The role of Information for Improved Irrigation in the Phitsanuloke Irrigation Project: Implication for the Chao-Phraya Basin

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Abstract: *Improved operation of water and irrigation systems towards maximizing agricultural productivity can be obtained upon adequate decision making procedures. Reasonable s are made upon having the relevant information allowing to make the best selection among several alternatives.*

Water for irrigation in the Phitsanuloke Irrigation Project (PIP) is based supply via the canal system and local wells owned and operated by the farmers, primarily for rice growth. Having the information related to water supply vs *demand and the farmers' needs in regards to water can enhance better operation and increasing agricultural productivity. A survey conducted in the PIP regions during last years indicates possible directions for improvements. The lessons learned form the PIP can be expanded to other regions such as the Chao-Phraya Basin.*

1 Introduction

Application of water for cultivating of lands has been a common practice in Thailand for many years. The water, which originates from the northern mountains of the country and is stored in multi-purpose reservoirs and artificial lakes and subsequently is released and conducted in an open canal system for irrigation of the agricultural fields. The water is delivered via a reducing in size capacity branched open canal system until the very end of the last cultivated fields. The water is conducted to the cultivated fields by gravity flow and with supplementary support of small capacity pumps. These pumps, commonly owned by the farmers, are usually lifting the water up to a maximal height of approximately three meters and subsequently the water is released into an additional branched local canal. The pumps are usually operated by a small tractor engine that under conventional conditions also serves as the main vehicle for transportation in the cultivated areas.

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Main crop is still paddy that is cultivated twice a year during the dry and wet seasons (Yamazaki, 1992). Other crops (small percentages) include a variety of vegetables, soybeans and, fruit orchards (Anukularmphai, 1996). According to the Royal Irrigation Department (RID) of the Kingdom of Thailand the dry season begins around February and lasts around four months. The wet season begins around August and lasts up to five months.

The Phitsanuloke Irrigation Project (PIP) is located at the north most extremity of the central plain and is typically an agricultural region which is producing primarily rice. Water is supplied form the main canal system and local wells. The canal water is mainly obtained via the Nan River, which originates in the Doi Ohu Wae in the Luang Phra Bang mountain range. The Nan River is around 650 km long and the related basin size is around 33,130 km^2. Several dams (e.g. Naresuan and Sirikit dams) with large water capacities allow to control water delivery for irrigation via the branched canal system. The Nan and Ping rivers merge to form the main water source for the down stream Chao-Phraya river (Figure 1).

The PIP consists of three sub projects. (i) The most northern Plai-Chumphol (PC) sub-project. consisting of 273,000 Rai (one Rai is approximately 0.16 ha) of which around 218,000 Rai are irrigated. The project is divided into 7 zones (with 7 checks on the main canal). Water is supplied form the Naresuan Diversion Dam. The area is protected from floods from the Yom River by a parallel dike. Water is supplied continuously during the wet season and intermittently during the dry season. (ii) The central Dong-Setti (DS) sub-project, which consists of two main regions located in the central region between the Yom River and Nan River. Total irrigated area is approximately 186,000 Rai. The central Dong-Setti sub-project is not included in this work. (iii) The southern Tha-Bua (TB) sub-project that consists of about 168,000 Rai, which are regularly irrigated. Since this region is at the tail of PIP, water supply frequently is less regular and sometimes the farmers have to come-up with alternative solutions. Intense research efforts should be focused on this sub-project, mainly due the relative location in the entire water system.

Water supply for irrigation depends primarily on the growing season. Customarily, during the wet season water is provided for irrigation without restrictions. The situation is different during the dry season: subject to the conditions, when temporary water shortage situations come forth. The temporary water shortage forces the farmers to find alternative solutions or/and to delay the beginning of irrigation and to adjust the application regime to water availability.

Water allocation to the farmers is controlled by the zonemen in the different regions. The zoneman is actually the closet link between the water consumers and the water supply authorities, namely the Royal Irrigation Department (RID) of the Kingdom of Thailand. The canal system, subject to reliability of supply is classified into Good Operated Canals (GOC) and Poor Operated Canals (POC). This comparison is required since it might explain under some circumstances the need to have also the on-farm wells.

On farm water is required for three main purposes: (i) pre-irrigation to prepare the fields for the main growing season; (ii) water application for regular irrigation, and; (iii) to apply water when supply via the main canal system is insufficient. Most of the areas are irrigated by open-surface methods, namely furrow and basin irrigation which is the conventional practice for paddy.

2 The inspiration for the work

During water shortage periods and other unexpected circumstances of water scarcity the farmers dig out shallow wells on their farms. The wells reach a depth of around 20 meters. The on-farm local wells allow the farmers to pump water whenever water is needed on their farms in addition to the supply via the main canal system. The water pumped is mainly consumed during inadequate supply from the main canal system or serves as complementary quota to complete the crops requirements. Frequently the wells are operated with the engine of the small tractors used also for conventional travel, transportation on the farm and for cultivation. Control of the pumpage is usually by the family people (mainly wife) who stay most of the time on the farm.

Operation of the on-farm wells varies seasonally. The wells are primarily operated during the dry season (February to June). However, under specific circumstances the wells are also operated during the wet season (August to November).

The central water authorities of the Kingdom of Thailand have difficulties in controlling the number of wells per farm nor the amounts pumped and the related water quality. Most of the information regarding the wells is scarce. The lack of information holds both for the irrigation season and duration of operation. It was assessed that most of the time the wells are operated during the dry season. However, at the beginning of the study (1995) it was soon realized that the wells are operated during both seasons. The water from the wells is even used as part of the field preparation procedure. That was also true for the last years (1995 and 1996; 2538 and 2539, respectively), when the beginning of operating the main canal system was delayed due to technical damages in the canals due to extreme high floods.

The main purpose of this work is to determine the effectiveness of water supply via the main canal system and the need for on-farm wells use. The use of the water wells refers primarily to the farm characteristics, location along the canal system, pattern of crops, amounts and water quality, growing season and other factors, which might affect the wells operation. The specific objectives of this project are:

1) Quantifying the number of wells per farm considering the farm size and crop pattern.

2) Assessing the amounts of water pumped as related to the season and crop pattern, wells per farm considering the farm size.

3) Finding the main triggers and considerations in digging and operating the on-farm pumps.

4) Only farmers who have paddy fields were included in the analysis.

TABLE 1. NUMBER OF FARMERS AND REPRESENTATIVE AREAS SAMPLED IN THE COMMAND SITES

Sub-project	Perfor-mance level	Canal No.	No. of farmers sampled	Acreage sampled in Wet season 1995, rai	Acreage sampled in dry season 1996, rai	Total area in the project, rai*	Percent sampled out of total area
Phai--	Good	5	37	516	507	9059	5.6
Chumphol	Moderate	17, 18	65	1101	993	5362	18.5
Dong-	Good	67	30	725	725	17946	4.0
Setthi	Poor	45, 58	58	1253	1167	4174	28.0
Tha-Bua	Good	90, 91	29	913	846	4492	18.8
	Poor	106	24	745	722	6421	11.2

* - one Rai is equivalent to 0.16 hectare.

3 Materials and methods

3.1 General

The field study was conducted in Phitsanuloke Irrigation Project. All observed fields are located between the Yom River and the Nan River. Water is primarily supplied via the Sirikat Dam, subsequently the Nan River and canal C-1 (Figure 1). Three complementary modes were adapted for evaluating the use of the alternative water sources:

1) Field interviews with farmers regarding their water use habits and equipment. Analysis of the results using the relevant water supply parameters was continued (Table 1).

2) Assessing crop water requirements before the activation of the main canal system. These calculations are based on crop requirements and historical RID cropping reports.

3) Detailed monitoring of on farm water use and quality (mainly salinity) during the various seasons. This approach had some drawbacks and the information obtained was frequently incoherent.

3.2 On-farm well monitoring in the command sites

In order to have better prospect of the water application practice and performance a detailed survey of the on-farm wells was conducted. It included detailed survey of several on farm wells in each sub-project, partially with the assistance and full cooperation of the farm owners and the irrigation authorities. The survey was conducted in several villages in the command PIP site. Despite the extent use of the alternative waters and its influence on the water consumption efficiency and ability of farmers to cope with water stress conditions, only limited work was accomplished in command site. During 1993 (2536), following a long drought, a tube wells survey was conducted as part of a government program to financially support the drilling of 50,000 tube wells in the Chao-Phraya basin. Unfortunately, the survey was executed several municipal districts and as the PIP is included, it turned out too difficult to determine which of these wells are located in the PIP.

Several parameters were identified and used in order to assess the performance of the water systems, primarily for agricultural irrigation. Quantification of the parameters allows to compare the water delivery systems efficiency, regarding amounts, timing and location.

1) The number of wells per farm represents the option of using ground water however, do not indicate actual use, which varies and is determined by local and individual needs.

2) The lifetime of tube wells is a parameter indicating ground water use as on overall indicator of development of the area.

3) Distribution of wells per acreage. The large variety of farm size requires a parameter that overcomes these differences. In this calculation (number of wells per farm and/or farm size) it is assumed that the water used from the wells can be distributed between all the farm plots on a single farm. The density of the wells is proportional to the ability to use ground water.

4) Total time use of wells. Duration of the tube wells operation consists of the use during field preparation and along the irrigation season. The information compiled during the interviews refers to the days of use and subsequently implication regarding the farm acreage (Rai). It is assumed that the water was used for all the plots equally. The discharge of the well pumps varies from 30 m^3/h to 60 m^3/h, depending on the pump capacity, engine characteristics and hydraulic conditions. The number of pumping hours per day was not observed, however, discussing the matter with farmers many of them pointed-out that the pumps run continuously except for short fueling breaks.

5) Wells dry-up and/or recovery during the season. Retaining on farm well does not necessarily mean that water is available for pumping all throughout the entire season. Well drying is commonly an indication that the water table has decreased to a level that is beyond the withdrawal feasibility of the specific pump (approximately 10 m). The recovery of the well indicates that the decline in the groundwater table level is a short-term phenomena that probably occurred due to over depletion of ground water in adjacent areas.

6) The number of mobile pumps per farm. There are two types of pumps widely used in the PIP. Fixed tube well pumps and mobile multi-purpose field pumps. Typical discharge of the mobile pumps is around 100 m^3/h, depending on the specification (diameter & length), the engine and the elevation, which is commonly up to three meters above the surface level of the water source. This type of pumps is used for many purposes.

Figure 1. The overall Phitsanulok Irrigation Project, Thailand

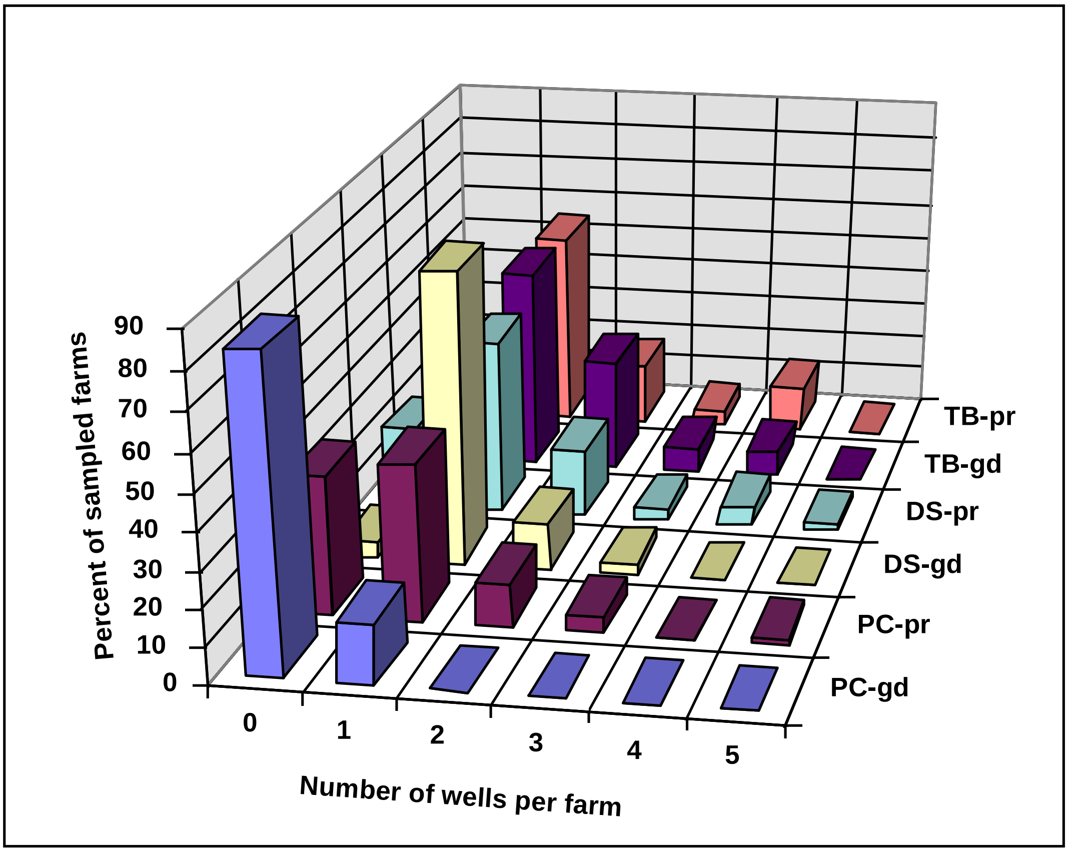

FIGURE 2. NUMBER OF WELLS PER FARM (PC - PHLAI-CHUMPHOL; DS - DONG-SETTHI; TB - THA-BUA; GD - GOOD OPERATING CANALS; PR-POOR OPERATING CANALS)

4 Results

4.1 The wells layout

The presented analysis reflects the analysis of the survey conducted during the last years. Part of the results can be further interpreted into practical solutions to be implemented in other regions as well. The relatively low number of wells observed in Phlai-Chumphol is probably due to inappropriate hydraulic conditions in the region. The information provided includes the number of wells per farm (Figure 2), number of wells per unit area (Figure 3), wells depth (Figure 4) and lifetime of tube wells (Figure 5). Commonly, most of the farms have up to two on-farm wells. A greater number of wells can be identified primarily in the regions which are subject to dry conditions, namely in the poor operated canals and in Tha-Bua. The implication of this finding is the mean number of pumps per Rai which is commonly up to 0.08 pumps per Rai. The prevailing wells depth is in the range of 20 to 30 meters (Figure 4).

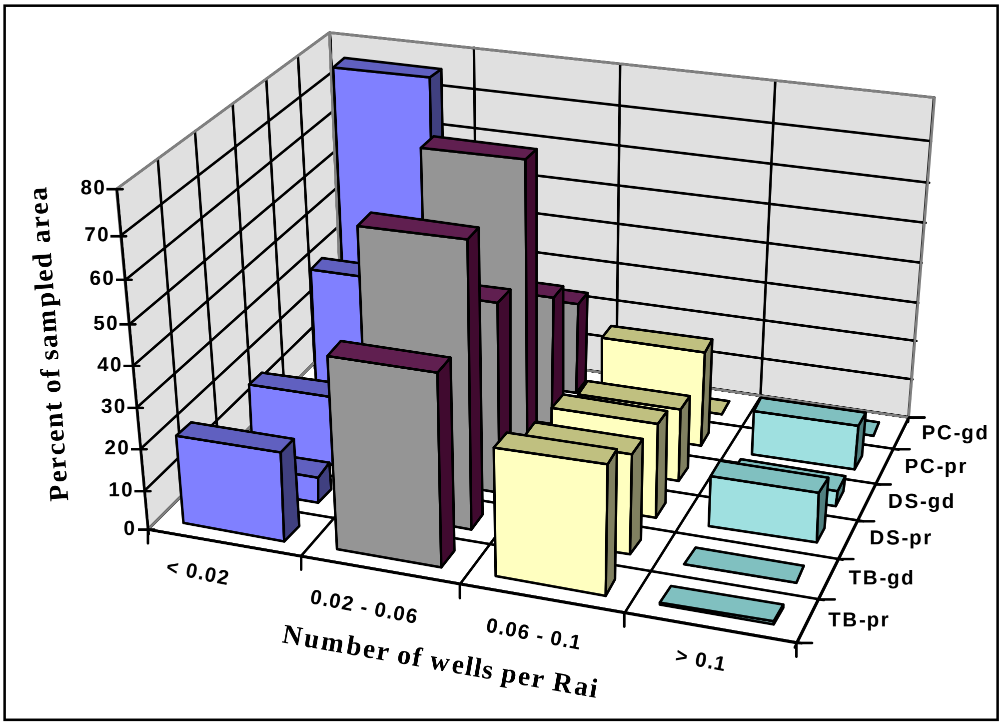

FIGURE 3. WELLS DISTRIBUTION IN THE VARIOUS AREAS(PC - PHLAI-CHUMPHOL; DS - DONG-SETTHI; TB - THA-BUA; GD - GOOD OPERATING CANALS; PR-POOR OPERATING CANALS)

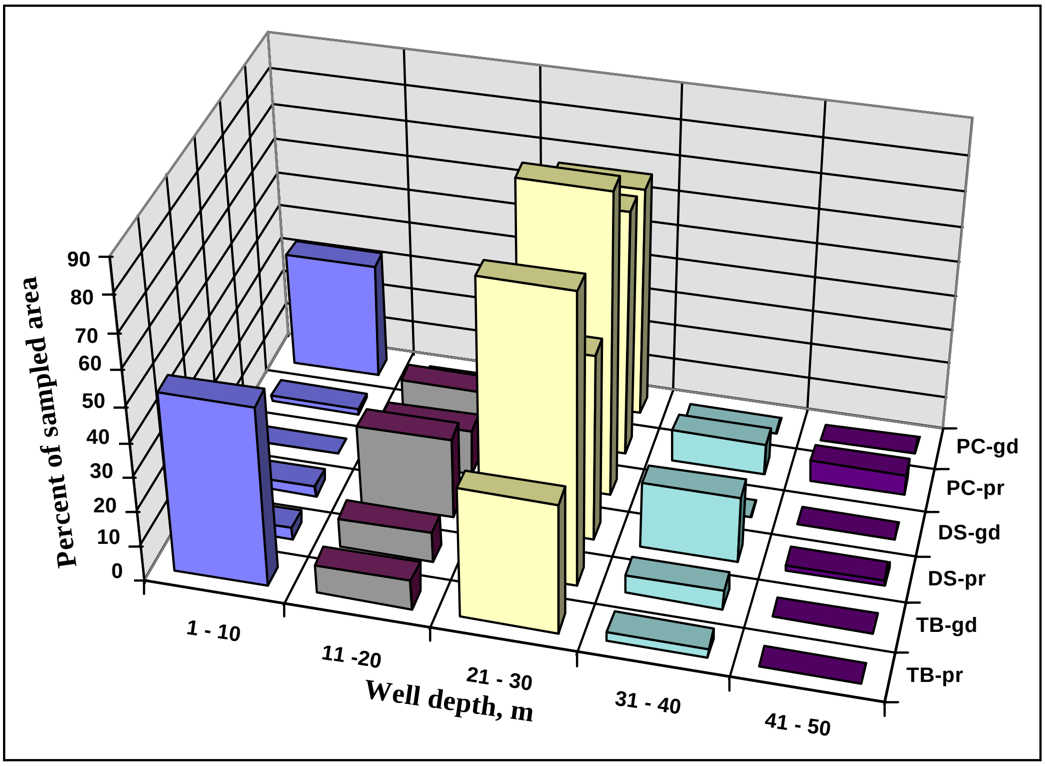

FIGURE 4. VARIATION OF WELLS DEPTH IN THE COMMAND SITES (PC - PHLAI-CHUMPHOL; DS - DONG-SETTHI; TB - THA-BUA; GD - GOOD OPERATING CANALS; PR-POOR OPERATING CANALS)

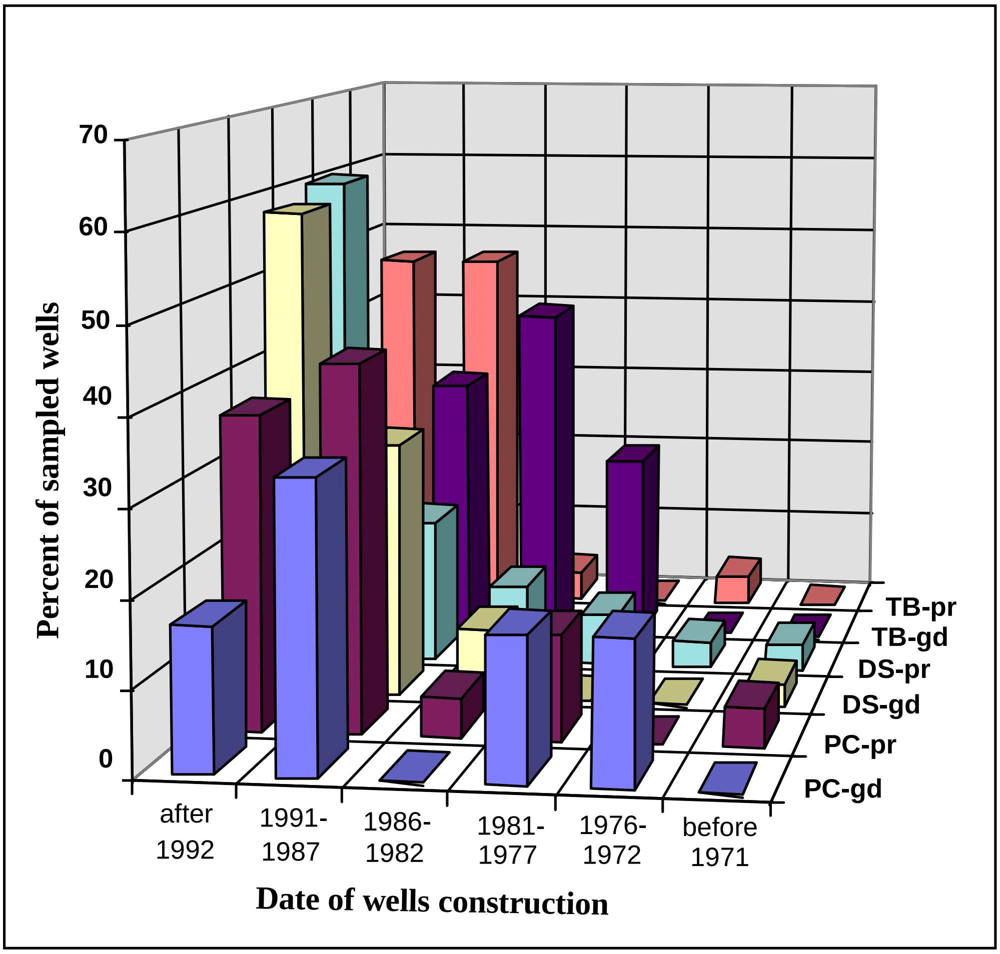

FIGURE 5. LIFETIME OF TUB WELLS (PC - PHLAI-CHUMPHOL; DS - DONG-SETTHI; TB - THA-BUA; GD - GOOD OPERATING CANALS; PR-POOR OPERATING CANALS)

4.2 Wells operation characteristics

Many of the permanent wells are dried-up during the dry season. Consequently, the mobile pumps are used intensively, which emphasizes the burden on the whole system. This finding was also concluded from the survey namely, the farmers are gradually installing new tub wells in order to increase the flexibility to supply water. The largest number of the pumps in all regions was installed after 1987. The number of dried-up wells during the wet 1995 season was small however, large during the dry season for 1996. The incompatible picture can be detected for the number of recovered wells: a large number for the wet 1995 season and a negligible number of pumps were recovered during the 1996 wet season.

Duration of the wells operation in Dong-Setthi region is intermittently between the Phlai-Chumpol and Tha-Bua regions. Duration of wells operation in Tha-Bua region is naturally the longest among all regions (Figure 6). That phenomena is mainly typical for the 1996 dry season and even for the poor operation canal region of Phlai-Chumpol (Figure 7). The inferior conditions in Tha-Bua region are also reflected by hourly operation of the wells (Figure 8).

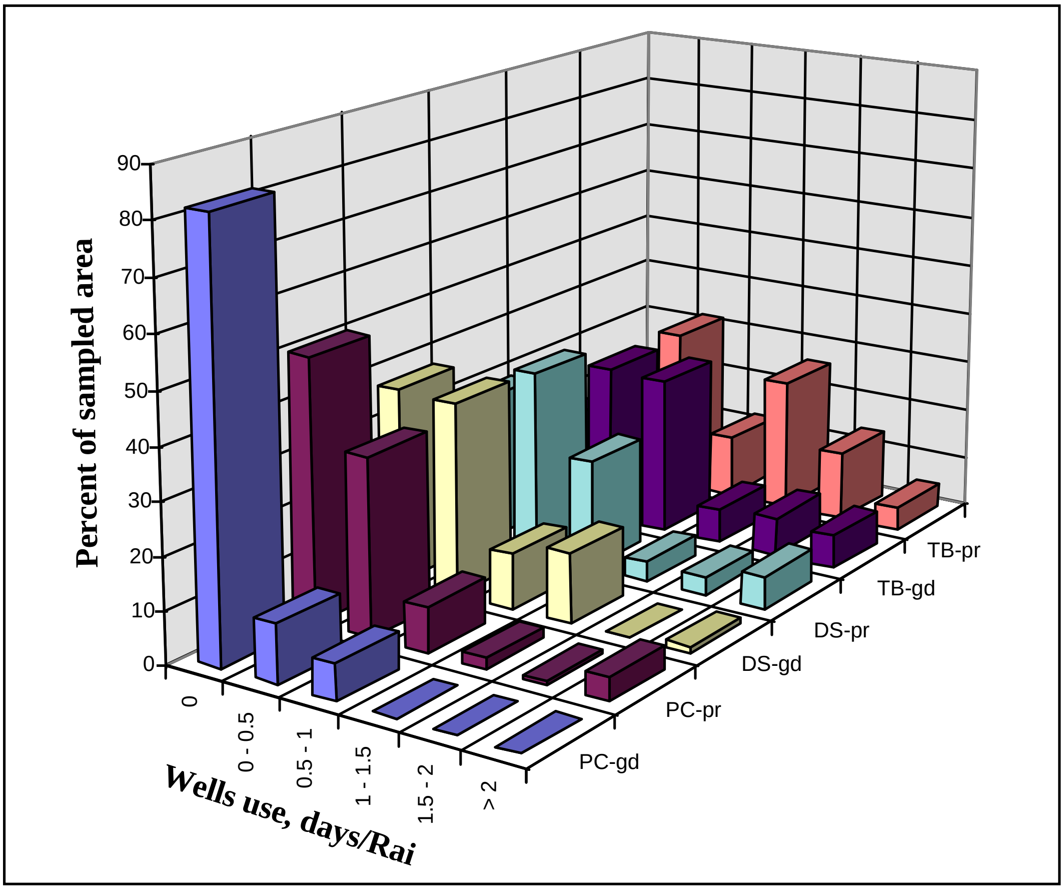

FIGURE 6. USE OF WELLS DURING WET SEASON, 1995

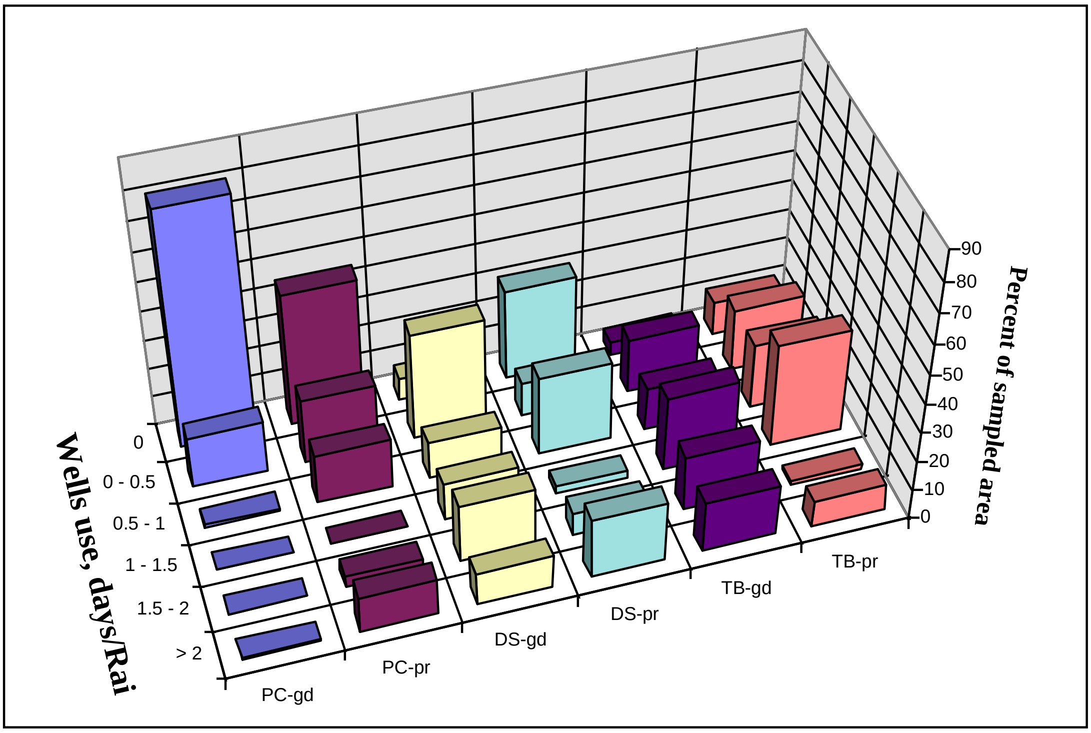

FIGURE 7. USE OF WELLS DURING DRY SEASON 1996 (DAYS PER RAI) (PC - PHLAI-CHUMPHOL; DS - DONG-SETTHI; TB - THA-BUA; GD - GOOD OPERATING CANALS; PR-POOR OPERATING CANALS)

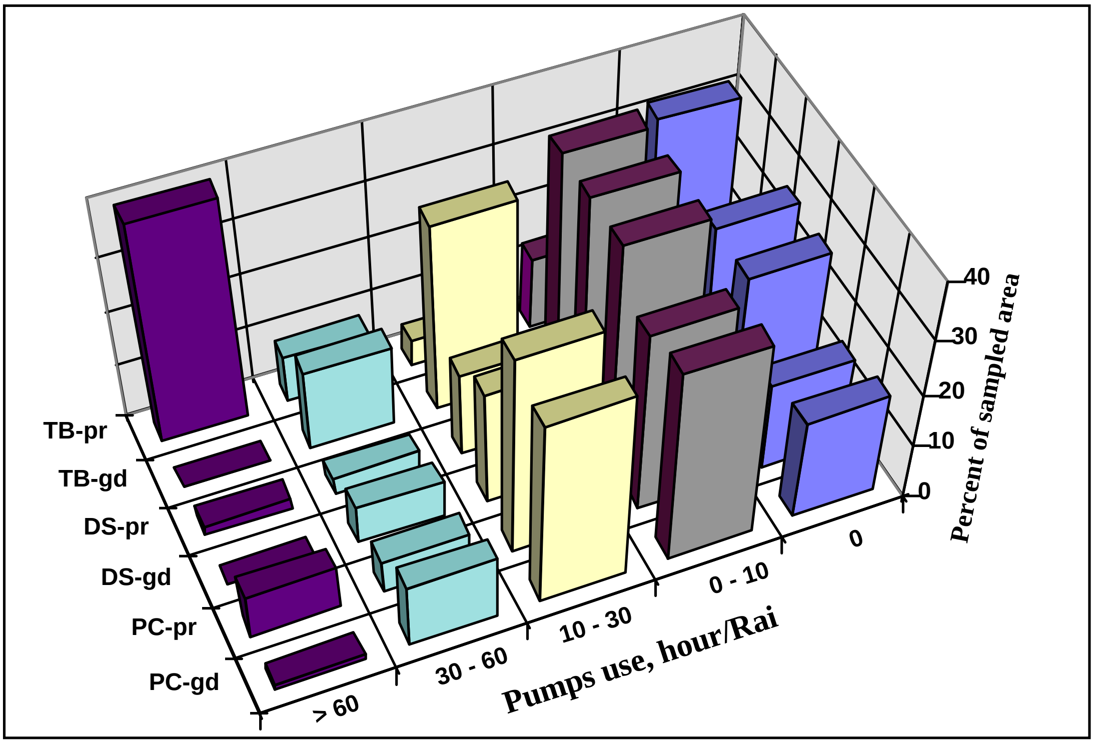

FIGURE 8. DURATION OF WELLS UTILIZATION DURING WET IRRIGATION SEASON 1995 (PC - PHLAI-CHUMPHOL; DS - DONG-SETTHI; TB - THA-BUA; GD - GOOD OPERATING CANALS; PR-POOR OPERATING CANALS)

4.3 Pumps utilization in the command sites

Additional information refers to the inventory and duration of pumps utilization (Figures 9 and 10). Mobile pumps are used according to temporary needs and moved to the fields which need to be irrigated under the highest priority. Both the number of pumps and duration reflect the water state in the command sites. Consequently, it looks as if the highest number of pumps can be found in Tha-Bua region and the lowest in Phlai-Chumphol areas (Figure 9).

It can be observed that a relatively low number pumps are operated in the good performing canal region of Phlai-Chumpol (PC-gd) during both dry and wet season (Figure 10). Duration of pump operation is longer as compared with the good performance region in Phlai-Chumphol area. Duration of pumps operation in Dong-Setthi region is naturally higher during dry season and lower during wet season (Figure 10).

The pumps are operated at various duration in all regions. However, the findings indicate that under most conditions the pumps are operated up to 30 hours per Rai. Similar to previous findings, under extreme conditions the duration of pump operation is extended to 60 hours and above (Figure 10).

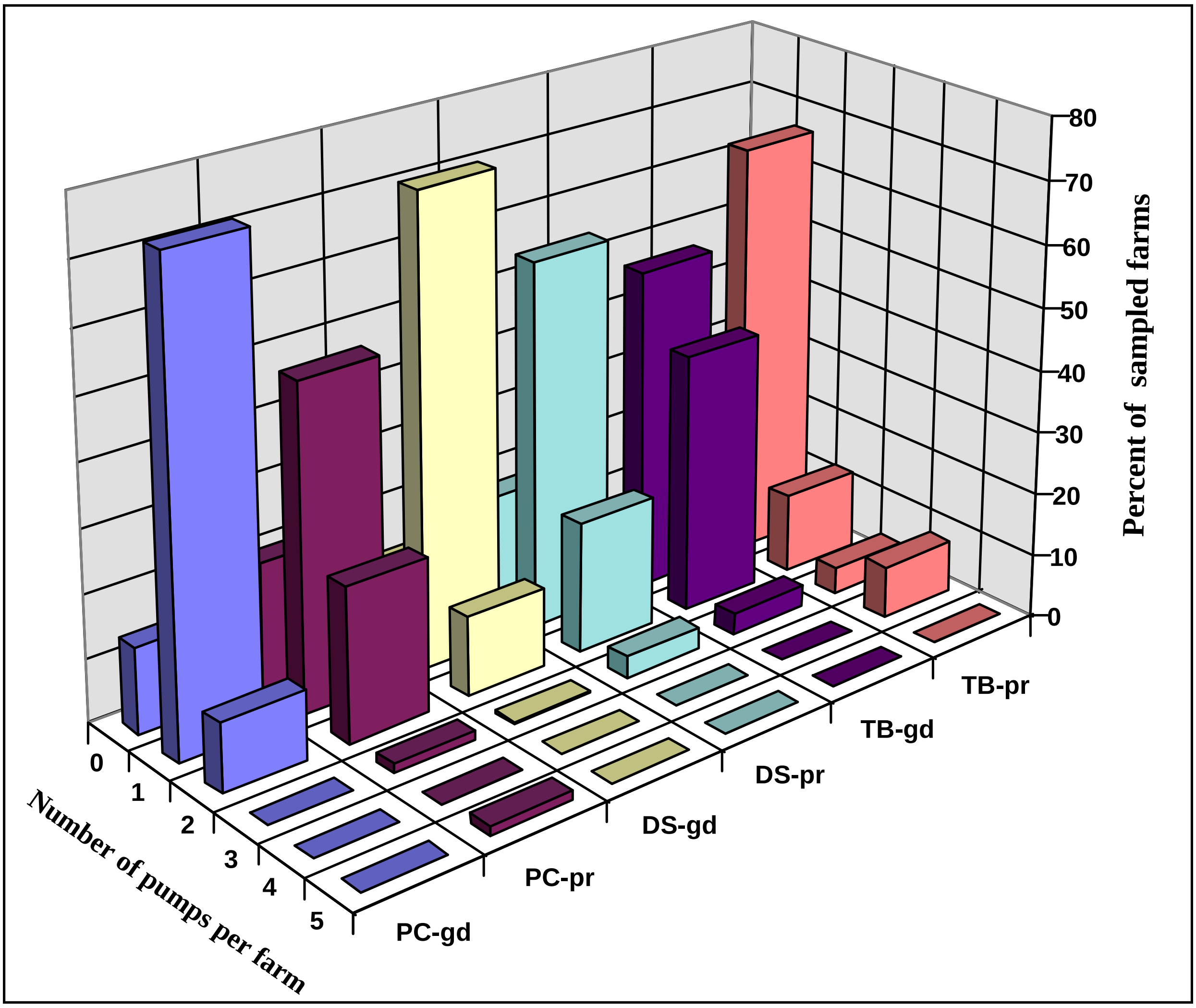

FIGURE 9. THE NUMBER OF PUMPS IN THE VARIOUS IRRIGATED REGIONS (PC - PHLAI-CHUMPHOL DS - DONG-SETTHI; TB - THA-BUA; GD - GOOD OPERATING CANALS; PR-POOR OPERATING CANALS)

4.4 Water supply from alternative sources and the linkage to the central system

Water consumption for irrigation is divided into two periods: (i) The period prior to supply via the main canal system; (ii) the period in which water is utilized simultaneously from the alternative sources and the main system.

Commonly the expenses for water supplied from the alternative sources are higher than the water delivered from the main central system. The reason is primarily the initial capital investment made by the individual farmers in equipment (well and/or pump) and the related operational expenses (fuel and regular maintenance). Since water from the main central system is supplied free of charge (the common approach in Thailand), for given options, this is the preferable alternative selected by the farmer. The use of the local waters simultaneously during the supply from the central system is usually supplementary and is linked to the performance of the canal system. It is subject to the efficiency of performance which varies in time and location.

Based on field observations, farmers' interviews and RID officers, it seems that most of the water from alternative sources is used prior to the water supply from the main central system. In order to assess the quantity consumed during the period prior to operating the main central system, an indirect estimation procedure was adapted. The assessment was based on the fact that paddy production requires water, however, if there is paddy production and no water available in the main central system, by elimination, all the water being used is from the alternative sources

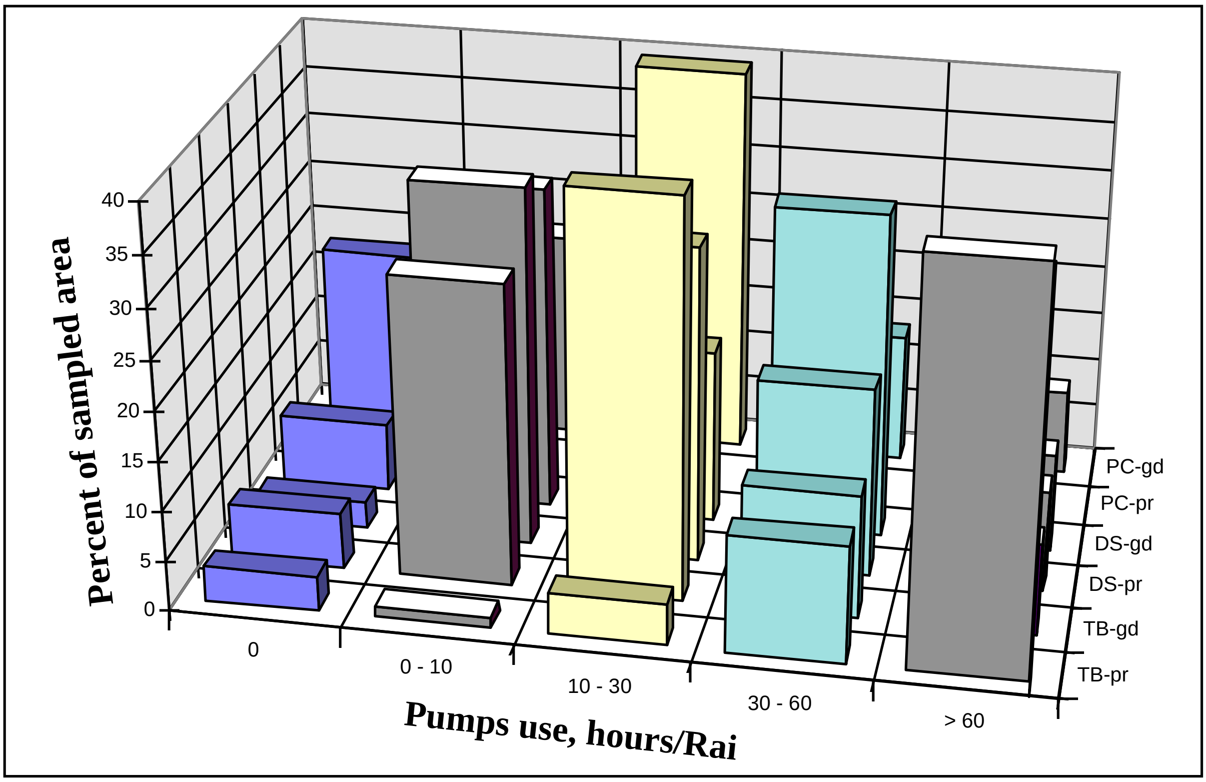

FIGURE 10. DURATION OF PUMPS OPERATION DURING DRY SEASON 1996 (HOURS PER RAI)

Information regarding the cultivated paddy acreage was obtained from RID weekly reports that include information on the crop growing stage. These reports have different versions in the various sub-systems, but all of them have the same basic information: crop varieties, acreage sowed or transplanted, areas damaged (due to floods, drought, or disease) and areas harvested. In some cases water is also supplied to regions that are not included in the PIP responsibility. The basic information of the report is filled out by the RID zonemen and is transferred to higher and more detailed service level [approximately 200 - 1000 Rai each (32 to 160 ha)]. Commonly these reports are modified at higher levels and are also utilized by the operational level of the canals, zones, sections and sub-systems. In some regions there are made additional modifications subject to municipal districts and special needs.

4.5 Crop water requirements (ET_{crop})

Crop water requirements are given by Et_{crop} mm/day (Figure 11). The ET_{crop} is defined as "the depth of water needed to meet the water loss through evapotranspiration of a disease-free crop, growing in large fields under non-restricting soil conditions including soil water and fertility and achieving full production potential under the given growing environment" (Doorenbos et al., 1984). The effect of the crop characteristics and growth stage on water requirements is given by the crop coefficient (K_c) which represents the relationship between a reference crop potential evapotranspiration (Et_o, mm/day) and crop evapotranspiration (ET_{crop}), namely (Figures 11 and 12):

$$ET_{crop} = K_c * Et_o \qquad (1)$$

4.6 Seepage and percolation (SP)

Seepage and percolation is the lateral and vertical subsurface movement of water respectively. Texture and structure of the soil profile, elevation of water table, soil permeability, depth of impervious layer, and topography generally determine these natural phenomena. It might as well be influenced by the roots pattern.

Soils suitable for paddy are estimated to have a seepage and percolation rate of 1 to 4 mm/day, depending on the soil characteristics. Kerdsakul (1996) conducted experiments for deep percolation at the Tha-Bua Irrigation Project and found that the average percolation rate was 1.4 mm/day during the wet season 1995 (2538). For this presentation we have used the value of 1 mm/day.

4.7 Water requirements for land preparation (LP)

One of the basic agricultural activity in the paddy fields is the land preparation. The land is first soaked, sloughed and then puddled and leveled in muddy conditions. The three components of the total water requirement for land preparation are:

1) Water used for land soaking.
2) water losses through seepage and percolation.
3) water losses by evaporation.

Common design of irrigation systems in Thailand assumes that an amount of 200 - 300 mm is applied over a one month period is required for land preparation. Songiripon (1990) related study focused in the land preparation requirements for Dong-Setthi, region found that mean requirement was around 270 mm for the dry season. It was found in the PIP survey (Rieser et al., 1997) that land preparation lasts for 2 weeks before sowing. In this study the value of 200 mm two weeks prior to sowing.

4.8 Seasonal field water requirements (ET_{field})

Total water consumption is based on all plants needs and all auxiliary losses. The ET_{field} (mm/season) is defined as the depth of water needed to meet the water loss of the crop during the season for a specific area and definite crop pattern:

$$ET_{field} = \sum^{days} (ET_{crop} + SP) + LP \qquad (2)$$

where, Et_{crop} - Crop water requirements, mm/day.
SP - Seepage/percolation losses, mm/day.
LP - Land preparation requirements, mm/season.
Days - total duration of irrigation season, days.

By multiplying the value of ET_{field} with the cropping field acreage total required water quantity can be assessed.

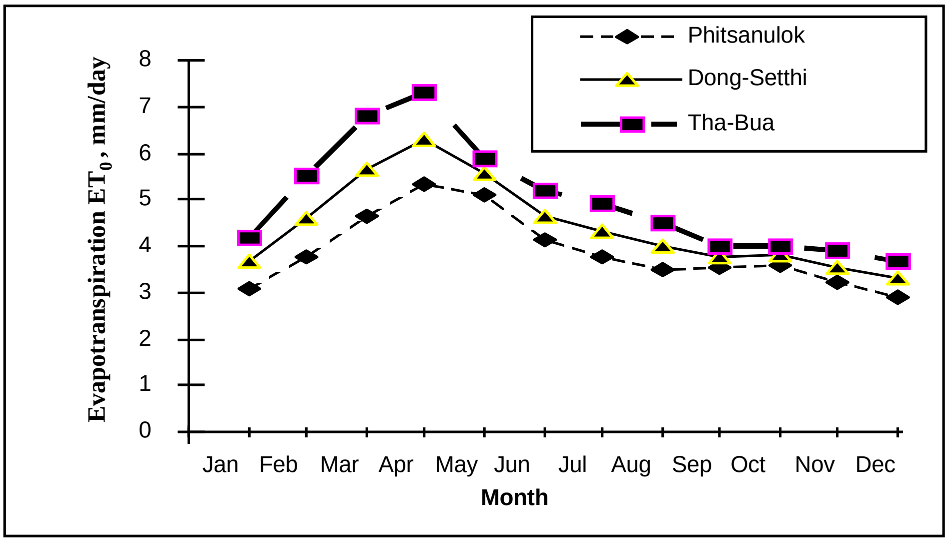

FIGURE 11. MONTHLY MEAN POTENTIAL EVAPOTRANSPIRATION, ET_o

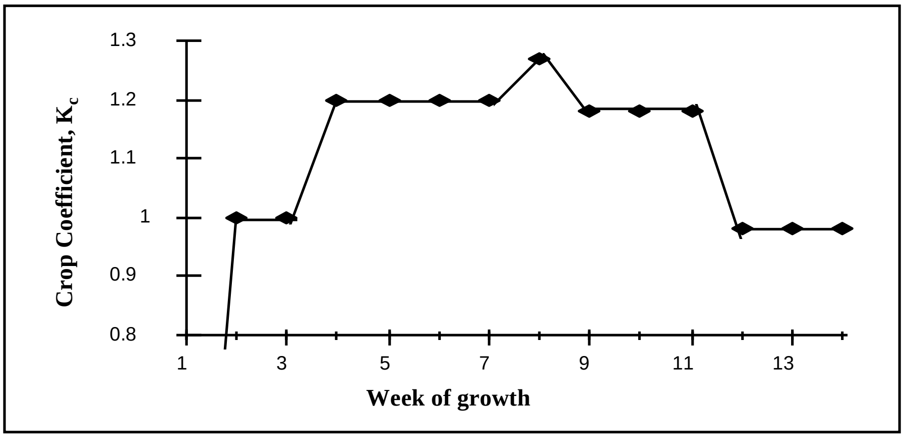

FIGURE 12. CROP COEFFICIENT FOR HIGH YIELD VARIETIES OF PADDY

4.9 Assessment of water supply and use

The crop pattern, the various growth parameters were assessed, subject to the approach that complementary information for water use can be obtained indirectly from the water consumption and acreage. This information was combined with the water requirements.

Monthly mean values for ET_o for PC sub-system were obtained from the Phitsanulok meteorology station. Data for ET_o for Tha-Bua was obtained from the Nakhon Sawan meteorology station and mean values were assumed for Dong-Setthi sub-project. Values for the crop coefficients K_C for different growth stages of high yielding varieties of paddy were obtained from the RID office in Dong-Setthi.

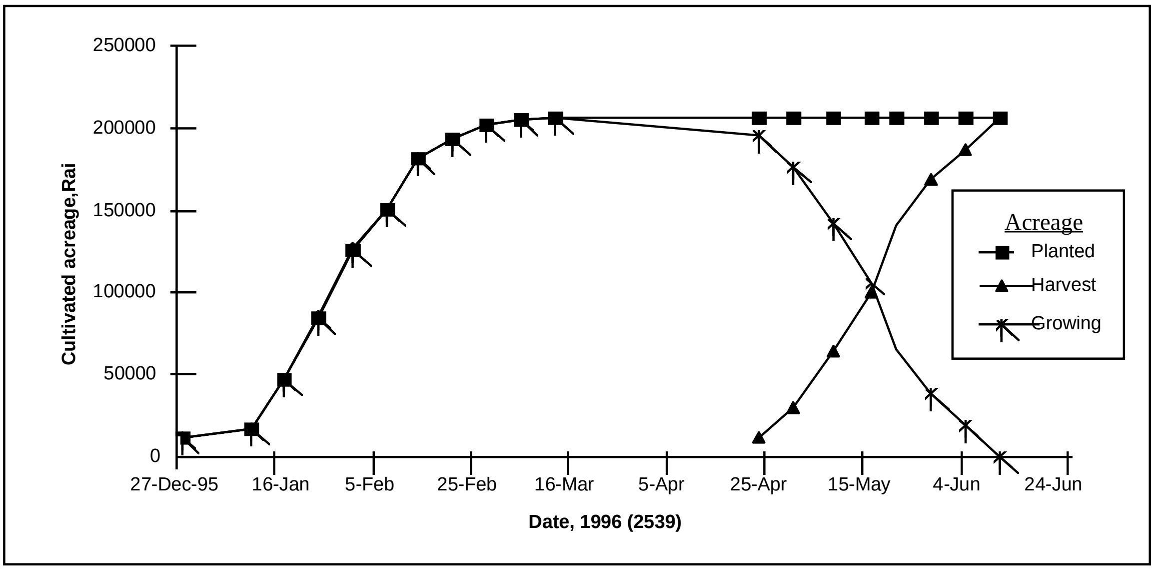

FIGURE 13. SEASONAL CROP ACREAGE VARIATION IN PHLAI-CHUMPHOL DURING 1996 (2539) DRY SEASON

Actual cropping area was obtained from the “Planted Area Progress Report” which is a standard weekly RID report (e.g. RID form code O&M 1-44) and from similar lower level more reports (Figure 13). The data (Figure 13) refers to the Phlai-Chumpol sub-project, for the dry season of 1996 (2539). Since this data is for the dry season there was no flood problem. The data for the acreage of the “land preparation” stage is very similar to the “planted area” acreage stage. It can be explained by recording the end of the field preparation season that is similar to the sowing timing. For this reason instead of using this value it was assumed that the field preparation stage begins two weeks before sowing (Rieser et al., 1997)

The accumulative active cultivated area value is a calculated variable which is given by :

$$A_g = A_p - A_h - A_f \qquad (3)$$

where, A_g - total cultivated acreage, Rai
A_p - planted acreage, Rai
A_h - harvested acreage, Rai
A_f - flooded acreage, Rai

The water delivery from the central canal system during 1997 season was initiated towards the beginning of February. Until then local well water was applied for land preparation and irrigation.

One of the limitation of the presented approximate method is that it does not specify the water source. An additional difficulty is that the quality and accuracy of the data. In some areas monitoring is conducted primarily according to the planned RID cropping schedule. Under these circumstances there is only information regarding the system situation at the beginning of the growing season. In some regions the planted area can be estimated from the harvested acreage. In others the harvested data as well was not complete and then the assessment is based on the existing partial information thus under estimating the use of on farm local waters

An imprecise link in assessing the contribution of the local wells is the water which is utilized in the agricultural plots that by the rotation schedule are not planned to receive water from the main canal system. Hypothetically, it could be claimed that if farmers do not receive water from the canal system - hence, by elimination, use alternative water sources. In practice the picture is different. Field observations show that even during this period, large quantities of water are delivered for irrigation from the main canal system. The farmers from canals close to their plots pump part of the water frequently and intentionally. Complementary amounts of water are supplied via the main canal system in response to strict requests from the farmers. In the future it will be reasonable to develop and adopt a monitoring scheme for assessing the water consumed from the alternative sources primarily in these not planned for irrigation.

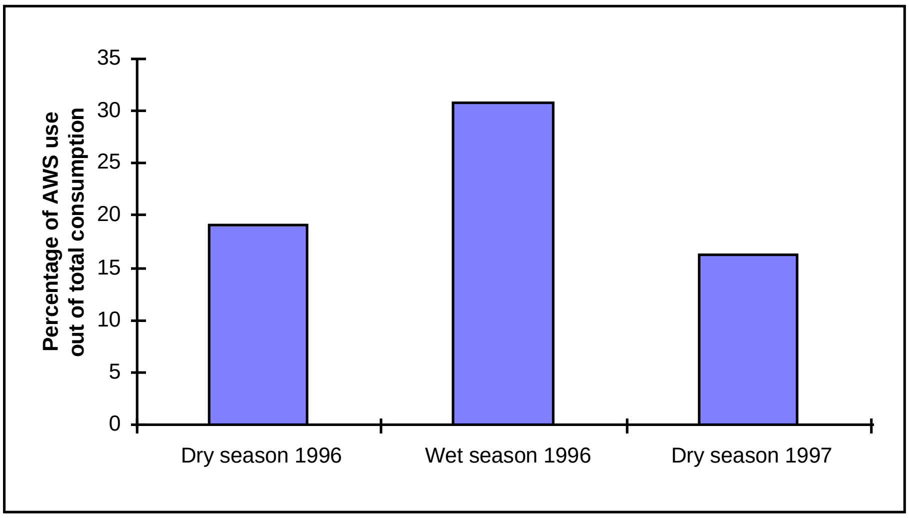

FIGURE 14. PERCENTAGE OF ON FARM LOCAL WATER SOURCES USE OUT OF TOTAL CROP WATER REQUIREMENTS IN THE PIP DURING DRY SEASON 1996, WET SEASON 1996 & DRY SEASON 1997

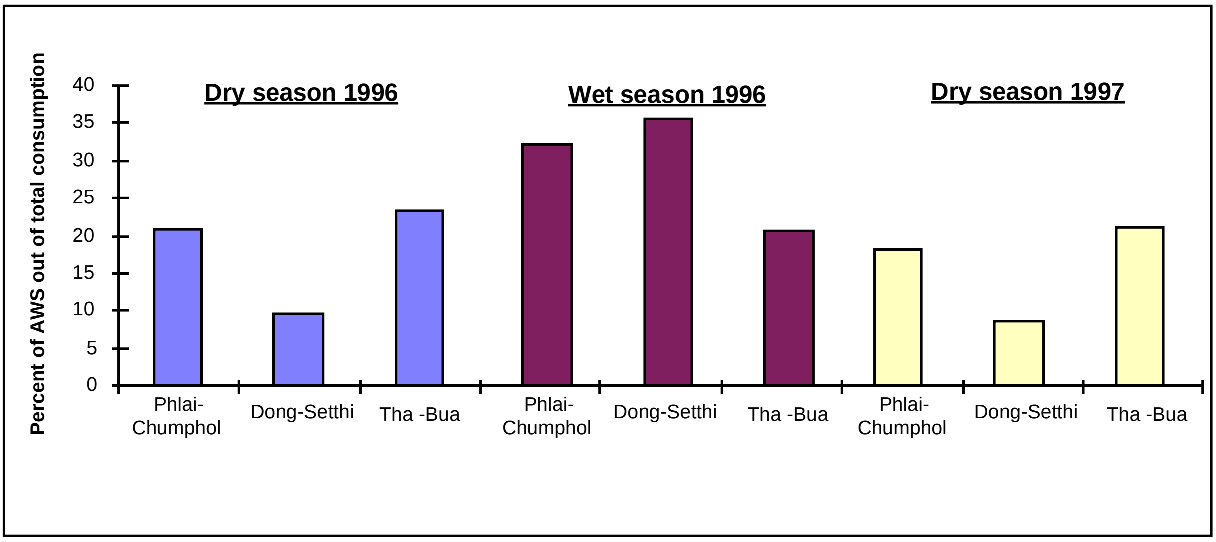

FIGURE 15. PERCENTAGE OF ON FARM LOCAL WATER SOURCES USE OUT OF TOTAL CROP WATER REQUIREMENTS IN THE 3 SUB-SYSTEMS DURING DRY SEASON 1996, WET SEASON 1996 & DRY SEASON 1997

The percentage of water used from alternative sources relative to the total crop water requirement is presented in Figures 14 and 15. As there is no distinction of the on farm local water sources it is reasonable to assume that in the wet season there is a higher dependence on natural precipitation.

Since the assessment method is based on data that is collected commonly by the RID staff, it can be implemented to evaluate water use during preceding irrigation seasons. If necessary, it is relatively simple and inexpensive to implement this approach also on a broader scale in the future.

5 Discussion

Information regarding the number of wells on the farms and their operational routines as a complementary quotas supplied from the main canal system were examined in PIP. It included surveying the number of wells and pumps per farm and per Rai and the operational regime. The survey took into account the irrigation season, the reliability of water supply from the main canal system and practice of irrigation in the region. According to the results large sectors of the farmers in the entire PIP own pumps and wells. These are operated primarily under stress conditions, namely when there is a relatively high probability of insufficient water supply from the main canal system.

The method developed for assessing the alternative water sources use can be implemented in most cases beginning at the service unit level up to the project level. Estimating the use of water from alternative sources after the main system is activated is problematic, but in the irrigated areas seems to be relatively negligible and therefore less significant. The question of water use in areas that are not planned for irrigation during the dry season remains pending.

Mobile pumps are put into use when the water supply system is inadequately operated. It includes water pumping from main canals when the water level restricts gravity flow to the branched canals. The pumps are also used to pump water from local small storage facilities, primarily on the farm. Pumps are also put into use for drainage purposes. Drainage is maintained directly after germination, prior to harvesting and to dispose water during flood events.

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