DORAS - DELTA : research report n°5

Improvement of rice cultivation and water management in the flooded area of the Central Plain of Thailand

A zoning of rice systems by using remote sensing imagery

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DORAS CENTER

Kasetsart University **ORSTOM**

with the collaboration of

the Royal Irrigation Department and the Office for Agricultural Economics

Report presented to the National Research Council of Thailand

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François Molle (DORAS Centre - ORSTOM)

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Chatchom Chompadist (Royal Irrigation Department - DORAS Centre)

Alexandre Joannon (DORAS Centre - ORSTOM)

Yuphaa Limsawad (Office of Agricultural Economics)

Advisers to the project : Apichaart Pongsrihadulchai & Supan Karnchanasutham

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Please direct inquiries and comments to :

DORAS Center
Kasetsart University
Administrative building, 10th floor
Bangkhen, 10900 Bangkok
Thailand
odoras@ku.ac.th

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Executive Summary

The natural hydrologic conditions of the Chao Phraya delta have been deeply modified all along this century. With the implementation of the different phases of the Greater Chao Phraya Project, together with the construction of two main dams in the upper Chao Phraya basin (Bhumipol dam in 1968 and Sirikit dam in 1976), modern irrigation developed, allowing the adoption and expansion of High Yield Varieties (HYVs) in most of the area. The Improvement of drainage was gradually given priority only from the late sixties onward.

However, many low lying, ill-drained or flooded areas in the Central Plain are still planted with traditional rice varieties (TV), including both deep water rice - DWR - (suitable for water depths between 50 and 100 cm) and floating rice – FR - (adapted to water depths between 100 and 350 cm and provided with rapid elongation ability). The area cropped with Traditional Varieties (TV) corresponds to almost 400,000 ha (2,500,000 rai), more than half of it located in the Chao Phraya/Lop Buri flood plain where it makes up a total gross area of 300,000 ha (2 million *rai*).

Nowadays, however, "flooding" must not be thought of according to the old idea of river overflow but, rather, as a situation in which the main rivers - channelled between lateral dikes - show (or at least may show) high levels which impede full drainage of inner lands. These areas are protected from the rivers by dikes but, on the other hand, cannot evacuate the water coming from different sources and accumulating inside. Therefore, the solution chosen to stabilise rice cultivation in these flood-prone areas consists in *regulating* the rise of water in terms of increase rate, maximum level and flood duration.

Oddly enough, while there are numerous and sometimes redundant studies about irrigation and water distribution in the Chao Phraya delta, there is almost no information available on drainage regulation and flood-prone rice systems. This report presents an in-depth analysis of rice cultivation – its characteristics and trends -, and of water management in these areas. It combines information originating from field surveys (near 900 observation points, a third of them including a detailed questionnaire), satellite images, GIS, DEM (digital elevation model) and hydrological data from RID.

Drainage boxes

A description of the functioning of drainage units (“boxes”) in terms of water management is followed by a detailed inventory of all main and sub-boxes, with their respective regulators and topographical characteristics. The boxes generally include HYV on the high lands, deep-water rice in middle elevations and floating rice in the lower parts. They are bordered by dikes or irrigation canals and their drainage to the river system is controlled by regulators. The total flood plain is comprised of 18 main boxes, making up a total of 120 sub-boxes.

Water management in the boxes follows four different phases. (1) First is the crop establishment phase (rice is sown with dry-broadcasting), during which the box outlet regulator is closed to store water in the drain for dry-season cropping but no water accumulates in the fields. (2) During the box filling up phase, the regulator is normally closed to allow the accumulation of water and the steady rise of the water level; (3) when the regulation level is attained, the regulator is operated to evacuate possible excess flows; (4) when the rice is almost ripe, the box is fully drained and the rice harvested, starting with the high lands.

It is shown how diverse water inflows (rainfall, inner runoff, return flow from irrigation, inflows from rivers and, sometimes, sideflows) combine to define, together with the box topographical characteristics and the regulation water depth, the hydrological behaviour of each box, in particular their sensitivity to dry or wet years.

The Digital Elevation Models has allowed the accurate determination of the storage capacity of each box and of the whole upper-delta.

Rice systems

Valuable information has been obtained through the survey of approximately 300,000 ha cropped with deep water and floating rice, totalling close to 900 observation points. The main features of these rice systems can be summarised as follows :

- rather good control and risk reduction provided by land development and water control devices;
- a productivity approximately 60 % of HYVs' productivity;
- the substitution of natural fertilisation with chemical fertiliser; 72 % of the plots cropped with traditional varieties receive fertiliser (an average of 32 kg/rai, when they do);
- the common absence of on-farm structures and/or a location far from irrigation canals;
- a low or irregular frequency of double cropping, partly due to the above factors; <u>but</u> a trend towards increasing this frequency, with significant investments in plot improvement. This trend has been boosted by the high water allocation experienced in the last 3 years.
- a trend towards mechanisation of harvest, with 72 % of plots using mechanical harvesters;
- a reduction of the diversity of rice varieties used in the area; six main varieties make up 58 % of the TVs and, together with the next 17 main varieties, 82 % of the whole.
- 60 varieties were reported in use at present, while 80 were mentioned by farmers when asked about cultivated in the past; Out of these, 43 disappeared (were not found in the survey).
- A low level of occurrence of recommended varieties

The main yield-limiting factor is probably the risk which prevails at the time of crop establishment under rainfed conditions. Little can be done to circumvent hazards derived from irregular rainfall, apart from expanding irrigation facilities.

Regarding cropping techniques, the survey demonstrated that there is no simple correspondence between the use of TVs and crop establishment through dry broadcasting. *DWR, and sometimes even FR, are established with both dry broadcasting and wet broadcasting*. The latter case is found in areas with a proper irrigation system but insufficient drainage (the risk of flooding is dealt with by using TVs) and when the plot is also used for dry-season cropping (growing HYV with wet broadcasting).

The disappearance of transplanting, in full realisation in the 80's and completed in the early 90's, is also an important point : it significantly eased water management and removed a major bottleneck in terms of labour and farm activity planning. The last bottleneck, harvesting, is now dealt with through mechanisation.

Water and flood management

The area cropped with Traditional Varieties has decreased and is now confined to a "flood-prone" area in which the water regime is largely controlled by means of dikes and regulators. Along the Chao Phraya river, for example, most of the floodways have been closed during the 70's. After the floods of 1975, the embankments have been raised 50 cm of the flood level.

Given that - except in dramatic years such as 1995 - the water level in the drainage boxes is controlled and artificially regulated, it is meaningless to speak of and derive statistics on "*flood depth*" : rather, attention must be focused on the spatial distribution of the drainage units ("boxes") and on the parameters of drainage regulation in each box : rate of filling up, optimal regulation level, date of gate opening, rate of box drainage, etc.

The boxes constitute off-channel reservoirs but are not 'conservation areas', like in the lower delta, because they don't store water to be later used locally. Rather, they are buffer areas, allowing the storage of excess water in the rainy season. *However, it is important to understand that their main purpose is to provide adequate flooded conditions for the growth of TVs in areas where (a) the plot conditions and/or (b) the conditions of access to water and/or (c) the risk of submergence as governed by the drainage conditions, do not allow the cultivation of HYVs. This suits the need for flood relief but it must be stressed that in most years, under the prevailing water regime, such buffer function is not fully needed.*

A few important findings are noteworthy :

1. During the month of October the water stock rises gradually from 40 to 100 % of the full storage capacity. When the drainage boxes attain their full storage capacity, sometimes around the 1st of November, *2 billion m^3 of water are stored*. The buffer capacity of the area - its normal capacity to act as a flood relief area - decreases accordingly.

2. This stock in an average year is estimated to be more than twice the quantity of water stored in the lower delta in a year with an overall 50 cm flood in the upper half of the West Bank. In a year with no particular excess water (like in 1998), the West Bank stores an equivalent of only 5 % of the volume stored in the upper delta, mainly in its canal system.

3. *The margin of box overloading is extremely significant* and corresponds to an increase of 50 % in the storage capacity for an overall 25 cm hike in the water levels. The mapping of the box status at a given instant may show where and how much additional storage capacity is available. Overloading can be achieved by several waterways depending on the box (drainage regulators, irrigation canals, wasteways, sideflows, etc) and the height of the dike.

4. A *monitoring "dashboard" is proposed*, in order to monitor the status of the boxes and orient decision-making in case of drastic flood. It allows to pinpoint which boxes still have storage capacity and which are overloaded (and with how much water). Its establishment would require to add a few observation points of the water level in some boxes which are not monitored.

5. *It does not appear* than any limited reduction in the storage capacity would significantly jeopardise the flood relief function of the area, especially from the 1st of November onward.

6. Water control in the boxes appears satisfactory, as intermediate regulators now also provides increased local control. However, in dry years, some boxes face difficulties in the filling up phase and the upper lands may lack of water.

7. The coordination of drainage within a "cascade box" pose some problems : the decision-making process on the date of gate opening (the date must be adjusted each year to some particular cases), and the congruence between water management and the choice of rice varieties are the object of discussions, and sometimes conflicts, almost every year in most of the boxes.

   This points should be investigated by agronomists. It is also hypothesised that the importance of knowing the rice characteristics (cycle, height, elongation ability, etc) before adopting them in a given box could be one of the factors explaining the low level of adoption of recommended varieties in the area.

8. There is a strong and quantitative evidence of the marginal re-use of the water drained out of the drainage boxes for DS cropping in the lower delta. This is due to the fact that the boxes drainage occurs in a period in which the water demand from the conservation area is still low. At least 85 % of the water is lost to the sea. *This dismisses any possible fears that a reduction in the storage volume would impact negatively on dry-season cropping in the lower delta*.

9. The drainage of the boxes generates an inflow to the Chao Phraya reaching a maximum discharge of 700 cms, in the second half of December.

Perspective of change and intensification

Several evolutions have been observed and can be extrapolated for the future. The main driving force is probably the low profitability of TV rice farming. In the long term, farmers are compelled to find some way either to intensify or to diversify rice farming, or to give up agriculture. The reports provides current examples of these trends, identifies their advantages, limits and constraints.

1. The first evolution is possible in areas where the water regime can be altered in order to accommodate HYVs instead of TVs. This has been possible in areas like Borommathad Project and *amphoe* Tha Wung and can be expanded to boxes like Lam Chuad or Don Tum box, or achieved on the higher land of the boxes by moderately lowering the water level in some boxes.

   The transition area on the eastern side, formerly using transplanting, still harbours a lot of DWR although it is little or not prone to submergence risk and has irrigation facilities; it remains one of the rare cases of TVs grown under irrigated conditions in Asia *and an in-depth investigation should be carried out in this area* to assess to what extend this situation could be remedied.

2. The second path is to increase the cropping area in the dry season : a first solution would be to tap water from the Mekong or Salaween rivers in order to increase the water available in the dams. Improvements may also come 1) from improved water scheduling and distribution ; 2) secondary water sources, namely tube wells, remaining water in drains, reservoirs excavated in low lying spots. Even under the current limitations*, it is advisable to achieve more equity and not systematically disregard these areas cropped with traditional varieties*. Most of them are now in a condition to grow dry-season rice and the sustainability of farming strongly depends upon the frequency of dry-season cropping.

3. The third path is to abandon wet-season rice cropping and start, as early as possible, a DS crop at the end of the rainy season. Depending on water sources available locally, two rice crops can sometimes be accommodated in the dry season. If the whole box follows such a path, then there is no more scope for storing and releasing water according to the former pattern : the receding of the flood must be let to natural conditions, allowing in most years a much earlier DS cropping. There is scope to allow Phak Hai project to follow the transformation initiated by the West bank 20 years ago.

4. The last evolution path observed is the abandonment of rice farming and/or agriculture. This move has been observed most especially in areas where agro-ecological conditions did not allow any of the above changes and where the proximity of main roads, industrial zones or main cities (Ayutthaya, Bangkok) have both generated other labour opportunities and provoked a high level of land ownership transfer to speculators and urban-based buyers.

It appears as a main evidence that an increasing differentiation of farming systems *has occurred in the area* during the last ten years, while sub-regions were preferentially evolving towards one or some of the above paths. In addition, in the last three years several factors contributed to sharpening the situation : TVs rice cropping suffered high levels of crop failure in 1995/96 and 1996/97 because of flooding and also in 1997/98 because of hectic rainfall during the crop establishment phase. This situation prompted RID to deliver exceptionally high supplies of water during the following dry-season (provided as a compensation). In addition, this happened to be concomitant with a surge in rice prices and triggered a crave for dry-season cropping, paving the way for a record area of 100,000 rai of triple-cropping in 1998.

These conditions - good water and price - provided farmers in the study area the incentive that was missing to engage in land development and embrace DS cropping, many of them for the first time. The responsiveness of TVs growers can be considered relatively high if one remembers that no assurance was given on whether such supplies could be renewed in the future.

The dry season cropping boom provided an incentive for land development, which, in turn, is making the possibility to shift from TVs to HYV in the rainy season more attractive, by removing one of the main constraints. More generally, WS and DS rice cropping appeared significantly interlinked, not only in terms of calendar or techniques (DS cropping implies the use of wet broadcasting in the rainy season, even for floating rice), but also in the long term farmers' strategy.

Another highly significant event of the last ten years was the economic crisis in 1997, which put a brutal end to land buying and to speculation, slowing the worrisome trend of agriculture disappearance and injecting increased labour in the agricultural sector.

The future of the flood prone area of the Chao Phraya area is likely to be governed by a few factors : crucial will be the rate of double-cropping which will be allowed by the available water (possible tapping of additional resources, better management of the existent ones, "reduction" of the flooded area in some boxes, improved cropping techniques, etc). National policies and the economic environment will also contribute to set key parameters : price of rice, daily wage differential between urban and rural areas, labour opportunities in other sectors, land market, etc.

Sarup samrap phuborihan

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Abbreviations used

TV	Traditional varieties (include DWR and FR)
FR	Floating rice (may elongate with the rise of water, suitable for depth from 1.00 to 3.00 m)
DWR	deep water rice (suitable for depth from 0.40 to 1.00 m)
DS	dry season
WS	wet season
DB	dry broadcasting
HYV	High Yield Varieties
DEM	digital elevation model
RID	Royal Irrigation Department

khaw / khao = white / rice (for the transcription of the name of rice varieties)

luang / leuang = royal / yellow (for the transcription of the name of rice varieties)

Units used

rai	1 ha = 6.25 *rai*
thang	1 thang = 10 kg (for paddy rice in the Central Region)
baht	1 US $ = 37 baht (average for 1998)

General background and objectives

Rice cropping in the Central Plain is an activity almost inseparable from historical human settlements. When Thai people settled in the Chao Phraya delta, they first tried to attune rice cultivation to the natural water regime. They cleared the most favourable areas of the flood plain, which roughly extends in a polygon which would nowadays be delimited by Ayutthaya, Lop Buri, Sing Buri and Suphan Buri. These areas were favoured with the annual flood of the Chao Phraya, bringing its fertilising sediments to the rice fields.

At the end of last century, some "artificialisation" of the delta was initiated, including canal digging, diking, the construction of regulators, etc. With the implementation of the different phases of the Greater Chao Phraya Project, together with the construction of two main dams in the upper Chao Phraya basin (Bhumipol dam in 1968 and Sirikit dam in 1976), the water regime was deeply modified and irrigation was developed, allowing the adoption and expansion of High Yield Varieties (HYVs) in most of the area. The Improvement of drainage was given priority only in the late sixties, with the progressive construction of main and lateral drains. Many of them were only excavated up to half their design capacity in order to achieve some effect over a relatively large area in a relatively short time, and were gradually further enlarged in the late seventies and eighties (ILACO, 1980)[1].

However, many low lying, ill-drained or flooded areas in the Central Plain are still planted with traditional rice varieties (TV), including both deep water rice - DWR - (suitable for water depths between 50 and 100 cm) and floating rice – FR - (adapted to water depths between 100 and 350 cm and provided with rapid elongation ability). The use of such varieties is a consequence of the water regime, both average and possible (risk) : these areas are either deeply flooded (generally for a quite long duration), or slightly flooded but with some risk of sudden short water fluctuation. Fig. 1 shows the extension of TVs in the Central plain of Thailand, as estimated by an identification study by Kasetsart University and ORSTOM (1996).

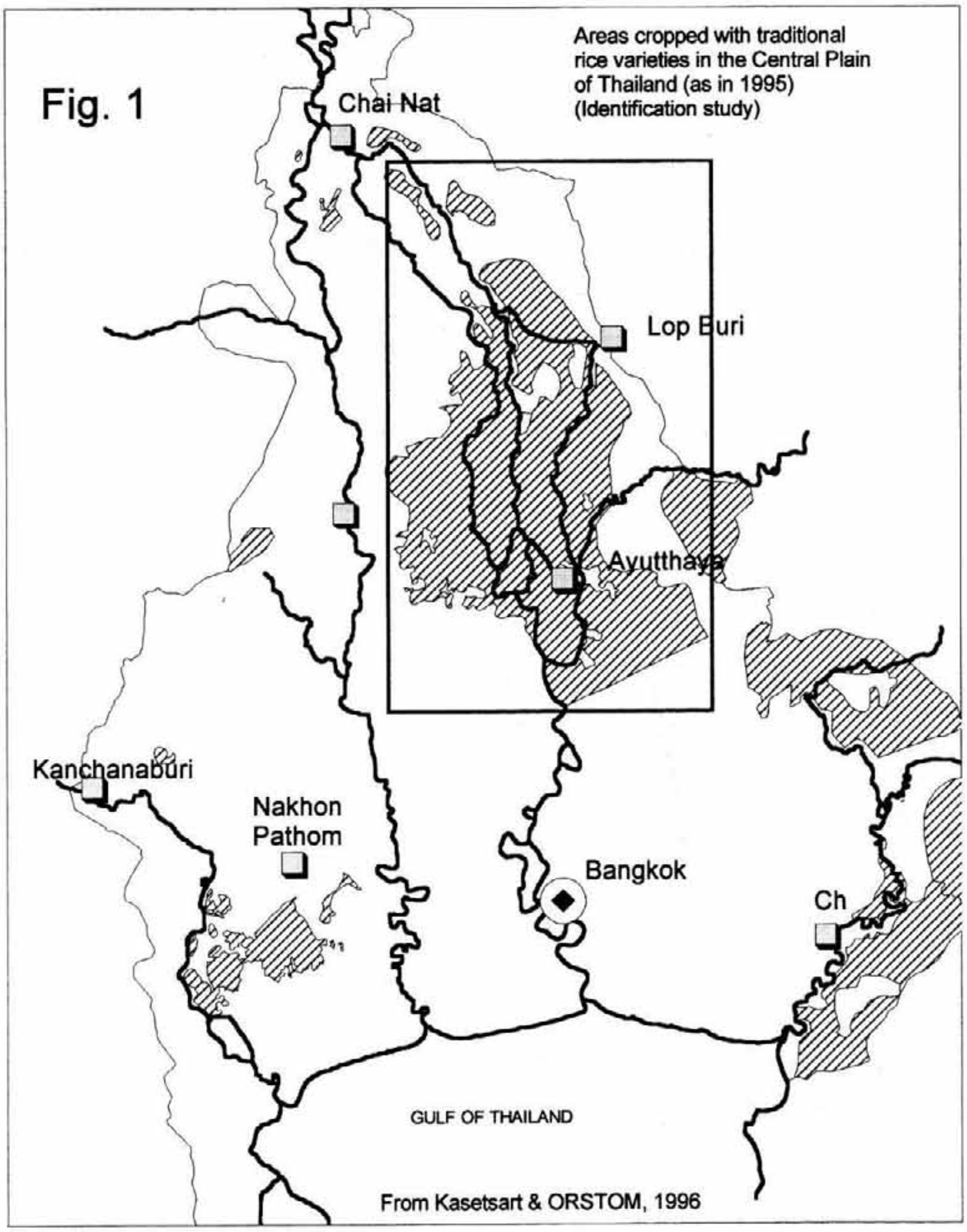
The area cropped with Traditional Varieties (TV) corresponds to almost 400,000 ha (2,500,000 rai), half of it located in the Chao Phraya/Lop Buri flood plain (Fig. 1).

This area is often called "flooded area", or "flood-prone area" or "deep water area". In the past, flooding occurred due to the spill of rivers over their embankments and to the backlash effect from high water levels in the main rivers on the drainage system. This pattern was deeply altered by the implementation of the Chao Phraya Project in the 50's and 60's but was still partly prevailing in the 70's, as described, for example, by Takaya (1989).

Nowadays, "flooding" must not be thought of according to the old idea of river overflow but, rather, as a situation in which the main rivers - channelled between

[1] The first phase (1965-1971) comprised the construction of several drains and lateral drains in the northern Chao Phraya area ; the second phase (1972-1985), considered the completion of the system by the construction of the remaining drains (and the widening of the former ones).

lateral dikes - show (or at least may show) high levels which impede full drainage of inner lands. These areas are protected from the rivers by dikes but, on the other hand, cannot evacuate the water coming from different sources (rainfall, inner runoff, return flow from irrigation and, sometimes, sideflows). Therefore, the solution chosen to stabilise rice cultivation in these flood-prone areas consists in regulating the rise of water in terms of increase rate, maximum level and flood duration.



The traditional varieties (TV) planted in these areas therefore undergo flooded conditions which impede the adoption of High Yield Varieties (HYV).

Oddly enough, while there are numerous and sometimes redundant studies about irrigation and water distribution in the Chao Phraya delta, there is almost no information available on drainage regulation and flood-prone rice systems. Former recent surveys on deep water rice cultivation include (Puckridge et al. 1989) and (Charoendham et al. 1993) but they focus on cultivation techniques rather than on water management, with no hint on the logic of the spatial distribution of these rice systems. Former inquiries on drainage improvement were also carried out by ILACO in 1980, with no further detailed work taking into account the evolutions occurred in the last 20 years.

The objectives of the study are as follow :

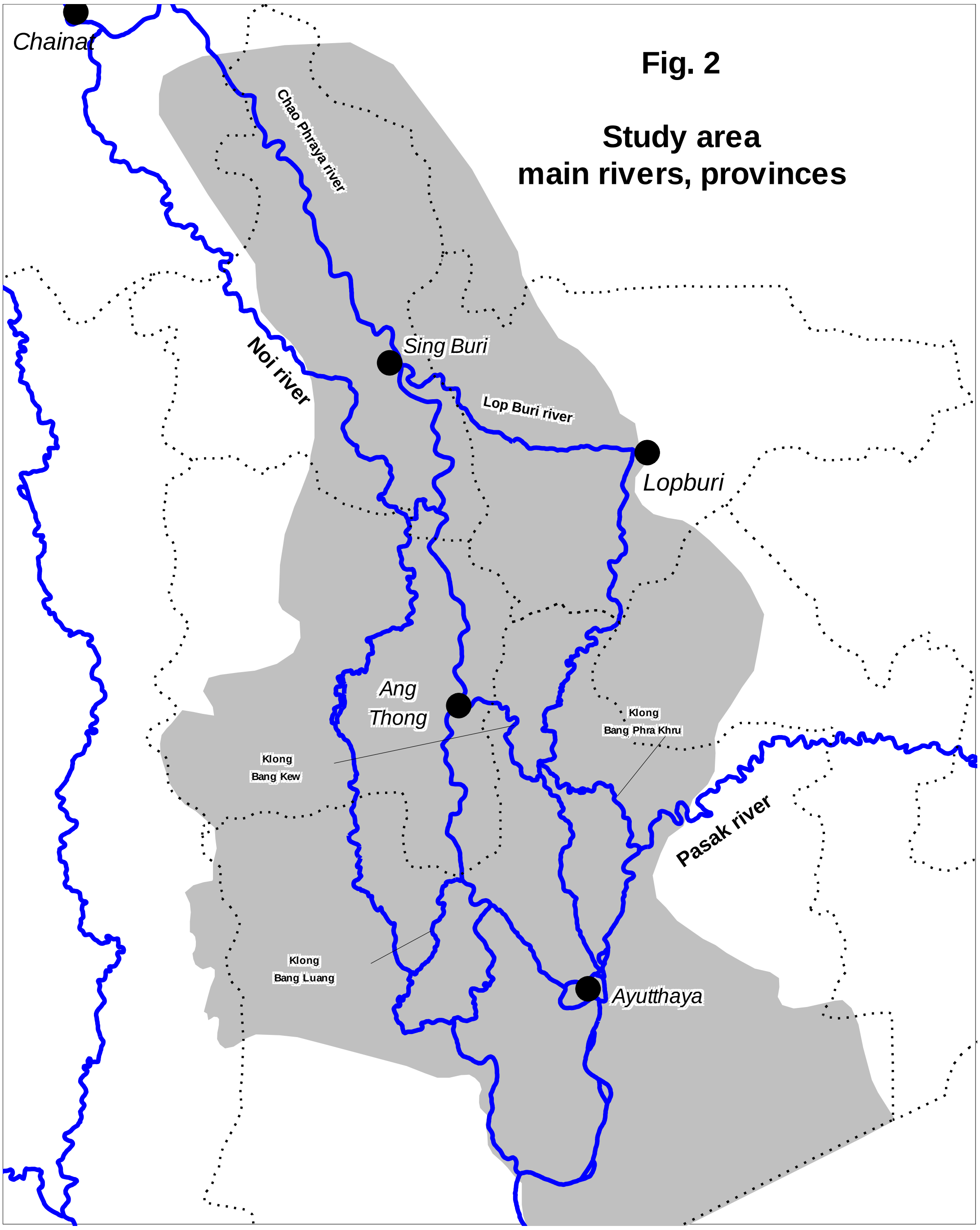
- Describe and typify TV rice cropping systems (varieties, fertilisation, calendar, yield, etc)
- Identify drainage units (boxes) and specify their features (topography, hydrology) and patterns of water management;
- Identify current trends and transformations in the TV rice systems;
- Indicate alternatives allowing some degree of intensification of rice systems and/or improvements in water management;
- Specify the relationships between water management in these areas and flood management : indicate the feasibility of using drainage "boxes" as storage units (possibly allowing overload) in case of excess flow, without harming rice production.

All these questions have been answered based on the following information :

1. Satellite images (TM) showing in particular the progress of rice harvesting (25/Oct, 10/Nov, 26/Nov; 12/Dec; 28 Dec 1994 ; 13/Jan 1995 ; 12 Jan 1994). This series has been chosen as being the sole and exceptional series of pictures with almost no clouds and providing images of the delta every two weeks during most of the harvesting period.
2. Digital Elevation Model (DEM) of the area (allowing to check the consistency of harvesting progress and Deep water/Floating rice zonings)
3. A survey at farm level totalling 850 observations points : about 30 % of these points correspond to interviews with a complete questionnaire, while the remaining correspond to "short" questionnaires (basic information about varieties, yield, etc).
4. The collection and analysis of series of water levels in the main drainage units and rivers.
5. Numerous discussions with RID officers from the concerned sub-projects

All these data have been integrated within the GIS of the DORAS-DELTA project.

The study area is comprised of the low lands located along the Noi, Chao Phraya and Lop Buri rivers (Fig. 2) which make up the flood plain, as typified by Takaya (1989). It encompasses parts of the *changwat* of Ayutthaya, Ang Thong, Sing Buri and Lop Buri, and smaller chunks of Saraburi and Chai Nat. A map given in the annexe shows how the study area overlaps with the RID Projects.



1. Identification and description of drainage units

1.1 General description of a drainage unit ("box")

1.1.1 Drainage "boxes"

Although classified as a gravity irrigation area, the study area mostly relies on flood and **drainage regulation**. If spill over embankments does happen in exceptional years (in 1995, for example, over two hundreds points of overflow have been reported), most of the time "flooding" does not originate from river spill, as one commonly believes. Flooding is basically regulated (and partly created) by a combination of dikes and regulators located in the main drains. The most important ones control outflows to the main rivers. Some of these regulators are very old, some have just been implemented.

A drainage unit can be described as a "box" with different components (see Fig. 3) :

- a surrounding dike on part of its boundary
- a drainage network collecting inside run-off and flowing into a major stream
- a regulator (or several) located in the dike and controlling the flow between the box drainage network and the river

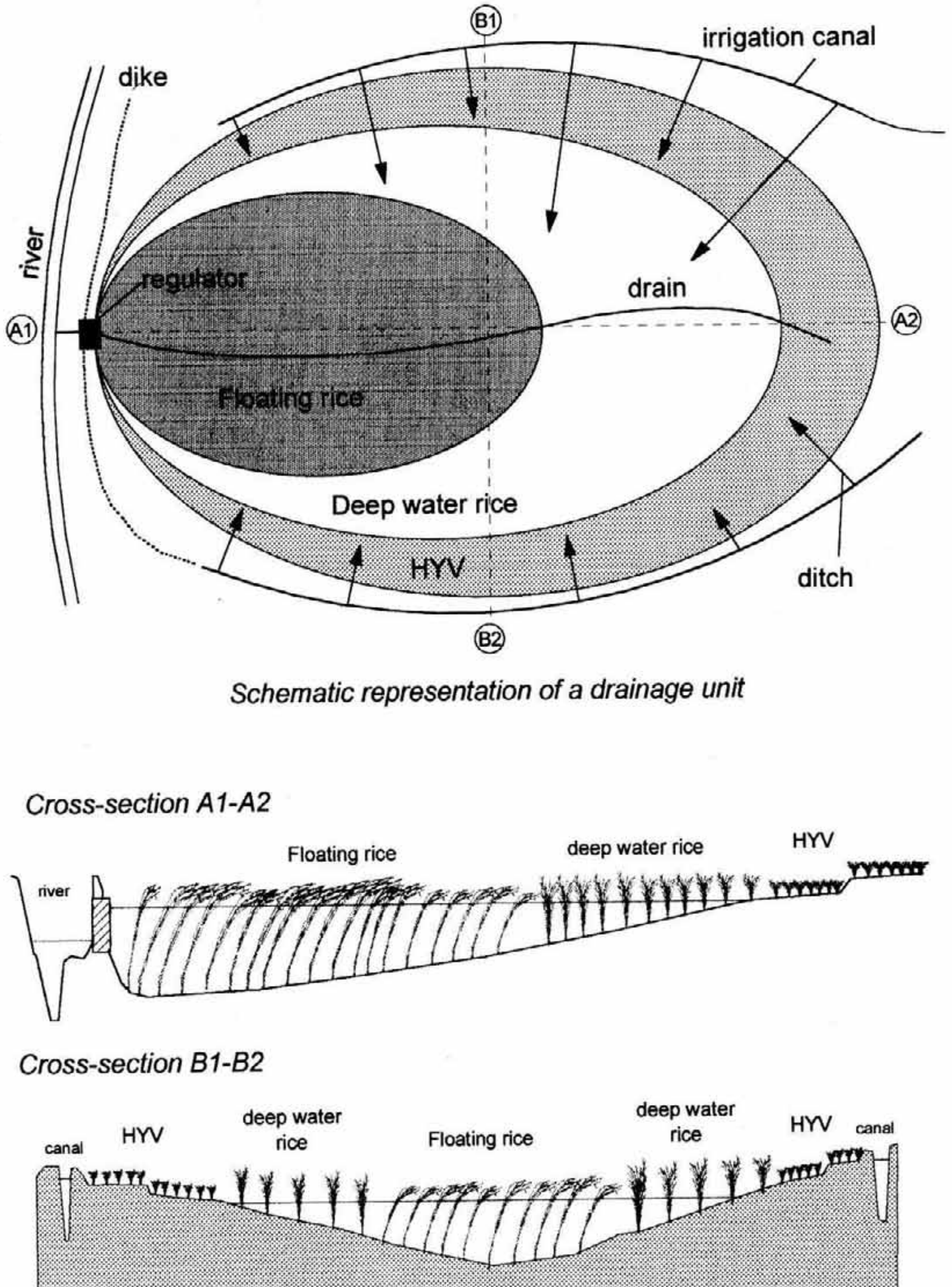
These regulators have several purposes :

- to raise the water level up to higher lands which - in some areas - are lacking of a proper water distribution system;
- to sustain the medium or long cycle varieties at the end of the year (when water is likely to recede rapidly);
- to regulate the water level in the flooded areas, in particular by preventing higher water levels in the downstream river to backlash in these areas;
- to help storing water in the waterways for the dry season;

1.1.2 Description of water management (drainage regulation)

A drainage "box" usually comprises two main areas : the upper one, with satisfactory drainage conditions and irrigation supplies through canals (often located on natural levees along the main rivers or former natural waterways turned into canals) ; the lower one, which is due to be flooded up to a given level by the adequate manipulation of the regulator(s).

Fig. 3 : Schematic representation of a drainage unit ("box")



While the upper part can be considered under *gravity irrigation*, the lower one can be said to be flooded under *drainage regulation*. The former will be planted with HYV and DWR, while the latter will be planted with DWR together with FR in the lower parts. These divisions can be seen in the cross sections of Figure 3.

The general hydraulic regulation allowed by the regulator can be briefly described as follows (see later section for further details) :

1. At the beginning of the rainy season, the gates are closed but little water accumulates. The drainage box and its dry-broadcast rice is under rainfed conditions. This lasts approximately until the end of July.

2. When rainfall and irrigation deliveries begin to be more abundant the regulator is kept closed in order to store inner run-off and to protect the plots from possible uncontrolled flood from the river. In dry years, however, inflow through the regulator is sometimes allowed into the box to sustain the water level. In case of excess water produced, for example, by too heavy rainfall, the regulator may be opened to evacuate excess flows. This possibility, however, will decrease as the wet season continues, because river flows increase until October-November and translate into higher water levels.

3. In case drainage through the regulator is not possible, then nothing can be done. Hopefully the inner water level will increase at a moderate rate and not too high. If the increase rate is high, then the deep water rice will be endangered. If it exceeds 10 cm/day, then even the floating rice will suffer some loss.

4. In case both the inside run-off and the outside water level are insufficient to allow the water in the box to reach the desired regulation level, then rice plots located in the upper areas, at the fringe of the flooded area, are likely to suffer from water shortage.

5. Sometimes before the maturity of rice, the regulator is opened to allow the drainage of the area and rice harvesting. The date and the opening rate (all of a sudden or gradually) depend on local conditions of the drainage box. Most of the regulators are opened during the month of December.

6. After all the area is drained and harvested, the regulator is closed again in order to retain water for possible dry season cropping along the drain. Some riparians farmers may use pumps to irrigate adjacent fields.

1.1.3 Topography of the flood plain

Land form in Southeast Asian deltas has been described by authoritative work from Takaya (1989). The flood plain is a complex area made of depressions alternating with high land, most often levees of the main rivers and their former "arms".

Fig. 4 shows a general elevation map of this area (and its surroundings) : elevation decreases from north to south and from east to west, from upper land at around 13 m of elevation to less than 2 m, south of Ayutthaya. A more careful examination shows some inner depressions or troughs, and levees along the rivers or some main canal (black lines).

Fig. 4

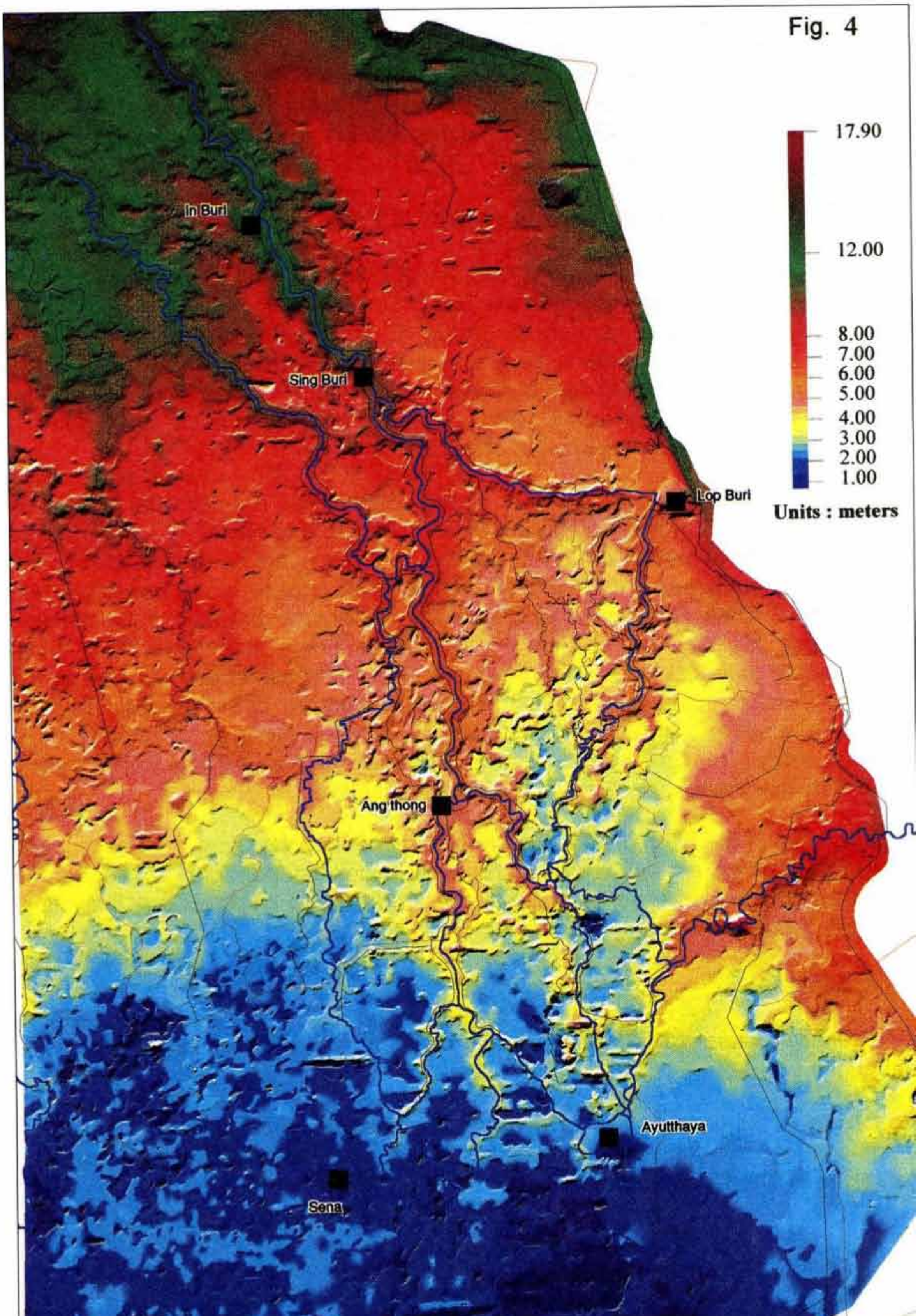

17.90
12.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
Units : meters
In Buri
Sing Buri
Lop Buri
Ang thong
Ayutthaya
Sena

Fig. 5 provides examples of lateral cross sections which show the succession of levees and depressions. Section A1-B1 shows the large low lying area of the the Watmanee box. Section A2-B2 shows how lateral flows are "blocked" by the Noi and Lop Buri rivers, while very low areas can be found in the central part (Maharat tract). Section N1-S1 and N2-S2 indicate that there is a quite regular natural slope from North to South.

1.1.4 Main drainage boxes in the Chao Phraya Delta

The main drainage boxes of the Chao Phraya delta, totalling 18 units (without considering the drainage system to the Tha Chin River), together with 7 additional small independent boxes, are shown in Fig. 6. Some of them, as will be shown later, are in fact sub-divided in several sub-boxes. Red arrows show the main boxes for which hydrological data is available ; orange arrows show smaller boxes (or boxes for which no data has been collected), while blue ones correspond to western boxes not considered in this study.

We can distinguish four lateral boxes on the eastern side (named after their main regulators) : Bang Chomsi, Wat Manee, Bang Khum, and Nakhon Luang[2]. These boxes are bordered by the Chao Phraya and Lop Buri rivers on their western side, while a gradual increase of the elevation provides a closure of the boxes on their eastern side. Their specific location as a transition zone between the delta and the uplands also implies that they may receive some side flows from these neighbouring uplands. These side flows are either intercepted and diverted to the Chai Nat-Pasak canal (which forms the eastern boundary of the irrigated area) or channelled under it, through inverted siphons, towards the irrigated area. On the western side, the Salay and Muang Tia boxes have similar topographical characteristics but no side flows from rainfed upland areas.

In the middle of the flood plain, Lam Chuad, Saladeng, Wat Ulom, *Khlong* Noi and Bang Kung boxes, as well as a several other minor independent boxes, can be considered as inner boxes, completely poldered and, to some extent, like "inner islands". Fig. 7 shows these polders.

1.1.5 "Split boxes"

The general pattern of a drainage box presented in Fig. 3 may also show some variations.

Especially in the case of a rather big box, it may become interesting to "split" the box along its main drain by constructing two lateral embankments which make the two sides of the drain independent.

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[2] The Nakhon Luang Project has four main regulators along the Chao Phraya River : Khaw Mao, Ban Pho, Ban Wa and *Khlong* Jik. It was not attempted to describe this box in details.

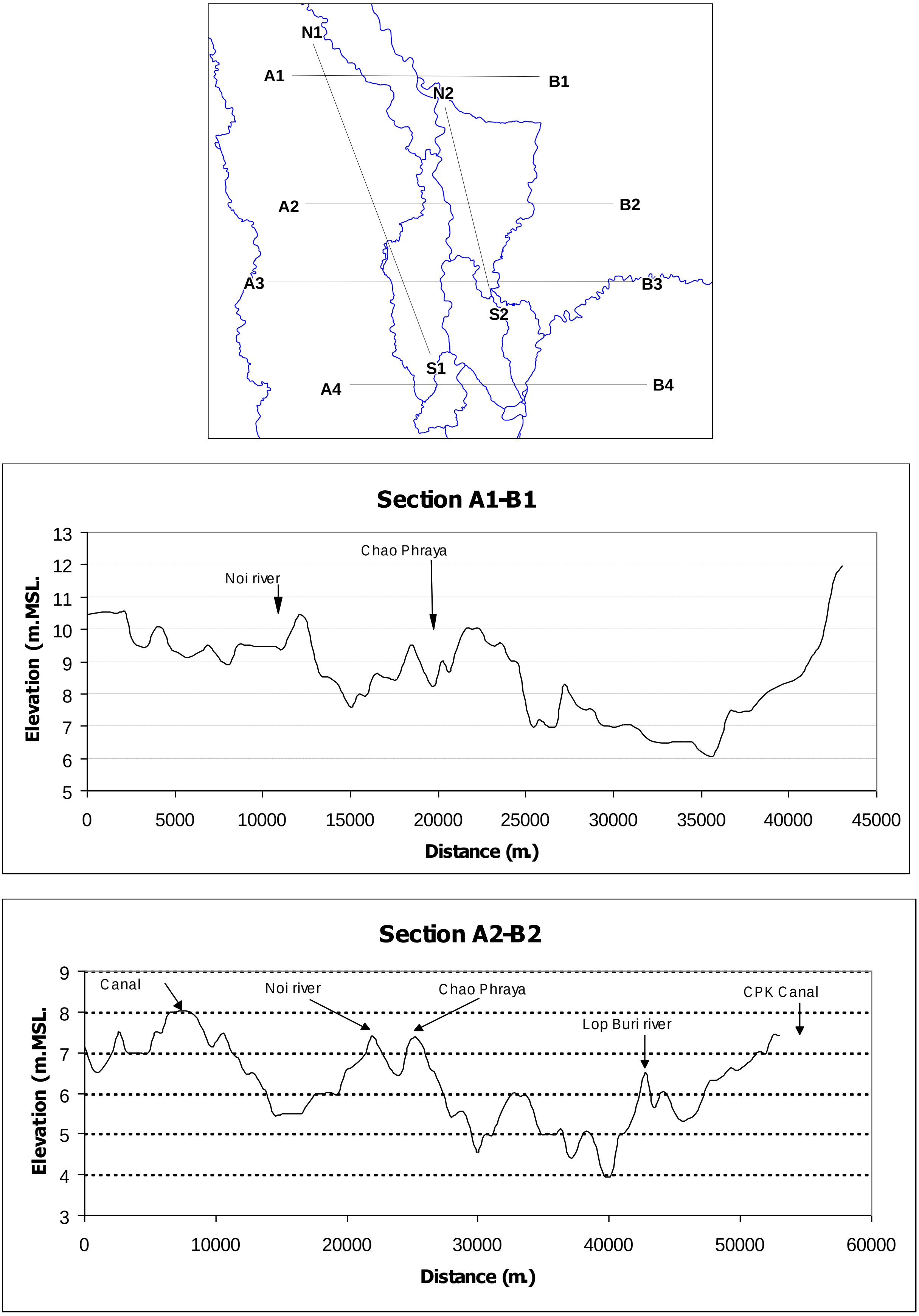


Fig. 5 : Cross-sections of the Chao Phraya flood plain

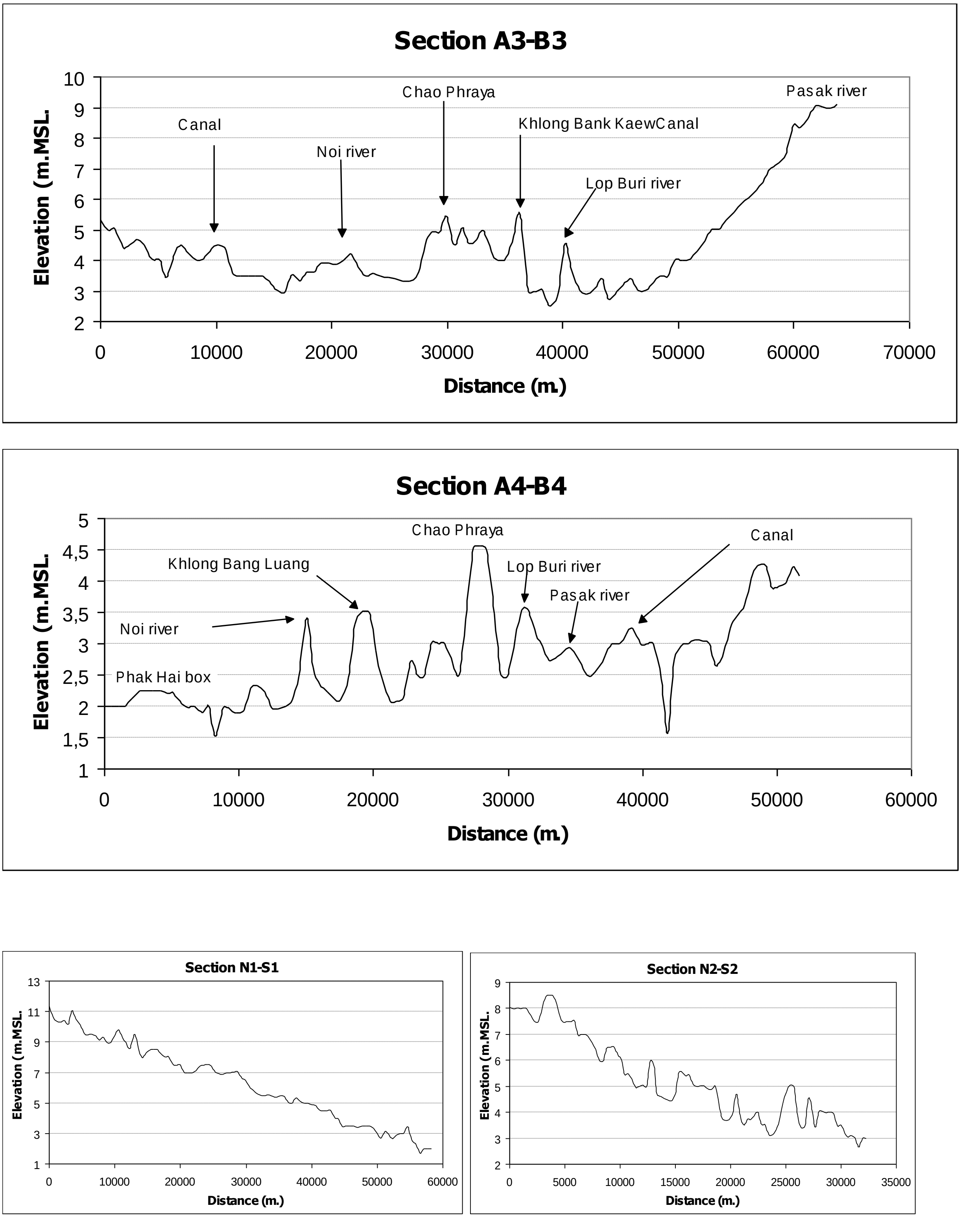


Fig. 5 : Cross-sections of the Chao Phraya flood plain (continued)

Fig. 6 : Main drainage units (or "drainage boxes") of the flood-prone area

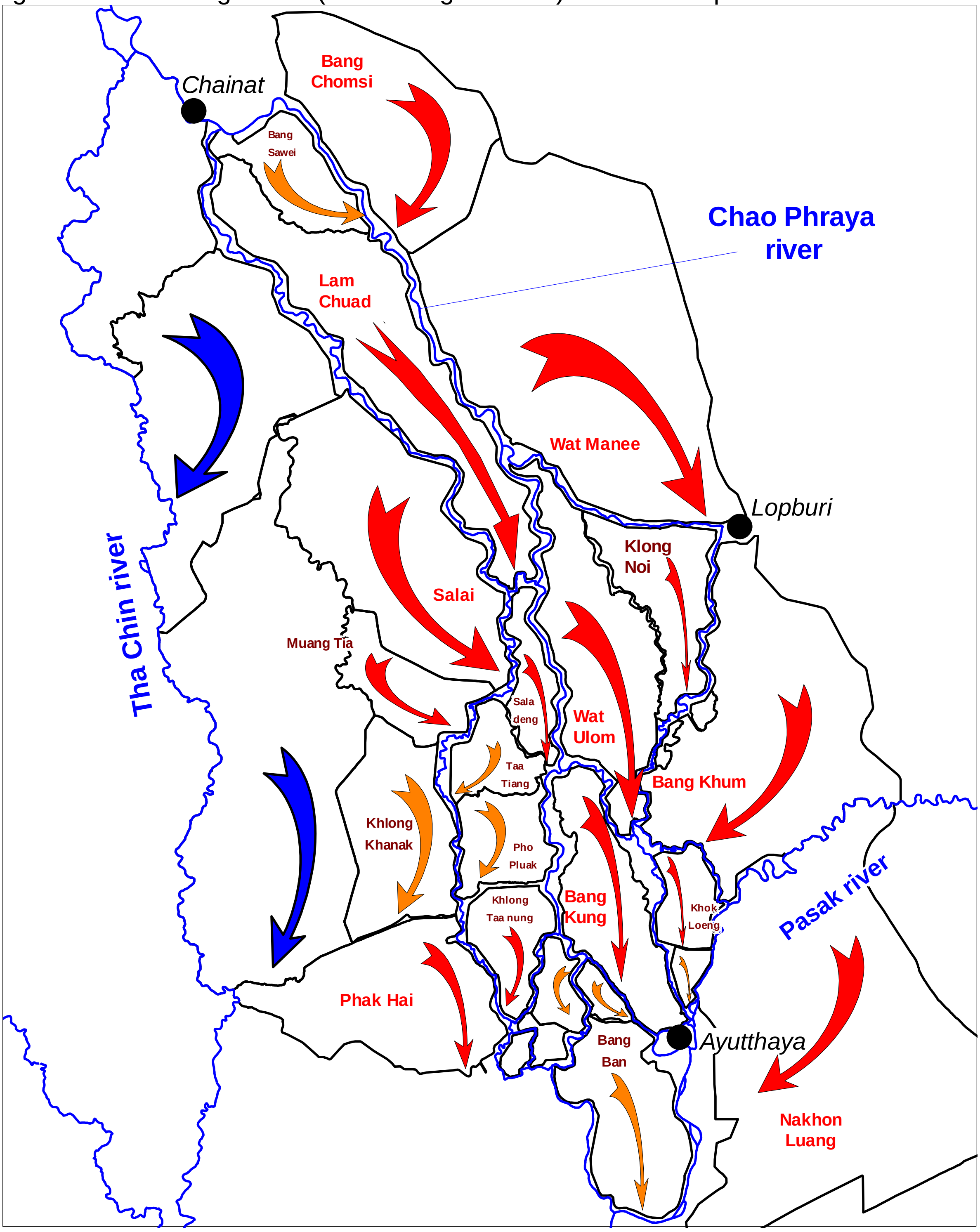
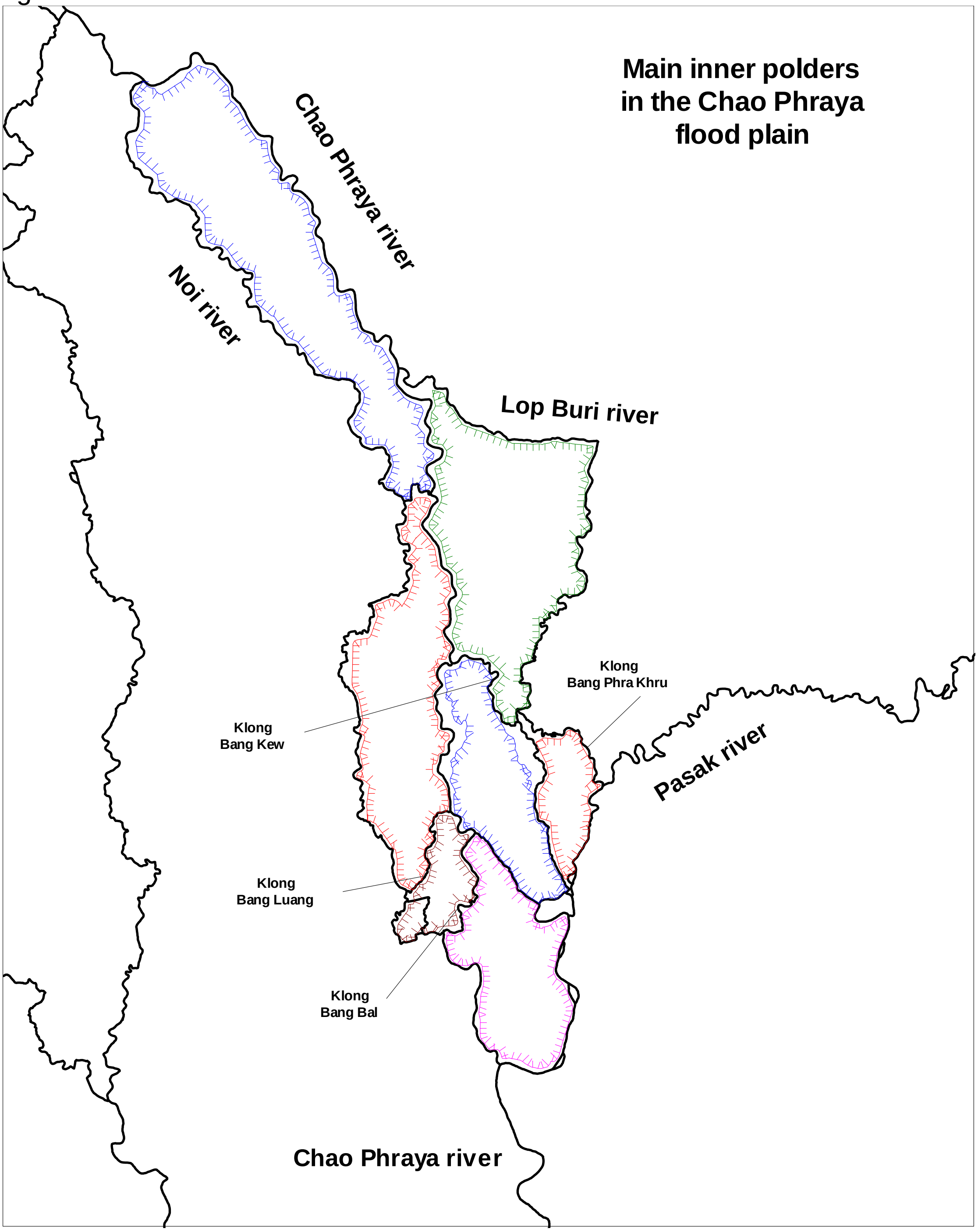


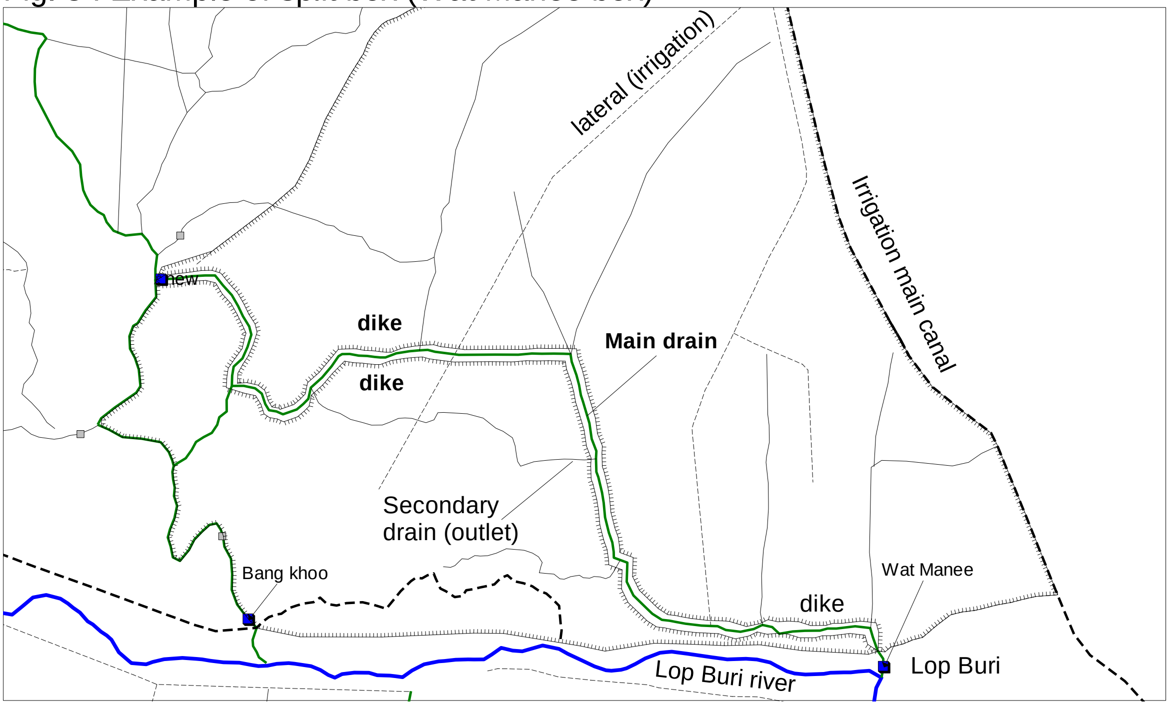
Fig. 7 :



This not only allows the protection of lateral areas from possible excess flows originating in upstream areas (these flows are channelled between the two dikes down to the regulator) but also allows both sides to be drained at different dates and with different rates if necessary.

The best example of such a "split box" is the Wat Manee box (the dike continues upstream of the area shown here but is not completed yet) (Fig. 8).

Fig. 8 : Example of split box (Wat Manee box)



However, as all the drains have embankments, most boxes could be considered as split. The central point is to check whether the outlets of the secondary drains to the main one are gated or not. In the first case, if in addition there is no submersion of the embankments, the box can be considered split, as both sides are independent, while in the latter case the water levels on both sides of the drain are not independent.

1.1.6 Cascade boxes

The case of "cascade boxes" is very common : in long boxes, the regulation allowed by the main regulator (exit to the main river) will be insufficient, as distant and higher areas will not always be reached by the water body. Therefore upstream and successive additional regulators are needed to provide proper local water regulation. Many regulators have been added in recent years with this purpose.

"Cascade boxes" eventually look like a staircase of successive water bodies. However, all of these regulators may not be used in all years, but chiefly in "drier" ones, when the main regulator cannot store enough water to reach the optimum regulation level : upstream gates are then used to retain local runoff in upper parts. This is in particular the case in Wat Ulom box, where 12 new regulators (King Project) have been added to the existing ones, all along the main drain (Maharat 2). In the Bang Khum box too, the Chaksaa[3] and Thong Yoi regulators may retain water in the upper reaches of the box ; they will be used mostly in case of a "dry" year. It is worth noting, nevertheless, that these regulators are also useful at the onset of the season, allowing the progressive flooding of the TVs before the water raised by the

[3] The difference between upstream water levels at Chaksaa and Bang Khum regulators is often close to 30 cm (Wiel 1996).

main regulator reach them.

The "*Khlong* Noi" box also provides a neat example of cascade box : the comparison of the topo map and the satellite image evidences the clear relationship between rice systems and the topography, and shows the inner sub-boxes.

1.1.7 Details of the drainage boxes in the Chao Phraya Delta

Figure 10 and Table 1 provide an accounting of all the main drainage boxes identified in the study, together with the corresponding regulators. It can be observed that the area varies between 751 km^2 (Wat Manee) to 50 km^2 (Saladeng) ; several smaller independent boxes, the boxes of the lower Yangmanee Project (for which no data on the water level are available) and the Nakhon Luang box are not considered here.

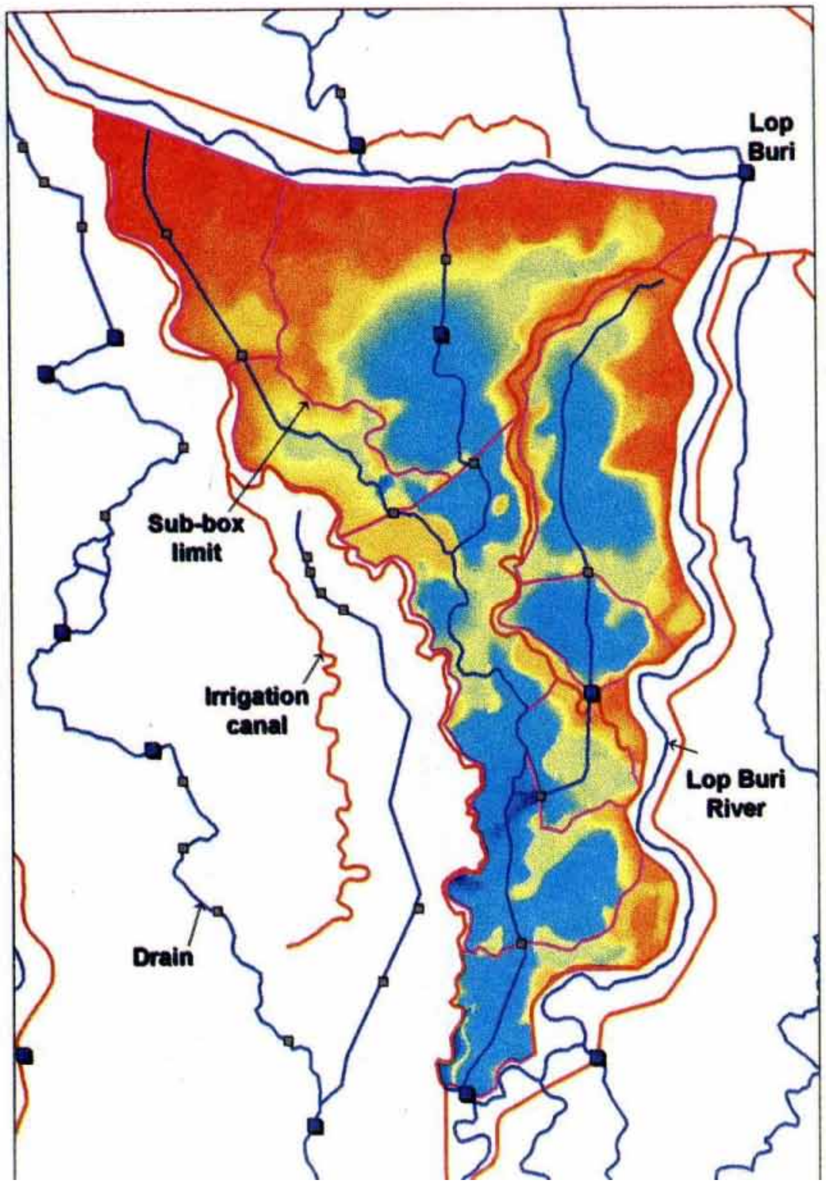
Elevation data refer to the values beyond which we have 5 % of the area (this stands for maximum and minimum elevation but avoids possible disturbances by exceptional points). While the eastern boxes have side flows, other boxes are closed drainage units. Most boxes have only one major outlet, but some (like Bang Khum box) have several regulators. We will see later how these characteristics translate into different hydrologic regimes.

For "normal" regulation levels, the maximum depth of the water body (often in the surroundings of the main drainage outlet) varies between 1.45 m (Muang Tia) and 4.00 m (Saladeng) ; most of the boxes have maximum water depths between 2.40 and 3.40 m.

By dividing the area by the box depth (defined as the difference between the 5 % and 95 % elevation values), we get an index indicative of the average slope in the box[4]. Phak Hai and Bang Ban appear quite flat (Wat Manee and Bang Khum, too, due to their big size), while Saladeng, *Khlong* Noi are the steepest.

[4] The higher the indice, the lower the average slope.

Fig 9 : Topography in Klong Noi Box



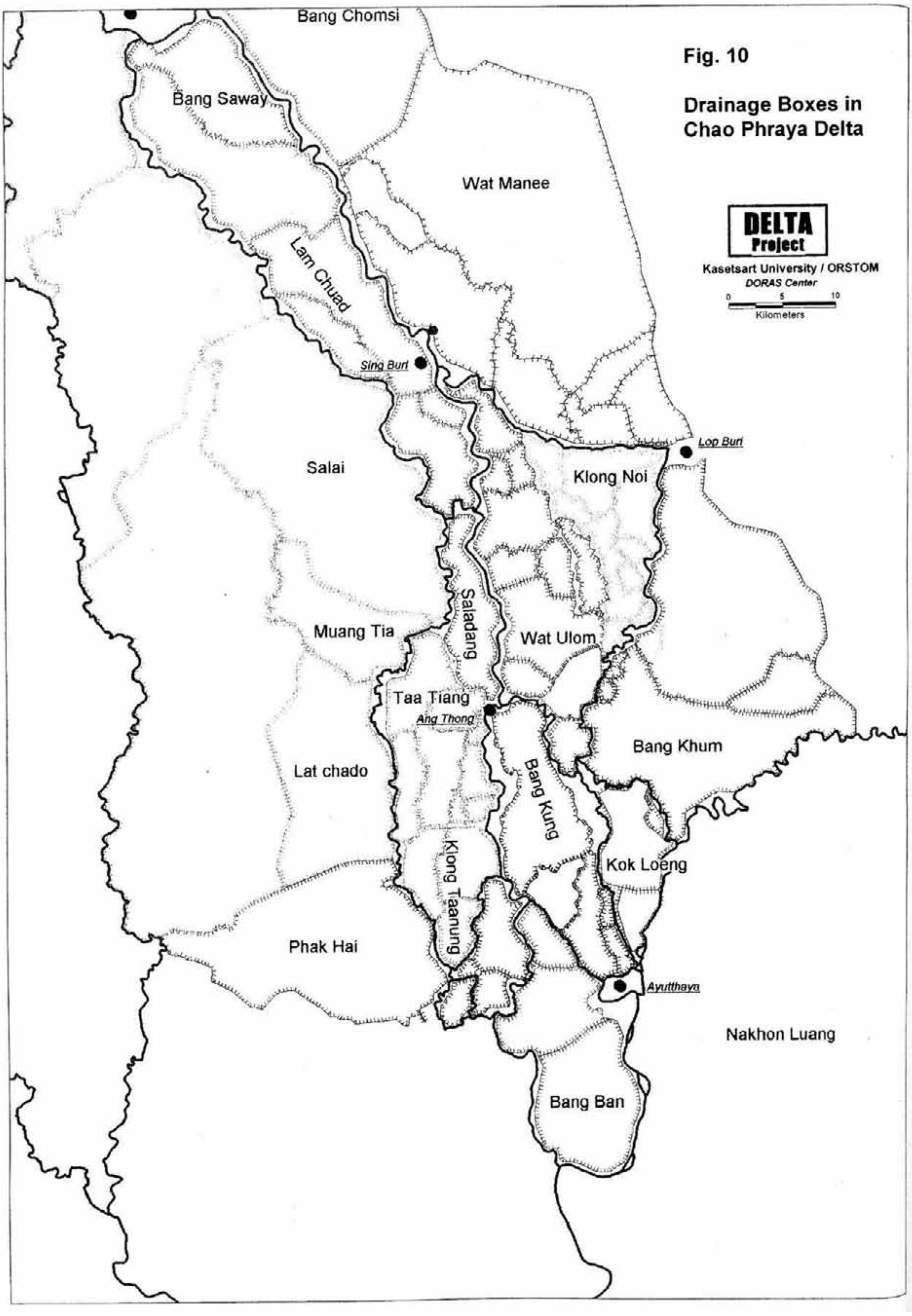


Fig. 10
Drainage Boxes in
Chao Phraya Delta
DELTA
Project
Kasetsart University / ORSTOM
DORAS Center
0
5
10
Kilometers
Bang Chomsi
Bang Saway
Wat Manee
Lam Chuad
Sing Buri
Lop Buri
Salai
Klong Noi
Muang Tia
Saladang
Wat Ulom
Taa Tiang
Ang Thong
Bang Khum
Lat chado
Bang Kung
Kok Loeng
Klong Taanung
Phak Hai
Ayutthaya
Nakhon Luang
Bang Ban

Table 1 : Main boxes and their characteristics

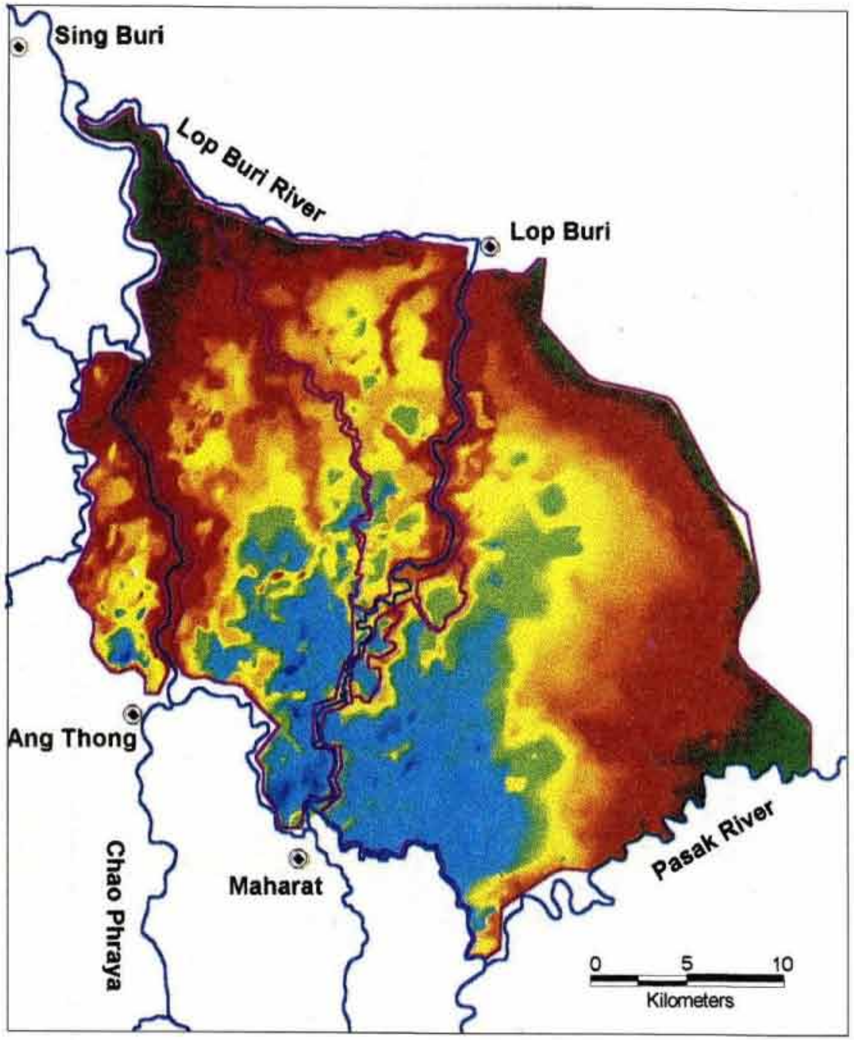
Box	Area (km2) (1)	Elevation (upper 5 %) (m MSL) (2)	Elevation (lower 5 %) (m MSL) (3)	Overall "depth" (m) (2)-(3)	Slope index (1)/(2)-(3)	Regul-ation depth (m MSL)	Max. water average depth (m)	Out regulators (main/sec.)	Inner regulators, weirs or pipes
Wat Manee	751	11.4	6	5.4	139	7.5	2.8	3 main	18
Bang Khum	453	7.4	3.0	4.4	103	4.5	3.2	3main/3sec.	12
Salai	360	10	5.4	4.6	78	6.5	2.7	1 main	2
Bang Ban	160	2.7	1.1	1.6		(2.0)	1.3	2 main/1 sec	0
Phak Hai	342	2.5	1.7	.8	428	3.1	2.4	6	0
Lam Chuad	315	13.1	7	6.1	52	8.4	2.5	1 main	4
Wat Ulom	222	8.0	3.0	5.0	44	4.5	3.1	1 main	25
Bang Kung	152	5.0	2.0	3.0	51	4.2	3.4	1 main/2 ?	4
Khlong Noi	119	7.2	4.0	3.2	37	5.4	3.0	1 main	3
Muang Tia	89	7.5	4.9	2.6	34	5.75	1.45	1 main	1
Khlong Taa nung	69	3.5	2.0	1.5	46	3.6*	2.1	1main/3sec.	2
Sala Deng	50	6.8	3.8	3.0	17	5.4	4	1 main	0?

(*) records for *Khlong* Taa nung regulator indicate a regulation level of 4.10 m. However, levels recorded at Wat Baibua - a nearby gate on the same box - show a regulation level of 3.60 m, more coherent with the elevation of the box. This last value has been eventually considered for this box and the records of *Khlong* Taa nung regulator are considered to be erroneous (incorrect absolute level). Water levels are not available for Bang Ban and Yangmanee projects.

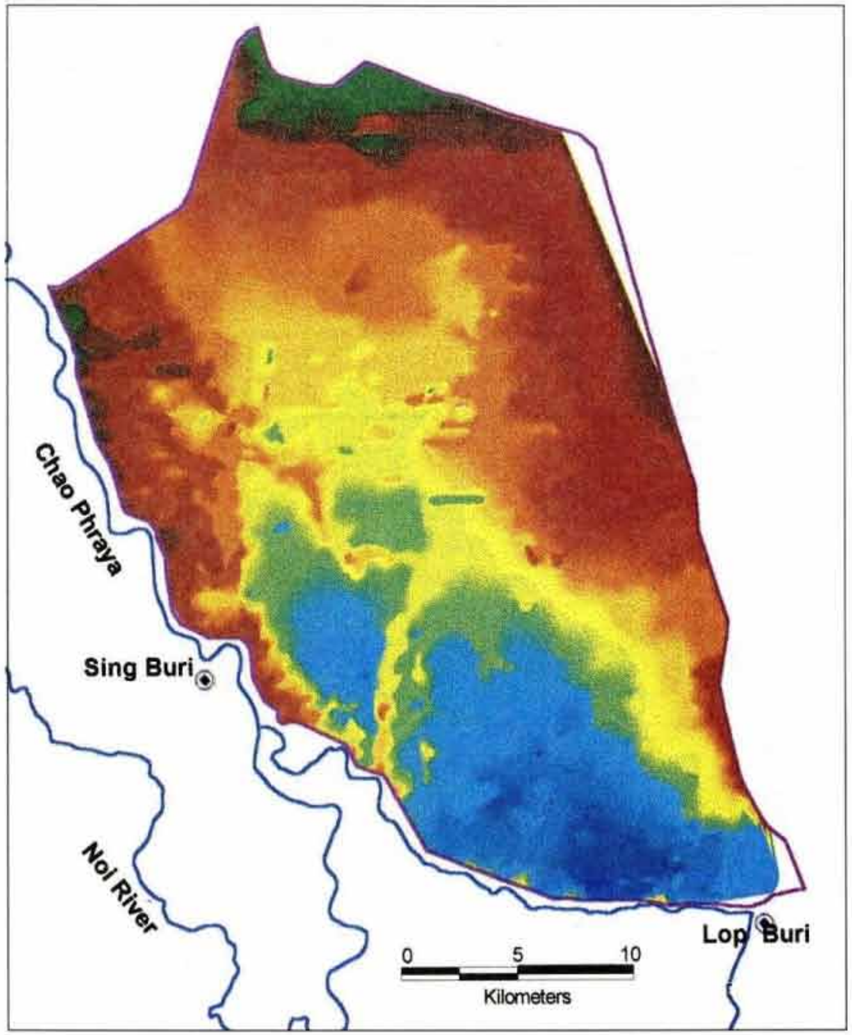
The relief of the main boxes is shown on the set of maps from Figure 11 (*a* and *b*). Most of the boxes follow natural boundaries and relief. However, diking, road constructions, poldering of industrial units or zones, etc. have notably altered the natural landscape and drainage. In some instances, it makes the identification of drainage flows extremely difficult over such a large study area.

The present study endeavoured to identify all the existing drainage regulators in the study area, with the corresponding drainage boxes. It must be said that even combining field surveys, RID data and satellite images there is no certainty as to whether the inventory is complete, but it is believed to be fairly comprehensive. Some secondary intermediary regulators are instrumental in helping to store water in the upper part of the boxes but does not always define a sub-box[5].

[5] For example, it has not been possible to define as many sub-boxes as there are intermediate regulators in the Wat Ulom box.

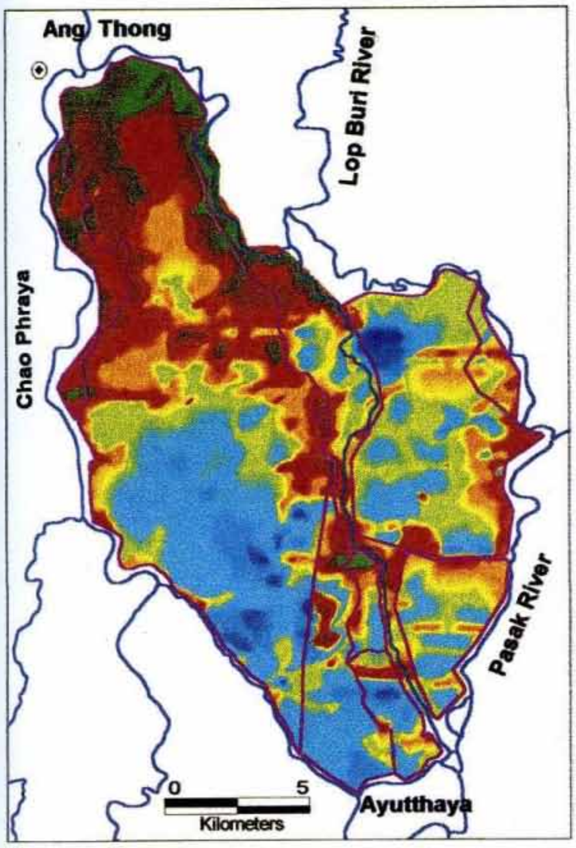


Maharat track, lower Khok Katiem, Roeng Rang projects

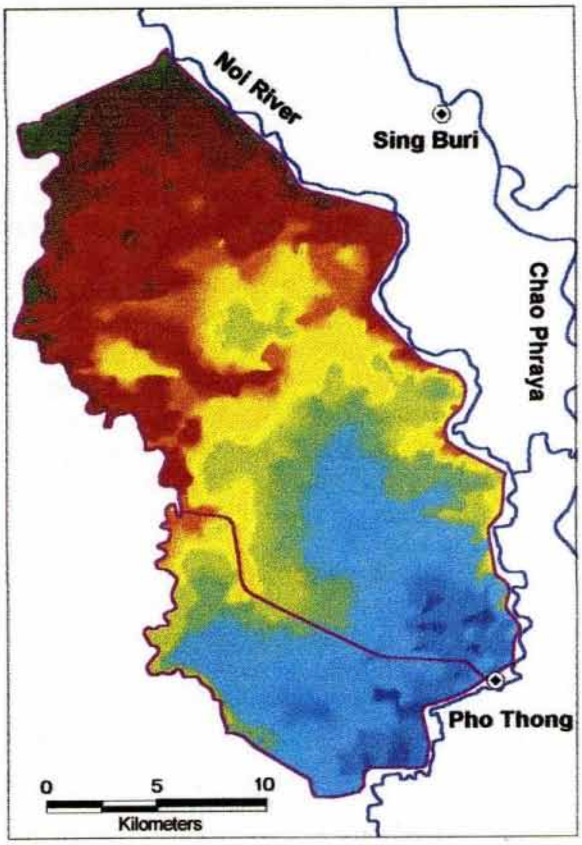


Wat Manee box (Chong Kae, Maharat, Khok Katiem projects)

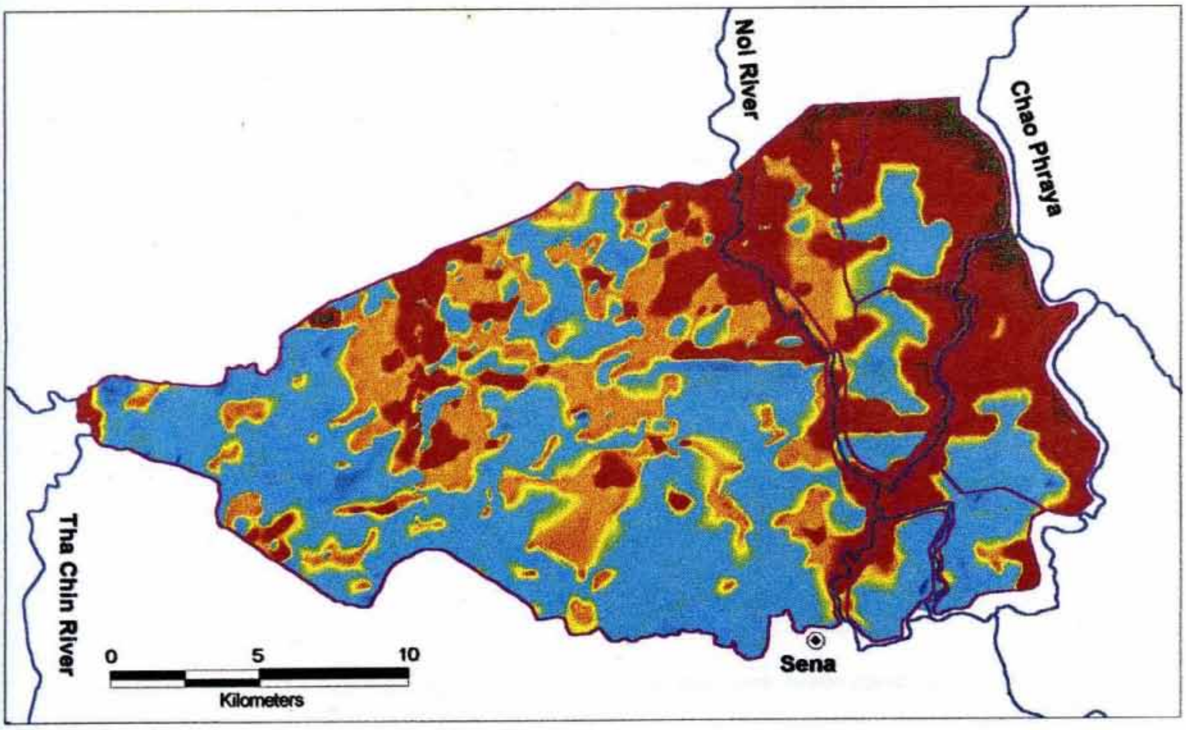
Figure 11a



Lower Maharat and Roeng Rang projects



Chanasutr project



Phak Hai Project

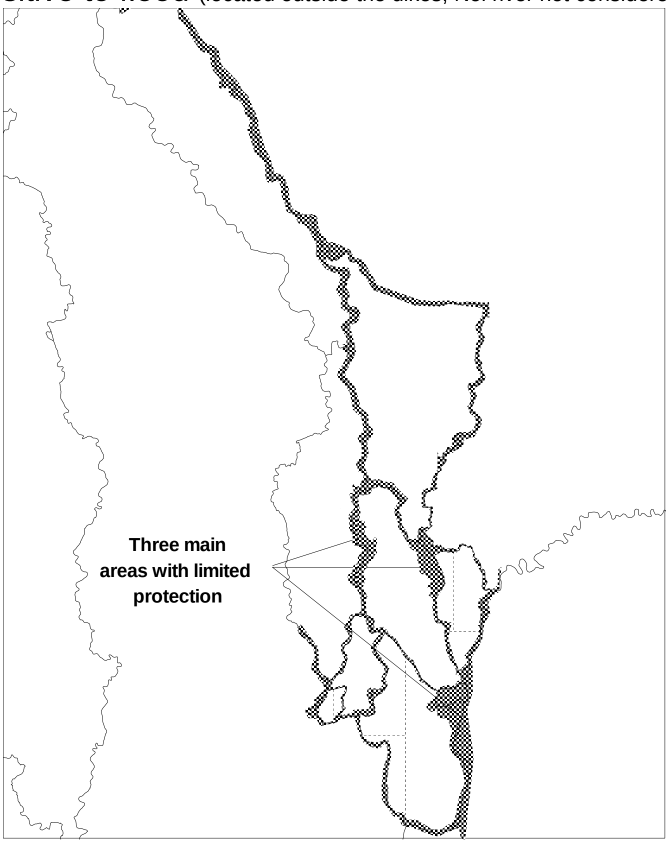
Figure 11b

As the definition of a sub-box is loose we can only propose tentatively a figure of approximately 120 sub-boxes making up the set of 18 main boxes (to which we can add the 7 small independent boxes). Figure 12 provides a map of the drainage system with all the regulators identified[6]. Around 100 structures were identified as regulators equipped with sluice gates, while the remaining (155) are mostly pipes through dikes which can be closed, or weirs.

1.1.8 Remaining unprotected areas

Apart from the area coming under box protection, we should also mention that there is still an area much sensitive to flood, located between the lateral dikes of the main rivers. These areas, in addition, correspond to dwellings (most houses are on stilts or earth-fills). Fig. 13 specifies their extent and show some larger areas near *amphoe* Maharat and south of Ang Thong, which have very limited protection.

Fig. 13 : Areas sensitive to flood (located outside the dikes; Noi river not considered)



[6] Some areas have a drainage network which could not be totally elucidated. This mostly applies to the lower Yangmanee project.

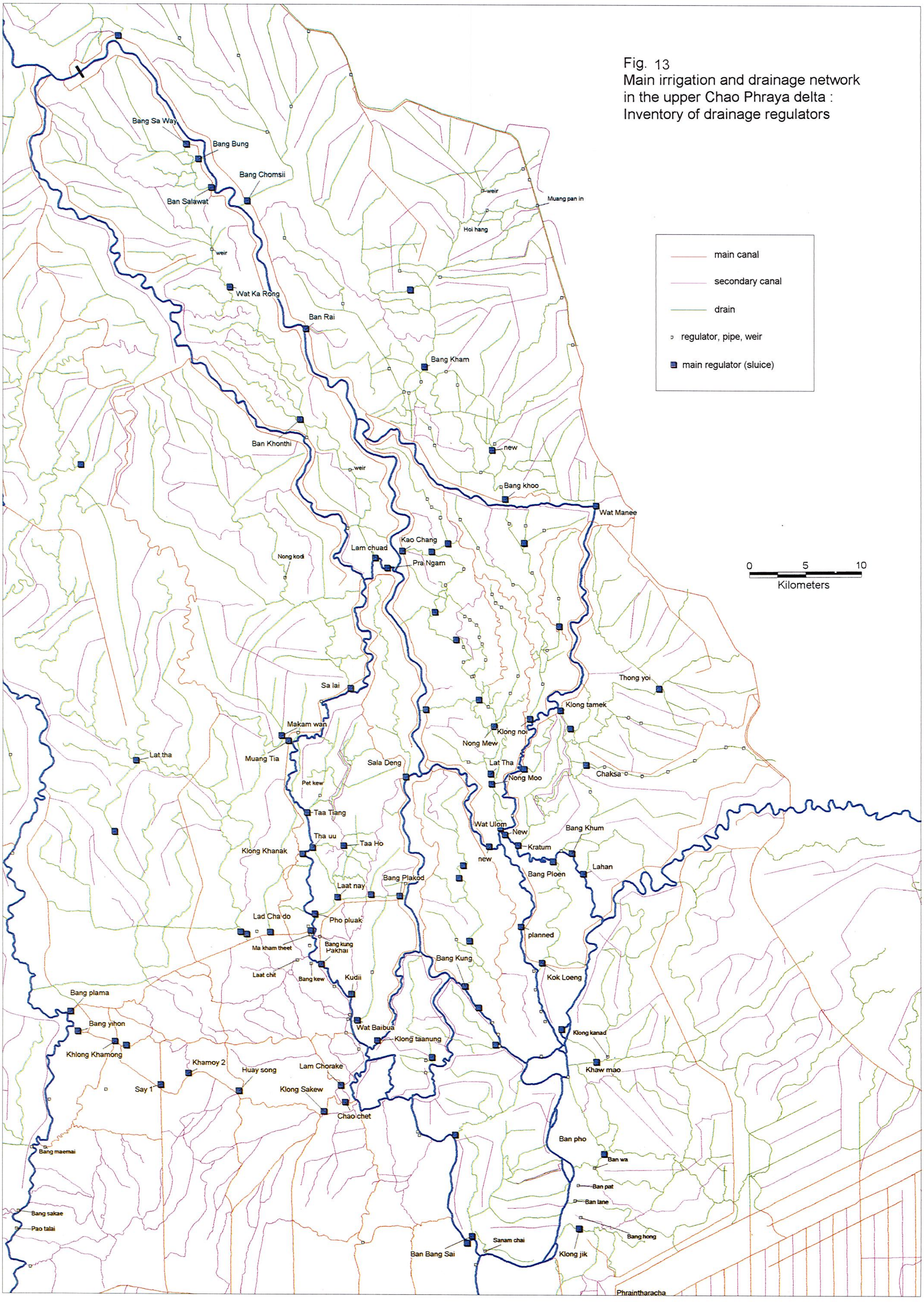


Fig. 13
Main irrigation and drainage network in the upper Chao Phraya delta : Inventory of drainage regulators

2. Analysis of field survey data

2.1 Rice types and varieties

The distinction between deep water and floating rice is not very sharp in farmers' language : *Khao khun naam, Khao fang loy, Khao napii, Khao phun muang, Khao nak* are used to differentiate traditional varieties (referring here to DWR and FR, even if they are improved cultivars) from short-stem non-photosensitive new strains (HYV). Many times farmers' terms were found to be relative to the local context : "khun naam" (rises with water), for example, was sometimes used for DWR to express a contrast with HYV also used in the area. Therefore the question aimed at distinguishing between DWR and FR was : can it grow up to 2 or 3 meters ? which proved to be a clear-cut question.

2.1.1 Spatial distribution

Traditional Varieties (TV) make up 90 % of all the varieties cultivated during the rainy season in the study area, with 59 % of DWR and 41 % of FR. The last 10 % correspond to High Yield Varieties (HYV). This percentage is based on the varieties which have been identified ; for 3 % of the varieties appearing in the sample (usually with one or few occurrences), it was not clear whether it was a deep water or floating rice variety.

HYV are located in 2 main zones (Figure 14) :

- the border of the study area, especially the western border : they actually mark the limit of the flooded area, as elevation increases with the natural slope. In fact, they materialise the boundary of our study area and could be considered as being outside of it.

- along the main rivers (especially the Noi river and, to the north of Sing Buri, the Chao Phraya river) but also on the levees of former arms of the Chao Phraya River (especially in the centre of the flood plain, between the Chao Phraya river and the Lop Buri river). Five years ago, HYV were already cultivated in this area, but the density was lower.

HYV can also be found in isolated areas, which correspond to particular conditions of topography and water management.

If we consider now the spatial distribution of the TVs (Fig. 14), we notice that both kinds of TV (DWR and FR) can often be found mixed together. This shows that with the density of observation points achieved it is in general not possible to see the high heterogeneity of the topography (which mainly governs the rice type choice). Nevertheless some major areas can be observed :

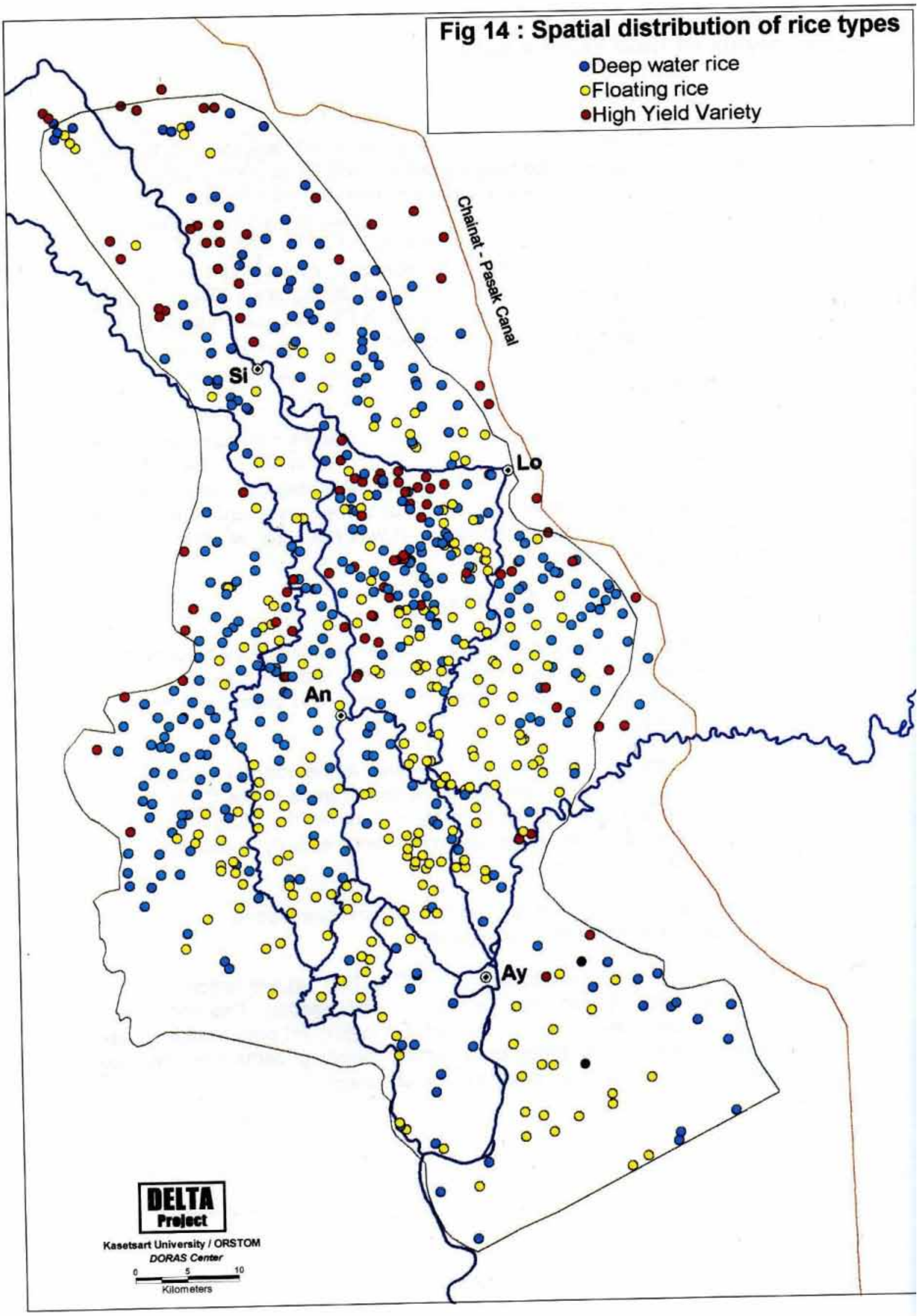


Fig 14 : Spatial distribution of rice types
Deep water rice
Floating rice
High Yield Variety
Chainat - Pasak Canal
Si
Lo
An
Ay
DELTA
Project
Kasetsart University / ORSTOM
DORAS Center
0 5 10
Kilometers

Floating rice appears alone in the lower parts of the main boxes (Fig. 14) : Wat Manee, Wat Ulom, Bang Kum and Bang Kung ; in the south-east of Ayutthaya (Nakhon Luang Project), in the Sena area (Phak Hai and upper Bang Ban projects) and parts of the narrowest corridor between the Noi and the Chao Phraya rivers : all these areas are very low lying and/or located at the exit of the main drainage boxes to the river system.

Concerning deep water rice, four zones can be identified : the north of Sing Buri, (where HYV are also present), the upper part of the "Maharat tract" (area between the Chao Phraya and Lop Buri rivers), the central part of Bang Ban project and the transition zones on the western and eastern sides of the study area : this matches the overall topographical features of the delta presented earlier.

2.1.2 Main traditional varieties

There is a large diversity of traditional varieties : 59 have been recorded as being currently used. However, six main varieties make up 58 % of the TVs and, together with the next 17 main varieties, 82 % of the whole. The last 43 varieties (18 % of the total) appear only 3 times on average in the survey. The full list of the varieties encountered in the survey is given in the annexe.

The differentiation between local varieties and recommended improved varieties was not addressed : Charoendham et al. (1993) have found that none of the 5 recommended varieties, namely TPG 161, LMN 111, PG 56, HTA 60 and RD 19, were used in the Central Plain in 1992. These varieties were not found either in the present survey[7]. Some improved varieties are still named after the cultivar they are derived from and there is little scope to determine what strain is in use.

2.1.2.1 Floating rice

Two varieties are predominant in this category : *Pin Gaew* and *Hom thung*. The area of extension of these varieties is well delimited (Figure 15) :

- *Pin Gaew* is present in the southern part of the study area, but still to the north of Ayutthaya,
- *Hom thung* is found in the northern part. The southern limit of its extent is a south-west/north-east line crossing Ang Thong.

Eight other varieties of floating rice are also well represented, but their percentage never exceed 3 % of all TVs. Among them, two are located in specific areas (Figure 15) :

- *Khaw metlek* which is present in an area delimited by Khlong Ban Kaew, Chao Phraya river and Lop Buri river, and in a secondary zone around the *amphoe* Pak Hai (*in what follows khaw stands for "white" and khao for "rice" in the varieties*

[7] "Play Ngam", one of the improved new varieties, more common in the Prachin Buri area, has been found once in the survey.

names[8]).

- *Khaw luang* located principally in the west of *amphoe* Pak Hai.

Other FR varieties include : *Khao puang*, *Khao puang klang*, *Khao puang nak*, *Khao suphan, Khao puang thong* and *Mali thong*.

These specific locations are partly due to differences in cycle duration (for example *Hom thung* fits conditions of longer flood duration than Pin Gaew). They also mirror the necessity to use identical varieties in a given units under one same water regime.

Pin Gaew 56[9] has been disseminated from 1959 onward. Its stands very deep water and harvest starts at the turn of the year.

2.1.2.2 Deep water rice

In this category four varieties predominate (Figure 16) :

1. *Kon Kaew* to the west of the Chao Phraya river and on the north of an east-west line crossing the *amphoe* Pak Hai,

2. *Leuang Pratew* : a principal zone between the Chao Phraya river and the Lop Buri river, and a secondary area to the west of the *amphoe* Wiset Chai Chan

3. *Leuang phan thong* : to the north of the Chao Phraya and Lop Buri rivers and to the south of Lop Buri. This variety is also scattered in other sites of the study area.

4. *Khao Tah Haeng* : this variety is more scattered, but we can nevertheless identify a main zone north of Sing Buri.

Three other varieties, Luang Kaset, Luang Pra Than and Phan Thong, represent 2 % of the TVs each, but show no specific spatial distribution, except Phan Thong which is located only in the Bang Ban project and north of Ayutthaya.

Khao Ta haeng and *Leuang Pratew* are popular deep water varieties disseminated in the late 50's and 60's. The former has a higher potential (470 kg/rai against 414 for *Leuang Pratew*); they both present a good quality for hulling and cooking ; *Leuang Pratew* has a strong stalk and is rather resistant to salinity.

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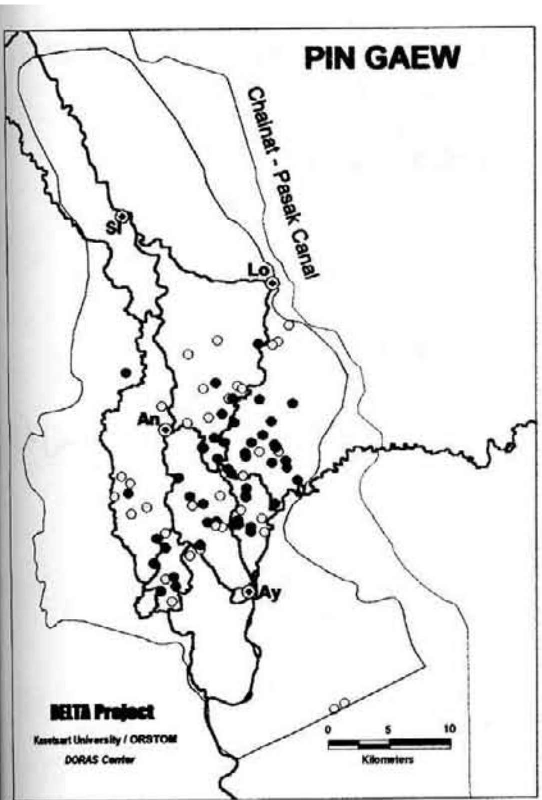
[8] This is to differentiate the two Thaï words which differ only by their tons.

[9] It is interesting to note that *Pin Gaew* 56 is completely different from the Pin Gaew variety which was considered one of the best rice varieties in the beginning of this century and even won a contest : "*General neglect at the end of the first WW with regards to selection and conservation of good seeds and above all the unscrupulous and indiscriminate mixing of different varieties of rice to meet the rising demand regardless of quality lowered the prestige of Thailand rice so noticeably that the government had to* take action. Local varieties were collected from all over the country and compared for quality of grain, Pin Gaew was judged to have the most perfect quality of grain. (...) The high quality of the selected varieties was proved at the world seed grain exhibition held in Regina, Canada in 1933. In that exhibition, Thailand won eleven honours out of the total of twenty, with Pin Gaew judged the best variety shown" (Ministry of Agriculture, 1950).



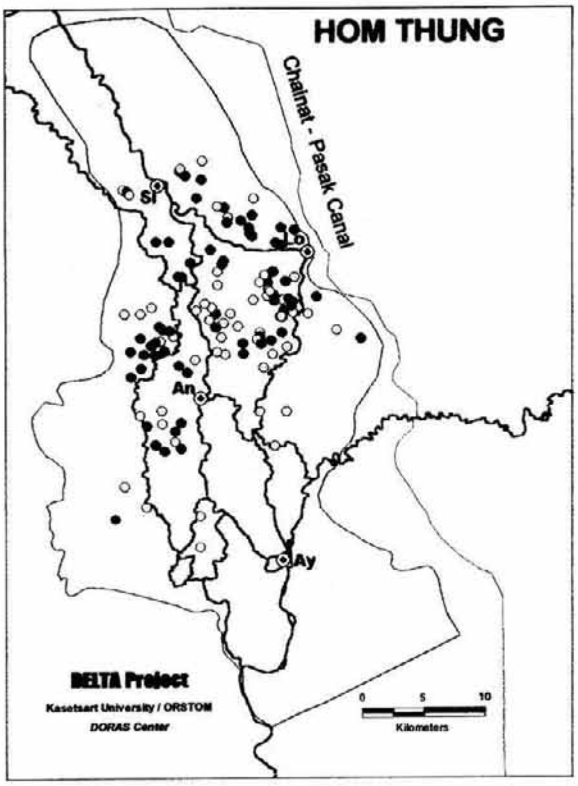
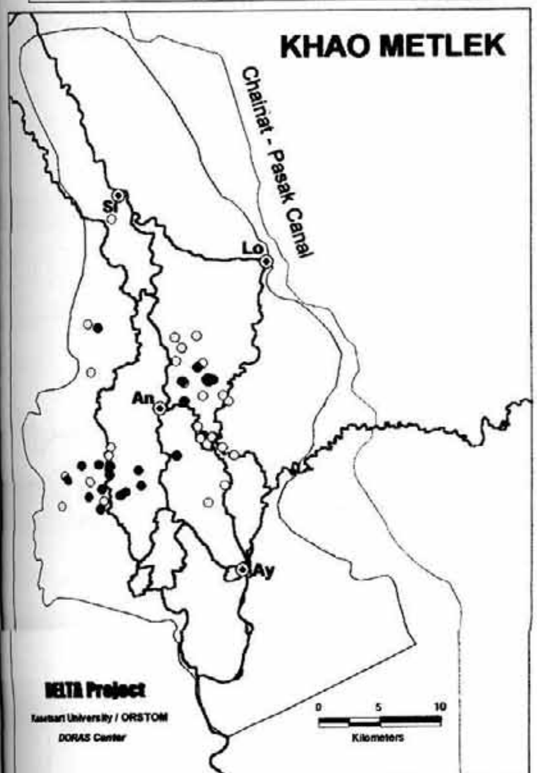
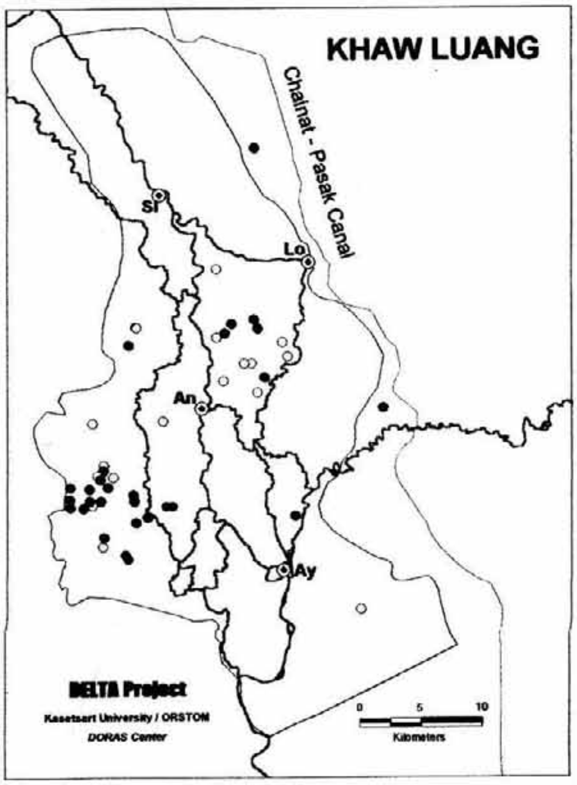


Fig : 15 Spatial distribution of the main floating rice varieties

•Variety cultivated by the farmer surveyed
○Variety cultivated in the surrounding area





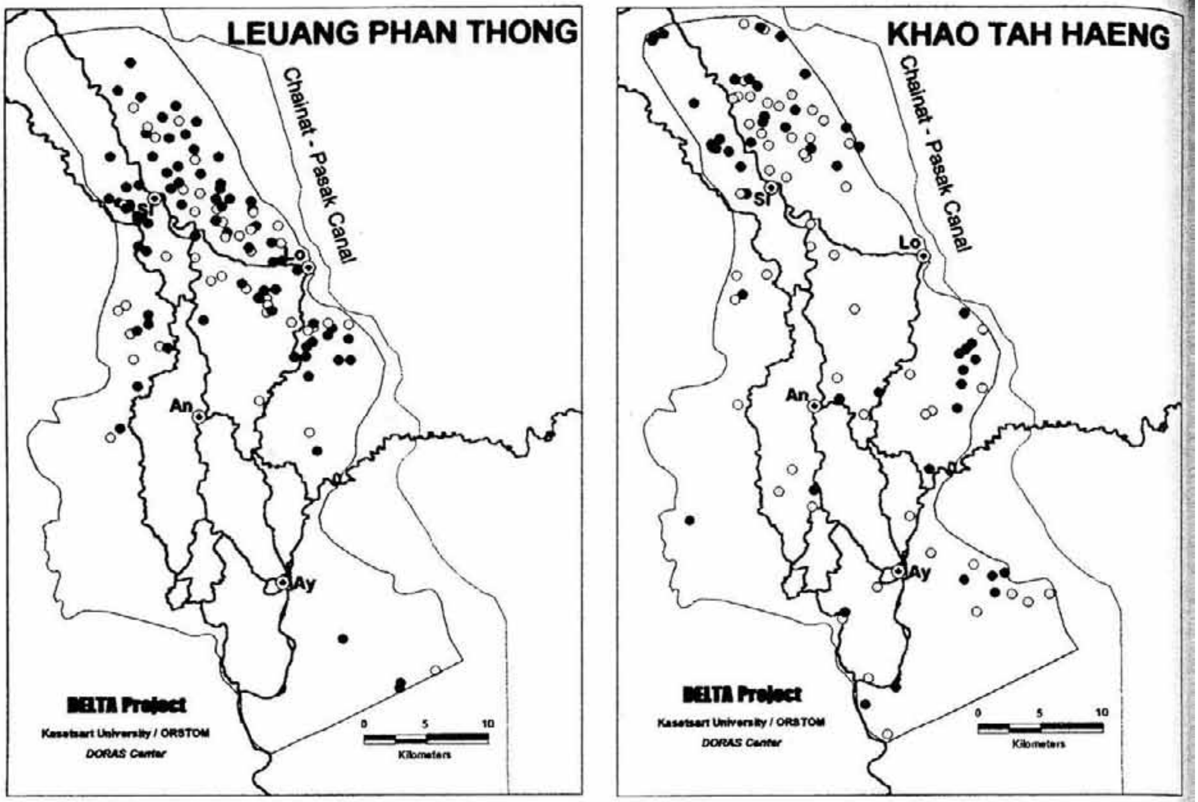
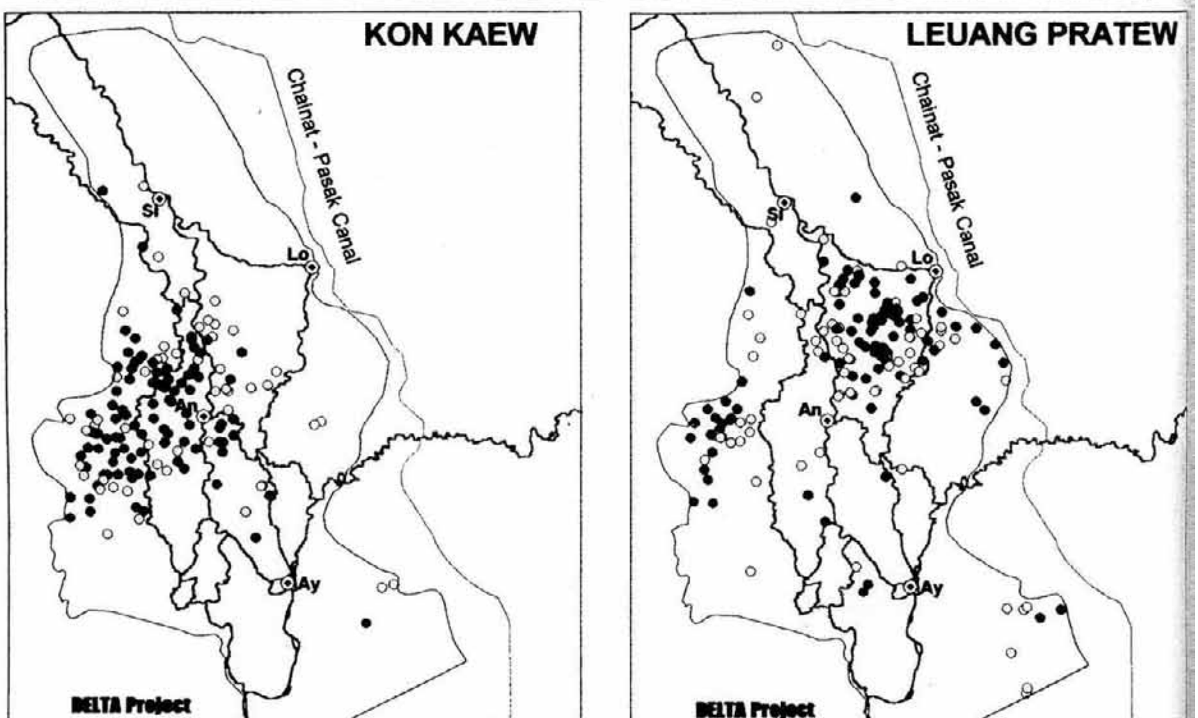


Fig 16 : Spatial distribution of the main deep water rice varieties

•Variety cultivated by the farmer surveyed
○Variety cultivated in the surrounding area



Kon Kaew is widespread and, while not a recent variety, seems to be little mentioned in the literature.

2.1.3 <u>Change in rice varieties</u>

2.1.3.1 Main change in rice types

Many factors account for farmers' decision to change rice variety. These include price in the market, resistance to given pests, productivity, adaptation to the local water regime, etc. In a context of overall long-term decrease of the water regime (see later sections), it has been found that this latter reason was dominant : a few main zones can be identified where a lot of farmers changed from FR to DWR, or from TV to HYV (Fig. 17) :

- Bang Ban project (south-west of Ayutthaya) ; this change has chiefly been made possible by the polderisation of the project, (zone A)
- around *amphoe* Wiset Chai Chan, on both sides of the Noi river, (zone B)
- in the upper Maharat tract (between the Chao Phraya and Lop Buri rivers, south east of Lop Buri), (zone C)
- along the eastern border of our study area. (zone D)

These last areas have experienced a decrease in the water level and in the flood risk. They have therefore chosen to shift from floating rice to deep water rice. It is worth noting that a few farmers have been found to have reverted to floating rice after the floods of 96 and 97 because their perception of the risk had been dramatically modified. However it was expected that a wider trend back to less risk-prone strategies would be observed : many farmers said that despite the flood they would continue with deep water or HYV. This is believed to be due to the evidence that the floods were exceptional and that even floating rice in most instances did not escape.

Regarding the change from TVs to HYV, the few concerned areas correspond to high land on levees and to areas on the margin of the study area (transition zone to HYV).

2.1.3.2 Year of change

In zone B and the center of zone C, the change of varieties occurred a long time ago : most of the farmers moved to DWR or HYV more than 10 years ago (Fig. 18). On the contrary, changes in zone A occurred during the last 4 years. As mentioned earlier, changes in this area are a consequence of the polderisation of the Bang Ban project and the gradual perception of the decrease of risk. In the other areas (zone D and the eastern border of zone C), farmers changed during the last ten years.

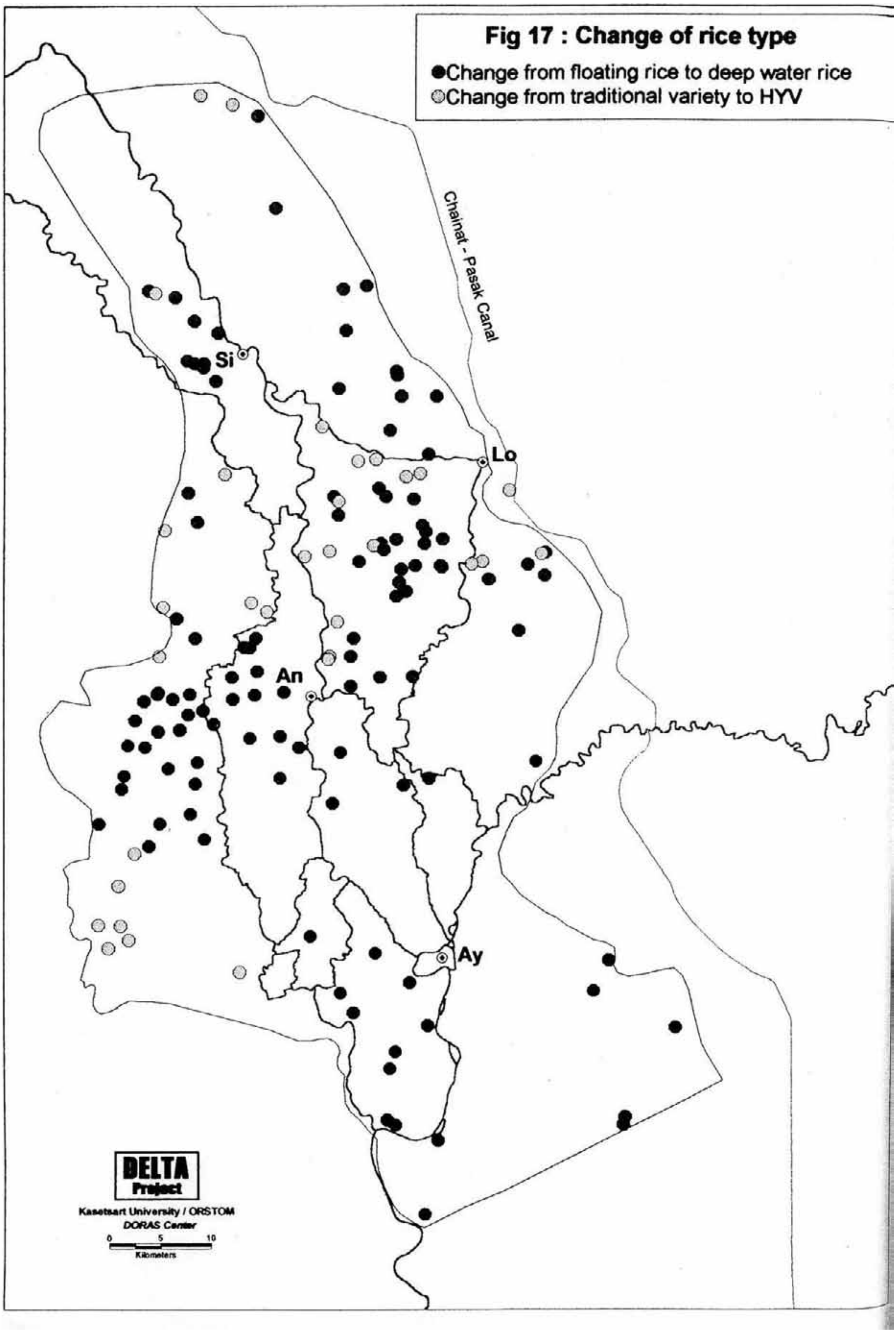


Fig 17 : Change of rice type
Change from floating rice to deep water rice
Change from traditional variety to HYV
Chainat - Pasak Canal
Si
Lo
An
Ay
DELTA
Project
Kasetsart University / ORSTOM
DORAS Center
0
5
10
Kilometers

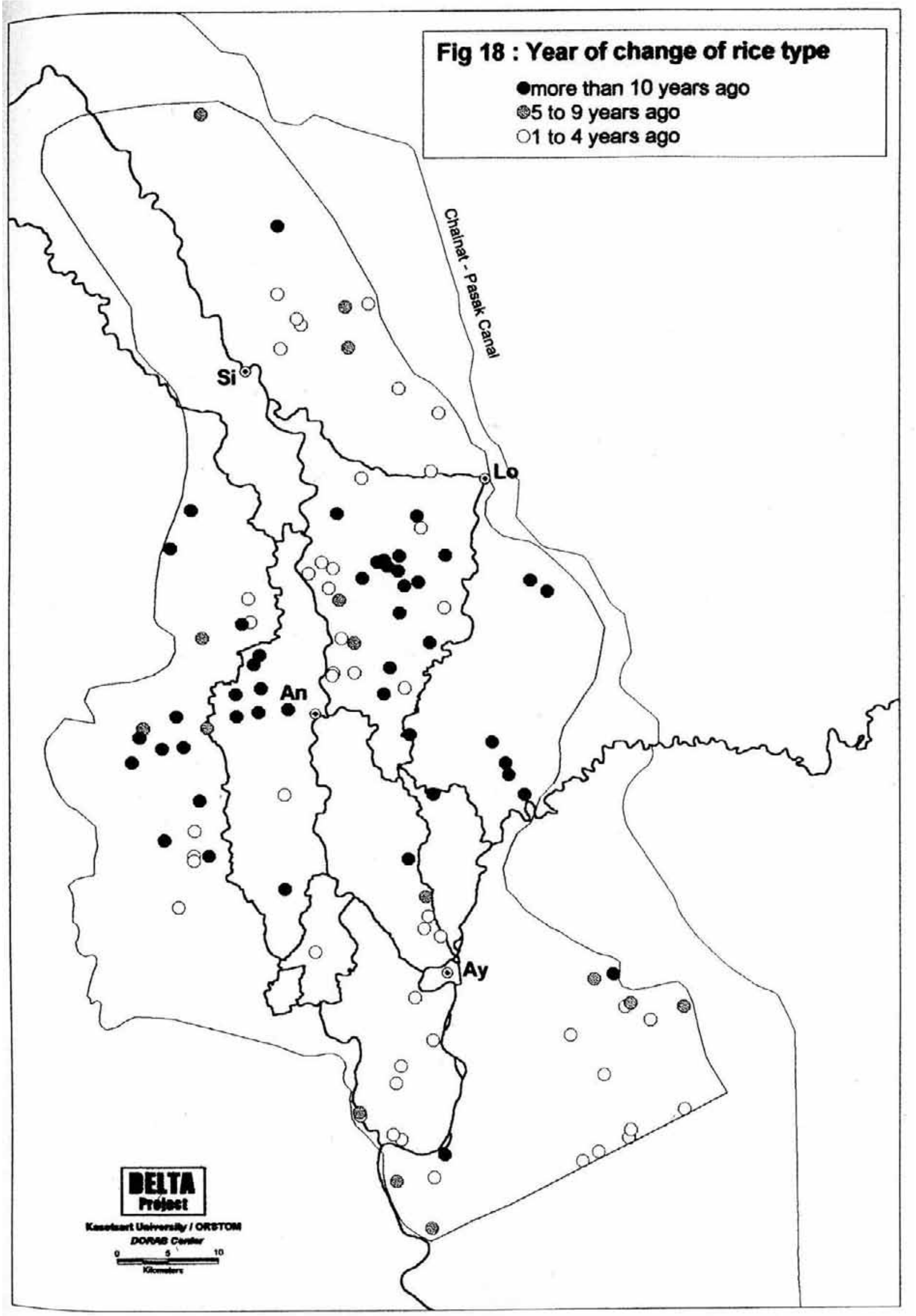


Fig 18 : Year of change of rice type
more than 10 years ago
5 to 9 years ago
1 to 4 years ago
Chainat - Pasak Canal
Si
Lo
An
Ay
DELTA
Project
Kasetsart University / ORSTOM
DORAS Center
0
5
10
Kilometers

Rice variety changes

80 varieties were mentioned by farmers when asked about strains cultivated in the past, against 60 cultivated at the present time (lists are given in the annexe). If we consider only the varieties which represent each more than 1 percent of the total, we can make the following observations :

- one variety disappeared : *Jed ruang* (group A)
- three varieties are hardly cultivated : *Puang ngen*, *Nang ngam* and Khao *Pom*[10] (group B)
- five varieties are grown less, but are still common : *Luang Pra Than*, *Luang kaset*, *Khao Tah Haeng*, *Khaw luang* and *Puang*, (group C)
- three varieties are cultivated more now than before : *Pin Gaew*, *Kon Kaew* and *Leuang Pratew* (group D).
- The last main varieties which are used now were almost not cultivated before. They are : *Leuang phan thong, Hoom thung, Khao meltek, Puang thong, Khao Suphan* and *Mali thong* (group E).

On the whole it can be stated that there has been a significant reduction in the number of traditional varieties used. 43 varieties mentioned as being used in past times were not found in the sample of actual varieties in use. A few varieties make up the bulk of the cropped area, a few of them being new varieties.

2.1.3.3 Choice of varieties

Very little information could be obtained concerning the varieties which have almost or completely disappeared. Two reasons for their disappearance were given : the low yield of these varieties and their low price. This is notably the case for all the varieties with short grain (*met san*), which fetch lower prices in the market because of the evolution of the demand and consumers' preferences.

The varieties of the group C are still cultivated by the farmers because of their good price, their specific disease resistance, and their high price.

In the case of the other varieties which are grown more now than before (group D and E), the main reasons of farmers choices are :

- a good yield, a high price, diseases resistance,
- and also : a low harvesting cost (*Leuang phan thong* and *Leuang Pratew*), a good taste for consumption (*Pin Gaew*) and because rats do not eat these varieties (*Leuang phan thong* and *Kon Kaew*).

On the other hand, some varieties are said to have been abandoned because of their

[10] This variety is the same that Metsan (Kupkanchanakul, pers.com.)

sensitivity to pest (eg : *Khaw luang*, sensitive to rats).

As stressed above, the characteristics of the water regime are also very important in the choice of the variety : maximum water depth and flooding duration are two main parameters of the water regime. They are now partly controlled by the dikes/regulators of each box. For example, boxes with flooded conditions until January but rather limited water depth, such as Salai or Muang Tia, will chose some deep water variety of long duration (with late flowering date). This area (Yangmanee and lower Chanasutr) is harvested very late but is not deeply flooded : the reason is that these boxes are drained quite late.

The change in hydrology drove a shift from FR to DWR : For example *Khao Pom, Puang, Lep Mue Nahng, Luang Pra Than gave way to Leuang Pratew ; Hom Thung, Nang ngam, Puang ngen* and *Khaw luang* to *Leuang phan thong* and *Khao Tah haeng; Khaw luang* and *Jet Ruang* to *Kon Kaew*. In other instances a shift from *Leuang Pratew* and *Puang Thong* to HYV was observed.

In one place a significant change from *Puang nak* to *Pin Gaew*, and further to *Leuang Pratew* is illustrative of the evolution of the water regime.

It may be the place to add a remark on the traditional classification of rice varieties in 3 categories : early maturing ("bao"), medium maturing ("klang") and late maturing ("nak"). Although these categories are said[11] to correspond to rice varieties of duration of, respectively, 2-3, 3-4 and 5-6 months, interviews with farmers provide ample evidence that these categories - or rather the way farmers use the terms *bao, klang, nak* - are rather relative. Medium-to-long cycle varieties, for example, can be referred to as "light (*bao)*" by farmers, relatively to very "heavy (*nak*)" strains, while for other farmers they will be "heavier" (*nak kwaa*) than other shorter varieties used in higher land.

2.2 Yields

The average yield has been computed only for the main varieties. It must be noted however that the question referred to the "normal" year yield, regardless of possible damage by drought or flood. The answer to this question is admittedly biased by the yields of former years ; some farmers having had, for example, very poor yields in the last two years are likely to report values less than the overall average.

However, the average values given here are likely to be closer to the "yield in a normal year" than to the average value, which should also consider years with failure. The frequency and degree of crop failure are rather site-specific and difficult to assess through a questionnaire. Two other questions about the yield in "bad years" and in "good years" were also asked when the informant was found to give a

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[11] See for example (Thailand, 1930), with a classification of farmers in the beginning of the century : khaw bao ripens in 2 ½ months from the time of planting, 3 or 4 for khaw khlang and 5-6 for khaw nak. Another reference to khaw bao as pre-monsoon rice is also common. See for example (Graham,1904), who states : "Two crops of rice are habitually raised each year in the plains of Siam, the first called " Kao Bao," or light crop, and the second, " Kao Nak," or heavy crop. The " Kao Bao" is planted on irrigated land before the appearance of the rains in the plains, often as early as February, and is reaped in May or June. The "Kao Nak," is planted between July and September, and is reaped in December or January. The " Kao Bao" crop in no case amounts to very large quantity of rice."

straightforward and clear answer to the first question. Because of few answers to the question about the yield in “bad years”, no statistics could be derived.

While the average "normal yield" for all the farms which answered both questions about “good years” and “normal years” is 38 thang/rai, the average value corresponding to the "good years" is 50 thang/rai. For the whole sample (of TVs), the average yield is 41 thang/rai (1 thang (10 kg ; 1 ha = 6.25 rai), which tends to confirm the hypothesis that average yields given bellow correspond rather to a "normal year" and, therefore, are overrated relatively to a long term average which includes crop failures.

As expected, the yield is well differentiated between the three categories of rice (Tab. 2) :

1. First, the HYV, with a mean of 70.5 thang/rai,
2. then the DWR varieties, with a mean of 45.5 thang/rai, which is close to the general mean,
3. and lastly the FR varieties, with 38 thang/rai.

Table 2 : Average "normal year" yield, by type of rice

Rice type	**Variety**	**Yield (thang/rai)**
Floating rice	Hom thung	40.5
	Pin Gaew	36
Deep water rice	Khao Tah Haeng	48.5
	Kon Kaew	44.5
	Leuang phan thong	44
	Leuang Pratew	45
All traditional varieties		41
High yield varieties		70.5
All varieties		44

The overall average value for the traditional varieties is 41 thang/rai. This value is similar to the one reported in Kasetsart University/ORSTOM (1996), based on figures at the *tambon* level coming from the NRC2D database, where average yields of TVs in the Central Plain vary between 20 and 30 thang/rai (for FR; our average is here higher) and between 30 to 50 thang/rai (DWR).

They also are in agreement with values recorded by Charoendham et al. (1993), who exhibit average yields by Changwat ranging from 35 thang/rai (2.1 t/ha), for Ayutthaya to 55 thang/rai (3.3 t/ha), for Sing Buri.

With the restrictions mentioned on the validity of the yield values, we may also look at the distribution of yield. For DWR, the 30, 40 and 50 thang/rai values are most common, with a few examples of yields close to HYV' yields. For FR varieties, the distribution is shifted[12] left by around 10 thang/rai.

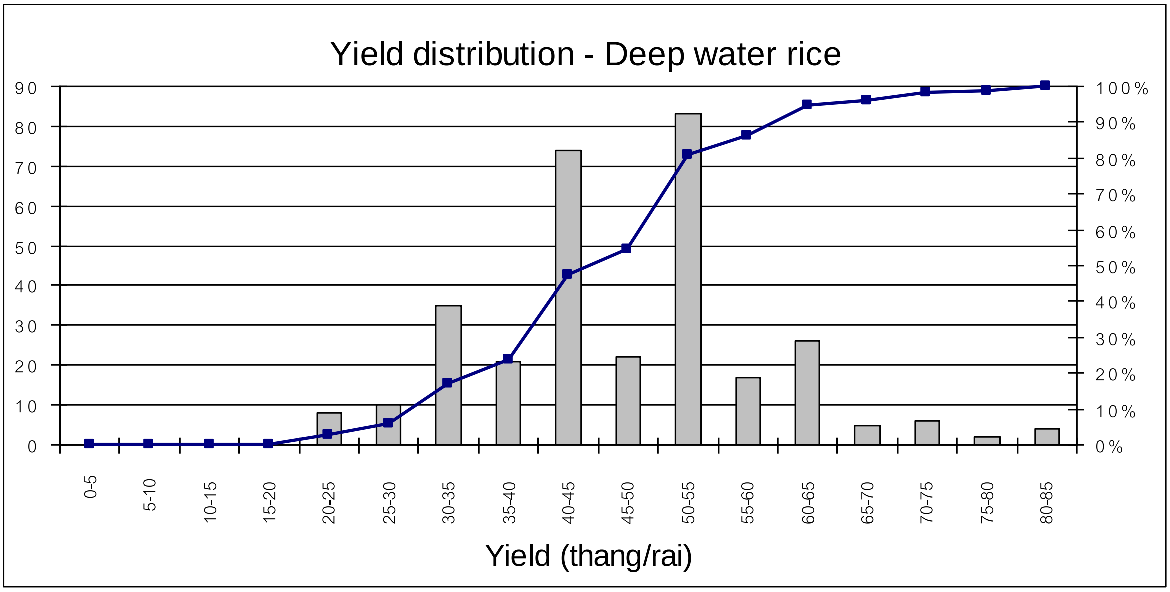

Fig. 19 : Yield distribution of deep water rice

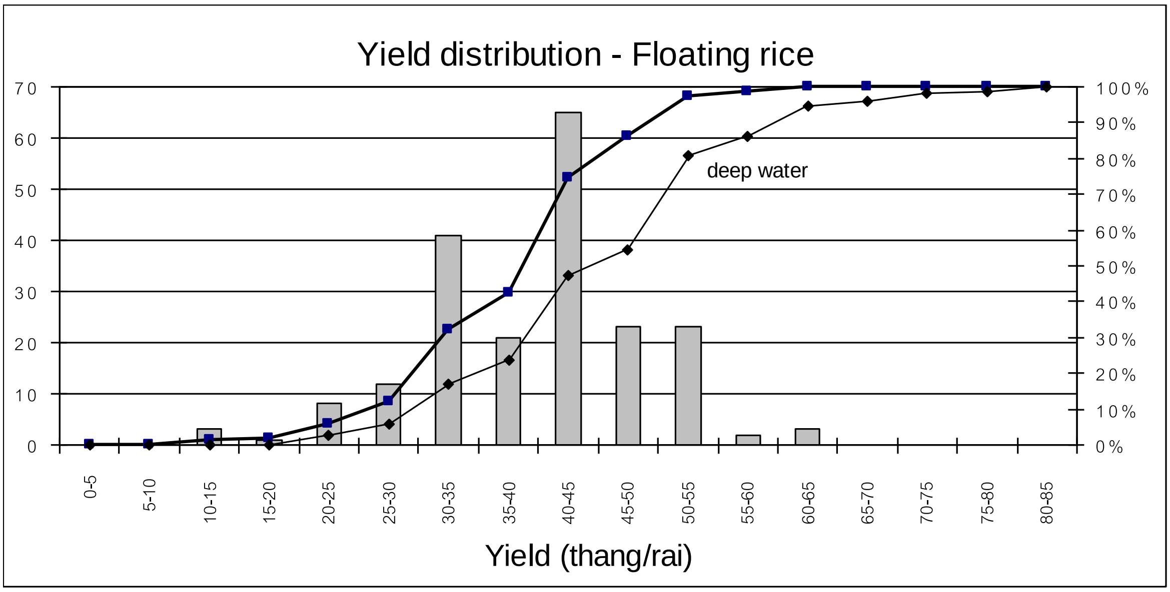

Fig. 20 : Yield distribution of floating rice

[12] The "hole" observed in these distributions is due to the fact that farmers tend to mention rounded values, firstly multiples of 10.

The spatial distribution of yields over the whole area gives little information. No specific zone with higher yields seems to stick out, apart from the ones where HYV predominate (for example the north of Sing Buri or between the Chao Phraya and Lop Buri rivers). On the contrary, the areas showing the lowest yields are the ones with a majority of floating rice (for example the south-east of Ayutthaya).

In the case of TVs the micro-topography has a very severe impact on yield. Micro-depressions will tend to have pounding water in case of medium to high rainfall while, conversely, high spots will be disadvantaged in case of dry spells. Such occurrences are common and yields vary accordingly.

2.3 Agricultural practices.

2.3.1 <u>Land preparation and crop establishment</u>

2.3.1.1 Sowing method

Rice farmers use two main sowing methods : dry broadcasting (*wan haeng* or *wan samruai*) and wet broadcasting (*wan nam tom*).

The dry broadcasting method (DB) is used more frequently (75 %), and we have the same differentiation that we observed for the yield (Tab. 3) :

- all HYV are sown with the wet broadcasting method (WB),
- dry broadcasting is commonly used for deep water rice varieties, but the percentage of wet broadcasting is higher than the average of 25 %,
- most of the time farmers use dry broadcasting (DB) for the FR, especially for the Pin Gaew variety (98 %), due to its location in lower parts.

The wet broadcasting method (WB) is widely used on the western border of the study area, and also between the Chao Phraya and Lop Buri river. In this last sector, DB and WB are both used.

Table 3 : Sowing technique, by rice type and main varieties

Categories	Variety	% Dry broadcasting	% Wet broadcasting
Floating rice	Hom thung	85	15
	Pin Gaew	98	2
Deep water rice	Khao Tah Haeng	58	42
	Kon Kaew	66	34
	Leuang phan thong	75	25
	Leuang Pratew	65	35
High yield varieties		0	100
All varieties		75	25

In fact, these considerations are widely biased by the fact that in the case of dry-season (DS) cropping, the ensuing wet season TVs are sown with wet broadcasting. Therefore the main technique used will be dry broadcasting in an area with infrequent dry-season (DS) cropping and wet broadcasting in the opposite case. The choice of cropping technique is in fact governed by water availability, the occurrence of DS cropping and the variety used, giving the following cases, distributed along the toposequence (Molle, 1999) :

- Higher land, HYV are grown with wet broadcasting exclusively, irrespective of the cropping intensity (from 1 to 3)

- Land with DWR (slight risk of flash flood) but good access to irrigation canal, therefore resorting to wet broadcasting. In case of DS cropping, HYV and wet broadcasting will be used.

- Land with DWR/FR but poor access to irrigation water, where dry broadcasting is preferred. In the (unusual) instance of DS cropping (HYV), however, both crops will be grown with wet broadcasting.

- Land with FR/DWR and no plot conditions for DS cropping will grow only one crop with dry broadcasting.

Therefore we may have particular situations of TVs established with wet broadcasting : DWR/FR after DS crops, or DWR with good access to irrigation water (even if no DS crops), which invalidate the correspondence between dry broadcasting and TV.

Consequently the mapping of cropping techniques appears to be delicate, as they are tightly correlated to the intensity of DS cropping, itself a rather hectic variable in both space and time.

2.3.1.2 Change of sowing method

The main change of cropping technique of the last years is the shift from transplanting (TP) to wet broadcasting, driven by labour shortage (Kasetsart University and ORSTOM, 1996). Though the yield may be slightly better with transplanting (especially if levelling is insufficient), farmers changed because transplanting requires too much labour force, most of the time either not available or non-affordable.

Another trend is the diminution of dry broadcasting, replaced by wet broadcasting. This has come alongside increased water control and land development. However, this change is almost absolutely correlated[13] with the engagement in dry season cropping (se above) : while the bulk of farmers who had plot conditions suitable for transplanting shifted to wet broadcasting, all the ones who were growing traditional varieties with dry broadcasting *could not* engage in dry-season cropping *without*

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[13] This statement is relative to areas with TVs in the wet season, not for others which grow HYVs all year round.

drastic changes : plot levelling, bunding, ditch digging and, often, investment in pumps or two-wheel tractors. This was made necessary by the fact that dry-season cropping can be carried out only with wet broadcasting (no rain is available for crop establishment) and HYV.

At the end of the dry season-cropping period, say July, it is too late to start a crop with dry broadcasting and the plot conditions (soaked soil, remaining field wetness) make it natural to start wet-season cropping with wet broadcasting. In addition, using dry broadcasting at a late date would result in endangering rice seedlings (higher risk of submergence, especially in lower plots). *That is why all the farmers who grow traditional varieties resort to wet broadcasting in the rainy season, <u>if</u> they have grown a crop during the preceding dry season*.

Therefore, many farmers who normally grow wet-season rice with dry broadcasting and have adopted wet broadcasting in case of double cropping could (and had to) change of technique because of these particular conditions of field wetness and because of the land improvement carried out to allow DS cropping.

Thus, the main reasons for not giving up dry broadcasting (and/or not growing DS rice) are :

- lack of irrigation water or/and ditch to access it;
- need of investment (pump, plot levelling, 2 wheel tractors); levelling by tractor costs between 250 and 350 baht/hour;
- higher cost for land preparation if they do not do it by themselves. Land preparation for dry broadcasting costs between 100 and 150 baht/rai (average of 120 baht), while for wet broadcasting it varies between 250 and 400 baht/rai (average of 300 baht), depending on local arrangements and the relative level of availability of tractors.

There are a few exceptions to these overall evolutions. Some areas which were formerly using transplanting (and therefore had convenient plot conditions), unexpectedly moved to dry broadcasting instead of wet broadcasting (in case of single cropping). This is the case, for example, in the Pasak Tai Project, the Sao Hay Project (Saraburi)[14], and of some parts of the Roeng Rang Project (see annexe). In this latter case, this was due to worsening conditions of water supply at the onset of the wet season in the lateral canals 23 and 24. This problem has been improved by the construction of a connection between these canals and the main off-take located upstream of the Roeng Rang regulator, but this was not so far sufficient to trigger a collective move to wet broadcasting.

Transplanting has now virtually disappeared and only a few site-specific exceptions can be encountered. Another traditional technique known as *pholei* (see, for example, Tanabe 1980) has also disappeared. *Pholei* was used in low lands in which pounding water did not allow dry broadcasting. The land was puddled and wet-

[14] located out of our study area

broadcasting like type of sowing was performed. To some extent, this technique corresponded to an intensive option used in the DB dominant area. As farmers now rather tend to abandon wet-season rice or substitute it with an early DS crop, this kind of technique is gradually disregarded. Some good informants were asked whether they knew this technique and about half of the answers were affirmative. On the other hand only one farmer mentioned that it was still in use.

2.3.1.3 Sowing period

Most farmers (78 %) sow between April and June, with 30 % sowing during the month of May and 45 % in the month of June. The answers relate to the "average" sowing date, given that the year-to-year effective date depend on the rainfall pattern of the early rainy season. The remaining are later sowings (July to October).

A few varieties seem to be sown at a precise period, but the relationship between the period of sowing and the variety does not always appear clearly. However, as expected, floating varieties, located in lower locations prone to early flooding, tend to be sown first, while deep water varieties in medium-high location are sown later (they will get flooded quite late in the season). That is why we can observe that :

- *Pin Gaew* is the first variety sown in May and June,
- Then *Leuang Pratew* and *Leuang phan thong*, in June and July,
- And at last *Khao Tah Haeng* in July.

Sowing can be delayed in case of scarce rainfall in the first part of the rainy season ; however, the lower the plot, the higher the risk to see the young seedlings (or even floating rice too young to elongate) destroyed by the accumulation of water. Sowing can be delayed as late as July if rainfall is scarce or if seedlings have been lost because of dry spells and re-sowing is necessary. Double or even triple sowing are not rare.

In a few cases, the problem of pounding water has been dealt with by preparing a nursery and using transplanting.

Some people prefer to use dry broadcasting even if they may have some irrigation water in July, because they would have to pump water for land preparation, increasing costs.

2.3.2 <u>Fertilisation</u>

The rate of fertilisation in the TV rice systems is higher than commonly thought (Catling, 1992). In our study area, 28 % of the plots only were found not to apply any fertiliser : this percentage, however, is neatly different for FR varieties (43 % of plots with no fertiliser application) and for DWR, with only 18.5 % not using them. This is close to what has been found by Charoendham et al. (1993), who give a percentage of 33 % of farms in the Central Region not using fertilisers (this percentage is higher in Ayutthaya and Ang Thong provinces where the proportion of FR is higher : 35 and 58 %). Statistics from the Agricultural Census of 1993 also indicate that 74 % of the farmers use fertilisers in Ayutthaya Province.

These rates, however, are much higher than the ones reported by Puckridge et al. (1989) for the 1981/82 season : only 16 % of farmers were using fertiliser in Ang Thong and Ayutthaya provinces (predominantly FR), 29 % and 56 % in Lop Buri and Sing Buri provinces. The increase in fertiliser use is a significant feature of the intensification of deep water rice farming in the last 15 years, even though the results from application of fertiliser to deepwater rice fields are said to be unpredictable (Puckridge et al., 1989).

The three categories of rice varieties are well differentiated by the amount of fertiliser used and the rating - as one may expect - is the same that the one observed for the yield (the last column of Tab. 4 is calculated considering only the fertilised plots) :

- floating rice is the least fertilised, with a mean of 12.5 kg/rai – 22 kg/rai,
- deep water rice receive higher input : mean of 32 kg/rai – 34 kg/rai,
- HYV are the most fertilised, with 58 kg/rai (all the plots are fertilised).

Tab. 4 : Level of fertilisation, by type rice

Categories	Variety	% with no fertilisation	Fertilisation (kg/rai) all plots	Fertilisation (kg/rai), fertilised plots only
Floating rice	Hom thung	42	13	22
	Pin Gaew	33.5	9.5	17
Average floating rice		**43**	**12.5**	**22.5**
Deep water rice	Khao Tah Haeng	5.5	44	46.5
	Kon Kaew	39	22	35
	Leuang phan thong	13.5	33	38.5
	Leuang Pratew	7.5	32	34
Average DWR		**18.5**	**29**	**36**
Average TV rice		**28**	**23**	**32**
High yield varieties		**0**	**58**	**58**
All varieties		23	26	47

We can see that the more productive the varieties are, the more fertiliser farmers use and the lower the rate of non-fertilised plots is. However, it is worth noting that the variety *Kon kaew* receives two times less fertiliser than the variety *Khao Tah Haeng*, although both are DWR varieties.

Fertilisation, in traditional rice systems, was fulfilled by the natural flood which used to deposit rich natural sediments on the flood plain. To this can be added the manure of buffaloes and ducks grazing in the fields after the harvest.

The gradual "artificialisation" of the water regime, however, led to reducing or even making the natural flood disappear. Dikes have been raised along all the main river channels so that spill from these rivers is now rare and only happens in cases of exceptional floods, like in 1995/96.

The boxes are supplied mostly by inner run-off and local rainfall, bringing in few nutrients. The gradual disappearance of this natural fertilisation has been sensed by farmers, some of them mentioning that in the former time they could have 60 thang/rai (3.6 t/ha) with deep water rice with no fertilisation, whereas now they can get only 40.

This, of course, triggered a move towards chemical fertilisation, since the early eighties, with farmers resorting increasingly to commercial fertilisers. It has been observed that in many situations of deep water rice, the amount of input is exactly the same than for the HYV, i.e 50 kg (or one bag)/ rai. Details of the formula were asked only in a few cases and there is evidence that a wide range of products are used, the main ones being urea and 16-20-0.

In most cases, if the amount is around 50 kg/rai, the fertiliser will be applied in two times.

One of the main constraints in the application of fertiliser in uncontrolled flood-prone areas is the dispersion of the nutrients beyond the plot boundaries (there are no bunds or, if any, these are submerged). While this problem is mentioned by farmers, some dismiss it and state that this is not to be feared.

Several farmers using floating rice varieties reported to use fertiliser only if they fear that some flood is coming and that they want to boost their plants to enable them to cope with it.

Several farmers reported that they don't have a fixed quantity of fertiliser to apply and that it depends on their available cash ; this is noteworthy as in the area with double HYV cropping, this case is very exceptional.

2.3.3 Pest management.

Farmers referred to a wide range of pests : fungus, insects, shells, worms, rats, etc. For the insects they mentioned aphids, grass hoppers and leaf hoppers, and for the snails, only "cherry snails" (*hooy cherry*). They also complained about worms. The average number of applications of pesticide is a little bit less than one time per crop (Tab. 5). In fact the number of applications varies a lot, for instance some farmers sprayed their crops more than 3 times.

Table 5 : Frequency of herbicide and pesticide application

Categories	Variety	Herbicides	Pesticides
Floating rice	Hom thung	0.69	0.8
	Pin Gaew	0.44	1.36
Deep water rice	Khao Tah Haeng	1.25	1.06
	Kon Kaew	0.39	0.73
	Leuang phan thong	1	0.81
	Leuang Pratew	0.45	0.85
High yield varieties		1	1.07
All varieties		0.61	0.92

Regarding herbicide, the average number of applications per crop is around 0.6, and the farmers never exceed two sprays per crop.

All these numbers are not very precise as farmers have difficulties in estimating the average number of applications over the years : this is due to the fact that in many cases the applications are done in case of need rather than by prevention and, therefore, change from one year to the other. For the sake of comparison, it can be noted that chemical weed control was already widespread in the beginning of the eighties, Puckridge et al. recording rates between 77 and 99 %. "Pak bung" (*Ipomea aquatica*) is the principal weed affecting TVs.

Several varieties of pest are indicated by farmers but the most serious is - by far - the damage caused by rats. Farmers expend a lot of wit in combating them but chiefly for HYV and very rarely for traditional varieties, which are also less sensitive to rodents because of their flooded conditions.

The most common defence is the electric wire, which is laid around the plot. Small lights are added at regular space in order to warn humans of the danger. Some mentions were made of drunken people falling in the field at night and killed by the device (water provoking some short circuit). Other chose to set a small fence (20 to 50 cm in height), made of plastic or wire mesh. Some use rodenticide while others place a mixture of oil and poison around the plot (licking its fur to clean itself, the rat will ingest the poison).

Some farmers spray herbicide when the rice plants are approximately 50 cm high and when there is already some water in the field because it is convenient to reload the sprayer with water.

2.3.4 <u>Harvesting</u>

2.3.4.1 Harvesting period

The first harvests are done in November, but the rice fields harvested during this month represent only 2 % of the surveyed plots. The main period is January during which 68 % of the rice is harvested, and there is no more harvesting after the end of February (Fig. 21).

1. the first variety harvested is *Khao Tah Haeng* (DWR) : most of the fields were harvested before mid January,

2. secondly we have *Leuang Pratew* and *Leuang phan thong*, at the end of December and in January,

3. thirdly *Pin Gaew* is harvested in January,

4. lastly, two varieties are harvested in January and February : *Kon Kaew* (January and begin of February) and *Hom thung* (end of January and February).

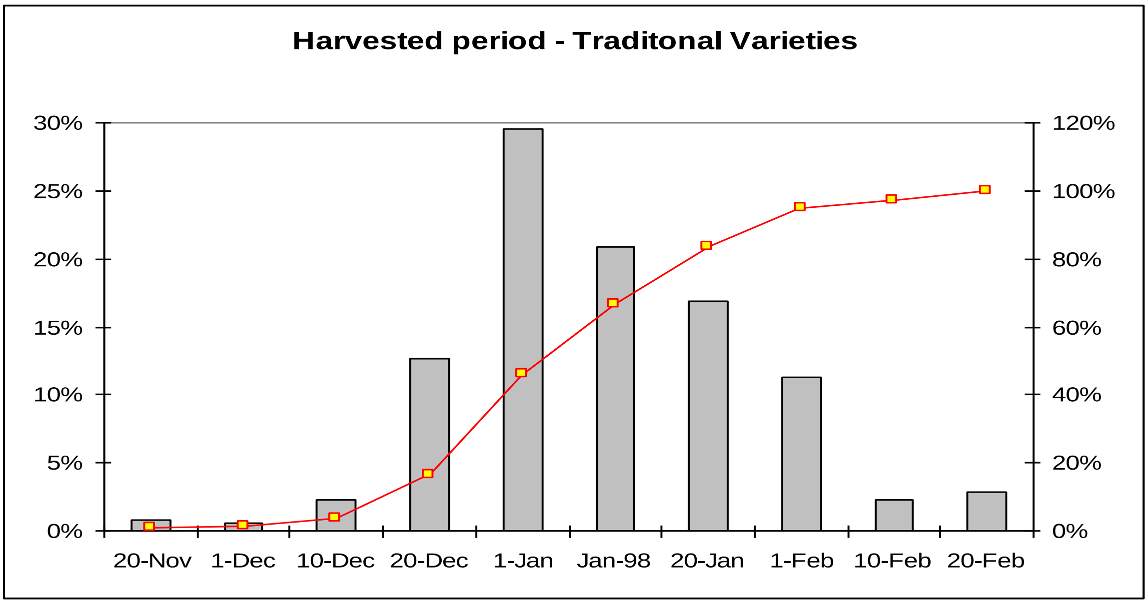


Fig. 21 : Harvest progress of all the TVs

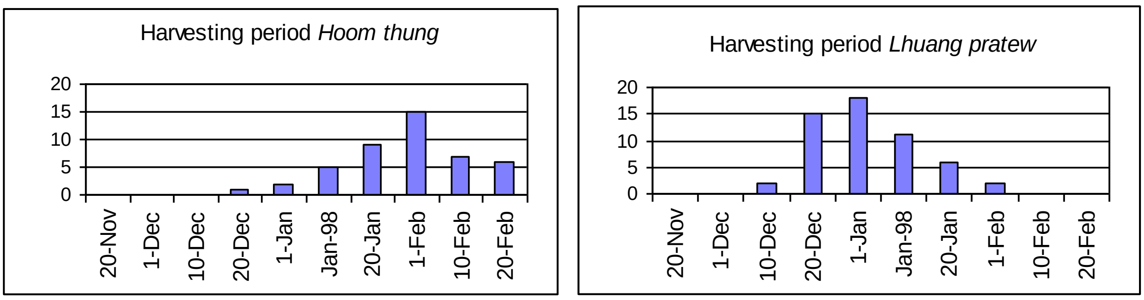
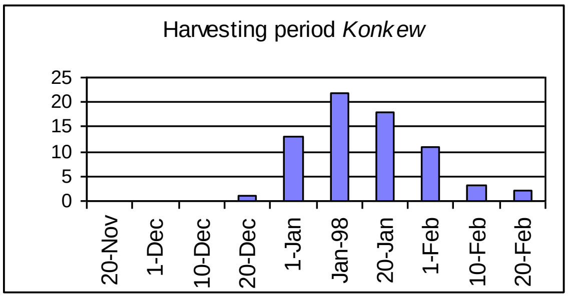
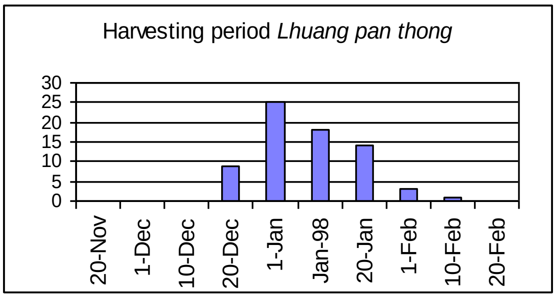
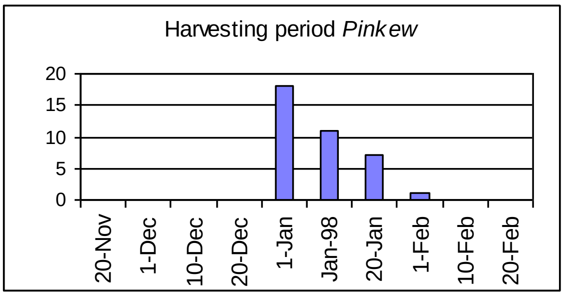


Fig. 22 : Distribution of harvesting period for the main varieties







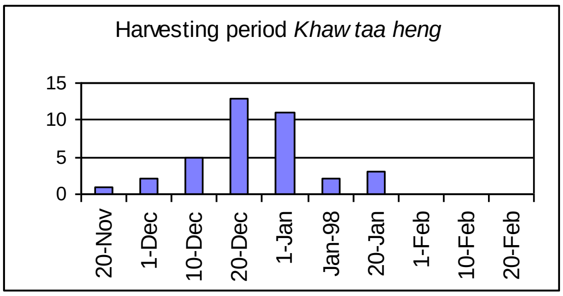


Table 6 : Flowering period of main varieties ; after (Parakrang, 1998)

Variety	Type	Occurrences in survey	Flowering	Harvesting	good water depth (cm)
Kon Kaew	DWR	99	3 Dec	2 Jan	110
Leuang Phan Thong	FR	98	1 Dec	31 Dec	
Leuang Pratew	DWR	91	14 Nov	14 Dec	90
Hoom thung	FR	69			
Pin Gaew	FR	49	27 Nov	27 Dec	150
Khao Ta haeng	DWR	47	30 Nov	30 Dec	
Khaw Luang	DWR	28	3 Nov	3 Dec	90
Khaw Metlek	FR	23	27 Nov	27 Dec	150
Puang nak	FR	21	1 Dec	31 Dec	
Puang thong	FR	19	17 Nov	17 Dec	
Puang		19			
Luang kaset		19			
Suphan	FR	14			
Luang Pra Than	DWR	13	16 Nov	16 Dec	90

If we compare the average harvesting date with the theoretical date (Table 6), there is a rather good fit for the varieties shown above, except for Leuang Pratew, which seems to be harvested one month later than the theoretical date (14 Dec).

In all cases, the harvest period of each variety appears to be much wider than expected. According to agronomic characteristics, the harvest time is fixed as 30-35 days after flowering. The dispersion observed is quite significant and probably due to the following factors (the first three ones being probably the most significant) :

1. error in farmers reports, some farmers having difficulties in specifying the date of a given event[15].

2. harvesting should normally take place as soon as the rice is ripe but constraints on labour or harvester availability may delay it for a few days. The seeds will tend to loose some water content and the selling price will probably be affected, as the quality of milling will decrease accordingly.

3. the rate of drainage of the box is slower than wished because of high water levels downstream. This delays the time in which farmers can access and/or use harvesters in their fields.

4. very late sowing. Photosensitive rice varieties have genetically fixed flowering period based on day length. However this is true for rice which reach the normal period of flowering <u>with</u> a development stage allowing it. If the rice has been established very late - as is the case in the recent years due to late DS cropping - then its development will be delayed for not having the suitable maturity to flower, even though day-length would allow it. For a FR variety, the development stages preceding flowering take a minimum of around 75 days. Rice sown after the flowering date minus 75 days, will therefore flower after the theoretical date.

5. possible differences of rice strains referred to by farmers with the same name. For example, we have *Leuang Pratew 28* (harvest time 13 December) and *Leuang Pratew 123* (harvest time 19 December); *Puang nak* 16 and *Puang nak* 26, etc.

6. slight differences of latitude between the north and the south of the study area (probably not significant).

7. another possible explanation is that farmers tend to pay little heed to late harvesting, because they were accustomed to this since the time when they were growing short grain varieties (Khao metsan), which was much less sensitive to delays of harvest. Maintaining ripe rice in water may also contribute to keeping its greenish aspect, giving the impression that full maturity is not yet attained (Kupkanchanakul, *pers. com*.).

2.3.4.2 Harvesting method

Most farmers (72 %) chose to harvest with a harvester instead of manual harvesting. The cost of mechanical harvesting is of the same order of magnitude than manual harvesting, or slightly lower in the case of HYV where it usually ranges between 320 and 400 baht/rai (lodged rice needs more care and increased time to be harvested, pushing prices up, although not in the same proportion to time increases). In the case of DWR and FR varieties, with longer straws, very often lodged, and plots in muddy or swampy conditions, the average price is higher, around 410 baht/rai.

Table 7 : Harvesting method, by rice type

---

[15] new year proved to be a good "separator" : "how many days before or after new year" was generally answered quite clearly by most farmers.

		Manual Harvesting	Mechanical Harvesting
% of plots		28 %	72 %
% of plots with TV		30 %	70 %
Price	Min	240	200
	Mean	305	411
	Max	550	450

Harvesting is still done manually in several FR areas (lodged rice with long stems) and in some specific cases, in general either because the plot is still under water (even slightly) or because the plots are small, family labour is available and farmers want to save money by harvesting by themselves.

However, there is a marked increase of mechanical harvesting in the deep water rice area, as compared with preliminary observations made 4 years earlier (Kasetsart University and ORSTOM, 1996), showing that the limitations identified (muddy clay land, lodged long-straw rice varieties) have been partly but significantly overcome.

In some cases, it was mentioned that labour force from other Changwat ("Phichit") was hired for harvesting. The costs given are quite variable, because they do not always cover the same expenditures : cutting, making sheaves, transporting them (3 baht/sheaf), threshing, food, etc.

2.4 Water regulation

2.4.1 Box regulation : overview

We have mentioned in the first chapter how hectic water regimes may - at any stage of the cycle - impact negatively on the final yield. Water regulation in the drainage boxes refers to the control of the water level : this includes the time at which water starts to rise, the steadiness and rate of increase, how constant and how long the water level is maintained at its maximum (optimal) value ; the date and rate of drainage of the box.

- Start of the season : During the crop establishment period, the box is under rainfed conditions. In case of heavy rainfall, water normally accumulates in the lower parts of the box and may impound for a while. This may cause the loss of recently broadcast seeds or impede sowing. In case of too scarce rainfall, resowing is sometimes necessary.

- Gradual rise of the water : during this phase the regulator is closed and water accumulates within the box. In case of sudden excess flow, the regulator must be opened in order to drain the excess to the river and avoid a sharp increase which could be prejudicial to DWR (or even FR if the rise is really sharp : in 1996, some FR was lost because the water level rose by 60 cm in 24 hours in some of the boxes). In other cases, some slumps are observed in the filling-up phase, as rainfall/water deliveries fail to sustain the rise of water.

Several sources of water, both controlled and uncontrolled contribute to filling up the box (Fig. 23) :

1. rainfall.

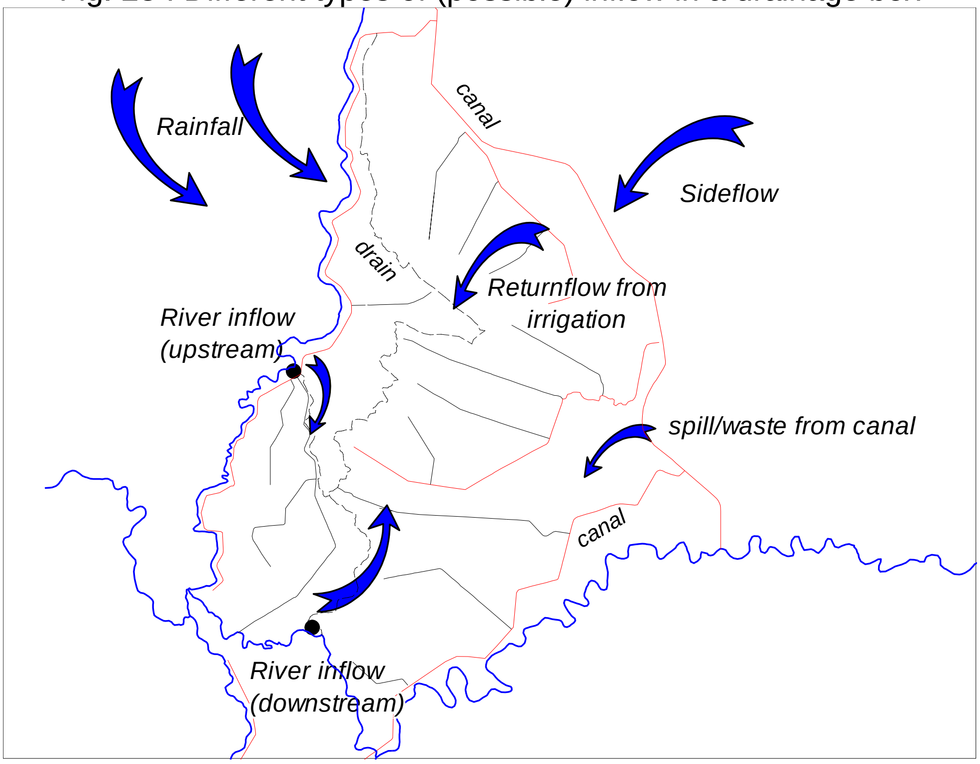
2. water from the river allowed in through the regulator(s). This is possible only if the water level in the river is sufficient, which is in general not often the case.

3. water supplied by return flow from the irrigation canals to the drainage system; this water is normally available quite late in the season (seldom before August).

4. water coming directly from the main canal (lateral spill or deliveries to the drains(wasteways)).

5. water coming from adjacent areas (side-flows) ; this applies to the three eastern boxes.

Fig. 23 : Different types of (possible) inflow in a drainage box



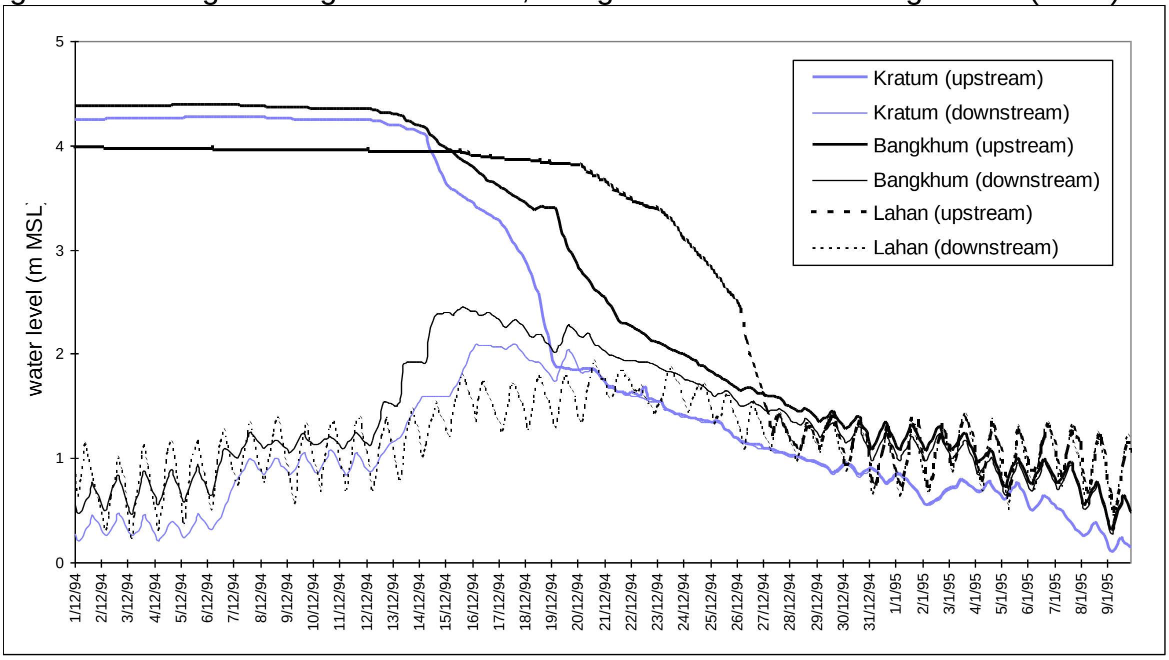
In some dry years, the sum of all these inflows may not be sufficient to fill up the box ; conversely, in wet years (or normal ones, for some boxes), the regulator may be often opened to reduce the rise of water.

- Once the regulation level is attained, the same principle is applied to control the water level : the regulator is opened in order to drain the excess water. In very wet years water accumulates beyond the desired level, while no drainage is possible because of higher levels in the river. The box must undergo an overload which can damage rice (especially HYV or DWR varieties), impact negatively on activities (industries, transport,..) and raise the risk of dike breaching.

- When comes the time of harvest, the regulator is opened, sometimes partly sometimes fully, to allow the drainage of the box. The rate of decrease depends on the box. If there is only one variety, quick drainage is desired to allow harvest of the ripe rice. If there are several, then the varieties located in the lower parts usually need water for a few more days and the rate is lower.

  The rate also depends on the downstream conditions (in the river) : if, for example, there is a strong flows coming from Wat Manee in the Lop Buri river, the *Khlong* Noi and Wat Ulom boxes located further downstream will not drain easily and the time for that operation will be lengthened. More generally, in a very wet year the drainage of the upper Chao Phraya basin may last until the end of the year, maintaining a rather high level in the river (and its arms, such as the Lop Buri river), slowing down the receding of water in the boxes. Fig. 24 shows the drainage curves of the Kratum, Bang Khum and Lahan regulators, located successively on Khlong Bang Phra Kru and draining the same box (Bang Khum); see map . It clearly shows how the upstream regulators impact on the following ones by delaying their drainage. Noteworthy, too, is the tidal effect on Khlong Bang Phra Kru, located 15 km upstream of Ayutthaya.

Fig. 24 : Drainage through the Kratum, Bang Khum and Lahan regulators (1994)



Things also sometimes get complex in case of "cascade boxes", the upper one in the chain draining successively into the lower ones. This goes together with co-ordination and is not always practicable or simple. Some farmers mentioned they are flooded when upstream people drain their plots, which relates to the case of cascade boxes.

The date of the gate opening has been reported to be decided by farmers and by heads of villages and districts. If the gate is a major one - such as Wat Manee - meetings are organised between farmers and RID staff. This date is very important in that it must be rigorously attuned to the cycle of the varieties present in the box. There, again, experience is the main guideline but farmers sometimes express frustration : the question of the collective determination of the water depth, date and rate of opening needs further inquiry, especially in the case of "cascade" boxes. While the agronomicaly fixed flowering (and harvesting) periods suggest that the date should also be fixed, year to year adjustments are deemed necessary. Apart from the reasons mentioned earlier relative to delays in harvesting, the reasons for this have not been clearly identified.

This also points out the importance of the choice of rice varieties. Any change is meant to be collective as the water regime must be adjusted accordingly.

The regulation level in each box is chosen by experience. If it is too high, irrigated plots in the upper parts will undergo problems of drainage. If it is too low, the first plots of DWR with poor or no access to the irrigation canal will be deprived of water. Farmers judge the situation by experience, based on the water level in their fields : "If I have only 50 cm of water in my plot, I know that other higher portions of the box will lack of water". When local conditions change, farmers may feel and request that the regulation level be altered, as it sometimes happened (see below).

Many farmers mentioned that the water regime was better in the past because it brought natural fertilisation altogether, because "water had no owner" ("*nam may mi jaokhong*") and could flow freely (less roads, dikes, etc), while one reckoned that rainfall was more certain.

Conversely, others acknowledged that the present situation is better because water is controlled, its level does not fluctuate too much during the wet season and it does not untimely recede.

2.4.2 Assessment of box regulation over the last 10 years

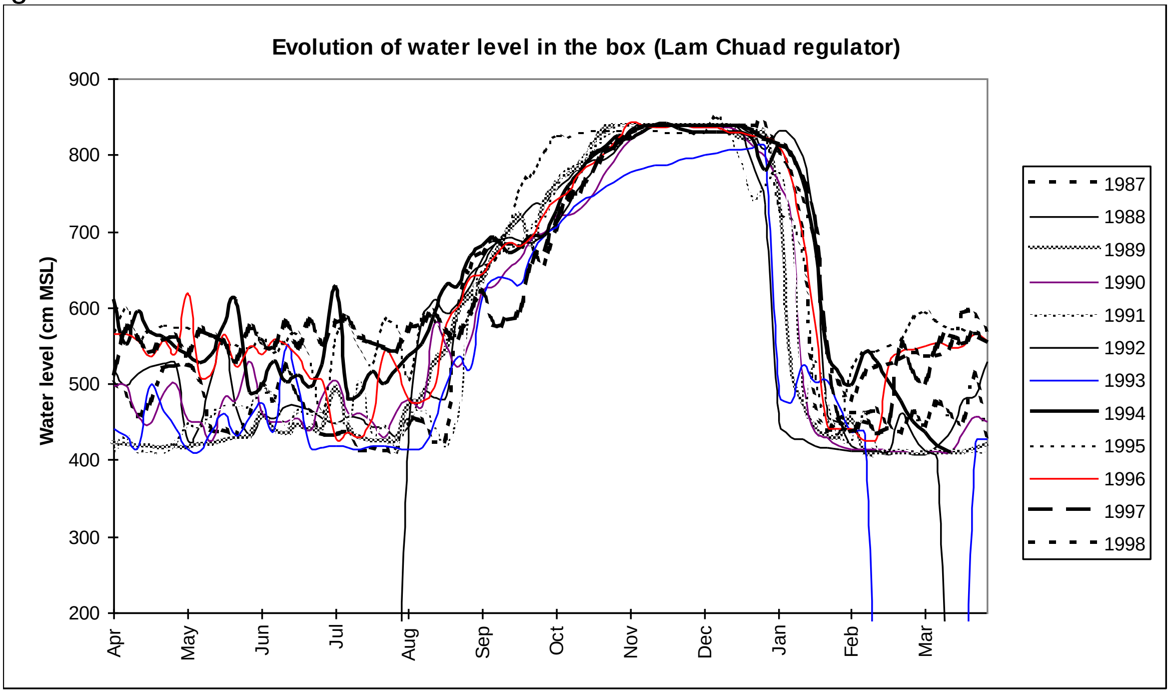
To what extent the dikes and hydraulic structures allow a sound control of the different phases of drainage regulation described above can be addressed by looking at the 10 years series of data collected for each main regulator.

2.4.2.1 Variability of the different phases : examples

We can divide the whole period in four phases : the crop establishment, the box-filling, the optimum level regulation, the drainage of the box.

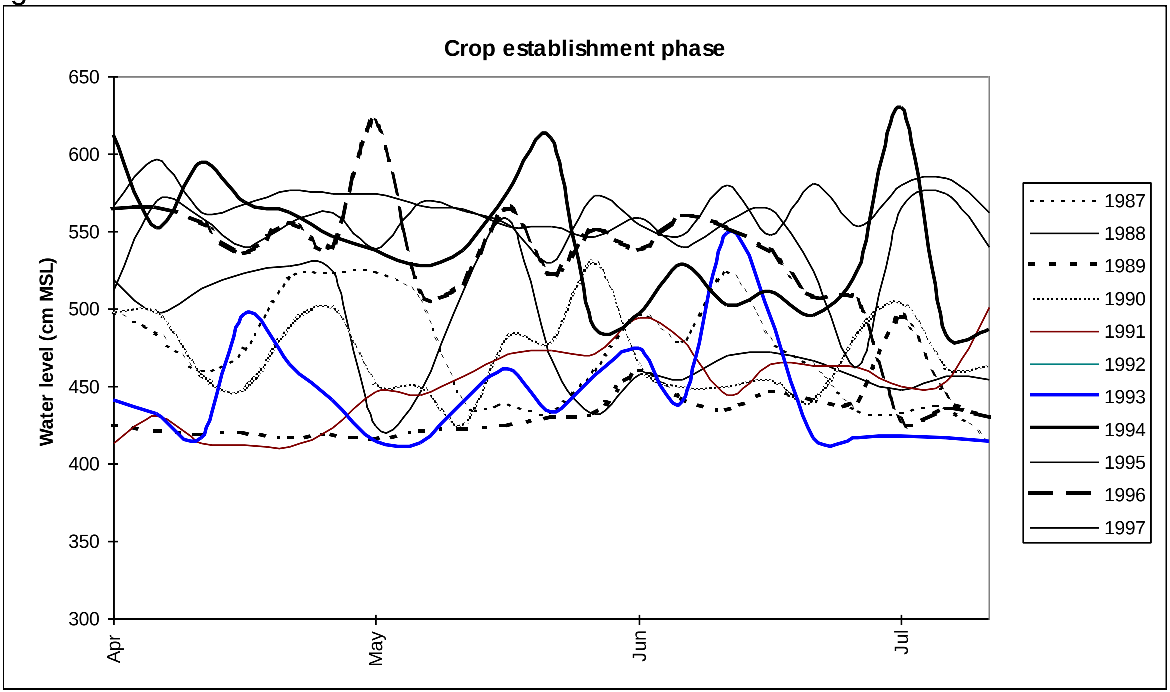
Fig. 25 to 28 provide an example of the different curves obtained over ten years for the Lam Chuad regulator. Even though the overlapping of the different curves does not allow a clear vision of the evolution in each year, these figures provide hints of the year-to-year variability. It must be noted, however, that the water levels shown are the levels in the drain. They may differ from the water levels in the fields, especially at the crop establishment phase. Unfortunately, there is no record of such data at the plot level.

Fig. 25 :



Evolution of water level in the box (Lam Chuad regulator)
Water level (cm MSL)
900
800
700
600
500
400
300
200
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998

Fig. 26



Crop establishment phase
Water level (cm MSL)
650
600
550
500
450
400
350
300
Apr
May
Jun
Jul
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997

During the first phase, the water level is much less regular than expected, with oscillations which probably mirror the state of the drain rather than of the fields. During the filling up of the box, starting approximately in late July, the increase rate is not very regular in August (with even some drops, like in 1997), gets more steady in September and the optimum level is reached near the beginning of October. The year 1988 is an exception, with the optimum level reached much before normal, while, on the opposite, in 1993 (a dry year), it cannot be reached.

Fig. 27

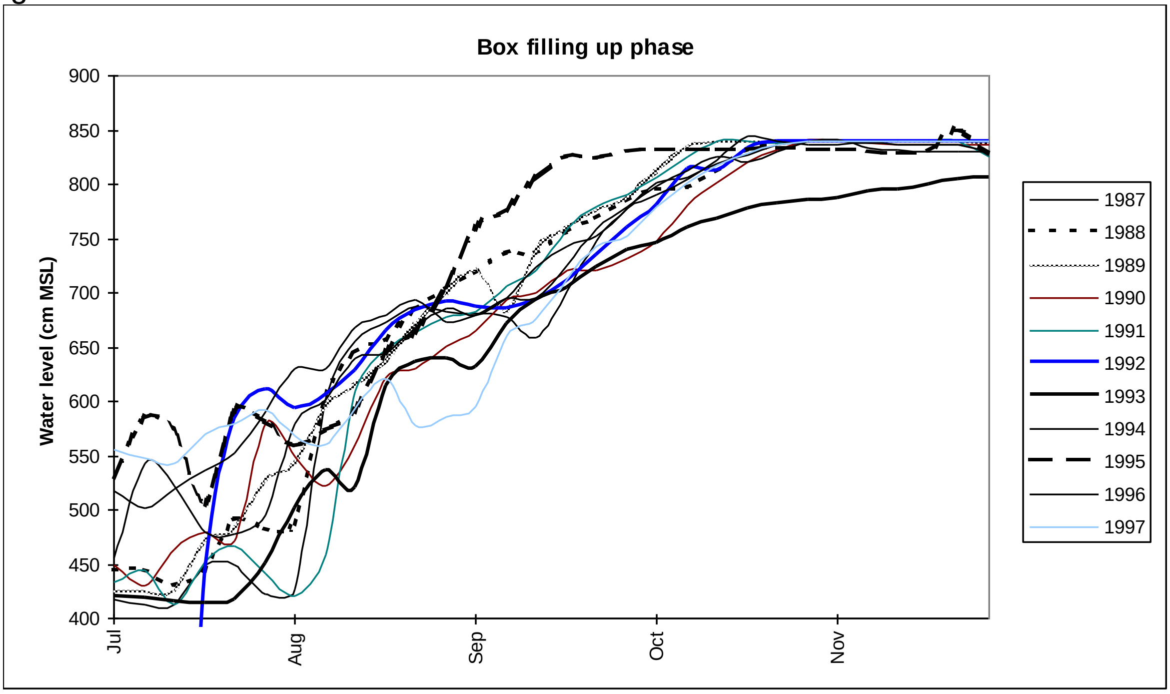
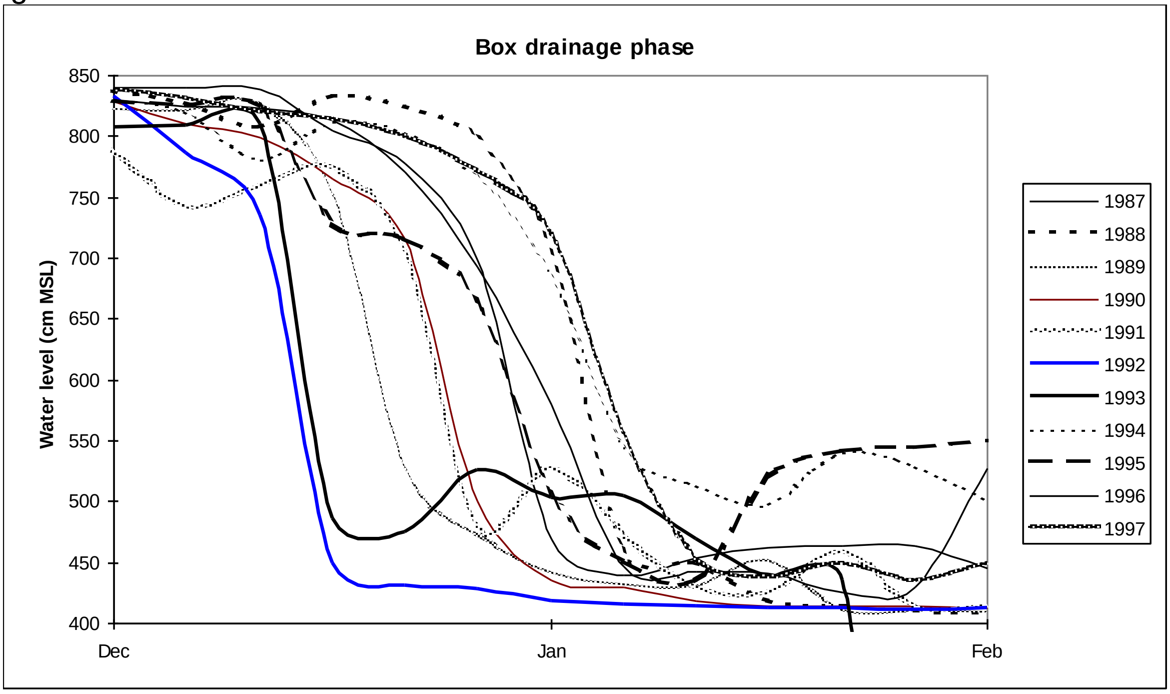


Fig. 28 :



The phase of drainage shows that while the gate opening seems to occur in the mid of December, it takes between 5 days and two weeks to drain the box. These differences may be partly explained by the varying downstream water level which modifies the discharge of the regulator. It is not clear, however, whether it also partly corresponds to a will of officers and/or farmers.

Fig. 29 and 30 provide similar sets of hydrographs for the Salai box and Saladeng boxes. For the Salai box, the filling-up phase is quite irregular but the regulation level is attained in most years (1990 sticks out as very irregular) ; drainage starts around the 15th of December but, in some years, it seems to be delayed until the end of the month.

Saladeng box, in contrast, is much more regular regarding the filling phase. Drainage is later than in Salai, quite regular too but with a similar delay in some particular years. The analysis of the water level in the Chao Phraya river shows that these delays are not due to high downstream levels in the river.

2.4.2.2 Regulation levels

For each box, a complete graph of the variation of the water level over ten years is presented in the annexe. These hydrographs also allow one to pinpoint some changes in the regulation of the water level, both in the dry and wet seasons.

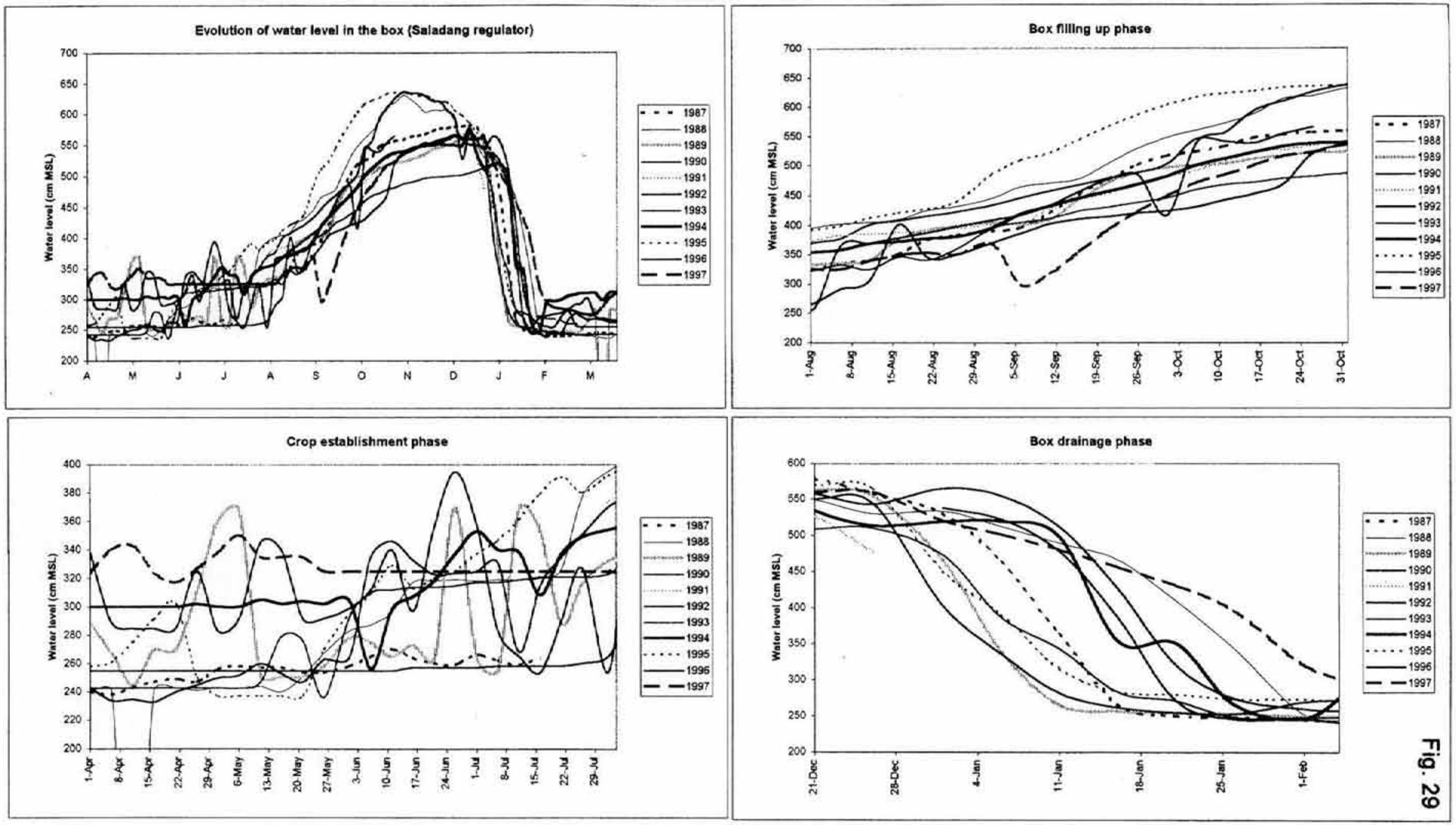
The water level in the **dry season** used to be allowed to attain its lowest level : the regulator would remain open and the drain would dry up. In the past few years, a sensitivity towards developing secondary resources to be used in DS cropping has strengthened. Most of the new drain regulators have been principally designed to store water in successive reaches of the main drains. They are closed when all fields have been allowed to drain, but before the water level drops. The drains thus trap the very last drainage flow and, possibly, also collect later sub-superficial run-off.

Changes in regulation are clearly visible in the hydrographs relative to Lam Chuad (from 4.00 to 5.50 m), Wat Manee (2.30 m to 4.50 m), Saladeng (2.50 to 3.00 m). It must be noted, and it is probably the reason why this policy has not been implemented before, that retaining water in the drain goes against the wish and interest of fishermen, who wait for the water to recede to capture fish after the rainy season. Fishing is a traditional activity of most farmers at that time.

In the **wet season**, too, an (opposite) trend exists, towards lowering the regulation level. This corresponds to three main phenomena.

0. *The development of intermediate drain regulators.* The Wat Ulom box provides a good example of change. While the regulation level ten years ago was around 5.20 m, it was later decreased to 4.50 and 4.00 m. 5.20 m was the level made necessary to expand the water body up to remote and higher parts deprived of irrigation facilities, without which these would face dry conditions ("*thii don may kin*" !). In fact higher lands would often complain of insufficient water, while the lower ones would be plagued with excess water. A solution was later provided by building intermediate regulators allowing local control and "adding steps" to the cascade boxes (Fig. 31).

1.



Evolution of water level in the box (Saladang regulator)
Water level (cm MSL)
700 650 600 550 500 450 400 350 300 250 200
A M J J A S O N D J F M
Box filling up phase
Water level (cm MSL)
1-Aug 8-Aug 15-Aug 22-Aug 29-Aug 5-Sep 12-Sep 19-Sep 26-Sep 3-Oct 10-Oct 17-Oct 24-Oct 31-Oct
Crop establishment phase
Water level (cm MSL)
400 380 360 340 320 300 280 260 240 220 200
1-Apr 8-Apr 15-Apr 22-Apr 29-Apr 6-May 13-May 20-May 27-May 3-Jun 10-Jun 17-Jun 24-Jun 1-Jul 8-Jul 15-Jul 22-Jul 29-Jul
Box drainage phase
Water level (cm MSL)
600 550 500 450 400 350 300 250 200
21-Dec 28-Dec 4-Jan 11-Jan 18-Jan 25-Jan 1-Feb
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997

Fig. 29

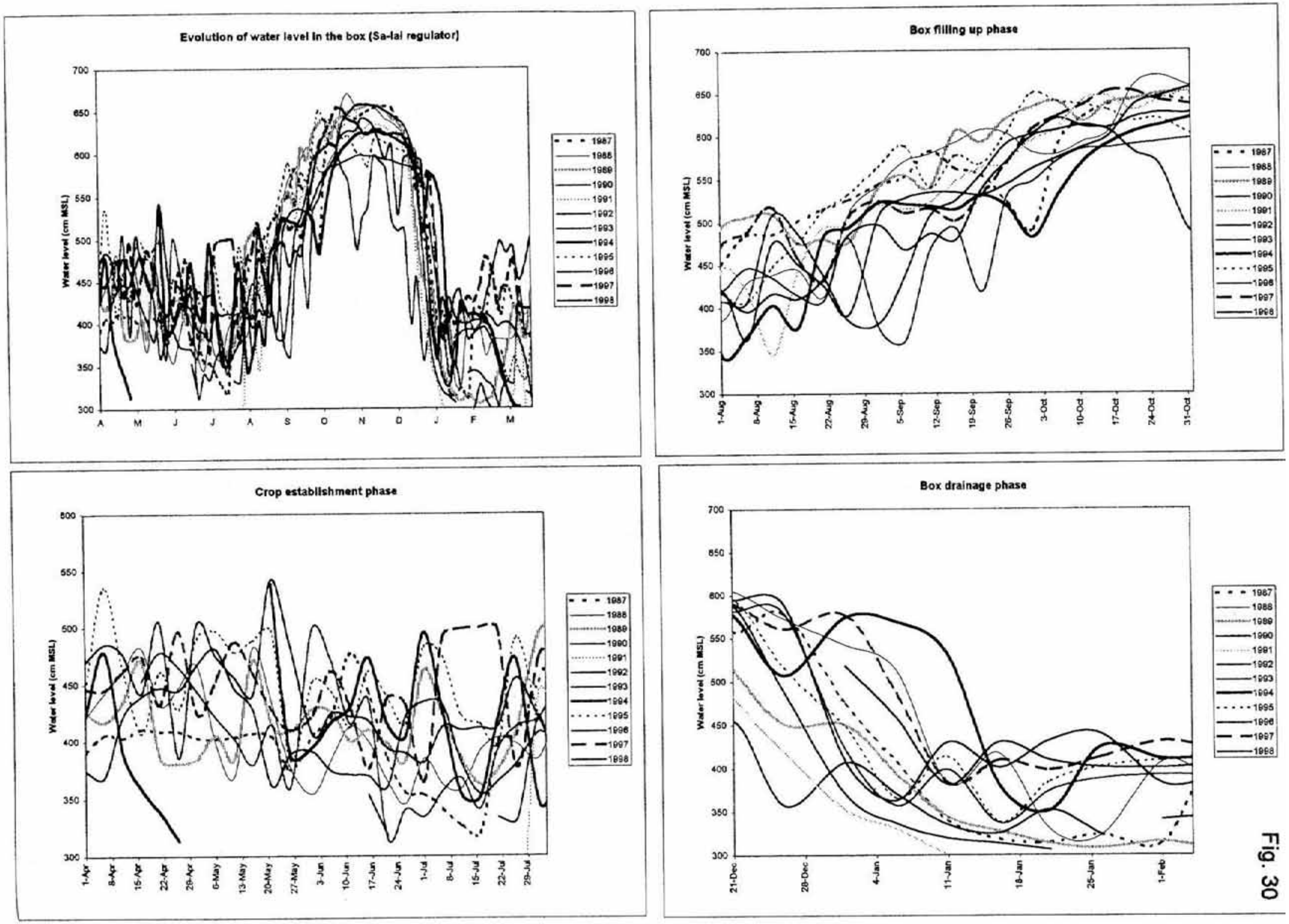

Evolution of water level in the box (Sa-lai regulator)
Water level (cm MSL)
700
650
600
550
500
450
400
350
300
A
M
J
J
A
S
O
N
D
J
F
M
Box filling up phase
1-Aug
8-Aug
15-Aug
22-Aug
29-Aug
5-Sep
12-Sep
19-Sep
26-Sep
3-Oct
10-Oct
17-Oct
24-Oct
31-Oct
Crop establishment phase
1-Apr
8-Apr
15-Apr
22-Apr
29-Apr
6-May
13-May
20-May
27-May
3-Jun
10-Jun
17-Jun
24-Jun
1-Jul
8-Jul
15-Jul
22-Jul
29-Jul
Box drainage phase
21-Dec
28-Dec
4-Jan
11-Jan
18-Jan
25-Jan
1-Feb
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998

Fig. 30

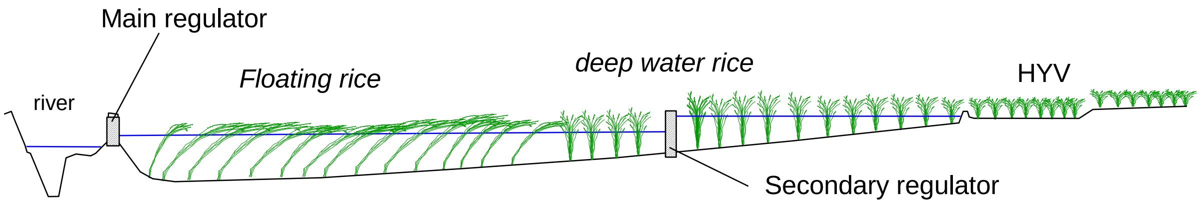
2. Twelve new structures have been built in the last 6 years, as part of a royal initiated project (see later section).

3. *An overall decreasing trend in the water regime*. Both rainfall in the delta and average monthly inflow at the apex of it show declining trends.

4. *A gradual development of on-farm infrastructure in the high land, allowing them to access irrigation supplies.*

In a context of decreasing water (the regulation water is not attained each year) and if a shift to HYV is not possible the lower locations are preferred ("thi lum di kwaa"). In fact some farmers reported to have lost some of their crops located in the highest parts because of insufficient water.

Fig. 31 : Adding intermediary regulators for better local water control



In addition to the case of Wat Ulom mentioned above, other boxes are known to have undergone modification of their regulation level : the Bang Khum box, which used to have a regulation level of 4.80 m in the 1986-89 period, is now regulated around 4.50 m (Wiel, 1996). The Ban Chomsii regulator, formerly regulated at 13 m MSL is now fixed around 10.5 m. It is possible, too, that the regulation level of Wat Manee was reduced, from 7.75 m in the seventies (ILACO, 1980) to around 7.50-7.20 m at present. Regulation levels given 20 years ago by ILACO, based on zoneman surveys, for the Salai and Muang Tia regulators, are also higher than the values in use nowadays : 7.00-7.50 and 6.00-6.50 m MSL against 6.50 and 5.75 m. A more detail analysis of the changes occurred in the different boxes could be made through the collection of 20 years data or more, instead of the 11 years considered here[16].

These changes would deserve to be more documented, to allow the understanding of how they originated, who proposed them and how they were eventually agreed upon. In the case of Wat Ulom, meetings were held to discuss the changes brought about by the royal project. In the case study documented by Molle and Keawkulaya (1998), one of the concerned *Kamnan* (head of district) was the initiator of the change and convened all the village heads of the area for discussion and common decision.

[16] But, this represent a quite considerable amount of data, probably not available for all boxes.

2.4.3 Water balance : where does the water in the boxes come from ?

The comparison of similar data for the different (main) boxes shows that while some have no problems in reaching the regulation level, others are more sensitive to hydrologic variations. Many factors account for such differences, including :

1. the size and geometry (shape) of the box.
2. the respective percentage of (1) rainfall/inner run-off, (2) supplies from the irrigation network, (3) sideflows (water entering the box), and (4) inflow from the river (through the drainage regulators), which make up the total inflow.
3. the ratio between the box capacity and the average inflow.
4. the obstacles which hamper run-off within the box (embankments, roads, dikes...).
5. the presence of secondary gates to help retaining water in the upper parts of the box.

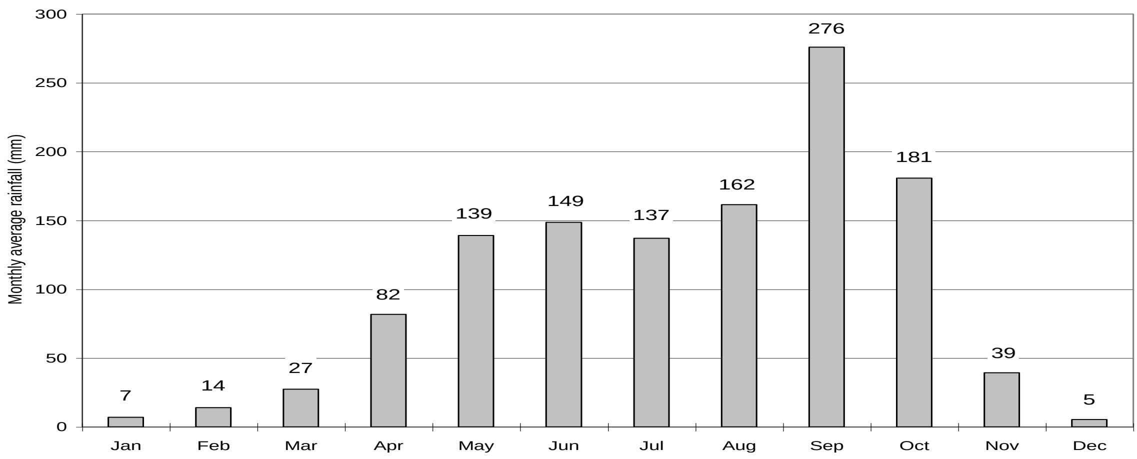
This section examines the different terms of the water balance in the boxes (Fig. 23).

2.4.3.1 Rainfall

Rainfall is rather homogeneous in the study area and varies between 1,000 to 1,200 mm, with small differences between the boxes. Table 8 provides the yearly average total of each box obtained by drawing Thiessen polygons and overlaying them with the box map.

Not all of the rainfall contributes to filling up the box, as shown above. In particular, the precipitation between April and July is mostly absorbed by the soil, as in rainfed conditions. This represents approximately 45 % of the total yearly rainfall. Fig. 32 shows, as an example, the distribution of the average monthly rainfall at Ang Thong station, with a yearly average of 1218 mm.

Fig. 32 : Average monthly rainfall at Ang Thong (1952-1996)



To have a rough idea of the importance of rainfall in the filling up of the boxes, we calculated an index as *[0.5*average yearly rainfall*area/ box capacity at regulation level].* This index is a mere proxy of the rainfall contribution and must not be taken as the real contribution : in boxes non completely flooded, such as the Salai box, only the remaining run-off should be considered ; in addition, 50 % is a crude estimate of the "effective" rainfall.

One difficulty arises from the fact that there are two ways to estimate the storage capacity of the box. We may consider the average regulation level and use the Digital Elevation Model to calculate the corresponding volume. This, however, will stand for the water body near the main outlet of the box. It will not capture the amount of water retained by secondary upstream regulators. In some cases (Lam Chuad, Salai, etc), the difference may not be very large but in others (Wat Ulom, Wat Manee), the storage volume will be grossly underestimated. We therefore calculated two values : the first one corresponds to the lower water body (and is quite precise), while the second also includes estimates of upstream "steps" based on the flooded area (approximated by the extension of the TVs).

The index varies from 0.3 to 0.55, for boxes fully flooded and rather high average water depth, to high values (from 1 to 4) corresponding to boxes partly flooded and/or with limited average water depth (Table 8). In all cases, rainfall appears as a significant contributing factor, with a high contrast between the boxes.

2.4.3.2 Inflow from the rivers

While some boxes partly rely on inflow from the rivers to fill up, others (such as Lam Chuad or Bang Khum boxes), never or hardly get any supply from them.

Figure 33 gives an example of management of the Salai regulator (year 1987/88). During the crop establishment [A], the regulator is set in order to maintain a low, constant level and closed in late July to allow the water level to start rising. As the increase provoked by the inner run-off is too quick, the regulator is opened during the second half of September (possibly too much) in order to relieve the box [B]. Two weeks later it is closed again to have the water level reach the regulation level. Drainage starts in the beginning of December and continues until mid-January [C] (slow drainage rate).

Fig. 33 : Regulation in Salai box (example of year 1988)

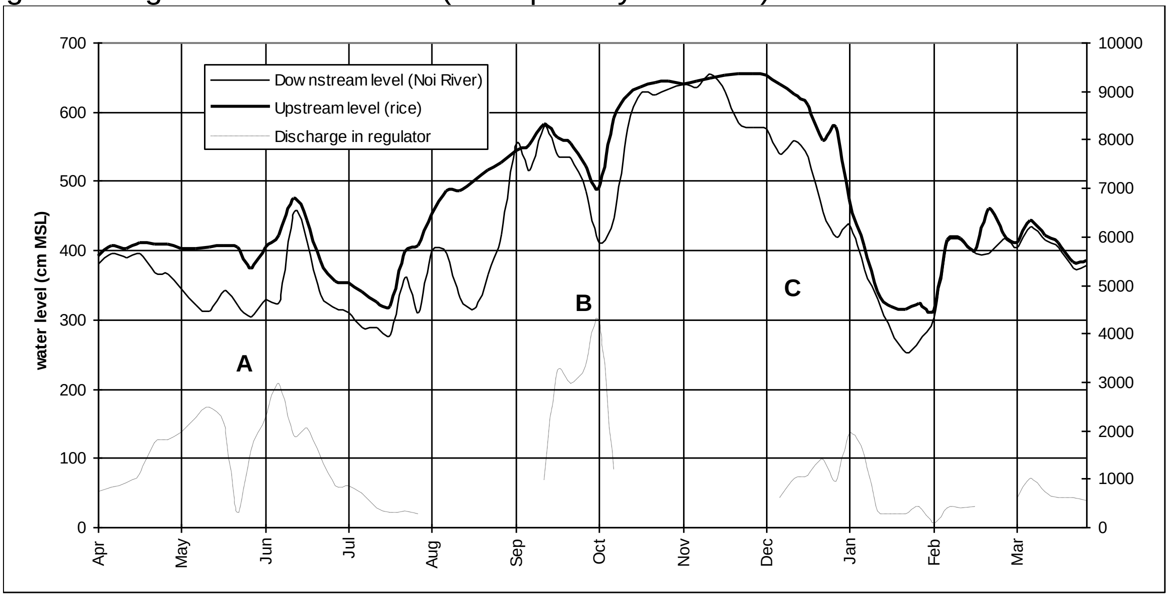
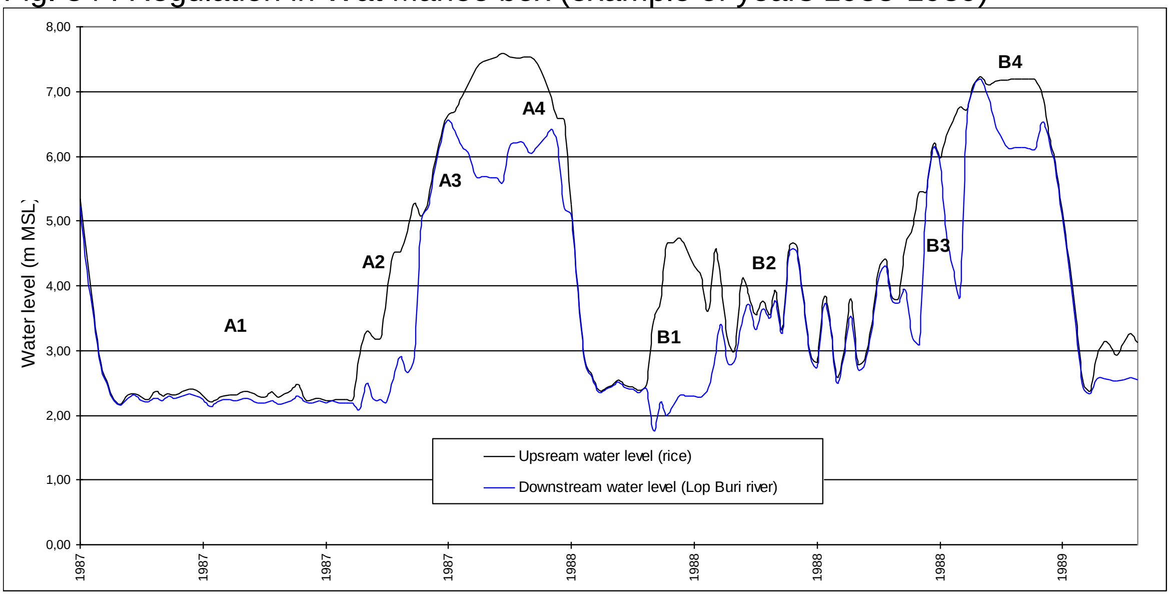


Figure 34 provides another example of regulation in the Wat Manee box. During the first part of the rainy season 1988, there is no inner flow within the box and the Lop Buri river is very low [A1]. In the middle of July the regulator is closed to capture some inner flow, while the Lop Buri river level also rises [A2]. In September, the box level subsides but fortunately receives the support of the river; the gate is opened to allow the river flow in and contribute to the filling of the box [A3]. When the water level in the river later drops, the gate is closed and filling up continues with the sole inner run-off (a slump in the increase rate is neatly perceptible) until reaching the desired regulation level. The gate is later opened for drainage [A4].

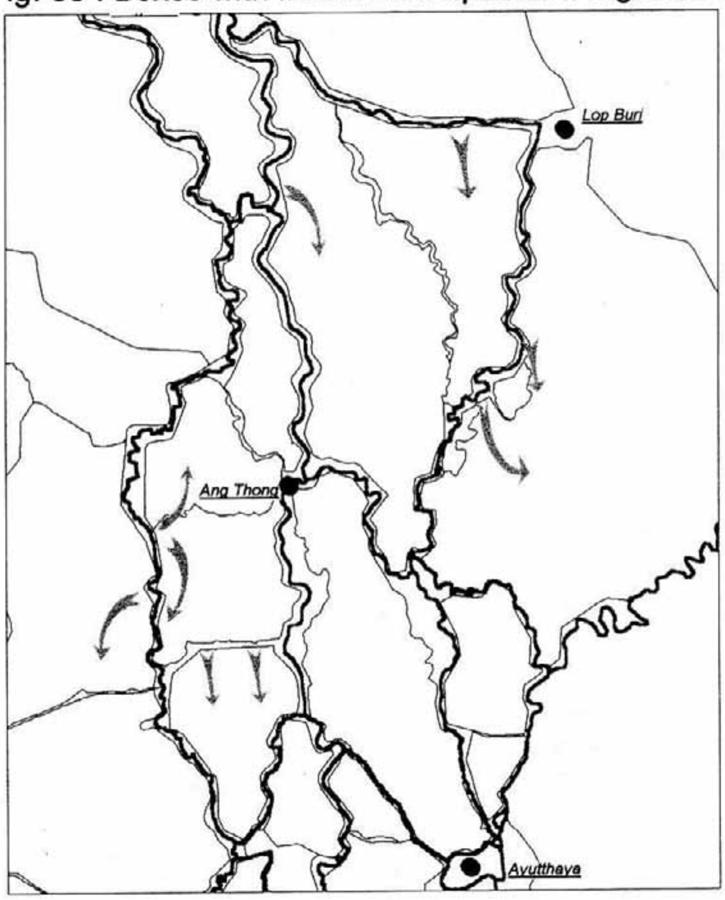
Fig. 34 : Regulation in Wat Manee box (example of years 1988-1989)



The following year, rainfalls generate some early inner run-off which raises the water level by 2 meters (the gate is closed) [B1]. Water later recedes and the gate is opened so that levels equate and fluctuate jointly [B2]. In October the gate is closed and the box starts filling up. Two neat periods can be observed in which the gate is opened to take advantage of the contribution of the river made possible by its rising water level [B3]. Again, the water level is kept stable at its optimum before the box is drained [B4].

Some boxes may also receive in-flow from upstream regulators, when the water level in the river is sufficient : the Bang Khum box receives significant supplies from the Lop Buri river through Khlong Ta Meek (Fig. 35) ; all the lower boxes of Yangmanee Project (Pho Pluak, Taa Tiang, Khlong KhanakLaat) receive some inflow from the Noi river, without which they would not have enough water ; the Phak Hai Project is mainly filled up by the Noi river and other return flows from upstream areas.

Fig. 35 : Boxes with inflow from upstream regulators



The analysis of the box hydrographs (shown in the annexe) allows the determination of the frequency and amount of water of river inflows[17] in the different boxes[18]. The

[17] Inflow from downstream main regulators ; regarding upstream regulators, the Ban Praek regulator of the Bang Khum box brings a significant contribution to this box, which does not suffer from lack of water.

[18] Some uncertainty remains, however, for some boxes for which only the water level, and not the discharge, is not available (or have been keyed in). In case the downstream water level is higher than in the box, the possibility of inflow can be ruled out only if this - as often is the case - occurs in times when the regulation water level has already been attained. The inflows recorded here correspond to sharp hikes of both upstream and downstream levels (free flow from the river). Inflow from the

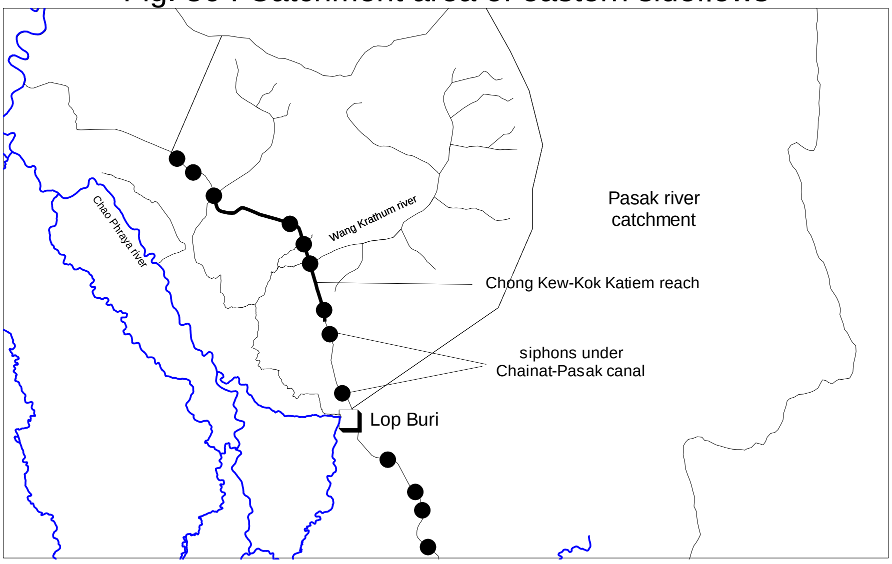
inventory of these events is reported in the annexe 7.4. Whereas some boxes like Wat Manee, Muang Tia and Khlong Taa nung commonly resort to river inflow (but, even though, not every year), others such as Salai, Lam Chuad or Bang Khum do not and, on the contrary, drain water out most of the time.

The last column of annexe 7.4 also translates the observed hikes in water levels into volumes : we can see that in some instances the inflow can amount to 60 to 80 % (case of Muang Tiaw) but that in most cases it is less than 40 %.

2.4.3.3 Sideflows

We have seen earlier that the three eastern boxes may get some inflow from neighboring areas : these flows can be either channeled underneath the Chai Nat-Pasak canal, or added to the main stream of the canal through 18 drain inlets. No record is kept from these inflows. Fig. 36 specifies the location of the nine inverted siphons allowing the transfer of sideflows into the irrigated area : they correspond to an estimated 50 cms potential inflow.

Fig. 36 : Catchment area of eastern sideflows



The magnitude of the share of the sideflow diverted to the Chai Nat-Pasak canal appears in the balance of the Chong Kaew-Kok Kratiem canal reach : if we plot the total rainfall amount in the catchment of the Wang Krathum river for the months of August, September and October against the water use along the reach during the same period, we found that in the most rainy years the consumption is negative (Fig. 37) : this shows that a hundred millions m^3 or more of sideflow were diverted to the canal. This gives no hint on how much water has possibly been diverted to the irrigated area but shows that the sideflows may be of significant magnitude. Hydrologic data from a station located near Khok Samrong (C24), 25 km before the river reaches the Chai Nat - Pasak canal, also indicate that the Wang Krathum river is able to generate a one-day annual flood discharge of 160 cms, while three-day-duration floods with a return period of 10 years can reach 540 cms (ILACO, 1980).

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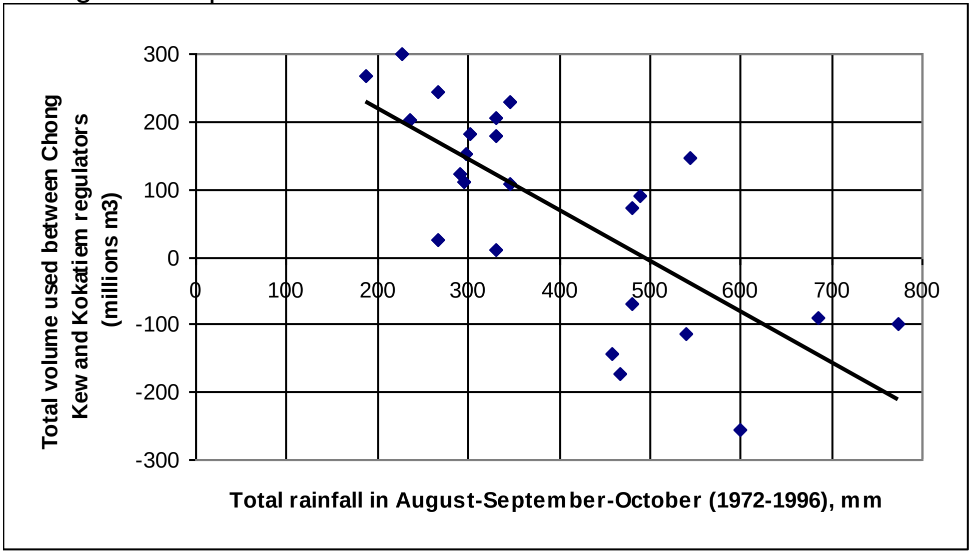
river with submerged conditions of the regulator is unlikely and there are probably few cases escaping the inventory.

Fig. 37 : Impact of sideflows diverted to Chai Nat-Pasak canal



2.4.3.4 Direct supply from the irrigation main canal to the drain

In addition to possible sideflows, the lower part of the boxes also receive contributions from the irrigation network : this flow partly comes from the return-flow from irrigated areas but can also be incremented by controlled lateral spill from main canals directly to the drainage system (there are two wasteways at km 69+400 and 95+915).

Considering the last graph we may compare the consumption of the canal reach in the driest years (between 200 and 300 millions m^3), in which the sideflow is reduced to a small amount, and the corresponding command area : 25,000 ha of rice. This consumption, relatively to this area, corresponds to approximately 1,000 mm in three months, while water requirements are estimated at 558 mm, or 192 mm after considering the contribution of the effective rainfall over the period (ILACO, 1980). This suffices to show that the reach of canal considered here has been delivering considerable water to the drainage box, in order to contribute to its filling up.

Similar calculation for other reaches or for the Chai Nat-Ayutthaya canal (Maharat Projects) give similar results. While this inflow can be considered as controlled and can be roughly attuned to requirements, it also may, in very wet years, escape control : in such instances the maximum discharge is diverted at Chai Nat through the different waterways, in order to relieve the flow in the Chao Phraya river proper. This excess flow is further diverted to the drainage system and the lateral canals of the upper delta to reduce the final discharge which will eventually reach Bangkok area and aggravate flood problems and damage.

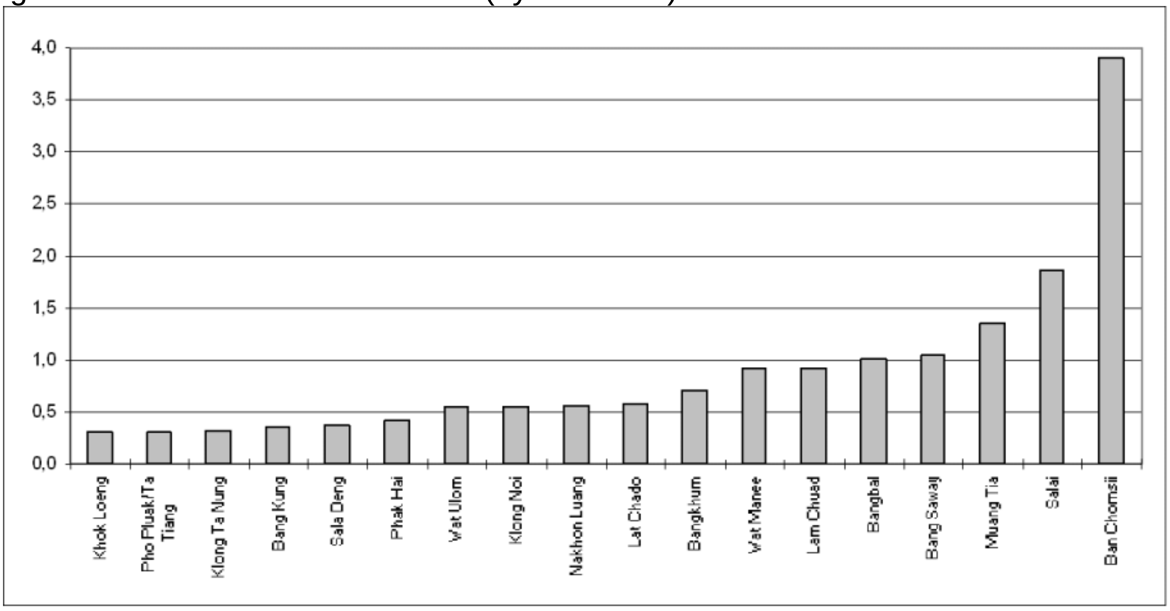
This can be neatly observed for the year 1996 on the hydrographs presented in the annexe for each box (1995 is atypical as many of the dramatic peaks observed are not the result of inner water diversion but of uncontrolled river spill/overflow).

2.4.4 Differences in box response and management

Table 8 provides a few parameters which allows one to understand the different hydrologic behaviours of the various boxes. The first of them is the comparison between rainfall (the 50 % of the yearly total which contributes[19] to filling the box : see above) and the storage capacity of the box, as commented earlier (Fig. 38).

The case of Ban Chomsii is interesting because its high index reflects the low value of the storage capacity after the modification of the water level. At the same time, it indicates that risk is higher, both in terms of internal drainage capacity and in terms of possibility of drainage to the Chao Phraya River.

Fig. 38 : Rainfall contribution index (by main box)



Some boxes (Salai, Muang Tia, Bang Khum) must almost constantly drain water out of the box. These are the boxes with large catchment areas and/or sideflows. This makes a lot of gate adjustments necessary in order to regulate the water level. This is one of the reasons that explain that the water level appears to fluctuate more than in other boxes where the gate is closed most of the time.

On the contrary, some boxes located at the end of the irrigation system (late irrigation supplies) and with no sideflows or inner run-off (such as the Bang Kung or Wat Ulom boxes) have difficulties to fill up and are sensitive to dry years.

The combination of all the factors which determine the reliability and magnitude of each contributing inflow governs the overall sensitivity of each box to dry and wet years (Table 8).

[19] this is an optimistic assumption as a significant part of this rainfall will be "captured" by irrigated plots on the higher land.

Table 8 : Hydrologic characteristics of the main boxes

Box	Rainfall (mm)	Sideflows	Inflow from river	Storage capacity (10^6 m^3) **lower/all**	Index Ef_rainfall/ storage capacity	Sensitivity to dry years	Sensitivity to wet years (flood)
Wat Manee	1142	yes	yes	141/259	0.9	little	medium
Bang Khum	1039	yes	very little	130/184	0.7	little	yes
Wat Ulom	1096	no	very little	69/125	0.55	yes	yes
Bang Kung	1209	no	very little	107/141	0.35	much	yes
Ban Chomsii	*1100*	yes	?	21	3.9	no	?
Bang Saway	*1100*	yes	?	23	1.1	no	?
Khlong Noi	1055	no	some	47/63	0.55	medium	yes
Lam Chuad	1057	no	no	54/100	0.9	no	no
Salai	1129	no	no	60	1.8	no	no
Sala Deng	1011	no	no	38	0.35	little	little
Muang Tia	1161	no	a lot	21	1.35	medium	no
Phak Hai	1134	yes	little or no	255	0.4	medium	medium
Khlong Taa nung	1156	no	yes	68	0.3	little	little
Bang Ban	1112	no	very little	48	1.0	-	-
Pho Pluak + Taa Tiang	1145	no	?	99/133	0.3	?	?
Lat Chado	1134	no	?	96	0.55	?	?
Khok Loeng	1160	no	?	47	0.3	?	?
Nakhon Luang	1200	yes	some	236/260	0.55	little	little

2.5 Dry season cropping

2.5.1 Location

Dry-season cropping is an issue of the utmost importance in the Chao Phraya delta. On-going research tend to show the strong correlation between the frequency of DS cropping, the sustainability of farming and farmers' strategies. The cropping area depends mostly on the amount of water delivered each year, itself a result of how much water has been stored in the dams.

Dry season cropping can be found in many parts of our study area, but with different magnitudes. Two zones show a higher density of dry season cropping (DS) (Fig. 39) :

- the north of Sing Buri,

- the centre of the study area, to the south of the Lop Buri river and to the north of a line crossing *amphoe* Maharat and *amphoe* Pak Hai.

In four small areas there is no dry season cropping at all :

- the east of *amphoe* Pak Hai,

- the south-east of Ayutthaya, along the Chao Phraya river,

- between the Lop Buri river, Pasak river and Khlong Bang Pra Khru,

- between the Noi river and Chao Phraya river, to the north of Sing Buri.

Fig. 39 shows the frequency of the DS during the last ten years. We considered only the plots where the farmers began more than 4 years ago : farmers who started dry season during the last 4 years did it almost each year (cf later section). The black points show areas with a frequency higher than 50 %, the grey ones areas with a frequency lower than 50 % and the small black dots areas with no data. We can see that most of the farmers who started dry season more than 4 years ago (see Fig. 43), did it quite regularly : around 80 % engaged in dry season cropping more than 5 times during the last ten years. Areas located along main canals in the Yangmanee and the lower Chanasutr Project, together with the upper Maharat tract, succeed in achieving DS cropping more than once in two years.

2.5.2 Impact on wet season rice cropping

Double-cropping may have several consequences on the wet-rice season : the most common is the delay in crop-establishment. The DS crop is sometimes started extremely late, as late as May, because farmers which are at the tail-end of the canals get water after all others upstream. Therefore, there is sometimes not enough time to start the next wet season crop.

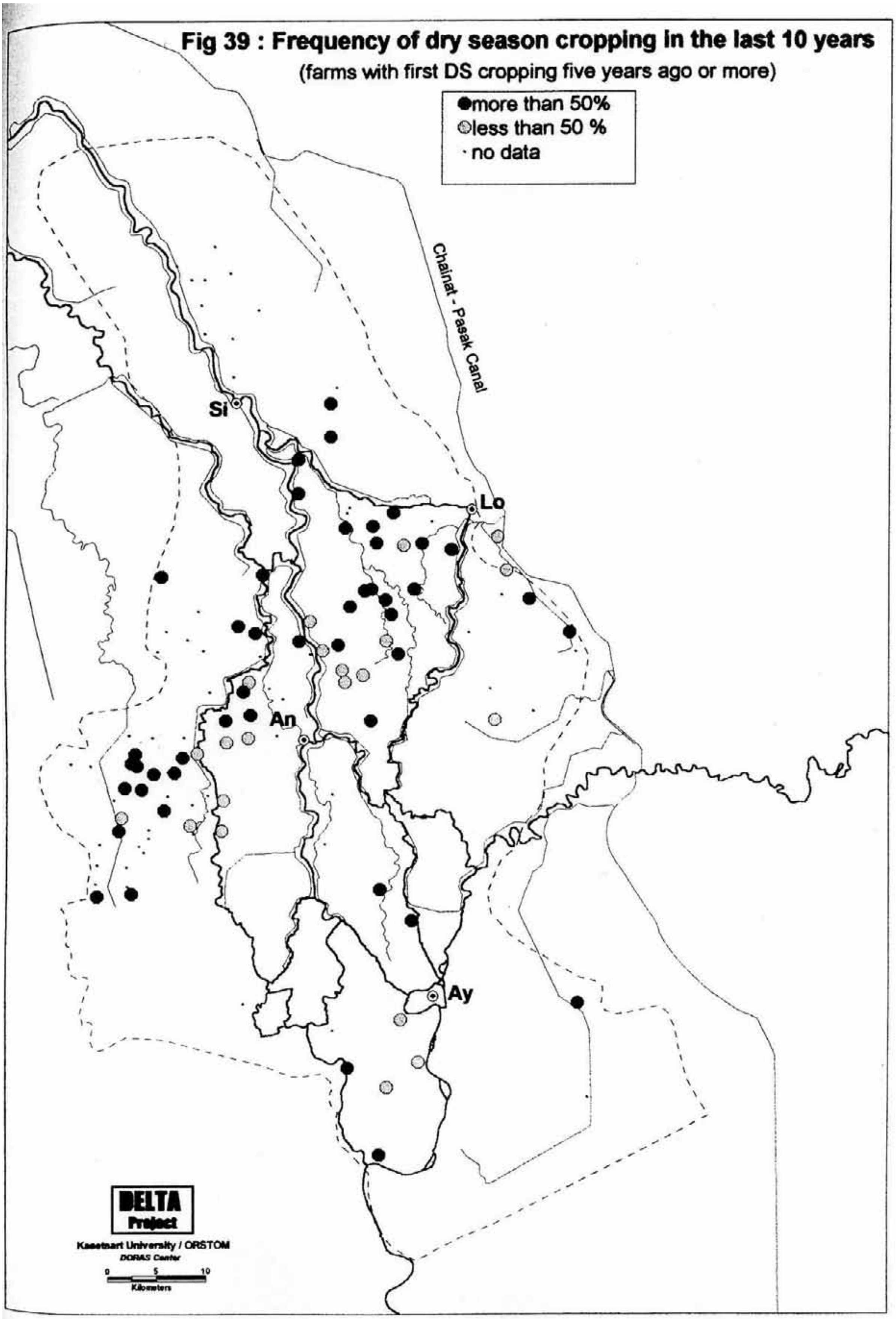


Fig 39 : Frequency of dry season cropping in the last 10 years

(farms with first DS cropping five years ago or more)

In all cases, as it has been noted in the section concerning the cropping techniques, the ensuing wet-season rice - even of the floating rice type - is established with wet-broadcasting because the plot is already wet and water requirements for land preparation are highly reduced. The problem is that if the plot is in a lower location, the risk for young seedlings to be drowned and that the rice may not have reached the sufficient vegetative development to be able to elongate (approximately 40 days) is too high.

This is why, especially during the last three years (96 to 98) where dry-season cropping reached its maximum, plots with no crop have been observed in the rainy season. Either the rice has been lost through drowning, or the farmers did not take the risk to lose it and did not sow. This risk is generally well accepted and several farmers said that, in any event, they prefer to grow a DS crop, be it at the expense of the WS one.

Those who did not do wet season rice because they have been compelled to wait (and not because they are tired of doing it), will generally wait until the end of the rainy season to start another dry-season crop, this time as early as possible, capitalising on field wetness which makes land preparation readily feasible with no additional water. In some cases, the farmer will hurry this by pumping water out from his field. If the rainy season is mild (like in 1997), farmers will be able to do that as early as November in the upper boxes.

The development of DS cropping in medium location was mentioned several times to have a negative impact on lower (mostly FR) land. Because of drainage water from the irrigated upper parts, water spreads to lower areas, sometimes pounding in depressions, making a subsequent WS rice cultivation impossible, either because of weeds growth or because of stagnant water. In some instances, this created some conflicts and in one case gave way to an indemnity of 10 thang of rice per rai.

2.5.3 Mungbean and other field crops

In the past the cultivation of mungbean in the early dry season, capitalising on the residual field moisture was quite common. Its cropping area has been dwindling because of poor profitability, sharp labour shortage at harvest time and rat damage ; a similar situation was encountered for sesame (a much less common crop). In addition, it seems that double-rice cropping leads to the compacting of the soil and that its structure becomes unfit for mungbean.

Rice is the main crop in dry season : 90 % of the farmers grow it. 8 % of farmers reported to grow mungbean, the second crop in the dry-season.

Some sub-regions maintain some activities through some specialisation : chilli in *amphoe* Ban Praek, Taro in the Roeng Rang Project are notable examples. Another noteworthy exception is the "rotating water-melon cropping" spearheaded by some families from Suphan Buri Province : these groups of farmers rent chunks of land in the Central plain with good water conditions, establish provisory dwellings and cultivate water melon over a few hundreds rai. After 2 or 3 years, they shift to another place to avoid drops in fertility and crop diseases.

2.6 Changes in rice cultivation in recent years

2.6.1 Giving up agriculture : land with no rice

The survey also showed that rice cultivation disappeared from several areas, in particular (Fig. 40) :

- Along the Chao Phraya river, north and south of Ang Thong,
- In the north of Ayutthaya.

In the south east of Ayutthaya (Nakhon Luang Project), rice also disappeared, but the fallow fields are more scattered, with a lot of small plots with no rice, spread over a large area of FR.

The two years of flood (95 and 96) have had a very serious impact on the dynamics of these traditional systems. There are countless mentions of farmers who have given up farming after losing their crops. This situation has been aggravated by a bad early rainy season in 1997 (April-June), during which many sowings were unsuccessful because of dry spells. "Every one is tired of the risk ; since two years there has been a lot of people selling their land". Repeated crop failures have had a dramatic impact on land selling. Farmers sell the land for the construction of roads, factories or town houses or for sand pits, but they may also often remain on their own land, with or without paying rental fees to the new absentee owners.

Other farmers did not sow in 1996 and 1997 because they feared a repetition of the flood. They often expressed no certainty on whether and when they would resume planting rice.

The price offered for the land is overwhelmingly attractive to them. In case of indebtedness or repeated crop failures the temptation to sell becomes very strong. The price per rai varies between 40-60,000 baht (in the TV rice area (*nay thung*)), 100-500,000 baht/rai in good locations (near a canal or a road) and 0.8-1.3 millions baht near the "Asia road".

Some chunks of several hundreds of hectares have been reportedly bought by Bangkok-based people or companies, notably in the Phak Hai and Maharat projects. This speculative trend has been stopped by the economic crisis in the mid-1997.

Figure 41 shows an example of the expansion of sand pits in the lower Yangmanee Project (north-west of Ayutthaya). The two images show the situation in 1994 and 1998 and the spread of sand pits is evidenced.

An opposite trend, however, is also perceptible. Because of the crisis, out-of-work people go back to their village and contribute to bringing idle land under cultivation again.

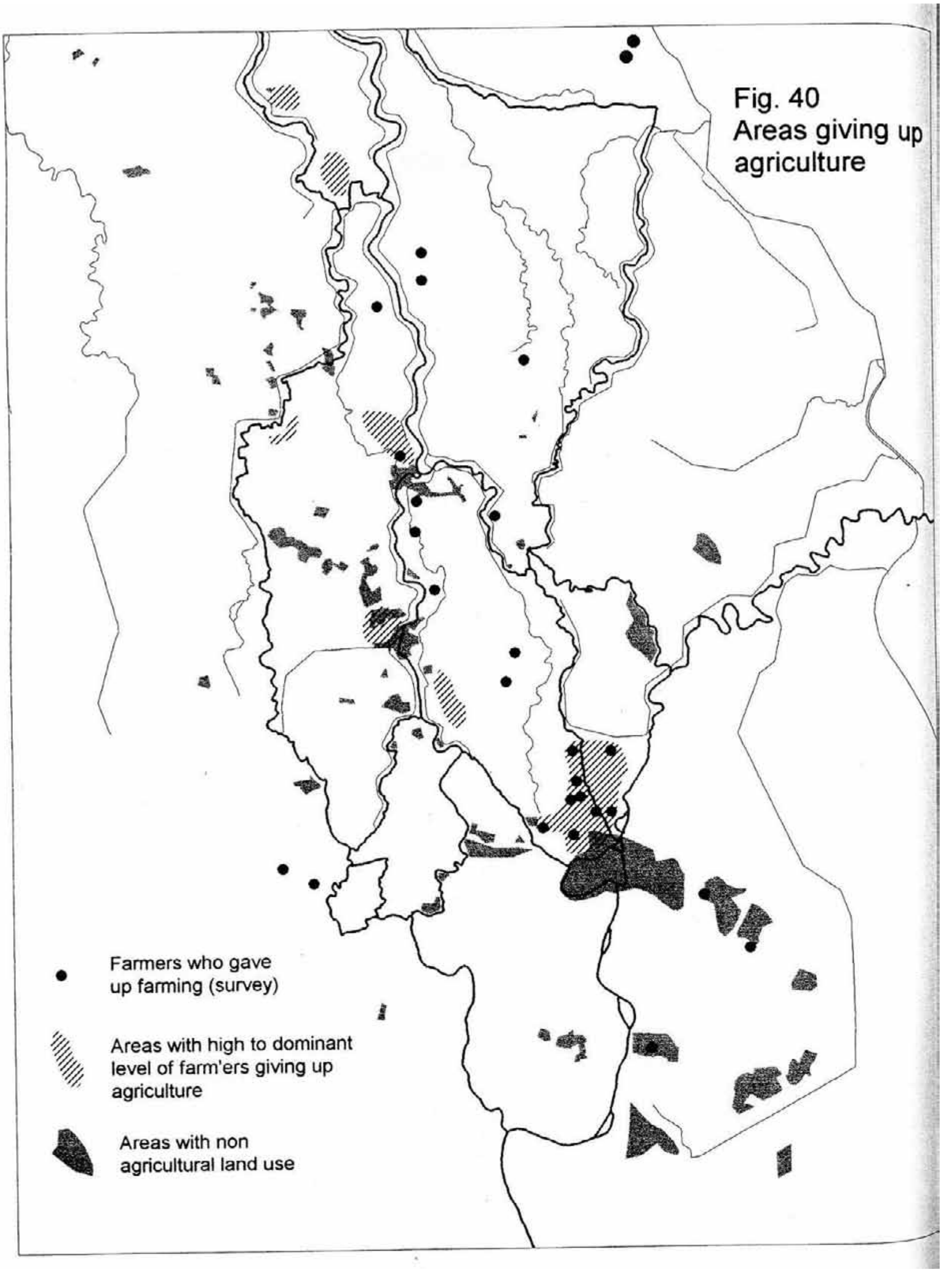


Fig. 40
Areas giving up agriculture
Farmers who gave up farming (survey)
Areas with high to dominant level of farm'ers giving up agriculture
Areas with non agricultural land use

Fig. 41

Show sand pond near Amphor Pamok

Shift from WS rice to DS rice cropping

Another significant trend has been observed : instead of doing wet season rice - with corresponding risks - farmers grow no rice in the wet season and wait for water to recede (either naturally, like in the west bank), or after the opening of the box regulators. They then rush to puddle the land and sow pre-germinated seeds for an early DS cropping (Fig. 42).

In case this can been done early (in "dry" years) and/or in case water is available long time enough, farmers will try to even grow two successive crops in the dry season. In doing so, farmers follow the steps of the west-bank, where such a change occurred 15 years ago and where double cropping is now well established, thanks to a dense network of canals. More recently, this shift also occurred in the floating rice area of the lower Don Chedi Project and in Phak Hai Project (see below).

This can be facilitated by poldering the plots and pumping water out before the time of the natural receding, thus gaining some time. Such a case can be found - for example - in the Chanasutr Project, near Pho Thong, in areas formerly grown with floating rice. In that case, additional water is provided by nearby (re-excavated) natural ponds. In the lower parts, water recedes and attains suitable low levels too late and this practice is made difficult.

Several examples of this situation can be found in the area, such as in the southern tip of Lam Chuad box (which is planted with FR, but a good part of it not cultivated any more in the wet season). Dry season rice is grown instead in the upper part of the area, using canal water. The Phak Hai Project provides the best example of shift. More than two thirds of the project has given up WS cropping and developed a ditch system in most of the area to substitute it by DS cropping. In some years with plentiful supply and in favourable locations, double DS cropping can be achieved, like in the west bank, further south.

The reasons why the Phak Hai project did not shift earlier to double DS cropping, like the west bank which is adjacent to it, are threefold : firstly, the area is deeply flooded and water recedes much later than in the west bank ; secondly, it is less flat and deprived of canals, demanding much more land development to shift to DS cropping ; thirdly, the crop failure of the past three years combined with the hike in rice prices provided the incentive that was missing for farmers to engage in such a land development[20].

We can see from the satellite images that the remaining part cropped with floating rice is the upper part of the project. In the DS, water passes through the area but there is no structure to retain it and prevent it from flowing further south. With the closure of the southern dike of the project, RID officers believe that it will be possible to extend DS cropping to this area in the future too.

[20] It is worth noting that this development of double DS cropping was often achieved by people coming from other nearby parts of the delta, renting land for the season.

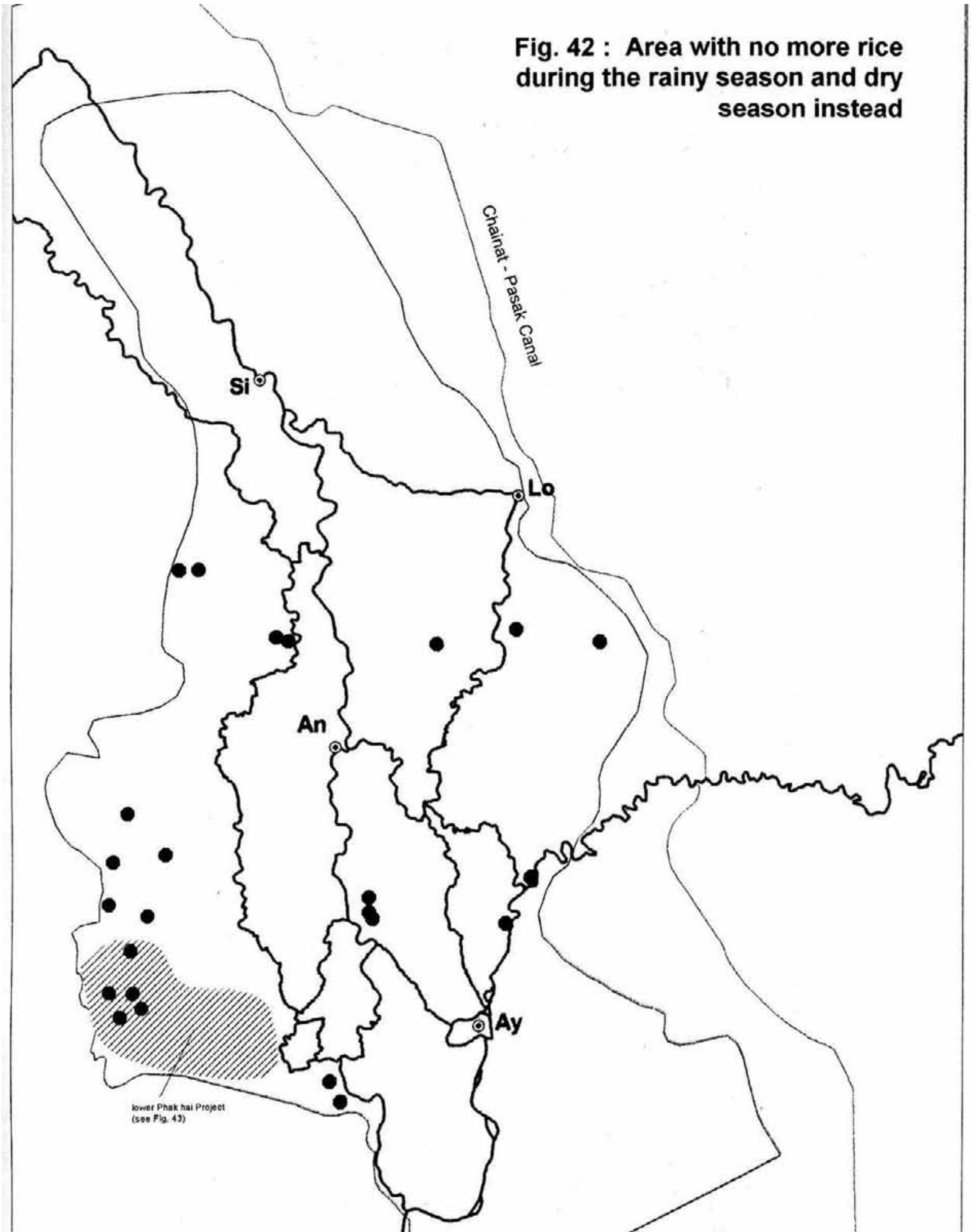
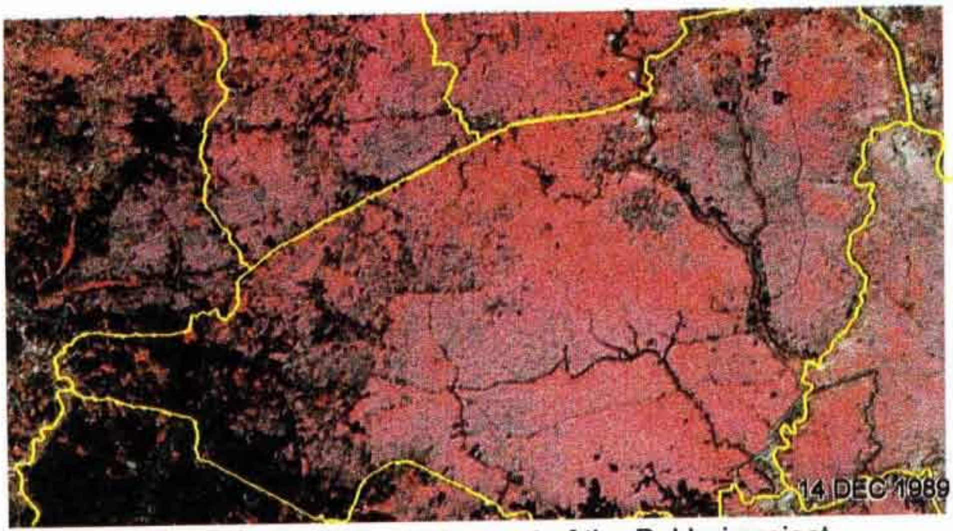
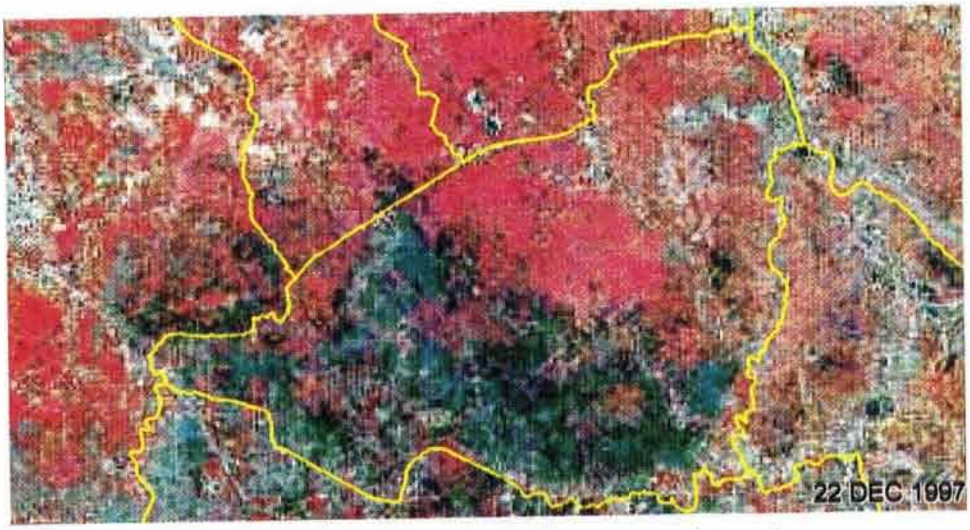


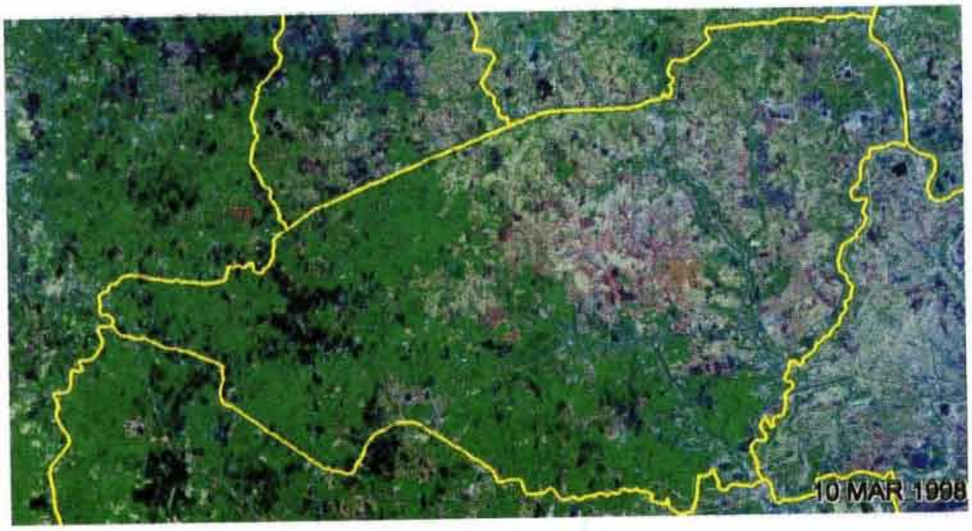
Fig. 42 : Area with no more rice during the rainy season and dry season instead
Chainat - Pasak Canal
Si
Lo
An
Ay
lower Phak hai Project
(see Fig. 43)
DELTA
Project
Kasetsart University / ORSTOM
DORAS Center
0
5
10
Kilometers



Wet season rice (red) in most of the Pakhai project



Rice (red) remains on the upper right part



Dry season rice appear in green

Another example of abandon of the WS crop to the benefit of DS cropping must be noted : in some areas farmers prefer to grow an intensive tuber crop or field crop in the DS and lack interest in WS rice, which in addition would delay the DS crop. This is the case of some taro plantation in DWR areas of the Roeng Rang Project and of crops such as groundnut or water melon in other places.

2.6.2 Growth of DS rice cropping

Dry season cropping started more than 25 years ago in the delta (Kasetsart University and ORSTOM, 1996), but it developed gradually, especially in our study area, in which much plot improvement was required and where little water is provided in the dry season. If we consider the map showing the year of the first dry season cropping (Fig. 44), we can notice that there are two different zones in the central area :

- the west of the Chao Phraya river, supplied through the Noi river, where more than 50 % of the farmers began dry season cropping more than 10 years ago, at the beginning on a year-to-year rotation basis.

- the east, where dry season cropping appeared in the ten or five past years. This area most often received water for DS cropping for the first time in 96, 97 or 98, years in which deliveries have reached records.

In the dry season 1996, 1967 and 1998, DS cultivation developed beyond expectation, as RID released important amounts of water in order to allow a second crop liable to relieve the impact of loss caused by flood hazards. The second year corresponded with a surge in farm-gate rice prices, contributing to a craze for DS rice, to the extent that some farmers have had difficulties in purchasing seeds. In 1998, an historical record was achieved, with over 100,000 rai (16,000 ha) of triple cropping (located mostly out of our study area).

Areas with DS cropping for more than 10 years (dark blue) are chiefly located on the western side (Yangmanee project) and some scattered point along main canals on high locations. Light blue points show areas with a first year of cultivation between 5 and 10 years, while red spots correspond to areas which started in the last 4 years. These include all the plots which have initiated DS cropping because of the exceptional deliveries in 1996, 1997 and 1998. Many points of the east side boxes are notably in low position, in the lower reaches of the secondary canals of Roeng Rang, Kok Kratiem, Pasak Tai and Maharat Projects.

2.6.3 Change in cropping technique

The previous sections have shown some of the main changes that affected cropping techniques in TV rice cropping. They include a reduction of the diversity of the rice varieties used, an increase in fertilisation and the use of wet broadcasting in case of double-cropping.

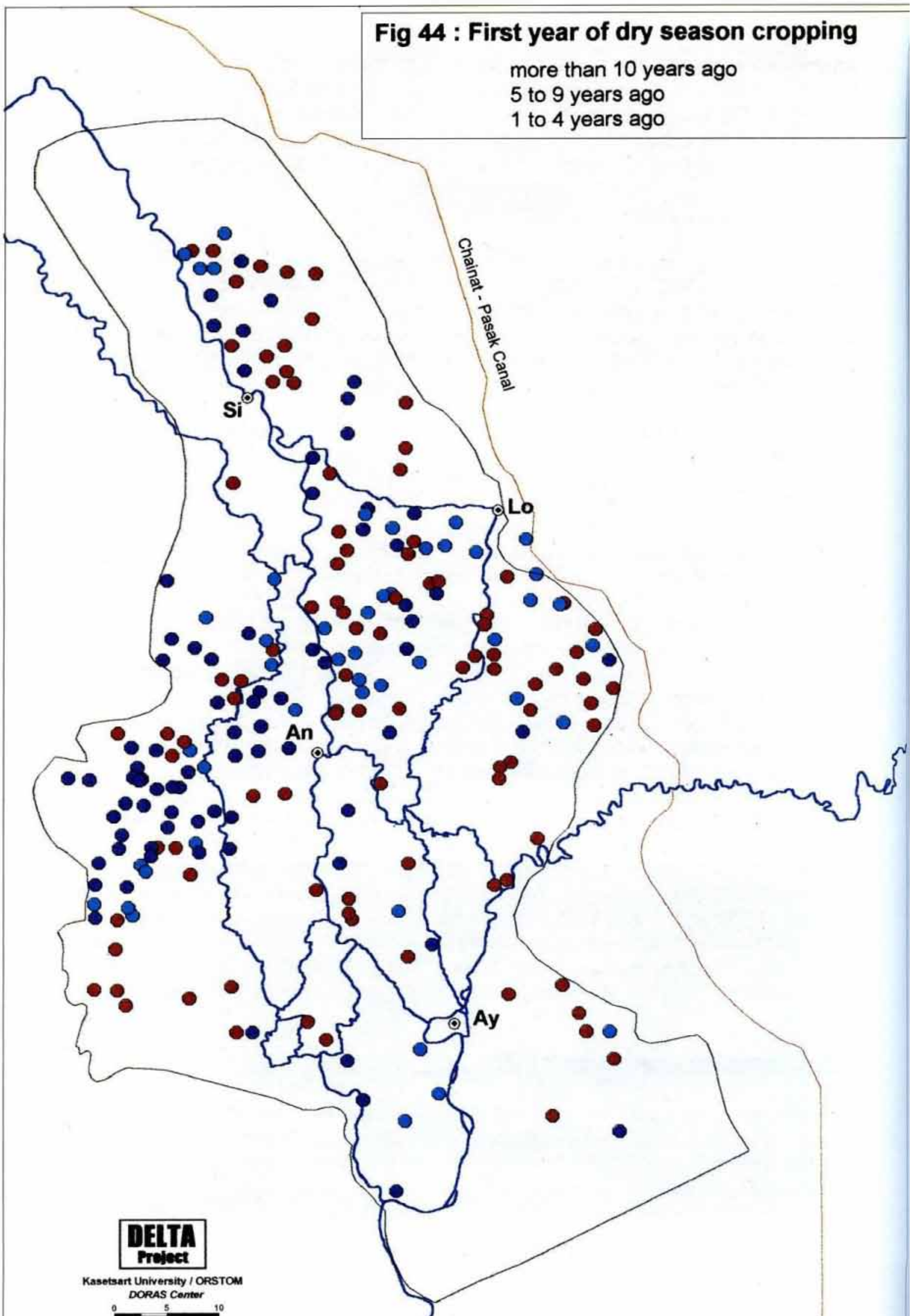


Fig 44 : First year of dry season cropping
more than 10 years ago
5 to 9 years ago
1 to 4 years ago
Chainat - Pasak Canal
Si
Lo
An
Ay
DELTA
Project
Kasetsart University / ORSTOM
DORAS Center
0
5
10
Kilometers

3. Mapping rice systems and drainage boxes

The overlay of satellite images, elevation grids and survey points has allowed the mapping of rice systems in the flood-prone area of the Chao Phraya delta. This includes maps of rice type, harvesting progress and cropping techniques.

3.1 Distribution of rice types

3.1.1 Methodology

The high variability of elevation in the study area, which strongly governs the choice of rice type, makes it difficult to devise a highly precise zoning. It is estimated that at least 2,000 observation points would be necessary (against 850 in the present study).

Areas with a same rice type (HYV, DWR or FR) first appear quite neatly on satellite images, allowing the specification of some zones. The distribution of the rice types along the toposequence is also a guideline which can be strengthened by additional information on water depth. If we consider that HYV is to be found in non-flooded areas, DWR in areas with less than 100 cm of water depth, and FR in the remaining parts (more than 100 cm of water), we might map a theoretical distribution of rice types, based on the static average water level in the main boxes (the level considered for regulation).

By doing so, however, we would dramatically overestimate the proportions of HYV and DWR. In fact, the water level is not static (some peaks over the regulation level may be experienced with) and farmers also include their perception/acceptance of risk in the choice of a rice type. This explains why, in particular, DWR is sometimes found in areas where HYV could be grown in most years (water level < 25 cm), while FR is also grown in areas with water at the level of one's knee. In addition such an approach is biased by the fact that the water body of the boxes is not flat : in boxes with almost continuous (controlled) outflow to the river, such as the Lam Chuad or Bang Khum boxes, there will be a significant slope of the water level between the upper parts of the box and the downstream ones.

The DWR and FR have been differentiated based on the harvest period and the survey information. In some cases, there are DWR varieties (*Kon Kaew, Leuang Pratew*) which happen to be harvested after some FR varieties (*Pin Gaew or Puang nak*). This does not allow a complete clear-cut distinction based on the harvesting period.

Regarding the limit between HYV and DWR, the harvest period is not always a decisive criteria, as some HYV are established very late (August). In addition, in some parts such as the eastern levee of the Chao Phraya river, HYV are mixed up with orchards, fallow land (quite frequent along Asia Road), built up, and are often scattered, making it difficult to single them out.

Another difficulty arises from the fact that DWR is sometimes used in areas where plot conditions allow the use of HYV. This case has been found on the eastern part of our study area. Farmers use HYV because they are led to resort to dry-broadcasting as a strategy against unreliable water delivery for land preparation. In that case, the choice of rice type is not governed by plot conditions or flood risk but by access to water, which determines the crop establishment technique and, thus, the type of rice[21].

3.1.2 Zoning of rice types

Fig. 45 presents a tentative map of rice types in the survey area. Gross areas of DWR and FR can be calculated as 160,000 and 130,000 ha respectively (1,000,000 and 812,500 rai). These areas make up 53 %and 41 % of the total area (areas predominantly cropped with HYV excluded).

HYV can be found in some high lands of our study area and, of course, all around in adjacent non-flooded areas : in these later case they have not been represented on the map.

The map also does not consider marginal rice areas located *outside* the boxes, generally interwoven with dwellings and backyard orchards, but they also include non negligible areas cropped with rice. These areas are of course exposed to any rise of the rivers between the embankments but, on the other hand, can grow DS rice by pumping water directly from the river. Most of the time they are cropped with HYVs in both seasons.

A rather significant area (6 %) has been classified as an association of HYV and TVs : it encompasses, between 8.1 m and 9.8 m MSL, a transition zone between the eastern uplands and the flooded area. The lower part of this area is under slight flooded conditions but the level of water during the rainy season never exceeds 30 centimeters : farmers can also grow HYVs, sometimes with specific plot dikes. On the contrary, although the upper part is under irrigation regime, some farmer prefer to grow DWR.

In most cases the main reason is untimely water supplies for land preparation : farmers prefer to resort to dry broadcasting and, *therefore*, DWR. Other secondary reasons include the cheaper cost of land preparation and the disadvantage of HYV regarding resistance to some specific diseases.

In addition this transition zone sometimes engages in DS cropping and, in that case, wet broadcasting will be used, as explained earlier. This, altogether, makes it very difficult to categorize rice cropping in this area under a simple description. Consequently, a mixed pattern category had to be added to the map.

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[21] HYVs are to sensitive to water stress and are not suitable for crop establishment under rainfed conditions.

A similar situation may also be found in the transition zones of the Chanasutr and Roeng Rang projects but is not shown here as HYV have eventually been found predominant. Detailed surveys would have been necessary to characterize these complex areas with more certainty.

It's worth mentioning too, that during the last two years, the number of farmers who grow HYV seems to have increased. Today, the percentage of HYV is around 50 %, and according to the farmers it should keep increasing during the next years, especially in the higher parts, where there is no risk of flooding.

3.2 Harvesting progress

The satellite images allow us to depict the progress of harvesting in the year 1994/95 by using images from November 26, December 12 and 28, January 13. Former dates do not show significant harvested areas and have been excluded. Maps have been drawn using three categories : non-harvested areas, areas being harvested, already harvested areas, and also show the areas with dwellings and backyard orchards on the natural river levees.

The picture from the 13th of January 1995 unfortunately has many clouds and it has been attempted to get complement information from a picture taken on the 10th of January 1994 (one year earlier). It was noted that harvesting in the year 1993/94 was later than in the following years, as some of the rice areas appearing on the 10th of January 1994 were already harvested on the 28th of December 1994 (next season). This supports the evidence discussed earlier that harvesting is not as fixed in time as thought once.

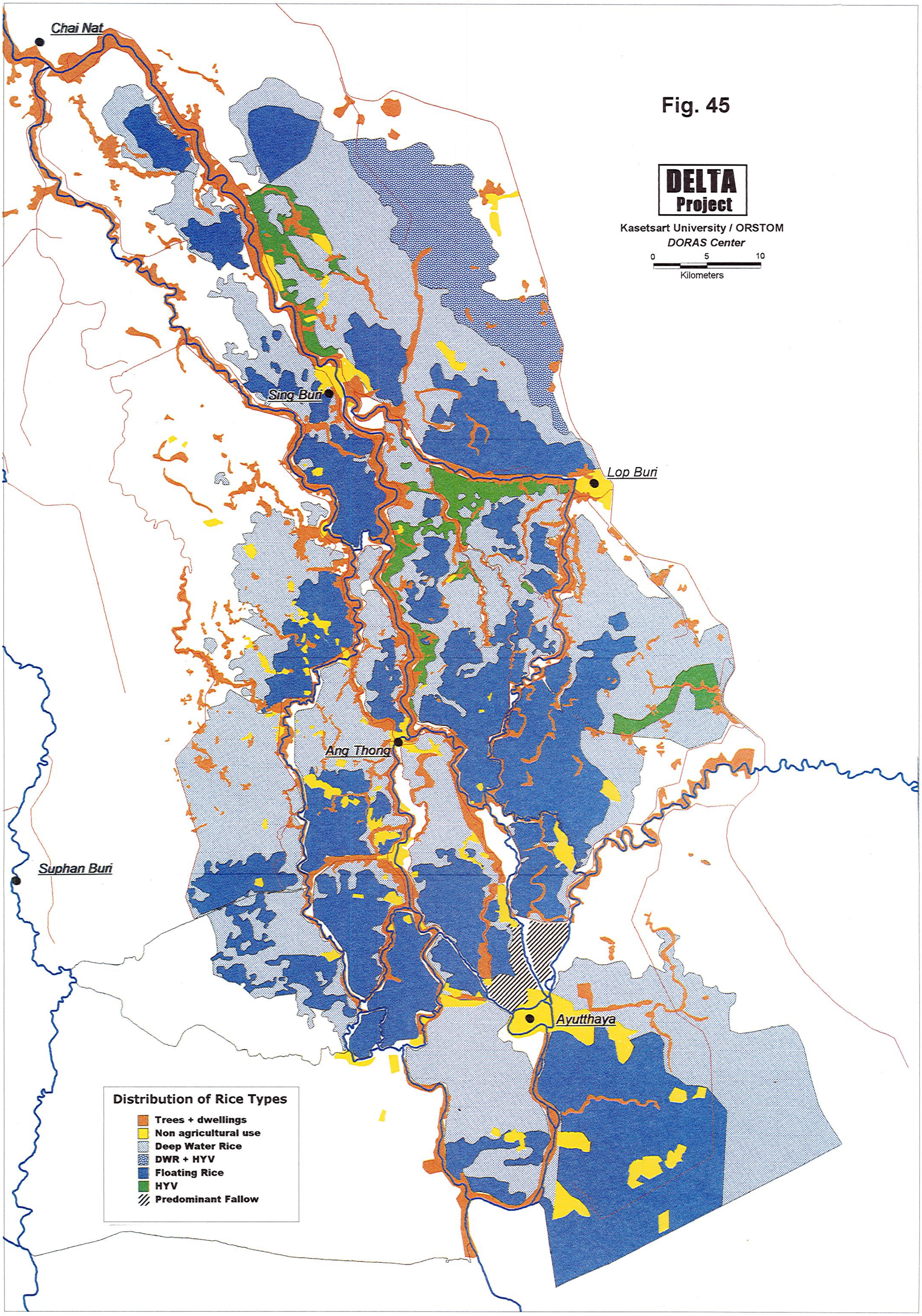
It must be emphasised here that the interpretation of the harvested area on the satellite images is not always deprived of errors : plots with lodged and ripe TVs, in particular when harvested by hand, may not appear significantly different just before and after harvest. The humidity of the plot was a strong differentiating factor in the image. As some plots are harvested while they are still very wet or even with ponding water, it is probable that the harvested area has been in some parts underestimated. On the other hand, some very dry non-harvested plots with lodged TVs may have been interpreted as harvested. This implies that these maps must be viewed cautiously.

Fig. 46 shows that most of our study area is not harvested by the end of November. Some exceptions can be found in high locations, near the houses, but these plots are scattered and often next to or within the tree area.

The maps show the gross area planted with rice. By adding fallow land, built-up and borrow pits we would obtain a much more parched vision of the rice systems. Fig. 45a shows all the main non-rice areas, without taking into consideration numerous scattered plots.

The area of non-agricultural areas (this only considers large units such as industrial parks, sand pits, golf courses, etc) correspond to an area of 115,000 rai, approximately 7% of the rice gross area.

The area with trees (backyard orchards and housings) makes up an area of 370,000 rai (but a part of it located on the margin of our study area).



Chai Nat
Fig. 45
DELTA
Project
Kasetsart University / ORSTOM
DORAS Center
0
5
10
Kilometers
Sing Buri
Lop Buri
Ang Thong
Suphan Buri
Ayutthaya
Distribution of Rice Types
Trees + dwellings
Non agricultural use
Deep Water Rice
DWR + HYV
Floating Rice
HYV
Predominant Fallow

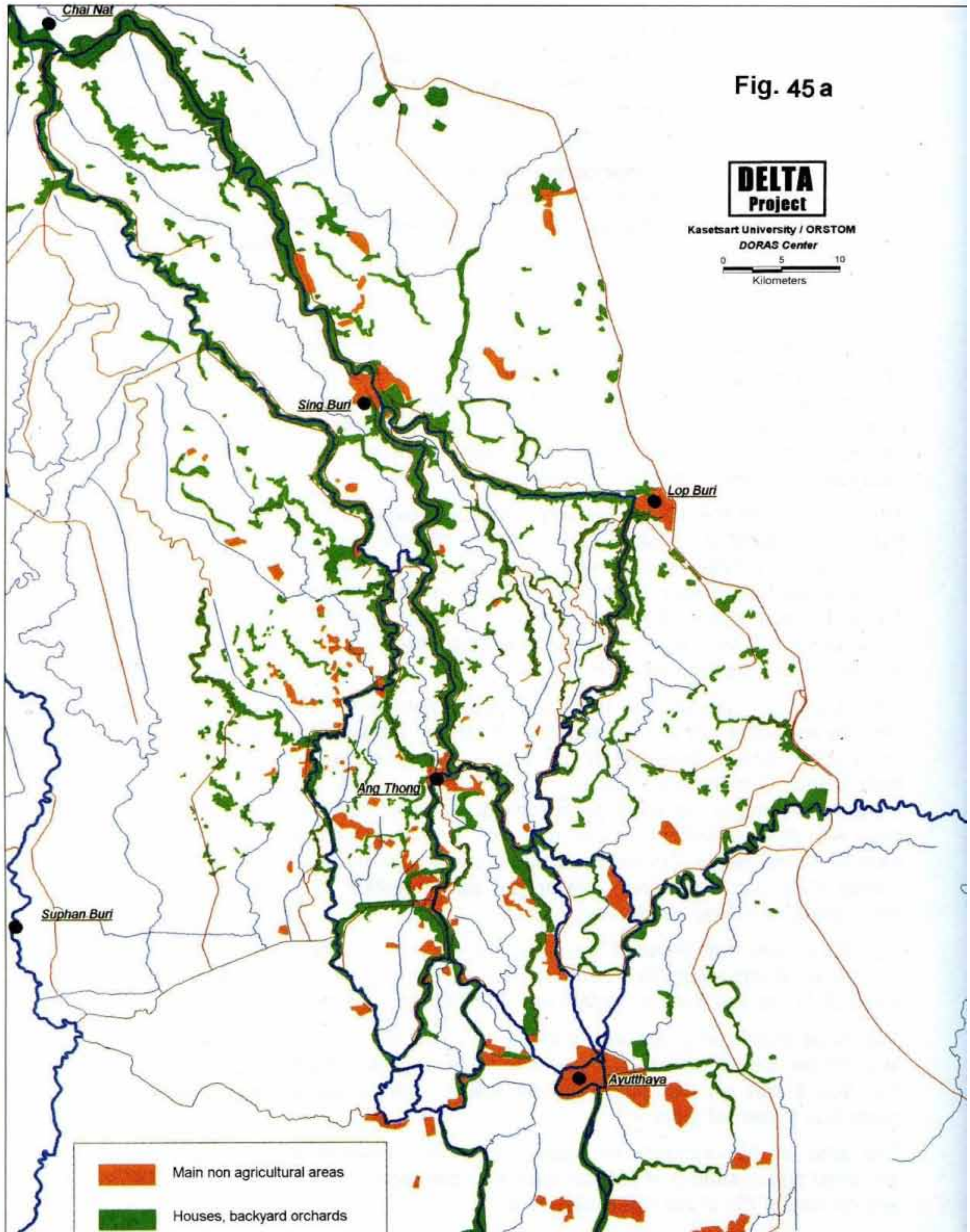


Fig. 45 a
DELTA
Project
Kasetsart University / ORSTOM
DORAS Center
0
5
10
Kilometers
Chai Nat
Sing Buri
Lop Buri
Ang Thong
Suphan Buri
Ayutthaya
Main non agricultural areas
Houses, backyard orchards
Main canals
Main drains

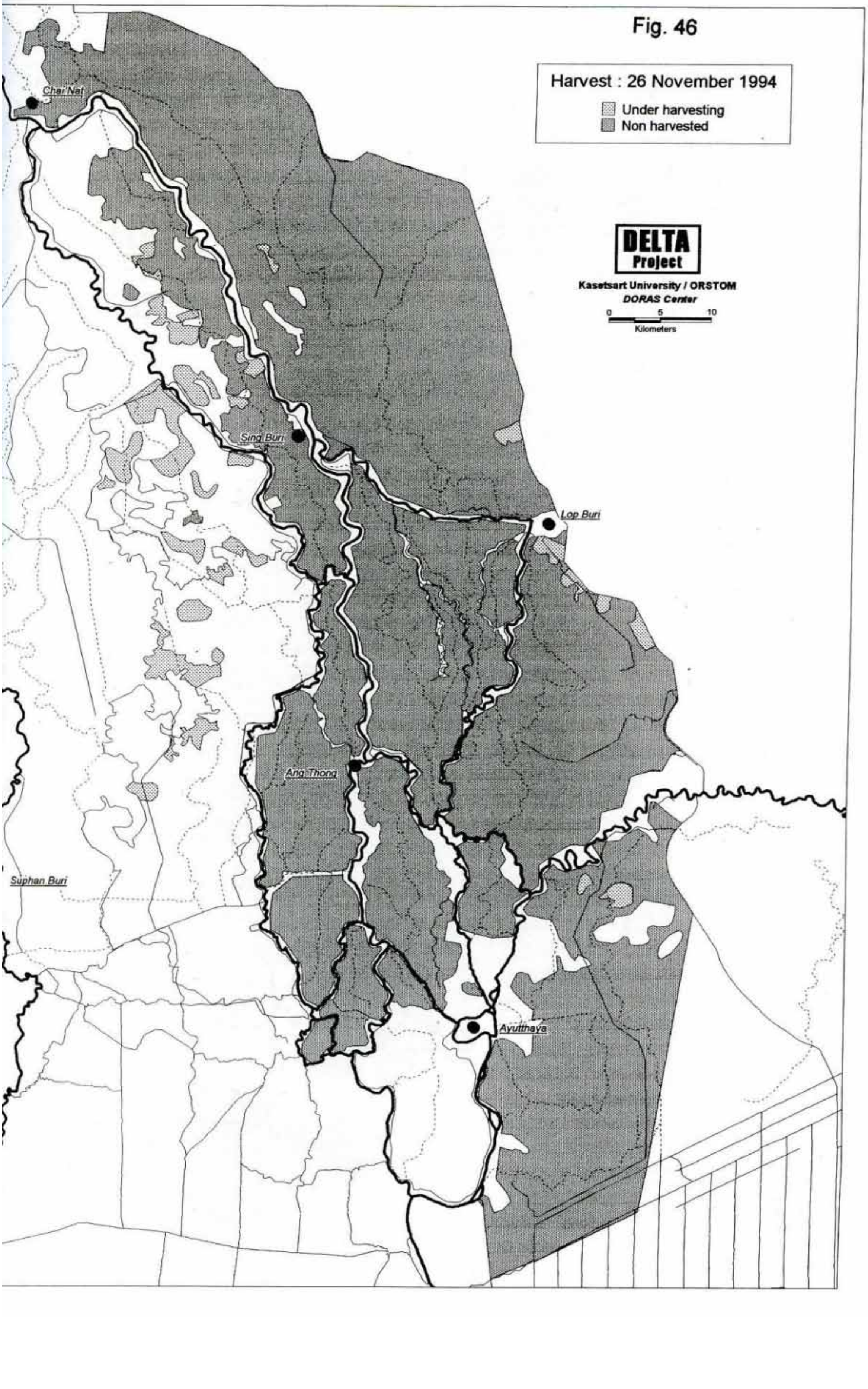


Fig. 46
Harvest : 26 November 1994
Under harvesting
Non harvested
DELTA
Project
Kasetsart University / ORSTOM
DORAS Center
0
5
10
Kilometers
Chai Nat
Sing Buri
Lop Buri
Ang Thong
Suphan Buri
Ayutthaya

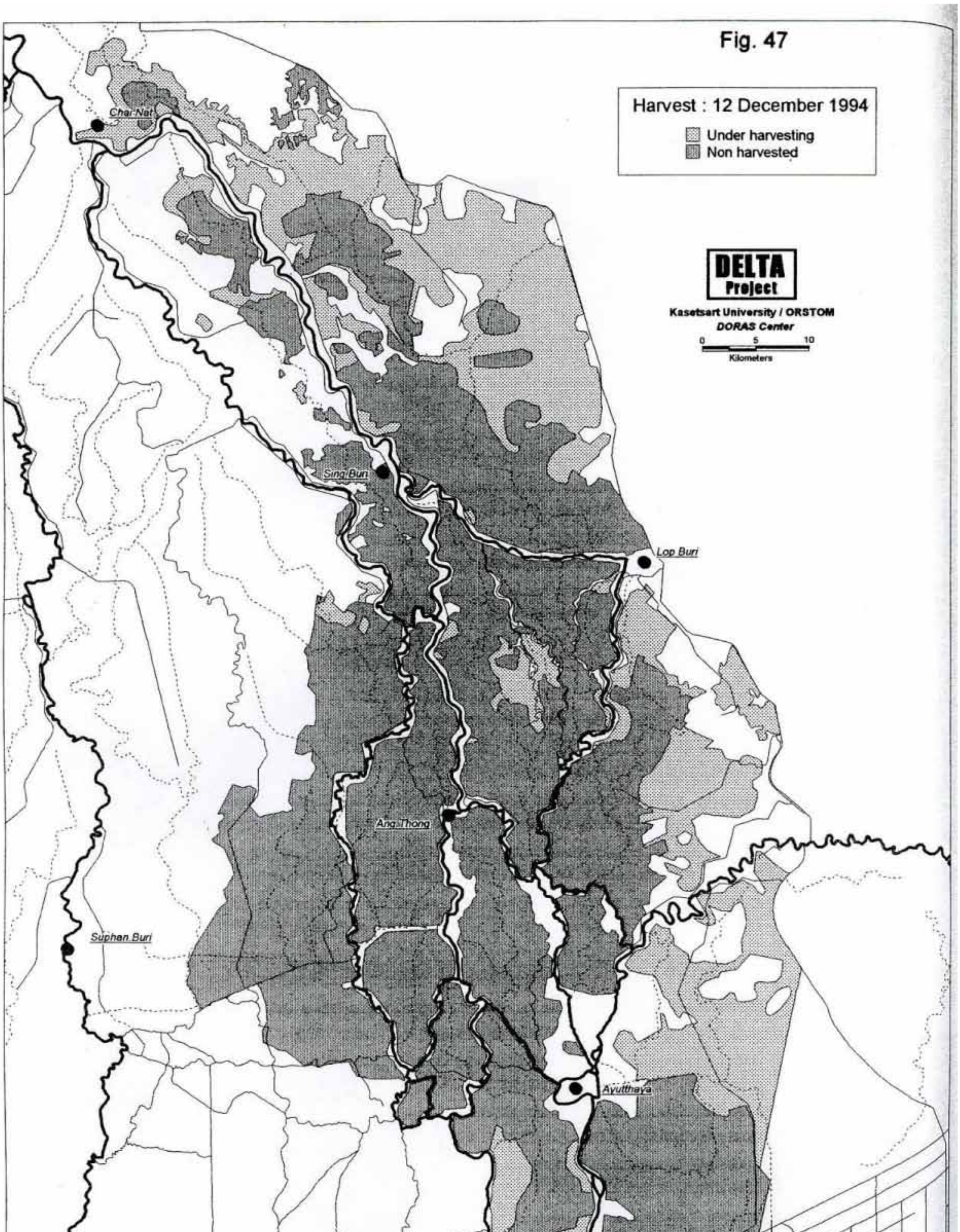


Fig. 47
Harvest : 12 December 1994
Under harvesting
Non harvested
DELTA
Project
Kasetsart University / ORSTOM
DORAS Center
0
5
10
Kilometers
Chai Nat
Sing Buri
Lop Buri
Ang Thong
Suphan Buri
Ayutthaya

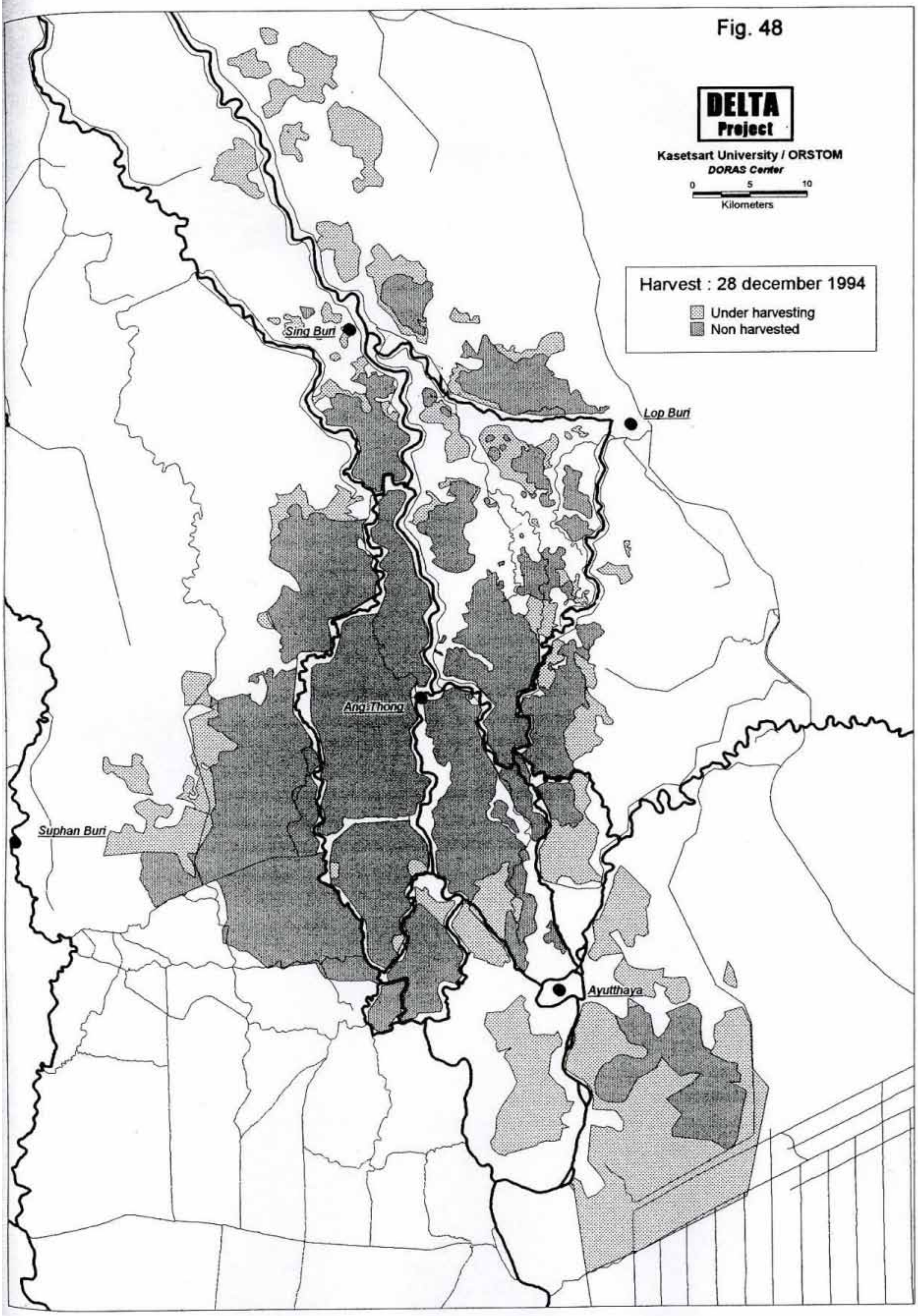
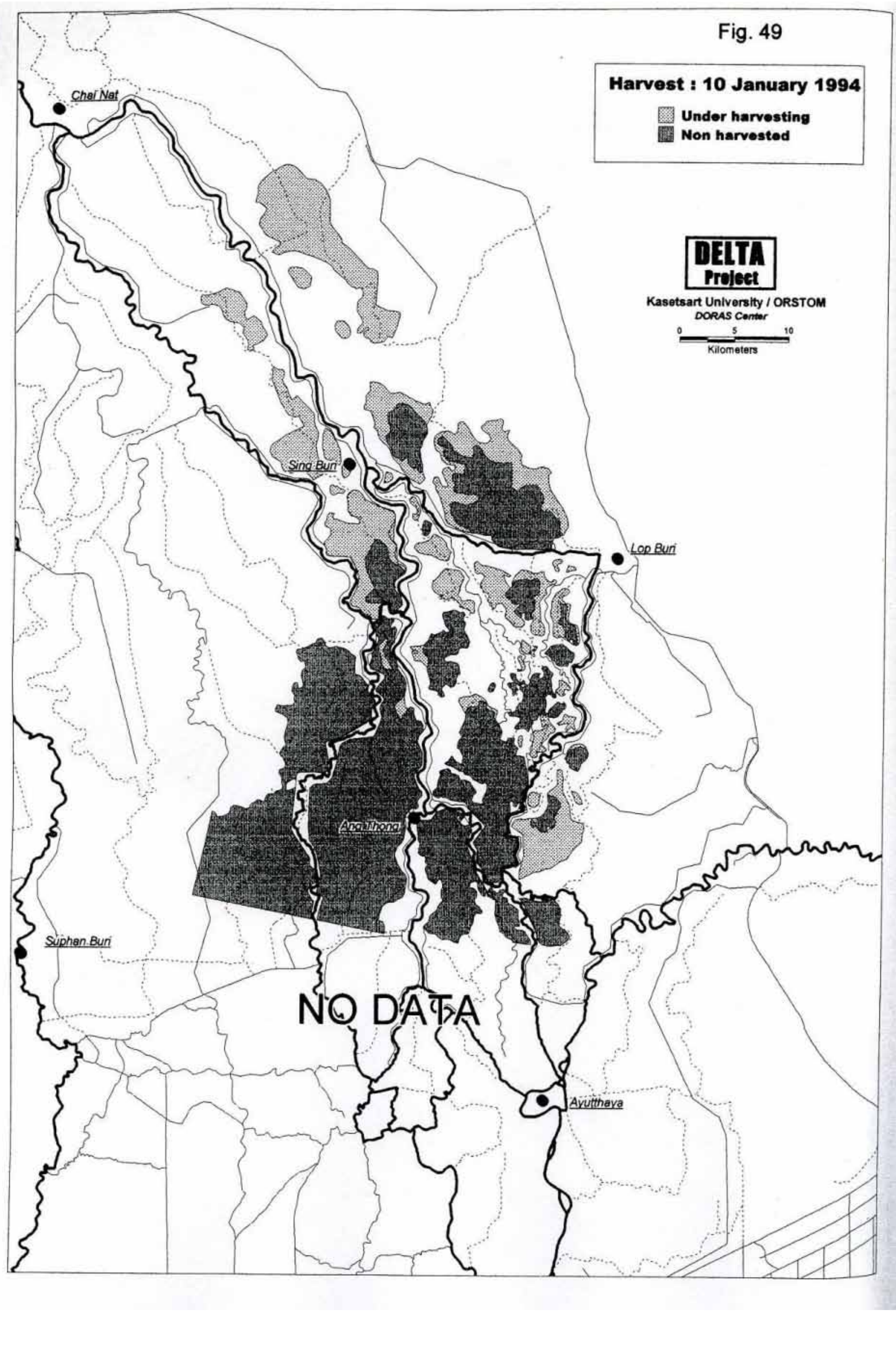


Fig. 48
DELTA
Project
Kasetsart University / ORSTOM
DORAS Center
0
5
10
Kilometers
Harvest : 28 december 1994
Under harvesting
Non harvested
Sing Buri
Lop Buri
Ang Thong
Suphan Buri
Ayutthaya

Fig. 49


Harvest : 10 January 1994
Under harvesting
Non harvested
DELTA
Project
Kasetsart University / ORSTOM
DORAS Center
0
5
10
Kilometers
Chai Nat
Sing Buri
Lop Buri
Ang Thong
Suphan Buri
NO DATA
Ayutthaya

Zoning of cropping techniques

The zoning of the cropping technique - a distinction between dry broadcasting and wet broadcasting - is made difficult by the fact that the choice of technique is strongly governed by whether farmers have engaged in DS cropping or not (see earlier section on sowing method).

In addition, in medium elevation parts, we also have cases of farmers using DWR varieties in irrigated conditions because they still fear some flood. These farmers establish and take care of their crops exactly like HYV growers do.

One way to estimate the area under dry broadcasting in 1994 is to map the flooded area in late October ; rice established with wet broadcasting, therefore under irrigation, is already dense and appears with quite sharp colours, whereas dry-broadcast rice is still sparse and the water body visible.

4. Prospects for improvements

The following recommendation focus on the possible improvements of the existing systems and on the conditions/options for a transformation or a substitution by more intensive systems.

4.1 Improvement of current water management

4.1.1 Regulation (or change ?) for higher areas

Some of the areas located in higher topographical position sometimes lack of water, because of the insufficient water level in the box. This problem has become more crucial in the last 10 years because of the overall decreasing water regime.

To offset this problem, some new regulators have been installed, sub-dividing the boxes in several smaller ones, adding "steps to the stairway" created by the cascade boxes. In case of good year, with abundant water, these gates may sometimes not be used ; if water is little, they are closed to prevent water from flowing to downstream areas.

There is qualitative evidence that the development of these gated devices is now quite complete. However a few of them have been found damaged or destroyed.

Should the regulation be made difficult because of decreasing water conditions, most particularly in the upper boxes, there may be scope for a shift towards HYV (see later section).

4.1.2 Matching gate opening and rice-farming

Farmers sometimes express some dissatisfaction about the timing of the gate opening, at the end of the wet season. Sometimes water is drained out of their fields before rice is ripe. In other cases, on the contrary, it takes too much time to recede and the plot is still very muddy at harvest time, making the use of machines impracticable.

The overall impression that rice is harvested after the agronomic optimal date also contributes to show that in most instances, harvest is delayed, with impact on the quality of grain.

It seems that there is, in some cases, insufficient co-ordination between farmers and RID staff regarding this issue. It is assumed that farmers know by experience how water will recede, because the date seems quite regular along the years. However, in case of insufficient water, or in case of late planting which may shift calendars, management must be adapted to cope with the situation. It is not clear whether such communication occurs. The analysis of the water level in the boxes does show some discrepancies between the years but this question needs further investigation.

4.1.3 Co-ordination problems and water management in a "cascade"

A particular case in which co-ordination is required is the cascade-boxes. The time and rate of gate opening must take into consideration the schedules of upstream boxes (and, ideally, of downstream ones).

With the construction of new regulators, defining new "boxes", new rules for water management are also required.

4.1.4 Improvement of flood management

It is often stressed that the flooded area acts as a buffer to reduce flood hazards downstream. *It is assumed that a significant part of the flood is diverted to the drainage boxes, thus alleviating the flow further downstream, especially in Bangkok*. A corollary from this statement is that flood management could be upgraded by knowing the status of each main drainage box and the regulators operated to allow some additional inflow and/or overload in some boxes, in some critical periods. The knowledge about the drainage boxes gained in this study allows us to shed some light on these important questions.

4.1.4.1 Assessing the buffer capacity and effect

The DEM (digital elevation model) was used to calculate the relationship v(h) between water depth (h) and the stored water volume (v) in each box. For each box, an average hydrograph [h(time)] has been calculated based on "normal years", that is to say disregarding the year 1995 (exceptional flood) and - for some boxes - the year 1993 (drought) and 1996 (flood). By combining these two equations we obtained a v(t) function for each box[22].

Fig. 52 gives the time evolution of the total amount of stored water, obtained by adding the curves relative to each box[23] (see detail per box in the annexe). It readily provides an estimation of the average maximum storage capacity (in normal years), which amounts to close to 2 billions m^3. This volume corresponds to approximately 5 days of the Chao Phraya extreme discharge of 3800 cms.

For balances of several days, the water which infiltrates and contributes first to saturating the soil and then to the percolation loss together with the volume lost by evaporation should also be considered : over a week for example, after the boxes are full, considering a percolation rate of 0.5 mm/day (Keutphitha, 1982) and an evapotranspiration of the water body plus the rice of 5 mm/day, *this total loss amounts to 136 million of m^3*, for a gross area planted with TVs of 3000 km^2. This means that, over a week, losses allow for an additional storage capacity corresponding to approximately 6 % of the total volume stored at the regulation

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[22] For boxes of the lower Yangmanee Project, the h(t) equations are not known, as no records of the water levels are kept. These relationships have been estimated based on the water depth in the fields and the time of gate opening.

[23] The curves were not available for the lower Yangmanee project (Lat Chado, Ta Tiang, Pho Pluak) and for Ban Ban Project). The v(t) functions of near by and comparable boxes have been used, made unitary (dividing by the maximum value), and multiplied by the maximum volume of the box with missing data.

levels.

The stored volume divided by this total area *gives an overall average water depth of 66 cm*.

Another important information derived from Figure 50 is the indication of the remaining storage capacity for a given date. On the 1st of October, only 40 % of the capacity is used, while at the end of the same month boxes are full (97 %). *This shows that beyond this date, the buffer area can provide relief capacity only by allowing overload of the boxes.*

Fig. 50 : Evolution of the average stored water in the upper delta (normal year)

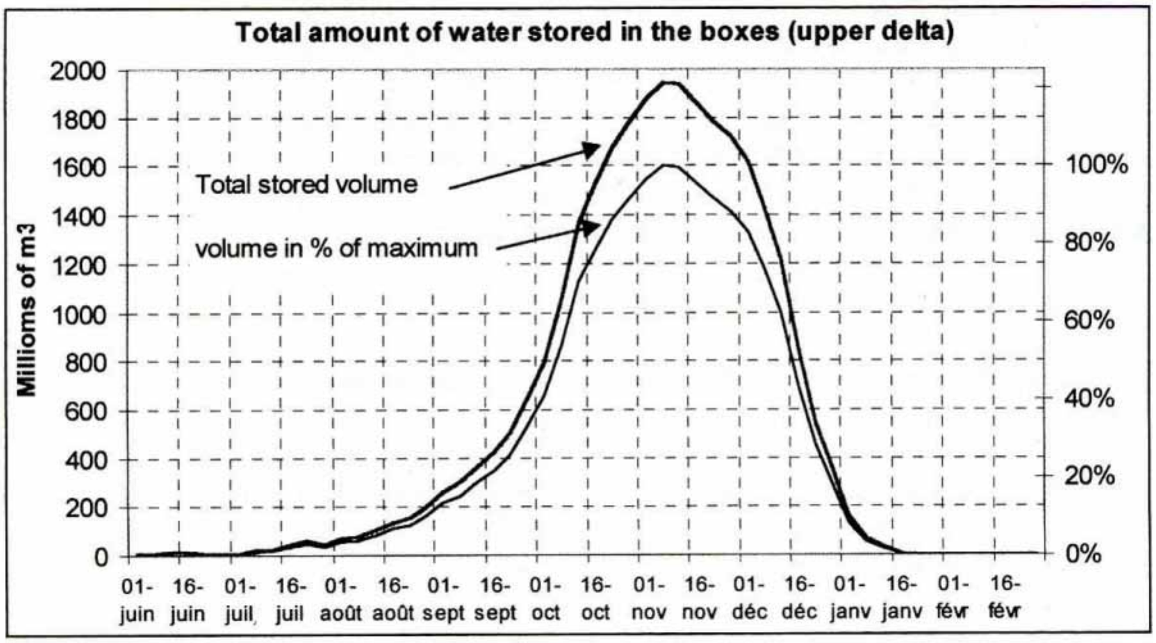

Fig. 51 desegregates this curve by main rivers : boxes draining to the Noi river, the Chao Phraya river, the Lop Buri river and the Pasak river have been grouped separately in order to distinguish the storage capacity of each group[24]. The Chao Phraya groups includes the Nakhon Luang box, and the Noi group the Phak Hai project, which contribute to make up a bigger storage capacity. The sets appear rather phased, showing that all sets of boxes accumulate water during the same period.

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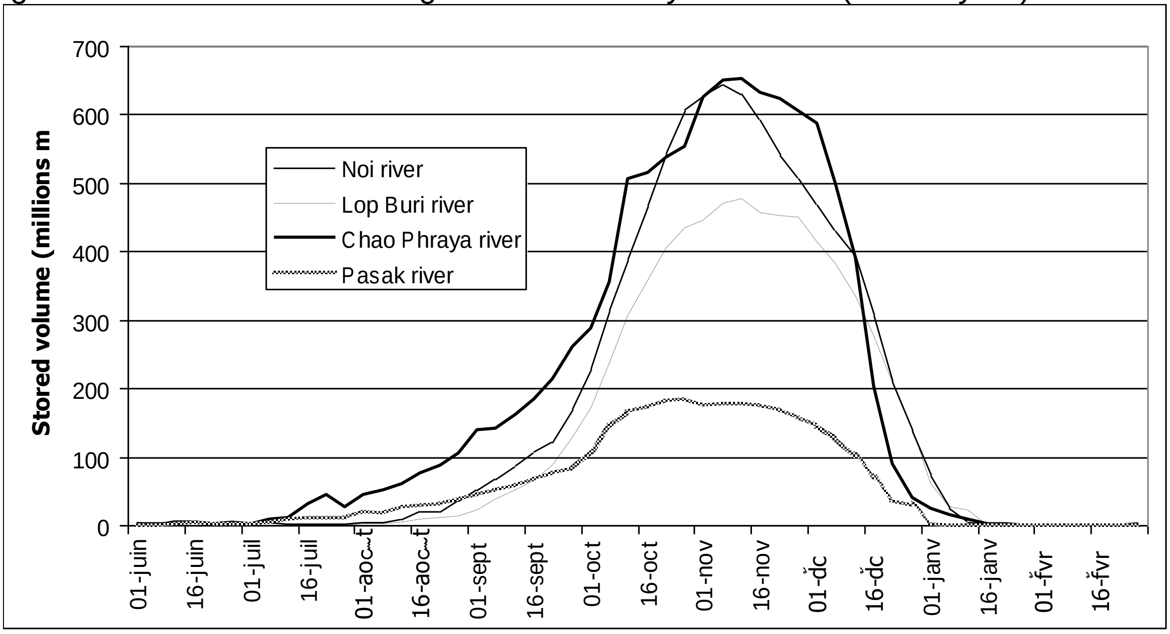
[24] This grouping is partly arbitrary as the Chao Phraya, Lop Buri and Pasak rivers are inter-linked and eventually merge together. The Noi river group includes all boxes draining into the Noi river plus Phak Hai Project. The Pasak group is limited to Bang Khum box. The Noi river set is mostly supplied by the Noi river itself. The Lop Buri + Pasak sets are supplied by the (eastern) Chai Nat-Pasak canal and a fraction of the Chai Nat-Ayutthaya discharge too.

Fig. 51 : Evolution of the average stored water by main river (normal year)



The storage capacity of the study area is quite high and should be compared with the capacity provided by the lower delta. There is no precise data on the latter. One reason is that the West Bank is flooded with various intensities depending on the year : it may be completely flooded until December or, on the contrary, like in 1998, have almost no water stored above natural ground. The East Bank is nowadays more or less deprived of flood and its storage capacity - in normal years - is limited to the capacity of its network of waterways.

The capacity of the channel network in the West Bank has been estimated at 80 million m^3 (TEAM et al. 1992). It is not clear whether the water depth considered relates to the maximum capacity but we may take tentatively 150 m^3 as an upper limit value[25]. If we consider that the area which happens to be flooded is around 1500 km^2 (mostly in the Phraya Banlue and Chao Chet Projects) and that the average water depth is unlikely to exceed 50 cm, this gives a crude estimate of 750 million of m^3 (without considering percolation loss). On the total, we may infer that the water stored in the West Bank is not greater than 1 billion m^3, or less than 50 % of the value for the upper delta.

4.1.4.2 Effect of overloading

The storage capacity calculated above (2 billion m^3) corresponds to a "normal" year in which the regulation levels are attained with no excess water. In case of severe flood, it is possible/unavoidable to divert part of the excess water to the drains and canals, which eventually leads to overloading the boxes.

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[25] Also allowing for some extra capacity provided by farm channels.

The DEM allows the estimation of the additional storage capacity obtained for a given increase of the water level in the different boxes (Tab. 9). It shows that *overloading is conducive to an impressive increase in the storage capacity* of the buffer area : for an overall increase of 25 cm, the stored volume is raised by 50 %, allowing the storage of an additional 1 billion m^3. For 50 cm, corresponding numbers are 100 % and 2.05 billion of m^3 added.

Tab. 9 : Estimation of the increase of the storage capacity through overloading

Storage level	**Average year**	+ 10 cm	+ 25 cm	+ 50 cm
Storage capacity (billion m3)	**2.01**	2.49 (+24 %)	3.018 (+50 %)	4.06 (+100 %)

4.1.4.3 Feasibility of flood management by using drainage boxes

From the data above, it is obvious that the buffer area in the northern delta is both considerable on the average and liable to be increased in case of need. In cases of severe floods, excess water is diverted to all the channels branching from Chai Nat dam and this diversion is probably more based on the capacity of each channel than on the effective possibility to get rid of the excess water further downstream.

Ideally, flood management should consider the water level in each (main) box in order to assess where water can be raised with the least trouble. Three variables must be considered : the "admissible" maximum level of overloading in each box (HLx), the rate of increase of the water level in case of diversion of excess water to the box (Ri), the time at which overloading is deemed necessary (To).

(HLx) relates to the level at which damages will go beyond acceptable levels. For each box, (HLx) depends on (1) the disposition of rice types along the toposequence and the average water level (in normal years) ; (2) the non-agricultural activities and their sensitiveness to flood. The first factor can be assessed by using the data gathered in this study. The second is much related to the degree of protection provided by the dikes of each non-agricultural unit (factory, urban area, golf, etc) : this is quite location specific and difficult to assess.

(Ri) will depend on the topography of the box and whether there is floating rice in the box. For FR, (Ri) should not be higher than 8-10 cm/day (for short periods) or 5 cm/day (for prolonged durations), otherwise FR will be damaged.

(To) takes into account the fact that after heading (in practice, flowering), the TV lose their elongation ability. We may refer to Table 6 and note that, except for Khaw Luang[26], all flowering dates are later than the 15th of November. As most of the serious problems of flood management generally occur between the 1st of October and the 15th of November, this constraint can be overlooked in most cases, while attention is required after this date for late floods.

[26] And, possibly, other varieties : the table is not complete and additional data is needed.

(HLx) cannot be simply extrapolated from the average regulation level : it could be envisaged to consider the DWR plots with the highest water level (h1) and - taking a maximum admissible water level of 1.00 m - infer that water can be raised safely by (1-h1). The same approach can be applied to FR (with a maximum admissible level which must be adapted to each variety) and the lowest of the two values chosen as an estimate of (HLx). In practice this approach is not realistic because (1) the DEM may not be accurate enough to capture local situations[27], (2) a value of (HLx) so defined might be too restrictive, as one may allow the loss of a limited acreage if the corresponding gain in storage capacity is significant (ex : 20 cm above (HLx) may result in the loss of a very limited area, while it adds a large amount of storage capacity) ; (3) the water surface cannot always be considered as flat[28].

The data of the study show that the water level in both DWR and FR (at the regulation level), tends to be quite lower than the one "agronomically" admissible. This is quite normal as it allows for some margin of security against water level fluctuations, which may arise in instances of heavy rainfall when the level is already at its regulation level. This implies that *limited overloading is likely to be practicable in all boxes without significant damage* (provided it follows constraints on (Ri) mentioned above).

Once a given overloading water depth has been decided for a box, it remains to see how, in practical terms, this overload can be achieved. This will depend on the existence of (1) waste ways in the main canals (lateral spill), (2) regulators allowing a water inflow from the river system at some point of the upstream box boundary ; apart from these possible solutions, remains the possibility to increase the return flow from the tail-end regulators of the laterals to the drainage system and to open the (downstream) box regulator to allow water in (in case of flood, the level of water in the river channels is very likely to be higher than in the box).

4.1.4.4 Establishment of a monitoring dashboard

In order to facilitate the spatial vision of the box status, it can be imagined to set up a monitoring map based on the current water level in the main boxes. Colors could help show the status of each box as related to its normal regulation level, and identify where remaining capacity is available - or where overloading is advisable. A joint table could calculate the total volume stored and indicate the remaining margin.

Fig. 52 shows a fictitious example of such a tool, as it could appear.

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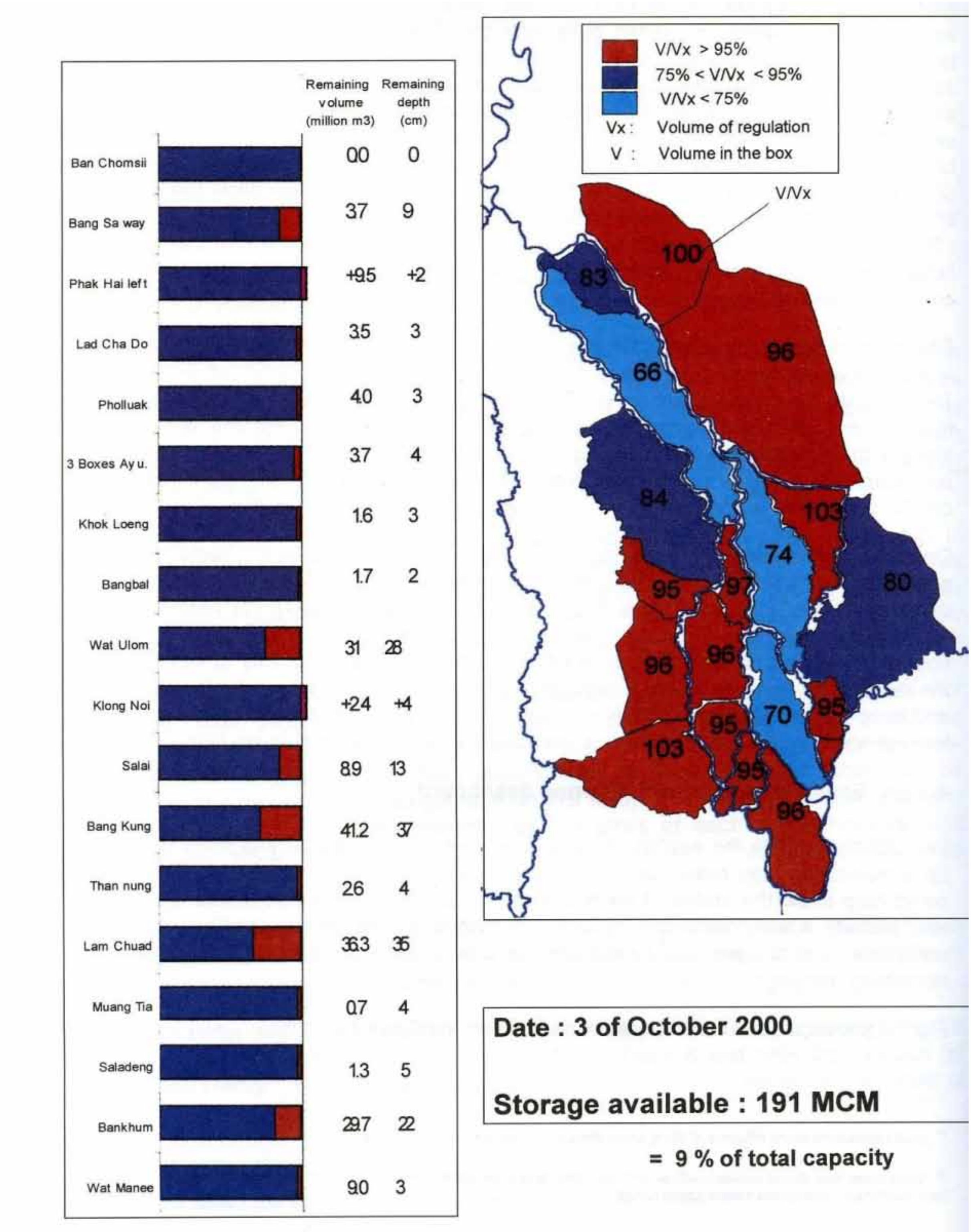
[27] Local depressions or the influence of diking which alters the significance of natural topography.

[28] Some boxes have almost constant outflows and road dikes also often hinder run-off within the boxes. Pipes do exist but often have insufficient capacity and increase head losses.

Fig. 52 : Example of "dashboard" for the monitoring of flooded area

Flood monitoring and management - Chao Phraya Delta



A difficulty comes from the cascade boxes : in the Wat Ulom box, for example, the downstream water level is no more representative of the water status in the lower sub-box ; in case of flooded conditions, however, the rise of the water level will tend to make intermediate steps disappear. The monitoring can be improved by considering the water level at the different successive (main) regulators.
The "dashboard" shows the status of each box (the actual stored volume appears as a % of the maximum storage capacity, not considering overloading) and indicates - on the right - the volume (in million m^3) which still can be stored. It allows managers to spot straight away areas to which water must/can still be diverted, as well as boxes already full, for which discharges coming from the irrigation network should be reduced.

4.2 Possible transformations of traditional rice-systems

4.2.1 A context of declining water regime

The principle of drainage regulation of the flood-prone area is based on the assumption that the risk of uncontrolled flood - or of a sudden rise of the water level in a given drainage box, even brief - is too high. Therefore deep water varieties are preferred, as long as risk cannot be reduced or eliminated. In several of the boxes visited, indeed, it appears that the average water level is very low, allowing - in theory - the use of HYV.

In the last twenty years, water conditions in the delta have slowly but continuously changed. FR and DWR areas have decreased and even disappeared in some Projects such as Phophya or (lower) Don Chedi. In other places, FR has been substituted by DWR and DWR by HYV. Areas which were commonly using boats twenty years ago are not using them any longer.

The overall feeling that "there is less water than before", often expressed by farmers and confirmed by Charoendham et al. (1993), who found 92 % of farmers indicating a decrease in water depth, is indicative of a very significant trend. Several reasons account for such an evolution :

- the continuous improvement of drainage in the delta;
- the construction of dikes and embankments (protection dikes and roads), which hinder runoff;
- the decrease of side flows coming from adjacent rainfed areas in the Central Plain, because of better control and increased water use in these areas;
- the diminution of runoff because of control by dams and higher water consumption (irrigation, urban areas) in the upstream part of the Chao Phraya (and tributaries) basin;
- a decrease in overall rainfall (Banchaa et al. 1998).

These changes allow us to state, as an hypothesis for research, that the "water retention management" of the drainage boxes could be, in some places, substituted by a "full drainage management", when downstream conditions allow sufficient drainage. Such a substitution would allow an increase of the area cropped with HYV and a hike in land use intensity, resulting in significant benefit for the farmers concerned. As such a drastic transformation is unlikely to be possible in many areas, the alternative solution is to examine whether a decrease of the regulation level is possible.

Such an hypothesis is supported by a case study which has been carried out in the southern part of the Borommathad Project, where such a change occurred four years ago (Molle and Keawkulaya, 1998). Agriculture has been completely changed in an area of approximately 6,000 ha (38,000 rai) because of the shift from drainage regulation (through the use of a drain regulator) to gravity irrigation.

These changes include : a switch from deep water rice to HYV; a large expansion of double and triple cropping; a marked increase of sugarcane which can now be planted in lower areas.

4.2.2 Conditions for a shift from TV to HYV

In *amphoe* Tha Wung, south of the west-east upper reach of the Lop Buri river, farmers have collectively shifted from DWR to HYV some three years ago. The change seems to have been fostered by the decreasing water levels in the flooded fields and by the difficulty to find labour for harvesting, prompting farmers to adopt HYV which can be more conveniently (and at a lower cost) harvested with machines.

The move was said to have been collective because of the impossibility to have HYV and DWR mixed in the same area : this would make the access to plots difficult (as harvesting periods would differ) and would marginalise some farmers regarding rice marketing, as rice mills prefer to process only one (or a few) rice varieties in order to minimise the burden of machine adjustment.

In the light of the case study of Borommathad Project (Molle and Keawkulaya, 1998), the transformation of one drainage box devoted to extensive rice-cropping into non-flooded areas with HYV cultivation appears to be possible under a set of conditions, both physical and socio-economic. These conditions for a change are :

- The downstream drainage conditions must allow excess runoff to be drained.
- The banks of the drain may need to be raised, so that flows coming from the upper part of the drainage box can be guided and evacuated without overflowing into the lower parts. For small "upstream" boxes or sub-boxes, this may sometimes not be indispensable.
- The secondary drains which flow into the main drain must have gated outlets, so that high water levels in the drain do not backlash into the fields.
- If the water is no longer provided “from below”, it must be provided “from above” : this implies that irrigation canals and ditches, or tube wells, be sufficient to deliver water to all the plots.
- At the plot level, farm drains and plot levelling possibly need improvements in order to allow the use of HYV.

- Farmers must have adequate equipment in order to cope with the change of land preparation technique. This constraint can be bypassed if enough farmers in the area have two-wheel tractors and can provide service for land-preparation. Another alternative is to use the four-wheel tractors usually used for dry ploughing for land preparation in wet conditions. Although this may seem not easy to achieve (small plots, muddy conditions), this has been observed frequently, probably where the soil characteristics allowed it.

- Farmers must have strategies compatible with rice farming intensification : lack of resources for input or labour, pluriactivity with agriculture as a secondary activity, high rate of tenancy or trends to land sale, ageing farmers, are factors likely to be indicative of a lack of interest for agricultural intensification.

The first factor to be considered is to what extent excess flow can be drained out of the box, so that the risk of submersion be reduced. The drainage capacity is directly dependent on the water level downstream of the box regulator : in fact, while we may close the regulator to protect the box from river water entering it, we will not be able to drain possible excess flow accumulating inside the box if the water in the river is higher than in the box.

If we look at the hydrographs presented in the annexe for the main boxes of our study area, we see that for most of them there is a succession of years in which drainage is always possible, while in others drainage is (or would) be prevented by high water levels in the river. The Salai and Muang Tia boxes, for example, offer absolutely no drainage into the Noi river[29].

4.2.2.1 Bang Khum box

In the Bang Khum box, we observe that - apart from the exceptional years of 95 and 96 - the drainage conditions are rather good, with the exception of two flash flood periods. There is some speculation on the future impact of the Pasak river dam which might contribute to decrease the water level in the river and, therefore, at the drainage exit of the Bang Khum box. It seems, however, that this regulation will have little impact in times of high tide and high flows in the Chao Phraya river (Laikarnchanapaiboon, 1993). Figure 53 shows that under the present conditions, the Rama VI dam can divert only a small share of the Pasak river flow to the Rapiphat Canal : the changes of the water level in the Pasak river are passed on to the lower reach (the level is maintained around 7.00 m upstream of the dam). The peak, nevertheless, is smoothened when we look at a further location, such as Bang Khum box outlet.

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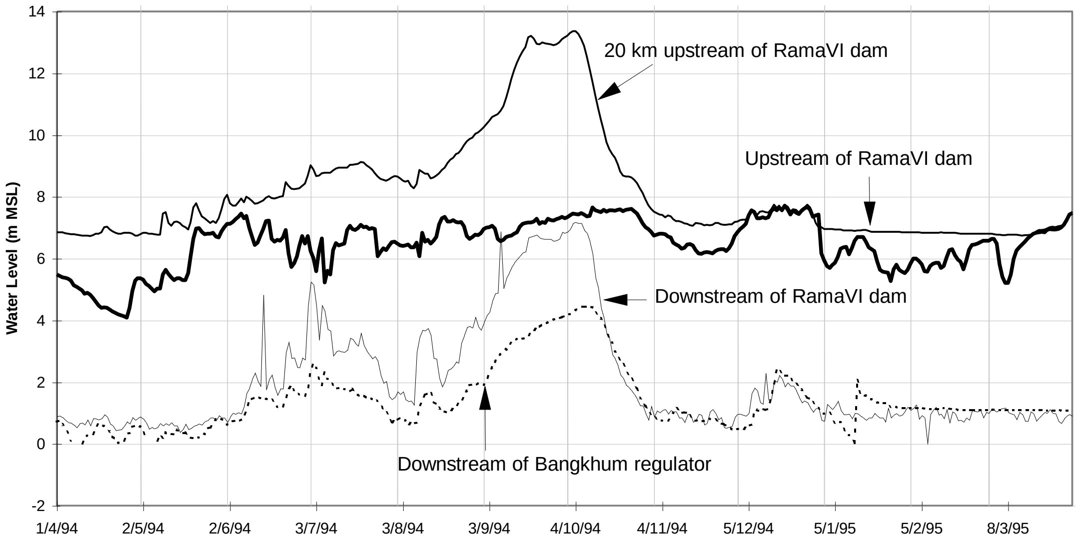
[29] But this is a consequence of the use of the Noi river as a trunk canal (and in that particular case of the Phak Hai regulator downstream)

Fig. 53 : Water levels upstream and downstream of Rama VI dam (1994)



4.2.2.2 Boxes draining to the Lop Buri river

Regarding the boxes which drain into the Lop Buri, little change seems possible, although drainage is possible in some years. The regime of the river, however, will be modified by the current construction of 5 new regulators, including one near its upper junction with the Chao Phraya river. This structure will allow the control of the flow diverted to the Lop Buri river but will probably have to be fully opened in case of flood or excess flow. The possibility to lower the regulation level in the boxes draining in the Lop Buri will be greatly enhanced but the share of the drainage capacity provided (in case of flood) by the Lop Buri river would be lost : it is not sure that the Chao Phraya drainage system can afford such a transformation at present.

4.2.2.3 Lam Chuad box

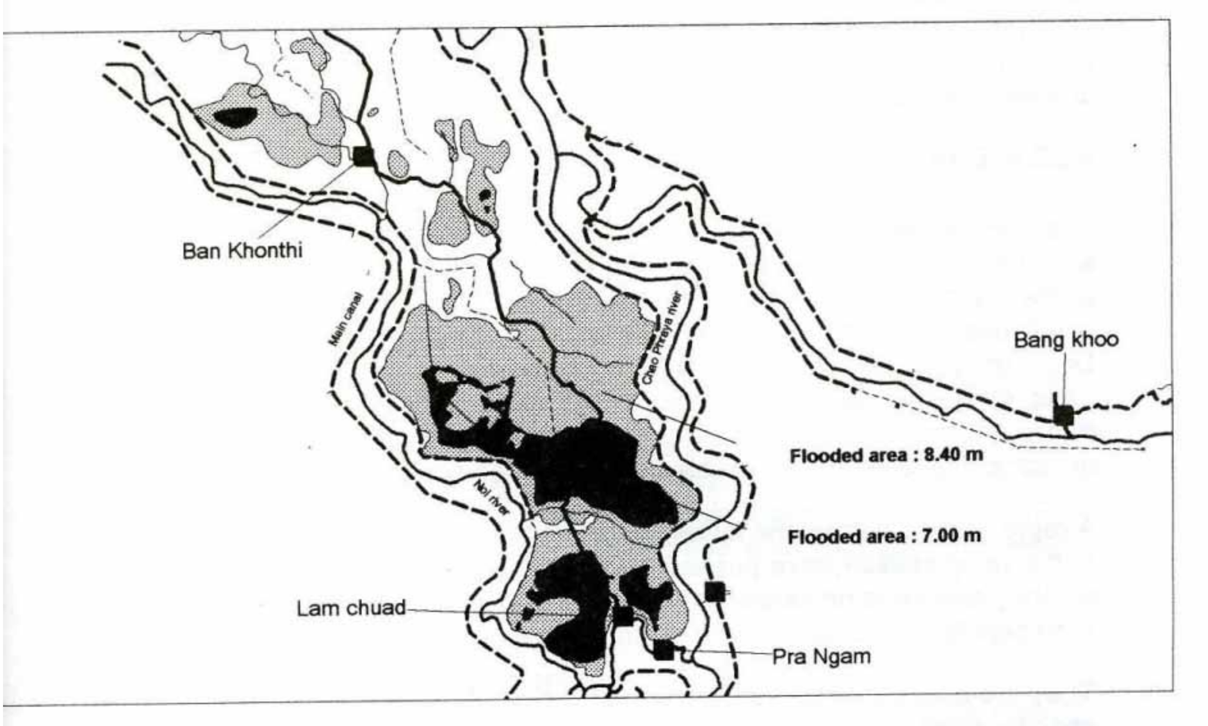
One box, however, seems to offer scope for a change in regulation : the Lam Chuad box. While its current regulation level is around 8.40 MSL, the downstream level hardly rises above 7.00 MSL, pointing out to the possibility to establish a lower regulation level. Lowering the inner level by say 1.40 m would allow some plots located along the main canal to shift to HYV. In addition the western side of this box has been shown earlier to include a large area in which WS rice has already disappeared.

The digital elevation model allows the specification of the area which would benefit from a change in regulation (Fig. 54). The area which could be freed from flood conditions is calculated at 25,000 rai. At this scale, moreover, this is a mere estimation : should a project be considered, a detailed survey should be undertaken, taking in consideration - in particular - the micro-topography, dikes and plot bunds. In addition, as mentioned in an earlier section, the water body in the box shows a significant slope (Lam Chuad box drains excess ware almost constantly through its regulator). This partly explains why the DWR area extends further upstream than calculated and shows that the area which might benefit from the change is larger than the estimate of 25,000 rai. The area is rather irregular, with scattered depressions *; it should be investigated what on-farm development would be needed* in case of change of the water regime.

Poor drainage is probably the main cause of the real area planted with DWR being larger than indicated on the map (on the other hand some high land on the levees and cropped with HYV appear in grey in Figure 54). As stressed in § 4.2.2, the change would probably also *require an increase of the internal drainage capacity* and this point must receive special attention.

The area includes several spots where farmers gave up WS rice (their plots are slightly flooded) ; they say that in case the water levels should be reduced in the main drain, the plots located half way between the drain and the main canal should be provided with ditches ; the outlets of the secondary drains to the main one should also be gated to both retain water in these drain and avoid backlash in case of high water level in the main drain. There is at first sight no reason why this area could not be upgraded with basic on-farm development, as most of the neighbouring areas in Borommathad and Chanasutr Projects have already been[30].

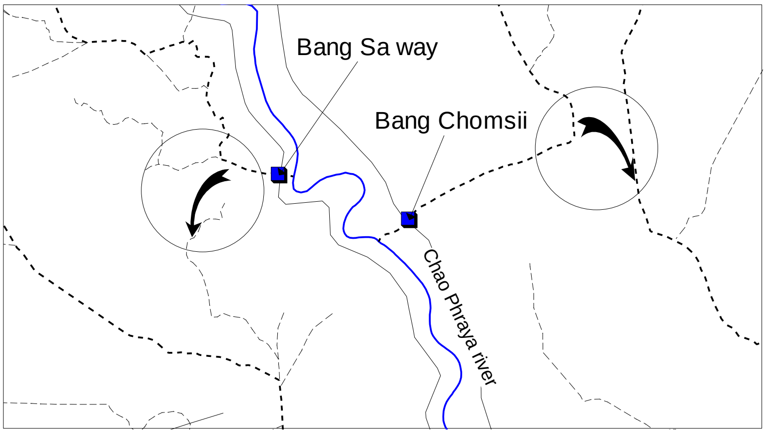
Fig. 54 : Example of modification of the regulation level (Lam Chuad Box)



[30] This is not the place to discuss about priorities and policies of investment in irrigation in the delta ; it suffices to say that the transformation referred to here are not more costly than any of the ones which can be observed (excavation of huge pounds, diking, dredging, etc); they could also match the search for work opportunities of the Office for Land Consolidation.

Should the Lam Chuad box be (partly) drained, another subsequent improvement could be feasible. A junction between the drain of Bang Sa Way box and the upper reach of the drain of the Lam Chuad box could be established (Fig. 55).

Fig. 55 : Possible drain junctions in the upper delta (Bang Sa Way and Bang Chomsii boxes)



More than 60 % of Bang Sa Way box is cropped with TVs, although intensive land consolidation has been implemented in this area. Such a junction would provide this box the drainage it is deprived of at the moment because of the unsuitable conditions downstream in the Chao Phraya river. It would capitalise on the investments already made and raise the productivity of the area. The junction would increase the box area by 33 %, which is reasonable if we consider the drainage capacity of the Lam Chuad box.

4.2.2.4 Don Tum sub-box

The Bang Khum box, which drains to the Pasak river, also provides an interesting exception. Although it is located in quite a high topographical position and close to the main canal, it is still planted with DWR. This sub-box undergoes flooded conditions thanks to regulators located in the drain which flows to and through Don Tum (Fig. 56). This area appears conspicuous as it is (together with some parts of Pasak Tai project) one of the rare cases in which farmers used to transplant their crops in the past and shifted to dry broadcasting instead of wet broadcasting when labour problems became too acute.

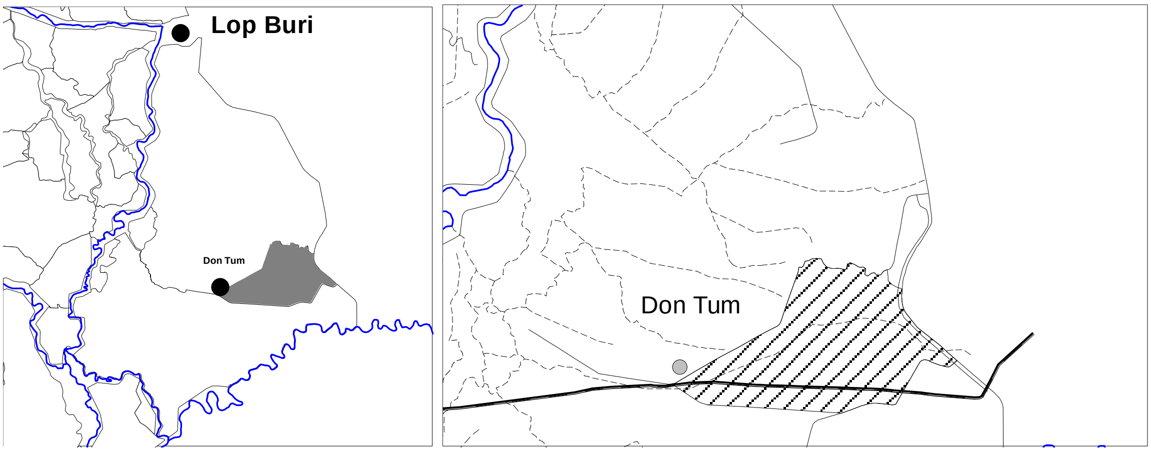
A rapid appraisal gave the following explanation : the degradation of water supply in the rainy season have pushed farmers to resort to dry broadcasting. By doing so, they also save on herbicide costs and land preparation, if they hire the service (130 baht for DB, against 350 baht for WB).

They are aware that this choice prevents them from using HYV (apart from some specific plots) but argue that, even though most farmers would find it desirable, a change is difficult because giving up the box regulation would deprive the higher plots from water. They stress that the change would have to be collective (it is impossible to have both water regimes : flood regulation and gravity irrigation) and doubt that a consensus could be possible.

This situation is exactly the one which was prevailing in the Borommathad case study (Molle and Keawkulaya, 1998), with the encouraging difference that in Don Tum plots conditions are already suitable for WB given that transplanting was practised before. The constraints appear to be both in terms of collective decision-making and irrigation facilities. A shift to irrigation would probably have to come alongside some improvements in farm drainage, both for dealing with heavy rainfall and drain water before sowing. It would also require to test/upgrade the drainage capacity of the existing main drain and to rehabilitate the ditch system.

None of these interventions appear to be very costly if compared with other current investments in the area (diking, excavation of huge ponds, land consolidation in marginal areas, etc). A technical feasibility could be achieved to provide a basis for a collective discussion with local stake-holders.

Fig. 56 : Location of the Don Tum sub-box



4.2.2.5 Bang Ban Project

Apart from drainage conditions, farmers strategies are also a possible constraint in agricultural change. The Bang Ban Project provides a good example : located on the west of Ayutthaya, this project is provided with a protection dike which turns it similar to an island or a polder. In theory, with possible on-farm improvements, this project can accommodate double cropping of rice (DWR + HYW) as it may pump water from the Chao Phraya river through its pumping stations.

Officers and farmers alike acknowledge that there is little impetus for such a dynamic in the area (again, such large-scale changes need to be collective). Farmers have long developed pluri-activity (the DS is occupied with brick making and other handicrafts ; a large part of the local labour force has been drained by industries in Ayutthaya province), a lot of land has been sold to speculators or for sand pits, farmers are ageing, etc[31].

[31] According to RID officers, 90 % of the land south of Ayutthaya has been sold already...

Should these conditions have been implemented earlier, a more intensive agriculture (double-cropping) might have developed in the area. However, as water can be distributed to spot areas (the project is comprised of several pumping stations located all along the dike), it could be envisaged to organise meetings to better assess whether some spot areas would be interested in doing dry-season cropping, or renting out the land to outsiders, as is being the case in the neighbouring Phak Hai Project. In fact, the project provides pumping facilities which are very similar to the "Pipe irrigation System" disseminated by the Department of Energy Promotion[32].

Some areas along the canals, especially the south-western side of the project, used to practice transplanting in the past. Their plot conditions are compatible with DS cropping and the 1997 dry season has shown a promising responsiveness of farmers in this area (12,000 rai of DS cropping in the whole project in 1997).

4.2.2.6 Upper boxes; high land

Apart from these main boxes, several upstream sub-boxes are likely to allow a shift to HYV, such as occurred in *amphoe* Tha Wung, as shown earlier.

This could include some (upper) parts of the Chong Kaew and Khok Kratiem projects, which seem to adopt TVs because of the necessity/choice of dry broadcasting, Khlong Taa Nung box.

Most generally, there is the feeling that most boxes could lower their level tentatively (by say 20 cm), as it happened in Bang Chomsii or some other boxes in the past : collective meetings and corrective actions in land development are needed in all cases.

4.2.3 Increase in dry-season cropping

Increasing dry-season cropping is a significant way to intensify rice farming in the study area. However, it faces several constraints : a first set comes under the category of access to water, a second relates to plot conditions and a third to the collective dimension of rice farming.

- Water constraints can be commented at two levels : the local level and the delta level.

[32] but in that case it would be very difficult to recover pumping costs as this has never been the policy in the Chao Phraya delta.

Farmers may have access to 3 kinds of water sources :

1. irrigation sources : plots are close to a canal, or in an area where the tertiary ditch network is well developed,

2. pond or reservoir or drain,

3. tube wells, which are an unusual solution for rice cropping in most of the study area (but very common in the northern part of the delta).

Farmers are dependent on irrigation water or on secondary resources they may tap or have access to. Regarding irrigation water, it is worth noting, in passing, that all the water abstraction from irrigation channels must be done through pumping at the farm level, as low discharges do not allow gravity flows into the ditches.

In several areas, farmers mentioned the existence of wells, mostly dug through governmental projects in 1992-94, but very few seem to use them. In one area with sandy soils, it was said that this particular condition was conducive to wells clogging up. Typical wells, 16 m deep, are not too expensive (4,500 baht for 3", 6,000 baht for 4") + pump (1,500 baht), when a two-wheel tractor can be used to power the pump. While they are intensively used in the north of the delta, few farmers resort to them in our study area, except along the banks of the Chao Phraya river, between Sing Buri and Ang Thong.

Reasons for not using wells include brackish water, insufficient underground water available (wells dry up after a few hours of use), lack of proper pumping devices. The east of the Chao Phraya river (south of a Sing Buri - Lop Buri axis) seems to have little convenient underground water, compared to the north of the delta.

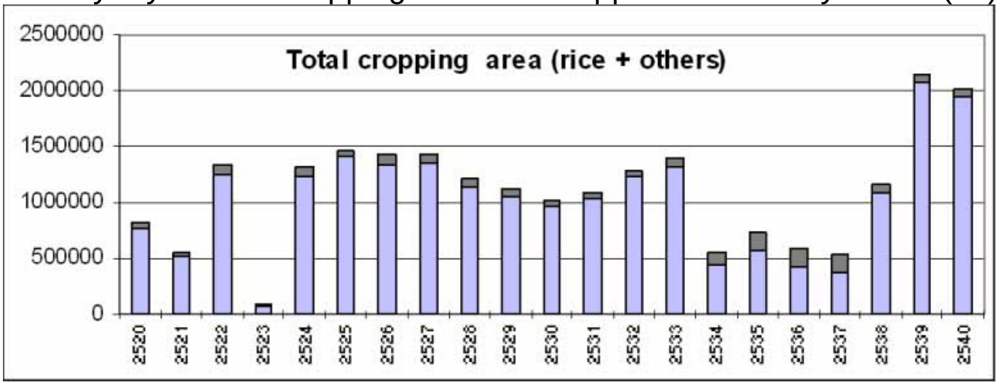
Other secondary sources liable to allow DS cropping are big reservoirs excavated in the lowlands. Many can be seen in the Maharat tract (Ayutthaya Province), but little DS cropping seems to develop in their surroundings.

The reasons for the ineffective use of wells and reservoirs are currently being investigated in another research project.

Regarding the macro level aspect of water allocation in the dry season, the first point which needs to be stressed is that the hydraulic system of the Chao Phraya Project has been designed for supplemental irrigation in the rainy season. Therefore, it does not have the capacity to deliver water to the whole of the irrigated area. The maximum cropping intensity estimated based on the ratio of water duties for the wet and dry seasons is 57 %, while operational constraints points out to an effective dry-season cropping intensity of 30-35 % (ILACO, 1980). Increase in cropping intensity can chiefly be achieved through the staggering of cropping calendars and the use of secondary sources (which is already the case).

In addition, the overall availability of water in the dry season is both insufficient and irregular. Fig. 57 shows the evolution of DS cropping in the upper delta which consumes approximately 50 % of the water diverted in Chai Nat from January to June. The question on how, when and where this limited supply must be allocated is probably the most important question for the sustainability of agriculture in the delta at present.

Fig. 57 : Yearly dry season cropping area in the upper Chao Phraya delta (rai)



- Secondly, it must be noted that not all of the irrigated area is provided with the plot conditions (ditch system, bunds, levelling, farm drains) which are necessary to engage in DS cropping. In particular, areas with FR are very often vast extensions of land almost in their natural conditions.

Land levelling is an important factor in the success of wet broadcasting. Many areas with newly adapted plots can be seen with some parts of them lacking water : this is obvious at the time of sowing, but also later, as higher parts are plagued with weeds. Farmers also mentioned the exposure of these poorly flooded portions to the rats, which will preferably attack them.

Rice cultivation during the dry season represents a high investment for farmers who never grew DS rice because of unsuitable plot conditions. In addition to land improvement, investments in pump and/or two-wheel tractors are often necessary. Levelling will often require several hours of tractor work (at 300 baht/hour). This deterred many farmers to start DS cropping, even though they may have access to a water source.

This latter case is nevertheless rare, as there is a high correlation between the plots which have access to water and the one with proper conditions for DS cropping. This is due to the fact that RID tends to supply water to areas with land consolidation and, on the other hand, to the fact that areas with frequent or permanent access to water have been indirectly encouraged to improve their plots.

This situation, however, has considerably changed during the 1996-1998 period. As a compensation to damages caused by floods (and early drought in the establishment of TV in 1997), RID delivered the highest amounts of water ever seen. This, along with a significant hike in rice prices, prompted those farmers who had never engaged in DS cropping to do so. Considerable investments have been made accordingly, much beyond what could have been expected if one considers the complete uncertainty on whether these supplies will be renewed in the future.

A point which may also hinder farm investments necessary to carry out DS cropping is the rather high level of land which is rented. Land tenure, in the survey, is equally well divided between owners and renters : 39 % of the farmers are full owners, 30 % are full renters and 31 % are both. If we consider the surveyed area, the whole rented area is a bit larger, with 4,000 rai, while the owned area is about 3,100 rai.

The lowest land rental fee is 250 baht/rai/crop. It commonly varies between 300 and 500 baht/rai/crop, and it can rise up to 1200 baht per rai, depending on the quality of land (HYV or TV) and the local demand. In a few cases (15 %), the rental fee was found to be in kind : 100 to 150 kg/rai.

Tenancy is known to often impact negatively on the level of farm investment. It is not possible to assess this impact within the scope of this survey. It may be noted however that a few cases of tenants investing in land levelling were also observed.

- The third aspect relates to the collective nature of rice-cropping, oddly enough little alluded to in the literature.

The first aspect is relative to pest pressure : if a farmer has a reliable source of water, and decides to grow rice, while his neighbours do not, he will certainly get a low yield : all the rats of the area will converge on his plot. To solve this problem, isolated farmers must install an electric fence around their plot. In fact, rice cultivation is almost impossible if the field of the farmer is not included in a larger area of rice. Moreover, if there is a big group of farmers who decide to grow rice, it will be also easier and cheaper to develop the irrigation network.

The second aspect deals with the question of water. If a group of a few farmers decides to engage in DS rice, water is likely to seep to neighbouring plots, resulting in a high growth of weeds which will make land preparation difficult. Conversely, if one farmer grows a DS crop alone, he is likely to suffer heavy seepage and percolation loss, with a corresponding hike in pumping costs.

A move towards DS must therefore be collective : this requires that the will and ability of farmers to engage in this (new) activity be homogenous. If many individuals are indebted, they will be unlikely to invest in land levelling or in a two wheel tractor, or even to buy the agro-chemicals needed. It also requires that access to water be acceptable for everyone and likely to be effective each year, at least one year out of two.

Other factors have also been mentioned earlier concerning this collective dimension : the necessity to have the same calendars (water management, access to plots) and few varieties (milling).

4.2.4 Conditions for a shift from WS rice to DS rice cropping

We have seen earlier that in many instances farmers would rather give up WS cropping provided that the conditions are - instead - suitable for an (early) DS crop. This crop is grown as soon as water recedes, the earlier the better. This is why, to some extent, DS cropping is developed *instead of* WS cropping rather than in *addition to it*[33].

Local polders are sometimes even built around a plot, or a cluster of plots, to allow for pumping water out in order to advance cultivation. With an earlier crop

[33] Beyond this constraint on calendar (the late harvest of TVs delays the opportunity for an early DS crop), the low profitability of the WS crop is also mentioned by farmers as one of the reasons to give up WS cropping.

establishment farmers fully capitalise on field wetness (the soil is soaked) and lengthen the period during which water will be available in the nearby canals.

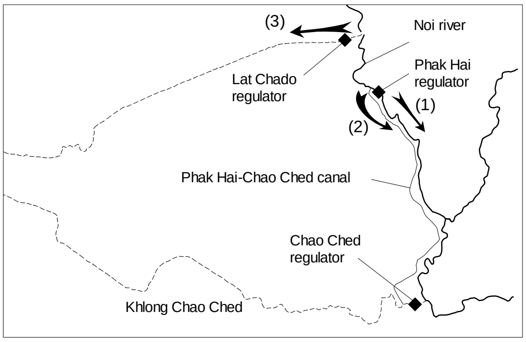
If such a trend is to expand to one entire drainage box, then the proper logic of the drainage regulation must be questioned. Instead of artificially storing water, the box could be left open (except in case of high flood in which protection is needed), and its drainage left to natural conditions. This will allow an earlier (average) water receding period and an earlier start of the dry-season cropping.

Similarly to the West Bank, which may admit excess water and even flooding, but waits for water to recede before starting DS cropping, areas which would give up WS rice cultivation could give up regulation (or keep it only for protection in case of floods) and let their box drain naturally. *This would happen between one and two and a half months ahead of the current drainage time, depending on the year, and would greatly facilitate single and double DS cropping*.

If we consider the case of the Phak Hai Project, we might envisage such a shift in the conception of water management, from artificial storage to free drainage. A problem may arise, however, in that Phak Hai Project also receives the drainage water from upper boxes at the time they are drained. This is probably incompatible with an earlier drainage of the project itself and possible DS crops could probably not be protected from this flow without additional land development. Upstream flows should be channelled towards the West Bank through a canal with convenient embankments and junctions equipped with control structures.

Another strong and meaningful argument commonly stated must be considered here : *the drainage of the different boxes in the December-January period is believed to provide most of the water which allows an early DS cropping in the lower delta*. Reducing the water stock - as would occur in case of modification of the box regulation - would then appear as prejudicial to downstream areas. Modifying the release of water from the drainage boxes must be seen within this wider scope of water management.

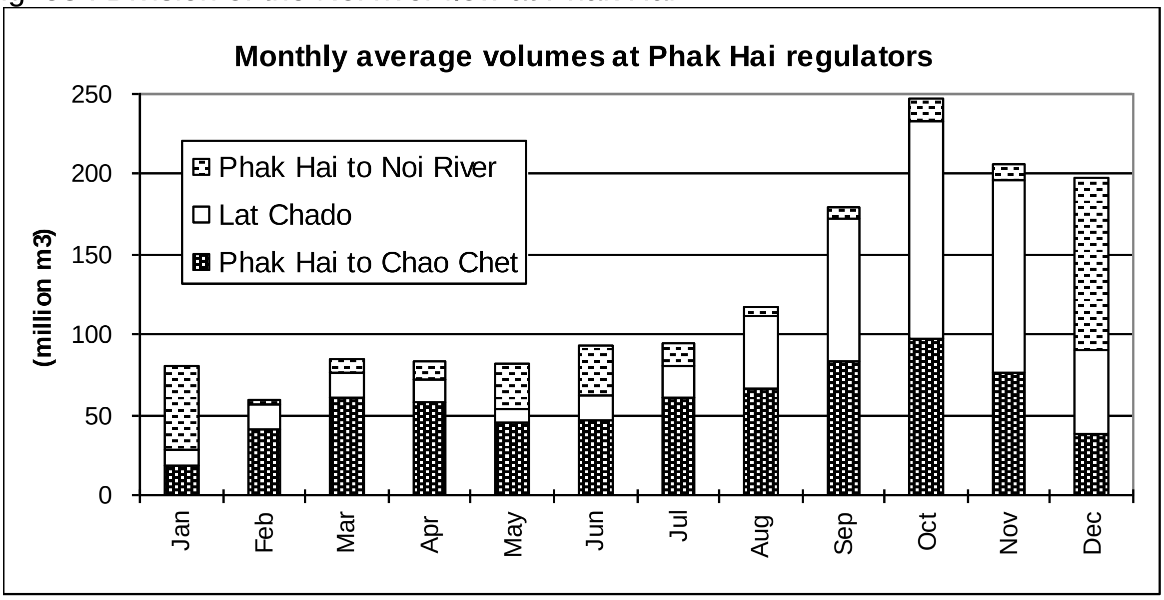
A first evidence is that the water stored in the boxes is *drained to the river system* and eventually contributes to the Chao Phraya flow south of Ayutthaya. The boxes draining to the Noi river constitute an exception as the corresponding flow can be diverted to the Wet Bank through the Phak Hai-Chao Ched canal.



To assess to what extent the Noi river flow is diverted and reused in the West

Bank, we plotted the monthly average flows of the Noi river (expressed in m^3, period 1977-1997) as divided into three flows : (1) the flow to the Noi river ; (2) the flow to the West Bank through Phak Hai-Chao Ched canal ; (3) the flow towards the Tha Chin river/Phak Hai Project, through the Lat Chado regulator and canals (Fig. 58). While most of the flow appears to be diverted to the West Bank from February onward, 58 % of the Noi river flow continues its way towards the Chao Phraya river during the drainage period of December and January. This is because the absorption capacity of the West Bank is still low or none at that time (it is still full of water and Phak Hai project is also partly draining into it). In fact, the final volume diverted to the West Bank is even lower than shown on the graph as a significant flow is also observed in the same period at the Chao Ched regulator[34] (drainage to the Chao Phraya river).

Fig. 58 : Division of the Noi river flow at Phak Hai



Therefore at least 87 % of the boxes drainage flow is eventually dumped to the Chao Phraya river. Its contribution to the irrigation of the early DS rice crop in the lower delta appears much more limited than thought. This flow contributes to maintaining the water level in the Chao Phraya river quite high, in its lower reach between Ayutthaya and the sea. It may partly enter the West Bank through the opened channels branching from the Chao Phraya along the eastern border of Phraya Banlu and Phra Pimon Projects, or at least slow down the decrease of the water level in the West Bank.

Data provided by TEAM et al. (1992) and obtained through running a hydraulic model of the lower delta confirm that the contribution of the Chao Phraya to the West Bank is negligible (Table 10) :

[34] This flow is quite variable depending on the year. It commonly reaches a peak of 50 cms during the second half of December but in early January the gate is closed again.

Tab. 10 : Inflow from Chao Phraya River into the West Bank (cms)

	November	December	January	February
Chao Chet Bang Yihon	0	0	0.6	8.5
Phraya Banlu	0	1.4	0.5	9.5
Phra Pimon	0.2	0.3	0.1	3.6
TOTAL	0.2	1.7	1.2	21.6

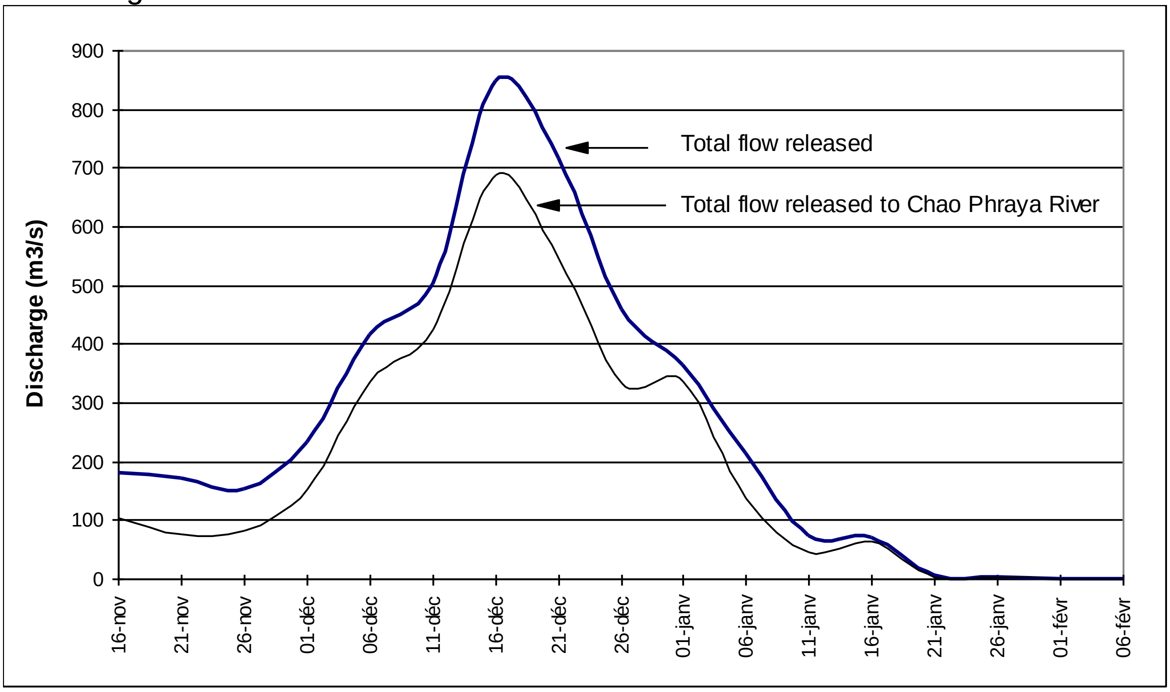
Now such data exist for the East Bank but as it is very much comparable in terms of landform and hydraulic regulation, there is no reason to think that much inflow from the Chao Phraya is allowed in during December and January.

Fig. 59 has been obtained by transforming the volumetric curve of Fig. 50 into discharge. It provides a very striking estimation of the flow originating from the drainage of all the boxes. The magnitude of the flow is quite considerable, with a peak around 850 cms in the second half of December, or 700 cms if we consider only the flow drained to the Chao Phraya River. This curve has to be compared with the average release of the Chao Phraya dam for the months of November, December and January : 550, 288 and 113 cms respectively (average over the last 20 years).

Most of the flow originating from the drainage of the upper buffer area flows in the Chao Phraya river at a time in which the East and the West Banks are still partly saturated and with a high water stock stored in their channels*. Thus, the contribution of this (huge) flow to DS cropping in December and January is almost negligible. This conclusion is extremely relevant because it dismisses any possible reluctance to diminish the northern buffer area on the argument that it would impact negatively on the early DS cropping of the lower delta.*

Boosting DS water demand goes against RID policy. Therefore, it cannot reasonably be envisaged - should it become possible, as far as the hydrologic regime is concerned - to support a wide shift from WS to DS cropping, because of the pressure it would add to the water demand in the DS season. However, this pressure would be notably reduced by shifting the DS cropping as early as possible, into the end of the rainy season.

Fig. 59 : Average cumulated discharge into the Chao Phraya river, originating from the drainage of the boxes



Such a change has occurred in the Mekong delta, in south-Vietnam, but in a context in which the river system is able to provide enough water to the DS crops. The whole of the floating rice area has now disappeared, being replaced by double cropping of short duration varieties.

4.2.5 Shortening the flood regulation period

Another related point deserves mention concerning facilitating DS cropping in TVs dominant areas.

We have seen that there is a decreasing trend in the water regime, so that many boxes have difficulties to reach their regulation level or to sustain it. In many instances, it seems possible to envisage a shortening of the regulated flood - together with a corresponding change in rice varieties - in order to be able to start DS cropping earlier (again, shifting DS cropping is conducive to a reduction in the irrigation water consumption and demand).

One example is provided by the Yangmanee project, which has to use late-maturing DWR to match the rather slow drainage of the boxes. Through discussions with concerned RID officers no evidence could be gathered as to explain why this project is not drained earlier.

5. Conclusion

5.1 Water regime and management

The water regime in the Chao Phraya Delta has gradually, constantly and significantly changed during the last 50 years, in line with the progressive land development and "artificialisation" of the natural landscape and hydrologic network. HYVs have expanded since the early 70's : although other socio-economic factors had noteworthy influence, the pattern of expansion has been widely governed by improvements in water control (Small, 1980). This expansion has been parallel with the development of double-cropping, which also appears as a push and pull contributing factor of this process.

The area cropped with Traditional Varieties (deep water and floating rice varieties) has decreased and is now confined to a "flood-prone" area in which the water regime is largely controlled by means of dikes and regulators. Along the Chao Phraya river, for example, most of the floodways have been closed during the 70's. After the floods of 1975, the embankments have been raised 50 cm of the flood level.

Given that - except in dramatic years such as 1995 - the water level in the drainage boxes is controlled and artificially regulated, it is meaningless to speak of and derive statistics on "*flood depth*" : rather, attention must be focused on the spatial distribution of the drainage units ("boxes") and on the parameters of drainage regulation in each box : rate of filling up, optimal regulation level, date of gate opening, rate of box drainage, etc.

The boxes constitute off-channel reservoirs but are not 'conservation areas', like in the lower delta, because they don't store water to be later used locally. Rather, they are buffer areas, allowing the storage of excess water in the rainy season. *However, it is important to understand that their main purpose is to provide adequate flooded conditions for the growth of TVs in areas where (a) the plot conditions and/or (b) the conditions of access to water and/or (c) the risk of submergence as governed by drainage conditions, do not allow the cultivation of HYVs. This suits the need for flood relief but it must be stressed that in most years, under the prevailing water regime, such buffer function is not fully needed.*

The study achieved a few important findings regarding flood management :

1. During the month of October the water stock rises gradually from 40 to 100 % of the full storage capacity. When the drainage boxes attain their full storage capacity, sometimes around the 1st of November, 2 billion m^3 of water are stored. The buffer capacity of the area - its normal capacity to act as a flood relief area - decreases accordingly.

2. This stock in an average year is estimated to be more than twice the quantity of water stored in the lower delta in a year with an overall 50 cm flood in the upper half of the West Bank. In a year with no particular excess water (like in 1998), the West Bank stores an equivalent of only 5 % of the volume stored in the upper delta, mainly in its canal system.

3. The margin of box overloading is extremely significant and corresponds to an

increase of 50 % in the storage capacity for an overall 25 cm hike in the water levels. The mapping of the box status at a given instant may show where and how much additional storage capacity is available. Overloading can be achieved by several waterways depending on the box (drainage regulators, irrigation canals, wasteways, sideflows, etc) and the height of the dike. A dashboard could be established to allow the monitoring of the status of the main boxes of the buffer area.

4. It does not appear than any limited reduction in the storage capacity would significantly jeopardise the flood relief function of the area, especially from the 1st of November onward.

Water control in the boxes appears satisfactory, as intermediate regulators now also provides increased local control. However, in dry years, some boxes face difficulties in the filling up phase and the upper lands may lack of water.

Other problems observed are the coordination of drainage within a "cascade box", the decision-making process on the date of gate opening (the date must be adjusted each year to some particular cases), and the congruence between water management and the choice of rice varieties. These points have not been addressed in-depth during this study and deserve further investigation.

Another important conclusion of the study is the evidence of the marginal re-use of the water drained out of the drainage boxes for DS cropping in the lower delta. This is due to the fact that the boxes drainage occurs in a period in which the water demand from the conservation area is still low. This dismisses possible fears that any reduction in the storage volume would impact negatively on dry-season cropping in the lower delta.

5.2 Deep water / floating rice cropping systems

The DWR/FR area has decreased a lot in the last 15 years. The upper west bank, part of the east bank, the lower Mae *Khlong* basin are large areas indicated by Puckridge et al. (1989) as cropped with TVs and which have now widely or totally shifted to other crops (or aquaculture), or adopted dry-season cropping as a substitute.

Valuable information has been obtained through the survey of approximately 300,000 ha cropped with deep water and floating rice, totalling close to 900 observation points. The main features of these rice systems can be summarised as follows :

- rather good control and risk reduction provided by land development and water control devices;
- a productivity approximately 60% of HYVs'productivity, despite significant increase in fertiliser use;
- the common absence of on-farm structures and/or a location far from irrigation canals;

- a low or irregular frequency of double cropping, partly due to the above factors; but a trend towards increasing this frequency, with significant investments in plot improvement.

- a trend towards mechanisation of harvest, with 72 % of plots using mechanical harvesters;

- a reduction of the diversity of rice varieties used in the area; six main varieties make up 58 % of the TVs and, together with the next 17 main varieties, 82 % of the whole.

- a low occurrence of the recommended rice varieties.

The main yield-limiting factor is probably the risk which prevails at the time of crop establishment under rainfed conditions. Little can be done to circumvent hazards derived from irregular rainfall, apart from expanding irrigation facilities. This however would add pressure on water demand and would require additional canal capacity.

Regarding cropping techniques, the survey demonstrated that there is no simple correspondence between the use of TVs and crop establishment through dry broadcasting. *DWR, and sometimes even FR, are established with both dry broadcasting and wet broadcasting*. The latter case is found in areas with a proper irrigation system but insufficient drainage (the risk of flooding is dealt with by using TVs) and when the plot is also used for dry-season cropping (growing HYV with wet broadcasting).

The disappearance of transplanting, in full realisation in the 80's and completed in the early 90's, is also an important point : it significantly eased water management (as nurseries are not necessary any longer) and removed a major bottleneck in terms of labour and farm activity planning. The last bottleneck, harvesting, is now dealt with through mechanisation.

There is an important point, at the interface of agronomy and water management, which should also receive special attention : while most varieties are roughly attuned to the water regime, it has been found that the time of box drainage was a point of much debate between users. It is hypothesised that this difficulty may also be partly responsible for the low level of adoption of recommended varieties, as farmers may not exactly know their characteristics in terms of cycle, height and elongation ability.

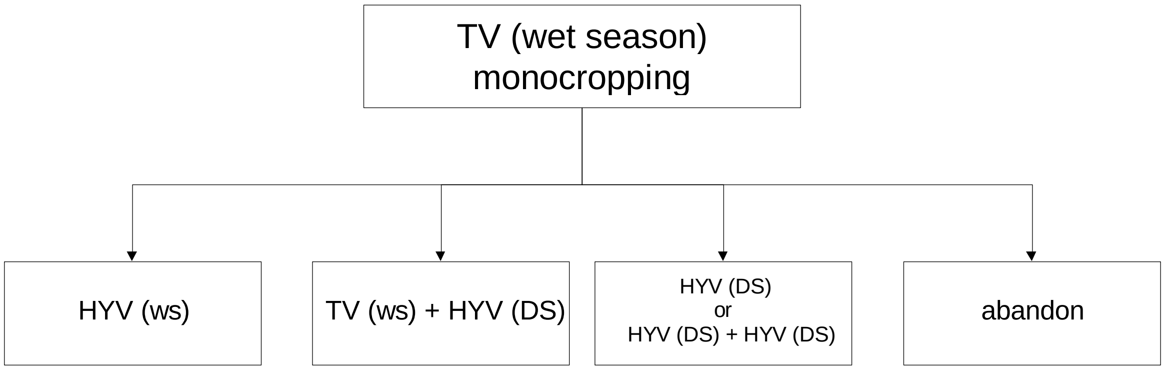
5.3 Perspectives of evolution

Several evolutions have been observed and can be extrapolated for the future. The main driving force is probably the low profitability of TV rice farming. In the long term, farmers are compelled to find some way either to intensify or to diversify rice farming, or to give up agriculture.

Because of the flood risk and often poor access to water, diversification is limited in the study area. Field crops are sometimes planted in the dry-season but traditional crops such as mungbean or sesame are declining because of labour problems at the time of harvest. Some sub-regions are specialised in specific crops (chilli in *amphoe* Ban Praek, Taro in the Roeng Rang Project, etc).

The mainstream evolutions can be summarised as in Figure 60.

Fig. 60 : Possible evolutions of DWR/FR systems in the Central Plain



① The first evolution is possible in areas where the water regime can be altered in order to accommodate HYVs instead of TVs. This has been possible in areas like Borommathad Project and *amphoe* Tha Wung and can be expanded to boxes like Lam Chuad or Don Tum box, or achieved by moderately lowering the water level in some boxes.

The transition area on the eastern side still harbours a lot of DWR although it is little or not prone to submergence risk and has irrigation facilities; it remains one of the rare cases of TVs grown under irrigated conditions in Asia and an in-depth investigation should be carried out in this area.

② The second path is to increase the cropping area in the dry season : a first solution would be to tap water from the Mekong or Salaween rivers in order to increase the water available in the dams. Under the current conditions, the available water volume in the dams depends on the year and impose a constraint in terms of available water quantity. Improvements may come 1) from improved water scheduling and distribution ; 2) secondary water sources, namely tube wells, remaining water in drains, reservoirs excavated in low lying spots. All these aspects are addressed in details by another on-going research project.

③ The third path is to abandon wet-season rice cropping and start, as early as possible, a DS crop at the end of the rainy season. Depending on water sources available locally, two rice crops can sometimes be accommodated in the dry season. If the whole box follows such a path, then there is no more scope for storing and releasing water according to the former pattern : the receding of the flood must be let to natural conditions, allowing in most years a much earlier DS cropping. There is scope to allow Phak Hai project to follow the transformation initiated by the West bank 20 years ago.

④ The last evolution path observed is the abandonment of rice farming and/or agriculture. This move has been observed most especially in areas where agro-ecological conditions did not allow any of the above changes and where the proximity of main roads, industrial zones or main cities (Ayutthaya, Bangkok) have both generated other labour opportunities and provoked a high level of land ownership transfer to speculators and urban-based buyers.

It appears as a main evidence that an increasing differentiation of farming systems has occurred in the area during the last ten years, while sub-regions were preferentially evolving towards one or some of the above paths. In addition, in the last three years several factors contributed to sharpening the situation : TVs rice cropping suffered high levels of crop failure in 1995/96 and 1996/97 because of flooding and also in 1997/98 because of hectic rainfall during the crop establishment phase. This situation prompted RID to deliver exceptionally high supplies of water during the following dry-season (provided as a compensation). In addition, this happened to be concomitant with a surge in rice prices and triggered a crave for dry-season cropping, paving the way for a record area of 100,000 rai of triple-cropping in 1998.

These conditions - good water and price - provided farmers in the study area the incentive that was missing to engage in land development and embrace DS cropping, many of them for the first time. The responsiveness of TVs growers can be considered relatively high if one remember that no assurance was given on whether such supplies could be renewed in the future (their repetition being very doubtful). Given the investments to be made, indebtedness, the necessity to resort to contracting for land preparation (because of lack of skill and equipment), it was not obvious beforehand that such a dynamic would take place. It is to be noted that in some cases, the shift to DS cropping has been initiated by outsiders : for example in the Phak Hai Project, farmers from neighbouring *changwat* came to rent land and engaged in DS cropping.

The DS boom provided incentive for land development, which, in turn, is making the possibility to shift from TVs to HYV in the rainy season more attractive, by removing one of the constraints. More generally, WS and DS rice cropping appeared significantly interlinked, not only in terms of calendar or techniques (DS cropping implies the use of wet broadcasting in the rainy season, even for floating rice), but also in the long term farmers' strategy.

Another highly significant event of the last ten years was the economic crisis in 1997, which put a brutal end to land buying and to speculation, slowing the worrisome trend of agriculture disappearance and injecting increased labour in the agricultural sector.

In summary, the future of the flood prone area of the Chao Phraya area is likely to be governed by a few factors : crucial will be the rate of double-cropping which will be allowed by the available water (possible tapping of additional resources, better management of the existent ones, "reduction" of the flooded area in some boxes, improved cropping techniques, etc). National policies and the economic environment will also contribute to set key parameters : price of rice, daily wage differential between urban and rural areas, labour opportunities in other sectors, land market, etc.

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7. Annexes

7.1 Characteristics of some main DWR/FR varieties

7.2 List of all varieties encountered in the survey (actual and used in the past)

7.3 Characteristics of main drainage boxes

7.4 Analysis of inflows from rivers into the boxes

7.5 Map of main river spills in the 1995-96 wet season

7.6 Map of the study area, with RID Projects

Annexe 7.2 : List of all varieties encountered in the survey
(actual and used in the past)

Now		Before	
Variety	Number of mentions	Variety	Number of mentions
Kon Kaew	99	Puang	35
Leuang phan thong	98	Khao Ta haeng	31
Leuang Pratew	91	**Jed ruang**	21
Hoom thung	69	Pin Gaew	18
Pin Gaew	49	pom	18
Khao Ta haeng	47	Kon Kaew	17
Khaw Luang	28	Luang	15
Khaw Metlek	23	Leuang Pratew	13
puang nak	21	Luang kaset	10
Puang thong	19	Lhoung prathan	10
Puang	19	Puang ngen	9
Luang kaset	19	**Metsan**	8
Suphan	14	Nang ngam	7
Luang Pra Than	13	Hoom thung	6
Mali thong	10	Puang thong	5
puang klang	7	Mali thong	5
Khaw Lum yai	7	Leuang phan thong	5
Puang bao	6	puang nak	4
Yuan	4	**Metyao**	4
Srisomnuk	4	Mali luei	4
samut	4	**Loungdew**	4
Puang ngen	4	**Luang oon**	4
Mali luei	4	Lep mu nang	4
Mali	4	Jam pa jin	4
Khao kaset	4	puang klang	3
B4	4	**Khao taa ex**	3

Sai bao	3	Khaw pra kuad	3
Pama hek kuk	3	Khaw Metlek	3
Nang phaya	3	Hom huan	3
Khiaw luen thung	3	Khaw Lot chong	2
Khaw Lot chong	2	Suphan	2
Ta yom	2	Sam rouang	2
Khao ko deaw	2	Puang bao	2
Kao Yai	2	**Nang mon**	2
Chai Nat 2	2	**Nang bon**	2
Khaw taa pee	1	Mali	2
Khaw Pra kuad	1	Luang nak	2
Khaw Luang nak	1	**Kon Kaew jud**	2
Taood	1	**Khao sakae**	2
Suphan 2	1	Khaw Lum yai	2
Sam rouang	1	Hoom duan 3	2
Roy phee	1	**Hang nokyoong**	2
Play ngam	1	**Chang peuak**	2
Pichit yao	1	**Cham pa kao**	2
Pamai	1	Yuan	1
Nang ngam	1	**Suphan pheuak**	1
Nang neuy	1	**Sue lak**	1
Lep mu nang	1	**Sua lao**	1
Kon Kaew 15	1	**Soung loung**	1
Khiaw thung	1	**Sao ko**	1
Khao settee	1	Sai bao	1
Khao phraya	1	**Sa rai**	1
Kee	1	**Puang oom**	1
Kaetung	1	**Phraya chom**	1
Jam pa jin	1	**Pheuum**	1
Hoom duan 3	1	Nang neuy	1
Hantra	1	**Na Khao**	1
Dok mali	1	**Ming kho**	1

Boo nak	1	**Mali sorn**	1
		Mali la	1
		Khiaw nok kaling	1
		Khao wang	1
		Khao tanoo	1
		Khao ta mho	1
		Khao sawat	1
		Khao ped ruang	1
		Khao patum	1
		Khaw lot chong	1
		Khao lep muu nay	1
		Khao klang pi	1
		Kao yay	1
		Khai Mangda	1
		Jep ceuy	1
		jam phathong	1
		Jam pha phee	1
		Hoom mali 11	1
		Hin hooy	1
		Boonma	1
		Bang rakham	1

ANNEXE 7.4 : Analysis of inflows from rivers into the boxes (* :uncontrolled flow)

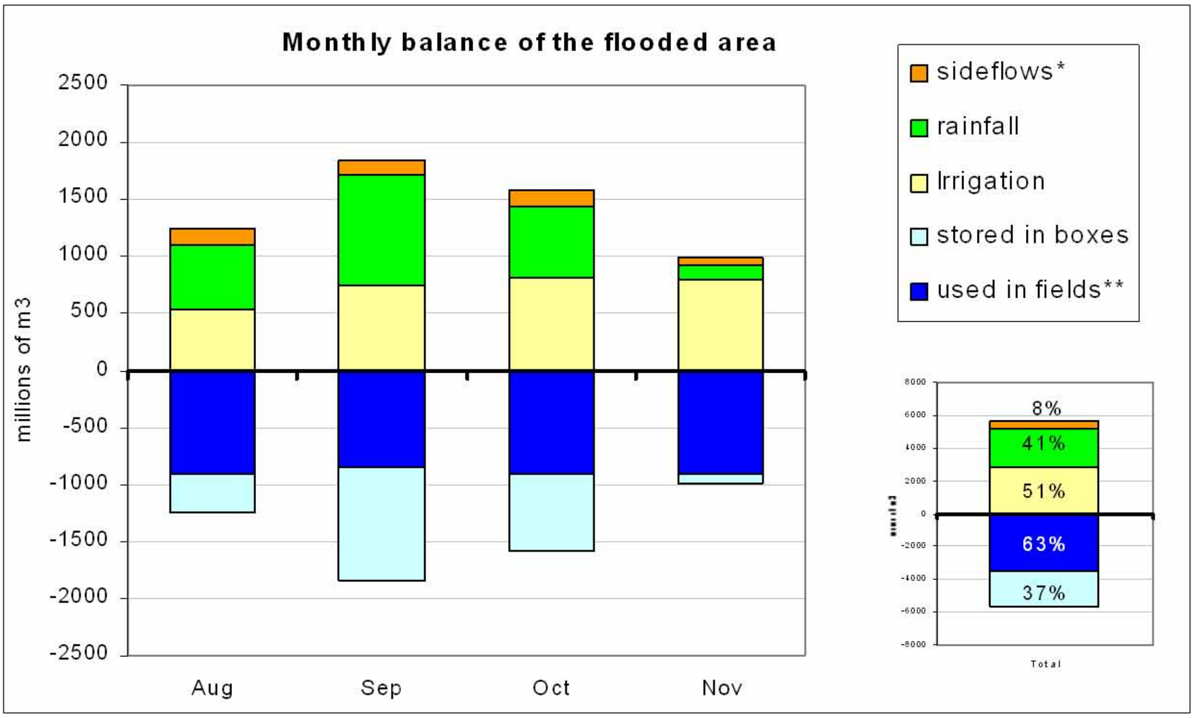
begin	end	H1	V1	Hfinal	V2	Vx	(V2-V1) %Vx
Wat Manee							
08/09/87	28/09/87	5	0,1	6,6	42,1	140,95	30
18/09/88	25/08/88	5,4	1,9	6,2	20,2	140,95	13
20/10/88	28/10/88	6,75	53,3	7,25	105,1	140,95	37
08/11/94	16/11/94	5,4	1,9	6,75	53,3	140,95	37
24/10/95	17/11/95	6	12,9	9	533,5	140,95	369*
25/08/96	10/09/96	4	0,0	5,8	7,7	140,95	5
01/10/96	16/10/96	6,5	35,6	7,75	183,4	140,95	105
05/09/97	12/09/97	5,5	2,9	6	12,9	140,95	7
Bankhum							
07/10/90	15/10/90	4,6	154,7	5	219,2	130,168	50
05/10/95	15/10/95	4,8	185,1	5,8	397,9	130,168	164*
15/11/92	18/11/92	1,6	0,1	3,5	45,0	130,168	34
Saladeng							
Q not recorded ; possible inflow from 1994 to 1996 but not likely ; good protection against flood							
end august 90 (little)							
08/10/92	15/10/92	3,6	5,1	4,2	11,4	35,28	18
Muang Tia	either get water or drain : a lot of manipulations						
19/08/87	30/08/87	3,5	0,0	5	3,8	19,705	19
01/10/87	10/10/87	4,6	0,5	5,6	16,5	19,705	81
10/10/88	20/10/88	5	3,8	6	31,2	19,705	139
10/08/89	30/08/89	2,6	0,0	4,6	0,5	19,705	3
01/09/90	03/10/90	3,5	0,0	5,6	16,5	19,705	84
15/08/91	05/10/91	3,5	0,0	5,5	13,6	19,705	69
22/09/92	10/10/92	3,6	0,0	4,4	0,0	19,705	0
01/10/93	10/10/93	3,4	0,0	4,6	0,5	19,705	3
18/08/94	05/09/94	3	0,0	4,6	0,5	19,705	3
05/10/94	30/10/94	4,6	0,5	5,6	16,5	19,705	81
03/08/95	30/09/95	3,4	0,0	5,8	23,2	19,705	118*
01/09/96	03/10/96	3,3	0,0	5,4	11,1	19,705	56
25/09/97	25/10/97	3,5	0,0	5,5	13,6	19,705	69
Lam Chuad	draining most of the time						
Than nung							
15/08/88	15/09/88	1	0,0	3	36,5	102,64	36
May be in 88 : end of filling							
2 inflows in June but followed by decrease							
20/08/91	30/08/91	0	0,0	2,6	17,2	102,64	17
10/09/93	30/09/93	0	0,0	2,2	4,2	102,64	4
20/09/94	30/09/94	0	0,0	2,4	9,9	102,64	10
01/08/95	10/08/95	0	0,0	2,4	9,9	102,64	10
22/08/96	30/08/96	0	0,0	3	36,5	102,64	36
01/09/97	08/09/97	0	0,0	3	36,5	102,64	36
Chiefly initial fill-up							
Bang Kung							
05/08/98	15/08/98	0,5	0,0	2,2	7,5	92,71	8
incomplete data ; possible inflow but unlikely							
Salai	drain most of the time						
16/08/88	02/09/88	4	0,1	5,6	74,8	259,75	29
***Khlong* Noi**							
01/11/93	07/11/93	1,6	0,0	3,5	1,4	47,428	3
15/08/97	05/09/97	1,8	0,0	4,8	21,4	47,428	45
25/08/96	07/09/96	3,2	0,5	4,6	15,8	47,428	32
inconclusive for 95; not much inflow on the whole							
Wat Ulom							
01/10/90	18/10/90	3,6	24,5	5,1	124,1	69	144
1995 and 1996 uncontrolled							

Addendum

Water balance of the flood prone area : average year, August to November

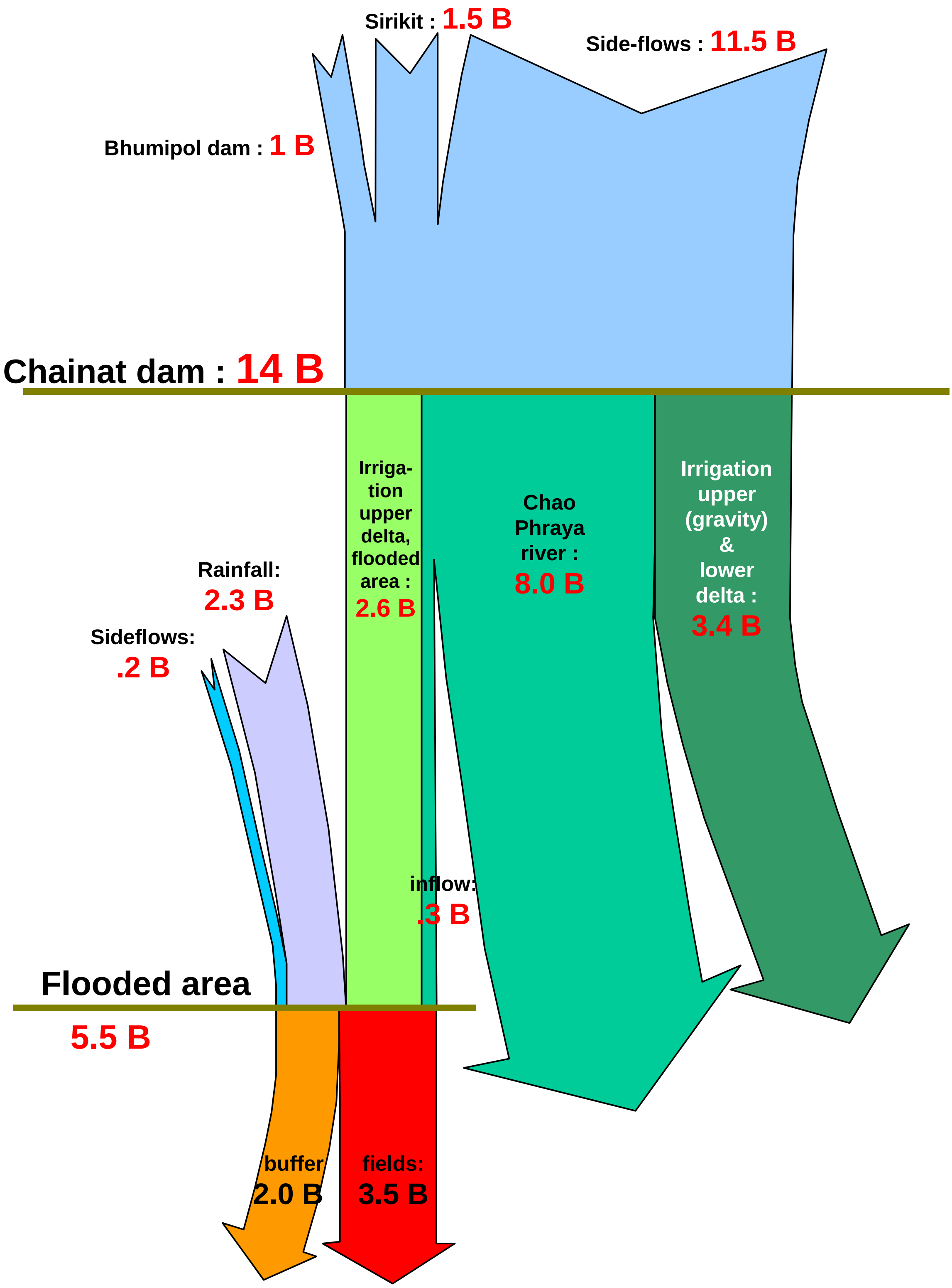
The average inflows in the flood prone area (rainfall, irrigation water, sideflows and inflows from rivers) can be compared, for each month, with the theoretical crop consumption and percolation loss, and with the effective stored volume in all the boxes. The balance proves extremely precise, with no particular adjustment on any parameter, and is summarised in the figure below. The breakdown by month shows the predominance of rainfall in the total inflow during the first two months. Water is mostly used in the fields** in August and December, whereas it chiefly fills up the boxes during September and October.

On the whole, 51 % of the total inflow (over 4 months) is due to irrigation canals, 41 % to direct rainfall and inner runoff, 8 % to sideflows*. These 5.5 billion m^3 are used to fill the 2 billion m^3 capacity of the boxes, while the remaining 3.5 billion are used by the crops and lost by percolation. This balance appears in the second figures, which also shows that most of the (average) 14 billion m^3 of water reaching Chainat during these four months come from sideflows, between Chainat and the two storage dams which deliver 2.5 billion m^3 during the same period. Less than half of these 14 billions m^3 are used in the delta, as 8 of them flow through Chainat dam down to the sea.

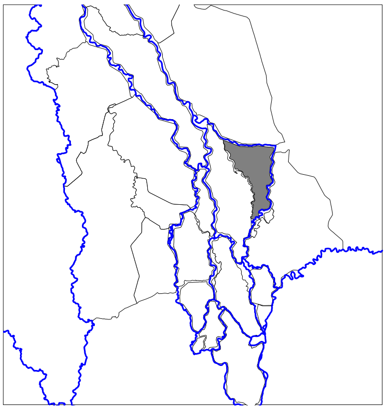


* “sideflows” are the total of the water entering the bow by the downstream regulators and of the real sideflows coming from the non irrigated area on the east.

** “used in fields” is the total of crop use and percolation

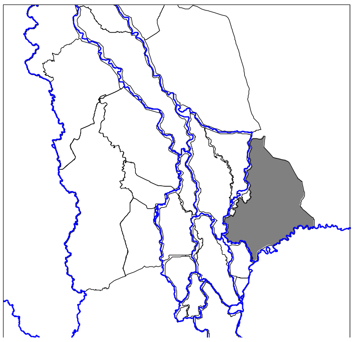


Water Balance over August-September- October - November



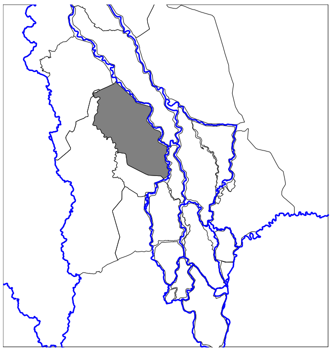
Klong Noi

Normal regulation level (NRL)	5.40 m
Box area (km2)	119
Average storage capacity (m3)	47 / 63
Average rainfall (mm)	1 055
Average maximum depth (m)	3
Ratio rain/storage capacity	0.55
Sideflows	No
Period for opening regulator	15-25 December
Rate of water receding	Sharp
Years with Max level > NRL	95 (+1.60 m), 96 (+.60 m)
Years with Max level < NRL	93 (-1.00 m)
Average drainage capacity	around 1.00 m
Secondary boxes	yes (3)
Inner regulators	3
Out-flow regulators	1 main / 0 secondary
Main out-regulator (nb.gates x height x	
Max. discharge in regulator	
Elevation (upper 5%) (m MSL)	7.2
Elevation (lower 5%) (m MSL)	4.0
Overall “depth” (m)	3.2
Slope index	37
Inflow from river	Some
Sensitivity to dry years	Medium
Sensitivity to wet years (flood)	Yes
Quality of regulation from 1 to 5 (best)	3



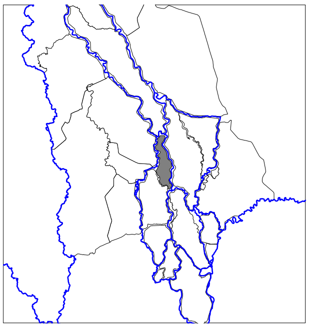
Bangkum

Normal regulation level (NRL)	4.5
Box area (km2)	453
Average storage capacity (m3)	130 / 150
Average rainfall (mm)	1 039
Average maximum depth (m)	3.2
Ratio rain/storage capacity	0.7
Sideflows	Yes
Period for opening regulator	
Rate of water receding	
Years with Max level > NRL	
Years with Max level < NRL	
Average drainage capacity	
Secondary boxes	2
Inner regulators	12
Out-flow regulators	3 main / 3 sec
Main out-regulator (nb.gates x height x	
Max. discharge in regulator	
Elevation (upper 5%) (m MSL)	7.4
Elevation (lower 5%) (m MSL)	3
Overall "depth" (m)	4.4
Slope index	103
Inflow from river	Very little
Sensitivity to dry years	Little
Sensitivity to wet years (flood)	Yes
Quality of regulation from 1 to 5 (best)	4



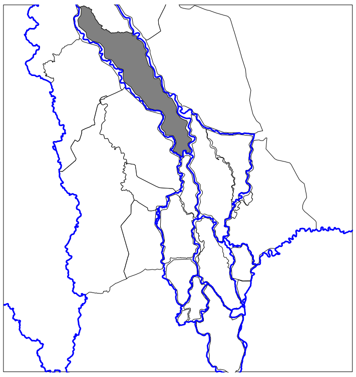
Sa-lai

Normal regulation level (NRL)	6.5
Box area (km2)	360
Average storage capacity (m3)	59
Average rainfall (mm)	1 129
Average maximum depth (m)	2.7
Ratio rain/storage capacity	1.8
Sideflows	No
Period for opening regulator	
Rate of water receding	
Years with Max level > NRL	
Years with Max level < NRL	
Average drainage capacity	
Secondary boxes	No
Inner regulators	2
Out-flow regulators	1 main
Main out-regulator (nb.gates x height x	
Max. discharge in regulator	
Elevation (upper 5%) (m MSL)	5.4
Elevation (lower 5%) (m MSL)	10
Overall “depth” (m)	4.6
Slope index	78
Inflow from river	No
Sensitivity to dry years	No
Sensitivity to wet years (flood)	No
Quality of regulation from 1 to 5 (best)	3



Sala Deng

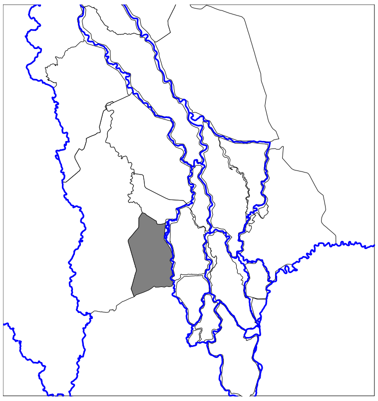
Normal regulation level (NRL)	5.4
Box area (km2)	50
Average storage capacity (m3)	35
Average rainfall (mm)	1 011
Average maximum depth (m)	4
Ratio rain/storage capacity	0.35
Sideflows	No
Period for opening regulator	
Rate of water receding	
Years with Max level > NRL	
Years with Max level < NRL	
Average drainage capacity	
Secondary boxes	No
Inner regulators	0 ?
Out-flow regulators	1 main
Main out-regulator (nb.gates x height x	
Max. discharge in regulator	
Elevation (upper 5%) (m MSL)	3.8
Elevation (lower 5%) (m MSL)	6.8
Overall “depth” (m)	3
Slope index	17
Inflow from river	No
Sensitivity to dry years	Little
Sensitivity to wet years (flood)	Little
Quality of regulation from 1 to 5 (best)	



Lamchuad

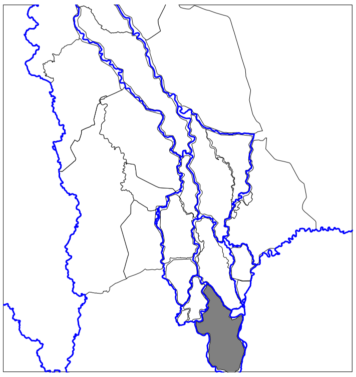
Pra Ngam

Normal regulation level (NRL)	8.4
Box area (km2)	315
Average storage capacity (m3)	54 / 106
Average rainfall (mm)	1 057
Average maximum depth (m)	2.5
Ratio rain/storage capacity	0.9
Sideflows	No
Period for opening regulator	
Rate of water receding	
Years with Max level > NRL	
Years with Max level < NRL	
Average drainage capacity	
Secondary boxes	5
Inner regulators	4
Out-flow regulators	1 main
Main out-regulator (nb.gates x height x	
Max. discharge in regulator	
Elevation (upper 5%) (m MSL)	7
Elevation (lower 5%) (m MSL)	13.1
Overall “depth” (m)	6.1
Slope index	52
Inflow from river	No
Sensitivity to dry years	No
Sensitivity to wet years (flood)	No
Quality of regulation from 1 to 5 (best)	5



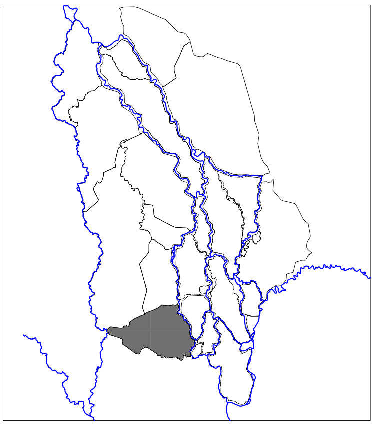
Lad Chado

Normal regulation level (NRL)	3.6
Box area (km2)	177
Average storage capacity (m3)	96
Average rainfall (mm)	1134
Average maximum depth (m)	2.2
Ratio rain/storage capacity	0.55
Sideflows	No
Period for opening regulator	
Rate of water receding	
Years with Max level > NRL	
Years with Max level < NRL	
Average drainage capacity	
Secondary boxes	No
Inner regulators	
Out-flow regulators	
Main out-regulator (nb.gates x height x	
Max. discharge in regulator	
Elevation (upper 5%) (m MSL)	5
Elevation (lower 5%) (m MSL)	2.1
Overall “depth” (m)	2.9
Slope index	
Inflow from river	?
Sensitivity to dry years	?
Sensitivity to wet years (flood)	?
Quality of regulation from 1 to 5 (best)	



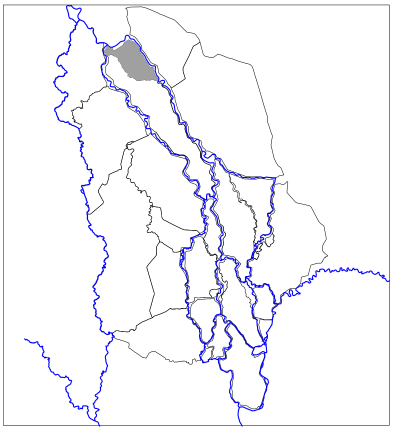
Bang Ban

Normal regulation level (NRL)	2
Box area (km2)	176
Average storage capacity (m3)	59
Average rainfall (mm)	1 112
Average maximum depth (m)	1.3
Ratio rain/storage capacity	1
Sideflows	No
Period for opening regulator	
Rate of water receding	
Years with Max level > NRL	
Years with Max level < NRL	
Average drainage capacity	
Secondary boxes	3
Inner regulators	0
Out-flow regulators	
Main out-regulator (nb.gates x height x	
Max. discharge in regulator	
Elevation (upper 5%) (m MSL)	1.1
Elevation (lower 5%) (m MSL)	2.7
Overall “depth” (m)	1.6
Slope index	
Inflow from river	Very little
Sensitivity to dry years	-
Sensitivity to wet years (flood)	-
Quality of regulation from 1 to 5 (best)	



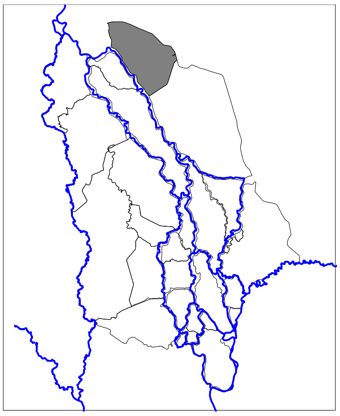
Phak Hai

Normal regulation level (NRL)	3.1
Box area (km2)	342
Average storage capacity (m3)	255
Average rainfall (mm)	1 134
Average maximum depth (m)	2.4
Ratio rain/storage capacity	0.4
Sideflows	Yes
Period for opening regulator	
Rate of water receding	
Years with Max level > NRL	
Years with Max level < NRL	
Average drainage capacity	
Secondary boxes	No
Inner regulators	0
Out-flow regulators	6
Main out-regulator (nb.gates x height x	
Max. discharge in regulator	
Elevation (upper 5%) (m MSL)	2.5
Elevation (lower 5%) (m MSL)	1.7
Overall “depth” (m)	0.8
Slope index	428
Inflow from river	Little or no
Sensitivity to dry years	Medium
Sensitivity to wet years (flood)	Medium
Quality of regulation from 1 to 5 (best)	4



Bang Sa way

Normal regulation level (NRL)	12.2
Box area (km2)	86
Average storage capacity (m3)	24
Average rainfall (mm)	1100
Average maximum depth (m)	2.3
Ratio rain/storage capacity	1.1
Sideflows	Yes
Period for opening regulator	
Rate of water receding	
Years with Max level > NRL	
Years with Max level < NRL	
Average drainage capacity	
Secondary boxes	No
Inner regulators	
Out-flow regulators	
Main out-regulator (nb.gates x height x	
Max. discharge in regulator	
Elevation (upper 5%) (m MSL)	14.5
Elevation (lower 5%) (m MSL)	11.5
Overall "depth" (m)	3
Slope index	
Inflow from river	?
Sensitivity to dry years	No
Sensitivity to wet years (flood)	?
Quality of regulation from 1 to 5 (best)	

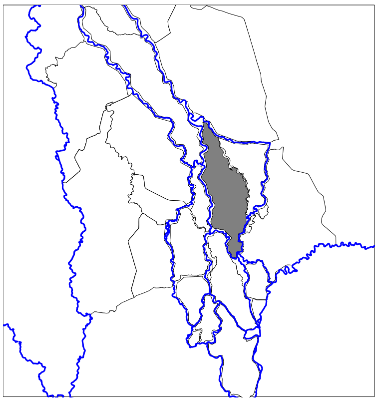


Ban Chomsii

Normal regulation level (NRL)	10.2
Box area (km2)	291
Average storage capacity (m3)	21
Average rainfall (mm)	1100
Average maximum depth (m)	1.3
Ratio rain/storage capacity	3.9
Sideflows	Yes
Period for opening regulator	
Rate of water receding	
Years with Max level > NRL	
Years with Max level < NRL	
Average drainage capacity	
Secondary boxes	No
Inner regulators	
Out-flow regulators	
Main out-regulator (nb.gates x height x	
Max. discharge in regulator	
Elevation (upper 5%) (m MSL)	14
Elevation (lower 5%) (m MSL)	9.5
Overall “depth” (m)	4.5
Slope index	
Inflow from river	?
Sensitivity to dry years	No
Sensitivity to wet years (flood)	?
Quality of regulation from 1 to 5 (best)	

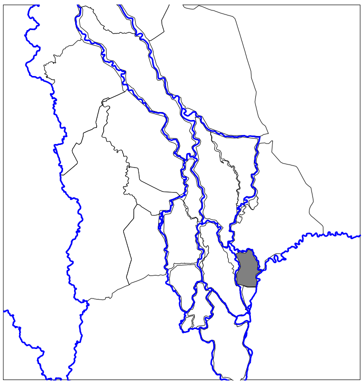
Nakhon luang

Normal regulation level (NRL)	2.75
Box area (km2)	
Average storage capacity (m3)	236 / 260
Average rainfall (mm)	1200
Average maximum depth (m)	1.5
Ratio rain/storage capacity	0.55
Sideflows	Yes
Period for opening regulator	
Rate of water receding	
Years with Max level > NRL	
Years with Max level < NRL	
Average drainage capacity	
Secondary boxes	
Inner regulators	
Out-flow regulators	
Main out-regulator (nb.gates x height x	
Max. discharge in regulator	
Elevation (upper 5%) (m MSL)	3.95
Elevation (lower 5%) (m MSL)	1.7
Overall “depth” (m)	2.25
Slope index	
Inflow from river	Some
Sensitivity to dry years	Little
Sensitivity to wet years (flood)	Little
Quality of regulation from 1 to 5 (best)	



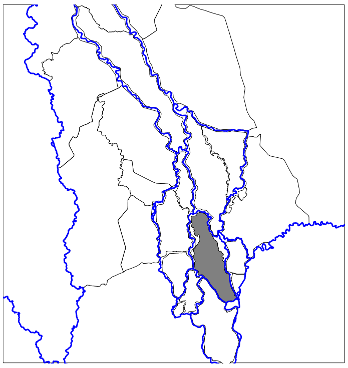
Wat Ulom

Normal regulation level (NRL)	4.5
Box area (km2)	222
Average storage capacity (m3)	69 / 121
Average rainfall (mm)	1 096
Average maximum depth (m)	3.1
Ratio rain/storage capacity	0.55
Sideflows	No
Period for opening regulator	
Rate of water receding	
Years with Max level > NRL	
Years with Max level < NRL	
Average drainage capacity	
Secondary boxes	11
Inner regulators	25
Out-flow regulators	1 main
Main out-regulator (nb.gates x height x	
Max. discharge in regulator	
Elevation (upper 5%) (m MSL)	8.0
Elevation (lower 5%) (m MSL)	3.0
Overall "depth" (m)	5.0
Slope index	44
Inflow from river	Very little
Sensitivity to dry years	Yes
Sensitivity to wet years (flood)	Yes
Quality of regulation from 1 to 5 (best)	



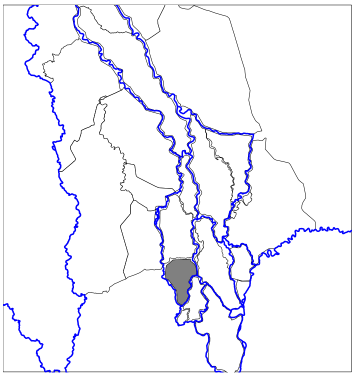
Kao Leang

Normal regulation level (NRL)	4
Box area (km2)	44
Average storage capacity (m3)	47
Average rainfall (mm)	1160
Average maximum depth (m)	3.1
Ratio rain/storage capacity	0.3
Sideflows	No
Period for opening regulator	
Rate of water receding	
Years with Max level > NRL	
Years with Max level < NRL	
Average drainage capacity	
Secondary boxes	No
Inner regulators	
Out-flow regulators	
Main out-regulator (nb.gates x height x	
Max. discharge in regulator	
Elevation (upper 5%) (m MSL)	4
Elevation (lower 5%) (m MSL)	2
Overall “depth” (m)	2
Slope index	
Inflow from river	?
Sensitivity to dry years	?
Sensitivity to wet years (flood)	?
Quality of regulation from 1 to 5 (best)	



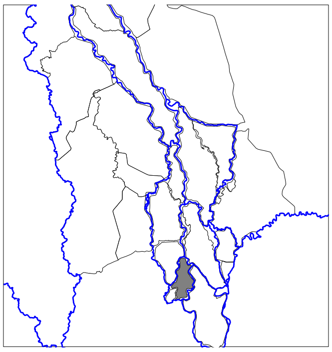
Bang Kung

Normal regulation level (NRL)	4.16
Box area (km2)	152
Average storage capacity (m3)	107 / 141
Average rainfall (mm)	1 209
Average maximum depth (m)	3.36
Ratio rain/storage capacity	0.35
Sideflows	No
Period for opening regulator	
Rate of water receding	
Years with Max level > NRL	
Years with Max level < NRL	
Average drainage capacity	
Secondary boxes	4
Inner regulators	4
Out-flow regulators	1 main / 2 sec?
Main out-regulator (nb.gates x height x	
Max. discharge in regulator	
Elevation (upper 5%) (m MSL)	5
Elevation (lower 5%) (m MSL)	2
Overall “depth” (m)	3
Slope index	51
Inflow from river	Very little
Sensitivity to dry years	Much
Sensitivity to wet years (flood)	Yes
Quality of regulation from 1 to 5 (best)	



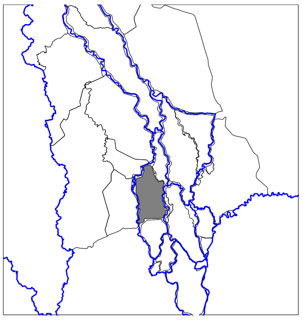
Klong Tanung

Normal regulation level (NRL)	3.5
Box area (km2)	69
Average storage capacity (m3)	70
Average rainfall (mm)	1 156
Average maximum depth (m)	2.1
Ratio rain/storage capacity	0.3
Sideflows	No
Period for opening regulator	
Rate of water receding	
Years with Max level > NRL	
Years with Max level < NRL	
Average drainage capacity	
Secondary boxes	3
Inner regulators	2
Out-flow regulators	1 main / 3 sec
Main out-regulator (nb.gates x height x	
Max. discharge in regulator	
Elevation (upper 5%) (m MSL)	3.5
Elevation (lower 5%) (m MSL)	2
Overall "depth" (m)	1.5
Slope index	46
Inflow from river	Yes
Sensitivity to dry years	Little
Sensitivity to wet years (flood)	Little
Quality of regulation from 1 to 5 (best)	4



3 boxes, west Ayutthaya

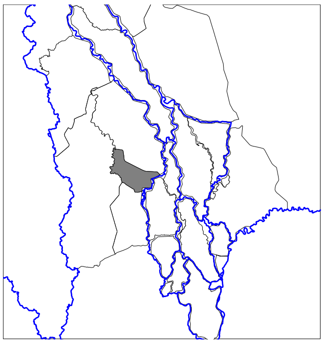
Normal regulation level (NRL)	4
Box area (km2)	53
Average storage capacity (m3)	74
Average rainfall (mm)	
Average maximum depth (m)	3.1
Ratio rain/storage capacity	
Sideflows	
Period for opening regulator	
Rate of water receding	
Years with Max level > NRL	
Years with Max level < NRL	
Average drainage capacity	
Secondary boxes	No
Inner regulators	
Out-flow regulators	
Main out-regulator (nb.gates x height x	
Max. discharge in regulator	
Elevation (upper 5%) (m MSL)	3.2
Elevation (lower 5%) (m MSL)	1.85
Overall “depth” (m)	1.35
Slope index	
Inflow from river	
Sensitivity to dry years	
Sensitivity to wet years (flood)	
Quality of regulation from 1 to 5 (best)	



Laat Nay

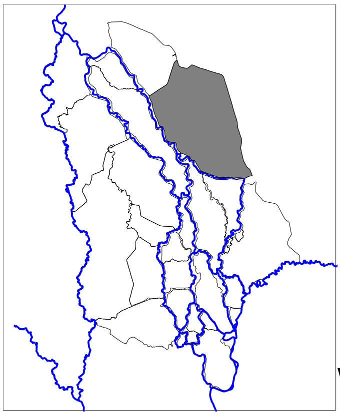
Pholluak

Normal regulation level (NRL)	4.6
Box area (km2)	129
Average storage capacity (m3)	99 / 133
Average rainfall (mm)	1145
Average maximum depth (m)	3.7
Ratio rain/storage capacity	0.3
Sideflows	No
Period for opening regulator	
Rate of water receding	
Years with Max level > NRL	
Years with Max level < NRL	
Average drainage capacity	
Secondary boxes	7
Inner regulators	
Out-flow regulators	
Main out-regulator (nb.gates x height x	
Max. discharge in regulator	
Elevation (upper 5%) (m MSL)	5.5
Elevation (lower 5%) (m MSL)	2.5
Overall “depth” (m)	3
Slope index	
Inflow from river	?
Sensitivity to dry years	?
Sensitivity to wet years (flood)	?
Quality of regulation from 1 to 5 (best)	



Muang Tia

Normal regulation level (NRL)	5.75
Box area (km2)	89
Average storage capacity (m3)	20
Average rainfall (mm)	1 161
Average maximum depth (m)	1.45
Ratio rain/storage capacity	1.35
Sideflows	No
Period for opening regulator	
Rate of water receding	
Years with Max level > NRL	
Years with Max level < NRL	
Average drainage capacity	
Secondary boxes	No
Inner regulators	1
Out-flow regulators	1 main
Main out-regulator (nb.gates x height x	
Max. discharge in regulator	
Elevation (upper 5%) (m MSL)	7.5
Elevation (lower 5%) (m MSL)	4.9
Overall “depth” (m)	2.6
Slope index	34
Inflow from river	A lot
Sensitivity to dry years	Medium
Sensitivity to wet years (flood)	No
Quality of regulation from 1 to 5 (best)	2



Wat Manee

Normal regulation level (NRL)	7.5
Box area (km2)	751
Average storage capacity (m3)	141 / 259
Average rainfall (mm)	1 142
Average maximum depth (m)	2.8
Ratio rain/storage capacity	0.9
Sideflows	Yes
Period for opening regulator	Yes
Rate of water receding	
Years with Max level > NRL	
Years with Max level < NRL	
Average drainage capacity	
Secondary boxes	7
Inner regulators	18
Out-flow regulators	3 main
Main out-regulator (nb.gates x height x	
Max. discharge in regulator	
Elevation (upper 5%) (m MSL)	11.4
Elevation (lower 5%) (m MSL)	6
Overall “depth” (m)	5.4
Slope index	139
Inflow from river	Yes
Sensitivity to dry years	Little
Sensitivity to wet years (flood)	Medium
Quality of regulation from 1 to 5 (best)	