

CHINESE - AMERICAN
JOINT COMMISSION ON RURAL RECONSTRUCTION

Forestry Series: No. 7

WINDBREAKS IN TAIWAN

By

Tse-cheng Sheng Han Kang



TAIPEI, TAIWAN, CHINA

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FOREWORD

In order to determine the achievements of windbreak planting since the Restoration of Taiwan, their present conditions and future needs for the basis of management, the Joint Commission on Rural Reconstruction initiated an island-wide windbreak survey project in 1959. The Taiwan Agriculture and Forestry Aerial Survey Team was the Executing Agency of this project while the Taiwan Forestry Bureau, the Taiwan Forest Research Institute and the Taiwan Provincial College of Agriculture were the Cooperating Agencies. The survey was based on a scale of 1/20,000 aerial photographs taken in 1956, plus field checks and delineations. The result of the delineations were then drawn on the 1/25,000 base map from which the data was compiled and obtained. This survey covered a belt of land 10 kilometers from the seacoast along the main island of Taiwan, excluding mountainous areas, the Pescadores and off-shore islands. Within 200 meters from the coast, land use types was also surveyed in the nonforested area.

A part of this survey had been re-checked due to damages from the flood on August 7, 1959 in central and southern Taiwan. Also, after the preliminary data was obtained, it had been sent to the agencies concerned and the local governments for final checking and correction. The progress of the whole survey project was as follows:

1. Aerial photos preparation: From February 2, 1959 to March 6, 1959.
2. Field check and delineation: From March 14, 1959 to October 4, 1959.
3. Mapping: From August 1959 to February 1960.
4. Data compilation: From January 1960 to June 1960.
5. Data correction: From July 1960 to September 1960.

As a result, sets of 1/25,000 blue print maps of seacoast forests and farm windbreaks of Taiwan and the basic statistical data consisting 14 tables were distributed to the related agencies in December, 1960.

The objectives of this interpretative report is to explain and analyze the survey result. The policy and goals for windbreaks in future are also discussed. In addition, the conditions of wind erosion or damage, the benefits and functions of windbreaks, and the windbreak planting techniques are also introduced for those who are interested in or engaged in this kind of work. The Chinese draft of this report was completed in March 1961 and had been sent to the related agencies, professors and experts for comment. Consequently, some parts have been revised and corrected.

The Joint Commission on Rural Reconstruction wishes to express deep appreciation of the cooperation lent by the Taiwan Agriculture and Forestry Aerial Survey Team as being the Executing Agency of this project, the Taiwan Forestry Bureau, the Taiwan Forest Research Institute and the Taiwan Provincial College of Agriculture, contributing to the successful completion of this project.

Special credit is due to Professor T. T. Wang of National Taiwan University, Professor Frank S. H. Liu of the Taiwan Provincial College of Agriculture, Messrs. P. L. Yang of the Aerial Survey Team, C. C. Lee and P. H. Wang of Taiwan Forestry Bureau, and W. H. Kan of

Taiwan Forest Research Institute in offering good suggestions and providing information during the course of the work.

Grateful acknowledgement is also made to Mr. Charles J. Kraebel, Chief of Forestry Division, JCRR and Mr. Ira K. Landon, Soil Conservation Advisor, JCRR, for their valuable suggestions and careful examination of this report. Special thanks are due to Messrs. P. Chung and K. H. Wu who helped partly in the translation of this English version.

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HIGHLIGHTS

Taiwan, due to its geographic position, is subject to typhoon and monsoon damages. It is estimated that the total area affected by monsoon is around 360,000 hectares. Of this total, half, (180,000 hectares) is most severely affected. During the winter, the west coastal area of Taiwan is constantly at the mercy of strong wind, flying sands or salt spray. Crops are severely damaged; farm land, roads, irrigation channels and even buildings may be buried by marching sand dunes unless windbreaks are established.

The benefits of the windbreaks are manifold. They increase farm productions by an average of 30%. Under proper management, they will provide the people in the coastal area with fuel-wood and timber that are always in great need. Besides, the clear-cutting of old or functionless seacoast forests provides more land for cultivation. Since the Restoration of Taiwan, for instance, 3,638 hectares of such forests have been converted largely to rice fields. The establishment of windbreaks can at the same time improve living conditions in the coastal area, benefit fishery development, and navigation.

The history of windbreak planting in Taiwan goes back at least fifty years. The Japanese, during their occupation of this Island, had actively engaged in the windbreak planting program. Up to the Pacific War, a total of 9,200 hectares of seacoast forests and farm windbreaks in 123,000 hectares of land had been established. Unfortunately, due to indiscriminate military uses during the war, and illegal cutting immediately after the Restoration, these windbreaks were largely destroyed with the result that only 15% were left. Since 1946, however, the government and the local people have gradually become aware of the importance of windbreaks and have started on the re-establishment program. Especially from 1951 on, the program has been carried out on a large scale and has had great success due to good coordination among all interested agencies. The present survey shows, consequently, that there are 7,024 hectares of seacoast forests, and that farm windbreaks have been established on a total of 143,729 hectares of farm land. Most of the critical area on the Island, therefore, have been protected.

However, the present survey shows that some 6,761 hectares of land are in need of seacoast forests, and that 200,000 hectares of cultivated land still require farm windbreaks. It is recommended to complete these plantings in two programs of five years each. In the first 5-year program it is expected to plant 4,000 hectares of seacoast forest along the coast, and 7,245 kilometers of farm windbreaks on land within 5 kilometers of the coast. In the second 5-year program the remaining 2,761 hectares of seacoast forest, and 8,597 kilometers of farm windbreaks in a belt 5 to 10 kilometers inland from the coast will be planted. The farm windbreaks, to give protection to the 200,000 hectares of cultivated land, are most urgently needed, and should be the principal goal for the government and the people to strive for. Also, farm windbreak program should be coordinated with the tidal land reclamation, mountain resources development, and land consolidation programs.

Strengthening forest management measures on the existing windbreaks is another important phase of the program. The government should work out practical and safe ways of rejuvenating the old windbreaks and of pruning and thinning the young ones. By doing so,

it will promote faster growth of the trees, obtain higher volumes, provide fuel or timber to the coastal people, and secure protection from wind at the same time. None of the direct and indirect functions and benefits of the windbreaks should be overlooked.

In existing seacoast forests, there are some 1,500 hectares of young forest in need of careful pruning and thinning, and 800 hectares of old forests in need of gradual re-generation. These are also ultimate goals to attain.

WIND AND WIND EROSION CONTROL IN TAIWAN

Taiwan is situated at 21°45' to 25°37' North Latitude and 119°18' to 122°06' East Longitude. It is 180 kilometers east of the Chinese mainland, 1,300 kilometers south of Japan and 360 kilometers north of the Philippines. Lying in the tropical and sub-tropical zone, the island is crossed by the Tropic of Cancer in the south. Its climate is influenced by both the Pacific Ocean and the Chinese mainland and is characterized by strong wind, torrential rains and warm temperature.

TYPHOONS AND MONSOONS

Because of its geographic position, Taiwan often suffers from damages of typhoons and monsoons.

Originating largely in the ocean between Caroline Islands and east of the Philippines and moving westward or northwestward, typhoons hit Taiwan mostly between July and September at a frequency of several or eight times a year. With a velocity of 20-40 meters and sometimes 60 meters per second, they are usually accompanied by torrential rains, causing disastrous damages. For instance, typhoon Shirley which swept the island on August 1, 1960, brought about damages valued at over one billion New Taiwan Dollars (Twenty five million US Dollars).

There are two kinds of monsoons in Taiwan: winter monsoon and summer monsoon. In winter, the difference between the high pressures created by cold weather on the continent and the low pressure in the Pacific causes a strong current of air moving seaward. Due to the deflection brought about by the rotation of the earth, the wind turns to a northeastern direction when it nears Taiwan. Its velocity is accelerated considerably by the northeast trade wind which blows in the same direction. The winter monsoon prevails from late October to March, coming from the directions of northeast, north-northeast or north, with velocity usually ranging from 7 to 15 meters per second⁽¹⁾. In some areas, the velocity exceeds 20 meters per second. According to statistics⁽²⁾, the average velocity of winter monsoons at Pengchiayu, the northernmost tip of Taiwan, was 8.7 meters per second in December, while that at Penghu (or Pescadores) in the same month was 9.3 meters per second. During October to March in Penghu Hsien area, there were as many as 109 windy days which wind velocity exceeds 10 meters per second; the maximum velocity reached 24.6 meters per second. At Hengchun, the southernmost tip of the island, the velocity of winter monsoon was once recorded to be as high as 33.5 meters per second. In Yunlin Hsien seacoast area, the mean velocity for one December was recorded as 9.6 meters per second, and the extreme maximum as 34 meters per second.

(1) 15.8 miles to 33.8 miles per hour.

(2) Taiwan Statistical Abstract, 1894-1945.

Table 1. Velocity of Winter Monsoons at Different Places in Taiwan
(M/Sec)

Place	Mean Velocity	Average Maximum	Extreme Maximum	Main Direction
Yilan	1.6	9.8	18.0	NE
Keelung	3.8	10.5	25.8	NNE
Taipei	3.6	9.8	15.3	E
Hsinchu	3.5	11.8	20.2	NE
Taichung	2.0	9.7	16.2	N
Tainan	3.5	10.1	31.0	N
Hengchun	5.3	15.1	33.5	NE
Taitung	3.6	10.6	21.2	NE
Hualien	3.0	10.7	20.3	NE
Penghu	8.3	17.1	24.6	NE
Pengchiayu	8.1	17.7	32.5	NNE

Period: November to March.

Source: "Weather Classification and Distribution" by Prof. Chen Chen-hsiang.

In summer, the temperature on the continent is warmer than that at sea, resulting in a higher atmospheric pressure in the Pacific. Therefore, the summer monsoons move in the opposite direction of winter monsoons, from the ocean to the continent. Also because of the deflection caused by the rotation of the earth, the wind turns to a southwest or southeast direction upon nearing Taiwan, and its velocity is rather moderate, as the difference between the pressures in the north and south is small, and the trade wind which moves northeastward counterbalances its force. At Hengchun, the annual average wind velocity is 4.1 meters per second, while during the summer monsoon period, the average velocity is only 2.8 meters per second. At Keelung, the annual average is 3.3 meters per second, while the average during summer monsoon period is 2.6 meters per second. During the period from May to September, the average at Penghu is 4.3 meters per second and at Pengchiayu 6.5 meters per second.

Because of its high velocity and longer period, the winter monsoon brings bigger damage to this island.

AREAS AFFECTED BY WIND

The total length of coast line of Taiwan is 1,566 km. The Central Mountain Range which runs longitudinally through the island cuts the island into two parts. In the east where there is little level land, the shore is composed mainly of fault formations. There are only some narrow strips of sand beaches made up of rather coarse grains which are not easily drifted by wind. This and the fact that the hsiens of Yilan, Hualien and Taitung are all protected by mountains in the north have greatly reduced the hazard of winter monsoons

The situation is quite different in the west part of the island, where the large expanses of plains with no natural shield are susceptible to the attack of monsoons. Hazards are especially severe in the protruded coastal areas of Taoyuan, Hsinchu and Yunlin Hsien and Pescadores. In west Taiwan many streams running through the plains from the high moun-

tains, and they bring out enormous quantities of sediment each year. Take Muddy River for example, the sediment washed out by the river totals 50,000,000 cubic meters annually.⁽¹⁾ Such sediments, due to their fine grain, are usually carried back to shore by tides after reaching the sea, and thereby large sand beaches are formed. At lower places, occasional tides make the beach wet and saline, while at places of higher elevation, dry sand dunes created by the action of wind move inland, also causing great harm to crops. Even sand deposited in stream beds is harmful, as most of the streams on this island are dry in winter, and during winter monsoon period the sand will be blown toward the south. Besides, because of the rising of the earth crust in the west coast,⁽²⁾ such as in Taoyuan coastal area, new sand beach is created each year at which the sand will move inland if not stabilized.

In addition to destroying houses and uprooting trees, wind is harmful in the following ways:

1. Thwart the growth of crops or even kill them through mechanical destruction or physiological interferences.
2. Blow away surface soil, thus reducing productivity of land.
3. Move sand dunes inland and cover farm land, houses and irrigation ditches, making them useless. The dust-filled air is also bad for people's health.
4. Lessen the moisture content of soil. The salt spray carried by wind also brings harm to crops and soil.

Damages of wind are of four kinds, i.e., direct wind damage, sand drifting, torrential rains brought by typhoons, and salt spray. Farm land consisting largely of rice paddy fields, suffers mostly from direct wind damage, and the area affected is the largest. Sand drifting is harmful only to areas along seacoast and river banks where sand dunes abound. Torrential rains occur chiefly during typhoon season, and salt spray comes together with typhoon as well as monsoon at the seacoast.

The degrees and kinds of wind damages are various. In general, typhoons are the most destructive, as their radius usually encompasses the whole island and their destructive power is limitless. The windbreaks are only partly effective against them. It is for monsoons, especially the winter monsoons, that the windbreaks in Taiwan are designed. For instance, most of the farm windbreaks are east-west direction, at right angles to the direction of the monsoons; and south banks of rivers are planted with sand-checking forests to prevent sand dunes from moving southward.

Often in winter, sand can be found flying all over the sky in the strip of land within several kilometers of the western coast. This shows roughly the scope of damage which wind is capable of doing. According to Taiwan Forestry Bureau, a result of 1941 investigation showed that the area of farm land affected by wind in Taiwan amounted to 560,000 ha., over one half of the total area of farm land on the island. Of that amount, about 180,000 ha. is constantly subject to wind damage. The recent aerial survey shows that the total area of the level land within 10 km. of the coast of Taiwan is about 360,000 ha. (excluding off-shore islands). This is the area where windbreaks are needed. In an area within 5 km of

(1) Prof. Sung Hsi-shang "Tidal land of Taiwan". Taiwan Engineering Vol. 13, No. 11.

(2) Dr. T. Y. Ma and Dr. B Gutenberg were of the opinion that the earth crust would rise from 17 to 18 cm. per hundred years.

the coast is considered as "first belt" where farm windbreaks should be urgently planted in addition to seacoast forests. The "second belt" is in the area from 5 to 10 km. along the coast, where farm windbreaks are of primary importance.

The areas along the coast and stream banks, where measures for sand-dune stabilization tide and salt spray preventing and windbreaking are needed, have been designated by the government as protection forest areas. These protection forest areas may be released or increased according to actual needs. Up to the end of December 1959, such areas total 11,531 ha.

Table 2. Area of Protection Forests Along the Coast of Taiwan

Dec. 31, 1959

Unit: ha.

Place	Seacoast Windbreaks	Sand-checking Forests	Tide-blocking Forests	Others*	Total
Keelung City	—	—	—	—	—
Yilan Hsien	49.4	814.9	—	—	864.3
Taipei Hsien	31.8	524.1	—	—	555.9
Taoyan Hsien	—	994.3	—	—	994.3
Hsinchu Hsien	26.5	211.6	—	—	238.1
Miaoli Hsien	20.6	1,837.1	—	—	1,857.7
Taichung Hsien	58.9	59.4	—	—	118.3
Changhua Hsien	222.7	979.2	—	—	1,201.9
Yunlin Hsien	383.9	1,484.6	—	722.0	2,590.5
Chiayi Hsien	95.4	129.6	—	—	225.0
Tainan Hsien	106.1	48.5	—	723.5	878.1
Tainan City	—	234.9	—	—	234.9
Kaohsiung Hsien	—	32.0	53.3	—	85.3
Kaohsiung City	—	—	86.5	—	86.5
Pingtung Hsien	188.7	62.1	104.8	—	355.6
Hualien Hsien	263.5	68.9	—	—	332.4
Taitung Hsien	290.0	490.5	—	65.5	846.0
Penghu Hsien	—	13.7	—	52.5	66.2
	1,737.5	7,985.4	244.6	1,563.5	11,531.0

* Including areas of fish-attracting forests on level land and sandy islets.

Source: Taiwan Forestry Bureau

WIND EROSION CONTROL

There are two ways of controlling wind damages in Taiwan:

1. Planting of tree windbreaks.
2. Practicing agricultural wind erosion control measures.

Tree Windbreaks are not only essential to agricultural production, but also contribute to the improvement of living environment in coastal areas and beautifying of sceneries; they are useful to fisheries and national defense, and may serve as landmarks for navigation. The types and characteristics of different windbreaks will be discussed in next section.

Agricultural wind erosion control measures are practiced mainly on farms which are



Sand-dunes in the coastal area of western Taiwan.

If this sand-dune moves further inland, the rice paddy will be buried.



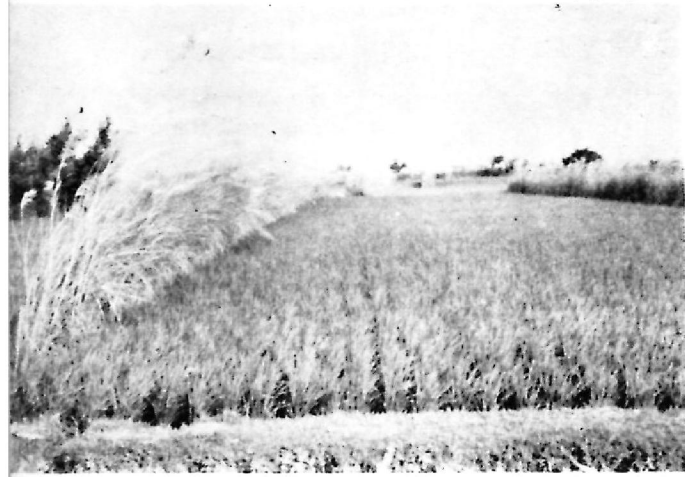
Irrigation channel is filled up with sand because there is no seacoast forests to stabilize the flying sand along the coast. (Meiliao Hsiang, Yunlin Hsien).



Top soils and fertilizers are blown away on this saline land. (Note a foot-print at the left to compare with the degree of wind erosion).



Farmers usually build temporary windbreak fences in winter in the areas without tree windbreaks.



Or planting Miscanthus grass for windbreaking.

Or inserting straw on the ridge of the furrow (sweet potato) for windbreaking and sand-fixing.



Or building coral wall for windbreaking.

without the protection of, or not adequately protected by windbreaks. The methods commonly used are as follows:

1. **Strip cropping:** High-stem wind-resisting crop in east-west alternative strips with ordinary crop, or of dense-growing crop with clean-cultivated crop. This method is especially popular with farmers of dry land farms along the coast.

2. **Miscanthus windbreaks:** Planting of permanent belts of *Miscanthus* grass running from east to west at intervals of 15-30 meters. Such grass may grow to a height of 2.5 meters. Farmers of paddy fields along the coast use this method frequently to protect their rice crops.

3. **Straw insertion:** Inserting of erect straws in sandy fields along the coast, where sweet potatoes, peanuts or watermelons are grown. Intervals may vary according to needs, and in sweet potato fields the straws are inserted on top of rows for sandfixation and wind-breaking. This method is practiced in winter time.

4. **Cover crops and mulching:** Planting of cover crops such as *Colotalaria*, Lupine, Rape seed, *Astragilus* etc. during monsoon season after harvest of winter crops. These cover crops serve as protection for soil and at the same time as green manures. Sometimes, farmers leave the roots of rice in the field after harvest, or leave the leaves of sugarcane half-buried in the ground to protect the soil from being blown away by wind.

5. **Windbreak fence:** Erecting of bamboo fences woven with *Sesbania*, with height of about two meters, set at intervals of 30-50 meters for protecting the fields against winter monsoons.

6. **Windbreak wall:** At Penghu, because of the severe winter monsoons, farmers usually construct walls of coral rocks with a height of two meters, at intervals of 10-20 meters to protect the crops.

In this report, more detailed description and analysis will be devoted to tree windbreaks. Only a brief introduction has been made about the agricultural wind erosion control methods here. However, it is suggested that some of the above methods be further studied, improved or extended in Taiwan.

TYPES OF WINDBREAKS AND THEIR CHARACTERISTICS

The windbreaks mentioned in this report actually include seacoast windbreaks, farm windbreaks, sand-checking forests, tide-blocking forests and fish-attracting forests etc. They may be classified into the following two types according to their characteristics and sites of growth.

1. Seacoast forests:

a. Seacoast windbreaks: They are planted mostly on beaches and at river mouths, running parallel to the seashore or river, with width ranging from about 50 to 200 meters. Their sites for the most part are saline soils, gravelly land, grassland and a part of sandy fields. Special planting techniques are required to enable the trees to adapt to these site conditions. At present there is a total of 1,737.5 ha. of protection forests classified as "seacoast windbreaks" in the coastal areas of Taiwan, which are distributed mainly in Tanshui, Taipei Hsien, Changhua Hsien, Mailiao, Yunlin Hsien and along the beaches

of east Taiwan. A special feature of this kind of windbreaks is that as soon as their outer part plantings grow successful, their sites can be safely released for farming.

In fact, forests along seacoast or on sandy islets for the purpose of tide-blocking, salt-spray-checking and fish-attracting fall into this category, thus making a total of 3,546.6 ha.

b. Sand-checking forests: Forests on sand beaches and along river banks, which are planted for the purpose of checking and stabilizing sand dunes, belong to this category. According to Taiwan Forestry Bureau, the total area of this type of protection forest is 7,985.4 ha. Grown entirely on sand dunes or flat sandy beaches, they are spread over a wide area, and even a part can be seen scattered in paddy fields, especially at Yuanchang, Taihsi, Mailiao and Lunpei in Yunlin Hsien and Fangyuan in Changhua Hsien. Sometimes at places beyond 10 km. from the coast, as along the south bank of Muddy River, such protection forests can also be found, which were planted to prevent tremendous sand dunes from moving south.

On the northwest coast of Taiwan, the beaches stretch out to the sea from several to over 50 meters a year as a result of the rising of earth crust and accumulation of sand. In order to prevent the outer rim of existing forests from being buried or damaged, it is necessary to extend out the forest belt on a yearly basis so that the sand can be checked and stabilized. This is a special characteristic of the coastal sand-checking forests. For instance, in Tatan area, Taoyuan Hsien, the forest belts has extended beyond the boundary of protection forests and is on the newly created tidal land, and the tendency is to extend still further out. There is no limitation as to the species of trees and plants to be grown in a sand-checking forest, so far as they can serve the sand-checking purpose. However, most of the trees that are found on the coast of Taiwan belong to the species of Casuarina. Therefore, it is difficult to distinguish between windbreaks and sand-checking forests by a glance, as the latter also have the function of wind breaking.

2. Farm windbreaks:

Usually farm windbreaks are planted behind the seacoast windbreaks and sand-checking forests on the level land within 10 km. of the coast. They run mostly from east to west, at right angles to the direction of the monsoons. The interval between the two farm windbreak belts depends on the velocity of wind and the attainable height of the trees. Best results can be achieved if the interval is not more than 8 times the height of the trees; at 20 times, the wind force will still be reduced to some extent. On seacoast, if Casuarina can grow to a height of 7 meters, it is best to place a belt at every 60 to 70 meters. In inland areas where wind is less intense, the interval may be from 100 to 150 meters.

Because of the limited arable land and the fast growing population in Taiwan, farmers in general do not like to have wider windbreaks belts. These belts are mostly about one to two meters in width with one or two rows of trees, and there is no distinction of main belt and auxiliary belt. Many farmers prefer utilizing field boundaries, paddy levees and farm paths to plant windbreaks as can be seen in Taoyuan, Hsinchu, Miaoli and Taichung Hsiens. These can also provide functions of windbreaking to a great extent.

MAJOR FUNCTIONS AND BENEFITS OF WINDBREAKS

The functions and the benefits of windbreaks are manifold, such as reducing wind hazard and increasing crop production; stabilizing sand dune and improving living environment; making sandy fields useful in providing timber and fuel; capturing new land from the sea and increasing the arable land eventually; serving as landmarks for navigation and aviation; and helping in the development of fisheries, etc. Some of the important ones are described in the following sections.

INCREASING CROP PRODUCTION

The beneficial effect of farm windbreaks on crop production is evident. The results of the rice production investigation carried out by Hsinchu Agricultural Experiment Station during Japanese occupation period are summarized as follows:

1. The windbreak affected area was 15 to 20 times the tree height at wind velocity 6-9.9 m/s and tree height 3.5-4 m. From 5 to 10.5 times of the tree height, wind velocity could be reduced as much as 50%.
2. In coastal area where there were windbreaks, the unit yield of second crop of rice was 30% to 40% higher than in area with no windbreaks.
3. In inland area, the increase was 10% for first crop of rice and 20% for second crop of rice.

More detailed figures are shown in the following table:

Table 3. Results of Investigation on Paddy Rice with Windbreaks
Vs. Without Windbreaks at Hsinchu Region

Location of paddy field Distance to windbreak belt (meter)	Hukou		Kuanyin		Hsinpu		Tayuan	
	Yield in gram*	Percentage** (%)	Yield in gram*	Percentage** (%)	Yield in gram*	Percentage** (%)	Yield in gram*	Percentage** (%)
0	637.9	171.1	—	—	—	—	416.8	73.3
2	824.3	221.1	1,217.0	195.0	948.8	136.0	726.6	127.7
4	850.9	228.3	1,128.0	180.9	693.8	99.5	852.3	149.9
6	626.3	168.0	1,848.3	237.9	909.5	130.4	915.3	161.0
8	569.7	152.8	1,252.1	200.7	1,042.5	149.5	762.8	134.2
10	555.5	149.0	1,086.8	147.2	956.3	137.1	789.3	138.8
15	614.6	164.9	788.1	126.3	1,023.8	146.8	683.8	120.3
20	474.5	127.3	827.8	132.7	1,035.0	148.4	782.7	137.6
30	499.8	134.0	973.5	156.0	1,028.8	147.5	894.3	157.3
40	—	—	849.8	136.2	—	—	761.8	134.0
50	416.3	111.7	883.8	141.6	734.3	105.3	828.1	145.7
80	372.7	100.0	732.7	117.4	948.0	135.9	662.5	116.5
100	—	—	757.5	121.4	—	—	662.5	116.5
Yield in non-windbreak area	372.7	100.0	623.9	100.0	697.0	100.0	568.5	100.0

* Yield from 50 rice plants, dried paddy rice.

** Percentage to yield from 50 rice plants not protected by windbreak.

Remarks: (1) Distance from the sites of the farm windbreak to the seacoast:
Hukou 8 km., Kuanyin 2 km., Hsinpu 8 km. and Tayuan 6 km.

(2) Second crop of paddy rice.

Dr. K. Shiratori of former Taihoku Imperial University had operated a windbreak experiment in Meiliao, Yunlin Hsien with a sesbania fence 7m high and 73 m long. The density of woven sesbania to the fence was 70%. At the wind velocity 14 meters per second, the most affected area was 8 times of the fence height. The wind velocity was reduced 50% at 5 m above the ground at 13 times of the fence height. Up to 30 times the fence height it still had some effect. In addition, this fence could significantly increase temperature and decrease evaporation of the soil.

Above mentioned are data from Japanese occupation period. The recent examples bearing evidence to the benefiting effect of windbreaks to crops are given below:

1. Rice production in Taoyuan Hsien: Data provided by Taoyuan Hsien Government.

a. At Tayuan Hsiang in 1950, the average per hectare yield of both the first and second paddy rice crops was 4,433 kg. In 1958, when farm windbreaks were established, the yield shoot up to 6,193 kg., registering an increase of 1,760 kg. or 40%. While the improved methods of cultivation and fertilization had played their part in the increase, the successful planting of windbreaks was definitely an important contributing factor.

b. Also in 1958, the average per hectare yield of rice at Hsinwu Hsiang where no windbreaks existed was only 4,922 kg. Compared with the yield at Tayuan in the same year, it was 20% less.

2. Sugarcane production in Yunlin Hsien: Reported by Taiwan Sugar Bulletin Vol. 23, No. 6, Taiwan Sugar Corporation (TSC):

a. At the sugarcane farm of Lungyai Sugar Mill, the yield per chia (0.9699 ha) has increased by 80%, from 45,000 kg. to 80,000 kg. since windbreaks have been successfully established. Naturally, the adoption of new sugarcane varieties has also contributed to the increase.

b. The average sucrose content of sugarcane has also increased by 50%, from the former 8% to 12%.

3. Crop production at Taihsi Hsiang, Yunlin Hsien: The production of different crops before and after the windbreaks were established are as follows:

Table 4. Comparison of Yields of Crops Before and After the Establishment of Windbreaks in Taihsi Hsiang, Yunlin Hsien

Crop	Acreage (ha.)	Before Windbreaks Establishment		After Windbreaks Establishment		Comparison	
		Yield per ha. (kg.)	Total (kg.)	Yield per ha. (kg.)	Total (kg.)	Difference (kg.)	Percentage (%)
Rice	286	1,950	557,700	1,500	429,000	128,700	23.6
Sweet potato	714	13,000	9,282,000	10,000	7,140,000	2,142,000	23.1
Sugarcane	280	48,000	13,440,000	30,000	8,400,000	5,040,000	37.5
Wheat	60	960	57,600	800	48,000	9,600	16.6
Barley	30	720	21,600	600	18,000	3,600	16.6
Peanut	630	1,400	882,000	1,000	630,000	252,000	28.6
Total	2,000		24,240,900		16,650,000	7,575,900	24.3

Data collected in 1951

PROMOTING PROPER LAND USE AND INCREASING TIMBER PRODUCTION

From the viewpoint of land use, the planting of windbreak forests on seacoast is highly proper, as the sandy, saline or gravel land there is unfitted for other uses than tree planting. According to the Land Use & Forest Resources Survey conducted by JCRR in 1956, most of the above types of land belong to "problem area class V." which are fitted neither for farming nor for forest cover. However, these beaches, tidal lands and sandy islets can all be used for establishing forest to produce fuelwood and timber.

Firewood is in great demand in the coastal areas, especially in central and southern Taiwan. If seacoast forests are planted and properly managed, pruning and thinning can be done within five or six years to produce fuelwood for local needs. After twenty years, about 150 cubic meters (M³) or 150,000 to 180,000 kg. can be harvested from each hectare (averaging 1,500 trees) with a total value of at least NT\$ 150,000 (US\$ 3,750). Together with the income from pruning and thinning, an average of NT\$ 6,000 to 8,000 (US\$ 150 to 200) can be netted from each hectare per year, while the total cost of planting for each hectare is only between NT\$5,000 and NT\$10,000 (US\$125 to 250).

Planting of farm windbreaks and roadside trees can also be profitable. In 1956 at Hsueh-chia Hsiang of Tainan Hsien, 130 twenty-five-year-old roadside trees of Casuarina species were felled and sold for NT\$50,000 (US\$1,250). At Chiali Chen, Tainan Hsien 1,100 trees were felled and sold for NT\$240,000 (US\$6,000), averaging NT\$220 to 380 (US\$5.5 to 9.5) per tree. During 1947 to 1951, the planting of farm windbreaks and roadside trees at Chiang-chun Hsiang, Tainan Hsien was completed, and since 1954 the yearly income from thinning has been ranging from NT\$ 100,000 to 200,000 (US\$ 2,500 to 5,000) which constitutes a great help to the local economy and is a source of funds for the construction of schools and water supply installation.

Therefore, the utilization of such lands in the coastal area in planting windbreaks not only step up the yield of crops, but also raise the local revenue and supply fuelwood and timber to coastal farmers.

INCREASING ARABLE LAND

On the west coast of Taiwan, due to the rising of the earth crust and accumulation of sand washed out by rivers, there is a tendency that the shore line will be continuously extending out. If no stabilization and windbreak measures are taken for the newly formed sand dunes, the existing coastal forests will be in the danger of being damaged or buried. Therefore, it is necessary also to extend the work on a continuing basis. The successful planting of the outer belts of forest makes the older forests in inner areas less important, and as a result, the sites of these older forests can be released gradually for farming purposes. According to Taiwan Forestry Bureau, up to the end of 1960, a total of 3,638.23 ha. of seacoast protection forest sites had been released since the Restoration of Taiwan, most of which have been cultivated into paddy fields.

Table 5. Area of Seacoast Protection Forest Sites Released for Farming Since the Restoration of Taiwan

Year	Area Released (ha.)	Remarks
1946	—	1. Most of the released sites were in Taoyuan, Changhua and Yunlin Hsien areas.
1947	—	
1948	862.90	2 Source of information: Taiwan Forestry Bureau.
1949	—	
1950	1,214.14	
1951	—	
1952	—	
1953	—	
1954	533.30	
1955	101.70	
1956	25.27	
1957	—	
1958	453.88	
1959	429.34	
1960	17.70	
Total	3,638.23	

Take Taoyuan Hsien for example, a total of 1,300 ha. of seacoast forests have been released since Restoration, most of which have become paddy fields. About 303 ha. released in 1958 and 1959 has been designated for resettlement by farmers who live below the water level of the Shimen Reservoir now being constructed. In the near future, another 100 ha. will be released. All of these will be irrigated and turned into paddy fields.

The utilization of the newly developed tidal land on the west coast will be impossible if it is not protected by seacoast forests outside and by farm windbreaks inside. To make tidal land arable, the cost of reclamation for each hectare will be from NT\$100,000. to NT\$150,000 (US\$2,500 to 3,750). However, if sand-arresting techniques are used and wind-break forests planted, the cost will be only 5% of the above. Consequently, timber can be harvested decades afterward and the sites can be gradually released for farming with the successful planting of the outer belts of seacoast forests.

INTRODUCTION OF WINDBREAK PLANTING TECHNIQUES

PRINCIPAL WINDBREAK AND SAND-FIXATION PLANTS

Before discussing planting techniques, this section will introduce the principal windbreak and sand-fixation plants which have more extensively been used in Taiwan.

For windbreak plants, the ideal species for this Island should meet the following conditions:

- (1) Wind and insect resistance, and tolerance of drought, salinity and infertile sites.
- (2) Evergreen tree with dense crown and deep roots.
- (3) Easy propagating, high survival rate, rapid growth and slow deterioration.

It is impossible for one species to fit all these conditions. However, through decades of planting, *Casuarina* spp. has been proved fitted for most of these conditions and has been widely used for windbreaks in Taiwan. According to Taiwan Forest Research Institute (TFRI) *Casuarina* was firstly introduced from Bonin Islands in 1897. From 1910 to 1913 there were ten more species propagated on this Island, with a result of nine existing at present. Among them, six species have better wind-tolerant nature and also have widely been planted. The first three in the following list are distributed most extensively.

- (1) *Casuarina equisetifolia* Forst.
- (2) *Casuarina glauca* Sieber
- (3) *Casuarina Huegeliana* Miq.
- (4) *Casuarina quadrivalvis* Labill
- (5) *Casuarina Fraseriana* Miq.
- (6) *Casuarina trichodon* Miq.

The obvious defect of *Casuarina* had been the long horn beetle damage. However, the use of Dieldrin emulsion or wettable powder to 3-5 years old forests has been proved a great success—85% of the beetle damage has been controlled in the treated area. The danger from the long horn beetle, therefore, is relaxed.

Besides *Casuarina* spp., there are some other species used for seacoast forests planting as follows:

- Hibiscus tiliaceus* Linn.
- Pandanus odoratissimus* var. *sinensis* Kanehira
- Acacia confusa* Merr.
- Dalbergia sissoo* Roxb.
- Leucaena glauca* Benth.
- Calophyllum inophyllum* Linn.
- Garcinia spicata* Hook. f.
- Terminalia catappa* Linn.
- Celtis formosana* Hay.
- Albizia lebbek* Benth.
- Melaleuca leucadendron* Linn.
- Pinus luchuensis* Mayer.

Pinus Thunbergii Parl.

Bambusa stenostachya Hack.

The planting of *Casuarina* on the dykes of saline sites in the coastal area is rather expensive and less successful. Since 1954, *Tamarix aphylla* (L.) karst. has been tried by cuttings on the saline sites. Even on high salinity sites, the survival rate has been found much better than *Casuarina* though it is less wind resistant. However, it can be planted as mixture with *Casuarina* or other species. On sandy sites, *Pithecolobium dulce* Benth. has also been tried.

Mangrove has been planted along the sides of river mouths and sea shores. There are six species of mangrove in Taiwan. The most extensively used two are *Kandelia candel* Durce and *Avicennia marina* Vierh. The former species is mostly from Tanshui, Taipei Hsien while the later is from Wu-tsu-lin, Kaohsiung Hsien and Tung Kang, Pingtung Hsien. Both of them are planted by means of seeding. Besides planted as fish pond windbreak and as good fuel, they have been used by Yunlin Tidal Land Reclamation and Development Committee for the purpose of raising sand in the tidal flats.

In addition, along the southern coast of Taiwan, Coconut Palms have also been extensively tried in the recent years.

As to farm windbreak, many tree species other than *Casuarina* spp. have been adopted. In the coastal area of Taoyuan Hsien and Hsinchu Hsien, *Leleba multiplex* Nakai are used for windbreak or planted with *Casuarina* as under growth. Also *Eucalyptus robusta* Smith are planted as windbreak or mixed with *Nerium indicum* Mill. The planting of *Sesbania sesban* (L) merr. in central Taiwan for windbreaks are also not uncommon. Likewise *Leleba dolichoclada* Hayata and *Bambusa stenostachya* Hack. are widely used for farm windbreak in Taichung Hsien and Changhua Hsien. Along Tanshui to Kingshan Highway, Taipei Hsien and in Green Island, Taitung Hsien, *Pandanus* are also used for windbreaks. *Calophyllum Inophyllum* has been planted with *Casuarina* as under growth in Yunlin Hsien. Besides the above mentioned species, *Acacia confusa*, *Hibiscus tiliaceus*, *Leucaena glauca* and *Melaleuca leucadendron*, *Alnus formosana* Markino. etc. used for farm windbreaks are also common.

There are many plants which can be used for sand-fixation purpose along the beach. The more applicable plants are as follows:

Miscanthus spp.
Ipomoea pes-caprae Roth.
Vitex rotundifolia Linn.
Spinifex littoreus Merr.
Scaevola frutescens Krause
Cynodon dactylon Perst
Agave americana Linn.
Canavalia microcarpa (DC.) Merr.
Eremochloa ophiuroides Hack.
Zoysia matrella Merr.
Cereus triangularis Mill.
Leucaena glauca Benth.

Paspalum distichum Hauss.
Myoporum bontioides A. Gray
Ricinus communis Linn.
Lantana Camara Linn.

GROUND PREPARATION FOR SEACOAST FORESTS

Due to different sites in the seacoast area, different methods of ground preparations are needed. Sites along the coast can be divided into four kinds namely, sand-drifting sites, saline or wet sites, gravelly sites and grassed sites. Among these, the sand-drifting sites are distributed most widely. The methods of various ground preparation are described in the following paragraphs.

SAND ARRESTING FENCE FOR SAND-DRIFTING SITES

The sand arresting method is applied on sand-drifting sites during winter monsoon by means of fencing. Its purposes and functions are as follows:

1. To set the fences all over low elevation site. After the sand is arrested and elevation is raised and levelled, damages from tide or from stream wash in the rainy season will be greatly eliminated.

2. To set fences only at depression places of the sand dune area. Wind or supplemented by human labor can gradually reduce the elevation of high dunes, and in the meanwhile also fill up the depressions. After the entire area is levelled, sand-fixation measure will be followed.

On sandy sites a fore-dune or so called "Tide protection sand dyke" is established at 30 m to 50 m parallel to the shore. The purpose of this dyke is to protect the sites against sea tide and foreign sands. Fences for the dyke and for the planting site could be built at the same time.

The sand arresting fence is made of bamboo and sesbania. Bamboo poles are set one meter apart with sesbania or bamboo wickers woven in. The height, space interval, direction, woven density, as well as the order of the fencing depend on actual conditions and needs.

1. **Height:** In general, one meter from the ground is the optimum height for fencing; However, this varies in accordance with the sand sources and topography. Poles are to be set at least one third underground to support the fences against wind. For tide protection dyke, a third fence needs to be set on the top of the sand piles, making a surface 1.5 to 2 m higher than the planting sites. (See Fig. 1.)

2. **Spacing interval:** This is usually 15 to 20 times the fence height or 15 to 20 m. Also, it varies with the velocity of prevailing winds and sand sources.

3. **Direction:** Set the fence at right angles to prevailing monsoon, or in an east-west direction.

4. **Woven density:** Density at 30-50% is good for sand passing. However, the density of the southmost and northmost fences are above 70%, keeping sand from blowing further away.

5. **Fencing order:** The order for fencing is from south to north, about three rows each time. As soon as the first three rows arrest sand over half, it is time for next three rows. Figure 1. shows fencing order of certain sand-drifting sites with NNE wind.

After the sand is arrested and levelled to a desirable elevation, straw insertion must be done for sand fixation.

The sand arresting work is essential to the success of tree planting. If the sand is not accumulated high enough, the site will be damaged by tide or water again. If it is not levelled, the higher places will be too droughty and too exposed for tree growing while on lower places trees will be eventually buried.

DYKE OR HEAP BUILDING FOR SALINE OR WET SITES

There are hundreds and thousands of hectares of saline land and tidal land in Yunlin, Chiayi, Changhua and Taichung Hsiens. Those lands either wet all the year round, or occasionally wet in the raining season but suffering sand-drifting during winter,

are all characterized by high salinity. For example, from the results of electrical conductivity tests of soil saturation extracts (ECS), most of the land in Meilliao Hsiang, Yunlin Hsien are above 16 mmhos/cm. The pH value of these land ranges from 7.9 to 8.4.

Prior to the tree planting, the building of earth dykes is needed. The specification of the dyke depends upon the amount of water. It varies from 0.5 to 1.0 m in height and 4 to 6 m. in width. The excavated area serves as drainage ditches with similar specification. If the dyke is 4 m. wide the lineal length per hectare will be 1,250 m. Then four rows of trees will be planted with the space of 0.8 m between rows and 1.0 m within the row. If the width is 6 m, the lineal will be 800 m per hectare, planted with 6 rows of trees. The number of trees planted per ha is around 5,000.

After building the planting dyke, *Miscanthus* grass and bank stabilized plants such as *Zoysia matrella* and *Eremochloa ophiuroides* etc. are planted in early spring. It is followed by tree planting at the beginning of the rainy season.

Besides saline soil and tidal land, sites of low elevation or poor drainage which have occasional flood by stream water during the raining season can be heaped in places for tree planting. The heap on which the tree is planted is usually 30-50 cm in height and 100 cm in diameter. Soil hilling is necessary year after year until the trees grow up or no water comes into the sites.

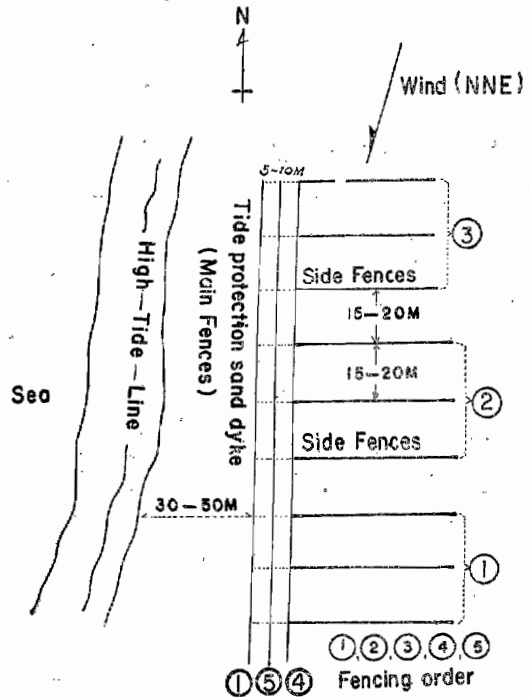


Fig. 1. Fencing Order on Sand-drifting Sites

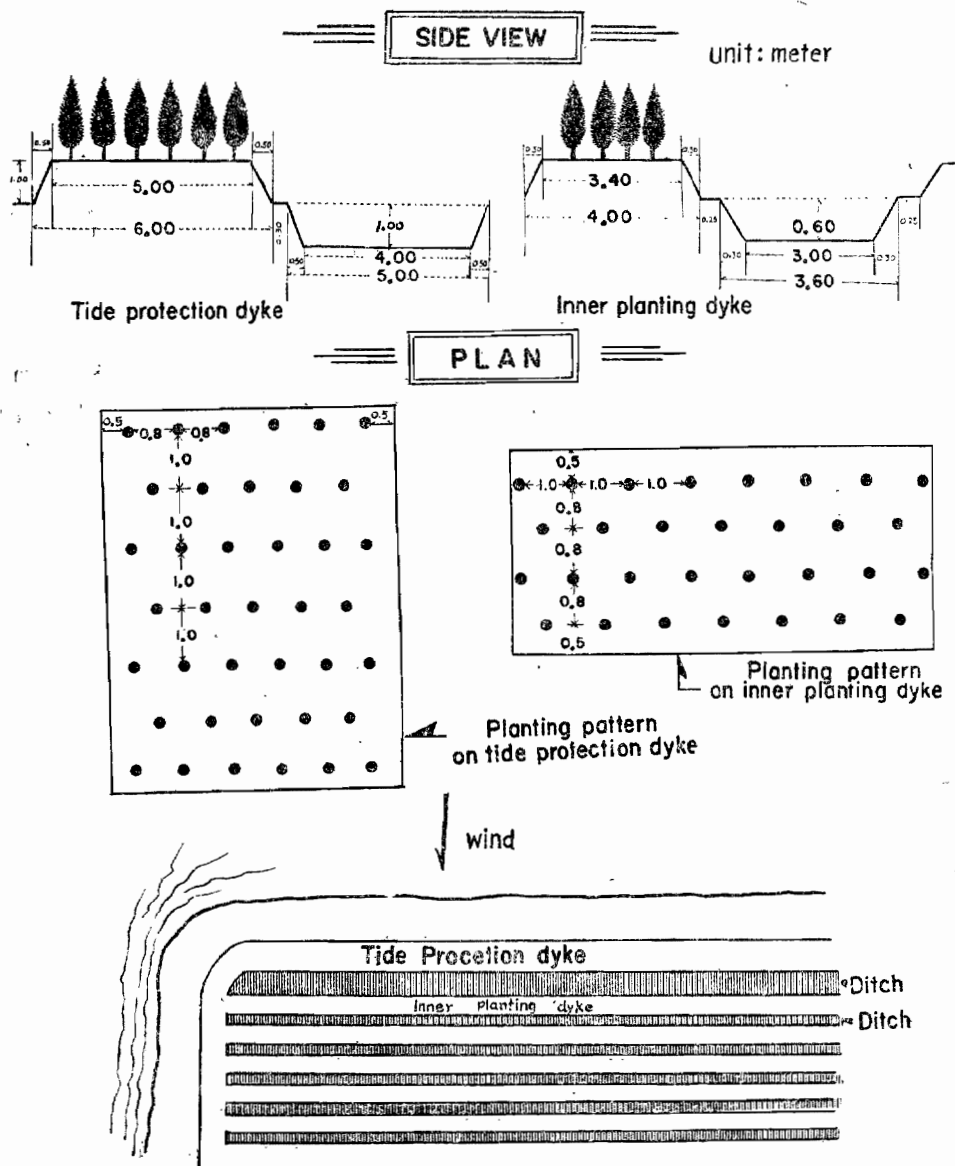


Fig. 2. Seacoast Forest Planting on Dyked Saline Sites

HOLE AND TRENCH DIGGING FOR GRAVELLY SITES

According to TFB, there are 1,000 more hectares of gravelly river wash along the seacoast of Taiwan. Head sized rocks can be seen in the coastal area of central and northern Taiwan. Because of the insufficient sand sources for sand arresting fence, these sites are prepared by hole digging method which will permit the tree planting.

Holes are dug before the winter monsoon, with a specification of 30 cm deep and 30-45 cm in diameter. The space between rows is 1 m and within rows 2 m, totalling 5,000 holes per hectare. The picked rocks are piled along the southern edge of the hole thus making the drifting sand fill up the hole during the winter monsoon. Trees are planted the next spring while the rocks at south edge still provide protection against SE or SW summer

monsoon. Just before the winter monsoon comes, the rocks have to be moved to the northern edge to protect the young seedlings.

In Penghu coastal area, there is another kind of site composed of coral gravel and coarse sand. Although the coarse sand does not blow during the winter, the extremely high wind velocity will hurt the young trees. Together with high evaporation and consistent drought which only has 1,000 mm (40 inches)* of rainfall annually and distributed unevenly with an average of 192 mm during planting season, (from April to May), the tree planting always get low survival. However, an "open trench" method has been applied since 1954 resulting higher survival rate of over 80%.

Trenches are dug in an east-west direction for moisture conservation with 1 m apart, 30 cm deep and 50 cm wide. Casuarina trees are planted in the trench with a space of 75 cm, totalling some 9,000 trees per hectare. On the top of the ridge Scaevola is planted to protect Casuarina.

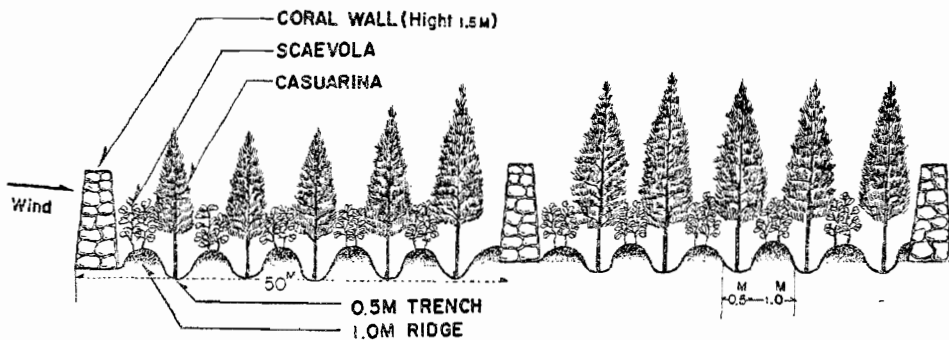


Fig. 3. Side View of Open Trench Planting on Gravelly Sites

PARTIAL WEEDING FOR GRASSED SITES

The ground preparation for grassed sites is nothing particular than that of ordinary reforestation in Taiwan. However, weeding is applied only to the hole sites. The remaining area is kept undisturbed.

SAND FIXATION

Ground preparation, sand fixation and tree planting are the three steps toward seacoast forest establishment. There are two kinds of sand-fixation work. One is to insert rice straw or tree branches to retard sand movements and the other is to vegetate with grass and vine etc. to cover the sand and to prevent from blowing. The former is usually undertaken in winter season immediately after the ground is prepared while the later is planted next spring, ahead of, or at the same time as the tree planting.

* Taiwan has an average of 2,500mm (100 inches) rainfall annually.

STRAW OR TREE BRANCHES INSERTION

As soon as the arresting fence is filled up with sand and levelled, it is time to do straw insertion work. Rice straw is usually used for inserting material. At the windward side the space between rows range from 30 cm to 60 cm while at the leeward the space is 1 m or more, averaging 10,000 m of straw will be inserted per hectare. For each meter, 0.5 kg of straw is inserted totalling 5,000 kg per ha. At inserting, the root of the straw is inserted to the leeward while the leaf to windward, thus keeping the whole straw erected. The inserting process is that one person lays the straw with leaf ends toward north and the other person inserting them with a long handle board by footpressing. It averages 200 m per manday including delivering, laying and inserting, etc.

Wherever sand source is abundant, inserting of straw may be done several times. If the first insertion is buried by sand, the second insertion should be followed. A third time will also be desirable during next winter if the miscanthus grass can't provide adequate shield to the trees.

The area of straw inserting is usually bigger than that of tree planting. If there is a large quantity of sand at the northern side of the plantation, straw inserting has to be extended in a belt of 30-50 m to the northern adjoining area.

In sand-dune area, straw is inserted only below the proposed elevation of the site. Dunes above this elevation will have no straw work so that the wind will gradually blow the sand off. Sometimes human labor supplements the levelling of the high dunes. Straw inserting should be repeatedly done in the depression area until the sand piles up to the proposed elevation.

If there is not enough straw, inserting of tree branches instead of straw will have same effect. The space between rows may be extended to 2-3 meters.

PLANTING OF SAND-FIXATION PLANTS

Sand-drifting sites, or saline sites having sand blowing in winter should be planted with sand fixation plants, such as *Miscanthus* grass, *Ipomoea pes-caprae*, *Leucaena glauca* etc. upon the completion of sand arresting or dyke construction. The purpose of this kind of planting is to provide a living shield to the young trees during the winter monsoon.

Miscanthus grass is usually planted in early spring. It is one or two months earlier than tree planting in the northern Taiwan, and four or five month earlier in the south. With 2 m spaced between rows, a total of 5,000 m or 4,000 kg is planted per hectare on sandy sites, at 0.8 kg each meter. The two most adaptable species are *M. sinensis* Anders. and *M. japonicus* Anders. both of which grow fast and dense. For example, *M. japonicus* planted in spring of 1960 on Yangliao tidal land, Hsinchu City has reached a height of 2.5 meter in autumn. General speaking, *Miscanthus* spp. planted on sandy beaches can reach a height of 1.5 m. Several local governments operate *Miscanthus* nurseries in the coastal area providing cuttings as well as roots for propagation. *Miscanthus* cuttings can also be obtained from three or more years old plantations where trees have grown up and *miscanthus* is being suppressed and not functioning.

Ipomoea pes-caprae is also widely planted for sand fixation. It is a dominant local species in the coastal area. Cuttings are used for planting before or after the trees are planted.

In general it grows slowly in the first year after planting. However, it can eventually form a dense ground cover against sand blowing. It is ideal for planting on tide protection sand dykes as permanent vegetative cover so that the straw inserting work could be eliminated.

Leucaena glauca is also an ideal species for sand-fixation. But its survival rate is rather low in dry sandy sites. Drought and heat in summer usually dries out their tender sprouts. Trial planting by roots instead of direct seeding has been proved successful in coastal area of Yunlin Hsien. Yet, it is still less adaptable than *Miscanthus* grass on the sandy sites. Direct seeding on the dyke of the saline soil is more widely used, however.

Areas where the winter monsoon is extremely strong will be planted with sand-fixation plants in the first year and trees in the succeeding year. Since the planting of sand-fixation plants and trees in the same year have been proved satisfactory in most places recently, the necessity of separating them in two years is therefore lessened.

NURSERY PRACTICE

Casuarina is the principal tree species of windbreaks. This section will discuss the method of its nursery practices which is more or less like other tree species. The important points in producing *Casuarina* seedlings are as follows:

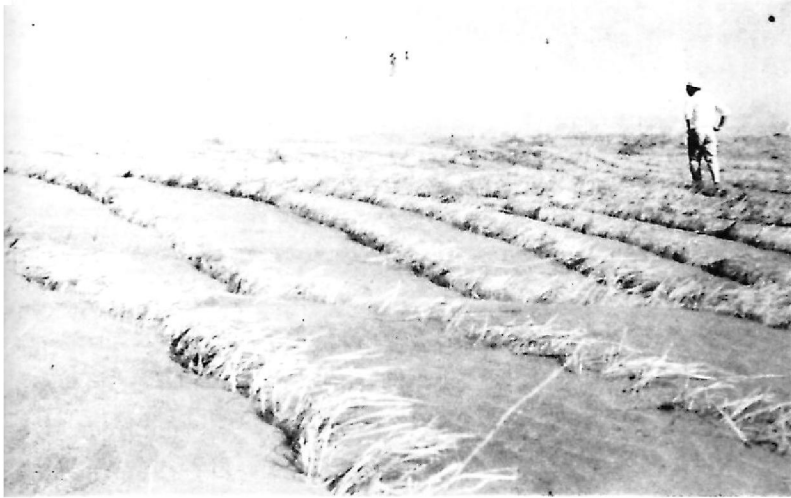
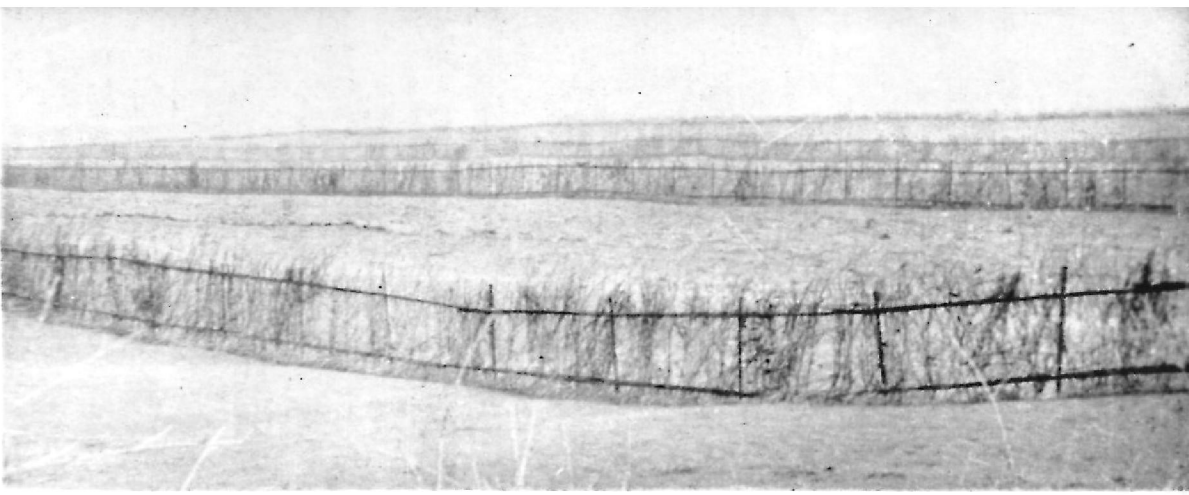
1. Seed quantity: 0.05 li/m² for broadcasting and 0.03 li/m² for sowing in drills.
2. Seeding time: From March to April. Autumn seeding, from August to September, is not uncommon in central and southern Taiwan.
2. Transplanting time: 3 to 4 month after seeding.
4. Number of transplants per m²: 42 or 36.
5. Ratio of seeding bed to transplanting bed: 1:7 to 1:10.
6. Lifting time: 6 to 7 month after transplanting when the seedlings have grown up to a height of 60 cm above ground.
7. Root pruning: "water root pruning method" is used. After pruning a little at the top of the seedlings, water is impounded at the nursery for several days until the color of the seedling turns a little brown. Then drain off the water and give time for the seedlings to recover. This should be done two or three times in one to two months before lifting. This results in development of good root system as well as high survival.

Most of the *Casuarina* nurseries for seacoast plantings are located at sandy sites along the coast. Some have poor water holding capacity while other have high salinity. Irrigation installations for sandy sites, and good drainage facilities for saline sites are necessitated. Both of them need organic fertilizers.

SEACOAST FOREST PLANTING

When the ground is prepared and *Miscanthus* grass or other sand-fixation plants are planted, it is time for tree planting as soon as the rainy season starts. However, the rainy season varies from place to place and so does the tree planting time. General speaking, from late March to the end of April is the suitable season for *Casuarina* planting in northern

*Sand-
arresting
fences.*



After sand is piled up by wind and levelled, straw insertion is made.

*Sand arresting fences for tide protection
dyke or fore-dune.*



*Planting Ipomoea on tide protection dyke as
permanent vegetative cover.*



One-year old Casuarina plantation in the coastal area of Tatan, Taoyuan Hsien. (Note Miscanthus grass, Ipomoea etc. are planted with trees).



Two-year old Casuarina plantation in the coastal area of Tatan, Taoyuan Hsien. (Note the sand arresting work at the newly risen beaches).

Four-year old Casuarina plantation in the coastal area of Tatan, Taoyuan Hsien.



Sand fixation and tree planting are needed for the newly risen beaches.



Casuarina seacoast forest planted on gravelly sites. (Taoyuan Hsien)



Casuarina seacoast forest planted on the dykes of saline sites. (Yunlin Hsien)



Casuarina seacoast forest planted in the open trench while *scaevola* are on the ridge. (Penghu Hsien)



Three-year old mangrove (*Kandelia candel*) planted along the mouth of Chiangchun stream. (Tainan Hsien)



New Casuarina farm windbreaks planted on the levee of the rice paddy by farmers in Miaoli Hsien.

Bamboo (Leleba dolichoclada) farm windbreaks in Changhua Hsien.



Farmers in Taoyuan Hsien like to plant one row of Casuarina with small bamboo (Leleba multiplex) as under growth on paddy levees for farm windbreaks.

Farm windbreaks of multiple rows in the sugar cane farm of Taiwan Sugar Corporation in Yunlin Hsien.



Taiwan, because the severe winter monsoon will have practically ended by that time. In central and southern Taiwan, April to June is desirable although planting in Autumn in some areas is not uncommon. Trees are usually planted 2 m apart between the rows, and 1 m apart within the row (see Fig. 4). Sometimes they are planted 1 m between rows and 2 m in the row. (see Fig. 5). Following figures are planting patterns on sandy sites. Planting pattern on gravel or grass sites are similar.

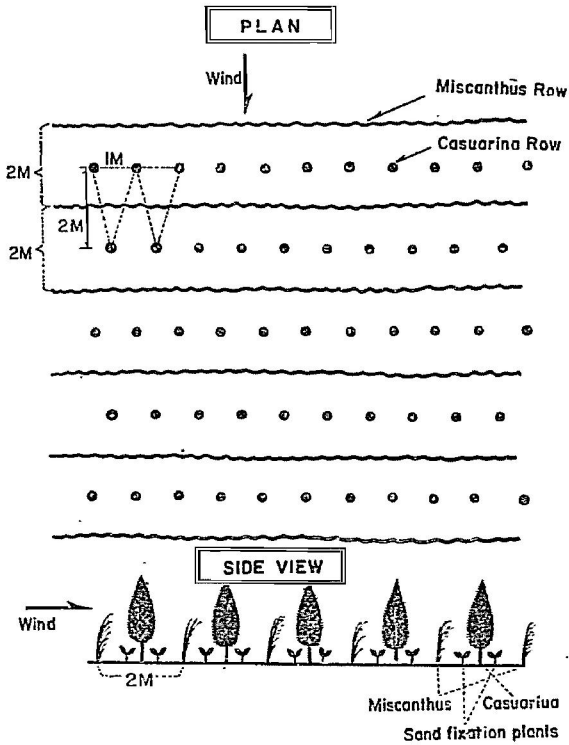


Fig. 4. Seacoast Forest Planting on Sandy Sites (Pattern A)

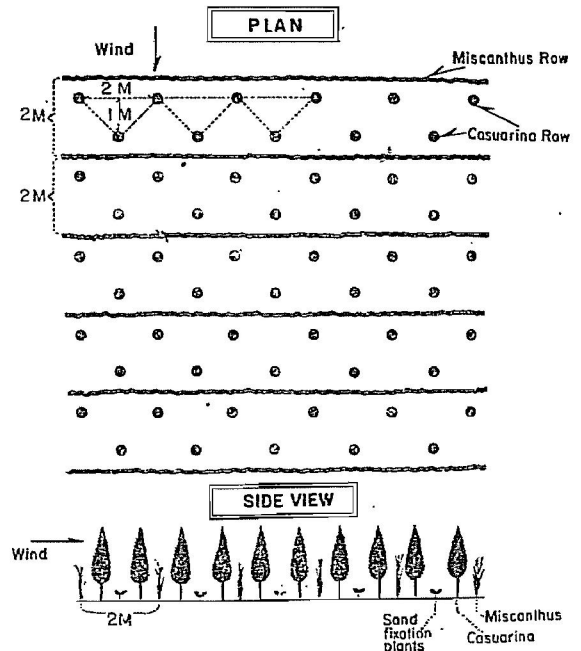


Fig. 5. Seacoast Forest Planting on Sandy Sites (Pattern B)

Planting 6,000 or 9,000 trees per hectare is also common. Some dyke plantings on saline soil of southern Taiwan are 6,000 trees per ha while 9,000 trees are usually planted in "open trench" in Pescadores.

Casuarina seedlings used for seacoast planting should be healthy and medium-sized. Seedlings of one year old, 3 months in seed bed and 9 months in transplanting bed, with a height of 60 cm above the ground usually result good survival rate. Use of over-sized seedlings not only handicaps transportation but also causes low survival. On the other hand, if they are too small they will not tolerate the winter monsoon. Seedlings with the roots packed with a earth ball are most desirable. However, for the convenience of transportation, the size of the ball should be minimized. By dipping the roots into mud after lifting also can increase the survival rate.

Weeding is unnecessary after planting. But the control of long horn beetle is necessary on trees from 3 to 5 years old. As to the other phases of planting technique, they are similar to the ordinary tree planting or reforestation.

FARM WINDBREAK PLANTING

Farm windbreaks are essential to better crop production in the area of 10 km along the coast in the west coastal plain. Within 5 km of the coast is called the "first belt" where the need of farm windbreak is the most urgent in addition to seacoast forests. From 5 km to 10 km along the coast is the "second belt" where farm windbreaks is also essential.

In east Taiwan, however, there is no big plain along the coast like the west but hills and fault formations. Therefore, the need of farm windbreak planting is rather small.

It is ideal to plant farm windbreaks with multiple rows of different trees, and shrubs to compose one thick belt, or to systematically plant them with principal belts and auxiliary belts. However, Taiwan can't afford to do so owing to the following reasons:

1. The arable land is so limited, that the farmers in Taiwan would not or could not afford to spare too much area for windbreak planting.

2. The average farm holdings in Taiwan is rather small—only one hectare or 2.5 acres. In addition, the fields are scattered and un-evenly shaped.

Except on public or enterprise owned farms, most farm windbreaks in Taiwan have narrower belts, one meter or so, and with one or two rows of trees planted. One row of Casuarina or Miscanthus grass planted on paddy levees for windbreak is not uncommon here.

Because most of the fields on this Island are rice paddy, dykes should be built before planting trees. The standard size of dyke is 1.4 m wide at the top and 0.3 m high. The trees are to be planted triangularly with 0.8 m between rows and 1 m within row. Between the space of Casuarina, small bamboo (*Leleba multiplex*) is usually interplanted by farmers in northern Taiwan. However, the specifications of the dyke, the spaces of the trees as well as the belts are varied in accordance with the actual needs. In general, the distance between farm windbreak belts is 70 m along the coast or on tidal land, 100 m in the area of 5 km of the coast, and 150 m in 5-10 km.

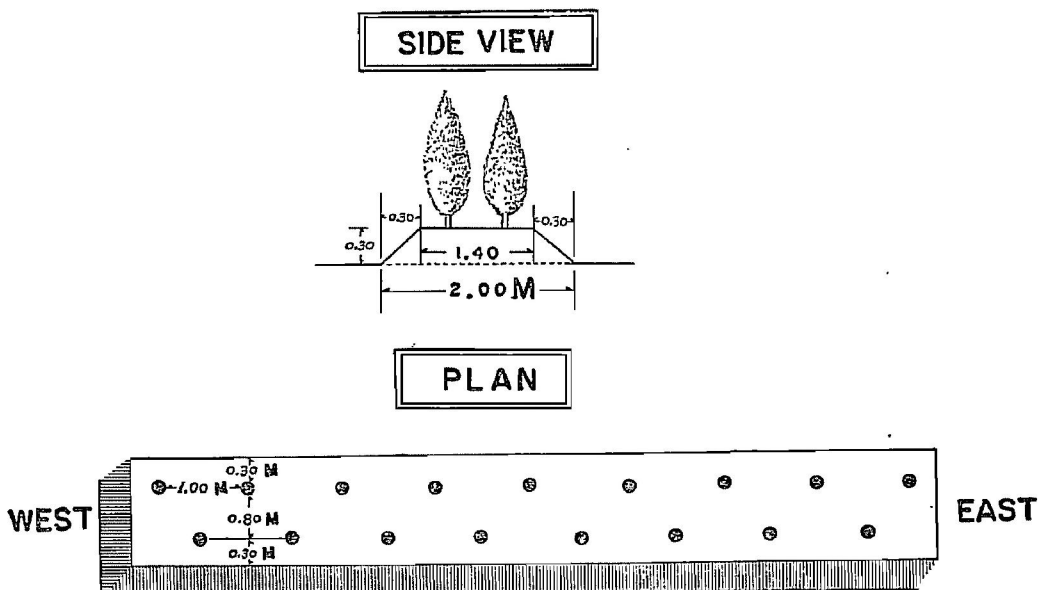


Fig. 6. The Model of Farm Windbreak Planting in Taiwan

Public farms such as TSC farms in the coast, usually have wider belts, 3 to 5 m wide, with 3 to 5 rows of trees planted. The distance between east-west belts is 100 m or 150 m. There is no limitation of how far between north-south belts. Yet it should not handicap the mechanical cultivation of these sugar farm field.

There are many *Leleba dolichoclada* windbreaks in central Taiwan. Due to its straightness, density and less shading, it is more ideal than other bamboo species. It can be used for making bamboo baskets, trays, and many other things. But the seedling is more expensive than *Casuarina* seedling, thus handicapping its extension.

Besides *Leleba* spp., *Eucalyptus robusta* mixed with *Nerium indicum*, *Sesbania sesban*, *Calophyllum Inophyllum*, *Bambusa stenostachya*, *Pandanus ordoratissinues* etc. are planted for farm windbreak farther inland. They occupy lower percentage of the whole farm windbreaks.

Because of extremely strong wind, farmers in Pescadores build coral walls for windbreaks. Tree windbreaks have been tried in recent years. The windbreak belt is 4 m wide with stone dyke, 1 m wide and 60 cm high, at the front on which the miscanthus or pampas grass are planted. *Leucaena glauca* is seeded 5 rows in a meter close to the stone dyke. In the final 2 meters, four rows of *Casuarina* are planted triangularly with 0.5 m between the rows and 1 m within the row. The distance between belts is about 50 m. Their effect is still under observation.

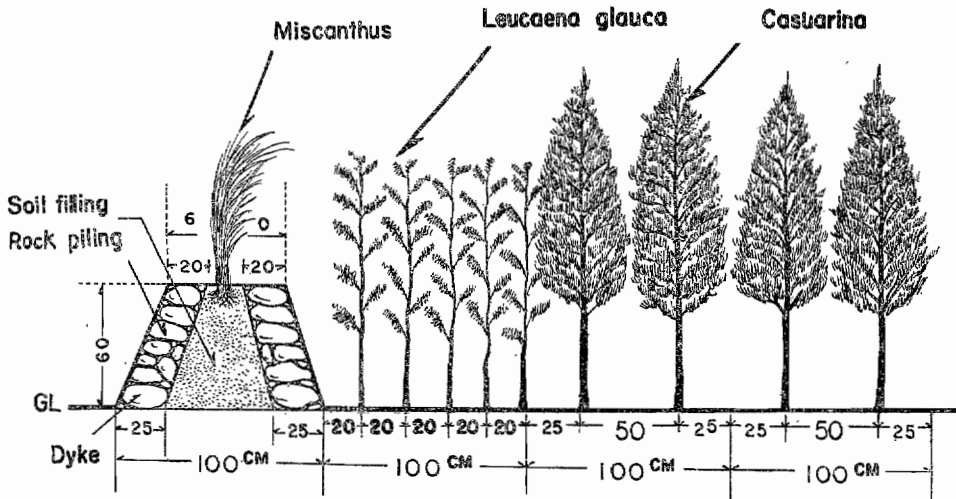


Fig. 7. Side View of the Farm Windbreak Belt in Penghu

PAST ACHIEVEMENTS AND FUTURE GOALS

WINDBREAK DEVELOPMENT BEFORE THE RESTORATION OF TAIWAN (1945)

Windbreaks were planted as early as the Ch'ing Dynasty (1644-1912). While there is no literature from which the details about windbreaks planting can be found, scattered groves of old *Pandanus* and *Hibiscus* along the coast from Tamshui through Lukang provide ample evidence that trees have been planted since then for protection against winds and sand. After the Japanese occupation of Taiwan, systematic sand stabilization measures and seacoast forest planting were first started at Mailiao, Yunlin Hsien and Erhlin, Changhua Hsien in 1906. The history of windbreak planting, therefore, goes back at least 50 years in Taiwan.

This was gradually followed by Houlung and Chungkang of Miaoli Hsien, Tayuan of Taoyuan Hsien and Kingshan of Taipei Hsien since 1908. Up to 1921, 4,398 hectares (ha.) of land had been sand-stabilized with *Miscanthus* spp., *Ipomoea pes-caprae*, *Vitex rotundifolia* and *Spinifex littoreus*; and 2,457 ha. planted with *Acacia confusa*, *Casuarina* spp., *Dalbergia sissoo*, *Leucaena glauca*, and *Ficus* spp. etc. This was the first period in which all programs were financed by the Japanese Taiwan Governors' Office.

After 1922, owing to financial difficulties, the Governor's Office only bore half the expenses, with the other half charged to the local governments. Up to 1933, 5,889 more hectares had been sand-stabilized and 4,095 ha. planted, costing a total of ¥865,000. This was the second period.

To intensify seacoast forests establishment, six-year and ten-year programs were drawn and put into practice. Unfortunately, the Pacific War broke out before the latter was completed. As a result, only 2,667 ha. were planted, covering Taitung, Hualien and Penghu. This was the third period.

All told, during the 35 years from the beginning of seacoast forests planting to the Pacific War, 9,219 ha. were planted, averaging 263 ha. a year.

The systematic planting of farm windbreaks began in 1927. Up to 1940, about 123,000 hectares of farm land had been protected with windbreaks.

ACHIEVEMENTS OF WINDBREAK ESTABLISHMENT SINCE THE RESTORATION OF TAIWAN

In the final period of World War II, forests in Taiwan were immensely exploited by the Japanese to meet their military requirement. Windbreaks were made no exception. This situation was aggravated by the illegal cutting and destructive cultivation shortly after the Restoration of Taiwan when forest administration had not been put into action. Windbreaks were badly damaged as shown in a Taiwan Forestry Bureau's estimate that only 1,403 ha. of seacoast forests were left at that time. Close to this figure, the recent survey has found that there exist 1,233.6 ha. of seacoast forests on the island which are more than 20 years

old. Since the Japanese practically stopped windbreak planting program at the outbreak of the Pacific War in 1941, windbreak trees planted in the Japanese Occupation period have now all exceeded 20 years of age. As to farm windbreaks, it was also suffered heavy losses except those in Hsinchu and Kaohsiung area.

Windbreak plantings after the Restoration may be divided into three stages as follows:

1. First stage (1946-1950):

In this stage, windbreaks were mainly planted by the Taiwan Forestry Bureau in cooperation of prefectural governments. 2,081.30 ha. of seacoast forests were planted in the five-year period, averaging 416.2 ha. per year. The work was not quite satisfactory at the beginning of this stage because the Japanese technical personnel were all repatriated and Taiwan was short of skilled hands. Technical difficulties was not completely overcome until 1950. Although extensive planting of windbreaks was not possible due to financial limitation, the technical personnel have established their confidence in re-establishing it. Taiwan Sugar Corporation (TSC), on the other hand, has successfully pushed the seacoast forests re-establishment program in sugar cane area in Yunlin Hsien.

2. Second stage (1951-1958):

Since the activation of Forestry Division/JCRR in 1951, windbreak planting has been greatly boosted and extensive programs put into practice. Taiwan Forestry Research Institute (TFRI) has also taken part in the research and investigation work. A windbreak experiment station has been installed at Peikang, Yunlin Hsien at the beginning of this period. Great strides were made in both finances and technique, resulting in remarkable achievements in windbreaks planting. The average tree survival rate has always exceeded 80%. Consequently, a total of 6,880.15 ha. of seacoast forests were planted in these eight years, averaging 857.5 ha. per year. As to farm windbreaks, through the encouragement of the Provincial Government which promulgated "Measures for encouragement of planting farm windbreaks in Taiwan" in 1950 and the cooperation with the TSC for farm windbreak development in Yunlin and Changhua Hsien, some 5,711.9 kilometers have been planted averaging 714 km per year. In this short 8-year period windbreaks had been established in the most critical area in coastal plain. The achievement was remarkable.

3. Third stage (1959-):

If first stage is called the "Rehabilitation stage" and second stage the "Expansion stage", third stage should be called the "Management stage". As windbreaks have been established in most critical area in coastal plain, the important question now facing us is how to manage them properly. Since no survey of the coastal areas was permitted formerly, the estimate of planted area in the past was by no means accurate. Besides, a lot of protection forests in coastal area has been released by the government and Taiwan has suffered several natural disasters in recent years. All of these have caused great change to seacoast forests. An island-wide survey of the windbreak conditions through aerial photos is therefore badly needed. The results of this survey can serve as a basis for future management.

Following is a table listing the area of windbreak planting since Restoration, 1945:

Table 6. Area of Seacoast Forests and Farm Windbreaks Planted since the Restoration

Year	Seacoast Forests (ha.)	Farm Windbreaks* (Km.)	Remarks
1946	146.00	—	First stage
1947	354.81	—	
1948	639.14	—	
1949	419.40	—	
1950	521.95	—	
1951	534.75	1,283.4	Second stage
1952	1,151.91	2,432.9	
1953	819.33	953.9	
1954	901.51	253.3	
1955	841.70	298.0	
1956	831.08	103.8	
1957	953.78	185.6	
1958	826.09	201.0	
1959	404.40	117.6	Third stage
1960	333.24	263.2	
Total	9,679.09	6,092.7	

Source: Taiwan Forestry Bureau

* Not including those planted by farmers themselves.

RECENT IMPROVEMENTS ON WINDBREAK ESTABLISHMENT TECHNIQUES

While the Japanese have laid a good foundation in the windbreaks establishment, it was not until 1951 that phenomenal improvements both in planting and nursery practice were made through the coordinated efforts of forestry authorities, research institutions, local governments and the JCRR. Some have resulted in great success, some are still under experiment. As a matter of fact, the survival rate of the newly established windbreaks in recent years have exceeded 80% provided no natural disaster occurred. The following are major improvements:

1. Planting techniques: The course of a successful planting on the drifting-sand beaches has been safely shortened as a result of the adequate implementation of sand-arresting and sand-fixation measures. In the Japanese days, sand-arresting and sand-fixation measures were usually started two years ahead of the tree planting. In recent years, however, more emphasis has been laid on the preparation of the ground. For instance, the location, space interval, direction, height and woven density of the sand-arresting fences are determined by the direction and velocity of winds, size and source of sand, and the topography etc., so that the surface of land can be elevated or levelled by wind. If a sand dune is too high, a ditch parallel to wind direction, or so-called windlane, is opened with human labor, which enables the wind to blow away the sand at both sides. The combination of wind and human

labor speeds up the leveling work. This arrangement is repeated again and again until the sand dune is leveled to a desirable elevation. After land preparation, straw is inserted in the sand. In the next spring *Miscanthus* grass, *Ipomoea pes-caprae* and finally *Casuarina* are to be planted. Fore-dune or tide protection dykes are built up by means of arresting fence before winter monsoon comes. Consequently, forests can easily be established in one year period.

In the Japanese days, 3,300 trees were planted in each hectare by rectangles, this is now changed to triangular planting with 5,000 trees per hectare. For some areas under strong winds, 6,000 or 9,000 trees were planted with excellent results.

Survival rate of coast forest in Pescadores has greatly increased since the adoption of the "open trench" method in 1954 as stated in previous chapter. Farm windbreaks which had never been established in Pescadores before the Restoration were established through the combined planting of *Miscanthus* grass, *Leucaena glauca*, and *Casuarina*. This success has been an inspiration to the foresters as well as the farmers. Matters of expenditure, extension and improvements are all that remain.

The recent successes in seacoast forests planting on the sandy islets in Tainan Hsien and Yunlin Hsien, and satisfactory establishment of *Casuarina* forests on the newly raised land in Taoyuan and other hsien have greatly impressed visiting foresters from Japan, Thailand, the Philippines, the Ryukyu and other countries that have the same problem.

2. Nursery operation: The number of seedling in the transplanting bed was 100 stock per square meter before the Restoration, which is now reduced to 42 or 36. Another revolutionary improvement is the adoption of "water root pruning method" as stated in the previous chapter. These two factors together have accounted for the successful production of vigorous seedlings. Besides, beginning from 1955, plastic tube have been used as pot for cultivation of seedling for seacoast planting. This practice has been gradually extended to the seedlings of valuable species, and those for reforestation in dry, un-favorable or special sites.

3. Tree species: Although *Casuarina* is the principal species of windbreaks in this province, it has certain shortcomings too, such as the vulnerability to the attack of long horn beetle (*Melanauster chinensis*), early growth deterioration and poor survival in saline soil. If it could be mixed with other suitable species, the result would be more satisfactory. Aiming at this, the Taiwan Forestry Research Institute (TFRI) supported by JCRR undertook in 1943 an island-wide survey of coast windbreak species, their ecology and adaptability. From this survey, it was envisaged that a new wind-tolerant and disease-resisting species can be developed by crossing *Casuarina glauca* with *Casuarina equisetifolia* or with *Casuarina Huegeliana*. Likewise, *Calophyllum Inophyllum*, *Garcinia spicata* and *Hibiscus tilliaceus* can be mixed with *Casuarina* spp., for which a further experiment is necessary, however. Later, with a technical breakthrough in beetle control, the need for crossbreeding and mixture have become less urgent.

In 1954, Peikang Windbreak Working Station, TFRI undertook to propagate *Tamarix aphylla* introduced from Hawaii with good results. Salt-resistance of *Tamarix aphylla*, as displayed by its coast plantation, is very high, but its wind-withstanding ability is weak. It can be used as mixture species for dyke planting on saline soils.

In recent years, mangrove was satisfactorily grown in wet sites in the coastal area, on the tidal land, and along the estuary where salt water and fresh water meet. The seeds were mostly *Kandelia candel* collected from the coast of Tamshui, Taipei Hsien, and *Avicennia marina* from Kaohsiung City, Kaohsiung Hsien and Pingtung Hsien. Besides, the JCRR has introduced some species of mangrove from Thailand and planted them in Chiangchung Hsiang, Tainan Hsien. All of them grow pretty well. There are six species of mangrove in Taiwan, which not only have some windbreaking efficiency but also provide fuel to the local people. Trial planting to determine its sand-arresting efficiency in the tidal land was recently made.

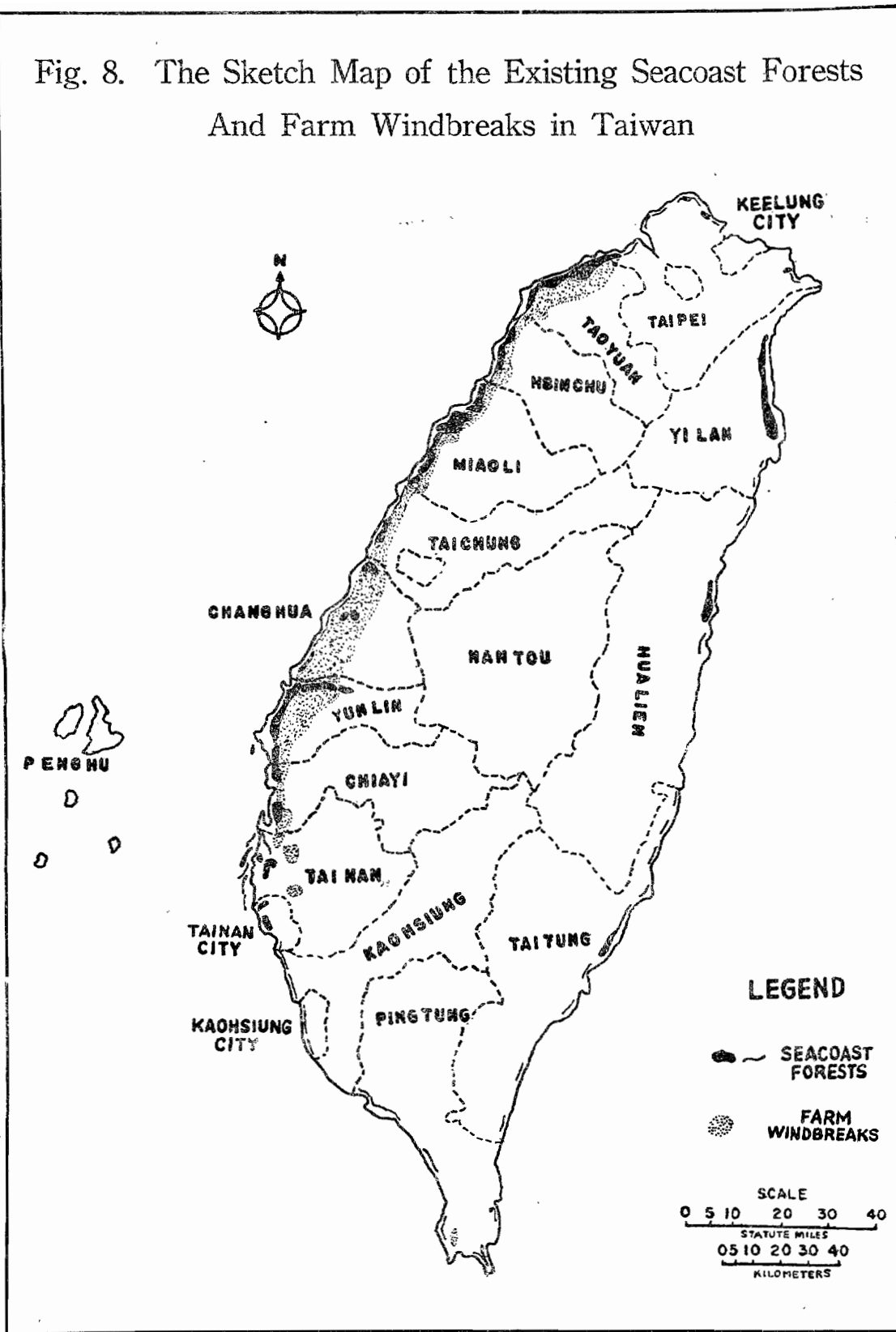
Coconut palms and *Pithecolobium dulce* were also planted on a trial basis in recent years. The former, besides serving as windbreaks, is expected to increase the land use value in the coastal areas. The latter serves mainly to supply fuel for the coastal inhabitants, also provides tannin for industrial use.

4. Insect control: Casuarina trees of 3-5 years old are susceptible to long horn beetles. Formerly, capturing methods were mainly resorted to, which require more time and labor but with very low efficiency. With the expansion of forested area, it is practically impossible to protect against beetles by using this method. In 1953 and 1954 damage caused by beetles was so serious that it endangered the whole windbreak plantations. Thanks to "Dieldrin emulsion", for which a test was made at Wenkang, Yunlin Hsien in 1954, the insects were brought under control. An extension program was carried out accordingly in the ensuing year. The emulsion, which contains 18.8% of active ingredient, should be diluted with water to 30-40 times, and then sprayed on the trees to the height of one meter from the ground. The Casuarina plantations south of Taichung were sprayed twice each year, i.e., at the beginning of April and the end of May. At northern Taiwan they were sprayed in early May and early June. The efficacy of Dieldrin, according to a statistics of the 1956 survey, was 86%. In carrying out the program, JCRR provided to forestry agencies and local governments both technical assistance and the supply of Dieldrin which was imported from abroad. Beginning from 1957, this was supported by the Taiwan Forestry Bureau (TFB). After 1959, Dieldrin in the form of wettable powder was used instead of the emulsion form and the trees were sprayed once a year instead of twice, thus saving a lot of labor and insecticide (The cost of this powder for each hectare was NT\$440). Each year 800 to 1,000 ha. of forest land were sprayed, with very nice results. A spotcheck conducted in 1960 by the TFB in Taichung and Miaoli Hsien shows an efficacy of 93%. The threat of beetle damage has thus been relieved.

STATUS QUO OF WINDBREAKS

According to the result of this survey, the total acreage of existing seacoast forests on this Island is 7,023.5 ha. Farm windbreaks has been established on 143,729.8 ha. of farm land in areas 10 km. from the seacoast. A brief description and analysis are given as follows:

Fig. 8. The Sketch Map of the Existing Seacoast Forests And Farm Windbreaks in Taiwan



Acreage

It is shown in previous section that, at the time of the Restoration (1945) there were 1,403 ha. of seacoast forests left, and that from the Restoration to the time of this survey, 9,345.85 ha. were planted, totalling 10,748.85 ha. However, our survey shows that the actual existing acreage is about 3,725 ha. less than the above total. This may be attributed to the following facts:

1. No survey of the coast was allowed by the Government formerly and the acreage of seacoast forests was estimated visually.
2. Losses caused by typhoons and floods.
3. Low survival rate in the early years after the Restoration due to financial and technical deficiency.
4. 3,620.5 ha. of seacoast protection forest land were official released for farming from the Restoration of Taiwan up to 1958, in which a part was forested land.

Of the existing seacoast forests, 200.8 ha. are planted on dykes and on saline soil, of which 109.4 ha are in Yunlin Hsien, 63.3 ha. in Changhua Hsien, 25 ha. in Taichung Hsien and 3.1 ha. in Chiayi Hsien. The area of seacoast forests belts of less than 50 meters in width (on sandy sites) is 274.1 ha. Their distribution are as follows:

Hsien or City	Casuarina	Pandanus	Bamboo	Other Spp. & Hardwood	Total
Taipei Hsien	—	0.5 (175)	—	—	0.5 (175)
Hsinchu Hsien	27.5 (9,150)	1.9 (650)	—	—	29.4 (9,800)
Maioli Hsien	3.8 (1,250)	0.5 (150)	—	1.4 (475)	5.7 (1,875)
Taichung Hsien	13.0 (4,325)	6.4 (2,125)	—	—	19.4 (6,450)
Changhua Hsien	55.9 (18,625)	—	—	5.6 (1,875)	61.5 (20,500)
Kaohsiung Hsien	3.9 (1,300)	2.3 (750)	—	—	6.2 (2,050)
Pingtung Hsien	7.0 (2,350)	5.1 (1,700)	—	—	12.1 (4,050)
Hualien Hsien	—	4.5 (1,500)	—	—	4.5 (1,500)
Taitung Hsien	—	101.8 (33,925)	6.0 (2,000)	1.1 (375)	108.9 (36,300)
Kaohsiung City	5.7 (1,900)	20.2 (6,750)	—	—	25.9 (8,650)
Total:	116.8 (38,900)	143.2 (47,725)	6.0 (2,000)	8.1 (2,725)	274.1 (91,350)

Remarks: (1) Area: Hectare. Figure in parenthesis is planting belt in meter which was measured from the photos.

(2) Area is calculated from the measured length in meter multiplied by average with 30 m.

The total area of farm land protected with windbreaks is 143,728.8 ha., which is bigger than what Japanese had established before. Of this total, however, only 50% minus are uniform belts and meet the specification of government standard. Nevertheless, farm wind-break in Yunlin Hsien and Changhua Hsien which grow in fair order are mostly those of

TSC farms. In other words, owing to the dispersion of farm land and the irregularity of terrain, only a small percentage of farmers have planted their farm windbreak in accordance with government standard. Farmers are inclined to plant farm windbreaks on the existing paddy levees, ditch sides and farm paths.

Species

In the existing seacoast forests, *Casuarina* is the principal species which occupies an area of 5,815.8 ha., or 83.8% of the total area. This is followed by *Pandanus odoratissimus*, which occupies 594.1 ha., or 8.5%. Species of less importance are *Acacia confusa*, *Agave american*, *Leucaena glauca*, *Bambusa stenostachya*, *Pinus* spp., *Dalbergia sissoo*, and *Hibiscus tiliaceus*, totally 7.7%. These are mostly forests of pure species with very few mixture. However, at some old sand dunes in Kuangying, Taoyuan Hsien; Yuanchang, Yunlin Hsien; and Fangyuan, Changhua Hsien; mixture can be occasionally found. These were all planted in the Japanese occupation period. After the Restoration, *Casuarina* was the main species used for seacoast forests.

Casuarina is also the species of prime importance in farm windbreaks, by which 118,535.6 ha. or 82.5% of the total farm land protected by the windbreaks. Next is the Bamboo family which protects 21,339.3 ha. or 14.8% of the protected farm land. *Leleba dolichoclada* and *Bambusa stenostachya* are distributed mainly in the central hsiens of Taichung and Changhua, and *Leleba multiplex* in northern hsiens of Hsinchu, Miaoli and Taoyuan. There are also many windbreak belts that are mixed *Casuarina* and *Leleba multiplex* which acts as under growth. But this mixture has been included in the *Casuarina* area. This survey also shows that of the total area of Bamboo farm windbreaks, only 443.8 ha. were planted in accordance with government standard, and the remaining 20,895.5 ha. at the farmers' discretion. In other words, most Bamboo farm windbreaks were planted at the farmers' own expenses. *Acacia* farm windbreaks are half as extensive as Bamboo windbreaks and *Eucalyptus* and *Pandanus* windbreaks are very few in number.

Age

A general picture of the seacoast forests established since the Restoration may be obtained from Detailed Table 2. "Area of Seacoast Forests by Age Class":

1. Above 20 years: 1,236.6 ha. which were left by the Japanese.
2. 11-20 years: 980.2 ha., mostly planted from 1945 to 1950.
3. Below 10 years: 4,806.7 ha., planted after 1951 under an extensive program.

Seacoast forests below 5 years of age (planted between 1955 and 1959) show two tendencies:

1. Species other than *Casuarina* tend to increase: Of the total area of species other than *Casuarina*, 52% plus is occupied by trees less than five years old, which is 12.6 times that of the 6-10 years old plantations.

2. The width of windbreak belts tends to narrow: Of the total area of windbreak belts less than 50 meters wide (on sandy sites), about 43% is occupied by trees less than 5 years old. This is because in recent years most plantations were planted on the new land bordering the original forest sites. The width usually is around 30 meters.

Stand Height

The height of trees is a very important factor as far as windbreak efficiency is concerned.

From Detailed Table 6 we can see that Casuarina trees can hardly grow to a height of 10 meters in the coastal region. Area and percentage of various stand height classes of Casuarina as of 1959 are as follows:

Below 5 meters:	44.2%	2,573.2 ha
6-10 meters:	50.9%	2,960.5 ha
Above 10 meters:	4.9%	282.1 ha
Total	10.0%	5,815.8 ha

Area of Casuarina forests more than 20 years old is 881.5 ha. Of this total, only 282.1 ha. are forests more than 10 meters in height. Among these, Taoyuan Hsien takes the leading place with 92.1 ha. because of its success in establishing some three hundred meters of forests on the outer border of the old stands. This is followed by Yunlin Hsien with 44.6 ha., Tainan City with 42.2 ha. and Taichung Hsien with 36.7 ha. Their conditions are similar.

The relation between the height and age of Casuarina can be seen from the following figure:

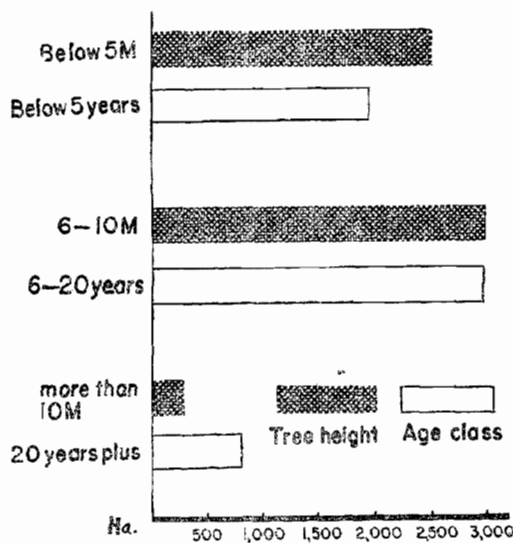


Fig. 9. Comparison of area of existing Casuarina forest with respect to age and height

Casuarina grows pretty fast in the early stage after planting, at a rate of about 1-1.5 m per year. They can serve, to a considerable extent, the windbreak purpose after three years. When they have reached a height of 7-8 meters, the growth rate slows down. In areas where strong winds prevail, they usually cannot grow any higher after having reached 5-6 meters high. In Penghu, those farm windbreaks which were planted in 1953 had reached a height of 4 meters in 1957, but after then, the twigs grown in spring were all blown away by the strong winds in winter, and they grow no more in height. Likewise, the outermost rows of seacoast plantations on the western coast can hardly grow to a height of 6 meters.

As to the other species, of the total area of 1,207.7 ha., 872.8 ha. or 72% plus are trees less than 5 meters high, 252 ha. 6-10 meters, and only 82.9 ha. more than 10 meters. These species grow still lower than Casuarina and are therefore less effective in wind control.

Crown Density

The purpose of surveying the crown density of seacoast forests is to supply necessary information for forest management. As shown in Detailed Table 9, area of Casuarina plantations with a density more than 70% is 1,577.0 ha. in which many are only 6-10 years old trees. In consideration of this situation, it is desirable to have these plantations which

occupy one quarter of the total area of Casuarina forests properly pruned and thinned. By so doing, the trees can grow normally and more forest capital will result. In the meantime, a great deal of fuel can be supplied to the coastal inhabitants.

The crown density of many old Casuarina plantations which were left by the Japanese is rather low, partly because of the declining in growth rate, and partly because of the ineffective protection against illegal cutting and indiscriminate cultivation. If the density is too low, strip re-generating of the old stands should be considered.

Area of Casuarina plantations with a density less than 40% is 2,080.4 ha., mostly young forest stands, because in the total, 1,977.7 ha. are Casuarina plantation less than 5 years old.

FUTURE GOALS AND POLICY

As the result of this survey, we have had not only a general picture of the achievements in windbreak planting in the past, but also a further understanding of the goals and policy for future. The recommended goals and policy are hereunder:

Goals

1. Seacoast Forests:

As shown in Detailed Table 12, "Area of Land Use Type 200 Meters Within Seacoast," except those slope lands which have been used as forest land; and flat lands used as paddy field, salt field, fish pond, urban area and denuded unplantable land; there are about 6,761.5 ha. available for planting of seacoast forests. As to their site conditions, please see Detailed Table 13, "Estimated plantable Area for Seacoast Forests".

The Detailed table 13. also shows that Pingtung, Hualien and Taitung, the three Hsien all with a long coast line, have a total area of 3,577.3 ha. available for windbreak planting. However, due to mountain ranges or narrow plains inshore and the existence of coarser sand and gravel on the sea shore which control the sand from flying, it is estimated that about 964.9 ha., or one half of the total sand-drifting area of the three hsien which are in urgent need of forests establishment. Planting on the sites of saline soil, grassland along the seacoast of all the hsien, and certain sandy islets are of secondary importance. But this does not mean that areas of secondary importance are not suited for seacoast forests. On the contrary, the only proper land use of those areas are to be forested.

Table 7. Estimated Area of Seacoast Forests Needed for Planting.

Stage	Area	Remarks
Stage I (urgently needed for planting in 5 years)	4,000.5 ha.	Half of the total sand drifting area in Pingtung, Hualien and Taitung Hsien and all sand drifting area and gravel land in the other hsien.
Stage II (to be planted 5-10 years.)	2,761.0 ha.	The other half of the total sand drifting area and gravell area in Pingtung, Hualien and Taitung Hsien; sandy islets in Miaoli Hsien; and grassland and saline soil in the other hsien.
Total	6,761.5 ha.	

These are just estimated figures from purely technical viewpoint. The ownership of

land, i.e., whether it is public or private, or whether it is protection forest land, has not been taken into consideration. Therefore there will be some variation when this program is put into force. In fact, forests planting on the seacoast is a continuous job because sand stabilization and wind control measures must be given to the new beaches that emerge from time to time. However, after the above goal is attained, there will be only a few areas needing planting in each year.

2. Farm windbreaks;

Farm windbreaks are to be planted in the first belt, land within 5 kilometers from the coast, in first five years. Farm windbreaks of the second belt, in an area 5-10 kilometers from the coast, are to be established in second stage, namely 5-10 years. Besides, farm windbreak rows in the first belt are to be run from east to west at an interval of 100 meters in average, and second belt 150 meters. According to Detailed Table 14, farm windbreaks to be planted in each stage are as follows:

Table 8. Estimated Area of Farm Windbreaks Needed for Planting*

Stage	Length of belts	Area to be protected	Remarks
Stage I (urgently needed for planting in 5 years)	7,245.3 Km	72,453.2 ha.	Belt interval averages 100 meters in area 5 Km from the coast, or 100 meters per hectare.
Stage II (to be planted in 5-10 years.)	8,597.2 Km	128,315.8 ha.	Belt interval averages 150 meters in area 5-10 Km from the coast, or 67 meters per hectare.
Total	15,842.5 Km	200,769.0 ha.	

* Not including farm road-side plantings and north to south belts.

Policy

Windbreak policy with respect to management, planting and protection are recommended as follows:

1. Management:

While plantings of windbreak has been developed to a considerable scale and a solid foundation has been laid in this regard, plan and experience on its management are lacking. This has become a pressing problem. Special attention should therefore be paid to the following points in accordance with the result of this survey:

(1) Study of regenerating method of old seacoast forests and farm windbreaks. (above 20 years of age.)

(2) Proper pruning and thinning of seacoast forests (6-20 years) to stimulate the growth of forest capital and to increase the supply of fuelwoods and timbers to the coastal inhabitants.

(3) Re-evaluation of the necessities of the coastal protection forests which were mostly designated in the Japanese days. Those which are no longer necessary should be released for farming. Lands which are necessary should be newly designated.

2. Planting:

(1) The seacoast forests and farm windbreaks program should consistent with the

development of tidal land, mountain agriculture and the consolidation of farm land in coastal plain.

(2) Lowering government standard about farm windbreaks encouragement; or extensively providing technical assistance and free supply of seedlings to farmers in the coastal areas for planting on the paddy levees, village roads, or around their houses to speed up the completion of windbreak program in area 10 Km. from the coast.

(3) Experiment on mechanized planting of seacoast forests on large tracts to increase working efficiency and to lower the cost of planting.

3. Protection:

(1) Coastal inhabitants must be prohibited from racking fallen leaves and cutting grass in the Casuarina seacoast forests because such litter and grass serve to improve the land so that it may be used for farming once the forests are removed. This can be solved one way or another as follows: (a) To effect a proper pruning and thinning of the seacoast forests, thus to provide supply of more fuelwoods for the coastal inhabitants. (b) To at least prohibit the collection of fallen leaves and cutting grass in the young forests stands. (c) To solve fuel problem through other means such as supply of fuels at a low price, development of fuel forests, etc.

(2) Coastal inhabitants, retired servicemen and troops stationed in the coastal area must be effectively prohibited from practicing illegal cultivation and indiscriminating cutting in the seacoast forests.

CONCLUSION AND RECOMMENDATION

1. Although the seacoast forests and farm windbreaks had been severely destroyed before and immediately after the Restoration of Taiwan, they have been effectively re-established in most of the critical areas since 1951 through joint efforts of various interested agencies, local governments and enthusiastic farmers. Up to the end of 1959, Taiwan, not including Pescadore and off islands, had a total of 7,024 hectares of seacoast forests, and had well established farm windbreaks on 143,729 hectares of farm land.

2. The result of this survey shows that there are some 4,000 hectares of land in need of seacoast forests planting in the first five years; and 7,245 kilometers of farm windbreak also need to be established in the same period. In the second five years, the goal will be 2,761 hectares for seacoast forests and 8,597 kilometers for farm windbreaks.

3. The future windbreak planting program should be closely coordinated with programs of tidal land reclamation, mountain agricultural resources development, land consolidation etc., in order to promote higher unit production of these lands by reducing the wind hazard.

4. It is recommended that the government should revise its present regulation about farm windbreaks encouragement to a more incentive and practical standard. On the other hand, forestry authorities should extensively provide tree seedlings and render technical assistances to all who are willing to cooperate. To speed up the completion of the farm windbreak program on 200,000 hectares of land, a democratic approach is very desirable. The exemption of land tax for farm windbreak belt should also be considered.

5. Taiwan has accomplished a great deal of windbreak planting in recent years. However, the management of windbreaks should not be overlooked. The Forestry Bureau and the Forest Research Institute etc. should jointly work out the practical and safe ways of pruning and thinning the young windbreaks and of re-generating the old ones.

6. Due to lack of fuel in coastal area, the raking of fallen leaves, tearing of branches and even theft cutting of trees in seacoast forests are very common. These bad practices endanger the forests and retard soil improvement to a great extent. The government, therefore, should seek a reasonable way to solve the fuel problem such as supplying the wood of prunings and thinnings from windbreaks under supervision of its trained technicians, allocating cheaper fuels, providing land for fuel forest establishment, etc. At the same time, the government should strengthen its protection from theft cutting and illegal cultivation.

7. Since the beaches of the west Taiwan are continually changing their condition, the necessities of wind erosion control and sand stabilization are not fixed or unchangeable. The Forestry Bureau, therefore, should actively look into this matter and periodically re-examine the necessities of seacoast protection forests, based on public interest and actual needs.

8. Taiwan's geographic position exposes the Island to severe damages from typhoons and monsoons. Windbreaks are therefore very important to this Island. Due to the fast growing population and limited arable land, every possible way of increasing unit production of the farm land is essential to national economy. The necessary windbreaks, therefore, should be completed as soon as possible in the west coastal plains and supplemented with agricultural wind erosion control measures. The windbreak program is important also to the success of tidal land reclamation, mountain resources development and land consolidation



Taiwan needs more "Green wall" along the coast for windbreaking and sand-checking. (Picture shows seacoast forests on sandy islet in Tainan Hsien)



Beautiful seacoast forests like this is a good place for resort and recreation.

There are still 200,000 hectares of farm land in urgent need of farm windbreaks in a belt 10 Km from the coast.



To set up nurseries and to produce great amount of healthy tree seedlings for free distribution to the farmers for planting farm windbreaks.

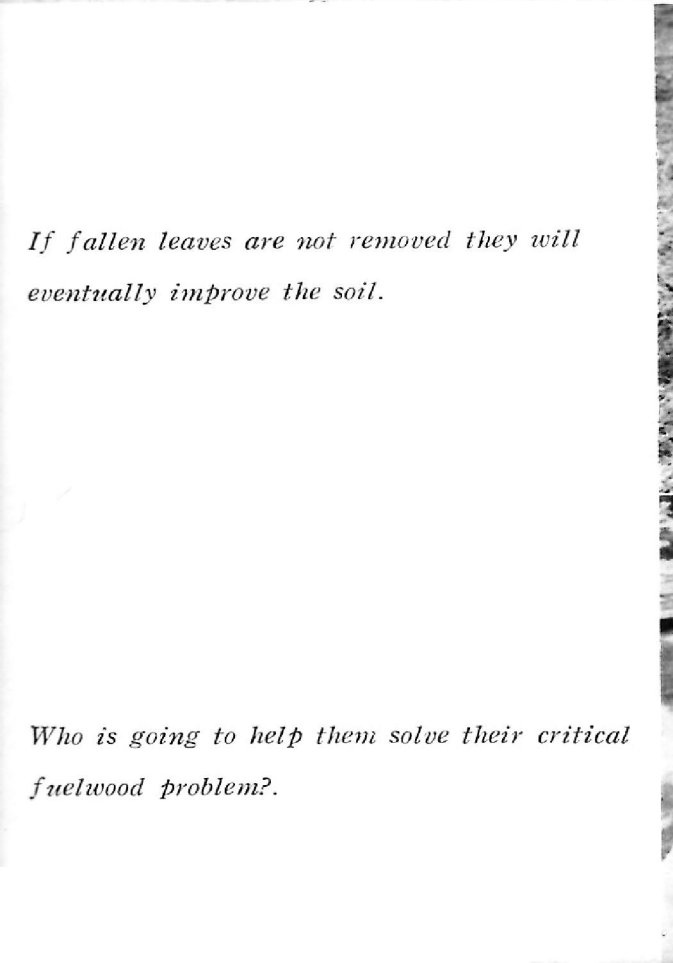




Farmers collecting fallen leaves, grasses or tearing off dead branches in the seacoast forests for fuel are very common in the coastal area where fuel is badly needed.



Each person may collect two basketful of fallen leaves like this in 2-3 hours



If fallen leaves are not removed they will eventually improve the soil.



Who is going to help them solve their critical fuelwood problem?



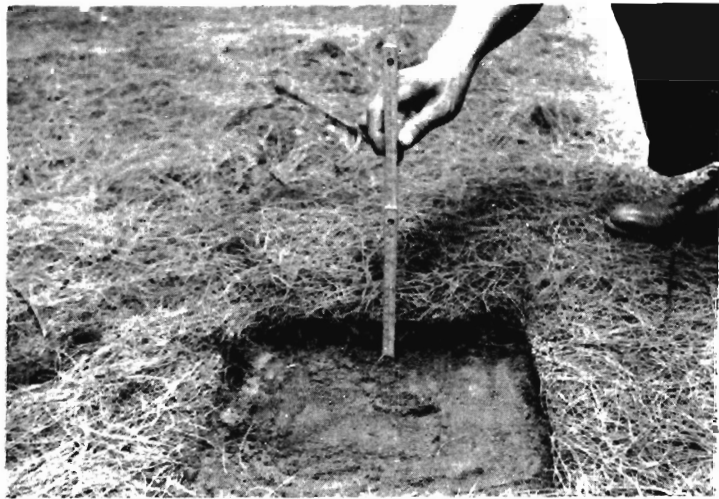


Farmers collecting fallen leaves, grasses or tearing off dead branches in the seacoast forests for fuel are very common in the coastal area where fuel is badly needed.



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Who is going to help them solve their critical fuelwood problem?



program. The gradual expansion of the western coast also requires continuation of seacoast forests planting so that the new plantings will provide a protection to the older ones, as well as to capture new land from the sea. For all these reasons, Taiwan requires a steady and active windbreak program at present as well as in the future.

APPENDIX

PROCEDURE OF SURVEY

These estimates of seacoast forest and farm windbreak areas are based upon data obtained from ground examination and photo interpretation of aerial photographs of the areas concerned. Working procedures are summarized as follows:

1. **Preparation of aerial photographs:** Aerial photographs were taken by the Chinese Air Force during July, 1956, on a scale of 1/20,000. Preparation of photo index map and selection of effective area were done in the office.

2. **Field Check and Delineation:** A two-man field crew was accompanied by the local foresters; in checking area of windbreak within each Hsien or City, boundaries and forest conditions were delineated directly on the photographs.

3. **Mapping:** Base maps were 1/25,000 topographic maps prepared by the Survey Department, Combined Service Forces, Ministry of National Defense. Windbreak boundaries were transferred from the photographs to tracing paper by use of Kail planimetric plotter and Vertical Sketchmaster, and were then printed on blue-print paper.

4. **Data Compilation:** The dimensions of windbreak areas were calculated by using of the Dot Count Method, and were then classified and broken down into Hsien or City.

5. **Correction of Data:** The data for windbreak areas were checked and corrected by the Hsien or City Government before releasing.

6. **Data Analysis and Report Printing.**

THE REGION OF SURVEY

A belt of land 10 kilometers wide along the seacoast, and the areas of so-called "sandy islet" were surveyed. Areas over 10 kilometers along the south shore of Chu-Shui-Chi (or muddy River) were also delineated. Hill and mountainous regions were excluded, regardless of their location.

SURVEY METHOD

1. **Seacoast forests survey:** Purpose of this survey is to determine the present conditions of seacoast forests, to obtain an accurate inventory of the seacoast forests as the necessary basis for planning their management. For mapping purpose, only seacoast windbreaks planted on dykes are shown by drawn decline lines within the belt, no different kinds of windbreaks was classified on the map.

Species or species groups, height class, crown density class, and age class of seacoast forests are shown by codes, and symbols.

Seacoast forests are drawn to a minimum area of 2 hectares. Classified areas less than 2 hectares are consolidated with neighbouring types. If width of a forest belt is less than 50 meters, only its length is drawn on the map.

Except the new plantation, crown densities less than 10% are omitted.
 Symbols and codes used in the seacoast forest map are as follows:

1) Species or species groups:

<u>Tree species</u>	<u>Symbol</u>
Casuarina spp.	CA
Acacia confusa Merr.	AC
Pandanus spp.	PA
Agave spp.	AG
Bamboo	B
Eucalyptus spp.	E
Other species and hardwoods	OP

2) Tree height: (Three height classes)

<u>Stand height class</u>	<u>Code</u>
Below 5 meters	1
6 to 10 meters	2
Over 10 meters	3

3) Crown density class: (Four density classes above 10% are recognized)

<u>Crown density class</u>	<u>Symbol</u>
10% to 19.9%	—
20% to 39.9%	==
40% to 69.9%	===
70% and up	====

4) Age class: (Age is calculated from the date of planting; four classes are recognized)

<u>Age class</u>	<u>Code</u>
Below 5 years	0
6 to 10 years	1
11 to 20 years	2
21 years plus	3

The symbols and code numbers are always noted in a definite order as follows:

Tree species—stand height—crown density—age

Example: "CA1—0" means Casuarina seacoast forest with a stand height below 5 meters, crown density 10–19.9%, and age no more than 5 years.

2. **Farm windbreaks survey:** Species, planting system, and texture of stand are tallied for farm windbreaks, symbols of tree species are as same as seacoast forests, planting system was checked with the specification of TFB.

The effective area of farm windbreak protection is determined from the first row of trees in the northern boundary to the last row of trees in the southern boundary. Its width is measured from east to west.

The symbols for farm windbreaks are as follows:

<u>Items</u>	<u>Symbol</u>
1) Farm windbreaks	WF
2) Species	(symbols same as in seacoast forests)

3) Planting system:

Those that meet the specification of TFB A
 Those that do not meet the specification of TFB B

4) Texture of farm windbreaks

Fair ---
 Poor ~~~~

The symbols are noted in the following order:

WF—species/texture—planting system

Example: WF CA A means farm windbreak of casuarina trees, with fair texture, and planting system meets the specification of TFB.

3. **Land use type survey:** Land use type survey was conducted in the nonforested area within 200 meters of the beach, whether in the open, within protection forest, or located between two urban areas.

The symbol of land use types are shown as follows:

<u>Land Use Type</u>	<u>Symbol</u>
Forested slope land	F
Cultivated land	NF
Grass land	G
Tidal land	T
Sand dunes	SD
Saline land	SL
Salt production field	SF
Fish pond	FP
Dry farm land	CD
Paddy field	CP
Water area	W
Gravel land	GV
Urban	U
Denuded unplantable area	LU
Bamboo	B

DETAILED TABLES

Table 1. Area of Seacoast Forests by Major Species

(Hectare)

Species Hsien or City	Casuarina	Acacia	Pandanus	Agave	Bamboo	Other Spp. & Hardwoods*	Total
Taipei Hsien	200.8	4.7	73.2	26.6	—	111.0	416.3
Taoyuan Hsien	1,168.8	—	—	—	—	0.8	1,169.6**
Hsinchu Hsien	191.2	—	1.9	—	—	9.4	202.5
Miaoli Hsien	626.6	—	0.5	—	—	15.5	642.6
Taichung Hsien	163.1	—	6.4	—	—	—	169.5
Changhua Hsien	361.0	—	—	—	—	38.4	399.4
Yunlin Hsien	1,035.4	—	—	—	—	—	1,035.4
Chiayi Hsien	345.2	—	—	—	—	—	345.2
Tainan Hsien	292.2	—	—	—	—	28.9	321.1
Kaohsiung Hsien	46.0	—	2.3	—	—	—	48.3
Pingtung Hsien	146.1	—	224.8	—	—	3.9	374.8
Yilan Hsien	542.3	7.9	7.8	2.3	—	46.9	607.2
Hualien Hsien	156.2	246.0	20.1	—	—	11.0	433.3
Taitung Hsien	425.7	26.6	236.9	18.0	6.0	9.7	722.9
Tainan City	75.8	—	—	—	—	—	75.8
Kaohsiung City	39.4	—	20.2	—	—	—	59.6
Total	5,815.8	285.2	594.1	46.9	6.0	275.5	7,023.5

* Other species & hardwoods are *Leucaena glauca*, Mangrove, pine, *Dalbergia sissoo*, *Celtis formosana*, *Hibiscus tiliaceus*, etc.

** Including 67.40 ha which were damaged by Typhoon Trix on August 8, 1960.

Table 2. Area of Seacoast Forests by Age Class

(Hectare)

Age Class Hsien or City	Below 5 years	6-10 years	11-20 years	21 years plus	Total
Taipei Hsien	179.4	151.6	19.6	65.7	416.3
Taoyuan Hsien	421.1	373.5	318.8	56.2	1,169.6
Hsinchu Hsien	93.6	54.1	3.5	51.3	202.5
Miaoli Hsien	238.8	176.7	59.7	167.4	642.6
Taichung Hsien	25.9	80.3	57.0	6.3	169.5
Changhua Hsien	20.4	312.8	53.2	8.0	399.4
Yunlin Hsien	128.0	577.4	54.0	276.0	1,035.4
Chiayi Hsien	166.4	38.2	121.1	19.5	345.2
Tainan Hsien	215.7	71.0	19.6	14.8	321.1
Kaohsiung Hsien	28.8	12.5	7.0	—	48.3
Pingtung Hsien	295.1	23.5	—	56.2	374.8
Yilan Hsien	553.2	54.0	—	—	607.2
Hualien Hsien	24.2	17.2	6.2	385.7	433.3
Taitung Hsien	177.4	178.9	243.4	123.2	722.9
Tainan City	24.2	45.3	—	6.3	75.8
Kaohsiung City	21.9	25.6	12.1	—	59.6
Total	2,614.1	2,192.6	980.2	1,236.6	7,023.5

Table 3. Area of Casuarina Seacoast Forests by Age Class (Hectare)

Age Class Hsien or City	Age Class				Total
	Below 5 years	6-10 years	11-20 years	21 years plus	
Taipei Hsien	35.1	141.4	8.7	15.6	200.8
Taoyuan Hsien	420.3	373.5	318.8	56.2	1,168.8
Hsinchu Hsien	82.3	54.1	3.5	51.3	191.2
Miaoli Hsien	222.8	176.7	59.7	167.4	626.6
Taichung Hsien	19.5	80.3	57.0	6.3	163.1
Changhua Hsien	14.7	312.8	25.4	8.0	360.9
Yunlin Hsien	128.0	577.4	54.0	276.0	1,035.4
Chiayi Hsien	166.4	38.2	121.1	19.5	345.2
Tainan Hsien	186.8	71.0	19.6	14.8	292.2
Kaohsiung Hsien	26.5	12.5	7.0	—	46.0
Pingtung Hsien	66.5	23.5	—	56.2	146.2
Yilan Hsien	505.6	36.7	—	—	542.3
Hualien Hsien	3.9	8.6	6.2	137.5	156.2
Taitung Hsien	73.4	164.2	121.7	66.4	425.7
Tainan City	24.2	45.3	—	6.3	75.8
Kaohsiung City	1.7	25.6	12.1	—	39.4
Total	1,977.7	2,141.8	814.8	881.5	5,815.8

Table 4. Area of Other Species Seacoast Forests by Age Class (Hectare)

Age Class Hsien or City	Age Class				Total
	Below 5 years	6-10 years	11-20 years	21 years plus	
Taipei Hsien	144.3	10.2	10.9	50.1	215.5
Taoyuan Hsien	0.8	—	—	—	0.8
Hsinchu Hsien	11.3	—	—	—	11.3
Miaoli Hsien	16.0	—	—	—	16.0
Taichung Hsien	6.4	—	—	—	6.4
Changhua Hsien	5.6	—	32.8	—	38.4
Yunlin Hsien	—	—	—	—	—
Chiayi Hsien	—	—	—	—	—
Tainan Hsien	28.9	—	—	—	28.9
Kaohsiung Hsien	2.3	—	—	—	2.3
Pingtung Hsien	228.7	—	—	—	228.7
Yilan Hsien	47.6	17.3	—	—	64.9
Hualien Hsien	20.3	8.6	—	248.2	277.1
Taitung Hsien	104.0	14.7	121.7	56.8	297.2
Tainan City	—	—	—	—	—
Kaohsiung City	20.2	—	—	—	20.2
Total	636.4	50.8	165.4	355.1	1,207.7

Table 5. Area of Seacoast Forests by Stand Height Class (Hectare)

Hsien or City	Height Class			Total
	below 5 meters	6-10 meters	Over 10 meters	
Taipei Hsien	297.3	68.9	50.1	416.3
Taoyuan Hsien	402.5	675.0	92.1	1,169.6
Hsinchu Hsien	88.4	114.1	—	202.5
Miaoli Hsien	286.5	356.1	—	642.6
Taichung Hsien	68.7	64.1	36.7	169.5
Changhua Hsien	229.4	136.3	33.7	399.4
Yunlin Hsien	196.9	793.9	44.6	1,035.4
Chiayi Hsien	209.3	131.2	4.7	345.2
Tainan Hsien	236.0	82.8	2.3	321.1
Kaohsiung Hsien	28.8	12.5	7.0	48.3
Pingtung Hsien	268.5	79.7	26.6	374.8
Yilan Hsien	607.2	—	—	607.2
Hualien Hsien	73.2	360.1	—	433.3
Taitung Hsien	378.7	319.2	25.0	722.9
Tainan City	28.9	4.7	42.2	75.8
Kaohsiung City	45.7	13.9	—	59.6
Total	3,446.0	3,212.5	365.0	7,023.5

Table 6. Area of Casuarina Seacoast Forests by Stand Height Class (Hectare)

Hsien or City	Height Class			Total
	below 5 meters	6-10 meters	Over 10 meters	
Taipei Hsien	131.9	68.9	—	200.8
Taoyuan Hsien	401.7	675.0	92.1	1,168.8
Hsinchu Hsien	77.1	114.1	—	191.2
Miaoli Hsien	270.5	356.1	—	626.6
Taichung Hsien	62.3	64.1	36.7	163.1
Changhua Hsien	223.8	136.3	0.9	361.0
Yunlin Hsien	196.9	793.9	44.6	1,035.4
Chiayi Hsien	209.3	131.2	4.7	345.2
Tainan Hsien	207.1	82.8	2.3	292.2
Kaohsiung Hsien	26.5	12.5	7.0	46.0
Pingtung Hsien	39.8	79.7	26.6	146.1
Yilan Hsien	542.3	—	—	542.3
Hualien Hsien	39.8	116.4	—	156.2
Taitung Hsien	89.8	310.9	25.0	425.7
Tainan City	28.9	4.7	42.2	75.8
Kaohsiung City	25.5	13.9	—	39.4
Total	2,573.2	2,960.5	282.1	5,815.8

Table 7. Area of Other Species Seacoast Forests by Stand Height Class
(Hectare)

Hsien or City	Height Class			Total
	Below 5 meters	6-10 meters	Over 10 meters	
Taipei Hsien	165.4	—	50.1	215.5
Taoyuan Hsien	0.8	—	—	0.8
Hsinchu Hsien	11.3	—	—	11.3
Miaoli Hsien	16.0	—	—	16.0
Taichung Hsien	6.4	—	—	6.4
Changhua Hsien	5.6	—	32.8	38.4
Yunlin Hsien	—	—	—	—
Chiayi Hsien	—	—	—	—
Tainan Hsien	28.9	—	—	28.9
Kaohsiung Hsien	2.3	—	—	2.3
Pingtung Hsien	228.7	—	—	228.7
Yilan Hsien	64.9	—	—	64.9
Hualien Hsien	33.4	243.7	—	277.1
Taitung Hsien	288.9	8.3	—	297.2
Tainan City	—	—	—	—
Kaohsiung City	20.2	—	—	20.2
Total	872.8	252.0	82.9	1,207.7

Table 8. Area of Seacoast Forests by Crown Density Class
(Hectare)

Hsien or City	Crown Density				Total
	10-19%	20-39%	40-69%	>70%	
Taipei Hsien	27.4	232.6	155.5	0.8	416.3
Taoyuan Hsien	8.6	91.6	341.3	728.1	1,169.6
Hsinchu Hsien	44.6	53.2	97.9	6.8	202.5
Miaoli Hsien	111.5	222.7	266.2	42.2	642.6
Taichung Hsien	29.8	35.0	66.4	38.3	169.5
Changhua Hsien	39.5	36.4	230.4	93.1	399.4
Yunlin Hsien	53.2	214.8	413.4	354.0	1,035.4
Chiayi Hsien	37.4	192.3	36.6	78.9	345.2
Tainan Hsien	28.9	91.4	173.5	27.3	321.1
Kaohsiung Hsien	19.5	21.8	7.0	—	48.3
Pingtung Hsien	23.4	320.1	29.7	1.6	374.8
Yilan Hsien	86.0	239.2	209.3	72.7	607.2
Hualien Hsien	24.2	152.3	244.3	12.5	433.3
Taitung Hsien	56.2	304.5	243.4	118.8	722.9
Tainan City	—	4.7	71.1	—	75.8
Kaohsiung City	5.9	29.0	24.7	—	59.6
Total	596.1	2,241.6	2,610.7	1,575.1	7,023.5

Table 9. Area of Casuarina Seacoast Forests by Crown Density Class
(Hectare)

Crown Density Hsien or City	Crown Density				Total
	10-19%	20-39%	40-69%	>70%	
Taipei Hsien	3.9	107.8	88.3	0.8	200.8
Taoyuan Hsien	8.6	90.8	341.3	728.1	1,168.8
Hsinchu Hsien	44.6	41.9	97.9	6.8	191.2
Miaoli Hsien	111.5	206.7	266.2	42.2	626.6
Taichung Hsien	29.8	28.6	66.4	38.3	163.1
Changhua Hsien	39.5	36.4	197.6	87.5	361.0
Yunlin Hsien	53.2	214.8	413.4	354.0	1,035.4
Chiayi Hsien	37.4	192.3	36.6	78.9	345.2
Tainan Hsien	—	91.4	173.5	27.3	292.2
Kaohsiung Hsien	19.5	19.5	7.0	—	46.0
Pingtung Hsien	23.4	91.4	29.7	1.6	146.1
Yilan Hsien	64.9	195.4	209.3	72.7	542.3
Hualien Hsien	15.6	132.0	8.6	—	156.2
Taitung Hsien	10.9	149.2	146.8	118.8	425.7
Tainan City	—	4.7	71.1	—	75.8
Kaohsiung City	5.9	8.8	24.7	—	39.4
Total	468.7	1,611.7	2,178.4	1,557.0	5,815.8

Table 10. Area of Other Species Seacoast Forests by Crown Density Class
(Hectare)

Crown Density Hsien or City	Crown Density				Total
	10-19%	20-39%	40-69%	>70%	
Taipei Hsien	23.5	124.8	67.2	—	215.5
Taoyuan Hsien	—	0.8	—	—	0.8
Hsinchu Hsien	—	11.3	—	—	11.3
Miaoli Hsien	—	16.0	—	—	16.0
Taichung Hsien	—	6.4	—	—	6.4
Changhua Hsien	—	—	32.8	5.6	38.4
Yunlin Hsien	—	—	—	—	—
Chiayi Hsien	—	—	—	—	—
Tainan Hsien	28.9	—	—	—	28.9
Kaohsiung Hsien	—	2.3	—	—	2.3
Pingtung Hsien	—	228.7	—	—	228.7
Yilan Hsien	21.1	43.8	—	—	64.9
Hualien Hsien	8.6	20.3	235.7	12.5	277.1
Taitung Hsien	45.3	155.3	96.6	—	297.2
Tainan City	—	—	—	—	—
Kaohsiung City	—	20.2	—	—	20.2
Total	127.4	629.9	432.3	18.1	1,207.7

Table 11. Farm Area Protected by Farm Windbreaks

(Hectare)

	Species	Taoyuan Hsien	Hsinchu Hsien	Miaoli Hsien	Taichung Hsien	Changhua Hsien	Yunlin Hsien	Chiayi Hsien	Tainan Hsien	Pingtung Hsien	Taitung Hsien	Total
Windbreaks meet the specification of T.F.B. (Fair)	Casuarina	12,408.6	44.5	--	4,566.5	33,968.8	14,452.4	841.4	732.1	9.4	--	67,023.7
	Acacia	--	--	--	--	--	--	--	--	--	--	--
	Bamboo	--	--	--	--	443.8	--	--	--	--	--	443.8
	Eucalyptus	2,642.2	--	--	--	--	--	--	--	--	--	2,642.2
	Pandanus	--	--	--	--	--	--	--	--	--	--	--
	Sub-total	15,050.8	44.5	--	4,566.5	34,412.6	14,452.4	841.4	732.1	9.4	--	70,109.7
Windbreaks meet the specification of T.F.B. (Poor)	Casuarina	--	--	186.7	--	--	10,402.5	4,282.8	978.9	39.1	--	15,890.0
	Acacia	--	--	--	--	--	--	--	--	--	--	--
	Bamboo	--	--	--	--	--	--	--	--	--	--	--
	Eucalyptus	--	--	--	--	--	--	--	--	--	--	--
	Pandanus	--	--	--	--	--	--	--	--	--	--	--
	Sub-total	--	--	186.7	--	--	10,402.5	4,282.8	978.9	39.1	--	15,890.0
Windbreaks do not meet the specification of T.F.B. (Fair)	Casuarina	--	66.4	--	1,089.0	162.5	25.8	160.9	--	--	--	1,504.6
	Acacia	--	--	--	272.7	--	--	--	--	--	--	272.7
	Bamboo	--	--	1,929.7	2,682.8	1,410.2	--	--	--	3.9	--	6,026.6
	Eucalyptus	--	--	--	--	--	--	--	--	--	--	--
	Pandanus	--	--	--	--	--	--	--	--	110.2	--	110.2
	Sub-total	--	66.4	1,929.7	4,044.5	1,572.7	25.8	160.9	--	114.1	--	7,914.1
Windbreaks do not meet the specification of T.F.B. (Poor)	Casuarina	8,927.4	2,141.4	9,977.4	1,530.5	154.6	70.3	511.0	--	804.7	--	24,117.3
	Acacia	4,788.2	1,875.7	89.9	4,063.3	--	--	--	--	--	--	10,817.1
	Bamboo	1,119.5	8,421.0	2,645.5	2,676.6	--	--	--	--	--	6.3	14,868.9
	Eucalyptus	--	--	--	--	--	--	--	--	--	11.7	11.7
	Pandanus	--	--	--	--	--	--	--	--	--	--	--
	Sub-total	14,835.1	12,438.1	12,712.8	8,270.4	154.6	70.3	511.0	--	804.7	18.0	49,815.0
	Total	29,885.9	12,549.0	14,829.2	16,881.4	36,139.9	24,951.0	5,796.1	1,711.0	967.3	18.0	143,728.8

Remarks: (1) The areas listed above are areas of farm lands protected by farm windbreaks.

(2) There is no significant farm windbreaks in Taipei Hsien, Kaohsiung Hsien, Yilan Hsien, Hualien Hsien, Tainan city and Kaohsiung city.

Table 12. Area of Land Use Type 200 Meters Within Seacoast

(Hectare)

Land Use Type	Taipei Hsien	Kee lung City	Tao yuan Hsien	Hsin-chu Hsien	Miao li Hsien	Tai-chung Hsien	Chang-hua Hsien	Yunlin Hsien	Chiayi Hsien	Tainan Hsien	Kao-hsiung Hsien	Ping-tung Hsien	Yilan Hsien	Hualien Hsien	Tai-tung Hsien	Tainan City	Kao-hsiung City	Total
Forested Slope Land	—	111.7	—	—	—	—	—	—	—	—	—	50.0	158.6	108.6	239.1	—	64.8	732.8
Cultivated Land	—	—	—	—	—	—	—	—	—	—	—	—	60.9	31.3	1.6	—	—	93.8
Grass Land	35.2	—	—	50.0	—	—	1.6	—	—	—	3.9	17.2	—	42.2	31.2	—	—	181.3
Tidal Land	1.6	—	206.2	10.9	—	14.1	—	123.5	71.1	132.0 (44.5)*	—	—	—	—	—	61.7 (29.7)*	—	621.1 (74.2)*
Sand Dunes	367.2	—	80.0	38.3	56.3 (41.4)*	38.0	143.0	114.1	10.1	26.6 (22.1)*	257.8	617.2	467.2	501.6	810.9	169.5	96.1	3,793.9 (262.5)*
Saline Land	—	—	—	—	—	—	—	7.0	9.4	—	—	—	—	—	—	—	—	16.4
Salt Production Field	—	—	—	—	—	—	15.6	—	43.0	150.8	—	—	—	—	—	5.5	—	214.9
Fish Pond	—	—	—	—	—	26.6	16.4	163.3	127.3	372.7	64.8	9.4	—	—	—	1.6	—	782.1
Dry Farm Land	447.6	23.4	—	—	3.1	23.4	12.5	—	9.4	—	127.4	589.1	22.7	183.6	396.1	10.9	10.1	1,859.3
Paddy Field	220.3	2.3	—	71.9	163.3	109.4	270.3	—	—	—	10.1	23.5	70.3	254.7	250.0	—	—	1,446.1
Water Aaea	17.2	—	—	—	—	—	9.4	—	—	—	10.2	4.6	27.3	7.8	—	4.7	10.2	91.4
Gravel Land**	402.4	77.4	10.0	3.1	70.3	59.0	—	—	—	—	1.6	456.2	316.4	532.8	568.0	—	10.2	2,507.4
Urban	34.3	150.0	—	—	13.3	12.5	3.1	—	6.3	14.0	81.3	64.9	61.0	90.6	41.4	6.2	45.3	624.2
Denuded unplantable Area	—	—	—	—	—	—	—	—	—	—	—	—	5.5	60.9	—	—	—	66.4
Bamboo	—	—	—	—	—	—	—	—	—	—	—	—	—	—	35.2	—	—	35.2
Total	1,525.8	364.8	296.2	174.2	306.3 (41.4)*	288.0	471.9	407.9	276.6	696.1 (265.6)*	557.1	1,832.1	1,189.9	1,814.1	2,373.5	260.1 (29.7)*	236.7 (336.7)*	13,066.3 (336.7)*

* Area of sandy islets.

** Including gravely river wash and coral gravely sites.

Table 13. Estimated Plantable Area for Seacoast Forests**
(Hectare)

Land Use Type Hsien' or City	Land Use Type				Total
	Grass Land	Sand Dune	Saline Land	Gravel Land	
Taipei Hsien	35.2	367.2	—	402.4	804.8
Taoyuan Hsien	—	80.0	—	10.0	90.0
Hsinchü Hsien	50.0	38.3	—	3.1	91.4
Miaoli Hsien	—	56.3	—	70.3	126.6
Taichung Hsien	—	(41.4)*	—	—	(41.4)*
Changhua Hsien	1.6	38.0	—	59.0	97.0
Yunlin Hsien	—	143.0	—	—	144.6
Chiayi Hsien	—	114.1	7.0	—	121.1
Tainan Hsien	—	10.1	9.4	—	19.5
Kaohsiung Hsien	3.9	26.6	—	—	26.6
Pingtung Hsien	17.2	(221.1)*	—	—	(221.1)*
Yilan Hsien	—	257.8	—	1.6	263.3
Hualien Hsien	42.2	617.2	—	456.2	1,090.6
Taitung Hsien	31.2	467.2	—	316.4	783.6
Keelung City	—	501.6	—	532.8	1,076.6
Tainan City	—	810.9	—	568.0	1,410.1
Kaohsiung City	—	—	—	77.4	77.4
	—	169.5	—	—	169.5
	—	96.1	—	10.2	106.3
Total	181.3	3,793.9 (262.5)*	16.4	2,507.4	6,499.0 (262.5)*

* Area of sandy islets

** Figures are estimated from Detailed Table 12.

Table 14. Estimated Area Needed for Farm Windbreak
(Hectare)

Hsien or City	Farm windbrteaks needed Area		
	5 km within Seacoast	5 km to 10 km	Total
Taipei Hsien	5,704.7	4,225.5	9,930.2
Taoyuan Hsien	124.0	—	124.0
Hsinchu Hsien	1,838.9	—	1,838.9
Miaoli Hsien	4,994.7	—	4,994.7
Taichung Hsien	270.3	10,615.3	10,885.6
Changhua Hsien	—	2,028.8	2,028.8
Yunlin Hsien	784.4	6,294.0	7,078.4
Chiayi Hsien	1,055.5	9,332.0	10,387.5
Tainan Hsien	4,606.2	13,244.5	17,850.7
Kaohsiung Hsien	7,826.6	26,354.0	34,180.6
Pingtung Hsien	8,311.9	22,287.1	30,599.0
Yilan Hsien	13,693.8	11,234.9	24,928.7
Hualien Hsien	7,726.6	6,447.7	14,174.3
Taitung Hsien	9,321.9	9,410.1	18,732.0
Keelung City	73.4	437.6	511.0
Tainan City	3,246.9	3,384.0	6,630.9
Kaohsiung City	2,873.4	3,020.3	5,893.7
Total	72,453.2	128,315.8	200,769.0

Romarks: Area listed above are areas of farm land which need to be protected by farm windbreaks.

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