Profitability and yield gap of sugar cane cultivation in the Mae Klong region

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Published in the Thai Agricultural Economic Journal

1. Background

1.1 Introduction

Sugar cane production is one of the major economic sectors in Thailand. There are several activities involved in the production process such as: sugar cane growing, sugar milling, credit banking, exportation, etc. The sugar production activities provide significant full time and temporary employment in sugar factories (46 sugar factories in 1997), sugar transformation, transportation and exports.

The Thai sugar production shows a pattern of progressive growth in both sugar cane cropping area and sugar mills production. The total sugar production in the country is about 5.6 million tons per year, with a breakdown of 1.3 million tons for local consumption and 3.5 million tons for exports. Thailand ranks third among sugar cane exporters in the world market, next to Brazil and Australia in 1997, and this activity contributed to its national income by up to 20,000 million baht.

The planted area of sugar cane increased from 3 million rai in 1985 to 6 million rai in 1997. Statistics data show that the average yield of sugar cane in irrigated areas is about 10 tons per rai (60 tons per hectare) and 7 tons per rai (40 tons per hectare) in rainfed areas. However, the share of the central region in the total national planted area decreased from 56 % (of 2 million rai) in 1985 to 36 % (of 2.8 million rai) in 1997.

There are several issues for investigation on how to improve sugar cane productivity in terms of economic output, qualitative and quantitative production scales. Some of the questions are: how to maintain sugar cane as an economic crop in the Central Region ? How to increase the yield of sugar cane production per unit area ? This paper focuses on commercial sugar cane plantation in the irrigated area of the upper Mae Klong area (with primary data from *amphoe* Kamphaengsaen, Nakhon Pathom province). Field surveys and interviews have been carried out with people involved in sugar cane production activities. Additional secondary data were reviewed to support the research.

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1.2 The Comparative Advantages of Sugar cane Production in the Mae Klong Area

The Mae Klong region is both highly suitable for sugar cane plantation and undergoing a significant process of agricultural diversification. The region has comparative advantages to other regions regarding the quality of soils, the irrigation network and the excellent infrastructure in terms of transportation and communication. However, sugar cane plantation is decreasing in the area while plantation is on the rise in the North and northeastern regions of the country. Crop diversification is driven by competitive crop prices ; new and high value crops (baby corn, asparagus, vegetables, etc) are introduced to the area and reduce the importance of sugar cane.

Nevertheless, sugar cane growing in the Mae Klong irrigated area is still a relevant option in terms of productivity per unit cost, which enables it to compete in the sugar world market. The irrigated land in the region totals 0.7 million rai, or 30 % of the total irrigated area in the lower Mae Klong basin. There is growing awareness that the future of sugar cane in this region is dependent upon gains in productivity. At the same time, still low average yields despite irrigated conditions suggest that there is significant scope for progress. The sugar cane industry corporation, with the possible support of the government and development banks, is now moving towards injecting massive investment in the region in order to raise yields. This raises crucial questions on what is the most cost-effective way to achieve such a goal.

2. Pattern of Sugar cane Production and Marketing

2.1 Quota marketing system and farmer typology

A quota marketing and production system prevails in the Mae Klong irrigated area, in order to ensure sufficient and regular supply to the sugar cane factories. Quota marketing is based on contracts signed between factories and representatives (or middlemen) from sugar cane growers groups. The groups are established by and sign a contract with the "quota head" (*huana quota*). The distribution of the quota from the 13 factories to quota heads is based on the capacity of each group of farmers, which is judged from the planting area and group members. The sugar factories partly control the amount of the production by providing growers with credit for crop production.

However, a fundamental point is to understand that not all sugar cane producers are alike : farming systems appear quite differentiated and can be conveniently grouped under a typology of three types (Srijantr, 1998) : the large capitalistic farm, the *quota head* type and the small farm type (*look rai*). For the sake of simplicity, only the "quota head" and "look rai" types will be considered in the following economic analysis[4].

- The "Quota head" type represents large-scale sugar cane plantations. He is the person who manages the quota contract for the sugar mill factories. The quota head commonly farms

[4] However, we considered, under the name "Quota head", a larger farm than in previous work (Srijantr, 1998): 100 rai against 50 rai, so that the corresponding type can be considered as an intermediate case between "quota head" and "capitalistic farms".

himself around 100 rai or more and generally owns the corresponding machinery (tractors, trucks,..). He resorts to wage labour for crop plantation, crop care and harvest.

- The "*look rai*", or contracting farmer is the farmer who depends upon the sugar cane quota head. The quota head will often provide farm inputs to his *look rai*, who are able to produce enough tonnage of sugar cane for their quota. The farm inputs usually supplied are capital, fertiliser, herbicide, insecticide. Other hired services include four wheel tractor service for land preparation, truck for sugar cane transportation and labour for harvesting.

2.2 Profitability of sugar cane plantation

The sugar cane growing rotation in this area generally covers a three year period. The first year plantation will be harvested after not less than 11 months of growth. The second and the third (ratoon) crops take around 10-11 months for maturing. The average yield is 13 ton/rai and decreases to 11 ton/rai and 8 ton/rai for to the second and third ratoon crops.

The three-year average yield is 10,7 ton/rai at the price 500 baht[5] per ton, the gross product of sugar cane production is about 5,350 baht/rai/year, with farm inputs amounting to about 60 % of the gross product. This gives a gross margin of sugar cane production per rai about 2,000 baht/rai. Most small farmers (*look rai*) in the Mae Klong area (this may be different in other regions), obtain credit loans from quota heads with 2-3 percent interest per month. They will get around 1,850 baht per rai per year (Table 1).

Under the current system price, the profitability of sugar cane production per unit area does not appear so attractive for both big and small farmers. Comparing the annual income with other crops and animal productions, it was found that sugar cane yielded less than double rice crops (2,600 baht per rai per year with sell price of 1997 : 3,400 baht/ton ; since then, prices have fluctuated between 5,000 and 8,000 baht/rai), but three times less than baby corn production and five times less than raising diary cows is association with baby corn (Srijantr, 1998). Sugar cane appears comparatively little labour-intensive and suits older farmers with little labour force, farmers engaged in other non-agricultural activities, and is a complement for farmers growing intensive cash crops on a small portion of their land.

If we look at production costs and income for our two types of farms, we can observe the following differences[6] :

The average cultivated area of sugar cane for the small farmer is about 12 rai (2 hectares), while for Quota heads it is around 100 rai (see earlier footnote). The fixed capital corresponds to farm machine and other equipment costs and amounts to 800 baht/year for the *Look rai*, against 33,700 for the Quota head[7]. Differences also appear in the cost of labour. Most of crop

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[5] The sell price of sugarcane was taken at 500 baht/rai in the following economic analysis. This price is assumed to be an average value in the present conditions of rather hectic year to year fluctuations.

[6] All production costs are derived from (Srijantr, 1998), reports from the Sugarboard (1998), Damwan (1998) and fieldwork surveys.

[7] This calculation is based on the investment costs. Regarding the tractors of the Quota head, we cannot consider his own sugarcane growing activity without the income derived from service work in other farms. The fixed cost has been taken as half of the total one corresponding to the tractor (67,400 baht) : because half of the area of sugar cane is under the direct control of quota heads and capitalist farmers, it has been considered that half of the tractor investment was devoted to hired tractor service on the other half of the area (*look rai* do not own any tractors).

care is achieved by the *Look rai* in his own plots, while Quota heads have to resort to hired labour. On the other hand, the cost of labour for harvest will be lower for the Quota head who is the organiser of this activity. Eventually, *Look rai* earn about 1,857 baht/rai or 22,280 baht on their 12 rai. The corresponding values for the Quota head are 2.416 baht/rai and 241,600 baht over the whole farm (Table 1).

We can observe that the quota head income per rai is higher by 30 %, while the total farm income, of course, is in line with the total area considered. It must be stressed, however, that these calculations do not consider interest rates (money borrowing) and possible land rental : the rental fee in the area varies between 800 and 1,200 baht/rai. With such an additional cost, the average yearly income of the landless *look rai* decreases to 850 baht/rai[8] ! Another noteworthy aspect is the difference of income between the years : the second year appears to yield 50 % more cash income than the average, while the first year is the lowest because of the investment for land preparation and seedling.

3. The yield gap and water management

3.1 Conditions of water use in the area

Average yields of around 10 t/rai are quite low for irrigated conditions. With proper management, it is widely accepted that average productivity is to be around 15-16 t/rai. In good conditions of crop care and watering the *sugar cane farm of Tha Muang (province of Kanchanaburi) obtains 20, 15 and 12 t/ha on the average along the three years*. In fact, such a productivity can be found in a few farms of the Mae Klong area with adequate management. It can be stated that there is a significant yield gap in sugar cane production in the irrigated area of the lower Mae Klong. Many reasons can be mentioned to explain such a situation, including labour shortage, shallow ploughing, inadequate fertilisation, soil salinity, etc. It is believed, however, that the main factor is the insufficient and inadequate application of water, as this section will show.

Before the completion of the upper part of the Greater Mae Klong Project - GMKP - (1974 for Kamphaengsaen and Nakhon Pathom Projects; 1988 for the Song Phinong and Phanom Thuam Projects, with some canals completed only in the 90's), sugar cane was mostly rainfed but some wells were already used to supplement rainfall. Over the whole upper Mae Klong area, the plot and access to water conditions are extremely varied (Kositsakulchai, 1995) : while some areas are provided with extensive land consolidation (part of Song Phinong and Tha Maka projects), other (the majority) have only locally developed ditch systems, with some plots close to rainfed conditions. However the use of tube wells significantly modifies this situation.It is widely believed that the modern infrastructures of the GMKP provide abundant water to its fields. However, because of the lack of initial on-farm facilities on most of the area, water access and water control at farm level are much below expectation. A detailed study over 1,000 ha of the Kamphaengsaen Project has shed light over this situation (Chompadist, 1997; Molle et al., 1998). It appeared that even though the ditch system developed along the years to reach

Furthermore, the tractor potential has been estimated as 200-250 rai, which is compatible with the average area considered here for the *quota head* type (100 rai, +100 rai of hired service).

[8] In the study area of the Kamphaengsaen Project, around 40% of the total land cultivated by small farmers was hired.

densities close to land consolidation standards (this was found to have been the result of both farmers and public investments, accounting for 50 % each), the patterns of water use were quite complex : conjunctive use predominates, farmers resorting to canals, ditches, drains, ponds and tube wells, 36 % of them using two sources and 5 % three sources. Despite the fact that the area is considered to be under gravity irrigation, the study also showed that only 20 % of the area - almost exactly corresponding to the rice growing area - could be supplied by gravity. All other farmers were found to use pumps.

Regarding sugar cane, 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). Some wells existed before the implementation of the irrigation system but they expanded later, as the water table was raised by dry season irrigation supplies, making it easier to access underground resources through the use of shallow tube wells and suction pumps. In all cases, it appeared that *irrigation demands additional individual pumping to raise water to the plot.*

Cropping calendar and cultural practices of sugar cane production depend on agro-ecological conditions and water allocation from RID irrigation project. The adequacy of the available soil moisture throughout the growing period is important to obtain maximum yields. In terms of water supply, there are two periods of water supply shortage, which are June-July, and December-January in the Mae Klong irrigated area. These periods correspond to canal maintenance and rice/sugar cane harvesting. The principal period of water deficiency is June-July, when farmers try to maintain the soil moisture content to keep the sugar cane growth rate (especially the farmers whose plant new sugar cane late in May), and often have to cope with an uneven distribution of rainfall. Farmers must resort to other water sources (mostly tube wells) or just accept the risk of water stress.

3.2 Characteristics of plot irrigation

Sugar cane is often grown on uneven land : furrow irrigation is therefore inefficient, especially for the ratoon crops. In many cases farmers have to use pumps and hoses through which they deliver water to the highest parts of the plot, from where it just (slowly) spreads onto the field. This method is very common and cannot be termed furrow irrigation. *This is conducive to very high pumping durations* : for a sample of 32 plots planted with sugar cane, average pumping durations have been found to be 7,1 hour/rai (45 hours/ha) for a ratoon crop (with values commonly reaching 10 h/rai/time or more) and half this value for newly planted plots (clean furrows allow better water advance). The impact of the large size of the plots, poor levelling and poor weeding, is well demonstrated by the comparison with baby corn plots : for a sample of 35 plots of baby corn, the average pumping duration was found to be only 2.8 hour/rai/time. This is coherent with irrigation durations observed in the Tha Maka experimental farm : two hours per rai of newly planted crops or 4 h/rai of ratoon crops.

The high variability of pumping duration mirrors principally differences in plot conditions and in pumping devices (these includes gasoline and diesel motors commonly ranging from 3 to 11 hp, conventional suction pumps or axial pumps with different diameters, most commonly 3" for the former and 6" for the latter ; electric pumps where excluded).

The second parameter of the economics of pumping is energy consumption. Again, the survey gave quite a wide range of values, most of them ranging from 0.45 to 1 litre of gasoline per hour. This variability can be explained by differences in power, suction head and state of maintenance (older motors may show consumption levels twice as high as the ones observed for similar new engines). We will consider here an average of 0.84 l/hour. For a retail price ranging from 8 baht/litre (station) to 10 baht/litre (village retailer), we may consider an *average cost of 7.6 baht/hour of pumping. This gives - for an average application of 7,1 hours/rai/time - a gasoline cost of 55 baht/application, rounded up to 60 baht to include transportation, tanks, etc.*

With the average parameters above, we must now consider the effective irrigation frequency, which will govern both the overall cost and the amount of water applied on the fields. This frequency is very varied, averaging - in the dry season - three times a month for newly planted crops and one time/month for ratoon crops, with some farmers irrigating only once or twice a year. In addition, the effective frequency varies each year with the rainfall pattern. This can be compared with the (optimal) frequencies used at Tha Muang farm in the dry season : one irrigation every 10 days for a new crop and one every 15 days for a ratoon crop.

It is uneasy to estimate to what extent the actual water application meets crop requirements. The pumping devices used by farmers commonly deliver between 13 and 20 m^3/hour, which represents between 60 and 90 mm/rai for our average applications. However, the extremely inefficient application of water translates into high percolation losses in lower parts and furrow tails, making it difficult to assess the satisfaction of needs. If we consider net crop requirements around 7 mm/day during the dry season, an average application provides *at the most* the water needed for 10 days.

Considering average frequencies of irrigation around 1/month and the limited contribution of rainfall (7, 7, 29, 50, 73 and 76 mm of effective rainfall for the first six months of the year), we may state that the actual water application is much lower than crop water requirements, roughly around 50 %, with a clear impact on productivity.

The reason for this under-use of water is very little due to water availability, as one could think at first sight, but, rather, to the cost of pumping, itself a result of long duration water applications due to poor plot conditions.

3.3 Relationships between water application and yield

Such a statement lead us obviously to investigate if there are any cost-effective technologies for the improvement of land levelling, which could reduce pumping costs per application and, therefore, encourage farmers to apply more water in their fields, resulting in significant yield increase. The response of sugar cane to water can be assessed by using the crop coefficient given by FAO (19). For a water stress constant along the cycle, the relationship between a diminution of the actual evapotranspiration (ETa relatively to its maximum value ETm) and the corresponding yield decline (actual yield Ya to maximum yield Ym) is :

$$(1-ETa/ETm)= 1.2\ (1-Ya/Ym)$$

An actual evapotranspiration of say 0.5*ETm leads to a yield of 70 % of the potential value Ym. The coefficient (1.2) varies if the stress occurs only during a specific period of the cycle.

For the sake of illustration, Table 2 gives examples of yield reduction estimated by the FAO coefficients, for different types of stress and a potential yield of 20 t/rai[9].

Tab. 2 : Yield under several assumptions of irrigation water use[10] and period of stress

Stress	**Potential**	**50 % irrigation**	**25 % irrigation**	**rainfed**
stress at ripening	*20*	19,5	19,2	(19)
stress at yield formation	*20*	17,5	16,3	(15)
stress at establishment/vegetative phase	*20*	16,3	14,4	(12,5)
stress on the total growth period	*20*	14	11,01	8,1

It is uneasy to apply this formula to our case study in a deterministic way[11]. However we can see that the yield reduction for 25 % and 50 % irrigation is compatible with the regional yield average.

3.4 Economic impact of a change in water use

The impact of water use upon the yield is extremely significant and we may estimate its cost/benefit relationship.

The first economic simulation applies to a *look rai* who would try to supply his crop with the optimal amount of water. We can take a frequency of plot irrigation of 1/10 days and 1/15 days for first new and ratoon crops during the dry season and a third of these values during the rainy season. This gives, tentatively, 24 applications for new crops and 18 for ratoon crops, with corresponding costs of 1,440 and 1,080 baht/rai over the year[12].

It is uneasy to assess the corresponding amount in yield as the high watering frequency and the average pumping duration (7.1 hour/rai) considered here does not necessarily imply that crop requirements are fully met. In fact, poor plot conditions in terms of levelling often have adverse impact on irrigation efficiency and, while some parts receive too much water, others are not totally supplies. Some remaining water logging and water stress impede reaching the full potential and define a lower (relative) value of the potential yield.

It can be seen from Figure 1 that an increase in water use, considering a corresponding yield between 16 and 18 t/ha[13], gives a significant increase in farm income[14]. The results of the

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[9] For a value Ym of the potential yield, the yield reduction can be obtained by correcting the table values by Ym/20.

[10] It is assumed that, over a long period, ETa/Etm can be assimilated to Dr/Req, where Dr represent the net real deliveries and Req the theoretical crop water requirements; this is true if the moisture in the soil profile is the same at the beginning and the end of the period considered.

[11] This can be done for a specific case in which the soil moisture and the water balance would be recorded but not for a regional approach in which all kind of situations can be found.

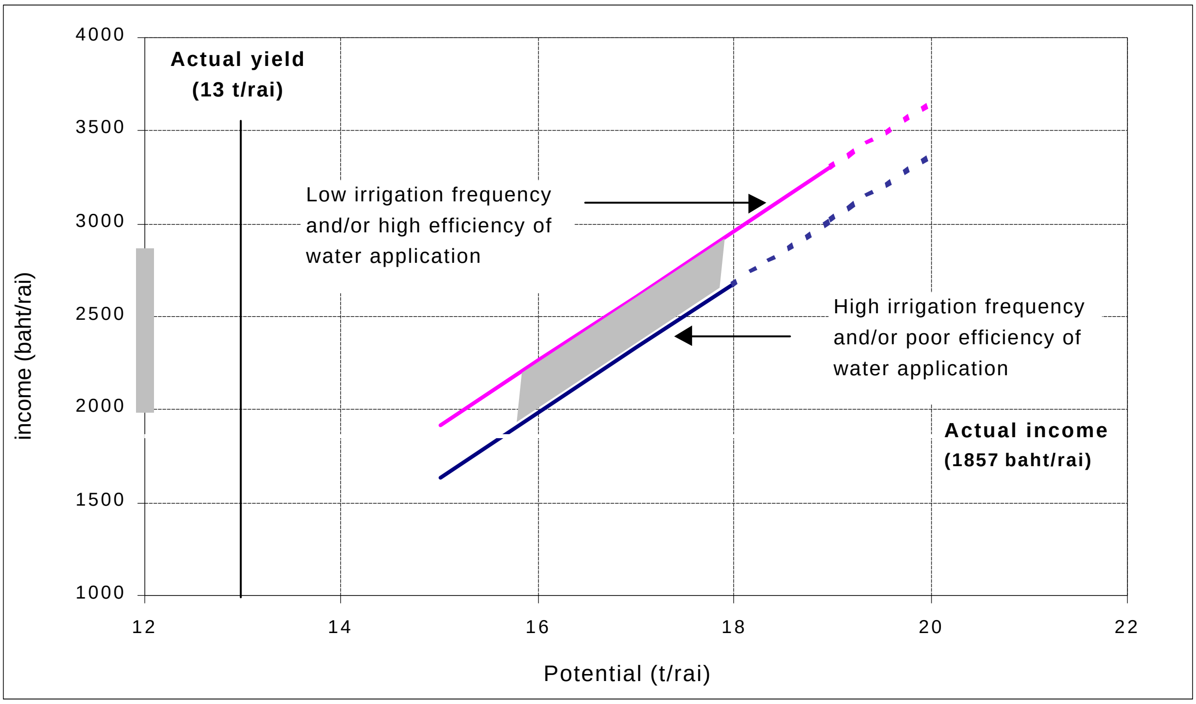
[12] These values are rather high but allow for a conservative economic assessment of the impact of irrigation. A number of 20 applications is also coherent with a net average application of 75 mm/irrigation, an application efficiency of 50 % and a net total irrigation requirement calculated in 750 mm (total requirements – effective rainfall).

[13] This yield stands for the first year yield. Values for the second and third years are interpolated in a way that their ratio with the first year value remain in line with the 19/17/15 proportion.

14 The increase in crop care is not computed here and is considered to be provided by the look rai himself.

simulation are also shown (upper curve) for a less conservative hypothesis on water use, corresponding to a lower irrigation frequency (18/14/14 instead of 24/18/18 for the three years)[15] : farm income is raised by 50 %. There is little doubt that, except for very specific situations with very poor conditions of soil and/or plot, applying more water is profitable.

Fig. 1 : Economic simulation of an increase in water use under different potential yield hypothesises *(look rai)*



This raises the question on why farmers do not chose to irrigate more frequently. The first natural answer which comes up to one's mind is that water is not available. Empirical evidence, however, shows that in most cases this hypothesis can be dismissed. Low yields and low irrigation efficiency can be found in plots bordered by ditches with good water supply.

We suggest here that the answer is twofold : first of all, farmers are faced with the problem of cash availability. Each irrigation – for 12 rai – has been calculated to cost an average of 750 baht and watering frequencies compatible with the optimal crop demand would require that farmers be able to exhibit the corresponding cash at almost any time. Secondly, the generally poor plot conditions force farmers to resort to very burdensome methods of irrigation : commonly, farmers must remove long hoses to several locations in the plots, from where water just spreads around. The long duration already mentioned of the application also forces them to spend long time in the fields and/or to make repeated rotations between the plot and the house. These efforts are not well rewarded as a large part of the water applied is lost and the uniformity of application is low.

[15] Or, in equivalent terms, to a situation in which water application is more efficient (lower pumping duration).

It is our contention that these factors are much more significant that water availability proper. Consequently, *it appears that complementary actions aimed at boosting the use of water should focus on making plot water application efficient and easy, rather than on water distribution devices.*

We may, in particular, look at the options for land improvement, most particularly land-levelling. High quality laser levelling is now available with much cheaper methods than the traditional scrapper. Tractor driven equipment is available at the cost of 1 million baht and can provide adequate land levelling for sugar cane.

A second economic simulation has been carried out to compare the cost of such a service and the likely return in yield. We will refer here to ten years of experience in Egypt, where land improvement has brought about significant production increase (El-Yassal and Wissa, 1990). Precision land-levelling with and without slope (3 cm/100 m) allowed – from an average 12 t/rai standard situation - very similar to the Mae Klong case –, an increase of 48 and 50 % in yield respectively (37 % and 43 % for new crops). Water use efficiency grew accordingly, by 82 % and 111 % in the two cases.

Precision Land Levelling equipment is estimated to have a useful life of ten years, with 1,000 hours of service per year (El-Yassal and Wissa, 1990). We considered, tentatively, a cost per hour equal to 700 baht/hour[16]. Technical parameters indicate that service on one rai takes an average of one hour of work[17]. We consider here, conservatively, that two hours/rai are required in the Mae Klong conditions

Economic calculation for full irrigation after levelling (with, now, only half the initial cost per application) gives, for a potential of 19 t/rai (19, 17 and 15 t/rai for the three years) an increase of 1,770 baht/rai/year, from 1,857 to 3,627 baht/rai (Table 3). It compares extremely favourably with the land levelling cost (1,400 baht/rai), even if we consider that levelling must be carried out every two cycles (every 6 years).

4. Conclusions and recommendations

The discussion above has shown that an increase in water use is profitable and pointed out for some of the reasons why farmers use less water than expected, although the access to water is often not a constraint. Evidence from yields obtained in some farms and in other countries also suggests that sugar cane production in the Mae Klong area is far from its optimum and that there is significant scope for improvement.

Any large scale plan to upgrade sugar cane production in the Mae Klong area must take into consideration the fact that access to water and farming systems are both extremely varied. This has concrete implication in terms of developmental options. *One should not think in applying large scale uniform or ready-made solutions but, rather, in characterising land and farm situations in order to devise adapted solutions, both in technical and financial terms*.

[16] This cost can be compared – on a basis of one hour service per rai – with a plain tractor service for land improvement (300 baht/rai), land preparation service for wet broadcasting (350 baht/rai) or hired service for "macro" excavator (750 to 1000 baht/hour).

[17] We have no way to compare the average machine requirements in the two countries and we will therefore consider the Egyptian data for the sake of comparison. The parameter is doubled for the sake of security.

① If we consider the areas where irrigation is established since the early 70's, we may extrapolate field observations carried out in the Kamphaengsaen Project, which show that an endogenous expansion of the ditch system associated with multi water source tapping has taken place (Molle et al. 1998) : in such areas, farmers and the local administration have already invested a lot in water resources tapping and pumping equipment : *it would therefore be highly anti-economic – a duplication of investments at the plot level - to invest in equipment devised to improve access or distribution of water : rather, it is argued, emphasis should be laid upon improving land levelling* and/or subsidising gasoline for farm pumping. Reducing the burden of irrigation and the cost of pumping is believed to be the key to production increase.

Furthermore, developing medium size pumping units on the berms of primary and secondary canals nullifies all the potential for gravity irrigation of the Mae Klong area. One must remember that the main distribution network of the GMKP has been designed and constructed to allow gravity irrigation. Water head has been obtained by raising canals at a high cost. It would also be anti-economic at the macro level to invest in pumping devices in areas where the potential for gravity irrigation is not realised.

② For areas recently provided with irrigation facilities (eastern part of Phanom Tuam Project, for example), such local investments may not have been made yet. It may therefore be adequate to study the feasibility of improving water distribution, for example **using low pressure pipe systems**. This is also particularly adapted for high, out-of-command, land, which cannot be reached even by excavated ditches. A pipe system with a collective pump for a 500-600 rai unit amounts to around 4,000 baht/rai[18]. Energy costs are lower than for individual pumping (40 baht against 60, for one application).

One constraint on such a system is its collective management (and maintenance). Some kind of scheduling must be established (the system cannot work if all farmers want to use water at the same time) and this may not well be accepted : in other regions, where no water supply pre-exists, collective medium-scale pumping units have proved successful because the dramatic change induced in agricultural conditions was strong enough to make farmers accept and comply with the collective constraints. *In situations where irrigation facilities exist since one or two decades and where individual pumping from several water sources eventually developed as the most common solution, it is doubtful whether this option will arise farmers' interest at the same level*.

③ One must not forget that individual pumping in well supplied ditches provides more flexibility, is less expensive and is often more cost-effective, as many farmers are already equipped with pumping devices. In many instances, **basic extensive land consolidation** (especially in areas where it would make full gravity irrigation practicable), or even the **improvement of the ditch system** (widening, deepening and prolonging ditches) is probably the best option under the present situation : this latter option has the advantage to maintain the independence of water users and does not demand scheduling.

[18] Or only 3,000 baht/rai, if low pressure pipes are chosen. However, possible problems with trucks and harvesters make the choice of normal PVC recommended.

④ In other situations, such as the large farms run by quota head or other “capitalistic” farmers, other kind of equipment adapted to capital availability and low labour resources may be more suitable : **water canons**, for example, may constitute a relevant option for large farms, with the advantage of making the necessity of levelling less crucial.

Table summarises the main advantages and constraints of some possible options.

Table 4 : Elements for the comparison of some technical options

(some) options	**Investment & operation**	**Advantages/drawbacks**	**Situation**
Land consolidation (extensive)	6,000 baht/rai	(+) decreases pumping requirements; improve access to water; (-) pumping may be still necessary on high land; levelling needed;	Good water head allowing gravity irrigation; Main system provides reliable water supply
or improvement of the ditch system	variable	(+) low cost; capitalises on existing pumping equipment; independent pumping (-) operation pumping costs	Farmers owning pumps
Low pressure pipe system	4,000 baht/rai 40 baht/application with no levelling (.5 baht/m3) unit > 200 rai	(+) easiness of application; lower operation costs; (-); maintenance; collective asset and management; duplication of investments in pumping devices	Areas with little ditch system or wells development. High or out-of-command areas
Canon (sprayer)	10,000 to 15,000 baht/rai	(+) Effective even with poor land levelling; limited labour need (-) Cost effective only in large farm ; maintenance; high cost	Large farms with capital Plots with very poor levelling
Furrow irrigation with precision land levelling	750 baht/rai ? 30 baht/rai by application	(+) Increases the efficiency of water use; decreases application time; boosts increased water use. (-) Pumping at plot level may be still necessary	Areas with on-farm ditch system already developed; small farms with little capital and labour endowment.

Economic simulations suggest that fostering the use of irrigation water is so profitable that it might even prove cost-effective for quota heads or factories to supply free land levelling to farmers, provided that the latter agree to increase irrigation and crop care. This is to remind that small farmers should not bear the brunt of such investment which, in addition, they often have already made in the form of pumping equipment : capital-intensive operators, principally the factories and some quota heads, should cope with most of the capital investment and find a way to boost the response of farmers and incentive them to increase their labour input in sugar cane cultivation for a mutual benefit.

One important point must also be noted : there is, at present, little constraint on irrigation in the Mae Klong Project. This is due to many factors, among which the high flexibility in agricultural calendars due to mechanisation and early maturing rice varieties, and the low level of water use (Molle et al. 1998) : because irrigation plots use less water than expected at the time of project design, and because secondary water sources are also tapped, full supply deliveries in the project goes together with a large margin of "extra-water", which provides the corresponding flexibility. *Any significant future increase of water input in the sugar cane plots will have to go alongside improvements in water management too.*

Further economic characterisation of the different options is required. Pilot projects could be a proper way to gain further insight on the suitability of each option and on the responsiveness of farmers. Regarding regional development, spatial zonings considering relevant variables should be achieved in order to orient investments. They require the acquisition of additional primary data to typify the actual situation in terms of actual and potential productivity, and farm characteristics. A careful spatial analysis of key variables should include : potential yield (based mainly on soil suitability), actual yield, yield gap (potential minus effective yield), tube-wells and ditch density (actual use of water sources), areas out-of-command even by using excavated ditch (priority areas for pump units), % of other crops (mixed cropping patters), farm characteristics (% of small farms, tenure).

A regional zoning will allow the specification of areas with higher potential where investments could be made in priority. At the level of the implementation projects (units of a few hundreds rai), however, site specific factors will always appear and cannot easily be forecasted : information meetings with the farmers, visits to experimental projects will help building a participatory approach towards the best adapted solution. In all cases, the responsiveness of farmers will depend on their perception of whether the situation will effectively improved in terms of both cost-effectiveness and facility of operation.

References

Aromrat, Uthai and Sukhakit Seri. 1993. Water management in sugar cane plantation in the west region, Soil Science Unit, Dept. of Agriculture, *in* Proceedings of first “Sugar cane and Sugar National Seminar”, Sept. 1993, pp. 14.

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

Damwan, Kasin. 1998. An analysis of cost and return on sugarcane production : a case study in Amphoe Thamuang, Kanchanaburi Province, M.B.A, Kasetsart University, 69 p. (in Thai)

Doorembos, J. and A.A. Kassam. Crop response to water stress, Irrigation and Drainage paper n°33, FAO, 230 p.

El-Yasal, Nabli S. and Zaki H.Z. Wissa. 1990. Effect of laser land levelling on sugar cane yield and water requirements. Sugar cane, n°4, pp. 6-9.

Information Center for Sugar and Sugar cane. 1998. Survey report for sugar cane production in 1998-99, 60 p. (in Thai)

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

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

Karnchanasutham, Supan. 1998. An application of remote sensing and geographic information system for sugar cane planted area suitability in Thailand, *in* Proceedings of 3rd “Sugar cane and Sugar National Seminar”, May. 1998, pp. 137-164.

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 p.

Molle F.; Chompadist C.; Sopaphun P. 1997. Assessment of water control at the tertiary and farm levels : a case study in the Kamphaengsaen Irrigation Project, Thailand, DORAS Project, Research Report n°3, Kasetsart University, Bangkok, 58 p.

Molle F.; Chompadist C.; Sopaphun P. 1998. Beyond the Farm-Turn-Out : on-farm development dynamics in the Kamphaengsaen Irrigation Project, Thailand, *Irrigation and Drainage Systems", Volume 12, no 4, pp. 341-358.*

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 p.

Srijantr, Thippawal. 1998. Transformations du système agraire de Thung Look Nok (Plaine Centrale) et perspectives de l'agriculture thaïlandaise. Ph.D dissertation, National Institute of Agronomy, Paris, 380 p.

System Look Rai
actual situation

	1 year	2 year	3 year	**Average**
Yield (t/rai)	13	11	8	10,7
Gross product	**6500**	**5500**	**4000**	**5333**
Tractor renting	680			
cane seeds	800			
herbicide	300	200	200	
fertiliser	450	360	360	
nb. of irrigation applications	6	4	4	
irrigation	360	240	240	
crop care	200	200	200	
transportation	1170	990	720	
Harvest labour	1040	880	640	
Total	**5000**	**2870**	**2360**	**3410**
Gross margin	1500	2630	1640	1923
Gross margin (12 rai)	18000	31560	19680	23080
Fixed capital (12 rai)				
sprayer	100	well	100	
pump	500	hose	100	
Total	800			
Value added (baht/12 rai)	17200	30760	18880	22280
Value added (baht/rai)	1433	2563	1573	1857

System Huana Quota

actual situation

	1 year	2 year	3 year	Average
Yield (t/rai)	14	12	8	11
Gross product	7000	6000	4000	5667
	0	0	0	0
Tractor renting	200	0	0	0
cane seeds	600	0	0	0
herbicide	350	250	250	0
fertiliser	550	300	300	0
nb. of irrigation applications	6	4	4	0
irrigation	360	240	240	0
crop care	100	100	100	0
transportation	560	480	320	0
Harvest labour	840	720	480	0
Hired labour	800	300	300	0
Total	**4360**	**2390**	**1990**	**2913**
Gross margin	2640	3610	2010	2753
Gross margin (100 rai)	264000	361000	201000	275333
Fixed capital (100 rai)	33700	33700	33700	0
Value added (baht/100 rai)	230300	327300	167300	241633
Value added (baht/rai)	2303	3273	1673	2416

System Look Rai
with increased water use and land levelling

Characteristic	1 year	2 year	3 year	Average
Yield (t/rai)	19,0	17,0	15,0	17,0
Gross product	**9500**	**8500**	**7500**	**8500**
Cons.				
Tractor renting	680			
cane seeds	800			
herbicide	300	200	200	
fertiliser	450	360	360	
nb. of irrigation applications	24	18	18	
irrigation	720	540	540	
crop care	200	200	200	
transportation	1710	1530	1350	
Harvest labour	1520	1360	1200	
Total	**6380**	**4190**	**3850**	4807
Gross margin	3120	4310	3650	3693
Gross margin (12 rai)	37440	51720	43800	44320
Fixed capital (12 rai)				
sprayer	100	well	100	
pump	500	hose	100	
Total	800			
Value added (baht/12 rai)	36640	50920	43000	43520
Value added (baht/rai)	3053	4243	3583	3627
Increase/rai	**1620**	**1680**	**2010**	**1770**