

High Input Cropping Systems¹

Kuang-chi Su²

A. Introduction

The practice of growing two or three crops either in sequence or simultaneously on the same field in a year has long been common in Taiwan. A favorable subtropical climate, good irrigation facilities, and technological experience, accumulated over generations of farming experience, make such multiple cropping a feasible way of increasing the productivity of land and labor on small farms.

Multiple cropping indexes showed a gradual increase from 116 in the 1911-1915 period up to 190 in 1964-1968, though in subsequent years the indexes started to decline gradually. In the later 1960's the rapid industrialization caused a considerable migration of rural labor into urban-industrial areas, and this outflow resulted in farm labor shortages and high wage rates. Such trends of migration away from agriculture have induced changes in cropping systems from labor-intensive to capital-intensive or labor-extensive. Labor shortages have also caused farm families to cut down on crop acreage which requires much labor input. The acreage under field and special crops decreased from 679,274 hectares in 1962-1966 to 550,495 hectares in 1972-1976. On the other hand, the acreage of fruits, vegetables, and fish ponds has been expanding very fast during these periods.

This paper discusses the recent changes in high input cropping systems and the subsequent agricultural technical change in Taiwan.

B. Cropping systems in Taiwan

Arable land in Taiwan totalled 918,143 hectares in 1978, of which paddy fields amounted to 517,061 hectares or 56.32% and dry farming fields 401,082 hectares or 43.68%. Cropping patterns in paddy fields are mainly determined by the reliability of the water supply. Fully irrigated areas, which can grow two crops of rice if they have adequate water for year-round irrigation, accounted for 396,010 hectares or 40.19%. The partially irrigated and rainfed areas can be used for single cropping or rotational cropping depending on the water supply. Single cropping paddy fields (with a single rice crop per year) accounted for 49,984 hectares or 5.45%. The rotational cropping areas (a single rice crop every two or three years) amounted to 98,067 hectares or 10.68%.

The leading multiple cropping patterns are briefly described belows.

1. Rice-based cropping patterns

¹ Paper presented at the symposium on "Potential Productivity of Field Crops under Different Environment" held on 22nd to 26th, Sept., 1980, at International Rice Research Institute, Los Banos, Philippines.

² Director of Taichung DAIS.

(1) Fully irrigated double cropping areas (Fig. 1)

Most land is cultivated under a fully irrigated double cropping pattern. From late October through the following February (which is the winter fallow period between the harvesting of one year's second rice and the transplanting of the next year's first rice crop) one upland or vegetable crop may be grown. If the growing time of the vegetable crops is short enough, two crops may be grown in sequence. This winter gap lasts about 120 days. In the summer, however, there is only a 30-40 day gap between the harvesting of the first rice crop and the transplanting of the second. Only a few vegetable crops are suitable for planting in this summer gap. They are pai-tsai, edible amaranth, yellow melon, and oriental pickling melons. Growing one summer crop and two winter upland or vegetable crops with two rice crops constitutes the most intensive method of land use in Taiwan.

The main upland crops grown in the winter gap are sweet potato, wheat, tobacco, flax, rape, soybean, azukibean, corn and sunflower.

Vegetables which are commonly planted after the second rice crop are Irish potato, carrot, onion, cabbage, cauliflower, pea, beans, tomatoes, radish, lettuce and garlic.

Some special techniques, such as relay-intercropping and no-tillage planting with short growth duration crops or cultivars are adopted by some industrious farmers. Two week old melon seedling are transplanted two weeks before the rice harvest, or melon seeds are planted four weeks before harvest, in the space which occurs every ten rows in the rice field. Melon can be harvested within 70-80 days after seeding in the summer. The same procedure of relay-intercropping is adopted for tobacco, corn, sweet potato and sugarcane before the harvest of the second rice crop. This practice enables the production of crops which are otherwise impossible to fit into the multiple cropping system. The adverse effect on rice yield, usually a 3-10% decrease in grain yield, is more than made up for by the multiple cropping returns as a whole. No-tillage planting is commonly practiced by Taiwan farmers along with relay-intercropping. In southern Taiwan, a winter soybean crop following the second rice crop is sowed by opening shallow holes close to the rice stubble and placing two or three seeds in each hole. No land preparation is involved. After sowing, the farmers spread rice straw from their preceding crop over the field and leave it as a mulch. Some no-tillage planting is adopted for wheat or peas immediately after the harvest of the second rice crop in central Taiwan. The advantages of this practice are saving both in time and labor. Several studies have shown that yields from no-tillage fields can equal or surpass those from field under conventional tillage.

(2) Rainfed and partially irrigated

Rice is grown under supplemental irrigation during the rainy season. Based on the available amount of supplemental irrigation water, the cropping patterns can be classified into four types.

a) Single rice crop per year (Fig. 2)

Normally this single crop of rice is grown under supplemental irrigation during the rainy season, and then followed by an upland crop. Depending on the rainfall pattern, the rice crop may be divided into the first single rice crop and the second single rice crop. Just over 9,000 hectares is

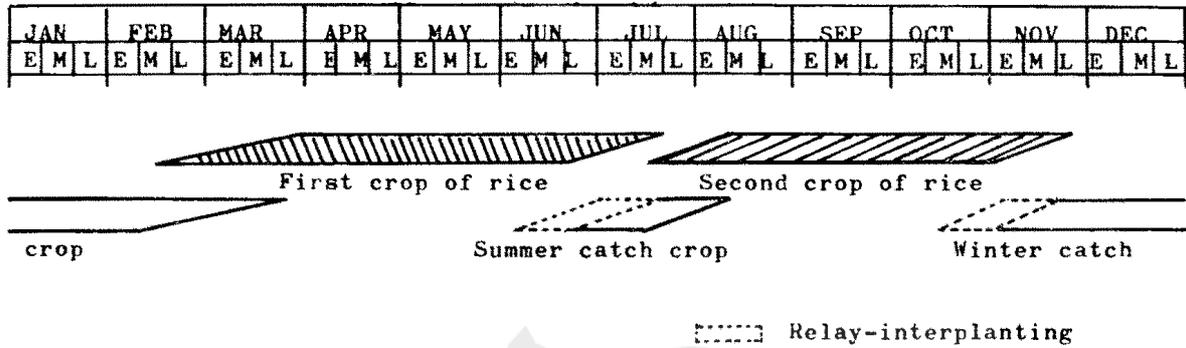


Figure 1: Double cropping rice area

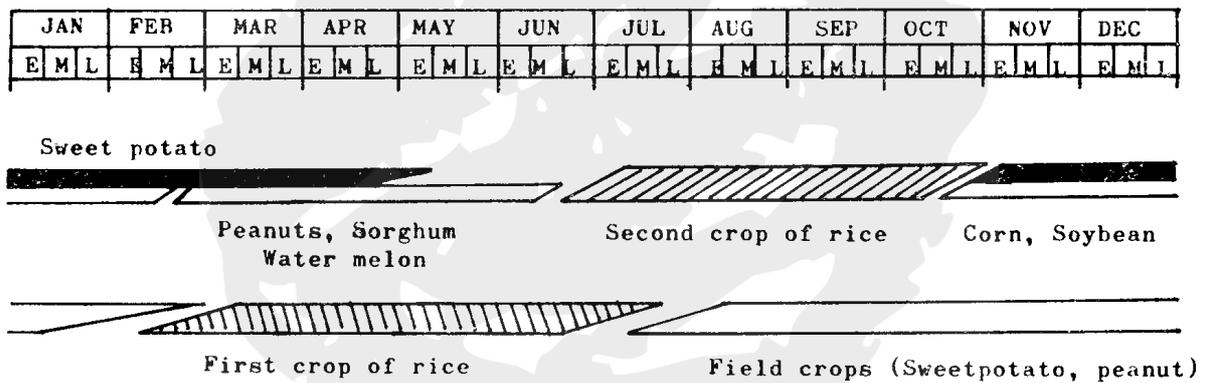


Figure 2: Single cropping rice area

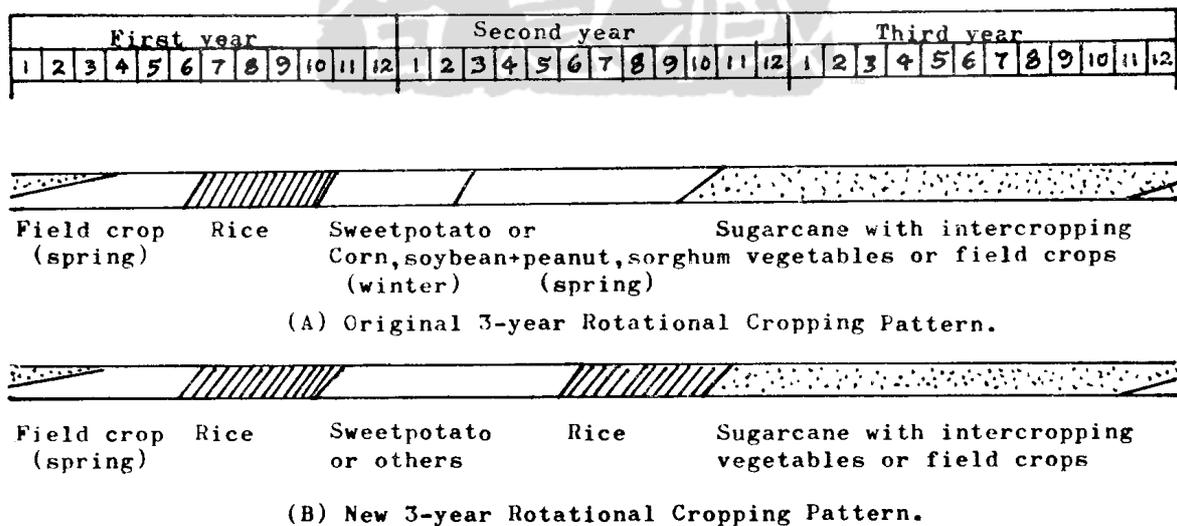


Figure 3: Rotational Cropping Area

given over to the first single rice crop and over 40,000 hectares to the second. Generally, the upland crops following the second rice crop are long-duration and drought-tolerant sweet potato or processing tomato. The paddy field along the west coast were formerly fully irrigated, but in order to escape the damage of the strong seasonal wind (October to March), transplanting of the first rice crop is now delayed until the end of March and the harvesting is thus delayed until the end of July. Since during flowering time the second rice crop is easily damaged by the winter seasonal wind, sweet potato, peanuts or watermelon are recommended to follow the first rice crop and replace this second rice crop.

b) Single rice crop every three years rotational cropping area (Fig. 3)

Because of the uneven distribution of rainfall and the dry winter and spring, water resources are insufficient to cover the entire irrigation area throughout the year, and a total area of about 120,000 hectares has been practicing three-year rotational irrigation for about fifty years. Under this three-year rotational cropping pattern, farm lands are divided into crop-rotation units of 150 hectares each. Each crop-rotation unit of 150 hectares is subdivided into three subunits of 50 hectares each. Three kinds of crop are planted in rotation between each subunit over a cycle of three years.

a) Rice June-October

b) Upland crops (corn, peanuts, sweet potato, sorghum, soybean, vegetables)
October-September

c) Sugarcane September-April, the year after next

Taking a spring dryland crop or green manure as the first crop, it will be harvested by June to have the land ready for rice transplanting. Rice may be harvested by October, and then followed by another two successive dryland crops, the last harvest of which will take place in the next September. Then sugarcane is grown on the same piece of land for about 18 months before another cycle of spring dryland crop starts again. The rice crop will have been sufficiently irrigated and the one sugarcane crop would have been irrigated twice with a total amount of water of about 180 mm. The upland crops will not have been irrigated, or irrigated only once with 90 mm during the growing season, and this will depend on the amount of surplus water in the reservoir in that years.

d) Two rice crops every three years

After completion of the lining of the irrigation canals and the construction of Tsengwen reservoir, a new water resource added to the system in 1973, sufficient water became available for full irrigation of two rice crops and for adequate irrigation of sugarcane (6-7 irrigation during the growing season) and upland crops (2-4 irrigation) in a three-year rotation. A winter/spring dryland crop can be harvested by June and paddy rice will follow. This will ripen in October. Two successive dryland crops will occupy the land for about 7 to 8 months until June, then an additional second rice crop will be transplanted and harvested in October. Sugarcane will be planted after the harvesting of rice or relay-interplanted before the harvest. Another cropping cycle for a period of the three years will be initiated after sugarcane is harvested.

Sugarcane is the main crop in such rotational cropping. Since it is a long duration crop (18 months), farmers are accustomed to adopting relay-interplanting to fit into the multiple cropping system. Cane that is interplanted into the paddy with the first rice crop is called spring paddy sugarcane, and sugarcane that interplanted with the second rice crop is called autumn paddy sugarcane. Sugarcane is normally interplanted about 50 days before the harvesting of rice. A general interest in a shorter growing period for cane is revealed both in extended ratooning and in the choice of spring paddy sugarcane. These factors mean that the spring cane needs only 8-12 months, as compared with 18 months for the fall planting cane. Spring paddy sugarcane has no significant effect upon the yield of rice. Farmers are also accustomed to intercrop the other crops with sugarcane to get some additional financial return before the cane harvest. Sweet potato, peanuts, soybean, corn, tobacco, rape, tomato, seed melon and vegetables such as cauliflower, cabbage, radish and so on are usually intercropped either at the same time or after the sprouting of the sugarcane.

2. Dryland cropping patterns (Fig. 4)

Dry farming fields exist on rolling hills, table terrace land, and other areas where the irrigation is economically impossible or the soils are low in water holding capacity. The prevailing cropping patterns are as follow:

(1) Annual dryland crop patterns

Dryland field crops are grown in the spring and summer, then followed by sweet potato during the autumn and winter. A crop of peanuts, sorghum, corn, soybean, sesame, mungbean or watermelon is planted in February or March and harvested in July, then sweet potato occupies the land for five to six months.

Long growth duration crops such as cassava or sugarcane are rotated with other dryland field crops or green manure crops. Cassava (planted in February-April and harvested after 12 months) -Spring peanuts-Autumn sweet potato. Green manure crops in spring-Fall planted sugarcane (18 months)-Spring ratooned sugarcane (12 months).

(2) Perennial crop patterns

The rolling hill region occupies the lower mountainous area below 1,000 m. Tea and citrus are the main crops in the north: tea, citrus, mulberry, pear, grape, loquats, lichi, banana and pineapple in the center; and banana, pineapple, sisal, longans and mangoes in the south. Sandy soils along the west coast and the river bank are given over to asparagus in central and southern Taiwan.

C. Improvements for increasing cropping intensity

In the last few years we have faced the following situation on crop production, (1)Overproduction of rice promoted by high guaranteed price and advanced technology. (2) A supply of corn, soybean, and wheat which still lags far behind the rapidly growing demand as feed and for industrial uses. (3) Increasing demands and prices for vegetables and fruits both for export and for the domestic market. (4)Labor shortages and depressed agricultural prices relative to inputs, which have caused some farmers to abandon winter catch crops. To cope with this situation, the new cropping patterns have been developed Which differ from the conventional

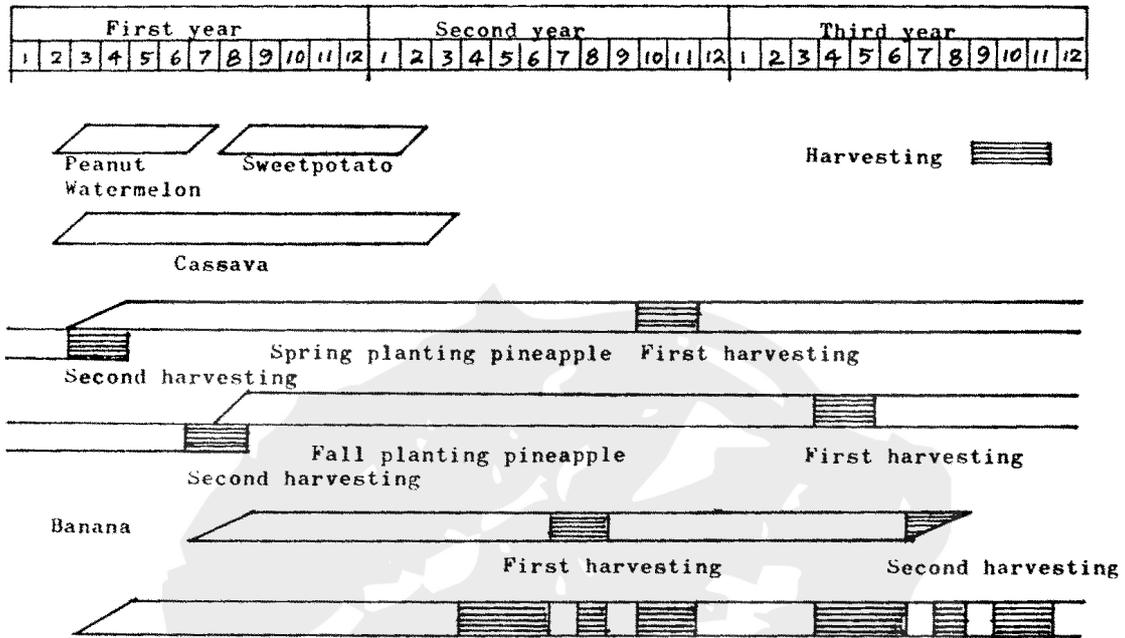


Figure 4: Dryland area.

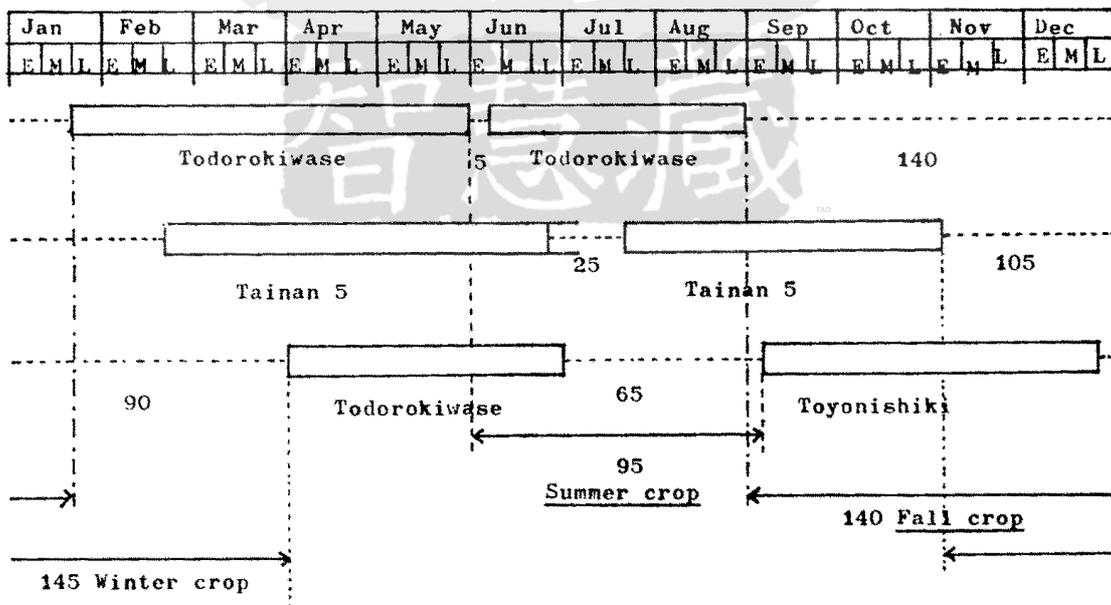


Figure 5: New double cropping rice area.

ones.

1. Diversification in fully irrigated paddy areas

Success in introducing early maturing and cold-tolerant Japanese cultivars has extended the planting season from the conventional late February through mid-August to early January through early September. Growing early maturing cultivars, adopting ratoon or older seedling methods could shorten the growing period of rice without significant yield loss.

The ratooned cultivars of the Indica type mature 22 days earlier than under conventional transplanting, but grain yield was 13% lower than under transplanting. Planting older seedlings shortens the growth duration by about 10 days and decreases grain yield by about 3-5%. However, if older seedling were to be planted at closer spacings, the grain yield would be similar to that of conventional method.

By combining cultivars which mature at different times, ratooning, and older seedling treatments, the main diversified cropping patterns can be classified as follows (Fig. 5):

(1) Maintaining the two rice crops patterns

a. Extending the summer vegetable growing duration from one month to three months.

It has proved difficult to grow common vegetables in the hot, humid and short summer fallow period, and only a few varieties of vegetables are suitable for growing in this fallow period. Once this fallowing time can be extended from one month to two or three months by early harvesting of the first rice crop and late planting of second rice crop, there are many leaf and cucurbit vegetables which can be grown without adopting labor intensive relay-interplanting. Watermelon (15 days nursery+85 days), melon (60 days after sowing), vegetable soybean (75 days), Chinese cabbage (heat-tolerant, 20 days nursery+45 days), water convolvulus (90 days with four harvests), oriental pickling melon (50-70 days), edible rape (45 days), edible amaranth (45 days), and radishes (50 days) may be grown successfully and command high market prices in the summer vegetable period.

b. Extending the growth duration of winter crops from late February to early April.

Some vegetables, which give high profits but have long maturation period (about four months), have been more widely grown in paddy districts in recent years. Since maturation period of pea, tomato, strawberry or garlic exceeds 120 days after the second rice crop, early maturing cultivars or the use of older seedling may be adopted after the harvesting of winter crops in late March or early April. Then the harvesting of the first rice crop could be accomplished before the mid-July.

c. Advancing the planting time of winter field crops from early November to early September.

During November to February, soybean grown poorly and the crop maturity delayed due to the cool dry weather in central Taiwan. However, early planting of corn or soybean before mid-September in the central region or mid-October in the south have resulted in shorter growth duration and higher yields than late planting. Therefore, shifting the two rice crops from February-October to January-August by adopting early maturing and cold-tolerant cultivars may be the most suitable cropping pattern for rice and field crop production.

(2) Replacing the first and/or second rice crop with vegetables or field crops.

Unfavorable climates and/or soil conditions will cause low yield or unreliable yield of the second rice crop. Under such conditions, vegetables or field crops can replace the rice crop and be harvested before the advent of the seasonal wind. The cropping patterns practiced by farmers are as follows;

First rice crop–watermelon–Chinese cabbage or minicorn*

(March-July) (60 days) (70 days)

*minicorn: the young ears harvested about three days after silking for utilizing as vegetable.

First rice crop-fishery pond

Whenever, the profit of other crops or land uses is higher than that afforded by rice, progressive farmers will adopt such crops or land uses even on highly productive paddy land.

First rice crop-tomato (prolonging the harvesting duration from November to January.)

(February-June) (July-following January)

Second rice crop-strawberry

(July-October) (November-following May)

(3) Shifting the paddy field to fruit or vegetables

On small farms, around 0.5 hectares in size, continuous vegetable production on raised beds with furrows for drainage is usually adopted on fully irrigated areas in central Taiwan. Leek, a biennial bulb crop, is grown on raised beds, spinach, cucumber, tomato, asparagus bean, cauliflower, and the second rice are interplanted sequentially on the corners of raised beds or in depression during the rainy season in the case of rice (Fig. 6). The other patterns are as follows:

a. Rag gourd or balsum pear+pai-tsai+mixed planting of pai-tsai, leaf mustard and celery+spinach+spinach.

b. Leek+intercropping spinach and Chinese cabbage+intercropping cucumber and cauliflower.

(early February to mid-April)

(mid-April to mid-June)

2. Harvesting two or three crops of temperate fruits, grape and pear, in a year instead of single harvesting and conventional management.

Grape is one of the most important temperate fruits for table use and wine in Taiwan. The growing areas, totalling about 4,000 hectares, are distributed over the slope land and paddy areas of central Taiwan. Generally, grape is harvested once a year between mid-July and mid-August. Since the size of grape farms is small, about 0.5 hectares, the growers adopt the physical techniques, such as topping and pruning, and chemical control for growth regulation and defoliation, to adjust the harvesting season and prolong the market season and to bring about two or three harvests for increased productivity. The methods of topping, pruning, and chemical control are shown in Fig. 7.

Pear is grown on lowland and mountain (above 1,500 m) in central Taiwan. Cool Weather in

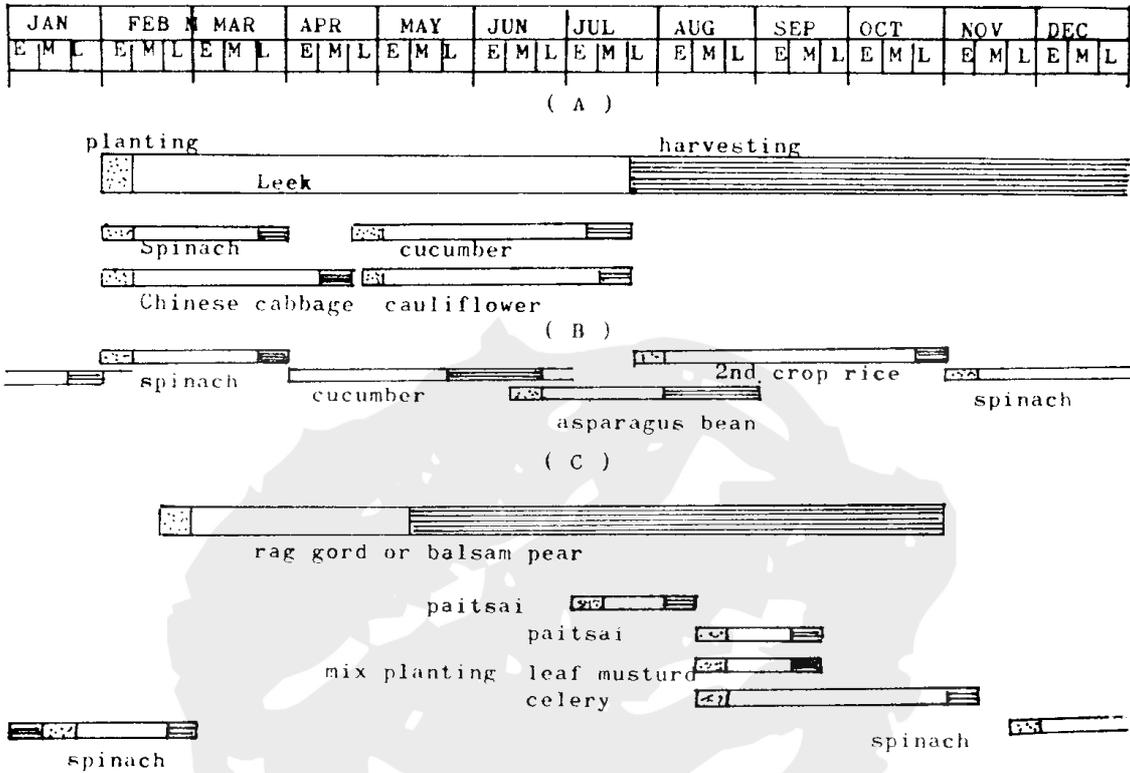


Figure 6: Vegetable farm in paddy field. (a)

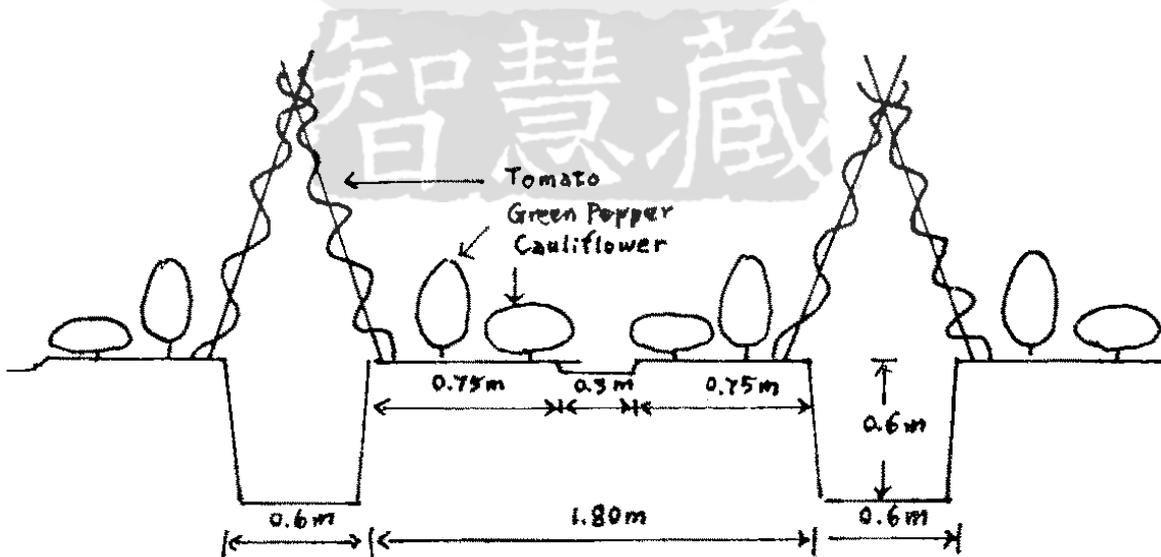


Figure 6: Intercropping of vegetables on the raised bed system. (b)

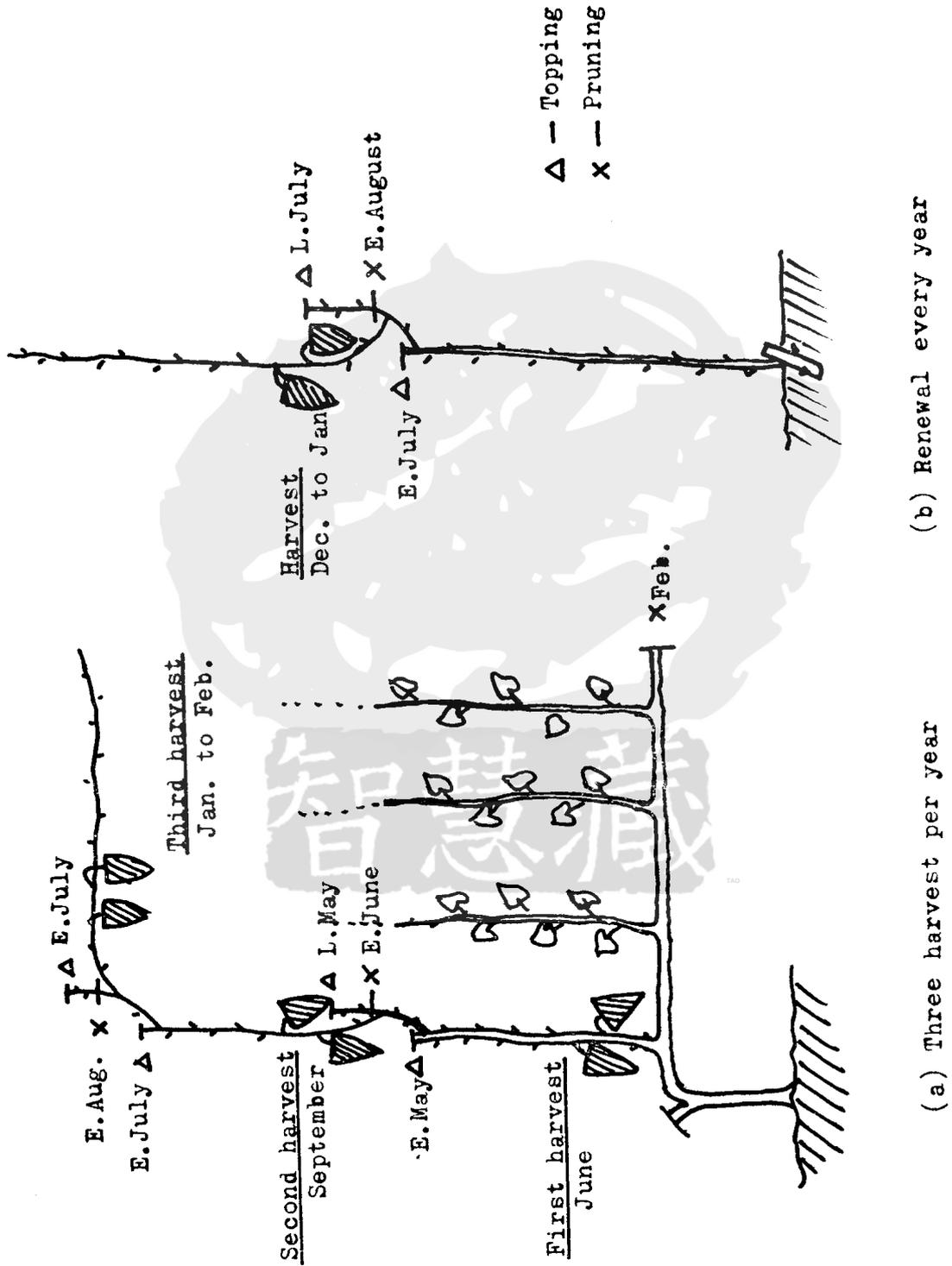
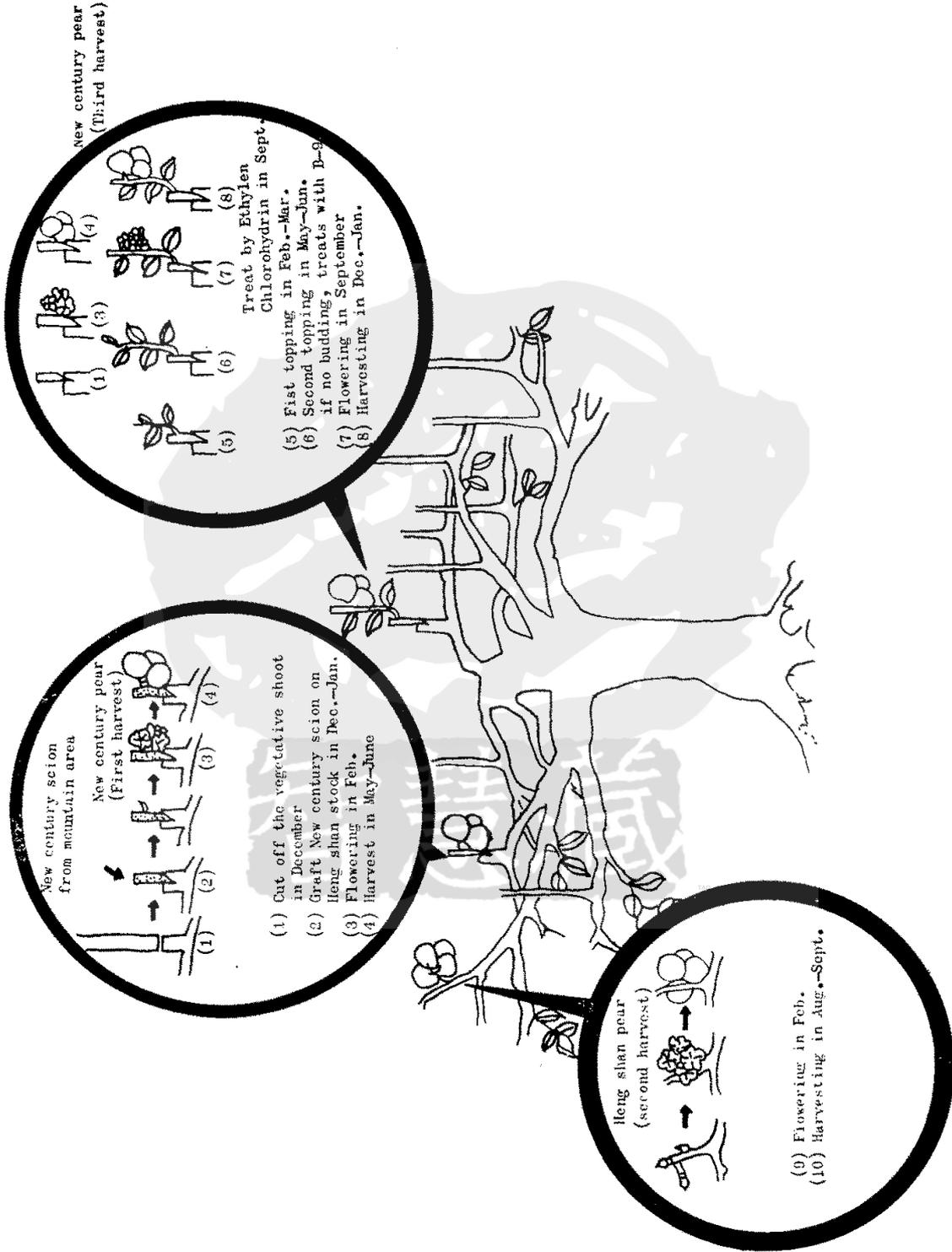


Figure 7: Methods of two to three harvest or renewal every year on grape production.



the mountain areas is suitable for growing high quality pear such as the cultivars New century. In subtropical lowland areas the heat tolerant cultivar Hengshan has to be grown, which is of low quality. If New century scion are grafted to Heng shan shoots in December, a first harvest of New century fruits will set on the Heng shan branches in early June. Then the Heng shan fruits will set on their own branches through August to September providing a second harvest. The New century scions on the Heng shan branch can either be topped during April to May or treated with B-9 (x800) during May to June for promoting flower bud differentiation. After pruning in August, the flower bud can be treated with ethylen chlorohydrin for promoting flowering in August or September. The additional New century fruits can be harvested in December to the following January making a third harvest (Fig. 8).

D. Future development of cropping patterns in Taiwan

As the already mentioned, the relative importance of agriculture in the national economy has declined considerably owing to the accelerated development of industry and of other sectors of activity. As a result, farmers today are faced with any difficulties such as shortage of farm labor, high cost of essential production methods, small scale farm operations, low rates of capital returns from agricultural investments, and the movement of farm youth to urban areas. Labor intensive cropping systems have gradually changed to different patterns depending on the sizes of farm.

Farmers of the small farms with less than 0.5 hectares are continuing to intensify their land use by adopting short duration crops, cultivars, or cultural practices. The management of 7 to 8 sequential cropping on raised beds or two to three harvests of temperate fruits in this kind of small farm can be conducted by small family labor (probably by a couple).

Small farms of around one hectare or more cannot be managed by such limited family labor. Such farmers need to rely on employed labor with high wages in the busy farming season, and have to become part-time farmers, seeking additional income from non-farm employment at the expense of their farming operation. Since they cannot afford to make investments in farm machines or purchase the land necessary to increase farm size, such farmers may give up labor-intensive crops or winter and summer catch crops. To overcome the above difficulties, some efforts have been made to promote joint or group farming operations by small farmers as a means of accelerating farm mechanization. Group farming will lead to technological agreements, joint operation of farms and joint use of machinery, and to the entrusting of part or all of the work of one's own production processes to others. In general, group farming is a device to enlarge the scale of farm operations and to promote farming efficiency, and hence to increase unit yield and reduce production cost without changing the ownership of the land. Therefore, diversified multiple cropping patterns are tending to change to monoculture and multiple cropping index will also decline as more farmers adopt group farming.

Summary

Depending on the availability of water, the farm lands in Taiwan are divided into many different cropping areas including double rice, single rice, rotational rice, and dryland cropping area. Growing two or more crops on the same field in a year to increase farm income have been attained by growing short growth duration crops or cultivars, and adopting some special cultural practices such as relay-intercropping, ratooning, notillage, older seedling, or raised bed method, etc.

Some highly efficient and productive cropping systems have been developed through the proper utilization and combination of the new cultivars and cultural practices. For example, the introduction of the new rice cultivars with early maturing and wide adaptability has shortened and shifted the rice growing season and duration, and thus extended the summer and winter fallowing period for being able to grow high value crops. Two or three harvests a year on grape and pear have been succeeded through the proper adoption of some physical or chemical treatments.

The trend of labor shortage by migration of rural labor to urban-industry sectors have induced changes in cropping systems depending on the size of farm. Farmers of the small farms with less than 0.5 ha are continuing to intensify their land use. Two to three harvest of fruit, or seven to eight vegetable crops in a year are adopted extensively on such farms. Small farms of around 1 ha or more cannot be managed by their family labor. They have to cut down on crop acreage which requires much labor input. Group farming operation as a means of accelerating farm mechanization have gradually been adopted. Therefore, diversified multiple cropping systems are tending to change to monoculture and multiple cropping index will also declines more farmers join the group farm.

高收益的複作栽培制度

蘇匡基¹

本省氣候高溫多雨，適合作物週年生長，地窄人稠，爲了供應軍需民食，複作栽培一直在本省行之有年。傳統之複作栽培方式，依據水資源（包含雨量分佈），及灌溉設施條件而分爲水田及早田方式。

1. 雙期作水田：以雙期作水稻爲主，加上夏季休閒及冬季休閒期各種一至二作雜糧或蔬菜。
2. 單期作水田：配合雨季及輔助灌溉，每一至三年種植一次水稻者。

(1)一年一作水稻，以雨季水稻配合旱季一至二作雜糧之輪作。

(2)三年一作水稻，由於灌溉水量不足維持全區一年一作水稻之栽培將灌溉區分爲三小區各小區以水稻（雨季配合灌溉）甘蔗、雜糧作三年輪作者。

(3)三年二作水稻，因灌溉水源之開發及灌溉溝內面工之完成，在三年一作區增加水源後，將各小區分爲二期水稻，二期水稻及甘蔗作三年輪作，各主作物間栽培雜糧或蔬菜。

3.早田栽培可分爲一年生及多年生作物爲主之二種方式，一年生栽培大都爲春夏季種雜糧及秋冬季雜糧的輪作爲主，多年生作物栽培則爲平地栽植甘蔗，坡地種樹薯或果樹，砂質土壤種蘆筍。

由於經濟結構之改變，農業成長相對的遲緩，再加上農產品價格低，導致農村勞力大量外移，農村勞力費用日漸昂貴及日感缺乏，作物栽培制度亦發生顯著改變，栽培模式受農家經營規模影響至鉅視自家勞力之供應程度，將傳統的作物經營方式，予以種種程度的改變，大致而言，大規模農家經營趨向單作化，小規模農家則更形複作化。

1.經營規模大的農家，在大部份地區仍維持兩期作的水稻或早作雜糧栽培方式，但對農地之利用率則大爲降低，同時，爲了提高農機具的利用率，仍配合共同經營或委託經營等作業方式，以擴大水田經營面積，使符合企業化之原則，來降低生產成本。

2.部份經營面積窄小的稻農，配合新育成之早熟稻品種之運用適當調整生稻生產期，以擴展夏季蔬菜或冬季裡作生長期，另外一種方式，則改種蔬菜或雜糧作物，以代替傳統的一期或二期水稻。有的農民全年以蔬菜或果樹取代一、二期作水稻，以追求更高之農場收益。

3.果樹的多收栽培技術之發展成功，利用剪定及化學處理，加上集約的栽培管理技術，葡萄可一年二熟或三熟，橫山梨高接溫帶梨一年三收等，爲農地高效率利用提供一新的可行途徑。

¹臺中區農業改良場場長