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Land and Water Resources Management for Crop Diversification in the Chao Phraya Delta, Thailand :

A Case Study of Citrus Cultivation in the North Rangsit Irrigation Project

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Abstract

With the economic growth of Thailand, change from monoculture of rice to diversified farming is about to occur in the Chao Phraya delta. Diversified farming offers high profit, but requires high initial investment for upgrading of farming conditions. Its expansion is still limited to scattered areas of the delta. The present study discusses effective land and water resources management in crop diversification in the delta based on an analysis of the impacts of urbanization, the land reform program, and irrigation and drainage conditions on the expansion of citrus cultivation in the North Rangsit Irrigation Project. Reliable irrigation and drainage conditions, stable land use and water availability, and direct access to irrigation and drainage canals and farm roads are identified as prerequisites for substantial expansion of citrus cultivation in the selected area. Therefore, instead of flexible and extensive land and water resources management for monoculture of rice, long-term planning of land and water resources utilization, and farm-level infrastructure development are recommended to encourage farmers to diversify their farming.

I Introduction

Rice has been a major product of the Chao Phraya delta and one of the most important exports of Thailand since the second half of the 19th century. It was first exported to China, and since the late 19th century exports had gradually shifted to neighboring countries such as Malaysia, Indonesia, Singapore and Philippines according to the spread of cash-crop plantations in these countries [Manarungsan 1989 : 59–60]. Since the late 1970s, the export volume of Thai rice has increased rapidly from one to two million tons of milled rice per year to more than four million tons per year, which accounts for around 40% of the world's rice trade. Destinations expanded to include the Middle East and Africa, while exports to neighboring countries remained almost constant in terms of volume [IRRI 1991 : 97–98]. Demand for Thai rice, therefore, seems to be increasing even though rice production is reaching sufficiency in Southeast Asia.

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Demand for non-rice food is, at the same time, rapidly increasing with the economic growth of Thailand and other countries in Southeast Asia, and this encourages meat, fish, vegetable and fruit production in the country. In the Central Plain, in particular, such farming provides high profitability to the farmers owing to the ready availability of transportation.

From the viewpoint of delta development, the Chao Phraya delta is about to enter the third stage. The first stage was monoculture of rice under uncontrolled water conditions. Rice was cultivated by various methods suited to the local hydrological environments [Takaya 1987 : 16–105]. This stage continued until the completion of the Chainat barrage at the head of the delta and reservoirs in the upstream areas from the late 1950s to the early 1970s. The second stage was also monoculture of rice, but under controlled water conditions. Dry season rice cultivation was introduced during this stage, and the planting method changed from direct sowing in dry fields or transplanting to direct sowing in wet fields. The third stage will be diversified farming consisting of rice, vegetable, fruit and fish cultivation and animal husbandry.

The emergence of diversified farming is, however, still limited to scattered areas of the delta, even though non-rice cultivation offers much higher benefits than rice cultivation. Proper support from the public sector may encourage farmers to diversify their farming. Public support such as marketing, variety improvement and technical extension service have been suggested in this context [Thongthawee *et al.* 1989 : 114–115]. Moreover, land- and water-related aspects such as irrigation and drainage, farm-level infrastructure development and land-use planning will also influence crop diversification.

The objectives of the present study will be, therefore, as follows. Firstly, the process of expansion of non-rice cropping in a selected irrigation project in the Chao Phraya delta is investigated. Then the effects of urbanization, the land reform program, and irrigation and drainage conditions on the expansion of non-rice cropping are analyzed. Finally, effective land and water resources management in crop diversification is discussed.

Citrus (*som khiao waan*) cultivation in the North Rangsit Irrigation Project was chosen for the present study. The project area had a typical deltaic hydrological environment [Takaya 1987 : 17–28], and had been a pioneer area of agricultural development in the Chao Phraya delta. Its canal network was developed in the late 19th century, since when rice cultivation spread to the whole area. Following the construction of upstream reservoirs, dry season rice was introduced. Recently, however, citrus cultivation has rapidly been replacing rice cultivation.

Field survey was conducted from January to April 1993. Necessary information was collected from related government agencies, interpretation of satellite images, and interviews and measurement at 148 citrus gardens, which cover about 7 % of the total fruit garden area in the study area [Saha 1993].

II Citrus Cultivation in the Study Area

1. *North Rangsit Irrigation Project*

The North Rangsit Irrigation Project covers around 460,000 *rai* (1 *rai* = 0.16 ha) in Pathum Thani province, about 50 km northeast of Bangkok (Fig. 1). A main road connecting Bangkok with northern and northeastern Thailand passes along the western boundary of the project, and a wholesale market of agricultural produce is located near the southwestern corner of the project area, which make the transportation conditions of the project area favorable.

The project area is almost flat, with elevations between 1.5 and 2.5 meters above the sea-level. Its soils are brackish clays with the properties of so-called acid sulfate soils and thinly covered with freshwater swamp deposits [Takaya 1987 : 124]. The original water regime was absolutely dry during the dry season and wholly submerged during the rainy

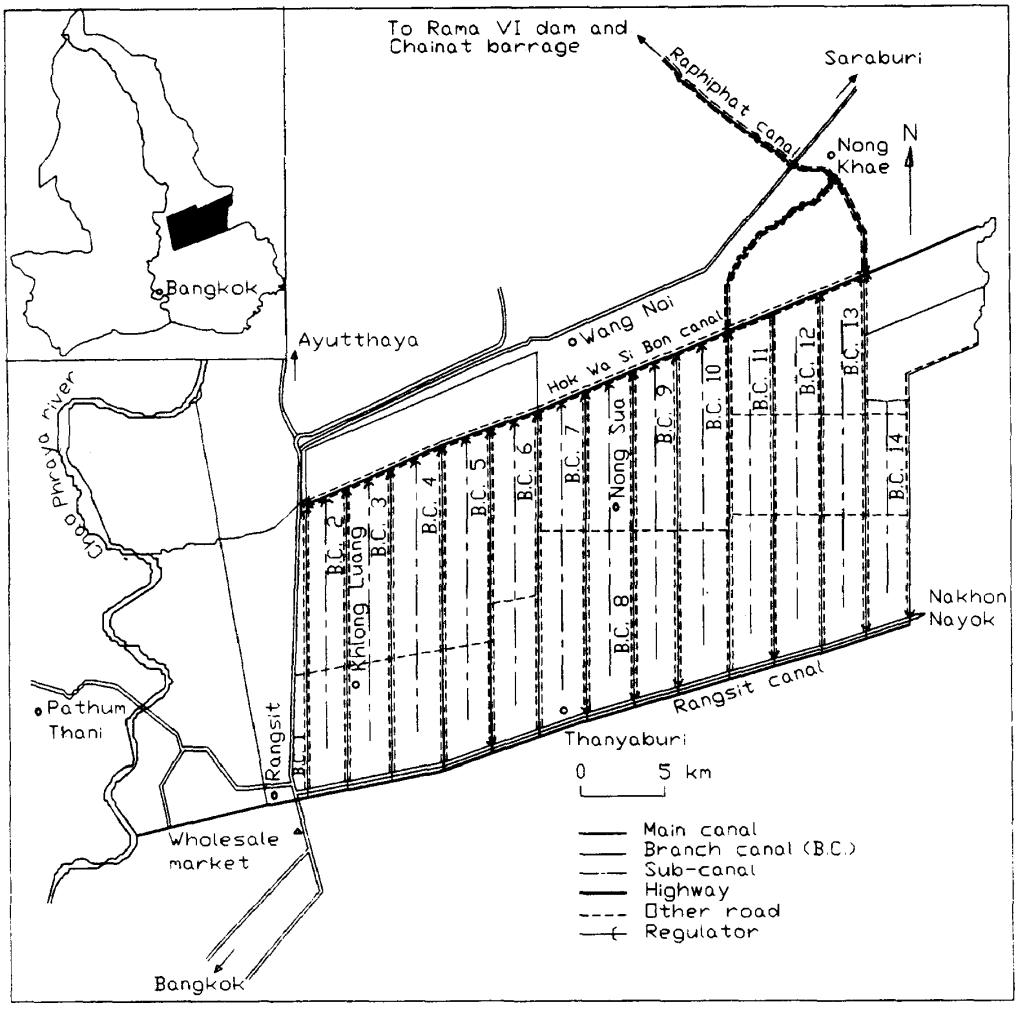

Fig. 1 Irrigation and Drainage System in the North Rangsit Irrigation Project

season under the tropical monsoon climate. However, irrigation water is now supplied to the project area from the Chainat barrage through the Chainat-Pasak canal and the Raphiphat canal even in the dry season, and excess water during the rainy season is drained through a series of canals to the sea and the Chao Phraya river.

There are 14 branch canals, numbered from 1 to 14 from west to east, connecting the Hok Wa Si Bon canal with the Rangsit canal at regular intervals of about two and a half kilometers, which serve both for irrigation and drainage. Additionally, sub-canals lying between the branch canals serve only for irrigation. Gates are set at the head of the branch canals and the sub-canals. Water allocation to the canals is controlled by the project office of the Royal Irrigation Department. Some branch canals also have a downstream gate to control water level within the canal. Motorable roads run on both banks of every branch canal, of which parts are paved. Linear settlements lie along the branch canals and local markets are located at the junctions of canals.

2. *Farm Size and Layout*

Farm size and ownership of fruit gardens are summarized in Tables 1 and 2. About 60% of fruit gardens are 10 to 50 *rai*, which is a typical farm size in the province. However, a considerable number of gardens are larger than this, some more than 100 *rai*, which

Table 1 Farm Size and Ownership of Fruit Gardens and Paddy Fields in Pathum Thani Province

		Fruit Gardens[1)]	Paddy Fields[2)]	Whole Province[3)]
Average area planted (*rai*/household)		59	29	34
Ownership (%)	– owner[4)]	76	27	42
	– tenant	23	68	54
	– others	1	5	4

1) Estimated from the results of field survey.
2) Calculated from the data of whole province and fruit gardens.
3) Obtained from Center for Agricultural Statistics [1993: 212–221].
4) This includes land rented in free of charge.

Table 2 Farm Size Distribution of Citrus Gardens in the Study Area

Ownership	Farm Distribution (%)						Average Farm Size (*rai*)
	–14 (*rai*)	15–34	35–54	55–74	75–94	95–	
Owner	12	31	14	8	7	28	66
Tenant	21	31	12	12	10	14	47
Others[1)]	60	40	0	0	0	0	18
Total	17	31	13	9	8	22	59

1) These are located in the land reform area.

makes the average farm size of fruit gardeners almost two times that of rice cultivators. Owner-cultivators make up the majority of fruit gardeners, but the minority of rice cultivators. Owner-cultivators' fruit gardens are slightly bigger than those of tenants.

Most gardens in the study area are rectangular, adjoining a branch canal and a motorable road on one side and a sub-canal on the opposite side. Farmers can take irrigation water from either the branch canal or the sub-canal and drain excess water to the branch canal independently.

3. *Farm Management*

Farm structure consists of a farm dike and a farm ditch, plant beds and feeder ditches, and irrigation and drainage facilities to control closely the soil moisture content of the root zone (Fig. 2).

The whole garden is surrounded by a farm dike to protect it from flooding. Where there is a high road, this serves as part of the farm dike. Just inside the farm dike, a farm ditch encircles the garden to allow in-garden transportation and increase the temporary storage capacity of excessive rainfall and dry season irrigation water. Inside the farm ditch, rows of plant beds and feeder ditches alternate. Citrus trees are planted on the beds at intervals of 3.5 to 4 m. Irrigation water is pumped up from the branch canal to the pond in the farm for temporary storage, then released to the farm ditch and the feeder ditches to keep the water level around 0.5 to 0.7 m below the bed level. Beds are watered by sprinkling by means of a pump mounted on a boat. This is normally done once a day, but is stopped during the pre-flowering stage to accelerate flowering, and increased to four or five times a day during the flowering stage. It is also stopped during the harvesting stage [Anwar 1994 : 39]. Excess rainfall is pumped up from the farm to the pond to keep the water level of the feeder ditch within the limits just noted, and from the pond to the branch canal, if necessary.

Lime, cow dung manure and herbicide are applied for upgrading soil at the initial stage and regularly after cultivation has started. Application of lime is necessary to keep pH neutral. Farmers stop watering for a few days before lime application to let the bed soil crack. Compound chemical fertilizer and insecticide are also applied during cultivation.

Agrochemical companies in collaboration with agricultural extension officers pre-

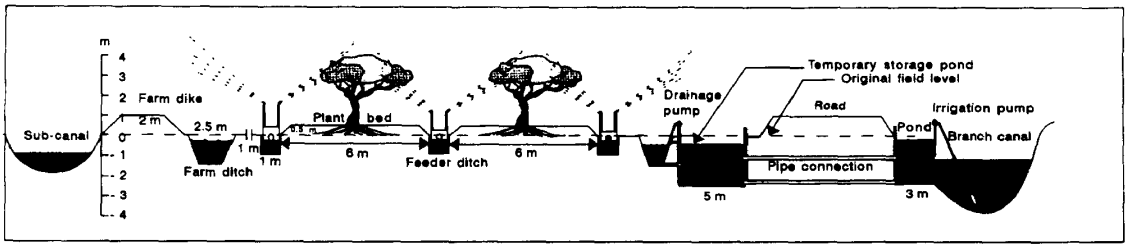

Fig. 2 A Typical Farm Structure and Necessary Infrastructure Setup of Citrus Garden

Table 3 Costs and Benefits of Citrus Cultivation for a 30-*rai* Garden

Item	Initial Stage		Running Stage (Annual)	
	Quantity	Value (*Baht*)	Quantity	Value (*Baht*)
Costs				
- Seedling	1,330	27,000	0	0
- Development of dike, ditches and beds[1)]	—	150,000	—	0
- Diversion pump	1 set	50,000	0	0
- Sprinkler pump and boat	2 set	16,000	0	0
- Sprayer	1 set	6,000	0	0
- Lime	9 ton	11,000	3 ton	4,000
- Manure	2 truck	7,000	1.5 truck	5,000
- Insecticide and herbicide	—	60,000	—	150,000
- Chemical fertilizer	0	0	6 ton	45,000
- Labor	60 man·day	5,000	2,100 man·day	168,000
- Fuel, oil, repair and maintenance	—	0	—	30,000
Total	—	332,000	—	402,000[2)]
Benefits				
- Production	—	—	100 ton	500,000 - 800,000

1) Height and width of farm dike are assumed to be 1.0 m and 4.0 m, respectively.
2) This does not include land rent in case of a tenant farmer.

pare a list of recommended chemicals for individual gardens based on measurements of soil characteristics made as part of their advertising. In most cases, farmers follow their recommendations. So far, no complaints about this method have been reported by farmers.

Estimated costs and benefits of citrus cultivation are summarized in Table 3. Total initial investment cost is around 11,000 *baht/rai* excluding land acquisition (25 *baht* ≒ 1 US dollar). Annual gross benefit is 17,000 to 27,000 *baht/rai* starting from the fourth to fifth year of planting. Net benefit is estimated to be 3,000 to 13,000 *baht/rai* depending on the price of citrus, which fluctuated between 5 and 8 *baht*/kg at the farm gates in the study area during the last ten years. These findings indicate that citrus cultivation needs a considerable initial investment, but that it is quite profitable, at least for the owner-cultivator, at the present price of citrus. This is borne out by the fact that most citrus gardeners are owner-cultivators.

III Citrus Garden Expansion

Changes in land use in the study area during the last 20 years are shown in Fig. 3. In the early 1970s, most of the area was occupied by single-cropped paddy fields. During the 1970s, irrigation water supply during the dry season increased, and double cropping of rice replaced single cropping (Fig. 4), which came to occupy more than 30% of the total area in the early 1980s.

Fruit gardens started to expand at the end of the 1970s, when farmers recognized the

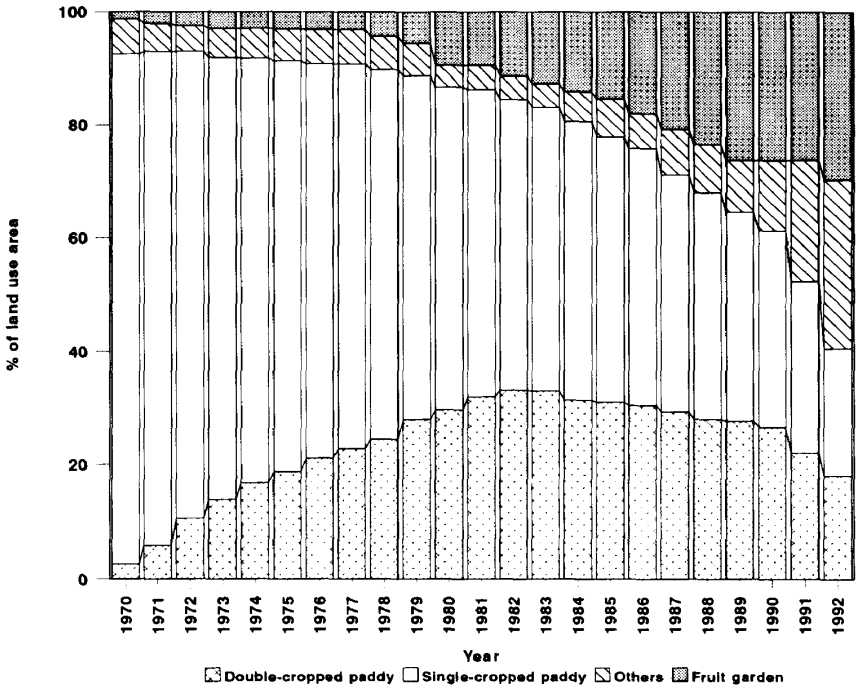

Fig. 3 Changes in Land Use since 1970

Note : Estimated from the data obtained at the North Rangsit Irrigation Project office.

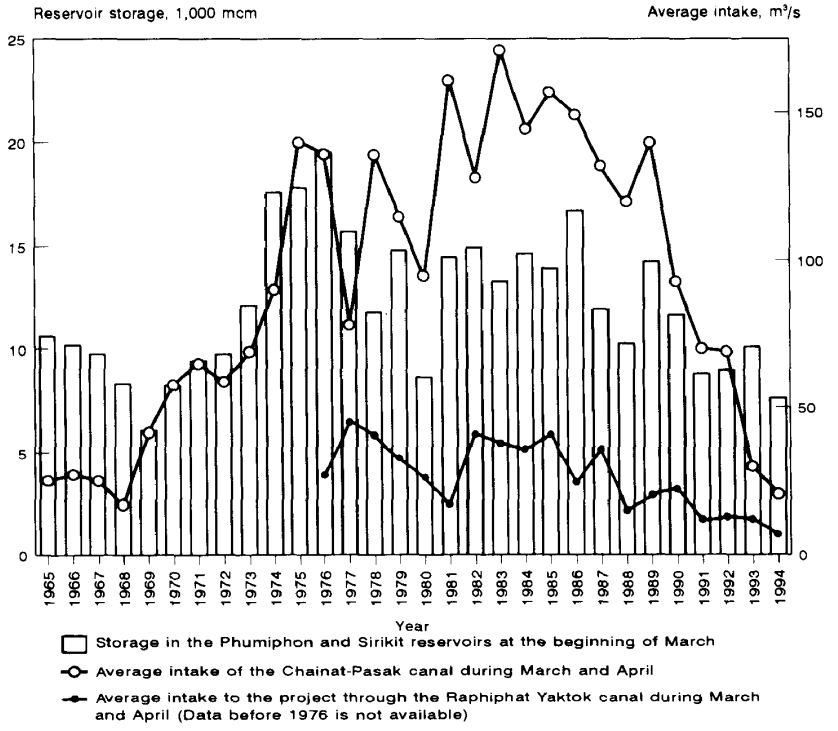

Fig. 4 Changes in Irrigation Water Supply during the Dry Season

Note : Estimated from the data obtained at the Royal Irrigation Department.

reliability of irrigation water supply during the dry season. This expansion accelerated during the 1980s, mostly by conversion of double-cropped paddy fields (Table 4). Irrigation water supply in the dry season is, therefore, a prerequisite for substantial expansion of fruit cultivation.

Urban use of land for housing, factories and government agencies has rapidly expanded since the late 1980s, promoted by the economic growth of Bangkok, and this is reflected in the increase of "others" in Fig. 3. Presently, fruit gardens occupy around 30% of the project area, of which almost all fruits are citrus (*som khiao waan*). Paddy fields occupy no more than 40% of the total area.

Spatial distribution of fruit gardens was traced from data of the Land Development Department and the interpretation of satellite images (Fig. 5). At the initial stage of the expansion, fruit gardens were concentrated in the area along branch canals 9 and 10. One of the earliest fruit gardeners along branch canal 9 was a migrant from Ban Mod, southwest of Bangkok, where his family had managed a garden with various kinds of fruit. In the late 1960s, with the deterioration of water quality due to urbanization in the surrounding area, he decided to sell his garden ; and with the proceeds he purchased his present land, ten times larger in area, to develop a citrus garden. Another farmer reported that he had moved from Damnoen Saduak, a major production area of vegetables and fruit for the Bangkok market. These migrants are thought to have initiated fruit garden development in the study area.

During the 1980s, the study area attracted a lot of migrants from traditional fruit production areas. At the same time, the original settlers began to convert their paddy fields to fruit gardens. They learned the technique of fruit garden development and management by working at a neighbor's garden during the off period for rice cultivation or simply by watching their neighbors. As a result, fruit gardens became scattered all over the study area by the late 1980s.

Recently, fruit garden expansion has decelerated and become limited to the eastern part of the study area around branch canals 11 and 12. Some gardeners migrated from the western part of the study area to the area along these branch canals because of the lower land price.

Table 4 Previous Land Use of Present Citrus Gardens

(unit : %)

Year Developed	Paddy Field			Fallow	Others
	Single Cropped	Single/ Double Cropped	Double Cropped		
−1977	61	12	3	23	1
1978−82	11	29	37	19	4
1983−85	20	10	64	5	1
1986−	11	16	40	17	16

Note : Estimated from the results of field survey.

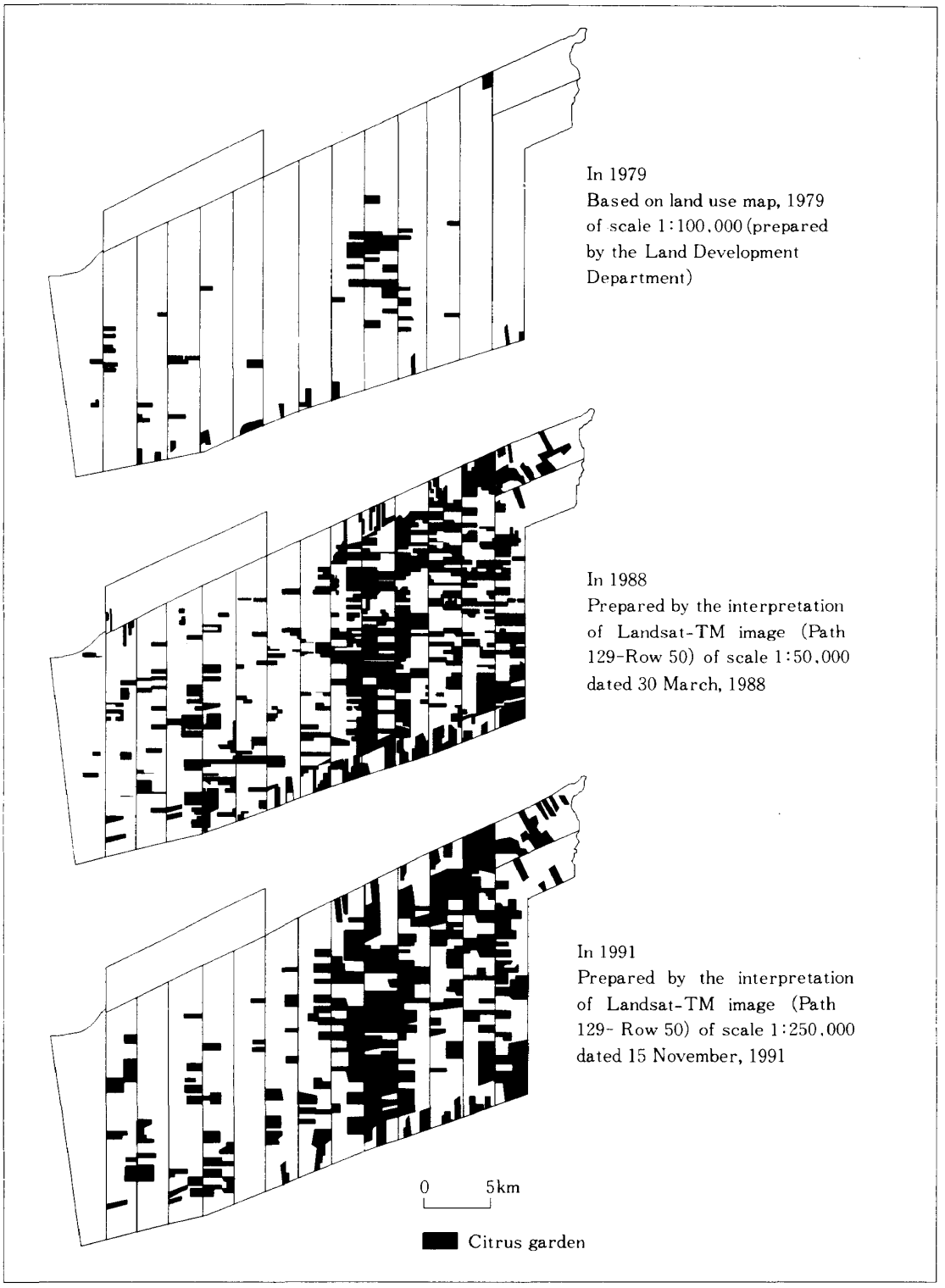

Fig. 5 Changes in Spatial Distribution of Citrus Gardens in the Study Area

IV Effect of Urbanization

1. *Spread of Urbanization*

The expansion of Bangkok is thought to have reached the study area in the mid-1980s. Before that, the land price showed no significant difference throughout the study area and was lower than 100,000 *baht/rai* in the early 1980s. However, it rose sharply during the 1980s, and presently it sometimes exceeds two million *baht/rai* in the western part of the study area, while it is lower than one million *baht/rai* in the eastern part [Saha 1993: 36]. The present spatial distribution of urban use such as for factories, offices, housing and shops in the study area is summarized in Fig. 6.

Urban use has mostly spread in the western part of the study area. Especially high concentration can be observed along branch canals 1 and 2, which are nearest to Bangkok and a highway. Large fallow areas also exist in these areas, most of which are thought to have been purchased by developers or reserved for urbanization. As a result, agricultural land occupies only 20 to 40% of the total land along branch canals 1 and 2, which is therefore identified as an urbanized area.

An area reserved for future urbanization lies next to the urbanized area. Urban land use here is not as extensive as in the urbanized area, but agricultural land still occupies less than 50%. The remainder is thought to be reserved for urbanization. A concentration of urban use can be observed in the tail reach of branch canal 6, where the district office of Thanyaburi is located.

Beyond the reserved area lies the agricultural area. Speculation in land also occurs

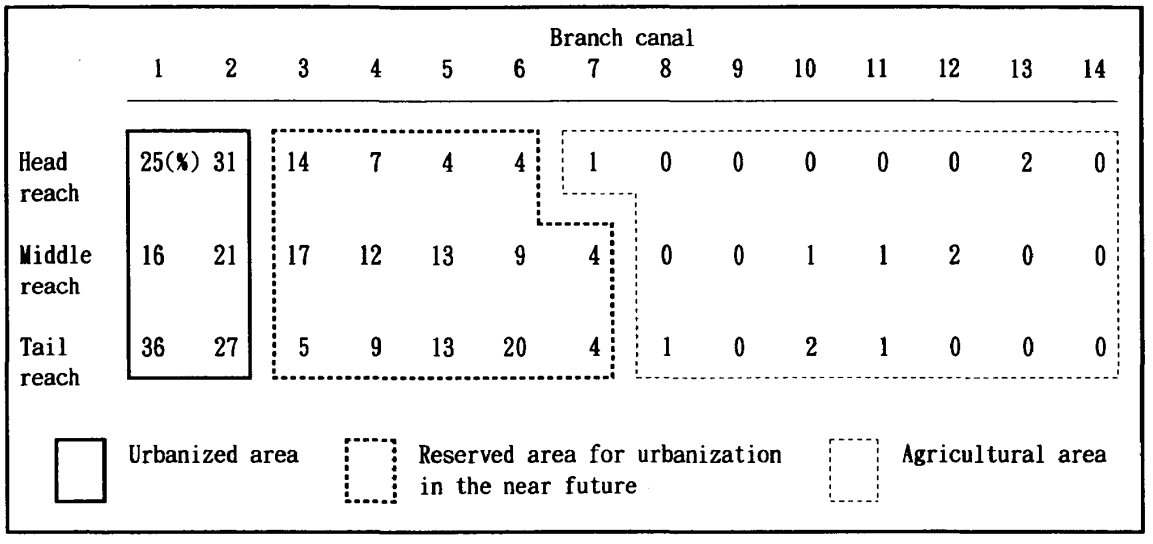

Fig. 6 Proportion of Urban Use in the Total Area

Note: Prepared from satellite imagery LANDSAT-5 TM (129-50) of scale 1 : 50,000 dated 30 Mar. 1988, and modified in the light of information gathered through field survey.

in this area, but it is presumably based on a longer perspective and does not substantially affect the present land use, as it does in the reserved area.

2. *Effect on Fruit Garden Expansion*

Urbanization affects the expansion of fruit cultivation in two senses. First, urbanization causes material changes in land use from agricultural to urban, sometimes through deteriorating environments for agriculture. Second, urbanization causes uncertainty about future land use, which discourages landowners from investing in upgrading their agricultural land for fruit cultivation. The latter impact is, so far, more significant than the former in the study area.

The area ratio of fruit gardens to total non-urbanized land in each canal reach is summarized in Fig. 7. In the urbanized area, most of the non-urbanized land is either occupied by paddy fields or under fallow. In the reserved area, the pattern is generally similar, and here again the impact of urbanization has been to halt the expansion of fruit gardens (Fig. 8). This is because paddy fields can be converted to urban use whenever necessary, while fruit garden development requires land use to be fixed for about 15 years to ensure maximum benefit. Irrigation water quality must also be maintained during this period. These findings indicate that long-term stability of land use on a canal command basis is a prerequisite for citrus garden development.

The agricultural area shows, in general, a high proportion of fruit gardens, which have continuouly expanded, rapidly in some reaches and gradually in others. This tendency is supported by the view held by landowners that the present land use pattern and the environment suitable for citrus cultivation will be preserved in these areas. Some

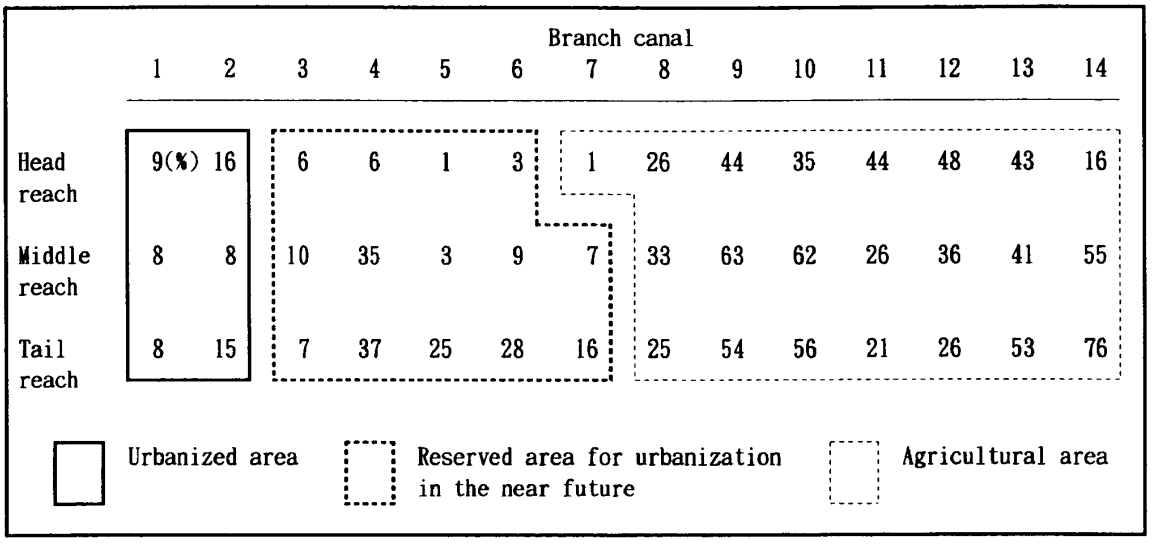

Fig. 7 Proportion of Fruit Gardens in the Non-urbanized Area

Note: Prepared from satellite imagery LANDSAT-5 TM (129-50) of scale 1 : 50,000 dated 30 Mar. 1988, and modified in the light of information gathered through field survey.

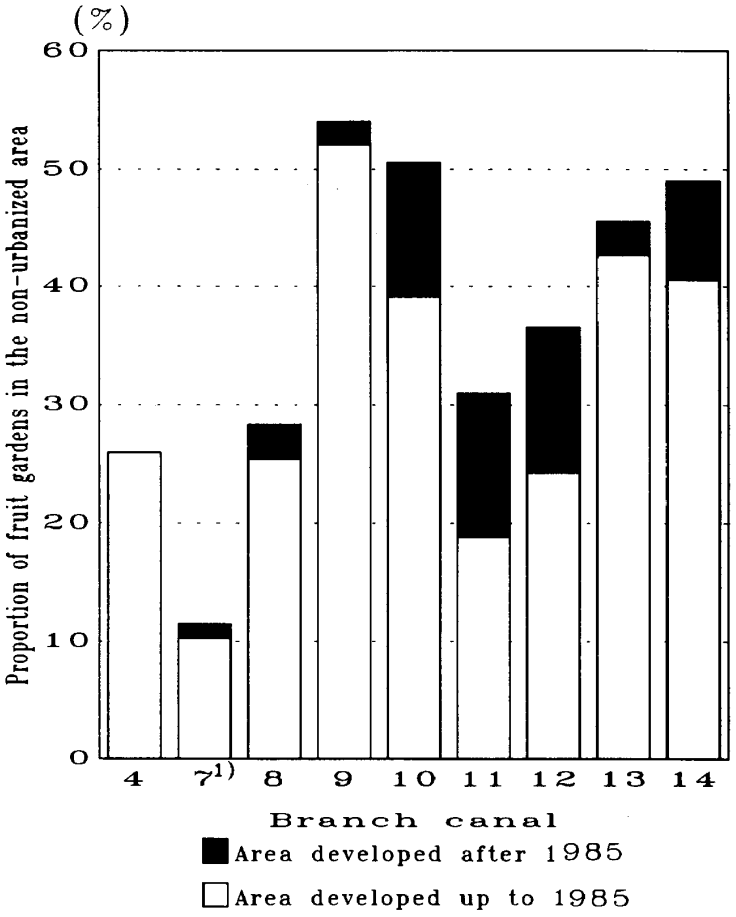

Fig. 8　Recent Fruit Garden Expansion along Different Canals

Note : Estimated from the results of field survey.
1)　Excludes the head reach.

reaches are exceptional : the area proportion of fruit gardens is comparatively low in the head reach of branch canal 7, the middle and tail reaches of branch canals 11 and 12, and the head reach of branch canal 14. This indicates that other constraints on fruit garden expansion operate in these areas as discussed later.

Land suitable for commercial cultivation of fruit and vegetable is also often suitable for urban use, because both require similar conditions such as favorable transportation and freedom from flooding. Moreover, urbanization, as well as the economic growth behind urbanization, are major reasons for the recent expansion of non-rice crops such as citrus. Thus, the effects of urbanization observed in the study area can be expected to arise in most areas where non-rice cultivation is presently expanding or will expand in the future.

V Fruit Garden Expansion in the Land Reform Area

1. *Land Reform Program in the Study Area*

The land reform program in Thailand started in earnest in 1975 under the auspices of the Agricultural Land Reform Office. It aims at providing land to qualified farmers or farmer organizations through hire-purchase, rent or right to utilize [Onchan 1990 : 80]. The land reform program in the study area started in the early 1980s. Land amounting to about 11% of the total study area was expropriated from big landowners and allocated to in situ tenant cultivators and landless farmers coming from outside the area. The farm size allocated was 20 to 30 *rai*, depending on family size. The distribution of the land under the program is summarized in Table 5.

Farmers are recommended to purchase the land allocated to them. However, most lack the resources to do so and therefore rent the land from the Agricultural Land Reform Office, paying an annual rental fee.

2. *Constraints on Fruit Garden Expansion*

Land use inside and outside the land reform area is compared in Table 6. In both areas, single-cropped paddy fields and fallow land mostly occupy only 10 to 20%, and the

Table 5 Distribution of Areas under the Land Reform Program in the Agricultural Area

(unit : %)

Branch Canal	7	8	9	10	11	12	13	14
Head reach	33	52	14	36	12	4	8	5
Middle reach	—	12	4	18	4	1	35	4
Tail reach	—	5	5	0	43	10	15	0

Source : Agricultural Land Reform Office, Bangkok.

Table 6 Land Use inside and outside the Land Reform Area

(unit : %)

Branch Canal	Land Reform Area			Non-reform Area		
	Fruit Garden	Double-Cropped Paddy Field	Single-Cropped Paddy Field/ Fallow	Fruit Garden	Double-Cropped Paddy Field	Single-Cropped Paddy Field/ Fallow
8	16	74	10	32	58	10
9	35	40	25	56	28	16
10	25	56	19	56	25	19
11	13	71	16	34	48	18
12	43	40	17	36	41	23
13	16	71	13	53	25	22
14	19	3	78	50	23	27

Note : The values are percentages of the non-urbanized area.

remainder is occupied by either fruit gardens or double-cropped paddy fields. This indicates that at least as much irrigation water is available during the dry season in the land reform area as outside. The proportion of fruit gardens, however, is significantly lower in the land reform area than outside. Two reasons were identified for this : one is financial, the other relates to farm layout and farm-level infrastructure.

Most farmers in the land reform area are still tenant cultivators, although a few have purchased their land and obtained a land title called S. P. K. 4–01, under which the land can only be transferred through inheritance and cannot be used as collateral for a loan [*ibid.* : 68]. So, even farmers who have purchased their land cannot get loans to upgrade their farms from the formal sector, such as the Bank of Agriculture and Agricultural Cooperatives or a commercial bank. The only possibility is a loan from the informal sector, where interest rates are about five times higher than in the formal sector. Lack of financial support for farm upgrading is one of the major reasons why fruit gardens have not expanded in the land reform area.

Another reason is lack of independent access to a branch canal for irrigation and drainage and to a farm road. In situ cultivators tend to occupy areas along the branch canals due to their long residence, leaving only land away from the canals and roads for allocation to newcomers. Typical patterns of land allocation are shown in Fig. 9 (a) and (b). In the land reform area, citrus gardens have been developed only in plots along a branch canal. The interior plots are mostly occupied by double-cropped or single-cropped rice fields. Citrus gardens require irrigation water throughout the year, while rice cultivation requires it only during land preparation and rice growing periods. Moreover, strict water management during the different growth stages is necessary for a good harvest of citrus, and this requires direct access to an irrigation and drainage canal. Direct access to a farm road reduces labor input for transportation of agricultural inputs and harvests. This land use pattern cannot be operated with a sub-canal in place of a branch canal, since sub-canals function only for irrigation in the rainy season and roads attached are not motorable.

This constraint can be overcome by allocating land as in the non-reform area or by constructing a lateral ditch from the branch canal to the farthest plot. Width-wise allocation of land would lead to a plot layout of around 1,200 m × 30 m, which would increase the area required and cost involved in construction of an encircling farm dike far above the present levels. This allocation would also infringe upon the privileges of in situ cultivators. In the non-reform area along branch canal 9, the cultivators themselves cooperatively constructed a lateral ditch between the branch canal and sub-canal (Fig. 9 (c)). Although not relatives, they were all migrants from Ban Mod who had raised sufficient funds to develop fruit gardens.

Such a spontaneous consensus or farmers' organization for ditch and farm road construction, however, must be difficult to achieve in the land reform area, because cultivators are, in general, financially weak and have different perspectives of future

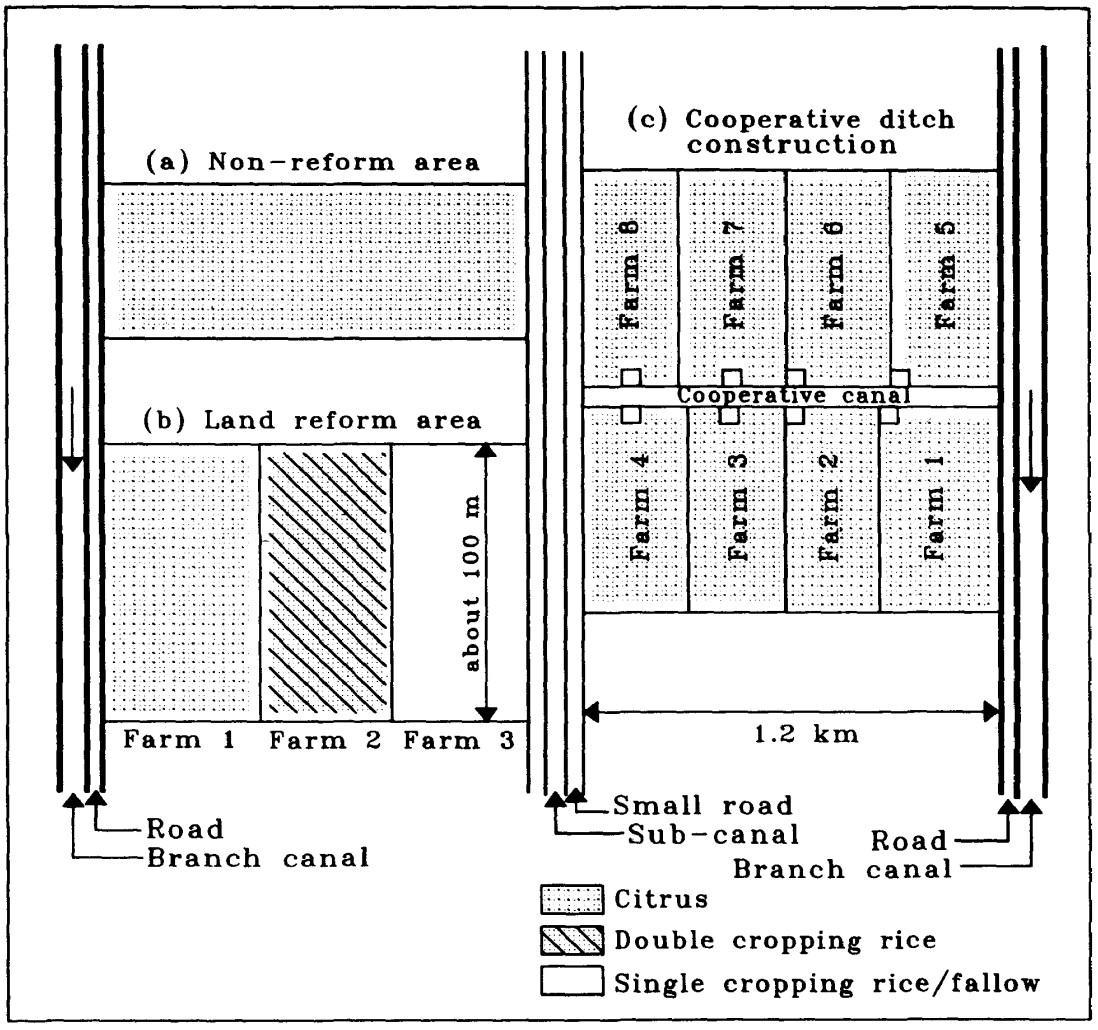

Fig. 9 A Typical Farm Layout in the Study Area

Table 7 Proportion of Fruit Gardens in Non-reform Area

(unit : %)

Branch Canal	7	8	9	10	11	12	13	14
Head reach	2	34	47	45	45	48	47	17
Middle reach	—	37	63	66	26	35	53	55
Tail reach	—	26	56	56	32	26	60	76

Note : The values indicate the proportion of fruit gardens in the non-urbanized and non-reform parts of the agricultural area.

cultivation. Prior construction of lateral ditch and road by the responsible government agency is, therefore, recommended to promote non-rice crop cultivation in the land reform area.

The proportion of non-reform agricultural land occupied by fruit gardens in each reach is summarized in Table 7. Compared with Fig. 7, significantly higher values are

found in the head reach of branch canal 8, the tail reach of branch canal 11 and the middle reach of branch canal 13. This reflects a significant effect of the land reform program on fruit garden expansion.

VI Effect of Flood Control

Heavy rainfall of 300 to 400 mm on two consecutive days in October, 1990 caused inundation damage to plants and farm structures, and affected a series of harvests during the following years in the study area. Some gardeners subsequently raised their encircling farm dikes. The spatial distribution of the floodwater depth at that time is shown in Fig. 10, while the height of the existing farm dikes is summarized in Table 8. Both results indicate that the head reach of branch canal 10, the middle and tail reaches of branch canals 11 and 12 and the head and middle reaches of branch canal 14 have lower elevation thus higher risk of inundation than other reaches.

These reaches have lower proportions of fruit gardens in the non-reform area, while in other reaches fruit gardens occupy 50% or more of non-urbanized and non-reform area (Table 7). This coincidence indicates that a major constraint on fruit garden expansion

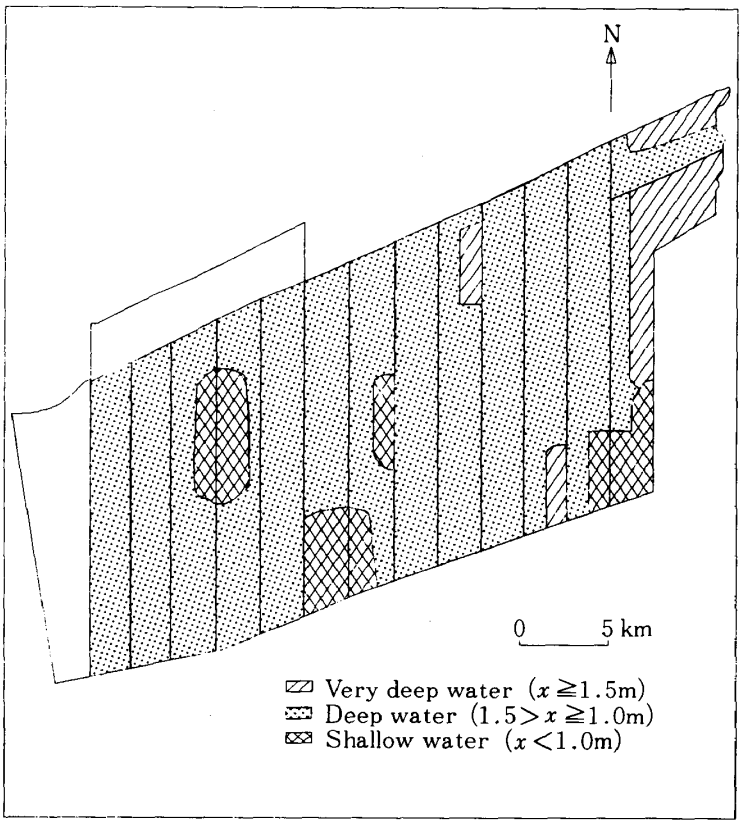

Fig. 10 Variation of Water Depth in the Study Area during the 1990 Flood

Note: Estimated from the results of field survey.

Table 8 Average Height of Farm Dikes

(unit : m)

Branch Canal	7	8	9	10	11	12	13	14
Head reach	1.20	1.36	1.17	1.45	1.30	1.28	1.21	1.28
Middle reach	1.23	0.97	1.16	1.10	1.40	1.17	1.37	1.90
Tail reach	1.14	1.02	1.13	1.11	1.71	1.94	1.32	0.99

Note : Estimated from the results of field survey.

in these reaches is high risk of inundation. Moreover, 1.5 m is estimated to be the maximum height of farm dike that the majority of gardeners can afford to construct under the present economic and technical conditions, because the proportion of fruit gardens decreases in places where farm dikes need to be higher than 1.5 m for flood protection. This finding indicates that the depth of flooding should be controlled within about 1.2 m, considering the freeboard of the farm dike, by the public sector in order to promote fruit garden expansion.

VII Conclusions

An analysis of the effects of irrigation and drainage conditions, urbanization and the land reform program on the expansion of citrus cultivation leads to the following major conclusions.

1) Reliable irrigation water supply during the dry season is prerequisite for substantial expansion of citrus cultivation in the deltaic area. Flooding during the rainy season is tolerable if the depth of flooding is within about 1.2 m.

2) Stability of land use and water availability, including quality aspects, are crucial factors for the expansion of citrus farming, which requires high initial investment but offers high profit.

3) Direct access to irrigation and drainage canals and farm roads is also important to maximize the effect of farm upgrading by farmers.

These conclusions clearly reflect the differences between monoculture of rice and recently expanding diversified farming in the Chao Phraya delta. Rice was previously profitable owing to the favorable natural environments over most of the delta during the first and second stages of the delta development. On the other hand, the original natural environments are not suited to diversified farming, and upgrading of farming conditions is essential for crop diversification. Moreover, the high investment for upgrading farm conditions requires long-term stability of land use and reliability of irrigation and drainage conditions. Flexible land and water resources management by government agencies based on a short-term perspective discourages farmers from upgrading their farms and hinders crop diversification, though it could maximize benefits of the government as well as cultivators when rice was the unique target crop.

Therefore, it is recommended to related government agencies that long-term plans be established for land use, that irrigation water supply during the dry season be stabilized and ensured based on long-term planning of water resources utilization, and that development of farm-level infrastructures such as irrigation and drainage canals and farm roads by farmers be promoted in order to encourage farmers to diversify their farming.

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