overall development and promotion of national botanic gardens, and our goal is to contribute more to forest conservation as a functional forestry research institute.

Our achievements in 2001 include the following.

1. More than 1000 beach plants, such as vitex trifolia, Fengkang persimnon, Morinda citrifolia, and Colubrina asiatica were collected and planted in exhibition areas.

2. More than 1000 sand-catching plants such as Ipomoea pesocaprae, Sesuvivum porulacastrum, and Canavalia were collected for planting.

3. A proposed report on planning of the Chiayi Botanic Garden was completed.

4. Improved walking trial facilities around the Szuhu Coastal Plant Garden were constructed.

5. Educational activities were organized on the Szuhu coastal environment and Chiayi Botanic Garden plans.

6. More than 300 signs about plant conservation were installed.

7. Work proceeded on watering, wind protection, and disinfection of nursery beds.

8. Routine work such as weeding, cutting, grafting, and insect and disease protection was carried out.

9. Research work on Albizia lebbeck (L.)Benth, Tusk Tree（象牙樹）and the Heng-Chun mountain loquat（恆春山枇杷）continued.

10. Plants of rare species such as Myoporum bontioides A. Gray, 海南草海桐, and Excoecaria agallocha L. were bred.

(V)Liukuei Station

1. Ecosystem management for the Liukuei Experimental Forest

Maintenance of biological diversity and sustainable utilization of natural resources are crucial problems for all countries under the circumstance of the rapid loss of forested lands worldwide. In this context, many treaties and conventions such as ITTO, CIFOR, and the compilation of sustainable development for tropical forests reveal the importance of forest conservation and environmental protection. Ecosystem management is considered the key to maintaining biological diversity and achieving sustainable utilization of forestry resources.

The Liukuei Experimental Forest has a total area of about 9616 ha which ranges from 350 to 2400 m in elevation. It contains several different vegetation covers including natural temperate forests, natural hardwood forests, artificial forests, and grasslands, as well as and different landforms of mountains, valleys, streams, landslides, and roads. With such landscape and climatic diversity, the experimental forest supports a large number species of vegetation and wild animals and is considered an ideal place for forestry and biodiversity studies. However, the selection of proper management strategies and the making of forestry-related policy should be scientifically based on the knowledge of interactions between animal, vegetation, and human activities. The Taiwan Forestry Research Institute has implemented a ecosystem management project for 3 years under the

leadership of Dr. Yang. In the initial period of this project, some basic investigations and research have been carried out with good results. They are summarized as follows.

(1) Nature conservation: The primary goals for this subproject are not only to protect the biodiversity of native species in natural forests but also to create artificial forests in as healthy and natural conditions as possible. In addition, natural forests should be managed to conserve their biodiversity and structural diversity and to promote forest productivity.

(2) Ecological education: It is crucial to educate people about visiting forests, loving forests, and understanding forests to achieve forestry conservation. TFRI has carried out many educational programs to help people understanding the role of forested land in the ecosystem and the importance of environmental protection.

(3) Riparian zone management: Streamflow quantity and quality monitoring systems have been established during the study period. In addition, monitoring of freshwater fish and bird communities in the riparian zone is also under development. The goals of riparian zone management are to provide habitats for wildlife and to protect water quality.

(4) Woodlot management: Research includes determining how forests grow, to help forest growth and to promote techniques of harvesting and renewing forests. Partial cutting has been carried

out in some China fir (*Taiwania cryptomerioides*) plantations which were planted more than 25 years ago. The purpose of woodlot management is not only to ensure the economic production of timber but also to maintain a well-developing forest.

(5) Forest protection: Protection includes fire prevention and reducing the damage from diseases and insects. In order to achieve these protective goals, a network of forest roads has been carefully designed and constructed in the past few years. All species in the experimental forest have been well cared for under this project.

2. Management of the Shanping Forest Ecological Garden

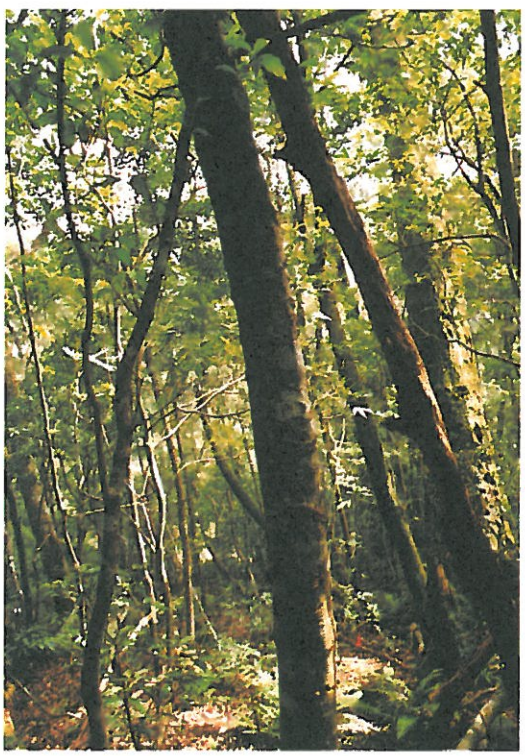
In cooperation with a series of activities of Ethnobotanical Month of Taipei Botanic Garden, the Shanping Forest Ecological Garden held a special program –"The festival of bamboo" on September 23, 2001.

This program was set up because of the close historical connection between Chinese people and bamboo. In addition, there is a famous bamboo garden in Shanping.

A about 80 elementary students with their parents from Kaohsiung County joined this activity. We planned coupled educational units to improve the knowledge about bamboo for kids and their parents. These units included: bamboo toys, bamboo feasts, learning how to make cooked rice filling a bamboo tube, bamboo-made wares, and how to identify the difference between some common bamboo species. We designed these lessons in order to impart more knowledge to participants in a relaxed and

interesting way. In addition, we designed an Ethno-plant Passport for tourists to learn about the diverse ethno-plants and their uses in the Shanping Ecological Garden. There were about 500 tourists who joined this activity that day.

The Shanping Forest Ecological Garden is located in southern Taiwan, and is one of a few intact low-elevation broadleaf forests there. Peoples have been paying increasing attention to ecological conservation, outdoor education, and ecotourism in Taiwan recently. The TFRI will work hard to make Shanping become an important ecological educational site in southern Taiwan.



◀Natural regeneration of Fagaceae and Lauraceae as seedlings are planted and trees are properly thinned.This operation not only can increases the production of forestland,but also forms a multi-crow forest with complete ecosystem functions.



▲Climate recording station. Date not only can be used to analyze the growth of trees, but also can serve as a database for preventing forest fires.

(VI)Taimalee Station

1. Coastal wetland conservation

Because of excessive utilization of coastal lands, coastal wetlands conservation conditions in Taiwan have not been great, and tourism quality to meet the intense ecotourism demands needs to be promoted. So how an equilibrium can be sustained between tourism and ecosystem conservation is now an important issue. Based on these ideals, the establishment of a coastal botanical garden would offer a place for public tourism and outdoor education. All of the design and planning ideals must follow the dual guidelines of landscape and educational requirements. The content must conform to the local situation, for example, land usage tracks, future development, traffic or road facilitates, and related aspects. We expect that particular and representative scenery of a Taitung coastal botanical garden can be built.

The exhibits will mainly focus on characteristics of coastal vegetation in Taiwan. Because of this, various surface features should be created to match the ecological habitats. Irregardless of what kinds of architectural construction are carried out, e.g., topographic reform, hydro-scenery construction, walking trails, etc., all of the transformations should be harmonious with the surrounding scenery according to environmental conservation thinking. We will emphasize various soil, water, air, living creature, humanistic, and environmental conservation courses to educate visitors.

We achieved the following results.

(1).One hundred seventy-two poles of an external boundary fence were put up and connected with steel wire.

(2).Eight hundred eighty meters of peripheral asphalt road and a rock-piled ditch were paved.

(3).An 84.6-m-long retaining wall was constructed, and 3 areas of horizontal drainage canals were built.

2. Metric Indicators of landscape ecology

In this study, 6 goals were achieved in 2001. First, geographic data on the Taimalee Experimental Forest were collected. Second, related papers about metric indicators of landscapes that could be applied on different spatial and temporal scales were reviewed. Third, silvicultural records of man-made forest stands was set up in a computer database system, and the silvicultural map was digitized into a vector format.Fourth, SPOT and TM satellite images of the Taimalee Experimental Forest District were purchased and transformed with an image fusion technique. Fifth, geographic information from the results of the third and fourth PC ArcView Desktop geographic information system were integrated to form a prototype GIS. Finally, the MS Visual Basic 6.0 software development tool was used to write a program that can improve the metric indicators of landscape structure analysis at different spatial and temporal scales.







(VII)Hengchun Tropical Botanical Garden and Station

1. Reproduction of endangered plant species in the Hengchuen tropical region, and conservation of these species outside the region

Hengchuen Branch has always endeavored to conserve rare plant species. Each year we collect seeds, and cultivate and plant rare tree species. If a seed is dormant, we will break its dormancy before planting to help in germination. In 2001, the Hengchuen Branch cultivated seedlings of many tree species, including *Dehaasia trianda, Garcinia multiflora, Litsea sasakii* Kamikoi, *Symplocos shilanensis, Aristolochia kaoi,* and *Phoenix hanceana* Naudin. Our experiment on the seed storage behavior of *Phoenix hanceana* showed that it uses dry storage of seeds. The seedlings we cultivated in 2001 have grown to a height of more than 50 cm. We will soon plant them in appropriate sites.

2. Long-term monitoring and management of Kenting Ascended Coral Reef Natural Reserve

For this project, we have studied and analyzed tree species and their population on a 10-ha permanent sampling area. We have also entrusted Dr. Mingchou Lai from the Landscape Department of Tunghai University to study the growth of an invader, *Zebrina pendula.* We are, for example, examining its rate of growth, condition after seeding and planting of cuttings, and the effect of different concentrations of the herbicide Glyphosate. Each year, 92 patrols frequent the reserve, which is fenced off with wires at present. An automatic microclimate data monitoring system was set up in June 2001. We have done chemical analysis on soil samples taken from

the reserve and have completed the analysis of Ca, Mg, Na, K, C, and N. Starting from June 2001, we began a monthly moth determine, in which we study moth species and their populations in the reserve. Our preliminary study shows that there are 41 species, including *Euproctis striata.*

3. Research on plant invaders in Kenting Ascended Coral Reef Nature Reserve--an entrusted project

There are 22 invading plant species in the Kenting Ascended Coral Reef Nature Reserve, among which the more rampant and destructive ones are *Z. pendula, Lantana camara* L., and *Mimosa pudica,* which is most threatening. This year we have continued to study *Z. pendula,* for instance its rate of growth, the condition after seeding and planting of cuttings, and its invasion rate in other regions after application of the herbicide Glyphosate. By understanding the growth patterns and possibly determining the dormancy period of *Z. pendula,* we may be able to prevent it from spreading. Our study on the growth rate of *Z. pendula* showed that its height increases approximately 3-4 cm and it grows 5 to 7 new blades every 2 months. When side branches appear, the growth of the main branches is reduced to about 1-2 cm every 2 months, and some even cease completely. Side branches, on the other hand, grow approximately 3-4 cm every 2 months. The plant cover increases 10%-15% in dry seasons, but after rains begin, it is reduced to a mere 0%-5%, and plant growth is severely retarded. At a 0.1% concentration, Glyphosate can completely wipe out *Z. pendula,* although the plant will reappear and invade other outside areas after 6 months. When Glyphosate at a concentration of 0.5%-2% was

applied, other plants around *Z. pendula* were affected, with certain plants being killed.

4. Tropical Forestry Symposium: The Art and Practice of Conservation Planting

The Tropical Forestry Symposium: The Art and Practice of Conservation Planting was held as scheduled in the International Conference Room of the Forest Conservation Buildingof the Taiwan Forestry Research Institute, Taipei, Taiwan on September 24-29, 2001. In addition to academics from Taiwan, invited participants included scholars from the US, Canada, Japan, India, Indonesia, Thailand, Philippines, Vietnam, Malaysia, Cambodia, Bangladesh, Nigeria, Malawi, and Ghana.

The symposium had 4 main topics: Tropical Forest Conservation, Tropical Tree Seed Research, Propagation of Tropical Trees for Conservation Physiological, and Ecology of Trees and Conservation Planting, among which Tropical Forest Conservation received the most attention. For instance, many people were interested in the Ascended plantation project in northern Thailand mentioned by Bunvong Thaiutsa from Thailand. The project began in 1981, and at time, Taiwan Forestry Research Institute and National Taiwan University were also participants, providing their technical expertise. For the project, seeds of broadleaf species and bamboo rhizomes from Taiwan and Japan were introduced to Angkhang, a highland at 1500 in Chiangmai Province. The goal was to study the growth of introduced plants in man-made forests in Thailand.

We took symposium participants to the National History Museum, the National Palace Museum, Longshan Temple, Martyrs Shrine, the Yingko Ceramics Museum, and several other attractions that demonstrate Taiwanese culture. This 2 day tour had a good turnout; all participants had a great time. We wish to give special thanks to the Taiwan Forestry Research Institute for their financial and kind assistance, as well as to Dr. Robin Rose from the Forestry Science Department of Oregon State University in the US for his generosity. The symposium was a great success.

5. Research on the ethnobotany of the Hengchun Peninsula

Ethnobotany is the documentation and study of the use of environmental resources–specifically plants–by ancient civilizations. It is a new science whose purpose is to preserve the cultural legacy of our ancestors, to scientifically research and analyze ethnic uses of certain plants, and to find important ways these plants can still be used. Through field research and active participation, we have documented the traditional ways that the Paiwan tribe of Mudan Township utilized plants. These tribal people make use of 84 plant species, among which 28 species are used for food, 25 for tools, 21 for medicines use, 7 for houses and shelter, 1 for fishing, and 2 for other purposes.

There are 26 *Ficus* species in Taiwan. The major subdivisions are the subgenera *Urostigma, Pharmacosycea, Eriosycea, Ficus, Sycidium, Synoecia,* and *Sycomorus.* The first 2 subgenera are monoecious. The characters of the morphology of the pyrnus, the life form, the ratio of male flowers, the characteristics of the ostiole during the male phase, the structure

of the synstigmas, the sex of the fig, and the distribution of male flowers in the fig. are important characters for the systematics of *Ficus*. The morphology and structure of the fig and its flowers could be important information for pollination ecology and symbiosis between figs and fig wasps. The morphology of the pyrnus provides a useful character for understanding seed dispersal.

6. Arboretum management--Hengchuen Tropical Arboretum

(1) Seed collection and cultivation project

This year we cultivated various seedlings as planned. These seedlings include 7 vine species, 6 fern species, 10 coconut species, 2 Fagaceae species, 2 rare species, 10 coastal species, and 3 fruit tree species. The coconut species were planted as seeds; the rest were planted as seedlings and later allocated to larger pots. In addition to the plants we already have in our exhibits, we have planted more coconut, Fagaceae, fruit trees, coastal plants, and other species to enrich the exhibits. To expand our seed collection, we have collected seeds which each exhibit needed, seeds of exotic species, and man-made forest tree species, and have exchanged seeds. When we have found mature tree seeds that are not included in our collection project, we have added them to our collection as well for germination and storage.

(2) Tending project

A. Weed control

Our arboretum tending project focuses on eliminating weeds in the

13 ha of our exhibit property, both in the exhibit and non-exhibit areas. This year, the Hengchuen Station has began to entrust this work to outside services. As of this year, weed control has been carried out 6 times.

B. Fertilization, irrigation, and pest control

Each year we use goat manure to fertilize the arboretum exhibits to sustain plant growth. The irrigation system and the water pump motor remain in good condition. We have temporary employees to assist with irrigation. Currently there are 2 slow filter basins in our headwater region to filter out high concentrations of calcium carbonate. The filtered water can be used by the arboretum for irrigation and by residents of Sheding. There is very little rainfall in the dry season, which begins in January and ends in April; although our water reservoir holds 450 tons of water, we need to conserve water and limit irrigation to new and shallow-root plants. As for pest problems in the arboretum, the Hengchuen Station will carefully monitor the situation and appropriately apply pesticides.

(3) Other completed tasks related to the reconstruction of arboretum exhibits

A. We have written a report of the reconstruction plan for an artificial lake.

B. We have written a basic plan for Araceae species and fern species exhibits.

C. We have finished *The Reconstruction of Hengchuen Tropical Arboretum 2001,* including the expansion of the Vine Species Exhibit, the Ethnobotany Exhibit, the construction of an elevated wooden trail, the addition of information displays for the Plants of the Hengchuen Peninsula Exhibit, and built a new slow filter basin (there are 2 now) in our headwater region.

D. This year we have made 269 illustration boards, including 128 small ones, 140 medium ones, and 1 large one.

(4) Maintenance plan of arboretum facilities

We have completed the yearly decontamination of the herbarium specimens and have regularly maintained our freezers and growth chambers. All other irrigation equipment, hoses, water pump motors, water pumps, the green house, shades, sprinklers, and other related facilities have also been maintained.

(5) Other tasks completed by the arboretum

A. We have studied the phenology of 7 species (a total of 35 individuals) including *Heritiera littoralis* Dryand, *Barringtonia racemes, Distylium racemosum, Terminalia catappa* Linn, *Barringtonia asiatica, Aleurites moluccana,* and *Goniothalamus amuyon.*

B. We have collected and made 150 herbarium specimens. Currently we have 14,055 documented herbarium specimens.

C. This year we mailed 260 seed exchange catalogs. Seventy international arboretums and research institutions have requested our seeds, and we have given away 624 seeds so far.

D. This year we examined the plants in 13 exhibits. We measured their dbh and tree height, and recorded each of their locations. We will hang permanent aluminum plates on each tree in the near future, make yearly measurements, and record the measurements on the plates. In addition to that, we will compile our reports into a book as a record.











VI The Most Important Knowledge: Refereed Papers

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