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Beyond the farm-turn-out: on-farm development dynamics in the Kamphaengsaen irrigation project, Thailand

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Abstract. Many large-scale state-run irrigation projects in the world have been constructed with limited investment in on-farm infrastructure. In most cases, it was expected that local farmers would themselves make improvements on their farms. In general, insufficient attention is paid to water control which has a negative impact on productivity. Farmers' strategies to offset poor access to water are very varied and depend on site-specific factors such as topography, the existence of other potential water sources, market opportunities or capital availability. This article presents a case study in the Central Plain of Thailand and describes the patterns of land development which occurred since the construction of the Irrigation Project 25 years ago. It shows how land and water use evolved as both a mover and a response to on-farm development and who initiated new investments, such as ditch and tube-well digging, regulators in drains, which have allowed secondary water sources to be tapped, the development of conjunctive use, increased reliability in water supply and crop diversification. The importance of individual farm pumps is shown. Poor land levelling is conducive to high costs and reduced water use. Prospects for land consolidation are assessed.

Key words: crop diversification, irrigation, land use, on-farm development, Thailand, water management

Introduction

The whole Central Plain of Thailand encompasses an irrigated area of about 2 million ha. The main investments carried out in the 50s and early 60s under the Greater Chao Phraya Project included the construction of a diversion 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. Rather than developing complete irrigation-facilities (with on-farm development generally accounting for 40% of the costs) in a limited area, planners chose to

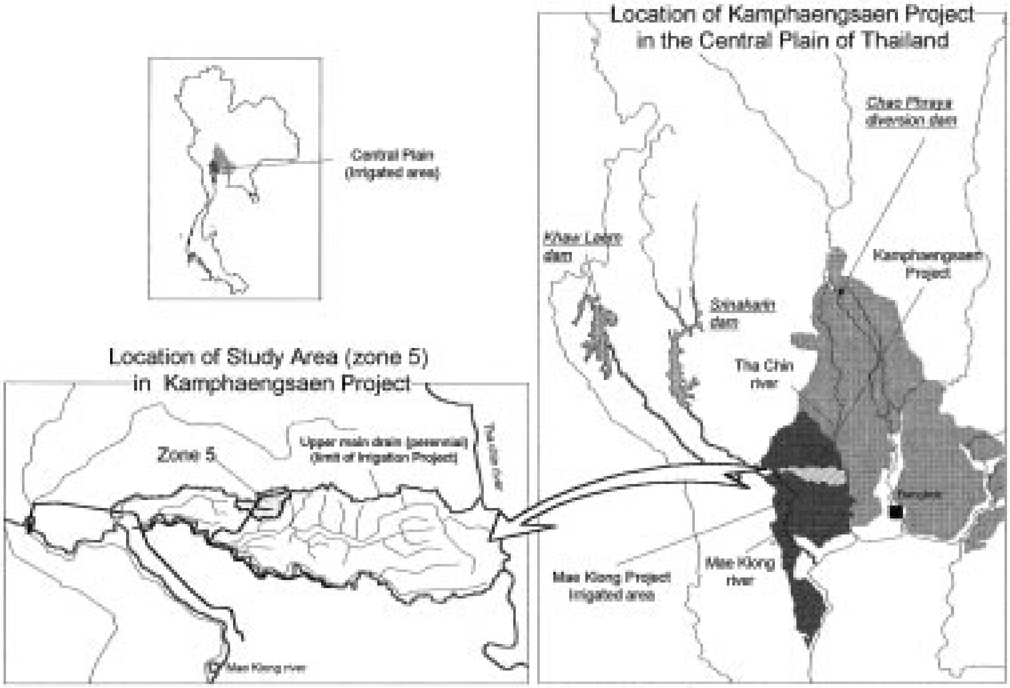


Figure 1. Location of the study area

implement a main infrastructure (primary and secondary canals) for the whole delta. It was assumed that farmers would gradually develop the ditch system, allowing canal water to reach their plots.

In the late 60s, however, with a yield increase much lower than expected, there was concern that the farmers did 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 of about 11% of the irrigated area (or 50% if the basic "Ditch and Dykes" Project is considered) was developed. In the early 70s, the implementation of the Greater Mae Klong Project was initiated on the western side of the delta (Figure 1), with only a basic ditch system, although most of the canals were lined and designed with increased capacity.

After this period of investment and experimentation, very little has been done, said and observed about this issue. A broad and rather vague assumption that the great majority of the farmers have eventually benefitted from irrigation seems to prevail. An assessment of water resource development, access to and use of water was deemed necessary and undertaken in the Kamphaengsaen Project.

The Kamphaengsaen Irrigation Project and the study area

The Kamphaengsaen Project has an area of 50,000 ha and belongs to the Greater Mae Klong Irrigation Project, located in the west of the Central Plain. The average annual rainfall is 980 mm, with only 58 mm during the December to April period. Irrigation water is delivered all year long, with two interruptions of about 6 weeks each, between the two seasons.

Sugar cane and rice are grown in 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 lower areas. With a few exceptions, paddy fields are double cropped. Agricultural diversification in the *Nakhon Pathom* province is a very salient feature of the past fifteen years and accounts for significant change in land use (Kasetsart University & ORSOM, 1996).

The study area (zone 5) is a 1,600 ha-wide hydraulic unit crossed by a lined distributary and surrounded by main drains (Figure 1). Relief is gentle, with elevation ranging from 6 to 10 m MSL, natural levees along the main drains and a few scattered depressions.

Water resources available in the area

Many and varied water resources are found on the farms, with the following six main categories (Chompadist, 1997):

1. *The irrigation canal*: The lined irrigation canal, with its two branches, provides water to some riparian farmers who generally use three possible devices: pumps together with hoses; pipes through the embankments ("ghost pipes"); or siphons. Water supply is reliable except during the two periods of interruptions.
2. *The ditches*: the (excavated) earth ditches, serving as tertiaries, have varied dimensions and water availability heavily depends on several factors: ditch length, maintenance, topography, etc.
3. *The main drains*: the area is bordered by main drains, the northern one being perennial. Riparian farmers use pumps to lift water onto the fields.
4. *Farm drains*: often equipped with a structure at their outlet to the main drain, they also constitute convenient water reserves at the beginning of the dry season and, sometimes, in the rainy season.
5. *The tube-wells*: tube-wells are 15 to 30 m deep and 7.5 or 10 cm in diameter, and water is extracted with conventional suction pumps.

6. *Ponds and borrow pits*: natural or artificial ponds and borrow pits along the main canals and roads are very useful temporary storage when deliveries are suspended (buffer tanks).
7. *Other*: a few sugar cane plots are also found to pump in from adjacent paddy fields. Plot-to-plot water conveyance is common in all the rice clusters.

Water management in the project

The Kamphaengsaen Project is basically a *demand-based project*. This term needs further elaboration in order to correctly typify the situation. It is neither an *on-demand project* (as understood in western countries, when water is available either permanently or a short time after having been requested) nor a *crop-based project* (where deliveries are calculated based on crop requirements), although it is theoretically supposed to be so. In short, field staff (zonemen) estimate every week how much water they want for their section (enough to satisfy farmers, not too much in order to avoid spillage or water logging) based on their experience, the situation the week before and whether new crops are likely to be cultivated. Demands are subsequently aggregated at the successive upper levels, with possible in-week adjustments in case of shortcomings or significant rainfall. This means that the demand referred to here is the crop requirement *with* a coefficient or efficiency, which includes a “flexibility margin” that could be defined as one which keeps users’ complaints at a low level.

This appears to be possible because of: (a) the lack of constraints on the available resource; (b) an irrigated area smaller than designed (other sources are used); (c) a canal capacity designed for peak discharges in the dry season, 1.6 l/s/ha, twice as much as the value adopted in the earlier Greater Chao Phraya Project (Plusquellec & Wickham, 1985). This contributes to avoiding most of the shortcomings which mar supplemental irrigation schemes in monsoon areas (Burns, 1993). Although some less favourable situations are sometimes encountered (dam shortage in 1993, higher irregularities in tail-end laterals, delays in supply because of sugar cane harvesting, etc.), this generally translates into rather satisfactory hydrographs upstream of the Farm-Turn-Outs (FTOs). Poor timeliness is common, but constraints on cropping calendars are rare, even with double cropping. Figure 2 displays the hydrograph obtained with a data logger in the dry season of 1995, for one FTO located at 8.3 km from the head of the lateral canal. It shows that canal overloading is practised at the beginning of the season, while the water level is almost always higher than the top of the FTO pipe. Design criteria ensure that lateral channels can be run at full supply capacity when the main canals are operated at 60% of their design capacity (ILACO, 1980).

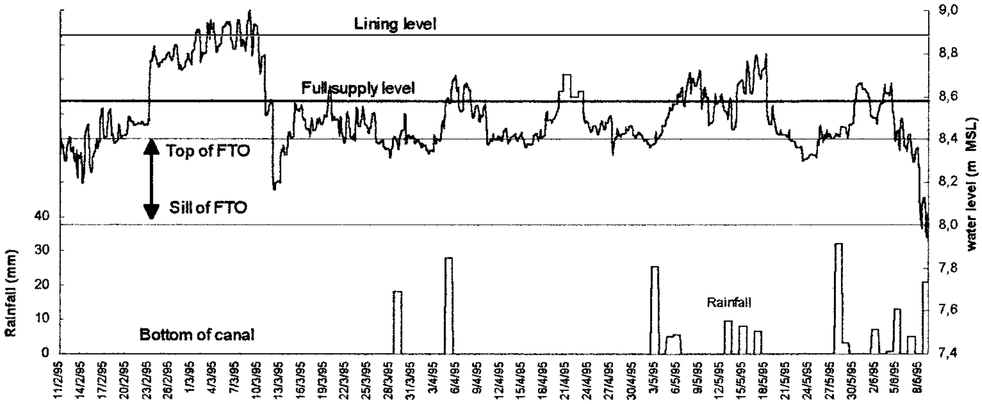


Figure 2. Hydrograph of water levels upstream of a selected FTO (km 8 + 350)

This situation concentrates our attention on the tertiary system, in order to determine whether it is capable of passing on the same level of reliability to lower levels of the schemes.

Little consideration is given to the efficiency of water distribution in the project (60% by design). In fact, it appears as a scale-related concept, difficult to assess (see Seckler, 1996) 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 and little water is eventually lost to the sea.)

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.

Change in land use

In 1969, just before the construction of the irrigation project, agriculture concentrated on rice and sugar cane, with a distribution closely following topographical features and an appropriate water regime.

An inventory of land and water use at the plot level was carried out in 1986, allowing the comparison of both land and water use with the current situation (year 1996). In 1986, land use was almost limited to sugar cane (75%) and rice (21%), with a few hectares of fruit trees and other crops. Data show that on 30% of the plots (and also of the area) the crops had been changed

Table 1. 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*
			sugar cane	60	3.7	18
			other	36	2.1	10
Sugar cane	1208	74.8	*sugar cane*	*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*
			sugar cane or baby corn	28	1.7	76
			other	3.6	0.2	10
Area with change of crop (%)					30	

during the 1986–1997 period (Table 1). In 18% of the paddy plots (60 ha), rice cropping was stopped in favour of sugar cane, but an even larger area has reverted from sugar cane to rice: these cross-changes occurred in middle-low elevation plots and mirror the fluctuating farmers' decisions: compared profitability and uncertainty in prices, labour availability and frequency of flooding in the sugar cane crops have been found to be decisive criteria for farmers' decision making (Molle and Kaewkulaya, 1996).

The most significant change is the shift from sugar cane to various cash crops (mostly baby corn, and also field crops, vegetables and fruit), which has affected more than 21% of the area.

Farmers are mostly driven to diversify by the low profitability of both rice and sugar cane. In order to diversify, they must, however, meet some prerequisites concerning:

- physical conditions (of soil, topography and access to secure 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 most instances a capital is required to allow a change of crops: well-digging, pumping device, sprayers, land transformation such as raised bed systems, etc.).

Favourable conditions regarding these factors have been found to be conducive to diversification in the Central Plain (Pitipunya, 1995) and especially in the Mae Klong area (Srijant, 1998). The decision to diversify is therefore influenced by risk-reducing factors (secure water, stable prices, contract farming), available capital (credit) and the existence of neighbours who have successfully demonstrated the viability of a new crop and can give technical advice. Similar conditions and developments can be found in most Asian countries (Valera, 1992).

Development of water resources

Before having a closer look at the changes that have occurred in water use and their relationship with land use, the transformation of the infrastructure must be specified.

The ditch system: in order to assess the endogenous development of the ditch system in the Kamphaengsaen Project, the original basic ditch layout built by the Royal Irrigation Department (RID) at the time the project was carried out has been compared with the existing one. Several cases have been observed:

1. Ditches excavated by RID: two years after completion of the main scheme, a few straight ditches have been excavated across the fields. Of these 12 initial ditches, only three are still in use, while the others have disappeared. However, other ditches have since been dug by RID.
2. Ditches excavated by the district authorities (*amphoe*), with different government financial resources.
3. Ditches excavated by the village head: in one case, the village head has had a ditch excavated for free; the payment for the service seems to have been the soil, which is used to build embankments.
4. Ditches 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. Ditches excavated by the farmers themselves, either individually or through a collective undertaking.

In qualitative terms, the balance of ditch development, compared with an original ditch network of 11,000 m, is as follows: out of a total of 55,400 m of ditches, 48% have been dug by farmers, 16% by the RID and 36% by district/province budgets. This on-farm development, half of it initiated by farmers, represents an overall growth of 500% since the beginning of the project and gives a current density of 31 m/ha, which is almost exactly the standard in use for land consolidation in the Chao Phraya Project. It is also worth noting that the ditch network constitutes a buffer area which can accumulate water during the night, during which only a constant flow irrigation in the rice fields is recorded (in periods of high demand, however, farmers also commonly irrigate at night). The storage capacity of one of the main ditches, which delivers water to an area of 210 ha, has been calculated at 13.000 m^3 for a total length of 7.9 km and a full supply level. This corresponds to about one day's consumption.

The fact that 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) obviously constitutes an encouragement for the farmers of the Mae Klong area, since they are sure to get water if they link a proper ditch to the main network (Bottrall, 1981). If topography or other constraints (such as neighbours unwilling to co-operate) do not allow them to dig a ditch, farmers will have to turn to other sources.

Tube-wells are also a relevant source: a survey carried out in 1994 at village level has counted 89,000 of them in the Central Plain, mostly in the upper Chao Phraya delta and the upper Mae Klong Project, where the study is located (Kasetsart University & ORSTOM, 1996). It was 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 90s.

Some of these wells in the study area are quite old, but a majority were dug *after the implementation of the irrigation project* to supplement rain-fed sugar cane; this development has been made possible by a rise of the water table provoked by the introduction of irrigation. At least 255 wells exist in the area and their growth in the last ten years is close to 100%. These figures correspond to densities of around 20 wells/100 ha, which are quite considerable. Tube-wells have become a prominent feature of many irrigation schemes worldwide, especially in Asia, where they developed as a response to water shortage and/or mismanagement. Whereas they often come along with water markets, with well owners selling water to surrounding farmers, such as in Pakistan (Strosser, 1998; Malik & Strosser, 1993) or in India (Muralidaran & Krishna, 1993), no such case has been observed in the area. Farmers' investments are individual, which relates to the investment capacity (if possible, individual options allowing independence in water use are preferred to collective ones, such as improved ditch management), the relative cost of well-digging and pumping, and to the fact that most farmers are already equipped with motors (or two-wheel tractors) used to power the axial-flow low-lift pumps.

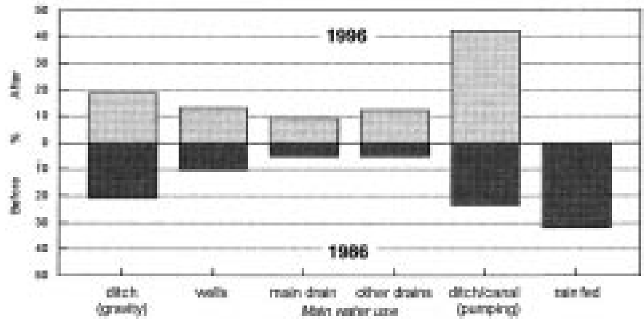


Figure 3. Change in main water use (1986–1996), in % of the total area

Apart from the development of the wells and of the ditch network, *other significant investments* have been made in water control and resource development: the main drain has been gated and made perennial; secondary ones are also gated at their outlet to keep water for the dry season; farm ponds have been excavated by farmers and used as storage buffer areas.

Change in water use and relationships with land use

Changes in main water use during the same 1986–1996 period are summarised in Figure 3. The main change corresponds to the disappearance of rain-fed crops (sugar cane), which covered 32% of the area 10 years ago. This major change was caused by the development of the ditch system and of the individual pumping capacity: 43% of the area relies on ditches as a main water resource, against 23% 10 years earlier. Other changes relate to the development of pumping from the drains and from wells, most commonly for sugar cane, baby corn (16% of the area) and flower/vegetables. The decrease in gravity irrigation reflects the slight decrease in rice cultivation.

Between 1986 and 1996, land use and water sources on 796 plots (48% of a total of 1,666), covering 30% of the area, were changed. The principal crop change was from sugar cane to baby corn and other diversification crops (vegetables, flowers, trees), which concerns 407 plots (260 ha): about half of these plots use the ditches and farm drains as principal sources, whereas the other half relies on wells and on the main drain (perennial sources); nevertheless, 87% of all these plots *also* intersect a 25 m radius buffer[1] drawn around the wells and the main drains, which shows that *agricultural diversification was accompanied by higher security in water use*.

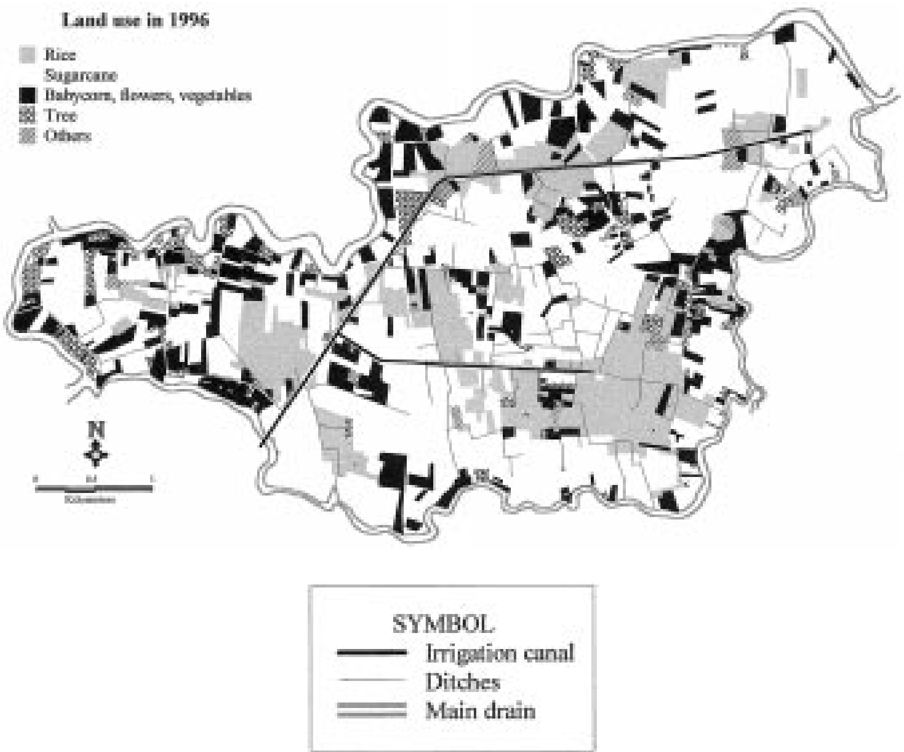


Figure 4.

Current cropping systems and water use

Main water use and water control

Rice

Rice plots form several clusters, found mainly in the low lands with heavy soils and often deficient drainage conditions. Because of this low-lying topographical location, water can be diverted to these areas by gravity (Figures 4 and 5) and distributed by a "plot-to-plot" system within these clusters. Only two small clusters obtain water by pumping from the main drain.

Drainage of the plots 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 and, whereas dry-season cropping is exclusively carried out with HYVs and wet broadcasting, in the rainy

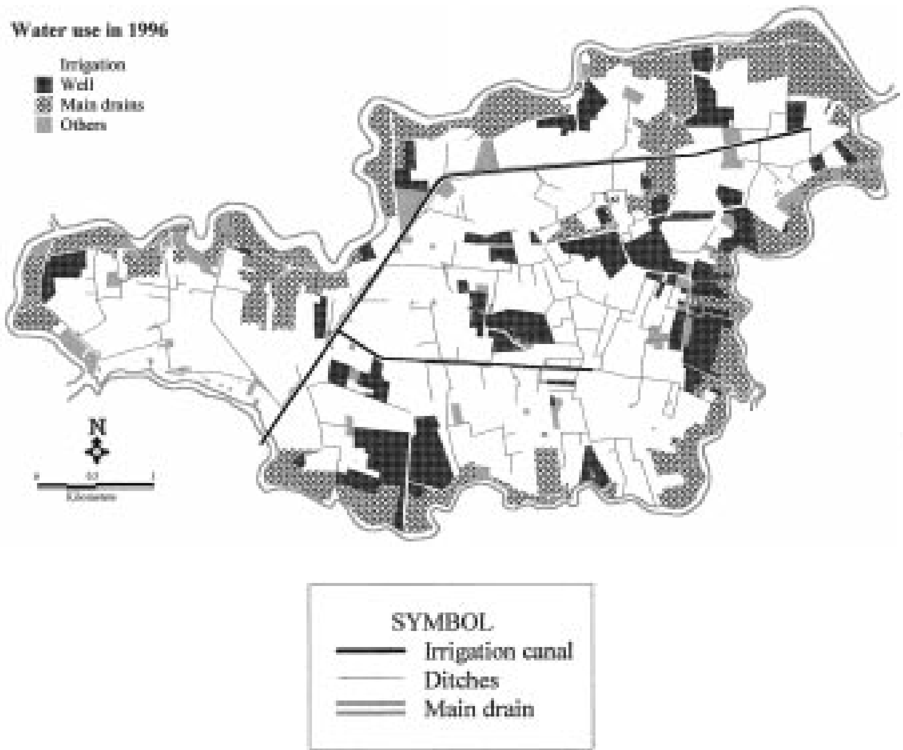


Figure 5.

season farmers adjust planting techniques (wet broadcasting, transplanting) and varieties (HYV, deep-water rice) to the conditions of their plots.

Sugar cane

This is the main crop of the area (57%). It was formerly mostly rain fed and is often grown on uneven land: furrow irrigation is therefore not efficient, especially for the ratoon crops. In many cases farmers have to use pumps and hoses to deliver water to the highest parts of the plot, from where it just spreads onto the fields. This is conducive to very high pumping durations: for a sample of 35 plots planted with sugar cane, average pumping durations have been found to be 45 h/ha for a ratoon crop and half of this value for newly planted plots (clean furrows allow better water advance), with values commonly reaching 60 h/ha/irrigation or more.

Although the main source of water is the irrigation network (canals and ditches: 61%), wells also act as both primary and secondary sources (when the ditch is deficient). *In all cases, it appears that irrigation demands additional individual pumping to raise water to the plot.*

Irrigation frequency is very varied, averaging – in the dry season – three times a month for newly planted crops and one time a month for ratoon crops, which some farmers irrigating only once or twice a year. It has been estimated that the average monthly water application corresponds to approximately 50% of water requirements, with a clear impact on productivity, with average yields remaining quite low in the area (50–60 t/ha).

Pumping costs, for an average duration of 45 h/ha, appear quite discouraging, amounting to 18 US$/irrigation, while the average net income is approximately 600 US$/ha, fixed costs not considered (Molle & Keawkulaya, 1998). Improving land levelling in sugar cane plots may arise as a priority to allow an increase in the application of water and, subsequently, in yields.

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. Much less resistant to water logging and water shortage than sugar cane, it is therefore grown on plots with good drainage and a secure water supply.

Irrigation at the plot level is always by furrow, with a rather high frequency (commonly more than twice a week in the dry season), but is faced with fewer problems of water application: plots are much smaller, with average pumping durations of 15 h/ha/irrigation. The drains and the wells are often the principal water sources: this is due to the development of baby corn in the well-drained levees, along the main drains, and in plots located near the houses (also in a higher location and often equipped with a well). This also reflects the need for more reliable water sources.

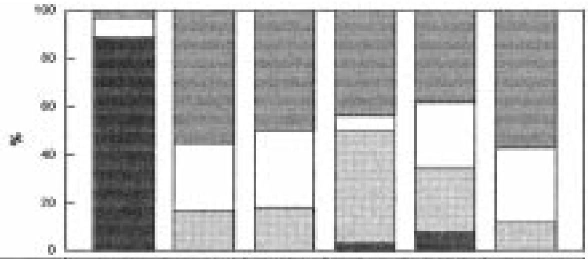
Vegetables, flowers

Fourty-one ha, i.e., 2.6% of the area, are cropped with a variety of vegetables (shallots, 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 (introduced in the last five years) are used, depending on the kind of crop.

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 wells. Orchards can also be accommodated in low lands, with a system of raised beds alternating with ditches. Common trees are coconut, guave, mango, rose apple, totalling 37 ha, not including backyard orchards.

The breakdown of the main forms of water application for each crop is summarised in Figure 6. There is an almost 100% correlation between rice



	rice	sugar cane	baby corn	flower	vegetable	fruit trees
gravity	89.1	0.0	0.0	3.3	7.9	0.0
pump (well)	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

Figure 6. Distribution of the main forms of water application for each type of crop

and gravity irrigation (and low lands). Pumping in ditches and drains appears to be the main source of the non-rice crops, with an additional 25 to 30% drawn from wells.

In terms of relative area, *only 60% of the land appears to have an irrigation-based supply* (delivered through canals and ditches) as its main water source, while remaining areas pump from wells and drains. The importance of individual pumping appears overwhelming, with *only 18.5% of the area being able to get water directly by gravity*. This relates to the lack of land consolidation and confirms that natural ditch systems, such as those in the fan-terrace of the Mae Klong basin, are not able to offer gravity deliveries, the head being lost at the level of the FTO. However, even with extensive land consolidation, it was found, in a similar area of the Mae Klong project, that only 20% of sugar cane farms could be fully irrigated by gravity (Kositsakulchai, 1994). Local topographical features make the issue of whether land consolidation is profitable highly site-specific.

The economic impact of pumping requirements on our area can be very crudely estimated by considering average values: pumping costs were found to amount to an estimated 175,000 US$ per year, while investments in pumping equipment, under a rather low hypothesis, have been calculated at 8×10^5 US$. For a life span of 20 years, the cost of pumping amounts to 4.3×10^6 constant US$. For the sake of comparison, this can be said to represent more than twice the cost of (extensive[2]) land consolidation for our study area: *2×10^6 US$ (≈ 1660 ha × 1230 US$ /ha).*

Conjunctive water use and secondary sources

The previous section has shown the relationships between land use and the main water source. These figures, however, stand for the primary water source used in the plot. Farmers often resort to several water sources. In some cases, three sources are used and their share may sometimes be balanced, which makes 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 between 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 a 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 1,666 plots, is clearly beyond average survey capability.[3] In order to try to assess the importance of conjunctive use, query and buffer techniques, as provided by GIS packages, were used.

Estimate of conjunctive use

Two-hundred-and-fifty-five tube-wells were found in the area: 97 in plots of sugar cane, 71 of baby corn, 17 of vegetable/flowers, 6 in rice, 21 near households, and 7 in orchards.[4] Well utilization has first been evaluated conservatively by considering the number of plots (255) provided with wells. Buffers with different radiuses have been drawn around the wells to estimate their potential use. For 50, 100 and 150 m radius, the number of intersected plots is 639, 946 and 1137. This tends to show, if we consider the lowest hypothesis, that the number of plots using wells (as a main or secondary source) is likely to be at least twice as high as the number of wells. Out of 208 plots relying principally on wells, 140 are found not to intersect the ditch/canal buffer (radius 25 m), *which suggests that two-thirds of the wells may have been drug because of poor or no access to the ditches, while the remaining third may find the ditches unreliable or inconvenient*.

Out of a total of 1,666 plots, 657 intersect the ditch/canal buffer with a 10 m radius; this number rises to 834 when the radius in increased to 25 m. This compares with the 778 plots which have a ditch (or canal) as the 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 rely on it as a primary source*: most of the time the ditch is located on the “bad” (lower) side of the plot, as in the case of the plots close to the main drain where farmers prefer to pump from the latter, which alerts the requirements of reliability and the natural slope.

These estimates of conjunctive use are summarised in Figure 7. It appears that *41% of the plots are found to have potential access to several water sources, among which 5% have access to three*.

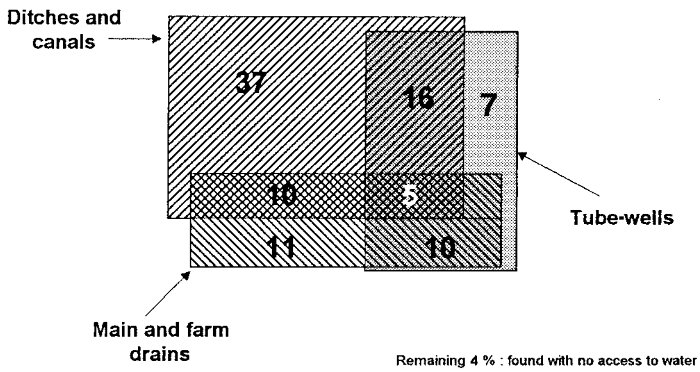


Figure 7. Distribution of plots according to potential water access (in % of the total area), as estimated through buffering

If we now consider the combination of (a) the heterogeneous level of water use in sugar cane, (b) the diversity of water sources and (c) the conjunctive use of many farms, it follows that the definition of the water demand is extremely difficult: this has negative consequences on the definition of a target and, thus, on the possibility of monitoring and post-season assessment.

Logic and priorities in tapping water resources
The different water resources are not equivalent in terms of investment, operation and reliability. In terms of *investment*, ditches are preferable (especially when their cost is borne by the district) because they allow the use of axial pumps, which can be powered by the engine of the two-wheel tractor: they are the cheapest individual pumping device (US$ 30–45). If no tractor is available or if irrigation is quite frequent, gasoline or diesel engines must be used, the latter being quite expensive (1,000 US$).

Regarding *operational costs*, the *cheapest* sources, as far as suction head and energy consumption are concerned, are the ditch and the canal, then the drains, and lastly the tube-wells (higher head): this is why tube-wells are only used when the ditch is dry.

The most *reliable* sources are wells (apart from exceptionally 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 (*if* they have access to it) can rely solely on irrigation water from ditches. Other crops need an uninterrupted (for an optimal land use intensity) and reliable supply, and will therefore rely – in addition or exclusively – on wells and/or on the main drain.

In addition to such rational considerations, farmers also choose or blend their water sources based on other personal criteria. Ease of farm operation often stands out as a very important criterion (what is "*saduak*" is what is enjoyable for being convenient, practical, easy going). Farmers often do not use the ditch because it is located at the lowest part of the plot and furrow irrigation (in sugar cane and baby corn) would require to first pump water up to the other end. This is often burdensome and requires pumps to be removed, and some farmers prefer to keep on using their wells which have been dug on the "good" side of the plot. The same happens when a ditch is too unreliable; farmers prefer a constant and more costly supply to removing the pump each time some shortage occurs.

The assessment of the burdens associated with farm irrigation practices is obviously a highly personal matter: it depends on the local layout, on the kind of pumping device, on the will/necessity to lower costs at the expense of increased labour, on whether one place is safe regarding theft, etc. Convenience is also a driving force in the development of sprinklers, definitely considered as "*saduak*" labour-saving devices.

Conclusions

On-farm development in the study area appears to have been driven by the investment capacity of most farmers (quite high for Asian standards), rather good deliveries at the FTO making investments in ditches worthwhile, and the need for reliable/perennial water sources (wells, main drain) for diversifying rice/sugar cane-based agricultural systems in order to increase farm income.

Assessing the government's policy to reduce the implementation cost per ha of the irrigation projects by not including on-farm management, it can be stated that this was correct, as on-farm development has been quite intensive since the construction of the project, reaching 55 km in ditch length, or 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 budgets.

Although labelled a gravity irrigation project, the Kamphaengsaen Project (and most probably the whole of the Greater Mae Klong Project) appears to be rather a pumping irrigation project. The lack of a raised tertiary system *offsets most of the benefits of the gravity system*: the head gained by means of costly lined raised main canals happens to be lost at the outlet of the FTO. Consequently, this deficiency has to be compensated for by an extensive pumping capacity at farm level, *77% of the farms use pumps to extract water*. Direct irrigation from the ditch by gravity is highly correlated with lowland and rice cropping.

The study also demonstrated the rapid pace of change affecting both land and water use in the past ten years and how these are interlinked. Crop diversification (especially baby corn, now making up 14% of the area) took off mostly as an economic response to the decreasing profitability of "traditional" crops, rice and sugar cane, and provoked a quest for security in water resource. This has been a driving force behind ditch development and well excavation, well density amounting now to 20 wells/100 ha in the area. It led to massive conjunctive use, as an estimated 41% of farmers resort to two or more water sources.

The study raises the question of the relevance of constructing costly raised canals if the head gained is to be lost at the FTO: land consolidation appears as an imperative *logical complement* of such a design option. Another issue deals with the contrast between the relatively good quality of deliveries in the main/lateral canals and the poor access to ditch water: this problem has now been widely offset by investments in on-farm infrastructure (ditches, drains), individual pumping devices and by tapping secondary water sources, *but* with obvious consequences in terms of labour and costs borne by the farmers. The way this deficiency in accessing water has been overcome has contributed to a reduction in the demand for irrigation water in relation to design assumptions, easing management by creating more flexibility.

While water access has gradually become satisfactory, the issue of water application at the plot level still remains: poor levelling in sugar cane plots *conducive to high pumping costs* has been shown to preclude adequate irrigation (also contributing to lower the effective demand), resulting in a very low water productivity. Testing the cost-effectiveness of new cheaper technologies in land levelling (such as laser-guided scrappers drawn by conventional tractors) appears as a priority, with the potential to increase current sugar cane productivity by as much as 50%.

At the macro level, the economic advantage of the present situation compared with an irrigation project including land consolidation is not clear. While it seems that an early (extensive) land consolidation at the time of the implementation of the scheme would have compared favourably with the present situation, such an on-farm development made 20 years later would partly duplicate all the investments already made. These economic aspects are currently being further investigated by the authors.

Notes

1. Buffers are areas defined as the set of points whose distance to a given geographic object (a well, a road, a lake, etc.) is less than or equal to a given length (radius). Objects included in or intersecting buffers are therefore characterised by their proximity to a given object.
2. Extensive land consolidation provides a ditch and a farm drain to all the plots, together with access facilities (road). Land levelling is only average to rough and there is no reallotment (ditches follow the existing layout).

3. The main water source has been determined visually informal interviews during field work.
4. This gives a total of only 227 plots because some plots may have several wells.

References

Bottrall, A.F. 1981. Comparative study of the management and organisation of irrigation projects. Staff Working Paper No. 458. World Bank.

Burns, E.R. 1993. Irrigated rice culture in monsoon Asia: the search for an effective water control technology. *World Development* 21(5): 771–789.

Chompadist, C. 1997. Analysis of water control at farm level in selected areas of Kamphaengsaen Project, Master Thesis, Department of Irrigation Engineering, Kasersart University, 157 pp. (in Thai).

FAO; UNDP. 1968. Survey mission for the Chao Phya delta, Thailand. Rome. 93 pp.

ILACO, Empire M & T, Royal Irrigation Department. 1980. Greater Mae Klong Malaiman Irrigation Project. Feasibility study, March 1980, 2 Vols.

Kasetsart University, ORSTOM. 1996. Identification of agricultural and irrigation patterns in the Central Plain in Thailand: prospects for agricultural research and development, DORAS Project, Bangkok, 220 pp.

Kositsakulchai Ekasit. 1994. Irrigation impact on sugar cane cultivation in the Mae Klong Irrigation Project, Thailand. Unpublished dissertation thesis, Master of engineering, AIT, Bangkok, 122 pp.

Molle, F. & Keawkulaya, J. 1998. Water management and agricultural change: a case study in the upper Chao Phraya delta. *Journal of Southeast Asian Studies* 15 pp.

Muralidaran, V. & Krishna, K.V.S.M. 1993. The dynamics of irrigation system performance. A comparative study of two secondary canal reaches in Mahi-Kadana, Gujurat. Colombo, Sri Lanka: International Institute for the Management of Irrigation (IIMI working paper No. 25), 68 pp.

Pitipunya, R. 1995. The economics of rice farming and crop diversification in the Central Plain, Thailand. Unpublished dissertation thesis, Tokyo University of Agriculture, 361 pp.

Plusquellec, H.L. & Wickham, T. 1985. Irrigation design and management: experience in Thailand and its general applicability. World Bank technical paper No. 40, 76 pp.

Seckler, D. 1996. The new area of water resources management. Research Report 1. Colombo, Sri Lanka: International Institute for the Management of Irrigation (IIMI), 17 pp.

Srijantr, T. 1998. Transformations actuelles de l'agriculture Thaïlandaise: étude du système agraire de Thung Look Nok. PhD dissertation, National Institute of Agronomy, Paris, 380 pp.

Strosser, P. 1997. Analysing alternative policy instruments for the irrigation sector: an assessment of the potential for water market development in the Chistian sub-division, Pakistan, PhD Thesis, Wageningen University, 243 pp.

Valera, A. 1992. Irrigation management for diversified cropping in rice-based systems in the Philippines. Colombo, Sri Lanka: International Institute for the Management of Irrigation, xvi + 76 pp.