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Assessment of water control at the tertiary and farm levels : a case study in the Kamphaengsaen Irrigation Project

François Molle
Chatchom Chompadist
Pongsathorn Sopaphun

DORAS CENTER

Kasetsart University

ORSTOM

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Please direct inquiries and comments to:

DORAS Project
Kasetsart University
Central Laboratory
Kamphaengsaen, Nakhon Pathom Province
Thailand
odoras@nontri.ku.ac.th

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1. Background

The Central Plain of Thailand encompasses an irrigated area of about 2 million ha. Further to earlier canal excavation mostly aimed at transportation (goods, military,..), land development started in the second half of the 19th century with the first canals dug to open virgin land to rice cultivation. These waterways provided communication by boat, embankments for homesteads, helped spreading the floods of the rivers and made water available for cultivation along their course (Takaya 1989).

Until WW II, the bulk of investments in land development concerned the lower delta, with canal excavation complemented by the construction of regulators, gates and embankments, such as the dike designed to protect the eastern coastal area from saline water intrusion. There, irrigation could only be done by using water-raising devices in the early rainy season and by controlling the recession of the flood at the end of it. In the upper delta, the flood plains of the Chao Phraya offered a natural environment allowing the growth of floating rice varieties with no artificialisation. The first project to be designed as a conventional gravity irrigation scheme was initiated in 1922 on the Tha Chin river, with the construction of a diversion regulator on the river and a few main canals. This project, however, lingered on and was to be completed only in 1955.

At that time, due to a high world demand for food grains ensuing at the end of the war, Thailand obtained a loan from the World Bank to launch the Greater Chao Phraya Project (Fig. 1). Main investments carried out in the 50's included the construction of a derivation dam at the apex of the delta and a network of primary and secondary canals to distribute water by gravity in the upper delta. The question of whether on-farm development should also be carried out was answered on the basis of insufficient financial resources : between implementing a main infrastructure (primary and secondary canals) for the whole delta or developing complete irrigation facilities (with on-farm development generally accounting for 40 % of the costs), planners have chosen the first option. It was therefore assumed that farmers would gradually develop the ditch system, allowing canal water to reach their plots.

In the 60's, however, with an observed yield increase much lower than expected, concern was raised about "why do the farmers not respond to the supposed opportunity for increased productivity ?" (FAO, 1968). Attention was drawn to the improvement of drainage and to the necessity to upgrade facilities at the tertiary and plot levels. During 15 years, different forms of on-farm development ("ditch and dykes", extensive and intensive land consolidation) were experimented with and a total corresponding to about 11 % of the irrigated area (50 % if we consider the basic "Ditch and Dykes" project) was developed accordingly (Kasetsart University, ORSTOM 1996). In the early 70's, the implementation of the Greater Mae Klong Project was also initiated on the western side of the delta (Fig. 1). There, also, only a basic ditch system was implemented, although most of the main canals were designed with increased capacity, 1.7 instead of 0.81 l/s/ha (Wickham and Plusquellec 1985), and provided with lining.

After this period of investments and experimentation in on-farm development, very little has been done, said and observed on this issue. A broad and rather vague assumption that the great majority of the farms have eventually benefited from irrigation, seems to prevail.

The characterisation of water control at the farm level is known to be a quite difficult task. It first depends on the availability of water at the Farm Turn Out (FTO)[1], featured by its appropriateness in terms of quantity, quality, regularity and timeliness. Second, it is the result of a combination of various factors, including physical ones (size and length of ditch, micro topography, percolation,..), agricultural ones (land use, cropping calendar,..) and institutional (organisation for water management, maintenance, etc). The resulting water control is highly site and time-specific, both within one season and between seasons, which makes it sometimes hard to characterise, either quantitatively or qualitatively.

This paper presents data from the Kamphaengsaen Irrigation Project, located in the Greater Mae Klong Project, in the west of the Central Plain, Thailand (Fig. 1). A first question relates to the dynamics of on-farm development since the implementation of the project in 1972. Did the ditch system develop as expected ? How, when and by whom has this been achieved ? A second set of questions deals with the characterisation of water use and water control at the farm level : who really benefits

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[1] The FTO (Farm Turn Out) is the gated outlet from which water from the main or secondary lined canals is delivered to the ditches (or tertiaries), which take it to the different plots.

from irrigation, what sources of water do the farmers eventually use, what is the risk and what is the relationship between water use and land use, both presently and in past evolution ? From such insights, it will be possible to identify some bottlenecks and to draw some conclusions on the margins for progress in agricultural performance.

Regarded as a conventional gravity irrigation system, provided with lined canals, basic sluice gates[2], FTOs and relatively abundant water supplies, the Kamphaengsaen Project, and more generally the Greater Mae Klong Project, may well show different realities when approached at the farm level.

2. The Kamphaengsaen Irrigation Project and the study area

2.1 The Kamphaengsaen Project

The Kamphaengsaen Project is a 50.000 ha wide area extending across the Mae Klong fan, from the high levees along the Mae Klong river, in the west, down to the Tha Chin river, on the east (Fig. 1). It receives water from a trunk canal which branches off the Mae Klong river some 15 km upstream (at the Vajiralongkorn diversion dam), and follows its course in parallel, down to the south. The whole Mae Klong Project is characterised by a rather abundant water supply[3] and good water storage facilities (see the two reservoirs in the upper basin, Fig. 1) : overall shortage is uncommon and average annual rainfall is 944 mm, with only 58 mm during the December- April period (Fig.2). The Kamphaengsaen Project is basically a demand-based project, as full supply deliveries can usually be ensured and are found to match requirements (of plots that have access to water).

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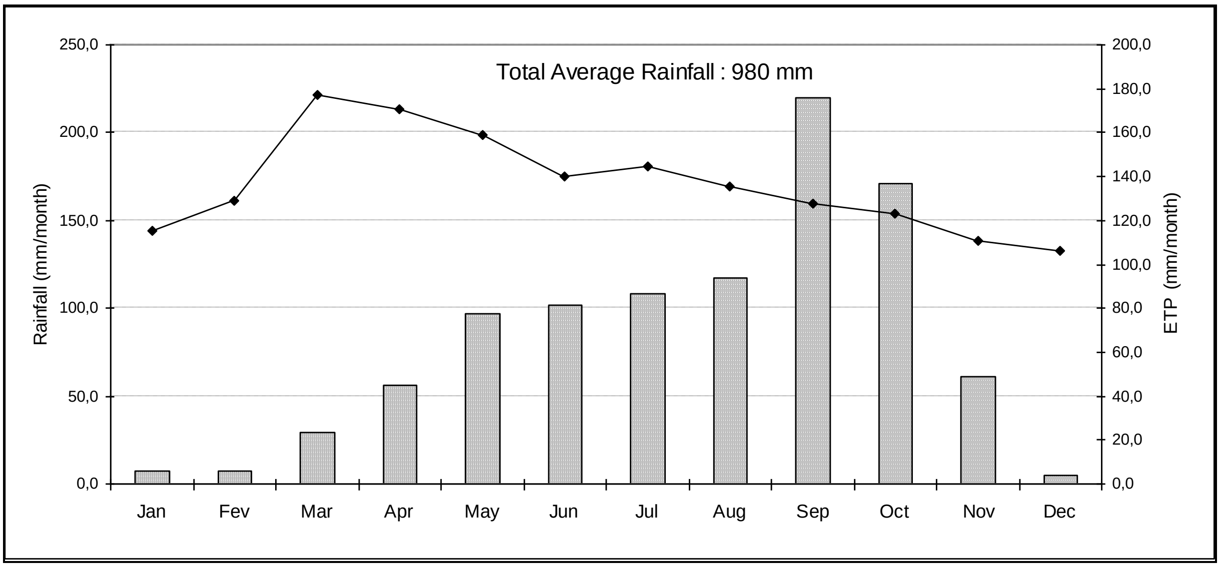
[2] Other parts of the Greater Mae Klong Project have been equipped with CHO or Rominj weir which never functioned as expected.

[3] This characteristic has induced policy makers to design projects to divert water to the water deficient adjacent Chao Phraya lower basin : in the dry season, around 80 cms is diverted to the Tha Chin river and further pumped onto its eastern bank. A canal is under construction to derive another 30 cms for domestic use in Thonburi (west of Bangkok Metropolitan Area).

Fig. 2 : Average rainfall and ET data for the study area (1975-95)

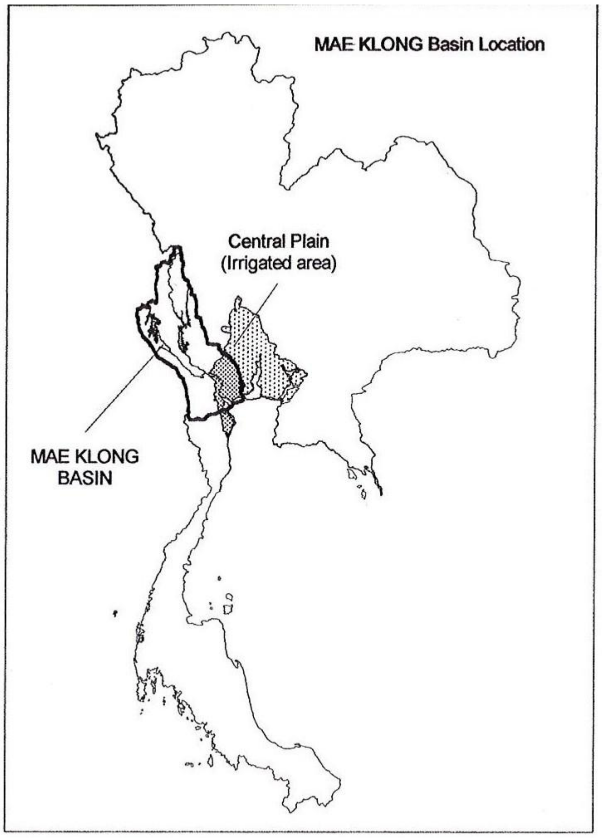


The project is divided into 27 hydraulic units called zones, with an average of 2,000 ha and two officers in charge. Water is delivered all year long with two interruptions of about 6 weeks between the two seasons (approximately 15 December - 5 February and 1 June - 15 July), which are taken advantage of for maintenance purposes.

Sugarcane and rice total 40 % and 30 % of the area respectively and are spatially distributed mostly according to topography, with the former on the high lands and the latter in the lowest ones. But for few exceptions, paddy fields are double cropped. Diversification in the *Nakhon* Pathom Province is a very salient feature of the past fifteen years (Kasetsart University, ORSTOM 1996) and includes fruit trees, aquaculture and a large diversity of field crops and vegetables. Historical records of diversification acreage are shown in Fig. 3. It is probably meaningful to note that these were not kept during the first 8 years of the Project, as they were probably considered marginal.

2.2 The study area : zone 5

The zone 5 is 1660 ha wide, crossed by a lined distributary and surrounded by main drains (Fig. 4). The ditch system is rather dense all over the area. Relief is gentle, with elevation ranging from 10 to 5 m, levees along the main drains (former natural watercourses) and a few scattered depressions. Soil characteristics are strongly related to topography, with clay in the depressions and lighter textures in the highest parts (Fig. 5 and contour map in annexe).


MAE KLONG Basin Location
Central Plain
(Irrigated area)
MAE KLONG
BASIN

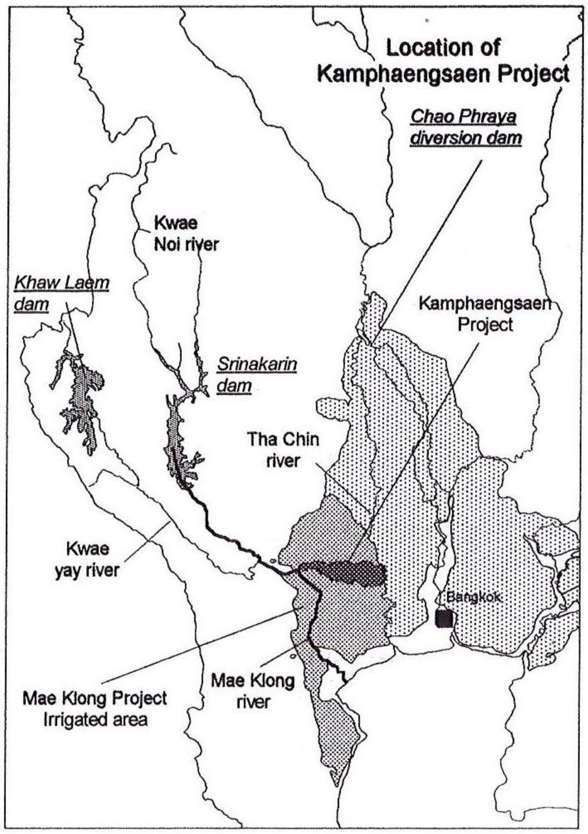
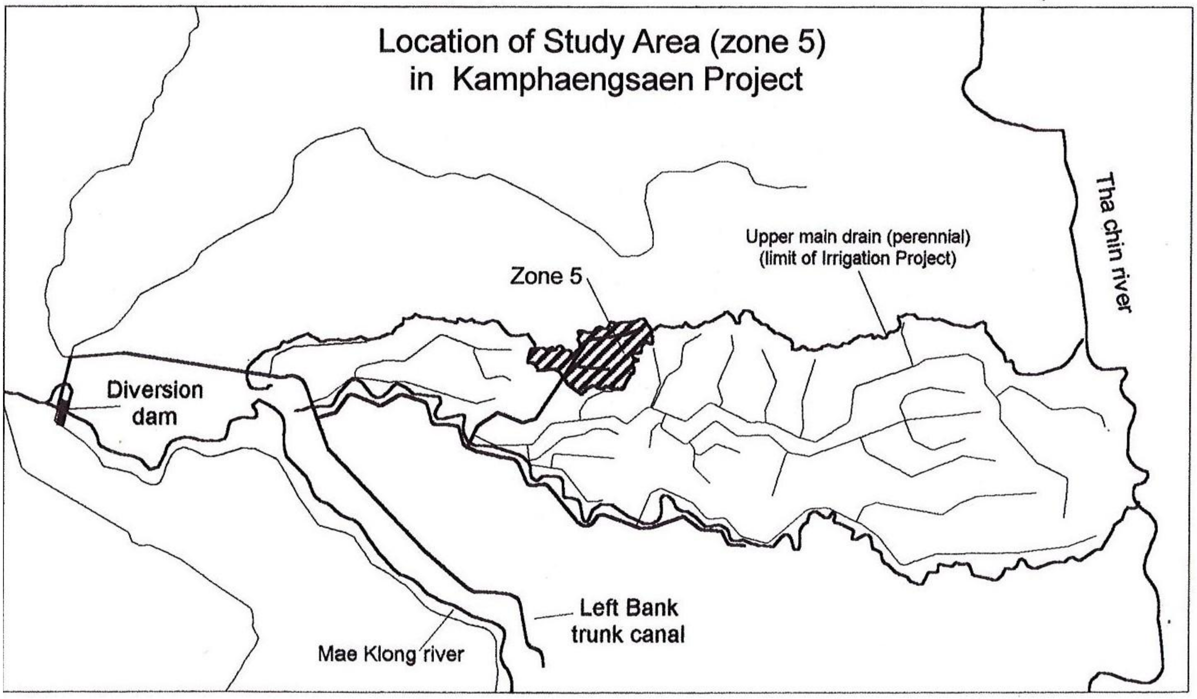
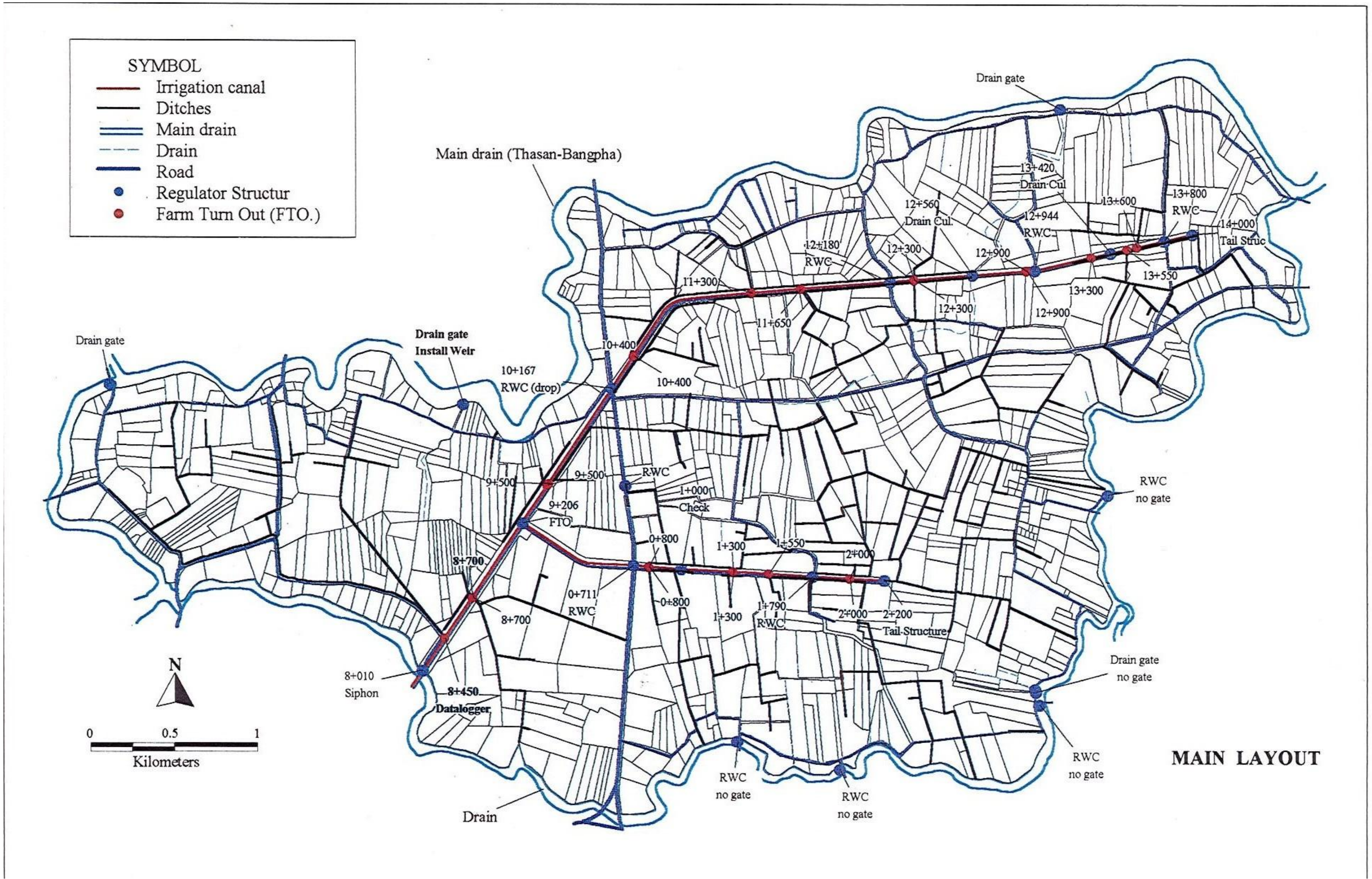

Location of
Kamphaengsaen Project
Chao Phraya
diversion dam
Kwae
Noi river
Khaw Laem
dam
Kamphaengsaen
Project
Srinakarin
dam
Tha Chin
river
Kwae
yay river
Bangkok
Mae Klong Project
Irrigated area
Mae Klong
river

Fig. 1


Location of Study Area (zone 5)
in Kamphaengsaen Project
Tha chin river
Upper main drain (perennial)
(limit of Irrigation Project)
Zone 5
Diversion
dam
Left Bank
trunk canal
Mae Klong river


SYMBOL
Irrigation canal
Ditches
Main drain
Drain
Road
Regulator Structur
Farm Turn Out (FTO.)
Main drain (Thasan-Bangpha)
Drain gate
Drain gate
Drain gate
Install Weir
10+167
RWC (drop)
10+400
10+400
11+300
11+650
12+180
RWC
12+300
12+300
12+560
Drain Cul.
12+900
12+900
12+944
RWC
13+300
13+420
Drain Cul
13+550
13+600
13+800
RWC
14+000
Tail Struc
9+500
9+500
9+206
FTO
RWC
1+000
Check
0+800
0+800
1+300
1+300
1+550
1+790
RWC
2+000
2+000
2+200
Tail-Structure
0+711
RWC
8+700
8+700
8+010
Siphon
8+450
Datalogger
N
0
0.5
1
Kilometers
Drain
RWC
no gate
RWC
no gate
RWC
no gate
Drain gate
no gate
RWC
no gate
MAIN LAYOUT

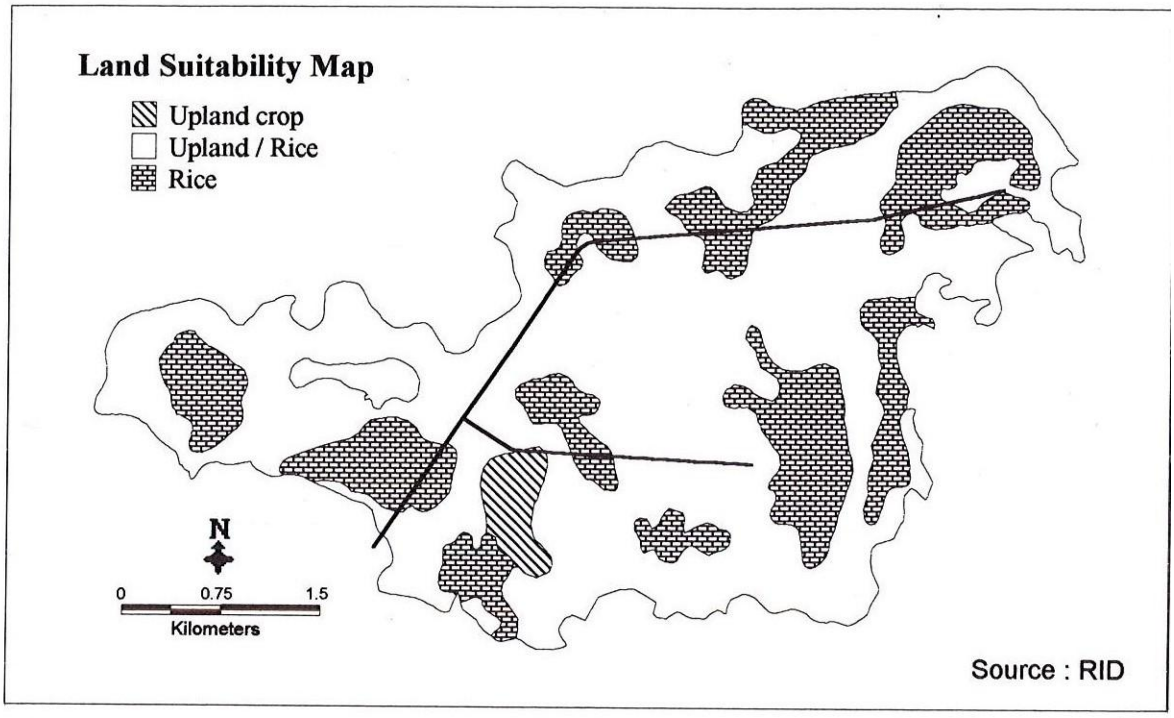

Land Suitability Map
Upland crop
Upland / Rice
Rice
N
0
0.75
1.5
Kilometers
Source : RID

Fig. 5

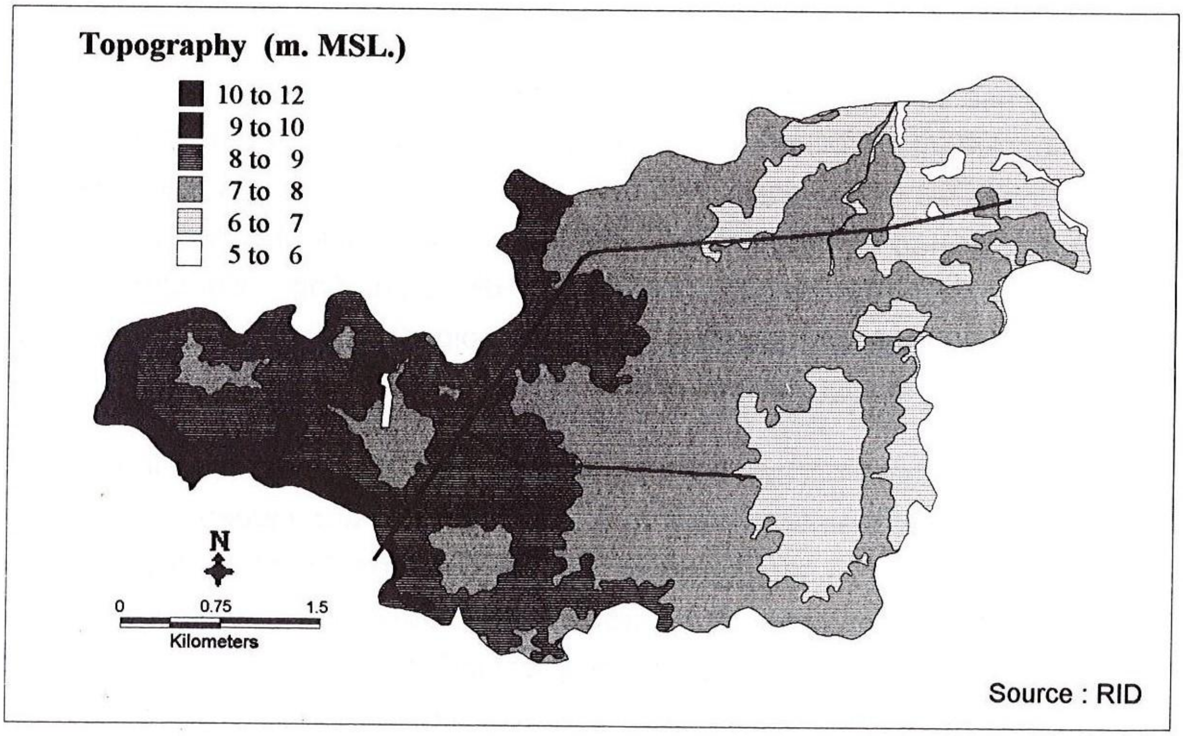
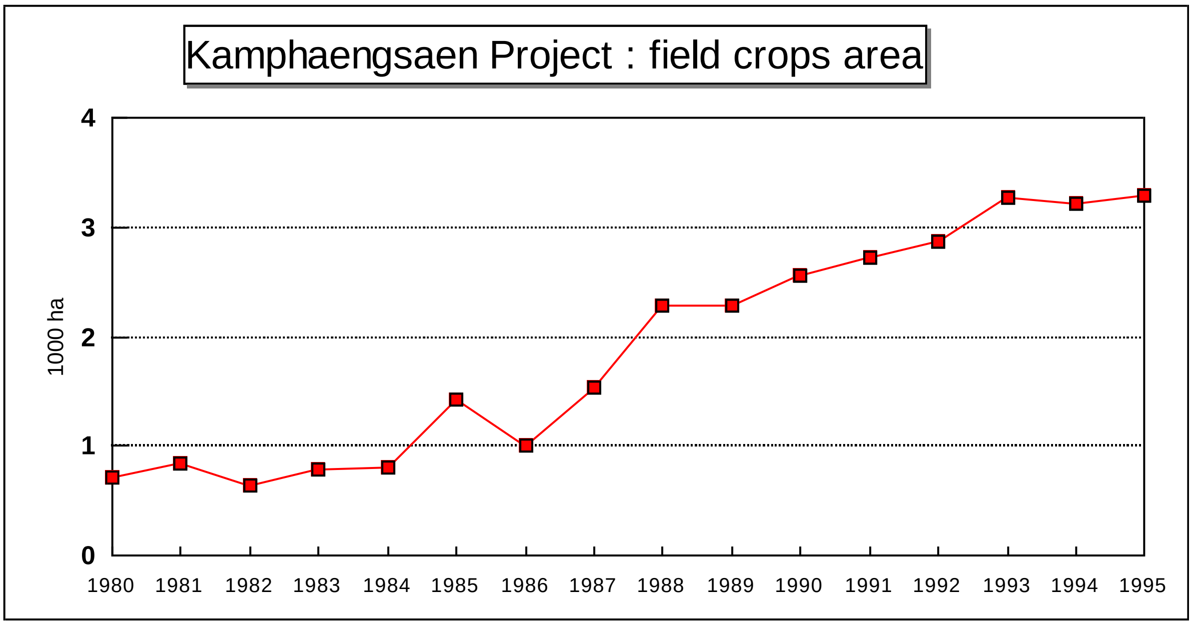

Topography (m. MSL.)
10 to 12
9 to 10
8 to 9
7 to 8
6 to 7
5 to 6
N
0
0.75
1.5
Kilometers
Source : RID

Fig. 3 : Evolution of field crops in the Kamphaengsaen Project (1000 ha)



2.3 Water resources management in the area

Water resources at the farm level are rather diversified and often multiple. We can distinguish the six main following categories :

1. **The irrigation canal** : The lined irrigation canal, with its two branches, provides water to some riparian farmers who manage to get their supply directly. These generally use three possible devices : pumps, together with hoses ; pipes through the embankments ("ghost pipes"); or siphons, the latter case being rare in the zone considered but common in others. This constitutes an inconvenience when the plot is located on the right side of the canal, for pipes or hoses must be laid across the road ("ghost pipes" avoid this difficulty). This also often requires frequent movements of equipment (pumps and pipes). Water supply is reliable but vanishes during the two periods of interruption.

2. **The ditches** : earth ditches have been excavated, branching from the irrigation canals, in order to distribute water further inland. They are, indeed, tertiary canals but are not labelled as such because they are dug (and, therefore, the water level is generally lower than the natural ground level), contrary to the former, which are raised over small embankments (and sometimes lined), in order to allow distribution to plots by gravity. Ditches have very varied dimensions and water availability heavily depends on the distance to the FTO, topography, ditch

maintenance and on the intensity of use along its course. Inflow at the plot level is by gravity in the paddy fields (lower parts), whereas - with very few exceptions - water has to be pumped onto the plots in all other cases.

3. **The main drains** : the area is bordered to the north by a perennial river (drain) which presents satisfactory levels even in the dry season because it is used to convey water from the Mae Klong to the Tha Chin river, where it is pumped again (see Fig. 1). The western drain is equipped with a regulator in order to retain water after the rainy season ; it is therefore perennial but water quality gets bad because of upstream pig farm effluents. The eastern drain freely flows to the main drain and therefore will dry up during approximately two months (April-May) ; in its upper reaches, culverts under roads crossing the drain are tapped to retain water but these resources also eventually dry up. So does the southern reach for three or four months because of higher siltation. Riparian farmers use conventional electric or gasoline/diesel motor driven pumps to lift water onto the levees.

4. **Farm drains** : A few small drains evacuate excess water from the area to the main surrounding drains. In the dry season, they generally dry up during two or three months, then gather the first water drained from the fields and supply adjacent farmers (through pumping). They are often equipped with some structure at their outlet to the main drain so that they can store water too. They also constitute convenient water sources in the rainy season, out of periods of heavy rainfall in which they perform as drains.

5. **The tube wells** : tube wells are 15 to 30 meters deep and 3" or 4" in diameter, linked at their upper extremity to a conventional pump. The pump is driven either by an electric motor or a gasoline one. They are present in most of the area, except for its western part, where available discharges are too low to enable an intensive use of them.

   Tube wells are very convenient sources but they may face two limitations : in some instances, the groundwater is salty, unfit for consumption but sometimes used to irrigate sugarcane. In the area, this problem seems to be quite site-specific and limited to a few superficial wells. Another point of preoccupation is the sustainability of the aquifer. During the dry spell of 1991-1993, less irrigation supply and higher groundwater extraction have depleted the aquifer below the effective suction limit of the pumps (around - 9 m). This has compelled farmers to dig out a 1 meter wide pit to be able to lower the body of the pump, this remaining connected to the motor by a shaft or a belt. This witty adaptation nevertheless has limits, as it can hardly go beyond 2 meters. At present, the water table has risen again and wells can be fully used.

It is noteworthy that most of the wells have been dug after the construction of the irrigation network. Dry-season water supply has raised the water table and made it accessible by shallow wells and suction pumps.

6. **Ponds and burrow pits** : some local storage can also be found. These are generally natural or artificial ponds (in this case often used to rear fish too) or burrow pits along the main canals and roads. Burrow pits often serve as a forebay for farmers to pump and irrigate their sugarcane or field crops. They are very useful temporary storage areas to be used when deliveries are suspended (buffer tanks).

7. **Other** : a few sugarcane plots are also found to pump in adjacent paddy fields. Plot to plot water conveyance is common in all the rice clusters. In these two cases, classifications proposed later have considered these plots to get water from the upstream source : ditches or drains.

3. Changes in land and water use

Significant changes, affecting both land and water use, have occurred in the project and will be reviewed in this section, with emphasis on the 1985-1995 period.

3.1 Change in land use

The upper part of the Mae Klong Project has been cleared only recently. Whereas rice, sugarcane, coconut and vegetable production could be found in the lower part in the second - or even first - half of last century (Terwiel, 1990; Hardouin, 1884), maps dating from 1912 indicate that the study area was covered with grass, bamboo groves and forests. Only a few sparse spots of rice could be found in some lowlands.

In 1969, just before the construction of the irrigation project, agriculture concentrated on rice and sugarcane, with a distribution closely following topographical features and the water regime that one may expect accordingly (Fig. 6).

Fig. 6 : Land use in 1969 (source : Thaï Army survey Map, 1:50.000)

An inventory of land and water use at the plot level was carried out in 1986 by irrigation officers, in order to provide data needed to calibrate software used for water allocation and monitoring. This allows the comparison of both land and water use over a ten year period (1986/1996). In 1986, land use is almost limited to sugarcane (75 %) and rice (21 %), with a few hectares of fruit trees and miscellaneous (Fig. 7).

Data shows that 30 % of the plots (and also of the area) have changed crops within the 1986-1996 period (Tab. 4). Rice has, in 18 % of the paddy plots (386 rai), been changed to sugarcane, but an even larger area has reverted from sugarcane to rice : these cross changes refer to middle-low elevation plots and mirror the fluctuating farmers' decisions : compared profitability and uncertainty in prices, labour availability and frequency of flood in the sugarcane have been found to be decisive criteria for farmers' decision making (see Molle and Kaewkulaya, 1996).

The most significant change is the shift from sugarcane to diversified cash crops (mostly baby corn and, secondly, field crops, vegetables and fruits), that has affected more than 21 % of the area.

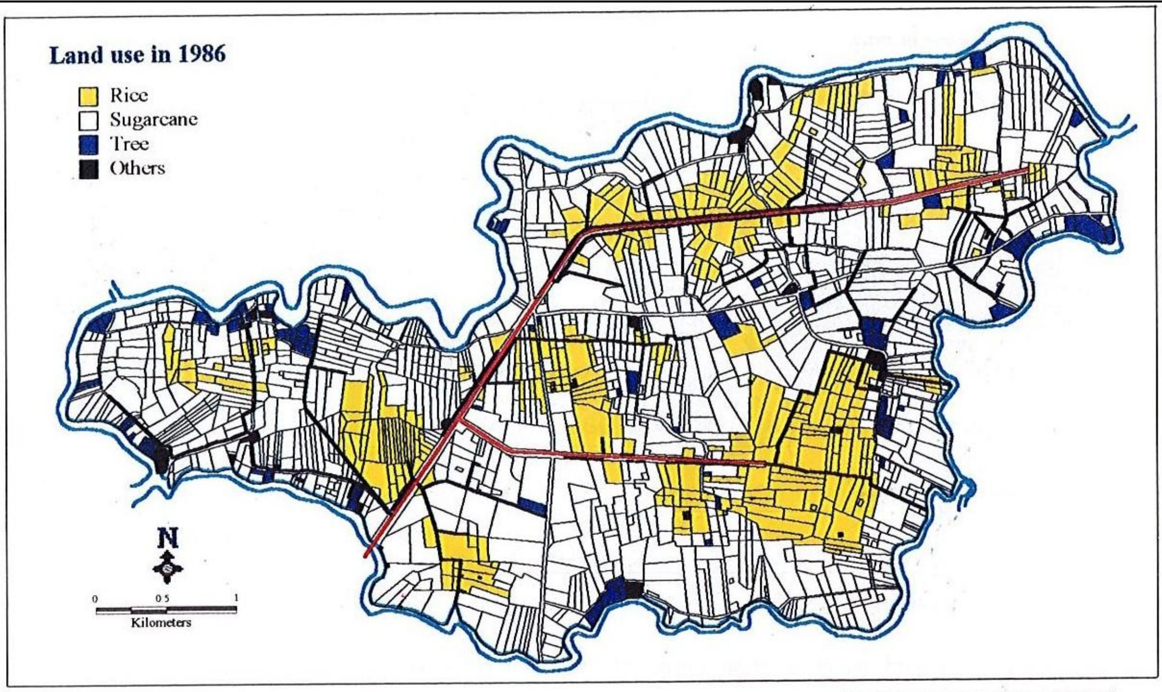


Fig. 7

SYMBOL
Irrigation canal
Ditches
Main drain

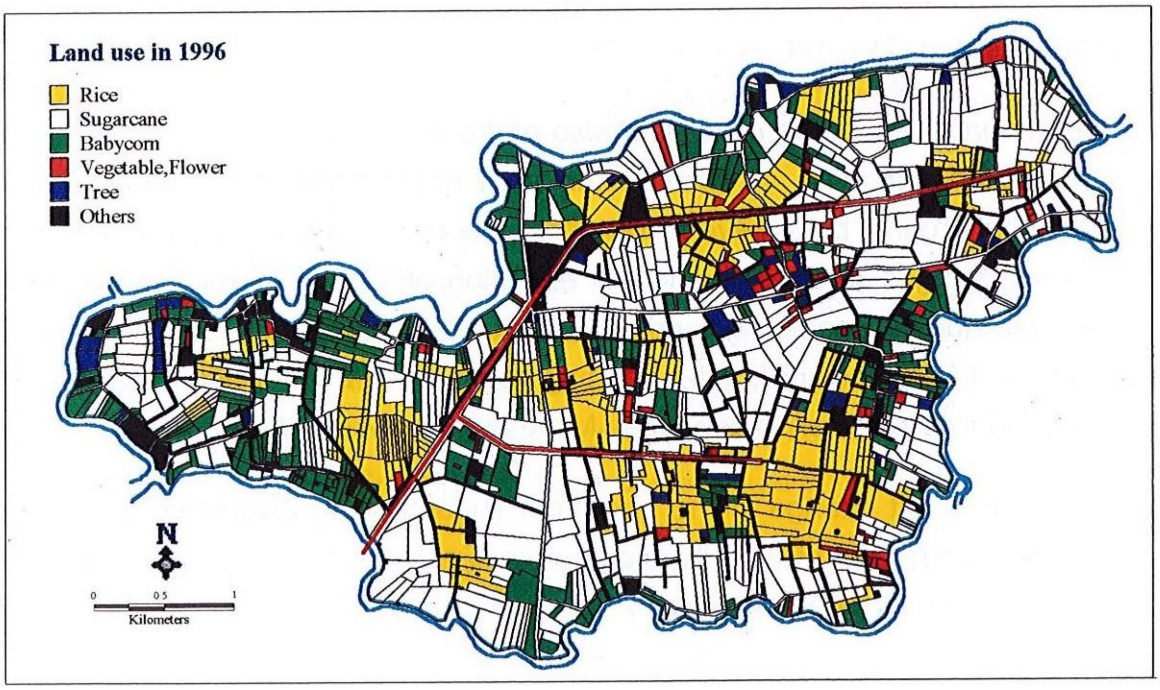


Table 4 : Change in land-use (1986-1996)

Crop in 1986	area (ha)	% area	Crop in 1996	area (ha)	% total area	% crop area
rice	344	21.3	rice	248	15.4 %	72 %
			sugarcane	60	3.7	18 %
			other	36	2.1	10 %
sugarcane	1208	74.8	sugarcane	839	53.5	70 %
			rice	75	4.6	6 %
			baby corn	200	12.3	16 %
			veget./fruit/flower	60	3.6	5 %
			other	33	2.1	3 %
fruit trees	36	2.2	fruit trees	5	0.3	14 %
			sugarcane or baby corn	28	1.7	76 %
			other	3.6	0.2	10 %
Area with change of crop (%)					30 %	

Although this was not the objective of the study to specify the factors conducive to agricultural diversification, the information provided by farmers allows one to roughly outline this process as follows : farmers are mostly driven to diversification by the low income which can be drawn from both rice and sugarcane. In order to do so, they must however meet some prerequisites concerning :

- physical conditions (of soil, topography and access to water)
- economic conditions (marketing facilities, selling price)
- labour availability (either family labour or hired labour must be available)
- skill (new crops require new skills to be learnt)

- capital (in some instances, capital is required to allow the shift of crops : well digging, pumping device, sprayers, land transformation such as raised bed systems, etc)

Decision making is therefore influenced by risk reducing factors (stable prices, contract farming), available capital (credit) and the existence of neighbours which have successfully demonstrated the viability of the new crop and can give technical advice. Similar conditions and evolution can be found in most Asian countries (Valera 1992). The investment capacity required to tap new water resources in order to decrease uncertainty in supply is of course a prerequisite to both intensifying sugarcane cultivation and to shifting to commercialised cash crop production. It appears, however, that the investment capacity - although a constraining factor - is quite significant in the area, when compared with average small farm holders standards in Southeast Asia. This is shown - for example - by a good level of farm equipment and by the fact that no claim could be found of capital shortage impeding the drilling of a tube-well. Sources of income are multiple within a rural household (on-farm, off-farm, remittances from family members working in non-agricultural sectors, etc) and farm micro-economics uneasy to assess.

3.2 Development of water resources

Before having a closer look at changes occurred in water use and to its relationship with land use, the transformation of the infrastructures must be specified.

3.2.1 The ditch system

In order to assess the endogenous development of the ditch system in Kamphaengsaen Project, the original basic ditch lay-out achieved by RID at the time of the project construction has been compared with the actual one. Ditches excavated with public finances and the ones achieved on private initiative have been distinguished.

Different cases have been found :

1. Ditch excavated by RID : Two years after completion of the main scheme, a few straight ditches have been excavated across the fields. Among these 12 initial ditches, only three are in use nowadays; however, other ditches have also been dug by RID ever since.

2. Ditch excavated by the district authorities (*amphoe*) : most of the main ditches have been dug with funds from the *KoSoCho* project ("Construction in Rural Areas"), or other similar budgets administrated by the districts;
3. Ditch excavated by the village head (phuyaybaan) : in one case, the village head has had a ditch excavated free; the payment of the service seems to have been the earth, which is used to raise embankments[4];
4. Ditch excavated on the initiative of the village head, but on a cost-sharing basis ; farmers along the ditch were asked to contribute based on the area to be served by the ditch;
5. Ditch excavated by the farmers themselves, either individually or through a collective undertaking.

In quantitative terms, the balance of ditch development is as follow :

* Initial ditch system (by RID) : 11,000 m

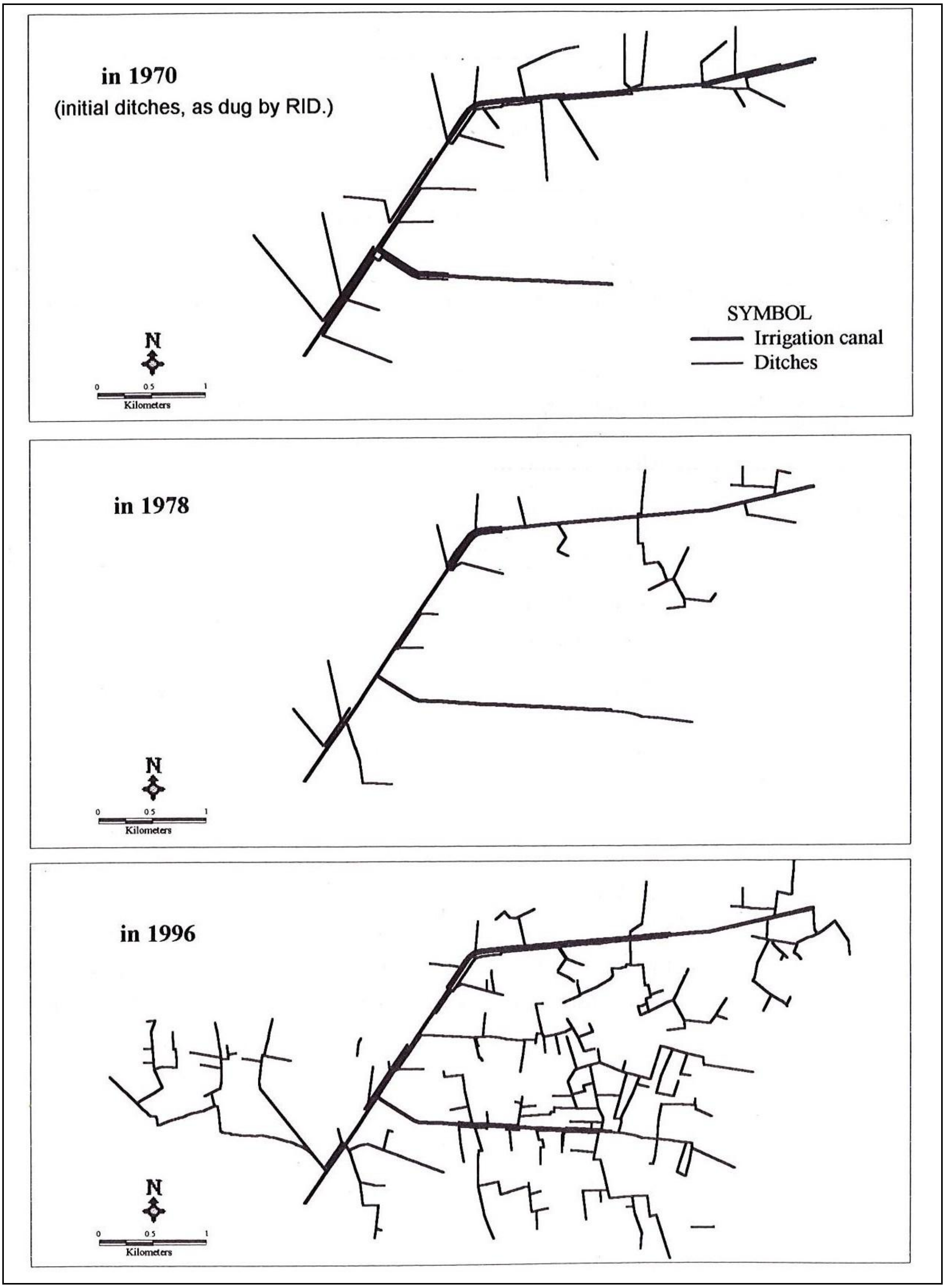
* Actual ditch system : 55,400 m

RID : 8,200 m	Farmers : 23,700 m
District/Province : 18,700 m	
(Burrow pits : 4,750 m)	
Government budget : 53 %	**Farmers' initiated : 47 %**

It is notable that almost half of the 55 km of existing ditches were dug at the farmers' initiative and cost.

Fig. 9 shows the development of the ditch system in three steps, with an overall growth of 500 % since the beginning of the Project. We can observe that most of the ditches first dug by RID were abandoned 8 years later : this is due to problems of design (improper declivity) and to the fact that these ditches were not following the layout of the plots and, therefore, were reducing the cropped area. Most farmers were dissatisfied with this situation and quickly had these ditches filled up.

[4] The earth-moving business is significant in the delta, where embankments have to be raised for roads and building construction : farmer receive 150 baht (6 US$, for each truck load taken out of their plots)


in 1970
(initial ditches, as dug by RID.)
SYMBOL
Irrigation canal
Ditches
N
0 0.5 1
Kilometers
in 1978
N
0 0.5 1
Kilometers
in 1996
N
0 0.5 1
Kilometers

This gives a current density of 31 m/ha (33, with burrow pits taken into consideration), which is almost exactly the standards in use for land consolidation in the Chao Phraya Project. Although the layout of a non-planned development is less rational, this shows that a very significant endogenous on-farm development has taken place in the area.

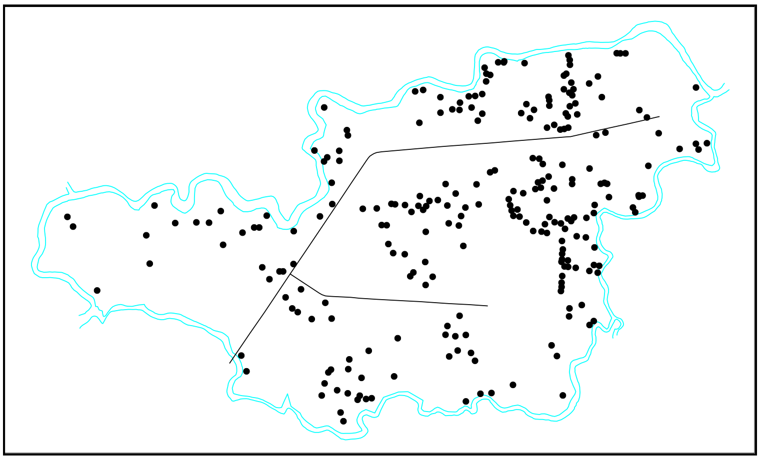
If we exclude some natural watercourses which have been transformed into drains, it is worth noting that the distinction between farm ditch and farm drain is not always very clear : in the upper parts - typically in the sugarcane -, ditches convey water delivered at the FTO but they tend to be quite deep, with no berms : this is because access to water is by pumping and because they serve as drains in case of flood. In lower locations, on the other hand, ditches often present berms which have two roles : to contain water when the ditch is obstructed in order to raise the head and get gravity water inflow ; to allow plot drainage by pumping, even if the water level in the ditch is higher than in the plot. In any case, ditches often flow down to a main drain : when they are used for supplying fields they are obstructed to impede tail losses ; when heavy rainfall occur, they serve as drains to convey excess water out of the area.

3.2.2 The development of wells

A survey carried out in 1994 at the village level has inventoried 89,000 tube wells in the Central Plain. This development chiefly concerns the upper Chao Phraya delta and the upper Mae Klong Project, where the study area is located (Kasetsart University & ORSTOM 1996). It has been driven by a need to access reliable water sources for both diversification and intensification, and constituted a response to the water shortage experienced in the early 90's.

In the study area, some of these wells are quite old but a majority have been dug after the implementation of the irrigation project to supplement rainfed sugarcane. At least 255 wells exist in the area and, although their number 10 years earlier is unknown, we know that only 163 plots were relying on wells (Fig. 10). As one well may sometimes supply more than one plot, we may assume that their number was lower than this figure, *which gives - as a broad order of magnitude - a growth of around 100 % in ten years.*

Fig. 10 : tube-wells distribution (256 units)



These figures correspond to densities of around 20 wells/100 ha, which is quite considerable if compared with Pakistan, where 7 wells/100 ha is common and where conjunctive use of superficial and groundwater also developed as a response to water shortage (Malik and Strosser, 1993). Subsidised gasoline makes pumping affordable and tube wells much appreciated as an independent and reliable source of water.

3.2.3 Other improvements in water control

Apart from the development of the wells and of the ditch network, significant other investments have been made in water control and resource tapping.

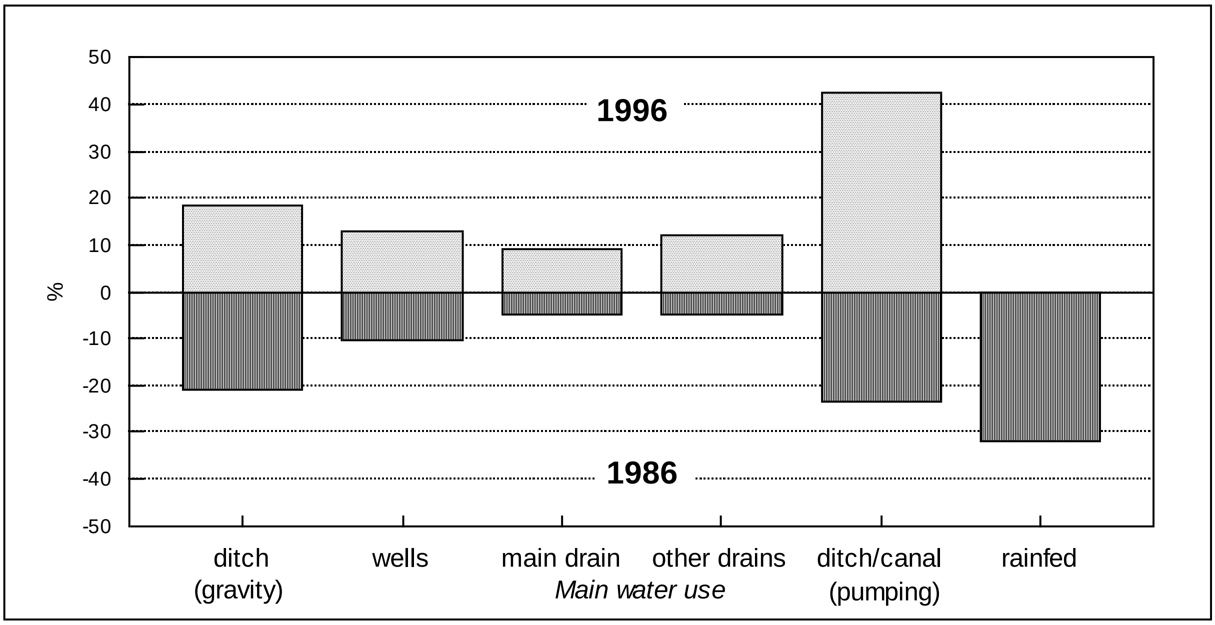
The (upper) main drain (*klong Ta San Ban Plaa*) was dredged and made perennial in 1988 : this explains why some plots along its course are still rainfed in 1989, whereas ten years later all neighbouring plots pumped from it. In 1991, one regulator was constructed in the western drain, just before its junction with *klong Ta San Ban Plaa* : by retaining water after the rainy season, this structure enables riparian farmers to pump from the drain during the dry spell.

Farm drainage has also been improved continually by RID : some burrow pits have been turned into drains linked to existing drainage waterways in which dredging is also carried out periodically.

3.3 Change in water use

Changes in main water use during the same 1986-1996 period are summarised in the figure below (Fig. 11) and in the maps of Fig. 12 and 13. The main change corresponds to the disappearance of rainfed sugarcane, which totalled 32 % of the area 10 years ago ; although this number may be overrated (as there is no certainty as whether the 1986 survey did identify and take into account all the existing wells and pumping from ditches), this major change has been allowed by the development of the ditch system and of the individual pumping capacity : *43 % of the area resort to the ditch as a main water resource, against 23 % ten years earlier*. Other changes relate to the development of pumping from the drains and from wells, most commonly for sugarcane, baby corn (16 % of the area) and flowers/vegetables. The decrease in gravity irrigation reflects the slight decrease of rice cultivation.

Fig. 11 : Change in main water use (1986-1996); in % of the total area



Between 1986 and 1996, 796 plots (48 % of a total of 1666), covering an area of 499 ha (30 % of 1660 ha), changed of both land use and water resource[5] *(Fig. 14)*. The principal crop change was the transformation of sugarcane into baby corn and other diversification crops (vegetables, flowers, trees), which concerns 407 plots (260 ha) : about half of these plots have the ditches and farm drains as principal resources whereas the other half relies on wells and on the main drain (perennial resources) ; nevertheless, 87 % of all these plots also intersect the well and the main-drain buffers, *which shows that agricultural diversification went alongside higher security in water use.*

[5] The discrepancy between the percentages (area and number of plots) is due to the emergence of numerous small plots cropped with field crops or flowers.

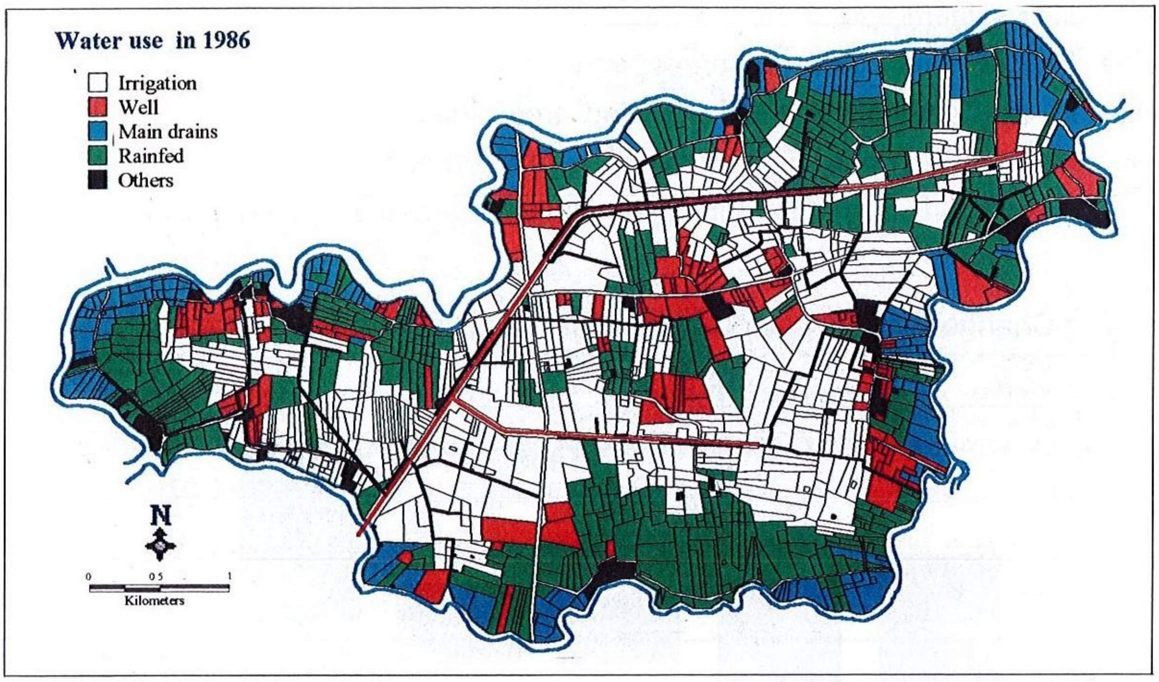

Water use in 1986
Irrigation
Well
Main drains
Rainfed
Others
N
Kilometers

Fig. 12

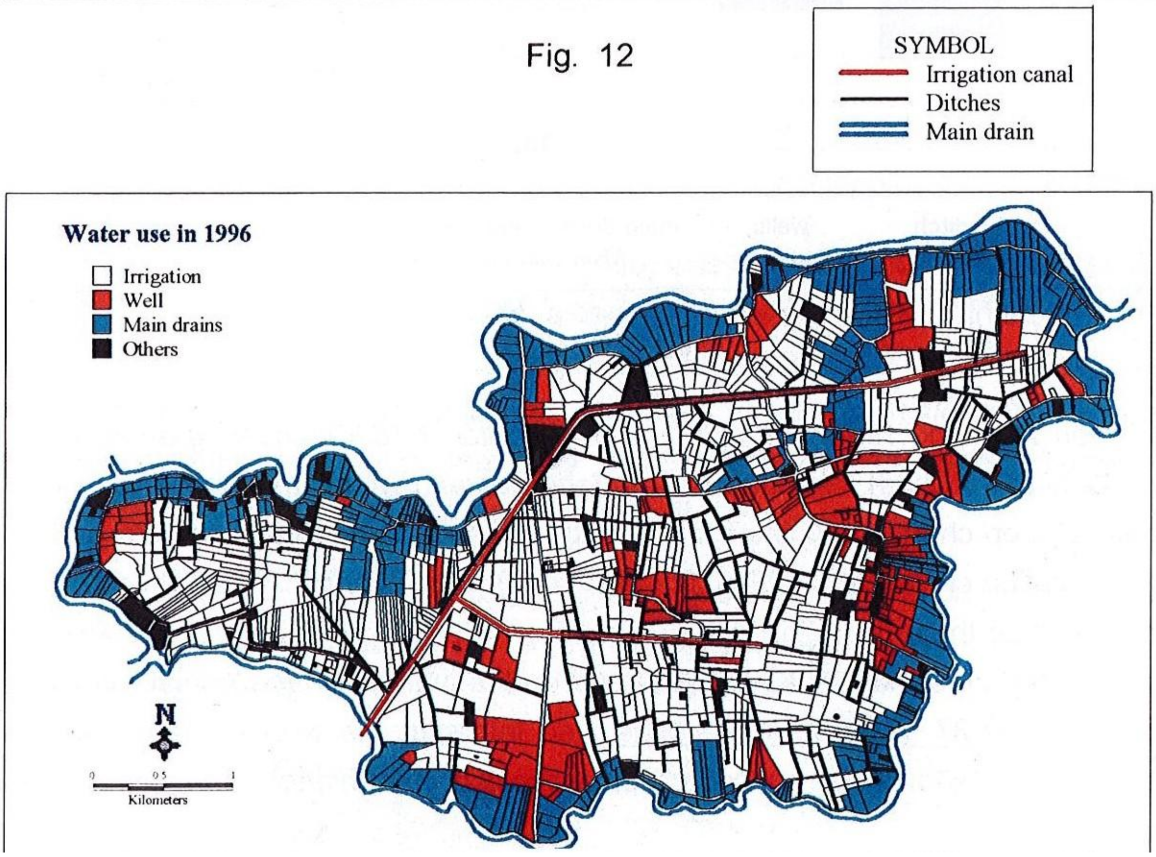
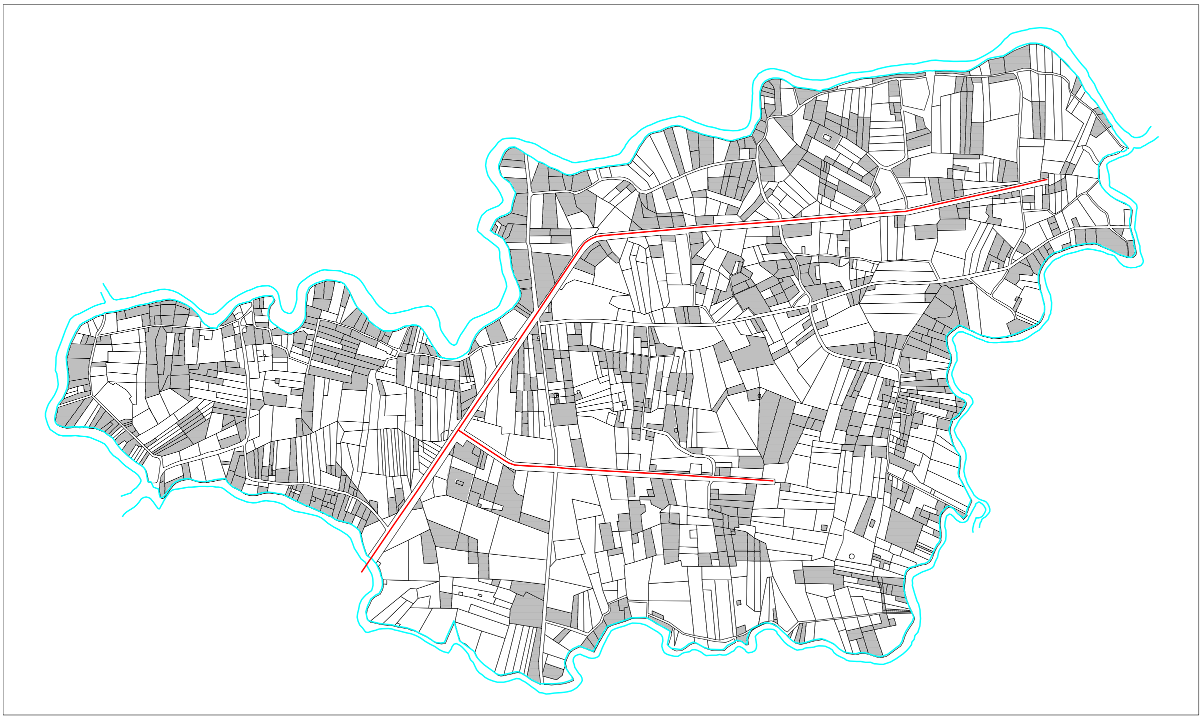

SYMBOL
Irrigation canal
Ditches
Main drain
Water use in 1996
Irrigation
Well
Main drains
Others
N
Kilometers

Table 5 : Matrix of water-use change (1986-1996); in % of total area (rounded values)

1986 \ 1996	ditch (gravity)	wells	main drain	other drains	ditch/canal (pumping)	rainfed	*Total (1986)*
ditch (gravity)	**14.5**	0.2		0.6	**4.8**		*20.1*
wells	0.5	**4.3**	1.6	1.7	2.1		*10.2*
main drain		0.3	**4.3**	0.3			*4.6*
other drains	0.1	0.9	0.1	**3.6**	0.4		*5.1*
ditch/canal (pumping)	1.4	1.9	0.5	0.7	**18**		*22.5*
rainfed	2.2	**5.3**	2.5	**4.7**	**16.5**	**0.00**	***31.2***
other		0.2	0.2	0.6	0.7		*1.7*
Total (1996)	*18.6*	*13.1*	*9.3*	*12.1*	***42.4***	-	

Fig. 14 : distribution of plots with change in both crop and water use



4. Current cropping systems and water use

Further details will be given in this section about the relationships between land use, irrigation techniques at the plot level and the main water resources used in each case. Main water resource refers here to both dry and rainy seasons : in fact, a good water supply in the dry season tends to reduce the contrast between both seasons, while secondary resources chiefly refer to the source used in periods between seasons or in case of failure of the main source.

4.1 Main water use

Rice : rice covers 20 % of the area. It can be found mainly in the lowest locations, with heavy soils and often deficient drainage conditions. Because of this low topographical location, water can be diverted to the plots by gravity. Rice fields form several clusters and the plots, within each of these, are supplied by the "plot to plot" system (water flows from successively from one plot to the other, from the upper ones to the lower ones).

Only two small clusters, located close to the northern main drain, obtain water by pumping from this. In the first case, water released by upstream plots is not sufficient ; in the second one, the ditch coming from the irrigation canal ends in the neighbouring sugarcane fields and has not been extended because of the opposition of their owners.

Drainage of the plots *in the rainy season*, at the time of sowing (by the wet broadcasting technique), is often ensured by axial pumps or by draining water to the next plot. Some of these areas have rather poor drainage : some farmers manage to pump excess water out into the ditch but, in some years, this may overflow. Therefore, farmers adjust planting techniques and varieties to the conditions of their plots :

- If drainage is good, wet broadcasting with High Yield Varieties (HYV) will be employed.
- If no easy drainage is possible (or if water impounds in the plot before irrigation supplies are available to start land preparation), then transplanting will be used.
- If the risk of prolonged excess water is too high, then deep water traditional varieties will be used, either with wet broadcasting, or with transplanting (as in the preceding case, which is more frequent).

- If the risk of flood is high (poor drainage), water supply inefficient and the plots uneven, then traditional varieties are employed with dry broadcasting. In that case, the system is often stabilised by a regulator placed in the drain, which retains water at the end of the season.

In the study area, the first case is the most common (70 % of cases : in particular in the largest rice cluster, see Fig. 8)), while the remaining 30 % make up the next two cases. The last case does not exist in the area but can be found in neighbouring ones.

In the dry season, rice cropping is carried out by all farmers and, in all cases, with HYV and wet broadcasting.

Sugarcane : this is the main crop of the area (57 %). It was formerly mostly rainfed (see later section) and is often grown on uneven land : furrow irrigation is therefore not very efficient. In many cases farmers use pumps and hoses through which they deliver water to the highest parts of the plot, from where it just spreads onto the fields.

Although the main source of water comes from the irrigation network (canals and ditches : 61 %), wells are also very present as both primary and secondary resources (when the ditch is deficient). A few plots are also watered by pumping from the adjacent rice fields*. In all cases, it appears that irrigation goes together with individual pumping at the plot level*.

Sugarcane is grown in the higher and medium location and may, in the latter case, sometimes be affected by excess water or floods (such as in 1995). This may have an impact on yields but, as it occurs in times when the plant is already six months old, plantations appear to be quite resistant to submersion. In normal years, the micro-topography of the plot is in general a more significant cause of heterogeneity in crop stand and yield. Depressions, or areas with poor drainage and located at the end of the furrow, often show sparser and weaker vegetation.

Irrigation frequency is very varied and reflects both the degree of easiness of water access and the care given by the farmers to their crops. It commonly ranges from once or twice per month, in the dry season, while the fields are mostly rainfed in the rainy season.

Baby corn : baby corn constitutes the most popular diversification crop (14 % of the area). Up to 5 or 6 cycles can be achieved in one year on the same plot[6]. Much less resistant to water logging and water shortage than sugarcane (Leroy 1996), it is therefore distributed on plots with good drainage conditions and secure water supply. When grown on medium location or in plots with insufficient drainage, cultivation is interrupted during the months in which there is excess water, reducing cropping intensity down to between 3 and 4.

Irrigation at the plot level is always by furrow, while water sources and pumping requirements are similar to what has been described for sugarcane, except for the frequency of irrigation (commonly three times a week in the dry season). The drain and the wells are nevertheless more frequent as principal water resources : this is due to the development of baby corn in the high levees of the western side, along the drain, and in plots located near the houses (also in higher location and often equipped with a well). This also reflects a necessity of water resources with higher reliability.

Vegetables, flowers : 41 ha hectares, i.e 2.6 % of the area, are cropped with a variety of vegetables (shallots, *kracha*, Chinese keys, chilli, coriander, asparagus, egg-plant, etc), tuber (taro) and flowers. Such an intensive production is also located where irrigation and drainage conditions are good. Furrow irrigation or sprinklers are used, depending on the kind of crop. Sprinklers have been introduced quite recently (in the last five years) and have spread significantly ever since. More than 30 plots with such an equipment were found in the area.

Fruit trees : fruit trees are traditionally grown on the levees and high land near the dwellings, and are irrigated by pumping from the drain or from some well (by using hoses, furrows or sometimes sprinklers). Orchards can also be accommodated in low lands : in that case, a system of raised beds alternating with ditches and protected by a surrounding dike must be excavated. Water constantly stagnates between the beds and is sprayed onto them by means of hoses or with little boats equipped with lateral sprinklers circulating between the beds. Common trees are coconut, guava, mango, rose apple, totalling 37 ha, not considering backyard orchards.

Aquaculture : fish or shrimp raising needs a full time connection with a perennial water resource. This could be found along the northern main drain, but soil on the levee appears to be too sandy to excavate ponds. Clay soils on paddy areas could

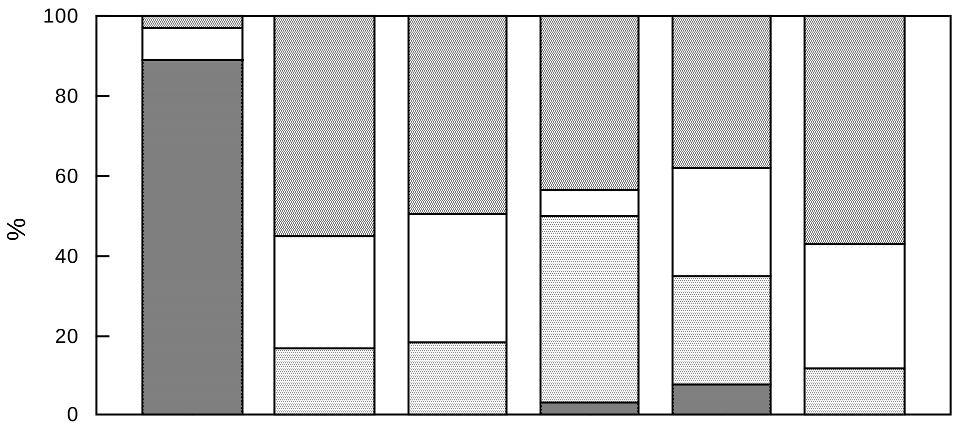
[6] Young ears are sold for food-stuff companies while the vegetative parts are given to milk cows.

be adequate but drainage is not easy and interactions with other uses and crops in terms of water quality would also be problematic. Extensive fisheries exist in several minor ponds at farm level (temporary storage) but intensive fisheries exist in only one location, along the main canal (access), close to the drain (drainage), and in a rice area (clay), where it is associated with chicken raising.

All these observations are summarised in Table 6.

The breakdown of main water uses for each crop is summarised in Fig. 15. There is an almost 100 % correlation between rice and gravity irrigation (and lowlands). Pumping from wells is higher for baby corn, while pumping in ditches and drains appears to be the main source of the non-rice crops.

Fig. 15 : Distribution of main types of water use for different types of crops



	rice	sugar cane	baby corn	flower	vegetable	fruit trees
gravity	89.1	0.0	0.0	3.3	7.9	0.0
pump (w ell)	0.0	16.7	18.3	46.7	27.0	11.8
pump (drain)	7.9	28.2	32.0	6.7	27.0	31.4
pump (ditch/canal)	3.0	55.1	49.7	43.3	38.1	56.9

If we now consider the breakdown in relation to the total area (in ha and in %), as given in Tab. 7, we can see that only 60 % of the land has an irrigation supply, delivered through canals and ditches, as it main resource, whereas remaining areas pump in wells and drains. The importance of individual pumping is also salient as only 18.5 % of the area can afford water application by gravity.

Tab. 6 : land use and related main water sources

Crop	Topography/soil	Irrigation (water sources)	Drainage	Irrigation technique	Observation
Rice	lower location clay	ditch (or canal), by gravity one case of pumping from the main drain in the dry season	variable : some areas with insufficient drainage	gravity surface irrigation; plot to plot within each rice cluster	Transplanting and/or traditio-nal rice varieties are used in case of insufficient drainage
Sugarcane	medium location	ditch or well or drain	often insufficient. Pounding water reduces yields but the plant does not die	(pumping onto the plot) + furrow irrigation if good levelling or basic flooding from upper parts (hoses are used to take water to these points)	Levelling is often insufficient. Water applica-tion is not easy and uneven. Fields are irrigated every 2 to 4 weeks in the dry season. In the wet season it is mostly rainfed.
	High location	pumping is required at plot level	good		
Baby corn	high location loamy to sandy	**well** or ditch or drain or a combination of these Water supply must be secured	good but sometimes insufficient, either for the whole plot or for some parts of it, when levelling is poor	(pumping onto the plot) + furrow irrigation. Uneven plots are common.	Local water retention in case of uneven levelling is prejudicial to yield. Plots with insufficient drainage are left uncultivated for two to four months
Vegetables/ flowers	high locations	**well** or ditch or drain or a combination of these	good	depends on the crop : hoses and sprinklers are the most common	
Fruit trees	high location	Trees are planted without plot development. Water is pumped from wells or main drains	No problem	Water is pumped and distributed with hoses or small sprinklers or by furrows (near dwellings)	
	medium/low location	Trees are planted on raised beds with a surrounding dike (polder) Water comes by gravity through the ditch. An additional source is required (well)	No problem of drainage because the plot is poldered. If the dike is not high enough, risk of flood.	Water is available in the ditches, and lifted onto the beds (manually or with a boat equipped with sprinklers. When trees are old, irrigation of the bed is unnecessary.	Investment in land development is high

Tab. 7 : Main water sources, by land use categories (rounded values)

Land use * ha * (%)	**Main** source of water							
	none	ditch (gravity)	plot to plot	ditch or canal (pumping)	main drain	other drains	well	**TOTAL**
built up	43 (2.7)							**43 (2.7)**
rice		**211 (13.1)**	**84 (5.2)**	6.2 (0.5)	10 (0.7)	12 (0.7)		**323 (20.0)**
sugarcane				**553 (34.2)**	88 (5.5)	142 (8.8)	138 (8.6)	**921 (57.1)**
baby corn				**94 (5.8)**	38 (2.3)	30 (1.9)	**59 (3.6)**	**221 (13.7)**
flower				11 (0.3)	0	0.7 (0.1)	4.9 (0.3)	**11 (0.7)**
vegetable		4 (0.2)		5.2 (0.3)	6 (0.4)	4 (0.2)	6.1 (0.4)	**30 (1.9)**
fruit tree				18 (1.1)	8 (0.5)	7 (0.5)	3.1 (0.2)	**37 (2.3)**
fallow	28 (1.7)							**28 (1.7)**
TOTAL	**71 (4.4)**	**215 (13.3)**	**84 (5.2)**	**687 (42.6)**	**150 (9.3)**	**196 (12.1)**	**211 (13.1)**	**1615 (100)**
	4.4 %	**gravity : 18.5 %**		**individual pumping : 77 %**				
	4.4 %	**irrigation water : 60.1 %**			**non irrigation : 35 %**			

4.2 Conjunctive water use and secondary sources

The above section has shown the matrix of relationships between land use and the main water resources. These figures, however, stand for the primary water resource used in the plot. Farmers often resort to several sources, depending on whether these are perennials and/or reliable. In some cases, three sources are used and their share may sometimes be balanced as to make the very definition of which one is primary dubious. First of all, irrigation water is not available during about three months of the year distributed in two inter-season periods. Farmers with all year round cash crops (such as baby corn, vegetables or flowers) must ensure water supply and, but for few exceptions, will have a well. Secondly, the reliability of water supply in the ditch is highly variable, both in time and space. Remote areas and-tail end users tend to get late supply (lengthening the period where water is not available) and unsteady deliveries (increasing the risk of water shortage and thus, the need to tap additional resources).

The specification of the blend of water uses adopted by each farmer, for each of the 1666 plots, is clearly beyond average survey capability[7]. In order to try to assess the importance of conjunctive use, we resorted to query and buffer techniques[8] as provided by GIS packages.

Well utilisation has first been evaluated conservatively by considering the number of plots (255) provided with wells. Buffers with different radiuses have subsequently be drawn around the wells and all the intersected plots are considered to possibly benefit from the well ; this is clearly an overestimate, given that some adjacent fields may not belong to the owner of the well. This latter information was only partially available and it has not been possible to discriminate the intersected plots according to land ownership.

Buffers with a 25 meters radius have also been drawn around ditches, canals and burrow pits : intersected plots are considered to be able to use these water resources. Lastly, similar buffers, with 25 m radius have been created along farm-drains and with 100 m along the main drains.

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[7] The main water resource has been determined visually or through informal interviews during field work.

[8] Buffers are regions drawn around objects (points, lines or polygons) in which the distance from any point to this object is inferior to a given number (radius); in case of a point, for example, the buffer is a circle. See annexe.

By computing the plots that intersect with several of these buffers we may therefore estimate the importance of conjunctive use in the area and provide insights about multiple access to water resource ; a breakdown by crop will also provide hints on the relationship with risk acceptance.

4.2.1 The role of tube wells

255 tube-wells were found in the area : 97 plots of sugarcane, 71 of baby corn, 17 of vegetable/flowers, 6 in rice, 21 near households, and 7 in orchards[9]. If we consider buffers around the wells of 50, 100 and 150 m radius, we find that the number of intersected plots is 639, 946 and 1137, which may be taken as (over)estimates of the number of plots resorting to wells. This suggest, if we consider the lowest hypothesis, that the number of plots using wells (as a main or secondary resource) is likely to be at least twice as high than the number of wells.

From the 208 plots relying principally on wells, only 68 are found to intersect the ditch/canal buffer (radius 25 m*), which suggests that two thirds of the wells have been dug because of poor-to-no-access to the ditches, while the remaining third still find the ditches unreliable or inconvenient.*

Out of a total of 1,666 plots, 657 intersect the ditch/canal buffer with a radius of 10 m ; this number rises up to 834 when the radius in increased to 25 m. This must be compared with the 778 plots which have the ditch (or canal) as main water source (120 fields with plot to plot system not taken into account).

Surprisingly enough, 261 plots intersect the ditch buffer (25 m) but do not choose it as a primary resource : most of the time the ditch is located on the "bad" (lower) side of the plot, such as in the case of the plots close to the main drain, where farmers prefer to pump from the latter, which both fits requirements of reliability and the natural slope.

These estimates of conjunctive use are summarised in Fig. 16. *41 % of the plots are found to resort to several water sources, among which 5 % have potential access to three*.

A typical set of land and water use is represented in Fig. 17 : it shows a toposequence and how crops and their water resources tend to be distributed.

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[9] This gives a total of only 227 plots because some plots may have several wells.

Typical land and water use along a toposequence (Kamphaengsean Project)

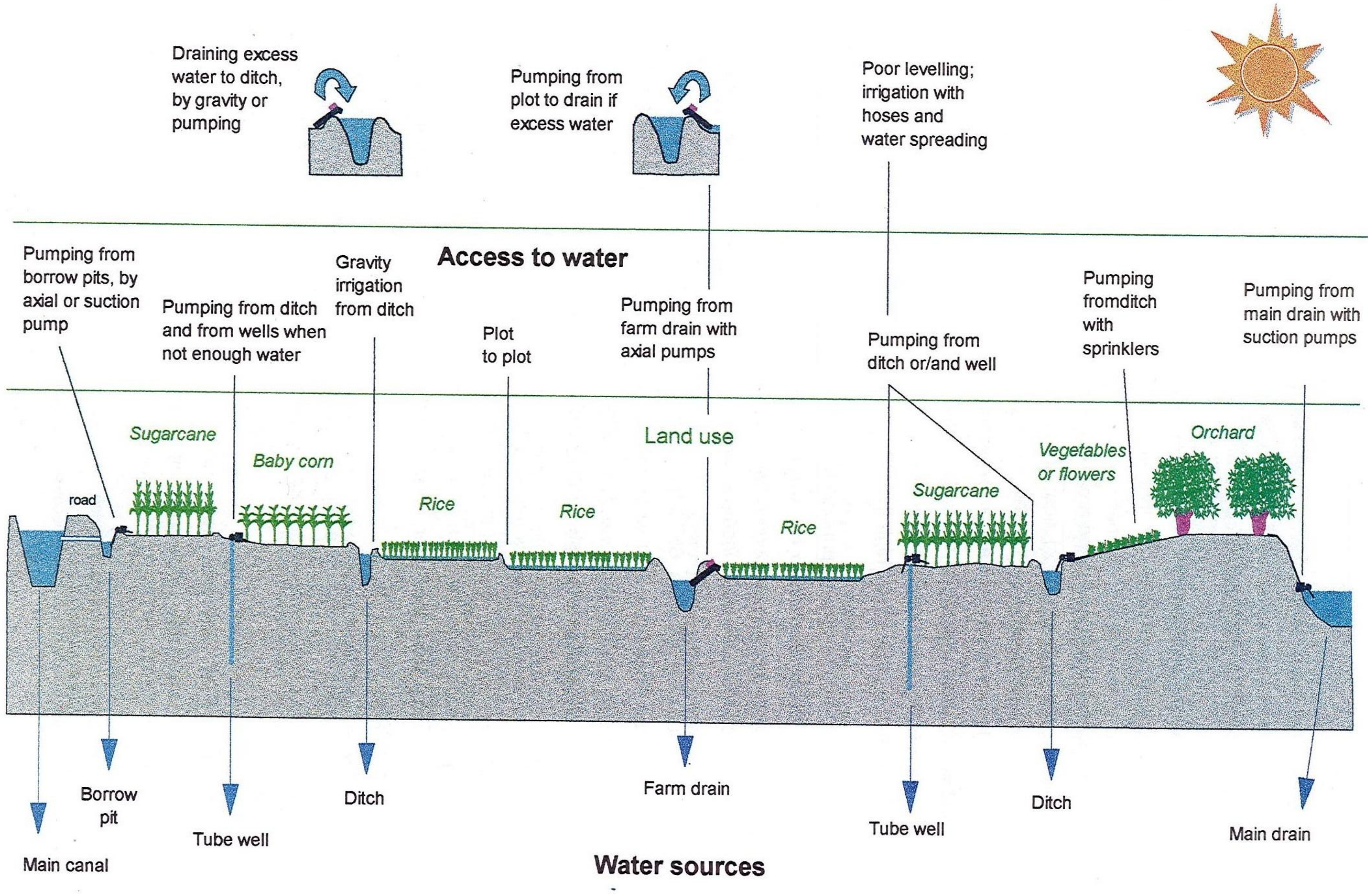
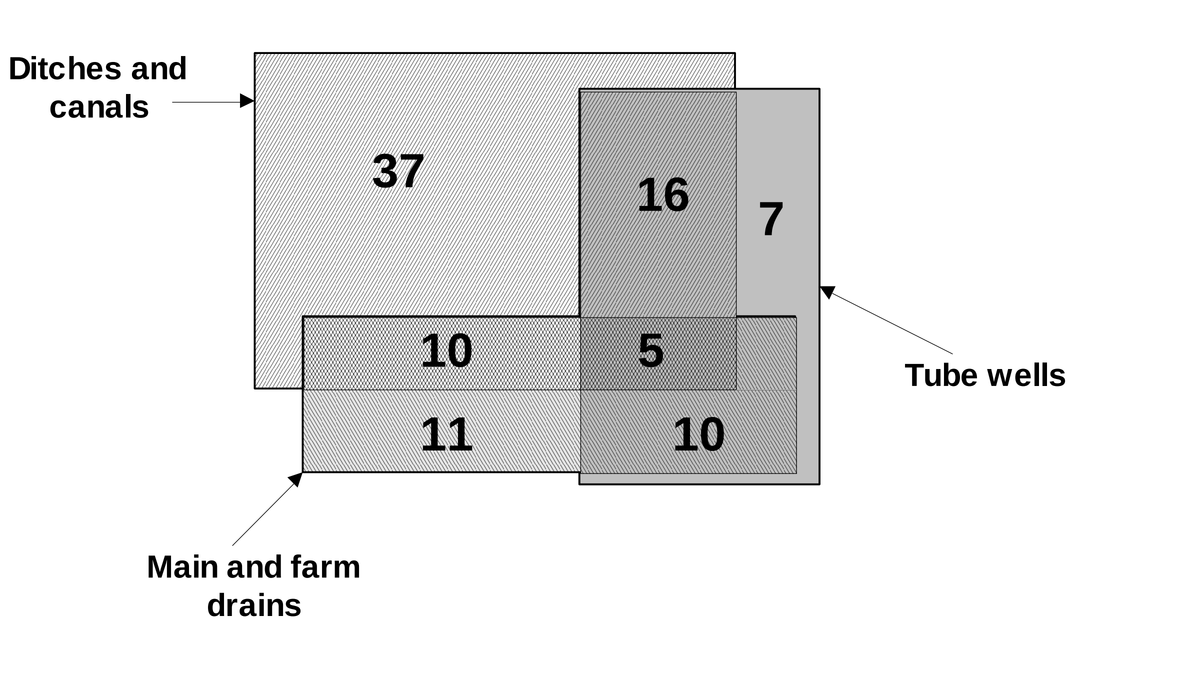


Fig. 16 : Distribution of plots according to water access
in % of the total area, as estimated through buffering



4.2.2 Logic and priorities of tapping water resources

The different water resources are not equivalent in terms of investment, operation costs and reliability. Their characteristics are summarised in Table 8.

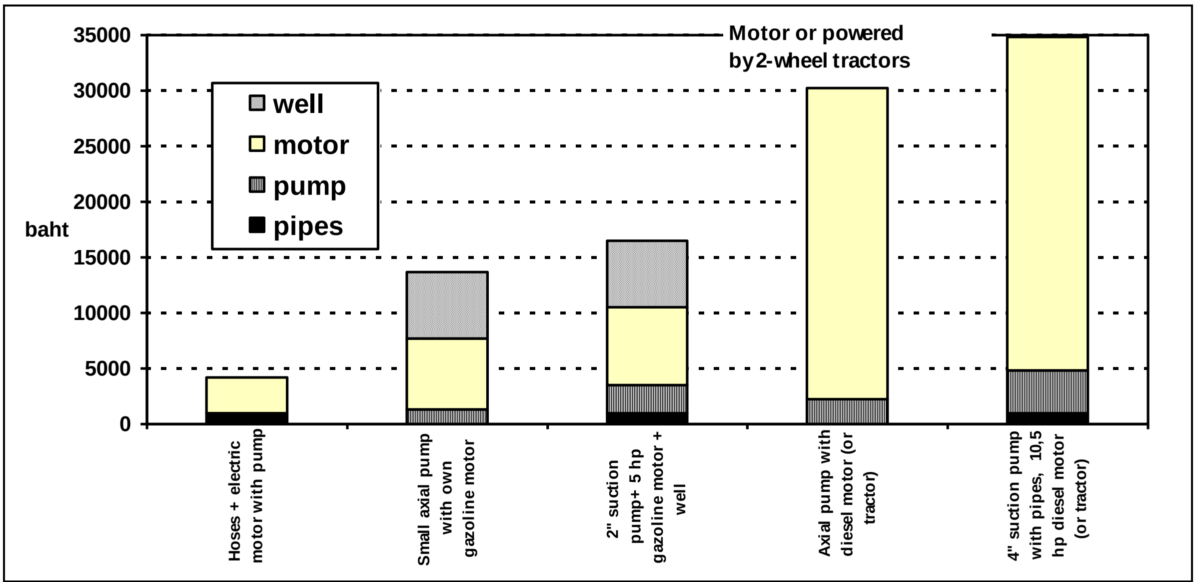
In terms of *investment*, the axial pumps, especially if they can be linked to and powered by the engine of the two-wheel tractor, are the cheapest individual pumping device (1,000 to 2,300 baht). However, they can be used only to lift water from the ditch to nearby fields (and/or to drain excess water out of the plots). Other sources also require the use of motor-pumps, together with a set of pipes and/or hoses. The cheapest is the electric motor (around 3000 baht). Suction pumps are quite cheap (1800, 2800 and 3800 baht for 2", 3" and 4" diameters), but they must be powered by a benzene or diesel engine : while the former generally have a power between 3.5 and 6 hp, with a price between 5,200 and 7,000 baht, the latter have higher power (commonly between 9 and 11 hp) but are almost 5 times more expensive (from 26,000 to 30,000 baht). Pumping from the main drains may require a slightly more powerful engine, because the head between the water and the top of the levee can be several meters. This is also the case for pumping from tube-wells.

Pumps are often used with hoses or pipes which increase the investment (they also have a shorter life span than the pumping devices). Typical costs for PVC pipes are

19, 40 and 62 baht/meter for diameters of 2", 3" and 4" respectively, whereas one meter of a 1" iron tube amounts to 10 baht.

Fig. 18 illustrates the variability of the investment cost for pumping, showing some of the most common devices. These costs, however, should be expressed in relation with the area that each pumping device is able to cover. This, again, given the diversity of situation (for example plot fragmentation will be a factor which will induce multi-equipment), is difficult to assess. Nevertheless, it clearly appears that the cost of diesel motors (around 28,000 baht) is very high, in comparison with other devices and investment costs. That is why the motor of the two wheel tractor is so often used to power the pump. The best combination is therefore an axial pump driven by the (already existing) two-wheel tractor, if any and if the water source is a nearby ditch.

Fig. 18 : Some investment costs for pumping



Regarding *operational costs*, these basically depend on crop type, crop care, soil percolation, plot levelling and ET on one hand ; and on the kind of pump and fuel, the pump efficiency and the suction head on the other hand. Irrigation frequency is quite low for sugarcane (monthly frequency ranging from .5 to 2) and high for rice (but only two minor clusters use non-gravity supply) and for diversified crops, especially baby corn (three times a week in the dry season). The *cheapest* sources, as far as energy consumption is concerned, are the ditch and the canal, then the main drains (higher suction), lastly the tube-wells.

Diesel motors have an average consumption of 0.9 l/hour (with variations according to power and maintenance), slightly more than the gasoline ones (Kongsej 1991), while the cost per litre is almost equivalent (8-9 baht for benzene, 9-10 for gasoline[10]). When pumps can be operated near the houses, electric motors are common and their use reduces the costs of energy, with an estimate of 4 baht/hour for a 2.5 hp motor In addition, these motor are easily operated by women, who appear very reluctant to deal with bigger thermic motors .

Tab. 8 : Main economic characteristics of the different water sources

Water sources	**Initial investment**	**water acquisition (energy consump.)**	**reliability**	**observations**
Canal	motor-pump + pipes/hose (sometimes electric pump)	low (to medium)	good with two periods of interruption	pump must be removed
Ditch	suction pump + pipes/hose (cheap if powered by the 2W tractor, expensive if a diesel motor is used) or axial pump (usually driven by the 2W tractor : cheap) extra cost of ditch, when excavated by farmers	low (low head)	very varied (in space and time)	other source required for year round diversified crops
(rice)	none (gravity)	none	good	pumping often necessary for drainage
Main drain	medium power suction motor-pump + pipe/hose or electric pump	medium (to high)	good (perennial)	
Drain	idem ditch	low (to medium)	good but non perennial	water quality gets poor in the western drain
Well	pump + pipe/hose, motor or link to 2W tractor Well digging (6000 baht)	high (high head)	good	aquifer drawdown may result from over-exploitation

[10] These prices have been increased by two baht since the middle of the year (1997)

Pumping costs must of course be considered in relation with the pump discharge. 8" axial pumps or 3" suction pumps powered by two-wheel tractors and pumping from a ditch have discharge around 24 m3/h (0.37 baht/ m3). Smaller 6" axial pumps or 2" suction pumps powered by 2-6 hp motors have discharge around 14 m3/h, which means costs of 0.64 baht/m3. Because of smaller discharges, 2 hp electric pumps have a cost per m3 estimated at 0.3 and 0.45 baht for ditch and well pumping : the lower energy cost is offset by lower discharges.

The most *reliable* sources are wells (but for exceptional dry spells) and the perennial main drain, followed by the irrigation canals and other drains (with predictable interruptions), and the ditch system, with good to very poor reliability. Rice and sugar-cane (<u>if</u> they have access to it) can rely solely on irrigation water from ditches. Other crops need uninterrupted (for an optimal land use intensity) and reliable supply, therefore they will rely - in addition or exclusively - on wells and/or on the main drain.

4.2.3 "Khwamsaduak" or the practical aspect of things

In addition to such rather rational considerations, farmers also choose or blend their water resources based on other personal criteria. Easiness in farm operation often stands out as a very important criteria (what is *saduak* is what is enjoyable for being convenient, practical, easy going).

At first sight, some situations of water use may appear conspicuous. This is the case, for example, of a house with its adjacent baby-corn field sandwiched between the main canal and a ditch/drain, which uses a well located near the house, at the extremity of the plot. By constantly using the well, although two sources of superficial water are available nearby, the farmer significantly increases his pumping costs. The reason for such a choice is that he considers these two superficial sources to be not *saduak* : getting water from the canal would make necessary the use of pipes across the road and the constant removal of the pump ; using the backyard ditch would be possible, but as it is not fully reliable, he would have to move his pump back to the well (at the other extremity of the plot) each time water is insufficient : to avoid such inconveniences he therefore chose to rely solely on the well.

Such an assessment of the burden that goes together with farm irrigation practices is obviously a highly personal matter : it depends on the local layout, on the kind of pumping device (some gasoline driven motors are very heavy and hard to remove, whereas the use of two wheel tractors is quite handy), on the will/necessity to lower costs at the expense of increased labour, on whether one place is safe regarding theft, etc.

Another case of not using water from the ditch is common in the sugarcane and baby corn fields : because of the use of furrow irrigation water must be delivered at the highest extremity of the plot. If the plot is rather long and the ditch located at the lowest extremity, farmers must use a hose or a pipe to deliver it at the other end. This is also costly and burdensome and some farmers prefer to keep on using their wells which have been dug, of course, on the "good" side of the plot.

"Convenience" is also a driving force in the development of sprinkler use. They allow adequate watering for some kind of crops which cannot easily be irrigated by other means, but they also constitute labour saving devices which are definitely "*saduak*".

5. Current water management

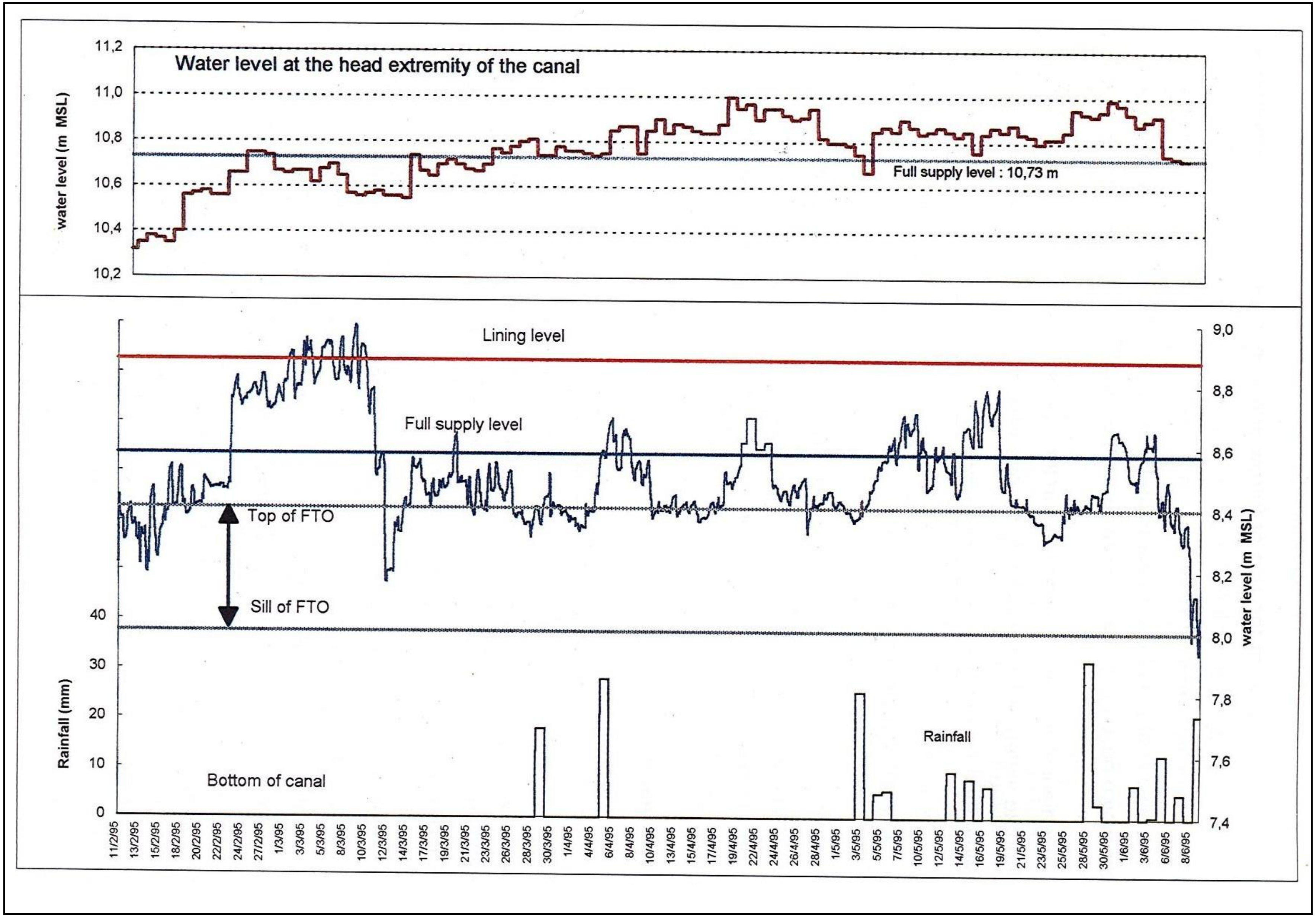
Although it is not the main objective of this paper to analyse water management in the project, a few important points must however be emphasised, as they contribute to the understanding of farmers' decisions regarding tapping water resources and crop choice.

5.1 Management at the project level

An initial point under scrutiny in the study has been the regularity of water supply at the FTO inlet. For the sake of simplicity, we may consider that the availability and reliability of water supply at farm level are the combined result of upstream conditions (all the factors that contribute to shape the hydrogramme at the inlet of the FTO) and ditch characteristics.

To supersede difficulties stemming from hand written hydraulic data, a data-logger has been set to monitor the water level upstream and downstream of the FTO 8-310 which ditch supplies the largest area. Data has been recorded over one year, with measurements every two hours. This allows one to have a clear vision of the quality of water access at this location, both in terms of quantity (water level) and regularity (fluctuation).

Fig. 19 presents the variation of the water level in front of the FTO during the 17 weeks of the dry season 1995 : It shows that the water level extremely high during the first month (land preparation) and that it further decreases down to a level lower



Water level at the head extremity of the canal
Full supply level : 10,73 m
water level (m MSL)
Lining level
Full supply level
Top of FTO
Sill of FTO
Bottom of canal
Rainfall
Rainfall (mm)
water level (m MSL)

than the theoretical full supply level, which is reached only during some periods. This may be related to the proportion of only 61 % of the area which draws water from the irrigation scheme. However, the water level very seldom goes under the top level of the FTO pipe.

Adjustments of the sluice gates along the secondary canal are made by the zoneman according to necessity and based on experience. The upper part of the figure shows that there is no relationship between the fluctuation of the water level at km 1+700 and at the FTO's level : three sluice gates and two siphons separate these two points and this is enough to create an (at least visual) independence of the reaches.

The setting of the 33 FTOs existing on this secondary canal have been recorded 5 times a day during fourteen days : some of the FTO appear to have been adjusted up to three times a day and the average daily number of adjustments per FTO is 0.4/day. Nevertheless, the settings of three sluice gates have been changed only once (for two gates) or twice (for the last one) during the same period (gate opening between 40 and 50 cm). This indicates that the inertia of the canal partly compensates the erratic demand of the FTOs and that rather few adjustments are required in routine management. These adjustments are done by the zoneman based on his experience. More interventions are required in times of shortage or heavy rainfall (excess water must then be spilled at the tail of the canal or in some FTOs which are connected to the drainage system) but this point needs must receive further investigation.

5.2 Management at the ditch level

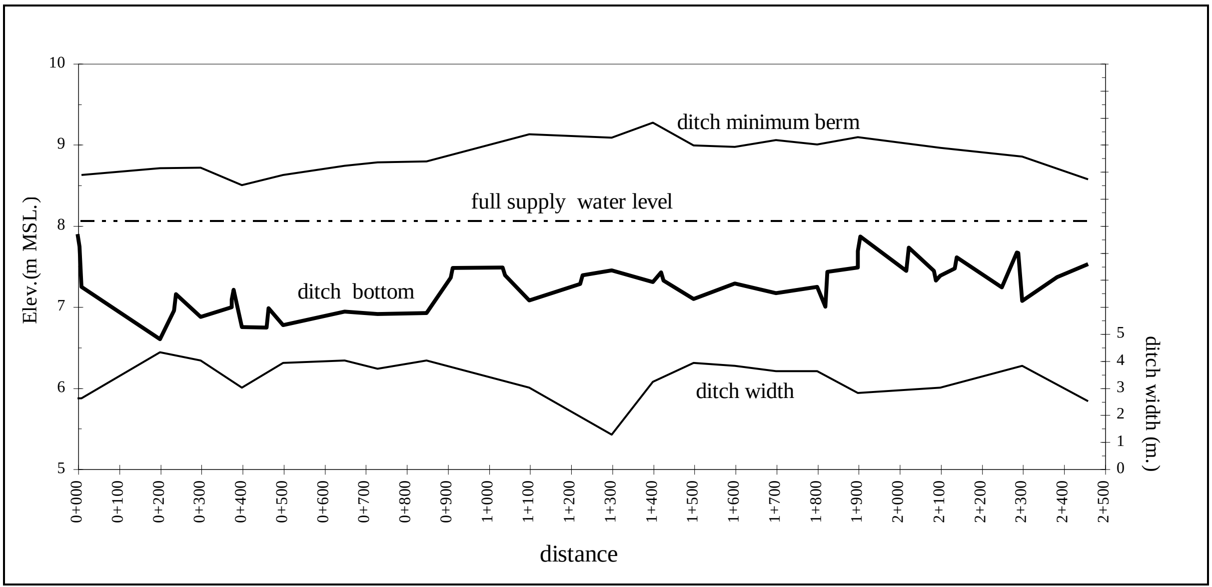
Water management at the ditch level is a more complex issue which combines physical aspects (topography, siltation, size, slope, length, etc), agronomic aspects (land use, agricultural calendar, techniques) and social aspects (social structure and management rules, water rights, etc). Collective arrangements are known to be increasingly necessary when water is scarce. In the present case, and without entering in details, two salient features must be emphasised : firstly, water is on the whole rather abundant. Tail-end users' disadvantages are often limited to receiving later deliveries, but as no problem of cropping calendar exists[11], this is, in general, little penalty. Second, equity in water supply along the ditch is seldom seen as an

[11] No climatic constraints exist in the area, in particular regarding rice cropping, and the use of varieties with shorter duration provides high flexibility ; in some cases late seedlings may suffer from early flash floods and suffer some damage.

issue liable to give way to conflicts : locational or topographical advantages tend to be considered as normal as social ones and farmers, in general, seek to solve their problems individually or through requests to the local administration : this may in particular include well or ditch digging.

Fig. 20 presents an example of a longitudinal section of a 2.5 km ditch, together with the corresponding variation of its width : it suggests that substantial size irregularities exist in the ditches. This necessarily has an impact on the quality of water access and induces inequities between farmers. It is worth noting, also, that the storage capacity of the ditch system, which delivers water to 210 ha located on the western size of the main canal, has been calculated at 13.000 m3 for a total length of 7.9 km and a full supply level. This corresponds to about one day consumption ; the ditches constitute a buffer area which can accumulate water during the night time, in which only some constant flow irrigation in the rice fields is recorded (in periods of high demand, however, farmers also commonly irrigate at night time). Four farm ponds also contribute to storage, with an estimated capacity of 7,000 m3

Fig. 20 : longitudinal section of a ditch, with width variation



5.3 *Irrigation efficiency in perspective*

5.3.1 Efficiency at the local level

The overall situation of abundant water supply - together with possible water waste and low efficiency - can be briefly specified by comparing requirements and real deliveries. This will be done only for the dry season, in which the analysis is more meaningful.

Only the inflow at the head of the secondary canal is available. The average observed discharge during the 17 weeks of the dry season 1995 was 1 cms, whereas the area using irrigation water - including our study area - has been estimated at 1320 ha, 58 % of which is cropped with sugarcane. Average theoretical requirements during this period correspond to a discharge of 0.71 cms in the canal. This gives a very reasonable efficiency for a "semi-gravity" irrigation scheme (70 %), due in part to the importance of pumping at plot level.

This figure, however, is flatly erroneous : comparing crop requirements and real deliveries to assess the overall efficiency of the system makes sense only if the implicit assumption that these requirements are fulfilled is correct. In fact, such an assumption is probably true for rice, acceptable for baby corn and cash crops in general, but absolutely false for sugarcane which represent 57 % of the area : several factors, including bad plot levelling and a high pumping cost, when compared with sugarcane net income, account for a very low rate of water use in the sugarcane plots. Whereas normal irrigation should take place every 7 to 10 days in the dry season, plots are hardly irrigated once a month, and sometimes less. If we assume that sugarcane irrigation is only 50 % of the "optimal" theoretical requirement, then we realise that crop satisfaction is only half of the optimal full supply and, therefore, that losses are much higher than expected driving efficiency down to a rough 50 % value.

Plot irrigation in the sugarcane plots is a very wasteful process : because of poor levelling and shallow furrows often full of leaves (for ratoon crops), it takes sometimes up to 10 or 12 hours of pumping to irrigate one rai. High infiltration losses are generated by a slow progress of water in the furrows and by accumulation in micro-depressions. Therefore, long and costly hours of pumping are required to irrigate one plot. Corresponding operational costs in fuel appear so high that they compel farmers to limit water use to a clearly sub-optimal level, with impact on yields, which average 8-12 t/rai. If we consider a root depth of 1.00 m and an amount of stored water available for the plant of 65 mm (Suiadee 1994), then irrigation frequency should be close to ten days, while - in reality - it is closer to 30 days : even taking in consideration some contribution from rainfalls, this points out for a rough 50 % under-irrigation rate.

Pumping costs can be roughly estimated as follows : considering discharges between 14 and 24 m3/h and application times per rai between 4 and 12 hours, we may consider, as average orders of magnitude, application volumes of 10 mm and pumping costs of 60 baht/rai/application. For a net cash income of 1500 baht/rai

(Molle and Keawkulaya 1997)[12], six months of deficit rainfall and a two-week time frequency would mean a cut of more than 50 % in the net income. Although such a calculation should be carried out more in details, the broad values used her suffice to understand why many farmers declare to "do 3 or 4 applications and let the rain take care of the rest".

This leads us to observe that *in the case of a demand-base irrigation project, with several kind of crops, conjunctive use and poor-on-farm development, the water demand as well as the efficiency are quite hard to assess :* the usual calculation of water requirements (target) in one unit is as follow :

Q required depends on :

1. the kind of crop [numerous in our area];
2. their respective areas [changing significantly over time];
3. ET, Kc, expected rainfall [showing discrepancies of up to 25 % according to sources];
4. crop progress or cropping calendar [quite flexible because of no calendar constraints];
5. loss in water application at the plot level [poorly known and very high for sugarcane];
6. loss by percolation in ditches (and canals);
7. the percentage of each crop which uses water from other water resources than the irrigation canal [changing over time];
8. the percentage of conjunctive use in the plots which have access to irrigation water [also changing over time];
9. and last, but not least, farmers' practices which, for sugarcane, correspond to a use of water well bellow theoretical requirements (probably around 50 % of these).

Such a situation sharply contrasts with irrigated areas with mono rice-cropping, pre-established cropping calendars, relying solely on irrigation water, for which the establishment of a target volume (or discharge) is easier.

These problems have made difficult the use of software for water allocation and monitoring. Currently used programmes may not have properly assessed the points 5) to 9), most specially the changes occurred in them*. Water requirements are likely*

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[12] Calculation of net income in the present case have been made considering lower yields than the

to be overestimated, chiefly because of the non-optimal irrigation in sugarcane and conjunctive use. As design and target discharges are calculated based on theoretical optimal values, it is little surprise that needs appear to be fulfilled, given that deliveries exceed by far real requirements.

Nevertheless, main non-irrigation supplies, coming from wells and drains, eventually originate from resources first conveyed by the irrigation scheme. Shallow aquifers are repleted by seepage from canals and by percolation in the fields. This has been clearly demonstrated, first by the fact that prior to irrigation, few places could rely on pumping from shallow aquifer, second by the drawdown observed in the 92-93 period, when a shortage was experienced. Drains also collect water from upstream fields or from the aquifer and, therefore, can also be viewed as waterways conveying water first made available by the irrigation scheme. Altogether, this makes the calculation of efficiency rather difficult.

5.3.2 Efficiency at the macro level

Another difficulty in assessing efficiency lies in the fact that it is a scale specific criteria which changes its facets with the adopted scale (Seckler 1996). The upper main drain, bordering the study area on the north, is used to convey water (as much as 40 cms) to the Tha Chin river, where it is (partly) pumped again into the canal network of the West Bank. This shows that efficiency must necessarily be taken in a broader sense, given that local "losses" appear to be often recycled through the drainage or underground system.

Consequently, real losses are eventually volumes discharged to the sea. As these are maintained close to 50 cms (the flow necessary to avoid saline intrusion), the overall efficiency must as a matter of fact be tending to 100 %, with the exception of losses by evaporation, deep infiltration or sinks of polluted water. Such an aggregated figure, however, tells nothing about the spatial homogeneity of water distribution and the inequity resulting from possible imbalances.

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ones observed in the upper delta.

6. Conclusions

6.1 An endogenous on-farm development

Kamphaengsaen Project - and zone 5 in particular - receives deliveries which globally match the demand of those farmers who have access to irrigation water. This happens to be true partly because of investments in on-farm and additional water resource development. In addition, the inflow provided by the main canals at the entrance of the different FTOs can be considered quite good : this contrasts with the upper delta, where - in the dry season - lifting water from the main canal into the ditch is, in most cases, necessary : this most obviously constitutes an encouragement for the farmers of the Mae Klong area, which are sure to obtain water if they link a ditch to the main network.

In fact, on-farm development has been quite intensive since the construction of the project : about half of the 55 km of ditches were achieved with governmental budget and the other half with farmers resources. This show a rather spectacular effort and investment on the farmers' part, especially intense in the last 10 years. Farmers' efforts and investments in levelling are also mentioned but generally for small plots (baby corn) and are of lesser magnitude than ditch excavation.

To some extend, we may infer that the government's policy to reduce the cost per ha of the irrigation projects (in order to expand the area more rapidly) by not including on-farm management was correct, as it later developed up to a density of 31 m/ha. If a secondary objective was to have the investment borne by the users, this partly failed, as 53 % of the investments originated from governmental budget.

6.2 Gravity vs pumping irrigation

Although labelled a gravity irrigation project, the Kamphaengsaen Project (and most probably the whole of the Greater Mae Klong Project, except for a few areas with land consolidation) *appears to be rather a pumping irrigation project* : the lack a of raised tertiary system *annihilates* part of the benefit of the gravity system : the head gained by means of costly lined raised main canals happens to be lost at the exit of the FTO. Consequently, this deficiency has to be compensated by an extensive pumping capacity at farm level, 77 % of the farms resorting to pumping. Direct irrigation from the ditch by gravity is, in 90 % of cases, correlated with lowland and rice cropping (this is confirmed in other zones of the Kamphaengsaen Project). Even in this case, axial pumps may also be required for drainage of the plots, making almost impossible to find a farmer deprived of a pump in the area.

In fact, the level of equipment in pumping device is extremely high in the Central Plain of Thailand. The number of pumping devices inventoried in 1993 in the 20 provinces which are partly or entirely included in the irrigated area of the Chao Phraya delta, was around 300,000 (of which 53,000 were electric pumps), with 340,000 farmers using such devices, against 211,000 in 1978.

Individual pumping devices provide flexibility to the farmers and allow conjunctive water use. However this has obvious consequences in terms of labour (removal of pumps back and forth) and costs (investment, maintenance and consumption). This economic impact on our area can be very crudely estimated by considering average pumping requirements (these are average values, because consumption and time vary a lot according to the equipment used and the pumping head), as detailed in annexe. It amounts to an estimate 5,2 million baht per year, which correspond to values per rai of around 330 baht for sugarcane and 1905 baht for baby corn.

6.3 Quick change in land and water use

The study also demonstrated the quick change that affected both land and water use in the past ten years and how they are linked with one another. Crop diversification surged mostly as an economic response to the reduced profitability of "traditional" crops, rice and sugarcane. Adapting to labour and markets availability, diversification has also provoked a quest for security in water resource. This has been a driving force of ditch development and well excavation, well density amounting now to 20 wells/100 ha in the area. It has led to massive conjunctive use, as an estimated 41 % of farmers resort to two or more water resources.

The main crop change observed has been the development of baby corn (now covering 14 % of the area) at the expense of sugarcane. This activity allows a good employment of family labour and it went alongside a development of cattle breeding, the animals being given the straw of the corn (Srijantr 1997). Plots in medium elevation have also shown some inter-exchange between rice and sugarcane.

6.4 Limitations of the irrigated system

Water supply in the area (as in the rest of the Project) is basically demand oriented and is in general good in the main canals. Poor timeliness is common but no constraints on cropping calendars - even with double cropping -, together with conjunctive water use ensure a rather high degree of flexibility. With most of the lost water recycled (through pumping in the drains or the aquifer), global irrigation efficiency is hard to access.

Problems of poor drainage appear to be more significant than problems of getting access to water ; some low-lying clusters of paddy fields in depressions still have insufficient drainage and, in some cases, the construction of the irrigation canals has hampered even more the evacuation of excess water. It follows that some plots still cultivate deep-water traditional varieties, sometimes with transplanting. Drainage requirements have also had a decisive influence in ditch excavation, as several farmers growing sugarcane dug deep ditches to improve drainage and connected them to the existent ditch system. In many cases, the ditch is primarily used to supply water but, in case of heavy rains, it is transformed into a drain : in lower locations, farmer will even pump excess water out from their fields over the berms of the ditch. Here, also, insufficient drainage is sometimes compensated by pumping facilities which can evacuate excess water.

On the whole, it can be stated that most of the deficiencies of the irrigation network have been overcome by investments for on-farm infrastructures (ditches, drains), access to new resources (tube-wells, regulators in drain to retain water for the dry season, farm storage ponds) and individual pumping devices*. This has driven by three positive factors* : the rather good and reliable deliveries in the main canals (making investment in ditches worthwhile) ; the need to diversify rice/sugarcane based agricultural systems to increase farm income (reliable *or* multiple water resources are needed) ; the investment capacity of most farmers, evidenced by the magnitude of the investment and also by the fact that individual options looking for independence in the access to water (especially tube wells) have been preferred to collective ones (improved ditch management).

One of the main deficiencies of the system is the very poor levelling of sugarcane (and baby corn) plots. This is responsible for a very low efficiency of water application at plot level and conducive to high pumping expenditures and, therefore, to a non-optimal use of water : in order to reduce these costs, it appears that the use of water irrigation is around half of full requirements. This is one of the salient reasons why average yields remain quite low in the area (8-12 t/rai).

6.5 Some aspects of water management

The study has also pointed out the difficulty to define a theoretical irrigation demand (target) because of the high number of poorly known parameter (% of ditch users, conjunctive use, effective irrigation frequency, etc). Deliveries are rather attuned to demand which means that an overall oversupply - meant to limit complaints, conflicts and the necessity of collective organisation - is to be observed. This is possible mostly because of the overall water availability and of the low level of water use in the sugarcane plots.

Irrigation efficiency also appeared to be a ticklish concept, both at the zone level (because of the reuse of drainage water and of the aquifer) and at the regional level (downstream areas in the delta use water released from higher parts ; little water is lost to the sea).

6.6 An economic rough assessment

At the macro level, the economic vantage of this situation compared with an irrigation project including land consolidation is not clear : the cost of (extensive[13]) land consolidation, around 5,000 baht/rai, can be compared with the investments made in our study area : ditch and well digging, pumping equipment and field costs.

The difficulties, however, lie in the assessment of the real water control derived from land consolidation : this is highly site-specific and depends on the topography of the area. Even with extensive land consolidation (farm tertiaries and drain network but no reparcelling), Kositsakulchai (1994) found, in a similar area of the Mae Klong project, that only 20 % of sugarcane farms could be fully irrigated by gravity ; other still had to use pumps, either partially or exclusively, because of poor plot levelling (not allowing furrow irrigation) or out of command location. It is not clear to what extend farmers would have turned away from investments in pumps and wells in case of land consolidation

The question as whether on-farm investments are profitable for sugarcane has no simple answer, too : it depends on the expected sugarcane price, the real area which will be able to irrigate without pumping and on the yield achieved which, in turn, depends on a few variables which do not directly refer to on-farm development. Brzesowsky and van Vilsteren (1988) have shown that, under actual yields, the benefit/cost ratio of on-farm development did not compare favourably with the main-system-only option. In the case potential yields should be realised, these options appeared comparable.

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[13] Extensive land consolidation provide a ditch and a farm-drain to all the plots, together with access facilities (road). Land levelling is only very rough and there is no reparcelling (ditches follow the existing layout).

In the present case, we may list some figures to evidence the difference between land consolidation and the present conditions.

Extensive land consolidation : 5000 baht /rai x 10,000 rai = 50,000,000 baht

Intensive land consolidation : 8000 baht /rai x 10,000 rai = 80,000,000 baht

Pumping costs have been evaluated at about 4.4 million/year, while investments in pumping equipments, under a quite low hypothesis, has been conservatively set around 20 million baht (see annexe). If we consider, for the sake of simplicity, that these pumping equipments together with such land development have a life span of 20 years, we see that investments in land-development are likely to be profitable : if we assume a reduction of pumping costs of 50 % with extensive land consolidation (for both investment and operational costs), the two situations appear to be balanced over twenty years in terms of costs, but the former will allow an increased use of water, with a corresponding increase in sugarcane productivity. This rough calculation will be reconsidered and dealt with in details in a further publication.

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In summary, Zone 5 of Kamphaengsaen Project appears to have undergone significant change in land development, land and water use, and does not show drastic problems of water distribution, in part because water is abundant and because the effective water use in sugarcane is much lower than designed. Flexibility and security of access to water have been largely achieved by farmers investments in pumping devices and conjunctive use development. The very high cost of individual pumping, however, is responsible for a sub-optimal use of irrigation water in sugarcane fields and tend to show that land consolidation options would have been markedly profitable to this area.

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ANNEXES

- Estimation of pumping costs in the area
- Estimation of pumping equipment in the area (current situation / low hypothesis)
- Contour Map of the study area
- Example of geographical queries using buffering

Estimate of pumping frequencies and costs in the study area

	AREA for each water source		(in ha)		Dry season	Rainy season	hours/ time/rai							
	ditch/ canal	well	main drain	Total	number of	applications	ditch/ canal	well	main drain	total time (hours)	total consumption	total cost (baht)*	cost/rai	time/rai
Sugarcane	695	138	88	921										
Sugarcane 1	231	46	29	307	6	1	4	5	5	56964	45571	410139	1337	186
Sugarcane ratoon	463	92	59	613	4	1	6	8	7	122586	98069	882617	1439	200
Rice	16	0	12	28	14	2	1		2	4000	3200	28800	1029	143
Baby corn	124	59	38	221	70	20	2,5	3	2,5	327375	261900	2357100	10666	1481
Other	35	10	14	59	70	20	3	4	3	105188	84150	757350	12836	1783
	869	**207**	**152**	**1228**	**167**	**37**				**616,112**	**492,890**	**4,436,006**		

* For an average consumption of 0,8 l/hour and a price of 9 baht/l for benzene

Estimation of pumping equipment in the area (current situation / low hypothesis)

Items	number	price per unit	total cost
gasoline engine	100	7000	700000
wells	255	6000	1530000
diesel engines	600	28000	16800000
suction pumps	600	3000	1800000
axial pumps	250	2000	500000
electric pumps	150	3000	450000
			21,780,000