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Water Management and Agricultural Change: A Case Study in the Upper Chao Phraya Delta

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I Background and Presentation of the Study

Landform and water regimes in deltaic areas are rather varied, as typified in previous extensive work by Takaya [1987]. In the Central Plain of Thailand, we can distinguish the southern part, or young delta, where elevation is lower than 2 meters, the land extremely flat and where water accumulates in the late rainy season. The northern part can be divided in two sub-regions: the first is often referred to as the *old delta,* because it corresponds to the former dejection fan of the Chao Phraya river, whereas the second is a complex set of flood plains which covers an area situated between the Lop Buri and the Noi rivers (Fig. 1).

These two sub-areas have a smooth relief, with alternating high natural levees—generally located along waterways—and depressions lying 4 meters lower, thus standing in sheer contrast with the southern part of the delta. The upper delta has long been inhabited and has been under Khmer influence before the Thai settled in larger numbers in the area: the first settlers naturally took advantage of the natural levees to set their stilt houses, plant backyard orchards, and cleared some of the lowlands to go in for extensive rice farming.

The water regime in the old delta and in the flood plain was extremely variable: in the rainy season, only the highest parts would remain unaffected by the flood, whereas rice cultivation in the lower parts, subject to hydrological risk and climatic hazards, was conducted with deep water or floating rice varieties, according to the local water regime. During the dry season, water would recede and remain trapped in numerous depressions and backswamps (*bung*). In the old delta, trees and bamboo groves long remained dominant until they vanished in the middle of this century, whereas in the flood plain rice cultivation was already covering most of the area at least 50 years earlier.

From the fifties onward, these natural conditions have been gradually modified by huge works of land development undertaken by the Royal Irrigation Department, first coming under the *Greater Chao Phraya Project (1952–1958).* This project aimed at

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implementing a network of irrigation canals to deliver water to the high or medium elevated land, thus expanding cultivation. The construction of the Chao Phraya diversion dam and several regulators on the Tha Chin and Noi rivers allowed the water level to be raised in some points from which canals would branch off and deliver water to areas deprived of a natural flood regime.

The delivery of additional water through the irrigation canals benefited part of the highest land but, on the other hand, tended to worsen the situation in the lower parts, where poor drainage conditions could not cope with this excess water [*idid.*]. This drawback was further partly offset by drainage improvement works and by the construction of regulators in some control points of the drainage system initiated in 1965 [Kaida 1978].

This case study presents a description of the transformation which occurred from this point in one area of the old delta, located in the south of the Borommathad Irrigation Project. The study area lies between the Provinces of Chai Nat and Sing Buri (see Fig. 1) and covers approximately 6,000 ha (37,000 rai[1]). It is bordered on the east by the Noi river and on the west by an old waterway (now turned into a canal: 1 R), both of which show rather dense settlements on their levees and evidence of ancient occupation.[2] Its southern limit is the trunk canal of the Chanasutr Project, which angles westward from the Noi river, and its northern limit is an area provided with on-farm development in which conditions of water control are comparatively superior.

Fig. 2 shows the contour map of the area. The levees, along the rivers, are generally between 12 and 13 meters elevation, whereas the inner lowlands lie between 9.50 and 11

Photo 1 Drain Regulator (km 21 + 300)

1) one hectare = 6.25 rai

2) A square area, with a cardinal orientation and a large surrounding ditch (*khu boraan*) can be found in the area and probably dates back to the Khmer period.

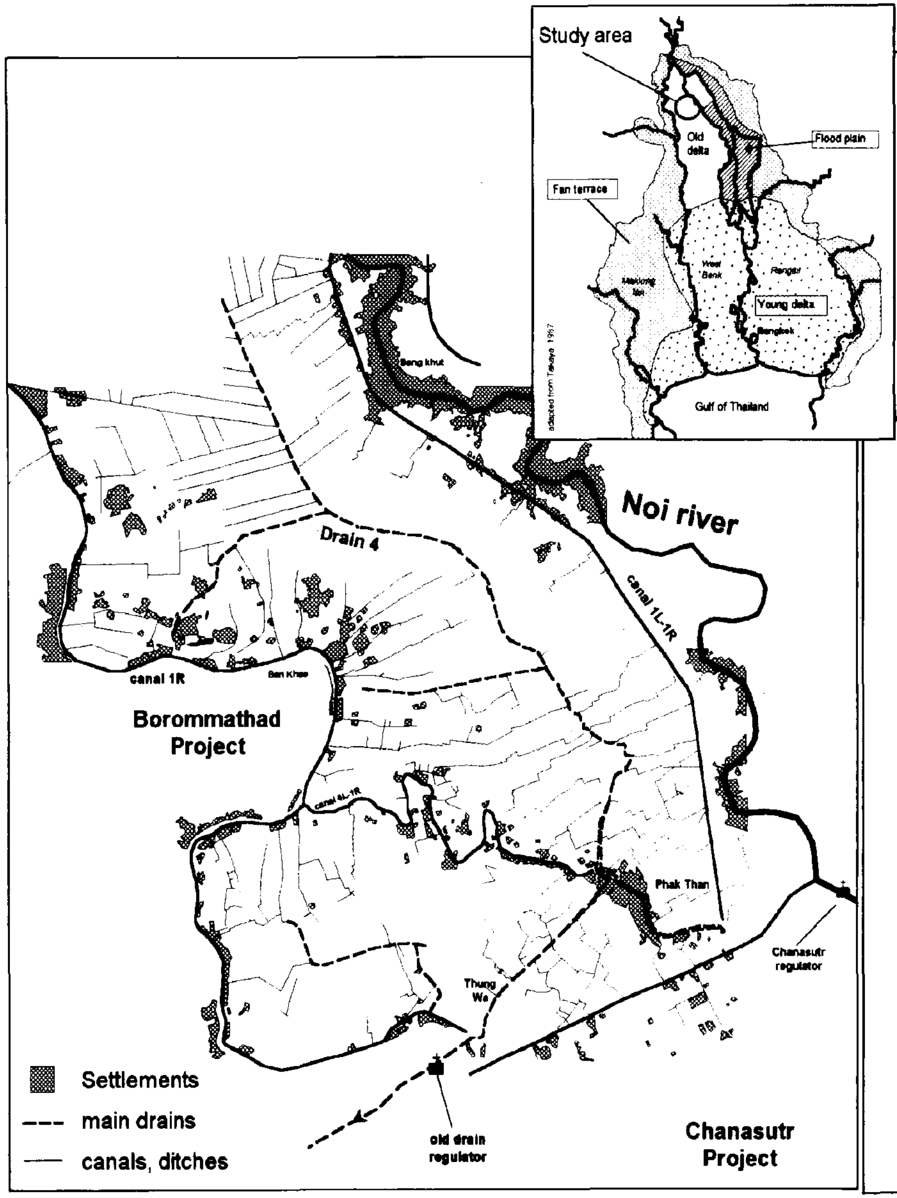


Fig. 1 Study Area

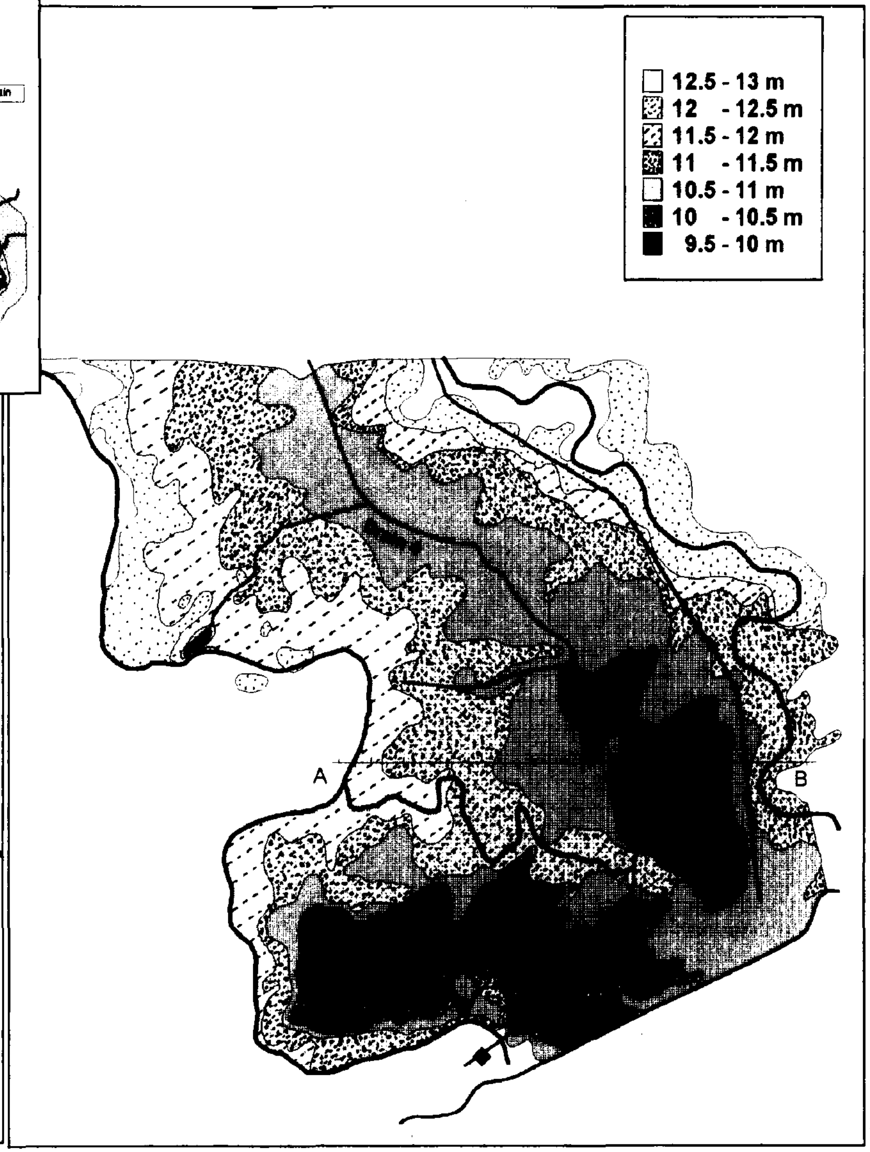


Fig. 2 Contour Map of the Study Area

m. All the area drains toward drain No 4, which has been partly excavated and rectified based on some former natural drainage water courses. The drainage outflow is controlled by a regulator located at the downstream extremity of our area (see Fig. 1 and Photo 1).

The irrigation system in the area suffers from the same overall limitations which can be observed in the northern delta [Wickham and Plusquellec 1985]. The main system is constituted by primary and secondary earth canals, designed to complement irrigation in the rainy season and with often poor regulation devices. The water level in the canals is often too low (especially during the dry season and at the onset of the rainy season), compelling farmers to resort to pumping in order to lift water into the ditches. On-farm development is poor: whereas most of the upper part of the Borommathad Project has been provided with land consolidation, few ditches could be found in the area until recently.

This case study considers concomitant changes regarding water management and agricultural patterns in the three past decades. A wider scope is later considered to discuss transformations of the hydrological regime and to draw prospects for future improvement of agriculture in the upper delta.

II Characterisation of the Agriculture in the 1960–1990 Period

In order to understand how the recent transformation occurred, we will first of all draw a brief historical retrospective of land development in the area. To exemplify it, we will consider the toposequence AB indicated in Fig. 2.

In the lowest parts, rice cultivation is traditional: before the advent of irrigation (1962), deep water rice was cultivated, either by transplanting—the most common case—, or by dry broadcasting after ploughing the land at the onset of the rainy season. The water regime was not regulated but flooding was mild enough to make the use of floating rice unnecessary. Yields were rather satisfactory, due to the high natural fertility of the inner lowlands [Fukui 1978]. The middle and upper locations were covered with bamboo and rather dense forests (Fig. 3). The rice cropping area as found in 1910 is indicated in the inset in Fig. 4 ; it represents about 45 % of the area.

After the implementation of the irrigation canals, excess water drained from the upper parts (which had gained access to irrigation deliveries), and eventually increased the average water level in the valley. As a result, in the beginning of the sixties, some farmers had to go to the Ayutthaya region to purchase varieties of floating rice in order to adapt rice cropping to the new water conditions. At that time, the increase in population density and the possibility of using irrigation water contributed to a swift expansion of rice fields : the forest area shrank and became an open forest (with canopy between 25 and 75 %). Fig. 4 shows the situation in 1969.

With the increased use of late-maturing (floating rice) varieties (*khaw nak*), regula-

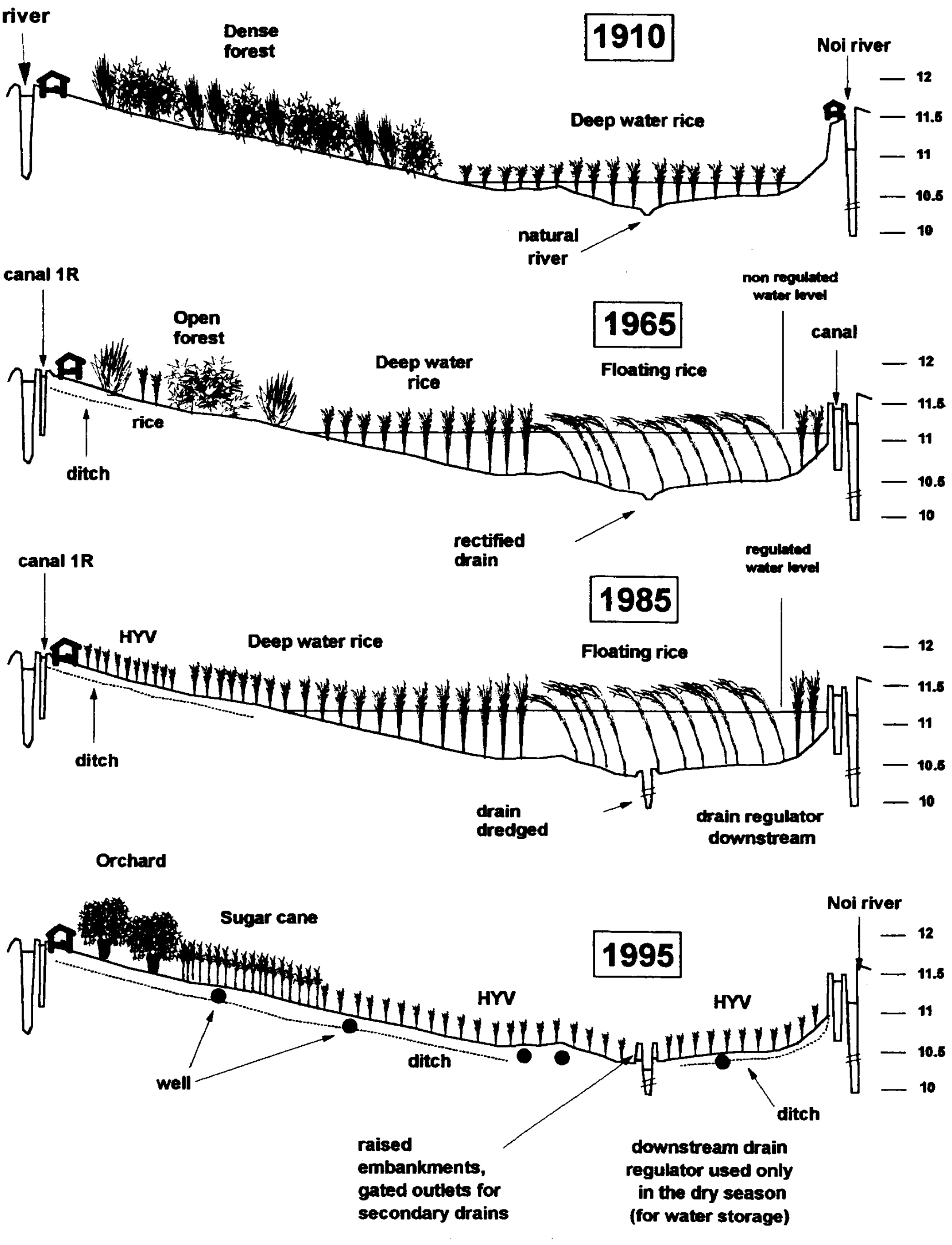


Fig. 3 Cross Section AB—Evolution of Land and Water Use

tion in the drainage system was soon deemed necessary, in particular because water tended to recede too fast : a regulator was constructed in 1971, in the main drain No 4, by the Provincial services concerned. This regulator, like all such structures constructed in the drainage system of the upper delta, has several roles :

- to raise the water level up to higher lands which—in some areas—are lacking a proper irrigation system ;
- to sustain the medium or long duration rice varieties at the end of the year, when

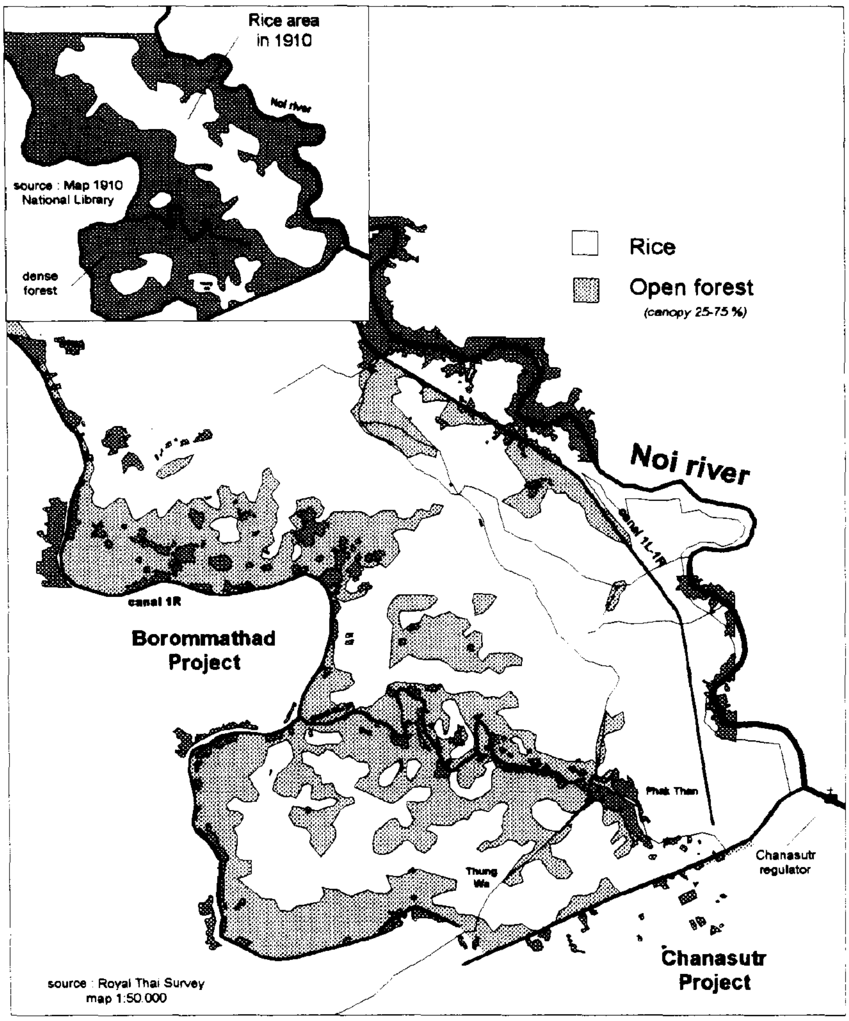


Fig. 4 Rice Traditional Varieties in the 1969 Rainy Season

water is likely to recede rapidly ;

- to regulate the water level in the flooded areas, in particular by preventing higher water levels in downstream areas to backlash in them ;
- more recently : to help storing water in the drain for later use in the dry season ;

Such regulators are therefore managed in order to maintain a constant water level in the upstream area: they are opened in case of excess flow and closed in case of insufficient runoff. At last, they are fully opened in December in order to drain the area before harvesting.

From this point, rice cultivation stabilised: in the lowest parts, deep water and floating rice varieties were grown according to topography, mostly with transplanting but this situation progressively reverted in favour of dry broadcasting in the late seventies and eighties, because of labour constraints. Harvesting was manual and sometimes had to be carried out with boats. Main floating rice varieties were ***khaw lamyay, khaw kon keew, khaw hom thong*** and deep water rice, ***khaw taa heng, luang pratiew***

Table 1 Rice Varieties Used in the Study Area

• Deep water varieties (non floating), before 1991		
khaw luang	khaw wang thong	khaw pakuat (f?)
khaw taa heng	khaw luang thong	khaw luang pratiew
khaw jet luang	khaw luang oon	khaw prayachomngen
khaw phuang	khaw phuang thong	choasoi, choanoi
porn sawan (?)	khaw foun	
• Floating rice varieties; before 1991		
khaw lamyay	khaw hom thong	khaw metlek
khaw lep muu naang	khaw khon keew	jampaa khaaw
• First HYV used (at the beginning and before the change)		
KK3, KK 7	KK 23	Suphan 90
• Actual HYV used		
Chainat: 95%	Others: KK9, KK 35: 5 %	

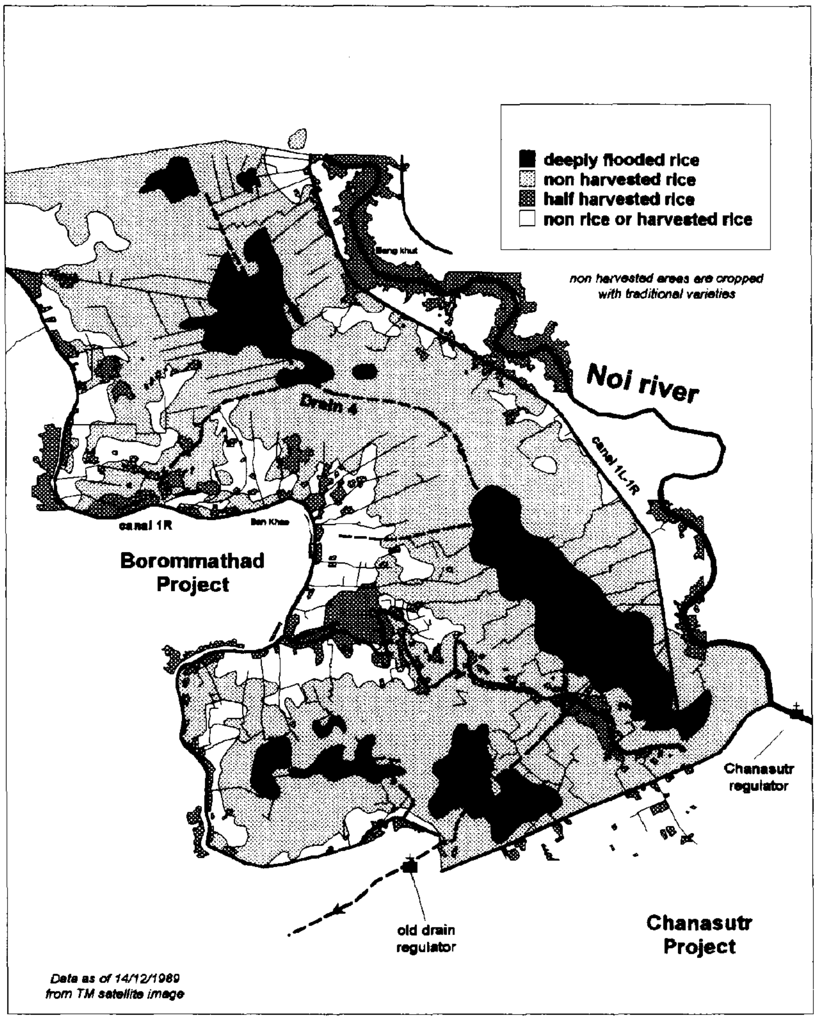


Fig. 5 Rice Area in the 1989 Rainy Season

and *khaw pakuat* (see detail in Table 1). In the highest parts, where the risk of flooding was low and where the proximity of irrigation canals allowed adequate land preparation, High Yield Varieties (HYV) appeared in the late seventies but remained limited to approximately 10 % of the area. On these plots, transplanting was replaced by wet broadcasting (*nam tom*), following labour shortage experienced in the whole Central Plain [see Kasetsart University/ORSTOM 1996]. Double cropping was also possible in some years, when water deliveries were sufficient,[3] but little developed.

In the eighties, the whole area was cleared and was grown exclusively with rice. Only traditional orchards and bamboo groves around the habitations broke the monotony of the paddy fields (Fig. 3). Fig. 5 shows the extension of the non-harvested rice in the middle of December 1989, with darker areas which corresponds to deeper flooding (see correspondence with the topography map). Higher locations along the canals appear in clear on the satellite image and were planted with medium duration rice varieties together with some HYV, both already harvested in the middle of December.

III The Turning Point: 1991

The situation outlined above, although little prone to risk and akin to "traditional" rice cultivation in the Central Plain of Thailand, soon appeared to be suffocating any chance of agricultural change. On one hand, little benefit had resulted from the irrigation infrastructure. On the other hand, constrained by a water management which resulted in flooded (but controlled) conditions in most of the area, the agriculture could hardly develop or diversify beyond the point of a single cropping of traditional rice varieties: this meant that farm income was drastically limited by yields ranging between 1.2 and 2.4 t/ha (20 and 40 thang/rai[4]). Farmers, after having cleared the whole area, thus endeavoured to increase marginally their productivity through some intensification. Such attempts remained limited to some rare cases of fertiliser use, in areas where water movements were controlled or reduced.

Aware of the benefit which can be drawn from improved water control—the area is located between two areas where land consolidation has been carried out almost two decades ago—, some farmers started to envisage the possibility of drastically changing the water management: instead of retaining water in the drain, the regulator could be kept full open in order to lower the average water level in the area and to allow the expansion of short-stemmed HYV.

Such a desirable change, however, hinged on the assumption that the following constraints could be given positive answers:

3) In the whole upper delta, during the eighties, dry season scheduling was done on a rotational basis: half of each Project was granted water every second year.

4) 1 thang = 10 kg, 10 thang/rai = 62.5 kg/ha

- in case of heavy rainfall, would the drainage system be able to evacuate excess water, without damage to the crops (short-stemmed HYV)?
- what would be the situation of people in medium or low topographical position with no more controlled standing water in their plots and no access to water from the irrigation canal?
- in particular, in case of bad access to water, how would they perform the land preparation required by HYV (puddling)?

Meetings were held among all the heads of villages (*phuyaybaan*) of the concerned area, under the initiative of *kamnan* Thanon of the Phak Than sub-district (*tambon*), located in the middle of the area, along the main drain. All agreed that a change of water management was both desirable and practicable, at least worth a try. This consensus was then conveyed to the *amphoe* authorities, who were in charge of the regulator and endorsed the decision. In the rainy season of 1991, water management was thus radically changed and the shift eventually proved successful.

All the farmers (a minority), who had not adapted at once their rice-farming to the new conditions, did it in the ensuing three or four years. Nowadays, the entire area, with few exceptions, is cropped with HYV and multiple cropping is dominant.

IV A Closer Look at Causes and Consequences

This overall change must however be specified by looking at transformations at farm level. A survey was carried out on a sample of 44 farmers, aimed at analysing change in water regime, water management and land use. A total of 84 plots belonging to these 44 farms have been considered (rice: 55 + sugarcane: 29).[5]

IV-1 *Rice Cropping*

Traditional cropping of deep-water and floating rice varieties, as found before the turning point of 1991, yielded production ranging from 1.3 to 2.5 t/ha (20 to 45 thang/rai), with an average of 2.2 t/ha (35 thang/rai), with no (or very little) application of fertiliser and predominant use of dry broadcasting.

Current rice farming with HYV is characterised by the use of *nam tom* (wet broadcasting) and of the Chainat variety, which substituted KK 23 in the last five years (the

5) Farmers have been randomly selected but they all live within the area: they therefore tend to have their plots close to their house; as the houses are located in the higher parts, the sample is likely to give more emphasis to plots in high location: this may eventually constitute an advantage because the conditions in the lower parts are much more uniform: everywhere rice cropping has shifted from traditional varieties to HYV after 1992 (2535), whereas in the higher parts HYV have sometimes been adopted before that date.

Table 2 Range of Yields for HYV (rainy season)

<= 60 thang/rai	61–70 thang/rai	71–80 thang/rai	81–100 thang/rai
10%	19%	44%	27%

latter is said to be more prone to pests and to be paid a lower price). But for few exceptions, the shift from deep water rice to HYV went alongside a shift from transplanting to *nam tom*. Average yields in bad years are as low as 3.6 t/ha (57 thang/rai), with a corresponding 5.6 t/ha (89 thang/rai) in good years. Overall average values follow the pattern given in the table above, with a global average of 4.8 t/ha (77 thang/rai). Yields in the dry season are slightly higher, but not significantly (81 thang/rai).

Fertilisation is quite uniform, with two applications of mixed urea (46–0–0) and (16–20–0). Fifty-two percent of farmers apply a total quantity of 50 kg per rai, 6 % less than this value, 38 % between 51 and 75 kg and 6 % between 76 and 100 kg.

Herbicide is used one time, either at the time of sowing, or after a few days. Pesticide applications vary a lot, from zero to four or five times according to pest pressure, with an average of 2.6 applications for both rainy and dry season.

Harvesting is almost entirely mechanised, with only 5 % of the area still harvested by hand, especially some of the remaining traditional varieties.

Khaw dok mali, khaw taa heng, khaw pakuat and *khaw lamyay* can still be found in scattered spot areas. Fig. 13 shows some of these locations, which correspond to limited depressions with poor drainage : the largest of these areas is located on the eastern part, along a former river associated with a *bung*, and covers approximately 150 rai. They are still cultivated with the dry broadcasting technique, unless they are associated with dry season cropping, in which case wet broadcasting (*nam tom*) will be used in both seasons.

Costs of production have been specified in order to assess the economic benefit of the transformation (see Table 3). We considered the average values of the different variables recorded in our survey and two hypothesis regarding labour. The "hired labour" case corresponds to farmers deprived of labour force—old people or single woman—who have to hire labourers for the whole of the tasks. The "partial labour" case corresponds to the more common situation in which farmers take care of land preparation, broadcasting, fertiliser application and crop maintenance, relying on hired labour only for harvesting and sometimes for chemical application. Amortisation and maintenance of equipment were computed as 50 baht/rai [OAE 1995], whereas land tax or rental fee were not considered (in any case, they are supposed to be similar for both rice and sugarcane). These calculations concern cash income and do not consider the opportunity cost of family labour.[6)]

6) Crop care and water management, valued at around 130 baht [OAE 1995], were considered carried out by the farmer himself and therefore not computed.

Table 3 Average Cost of Production of HYVs (per rai, in the rainy season 1995)

Input		Labour	Hired	Partial
Fertiliser	372	Land preparation	240	0
Pesticide	65	Spray	70	23
Herbicide	58	Fertiliser application	40	0
Seeds	75	Harvest	328	328
Benzene (pumping)	29	Rice transport	100	100
Equipment/amortisation	50	Crop care/water manag.	(130)	0 not considered
Yield (kg/rai)	770	Selling price (baht/ton)	4,491	
Land tax and rental fee not considered				
Gross income:	3,458 baht			
Total cost (hired labour)	1,466	Net income	1,992 baht/rai	
Total cost (partial labour)	1,084	Net income	2,374 baht/rai	

Note: Family labour not included

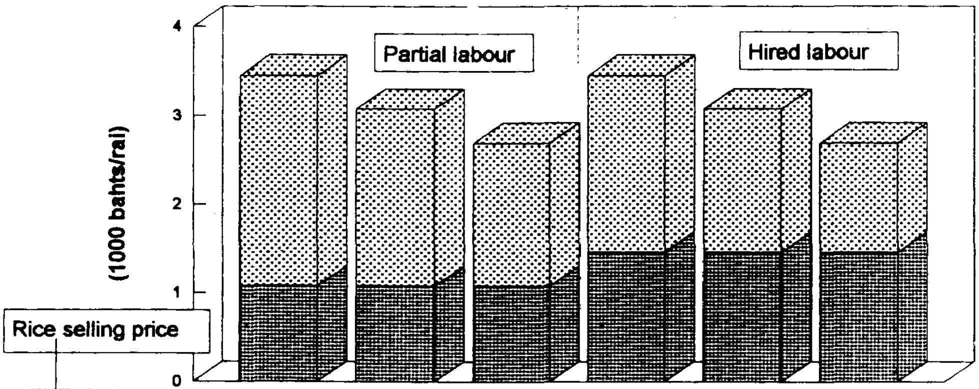
Under an average selling price of 4,491 baht[7]/ton in the last rainy season, which can be considered quite high, net incomes per rai amount to 1,992 and 2,374 baht for the two hypothesis on labour (1,000 baht/rai = 250 US $/ha). The corresponding total costs of production represent 41 % and 32 % of the gross income respectively. Fig. 6 gives the net income computed for the two hypothesis and for lower average selling prices of 4,000 baht and 3,500 baht/rai. Such prices are common, in particular in case of over production or high moisture content of the rice grains. In such cases, the net income is always less than 2,000 baht, and as low as 1,230 baht for the "hired labour option" and a price of 3,500 baht/rai. Figures for dry season cropping are very similar; yield is slightly higher together with the average cost of pumping.

If we consider similar calculations for cropping of traditional rice varieties (see details in Table 4), we find a net income of 820 or 940 baht/rai, according to whether land preparation (done by 4 wheel tractors) is hired or not. Cost of harvesting is often higher because of the propensity of deep water rice for lodging.

In four cases (of our sample), double rice cropping started 10 to 20 years ago. At that time, dry season cropping depended upon water delivered every second year (rotation system) and often in insufficient quantities. After 1991, dry season rice soon covered a good part of the area. Farmers with plots poorly or not supplied by the ditch system in the wet season had no choice but to dig individual tube wells. These wells were of course further used in the dry season and many other farmers followed the same trend, also digging their own wells. At the same time, this process was accelerated by government subsides to dig wells, firstly collective ones to tackle water shortages, secondly individual ones for purposes of agricultural diversification.

On top of the development of double cropping, several cases of triple cropping have

7) 1 US $ = 25 baht



(bahts/ton)	4 491	4 000	3 500	4 491	4 000	3 500
Production cost	1 084	1 084	1 084	1 466	1 466	1 466
Net income	2 374	1 996	1 611	1 992	1 614	1 229

Fig. 6 Net Income of Main Rice Cultivation

Table 4 Average Cost of Production of Traditional Varieties (per rai, in the rainy season 1995)

Input		Labour	
Fertiliser	66	Land preparation	120
Pesticide	0	Spray	0
Herbicide	0	Fertiliser application	0
Seeds	75	Harvest+post harvest+transport	380+60
Benzene	0	Crop care	0 not considered
Yield (kg/rai)	350	Selling price (baht/ton)	4,491
Amortisation and maintenance of equipment	25		
Gross income :	1,547 baht		
Total cost	726	Net income	820 baht/rai

Note : Family labour not included

been observed : isolated cases, relying mostly on tube wells, and a quite significant area, located in the southern part of the area, which benefits from supply of the main canal of Chanasutr.

IV-2 *Water Conditions*

This agricultural change was a result of the transformation which occurred in both irrigation and drainage. Before analysing the conditions of water use and control at plot level, we will describe the overall changes which have occurred.

Overall Transformation

Firstly, the success of the "full drainage" management has been possible because of the continuous improvement achieved in the drainage system. This concerns the main drain No 4 in our area, as well as its continuation down to the Tha Chin river, some 30 km further downstream.

As shown in Fig. 7, the reach south of Phak Than was dredged by RID in 1988 (2531)

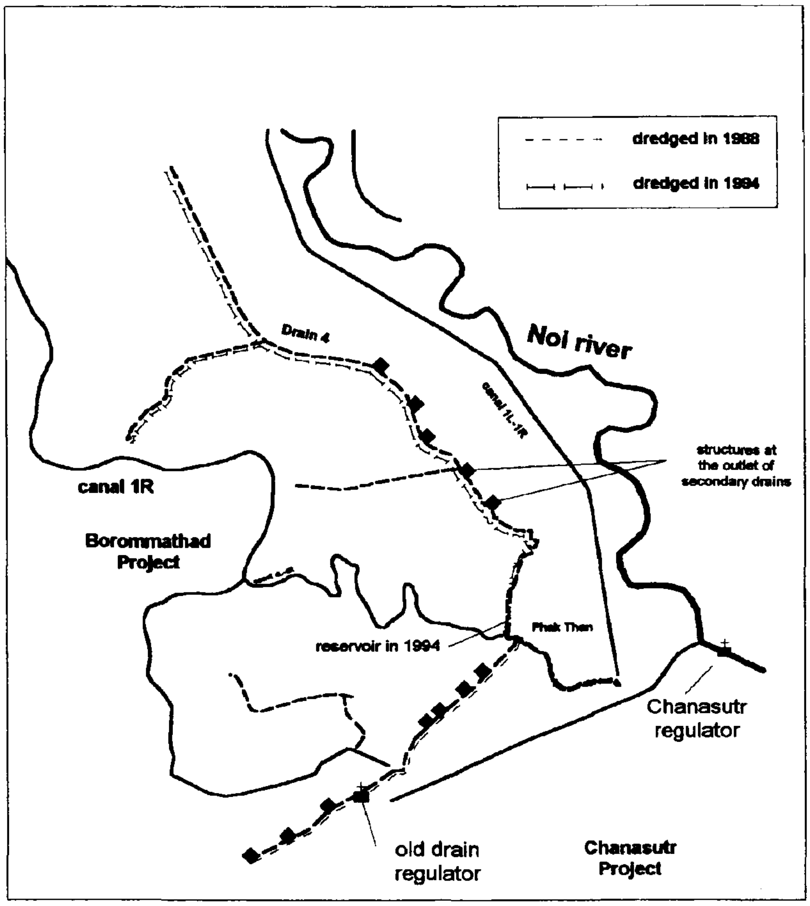


Fig. 7　Drainage Improvements

and 1989, whereas the 18 km length of the upper reach was entirely dredged in 1994 (2537). At the same time the drains were dredged, their berms were raised by the deposit of the material excavated from the bed of the channel. The dikes then protected the fields from possible spill from the drain.

Such a system also demanded that the outlet of the secondary drains which flow in drain No 4 be protected by adequate structures in order to prevent a backlash effect into the fields when the water in the drain is higher than in the plots. Also shown on Fig. 7 are the structures constructed by RID for this purpose; this system is now almost complete. In case of water intrusion in the field, RID sets some pumping equipment to drain the water out in order to relieve the crops.

Continuous road and dike construction is another relevant factor which also accounts for hydrological change. Embankments tend to cut or delay the runoff and therefore to contribute to lessen the drainage requirements.

Regarding water distribution, the change of water management deprived water from all the plots which did not have access to irrigation water (canal, ditch, or drain by pumping). This relates to the poor ditch distribution system of the area which had long limited the benefit of irrigation infrastructures. Three main situations were encountered :

- the plot had already access to some ditches ; since 1984 (2527) onward significant investment had been made by local administrations, through projects such as *KoSoCho* or *Nuan phasii* (*changwat* 20 % ; *amphoe* 10 % ; *tambon* 70 %), to develop the ditch system in the area. This strongly contributed to extend the use of irrigation water.
- the plot was out of reach of the existing ditch network, but investments made by the farmers allowed the expansion of this down to their fields.
- the plot was clearly unlikely to be reached by any ditch (due to distance or topography) ; in that case farmers had no choice but to resort to individual well digging. This, together with the water shortage experienced in the 1990–1994 period, gave way to the mushrooming of tube wells in the area,[8] as commented earlier. In particular, all the plots newly planted with sugarcane have been equipped with a well, as we will see later.

Actual Situation at Plot Level

The diversity of water accesses at the farm level is highly demonstrative of the heterogeneity of the irrigation scheme. Several situations can be encountered :

- the plot has direct access to the canal, either by pumping or gravity
- the plot has access to a ditch, either by pumping or gravity. In that case the diversion of water from the main canal to the ditch may also require pumping, especially in the dry season.
- the plot has access, by pumping, to other types of water source : drain, well, pond
- the plot has access to several of the above sources (the main one being the *primary source*, the other ones being *secondary sources* in what follows).

The quality and level of reliability of all these water sources often vary throughout the year (with contrasting situations between the rainy and the dry season), and from one year to another. The following table tries to assess the frequency of each situation encountered in the survey. For the whole area, however, the percentage of gravity irrigation with plot to plot systems would probably be higher (see comment in note 3).

Water delivered by the irrigation network (canal + ditch) is the main source of water for 78 % of the plots in the rainy season, but this share goes down to 48 % in the dry season. On the other hand, primary use of wells is 11 and 41 % respectively (Table 5). Plots located along the main drain, and therefore at the very end of the ditch system, rely on pumping from the drain all through the dry season, and for land preparation in the rainy season.

The right part of Table 5 shows the frequency of pumping, including pumping from

8) According to RID data, 5,000 wells used for agriculture have been dug in the Borommathad Project, 6,000 in the Chanasutr Project.

Table 5 Features of Water Use in Rice Fields

	Frequency of Use of:				Frequency of:		
	Ditch	Canal	Drain	Well/Pond	Pumping from Ditch to Plot	Pumping from Canal to Ditch	Pumping for Drainage
Rainy season					28 %	15 %	17 % often
Main water source	70 %	8 %	11 %	11 %			20 %
Secondary source	7 %		2 %	20 %			sometimes
Dry season					57 %	43 %	
Main water source	41 %	7 %	11 %	41 %			—
Secondary source	14 %		4 %	25 %			

canal to ditch (when the water level is too low), from ditch to plot, and pumping for drainage purposes (from plot to ditch or plot to plot). Pumping appears to be quite common, even in the rainy season (especially at the onset of the season), and cases of two-step pumping (canal ⇨ ditch ⇨ plot) are not rare in the dry season.

On the whole, additional water sources, especially wells which are used by two thirds of the farmers, together with individual pumping, appear to contribute significantly to lessen shortcomings in the water distribution. All the farmers have a pump without exception and often two or more.

Among the 29 plots of sugarcane considered in our survey, 18 are said to be high land (*thi don*), 6 medium and only 1 low land. The soils are correspondingly loamy to sandy (*luan* or *luan phon say*), with poor levelling.

In the rainy season, 71 % of the sugarcane plots rely on water from the ditch, 24 % on wells and 5 % on both or other sources. In the first case, pumping is nevertheless necessary in almost half of the plots, in general to raise water from the ditch to the furrows. In the dry season, only 5 % of the plots rely on the ditch. The remaining have to rely fully on underground water (33 %) or on both well and ditch (62 %), with pumping being always necessary (from the well, from canal to ditch and from ditch to plot). Almost all the farmers have dug one or several wells when shifting to sugarcane and this can be regarded as a prerequisite to such a shift.

Although drainage conditions are generally good, pumping out of the field is sometimes necessary. Last year, half of the plots had to rely on pumping, sometimes during two months non stop. These occurrences of flood have had a negative impact on sugarcane growth and resulting yields. Nevertheless, it is worth noting that mature sugarcane can stand water logging for a quite long duration without being totally lost, such as what happens with rice (which would be submerged under similar conditions) or fruit trees.

IV-3 *Emergence of New Crops : Sugarcane and Orchard*

The Booming Expansion of Sugarcane

Although it can be found since almost 30 years in the nearby Chanasutr Project, sugarcane was absent in the area ten years ago and appeared only in 1989 (2532). Under the then prevailing water conditions, its cultivation was drastically constrained or impeded. The change of water management happened to give way to a dramatic expansion of sugarcane cultivation in the area, the farmers have responded to the new possibility which was offered to them.

The reasons for such a surge are threefold : firstly the existence and proximity—since 1973—of a sugar mill located approximately 20 km south of our area, was a prerequisite to any cultivation. Secondly, once the drainage conditions were made suitable to sugarcane cultivation, water could be supplied by both ditches and additional tube wells. Thirdly, this option eventually was coherent with the farmers' objectives and constraints.

Sugarcane has two main advantages for the farmers : on one hand, it is claimed to be more profitable than rice cultivation and to have prices less subject to fluctuation and uncertainty. On the other hand, it requires less labour and care. However, these statements must be considered cautiously. First of all, we must analyse in detail the costs of production of sugarcane and its comparative profitability with rice cultivation (see details in Table 3).

Compared with rice, the fixed costs of sugarcane are quite high : crop establishment represents a significant investment, with ploughing, furrowing, seedling, application of *furadan* and urea, and planting. Detailed cost would amount to 2,790 baht/rai but farmers most of the time hire the complete service of crop establishment and this totals an average of 3,400 baht. This investment is made for an average of three years (first year + two ratoon crops). Similarly, harvesting is completely left under the responsibility of the head of quota : burning, cutting, loading and transporting represent a toll of 210 baht/ton which is subtracted from the selling price (520 baht/ton for last year). Fertilisation (97 kg of mixed urea and secondary formula such as 16–20–0) and herbicide also account for significant unavoidable costs.

Crop maintenance is generally provided by farmers. Income will therefore depend a lot on the average yield obtained over the three years. The yield generally decreases each year and production around 9–10 ton/rai is considered the least acceptable one. Precise data on yield for three consecutive years is hard to obtain from farmers. This year, in particular (1996), yields have been lower than expected because of excess water in ill-drained plots. We have considered for our calculation an average of 14 ton/rai (17, 14 and 11). This gives an average net income of 2,377 baht/rai.

Fig. 8 shows how this income varies with the average yield and the number of ratoons. In case of lower average yields (flood, disease, poor irrigation, etc.), the net

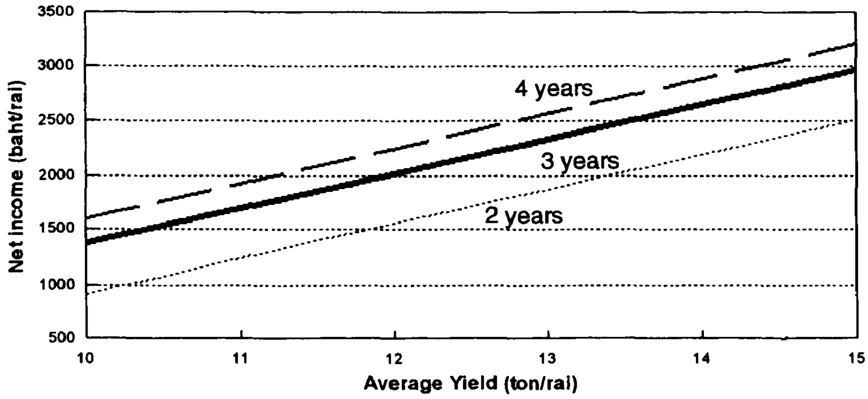


Fig. 8 Net Average Yearly Income of Sugarcane with Yield and Number of Years of Cropping

income will quickly fall under the threshold of 2,000 baht/rai: this can lead farmers to renew their seedlings after a single ratoon, with a disastrous impact on profitability which will fall under 1,500 baht/rai.

This average income (2,377 baht/rai) is similar to the one obtained for rice single cropping, which partly dismisses the claims that sugarcane is more profitable than rice. This comparison is eventually highly dependent on the respective selling price of rice and sugarcane. In order to get a vision of their relationship over a longer period, the corresponding net incomes have been computed for the last 12 years. Selling prices have been actualised based on the inflation index and production costs have been assumed unchanged.[9] Fig. 9 shows the trend of rice and sugarcane net incomes over this period. We observe that, since 1986, with the exception of 1994 and 1995 in which the price of sugarcane soared up. The rice income is quite significantly higher.

Figs. 11 and 12 display the evolution of rice and sugarcane selling price, both absolute and actualised. The standard deviations of the actualised selling prices are 15 and 21 % for rice and sugarcane respectively. It shows that farmers (and policy makers) may not be right in arguing that the rice price is more unpredictable than the one of sugarcane, which is often mentioned to explain the shift from rice to sugarcane. In addition the distribution of the yearly income derived from sugarcane is much more uneven: because of the investment required in the first year, the corresponding first year income is close to zero which constitutes a draw back of sugarcane.

Nevertheless, two slumps in the rice price can be noted in the recent years, in 1990 and 1993. This undoubtedly had a decisive psychological impact, as the sugarcane selling price increased at the same time. It contributed to spur sugarcane cropping in our area, disappointed farmers trying to look for other options, and sugarcane being the most easily accessible and allowing the farmer to revert to rice farming in case of failure.

9) In other terms, we assume that all costs have followed the inflation curve during the last 10 years. This is an approximation, especially for the price of fertiliser.

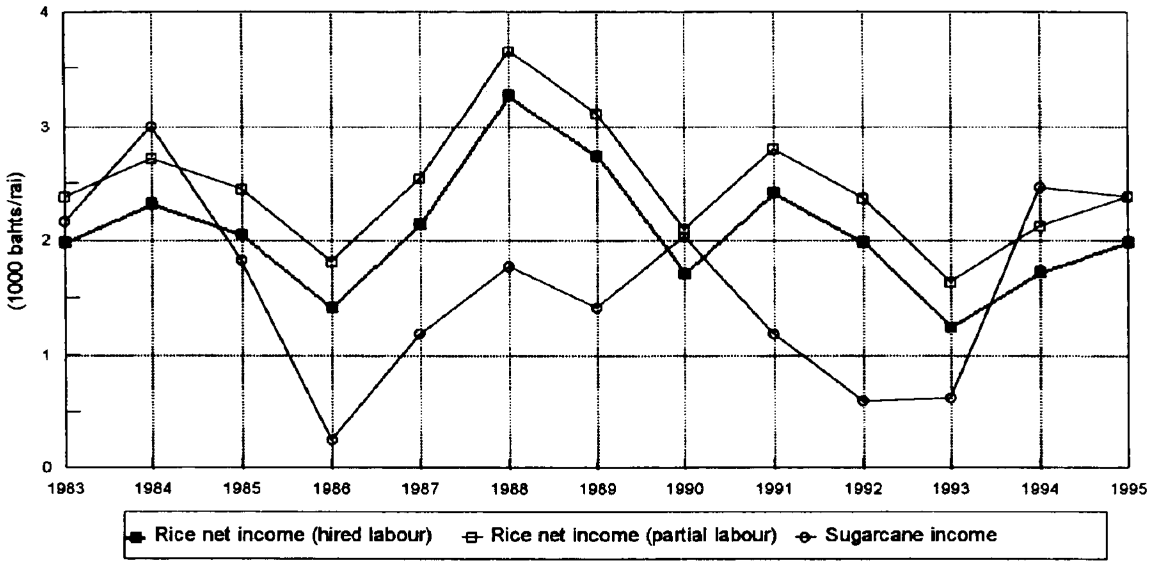


Fig. 9 Compared Profitability of Single Rice and Sugarcane (actualized net income in thousands bahts/rai)

Note: 1,000 bahts/rai = 250 US $ /ha
Family labour opportunity cost and land tax non considered

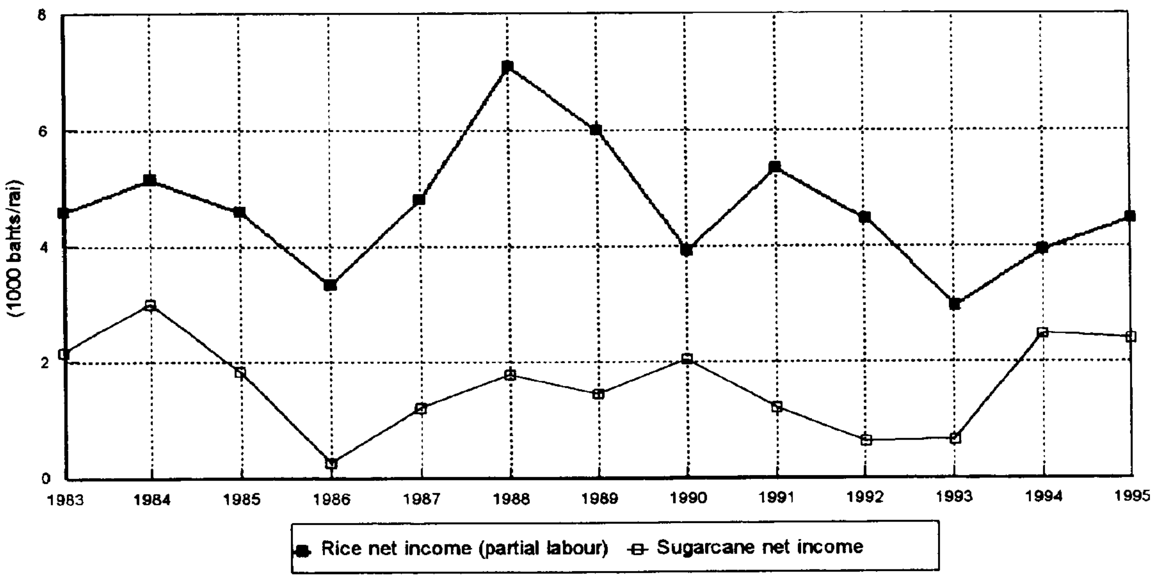


Fig. 10 Compared Profitability of Rice Double Cropping and Sugarcane (actualized net income in thousands bahts/rai)

Note: 1,000 bahts/rai = 250 US $ /ha
Family labour opportunity cost and land tax non considered

Although not expressed straightforwardly by farmers, one of the main factors which explain the dynamics of sugarcane is its much lower labour requirement (on the farmer's part), especially when the burden of harvest is completely taken over by middle men.

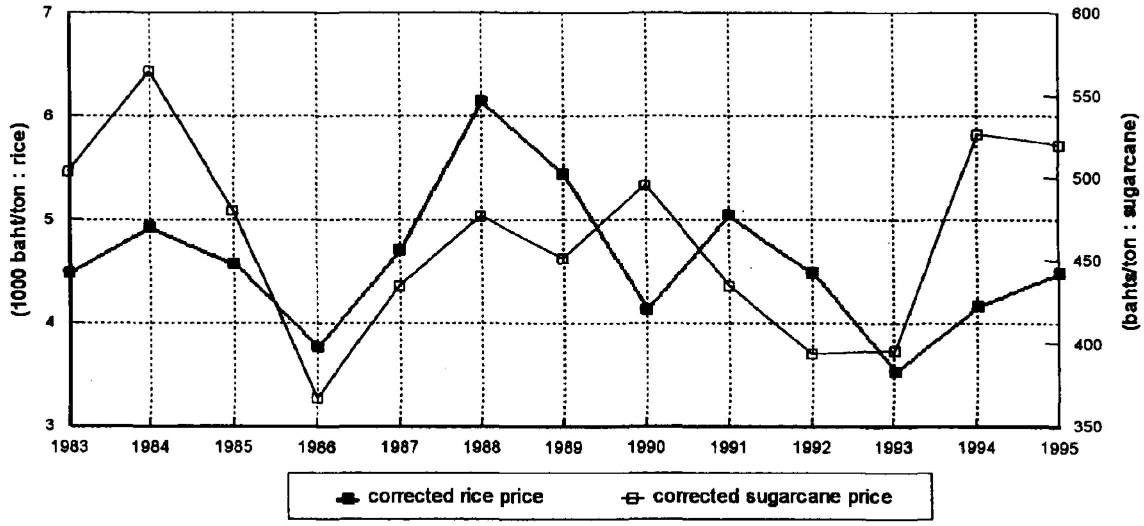


Fig. 11 Compared Selling Price of Rice and Sugarcane (corrected by inflation indice)

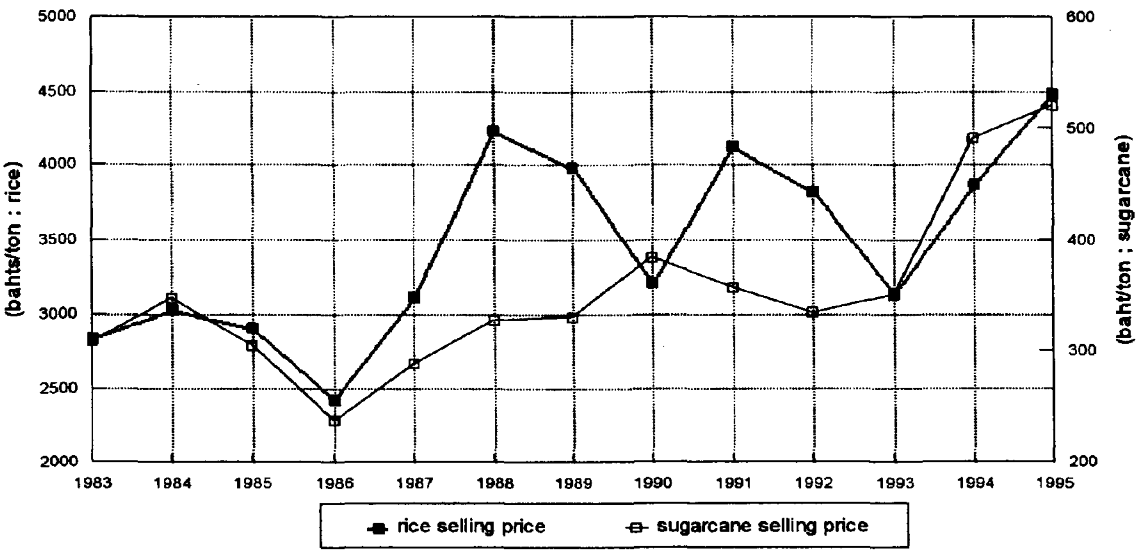


Fig. 12 Compared Selling Price of Rice and Sugarcane

Ageing farmers are common in the area and labour availability is depleted by migration and pluriactivity. This, we believe, is the underlying meaning of the farmers' mention of a better profitability for sugarcane, which, in other terms, would relate to (personal) labour productivity rather than cash income. In fact, if we now compare sugarcane with double rice-cropping—even under the hypothesis of hired labour—(Fig. 10), the argument of increased profitability for sugarcane is clearly unsustainable : the former fluctuates around 4,000 baht/rai/year, whereas the latter is unlikely to reach 3,000 baht/rai/year. On the other hand, regarding crop maintenance and, generally speaking, labour requirement and labour productivity, sugarcane is obviously a better option.

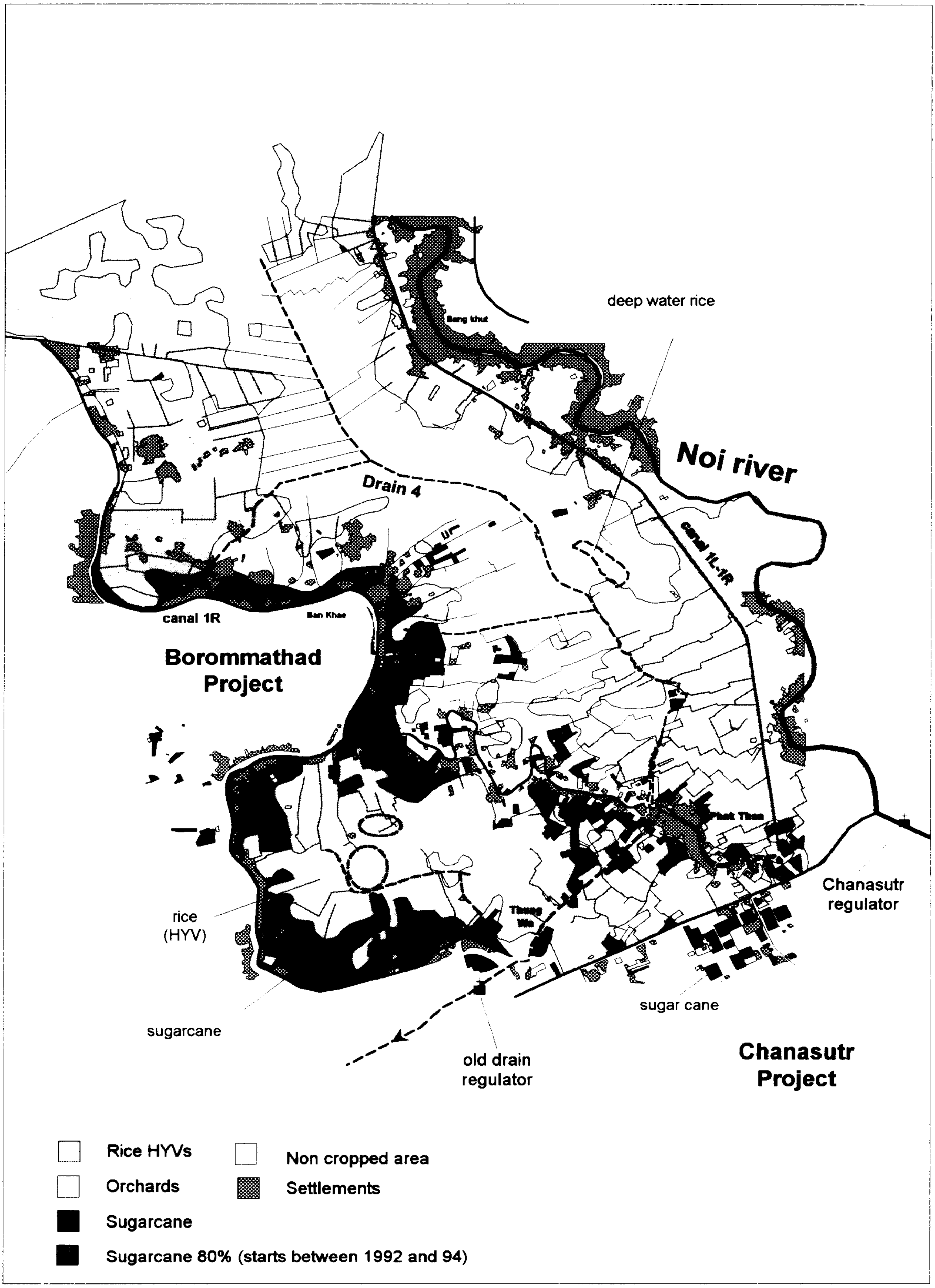


Fig. 13 Areas Cropped with HYVs and Sugarcane in the 1995 Dry Season

Other reasons for sugarcane expansion are also noteworthy. In the high lands located along canal 1 R, the shift from rice to sugarcane has been so overwhelming that remaining rice plots are forced to follow the same trend: this is due to the fact that percolation in isolated rice plots, with no longer surrounding flooded conditions, increases markedly and makes cultivation impracticable. In addition, bird and rodent pressure is also likely to be concentrated on such fields and the herbicide used for sugarcane is sometimes carried away by the wind and damages occur in dry season rice; these three factors show the collective aspects of agricultural change.

The continuous expansion of farm roads must also be mentioned as a decisive factor for the dynamics of sugarcane, as it allows the trucks to access the plots to load the production. Fig. 13 shows the area planted with sugarcane (data from aerial pictures). Part of it is referred to as "sugarcane 80 %," and corresponds to plots planted between 1992 and 1995 (not appearing as sugarcane on aerial pictures from 1992).

The Development of Orchards

Since the 1991 turning point, orchards also expanded beyond the scope of the traditional backyards. Fruit trees, mostly mangoes, are planted on raised beds, most of the time in locations close to main canals, where water is abundant (see Fig. 13). In any case, security concerns always lead farmers to dig additional tube wells and rely on underground water, too.

This trend is only emergent in the area but will, with no doubt, be the preferred option of farmers with both convenient capital and water control.

Dry season vegetable cropping is extremely rare. The almost single example is provided by a group of farmers who associate to grow water melon along drain No 4 (through pumping). They thus hire the land (1,000–1,500 baht/rai) and market the production together, with an income which can reach 20,000 baht/rai. This demonstrates the potentiality for diversification and the possible development of such activities which is nevertheless likely to be hindered by labour constraints. Regarding labour, orchards are—and will—probably be preferred by farmers.

V Conclusions and Perspectives

V-1 *Agricultural Transformation*

The agricultural transformations described in this paper have been made possible by a continuous change in water control, irrigation and drainage conditions. Such evolutions —slow and gradual—are not always easy to evidence and the fact that the change has been initiated by farmers is certainly worth consideration.

The change in water management, from a "full and regulated water retention" policy to a "full drainage" policy, has allowed farmers to transform their rice cropping and has

Table 6 Yearly Quantity of Sugarcane Processed in Sing Buri Factory (millions tons)

Year	1989	1990	1991	1992	1993	1994	1995	1996
	1.45	1.16	1.2	1.66	.86*	1.10	1.59	1.25**

* Low value due to a disease outbreak
** Estimate

made other options such as sugarcane cropping available to them. In economic terms, we can very broadly assess the impact of this transformation. If we consider that:

- 4,500 ha of traditional rice cropping have given way to HYV cropping;
- 75 % of double cropping and 3 % of triple cropping can be found in the area;
- 1,000 ha shifted from traditional varieties to sugarcane and, partly, to orchards,

we find a net increase of 16.4 million baht/year of the overall income, which corresponds to 3,000 baht/rai/year, or around 19,000 baht/ha/year. The former drain regulator is now out of order; its actual impact is eventually negative as it hampers drainage flows and reduces maximum discharge from 17 cm (drain allowance) to 10 cm (structure allowance). It should therefore be removed but some farmers seem to oppose such a decision arguing that this regulator (km 21 + 300) can still be used in the dry season to store water. According to design profiles, it seems that this role can also be achieved by a regulator located 10 km further downstream (km 31 + 422).

If we now compare yields and cropping intensity with adjacent areas provided with land consolidation, we find comparable situations. The ditch system in our area has been improved and wells have been dug when access to water happened to be poor. This tends to show that on-farm development carried out by farmers and local administrative levels can also be efficient. However, this is achieved through a quite intensive use of individual pumping devices, which means increased investments and operational costs for the farmers.

The opportunity of growing sugarcane has been seized by farmers in a quite spectacular way. This trend is likely to continue but is clearly reversible. Table 6 indicates that the milling capacity of the sugarcane factory (let alone other alternatives such as the Uthay Tani factory) of about 2 million tons can still absorb a significant additional production. Limitations to sugarcane are natural and economic: firstly, a good part of the highest loamy soils, suitable to sugarcane cultivation,[10] has already been planted with sugarcane; 60 % of the rice plots surveyed (with a location slightly higher than the average, see note 7) are said to be unsuitable for sugarcane cultivation. Secondly, a few disgruntled farmers with sugarcane yields too low (disease, water logging) were found to be about to revert to rice cropping. This could be boosted by

10) Former bamboo areas are said to be suitable for sugar cane and field crops, whereas areas with former "forests" (*pa may*) are suitable for rice cultivation.

unfavourable comparative selling prices with rice production.

Another threat may come from a possible non-sustainability of underground water use : in the last three years, almost all the wells located in the sugarcane area experienced shortcomings because of water levels lower than 8 or 9 meters. In such conditions, pumping by suction is impracticable and the well has to be widened over 3 or 4 meters deep so that a pump can be lowered.[11] This witty adaptation would nevertheless be impossible should the water level decrease another 2 meters or more. The crisis was generated by the over use of underground water, but also by water shortages since 1990, which depleted the aquifers. It is not clear whether this problem is going to stabilise or will worsen with time; research is necessary to tackle this issue which appears to be common in other irrigated areas of Asia where conjunctive use of surface and underground water developed [Abhayaratna *et al.* 1994].

The question of the risk related to the drainage capacity of the area must also be raised. Although little damage has been observed during the rainy season of 1995/ 96 (if compared with the situation in the Chao Phraya flood plain), limited damage has nevertheless been reported by 25 % of the rice farmers. The exceptional aspect of this year may allow one to consider that the risk is likely to be acceptable for the area. Some lower parts still need increased protection and the embankment of drain No 4 has been —and will be—probably further raised for this purpose.

The risk, in hydrology, is also often transferred to downstream areas. Increased drainage flows meet with runoff from other drains and may exceed overall drainage capacity if the conditions have not been improved down to the very end of the system. In the current case, severe flooding has in fact been registered along the following 10 kilometres of drain No 4 during the 1995 rainy season. This does not allow definitive conclusions but this situation will have to be monitored in the following years.[12]

V-2 *A Context of Changing Water Regime*

This case study shows that water control—irrigation and drainage—does change, slowly but continuously, in some parts of the delta. This statement, however, is likely to be acceptable at a broader regional level. Floating rice areas have decreased and even disappeared in some Projects such as Phophya, being substituted by deep water rice (or even by some HYVs). Areas which were commonly using boats 20 years ago are not using them any longer. Several reasons account for such an evolution [Molle *et al.* 1997]:

- the continuous improvement of drainage in the delta ;

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11) The pump being generally powered by the engine of the two-wheel tractors, shafts or belts must be used to transmit power.

12) This downstream area is controlled by a regulator in km 31 + 422 and has undergone a change similar to the one described here, with an even more dramatic increase of sugarcane. The specificity of this area has not been considered in the present study and no conclusion can be drawn.

- the construction of protection dikes along waterways, which prevent overflow from the main rivers ;
- the construction of embankments (such as roads), which hinder runoff ;
- the decrease of side flows coming from adjacent rainfed areas in the Central Plain, because of better control and increased water use in these areas ;
- the diminution of average yearly runoff because of better control (dams) and higher water consumption in the upstream part of the Chao Phraya (and tributaries) basin ; and
- possible hydrological change, evidenced in a decreasing trend of the amount of rainfall in the delta.

Opposed to the evolution above mentioned, stands the growing urban area, which demands increased dike protection and contributes—together with the expanding dike systems and farm polderisation (in the young delta)—to reduce the buffer area where floods can be diverted and mitigated. Areas such as the lower West Bank and Rangsit, which used to be flooded every year some 20 years ago, are now increasingly protected.

By a continuous improvement of water control, the Chao Phraya delta tends to modify its traditional features of flooded area dedicated to extensive rice cultivation. Agriculture seeks increasing protection but this contributes to worsen the situation in exceptionally wet years because excess flows find themselves concentrated in main waterways in which, consequently, embankments have to be raised [AIT *et al.* 1996]. As the dramatic floods of 1995 have recalled it, hydrology cannot be cleared of hazards : eventually, water and land development in deltaic areas still relates to risk management.

Further research is currently being carried out by the authors to characterise and quantify the change in both the hydrologic regime and water control.

V-3 *Possibilities of Change to Be Tested*

These changes allow us to state, as an hypothesis for research, that the "water retention management" could be, in some places, substituted by a "full drainage management," when downstream conditions allow sufficient drainage.

Instead of providing water *from below* (by raising the water level from the lowest point), it is beneficial to deliver it *from above*, by means of irrigation canals and proper on-farm infrastructures : such a substitution—if it happens to be possible—allows an increase in the acreage cropped with High Yield Varieties and in land use intensity, resulting in spectacular benefits for the farmers concerned, as shown in this paper.

Therefore it should be assessed if situations similar to the one here described are to be found elsewhere in the delta. The area under scrutiny is the flood plain of the delta together with some parts of the old delta, where traditional rice varieties are still grown under a partly controlled flood regime (see Fig. 14). All the drainage units, or "drainage boxes," defined as basins partly protected by dikes and with flooded conditions controlled by a regulator situated in their main drain, must be identified.

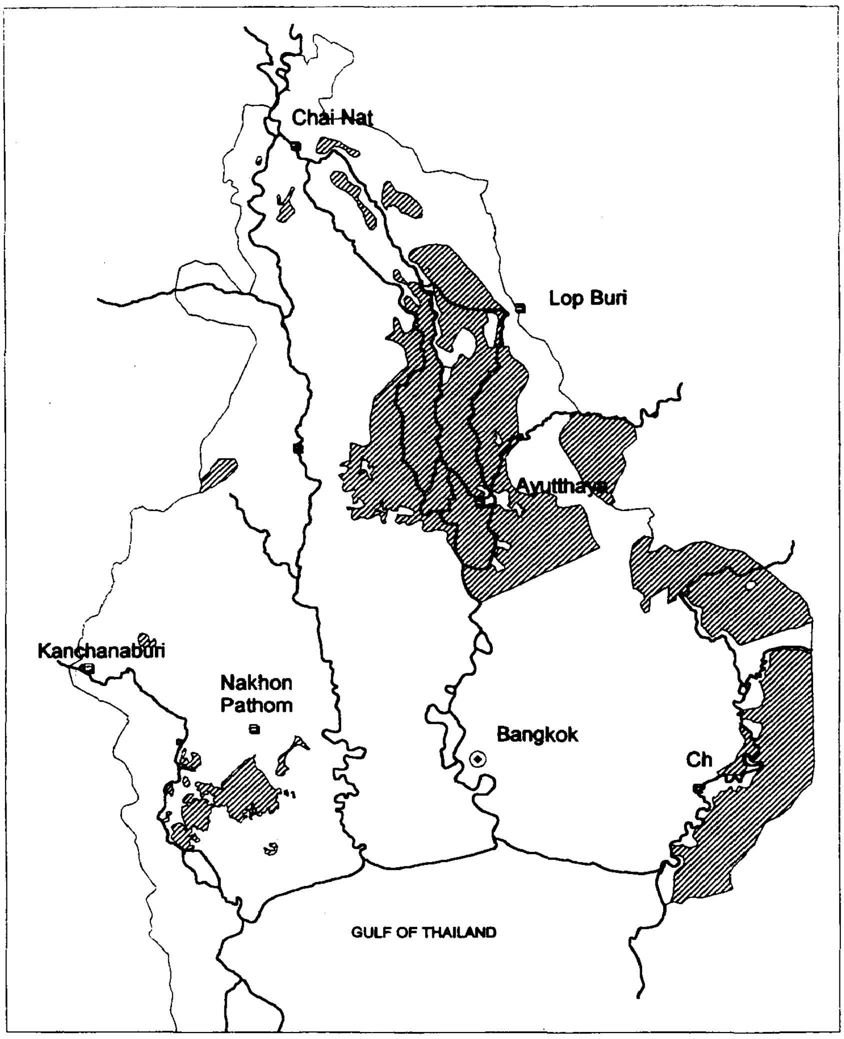

Fig. 14 Areas Cropped with Traditional Rice Varieties in the Central Plain of Thailand (as at 1995)

In the light of this case study, a transformation of one drainage box devoted to extensive rice-cropping into non-flooded areas with HYV cultivation appears to be possible under a set of conditions, both physical and socio-economic. These conditions for a change are:

1) The area must have good drainage conditions: this implies that the water level downstream of the area (in the river in which the drain empties) will be low enough to allow excess runoff to be drained.
2) The banks of the drain must be raised, so that flows coming from the upper part of the drainage box can be guided and evacuated without overflowing into the low-lying parts.
3) The secondary drains which flow into the main drain must have gated outlets, so that high water levels in the drain do not backlash into the fields.
4) If the water is no longer provided "from below," it must be provided "from

above": this implies that irrigation canals and ditches be sufficient to deliver water to all the plots (additional pumping being necessary or not).

5) At the plot level, farm drains and plot levelling must be improved to allow the use of HYV.

6) Farmers must have adequate equipment in order to cope with the change of techniques in land preparation. Most of the time four-wheel tractors will not be suitable and two-wheel tractors must be used.

7) Farmers must have strategies compatible with farm intensification : lack of resource for input or labour, pluriactivity with agriculture as a secondary activity, high rate of tenancy or trends to land sale, are likely to be indicative of a lack of interest in agricultural intensification.

The mapping of "drainage boxes," contour, irrigation facilities, relevant farm characteristics and rice cropping patterns in the area indicated in Fig. 14 is now under way by the authors. Possibilities of agricultural transformations will be assessed, especially in the upper delta where areas draining towards the Tha Chin river are more likely to allow change. New dams (such as on the Pasak river) and drainage regulators are under construction and will contribute to increase water control in the delta. Although increased regulation and agricultural benefits can be expected, hydrological hazards—as recalled by the floods of 1995, are likely to remain an everlasting feature of the Chao Phraya delta. The detailed description and understanding of the flooded area and its corresponding physical features, water management, cropping patterns is also expected to bear fruits regarding the improvement of flood management in the future.

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