DORAS - DELTA : Research report n°10 INCO: Topic 3

Agricultural Diversification:

Technical, environmental and socio-economic aspects of raised bed systems in the Chao Phraya Delta

DORAS CENTER

Kasetsart University **IRD**

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Cover: (a) Manual work on grapes *(b) Vegetable raised beds*
(c) Papaya trees on raised beds *(d) Mechanical excavation*

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agro-economic and environmental aspects of raised bed systems

These research reports are parts of a comprehensive comparative study between the Red River, Mekong and Chao Phraya Deltas. This project addressed three topics: 1) water management along the "water chain"; 2) social and institutional aspects of water resources management; 3) agricultural diversification in raised bed systems. Three companion reports are available for each of the three deltas

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ABBREVIATIONS

Alk: alkalinity
C: degree Celsius
Ca: calcium
$cmol_c/kg$: centimole of charges per kilogram of soil
Cu: copper
DORAS: Development-oriented research on agrarian systems
EC: Electrical conductivity
ETP: evapotranspiration
Exch: exchangeable
Fig.: figure
g: gram
GIS: geographic information system
ha: hectare
IRD: Institut de recherche pour le developpement
K: potassium
kg: kilogram
km: kilometer
KU: Kasetsart University
l: liter
m: meter
Mg: magnesium
mg: milligram
Mn: manganese
N: nitrogen
NPV: Nuclear Polyhedrosis virus
P: phosphorus
SS: Suspended Solid
TS: Total Solid
UK: unit of potassium
UN: unit of nitrogen
UP: unit of phosphorus
Zn: zinc

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General features of raised beds systems in the Chao Phraya Delta

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Environmental aspects of raised bed intensive farming

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Introduction

In Southeast Asian deltas, as well as in other parts of the world, the raised bed technique is used to reclaim lowland clay soils with shallow water tables. Unlike traditional rice-based systems, which provide nowadays a fairly low income, raised bed systems allow the cultivation of cash crops with high added value, such as fruits, vegetables and flowers.

The association of favourable environmental conditions in the delta (high water availability, strong sunshine all year round, fertile clay soils) and socio-economic conditions (proximity of Bangkok, development of urban and export markets, reliable transport infrastructures) encouraged farmers to develop cash crop productions on raised beds, which total approximately 100,000 ha at present. They constitute by far the largest agricultural wealth in the delta and are still expanding. It is therefore important to better understand how these systems function, what are their exact economic parameters, how is production linked to markets and what are the main constraints to their expansion.

The increase in production and the intensification of cropping systems goes alongside an intensive use of fertiliser and pesticide. Water quality also turns out to be an important concern. Therefore, the environmental aspects of raised bed cultivation must also be investigated in order to assess their sustainability and the possible impact on health.

This report first provides a general vision of the development of raised beds in the delta, examines their physical characteristics, the soil and water management. It further reviews a series of environmental aspects regarding grapes cultivation and lastly turn to socio-economic and marketing issues.

Part I

General features of raised beds systems in the Chao Phraya Delta

François Molle

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1 Introduction

The association of favourable environmental conditions in the delta (high water availability, strong sunshine all year round, fertile clayey soils) and socio-economic conditions (proximity of Bangkok, development of urban and export markets, reliable transport infrastructures) encouraged farmers to develop cash crop productions on raised beds, which total approximately 100,000 ha at present in the delta. They constitute by far the largest agricultural wealth in the delta and are still expanding.

This chapter gives an overview of the spatial spread and physical characteristics of raised beds in the delta.

2 Location and spatial expansion

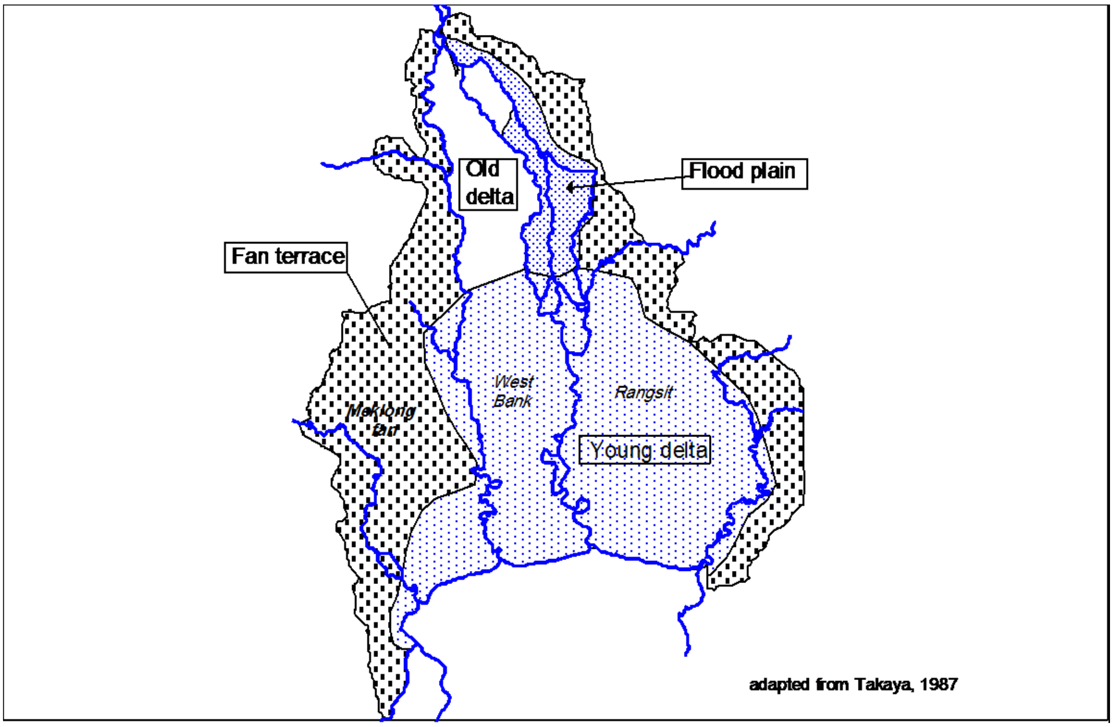
2.1 Land form

The location of raised beds in the delta must first be understood based on a crude description of landform (Figure 1). The lower part of the delta, or the young delta, is a flat track of clay soils in which cultivation was basically limited to rice. At the same time, this area is called 'conservation area' because it is criss-crossed by a network of natural and excavated canals where water is available most of the year. To take advantage of the presence of water for year round cultivation of non-rice crops, raised beds must be constructed.

In the flood plain, it is also possible to develop raised beds and they are sometimes encountered but they need much higher dikes in order to be protected from the flood. In the old delta and terraces, raised beds are sometimes found too, but mostly in lowlying depressions or heavy soils. In the upper and better drains parts, trees can be planted directly in the soil, without suffering from excess of water, and with less investment. However, they need to be linked to a perennial source of water, and a well or a farm pond are often used in addition to irrigation canals, the flow of which is sometimes interrupted.

The young delta thus presents both adequate water conditions and soil types which require the transformation of land by the raised bed technique in order to accommodate non-rice crops. It encompasses the great majority of the raised beds of the delta.

FIGURE 1: LAND FORM IN THE CENTRAL PLAIN



2.2 Historical expansion

Historically, raised beds have first been constructed along the lower reach of the main rivers for more than three centuries, particularly in Chachoengsao (Bang Pakong River), Bangkok (Chao Phraya River) and along the Mae Klong River. It is not sure whether raised beds have been initiated by Chinese migrants (as would the alias 'Chinese bed' suggest), or if they were the result of local innovation. The locations mentioned above all correspond to areas with significant Chinese settlements but they are also and foremost areas with adequate soils, located at the interface between saline and fresh water, which can benefit from the tidal effect for both irrigation and drainage.

From a first concentration in the lower reach of the Mae Klong River, raised beds expanded along the Damnoen Saduak canal, after its completion in 1868. From Bangkok, they spread on the western bank of the Chao Phraya River, and later to the Rangsit area.

Figure 2 shows the gross area of existing raised beds, together with a crude delineation of the area deemed most suitable for their development (the conservation area). Figure 3 specifies the Damnoen Saduak and Rangsit areas by period of construction and also indicates the more isolated orchards that have been surveyed outside these main areas.

FIGURE 2: MAIN GROSS AREAS WITH RAISED BEDS IN THE LOWER DELTA

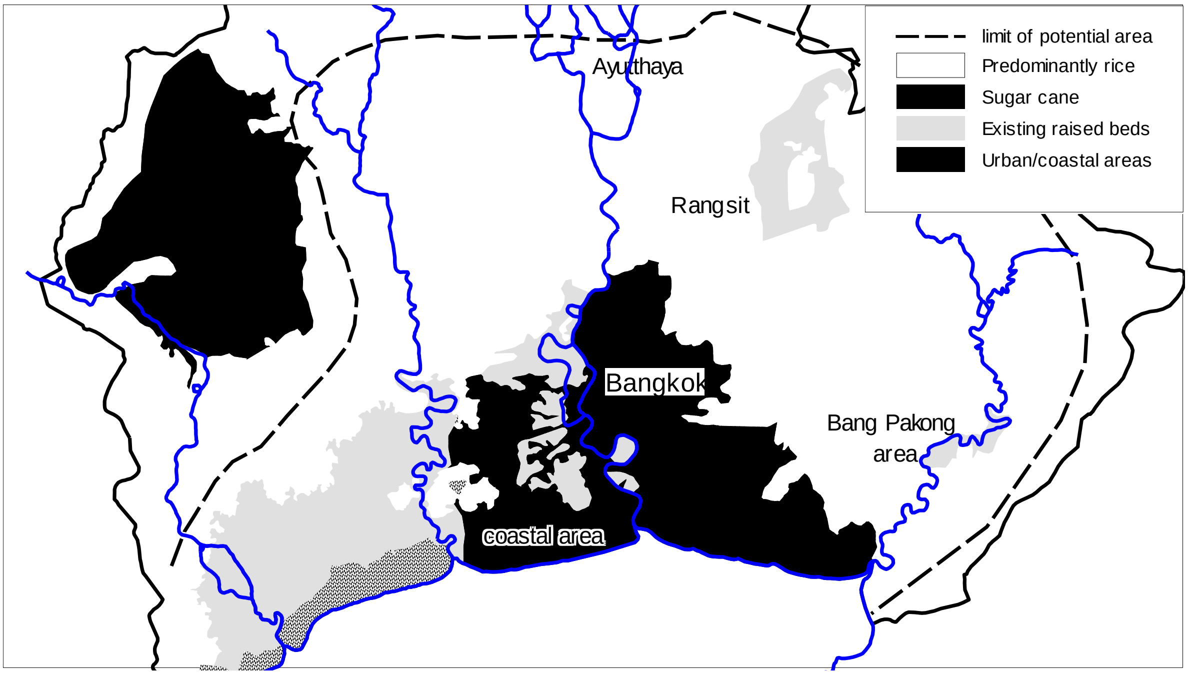
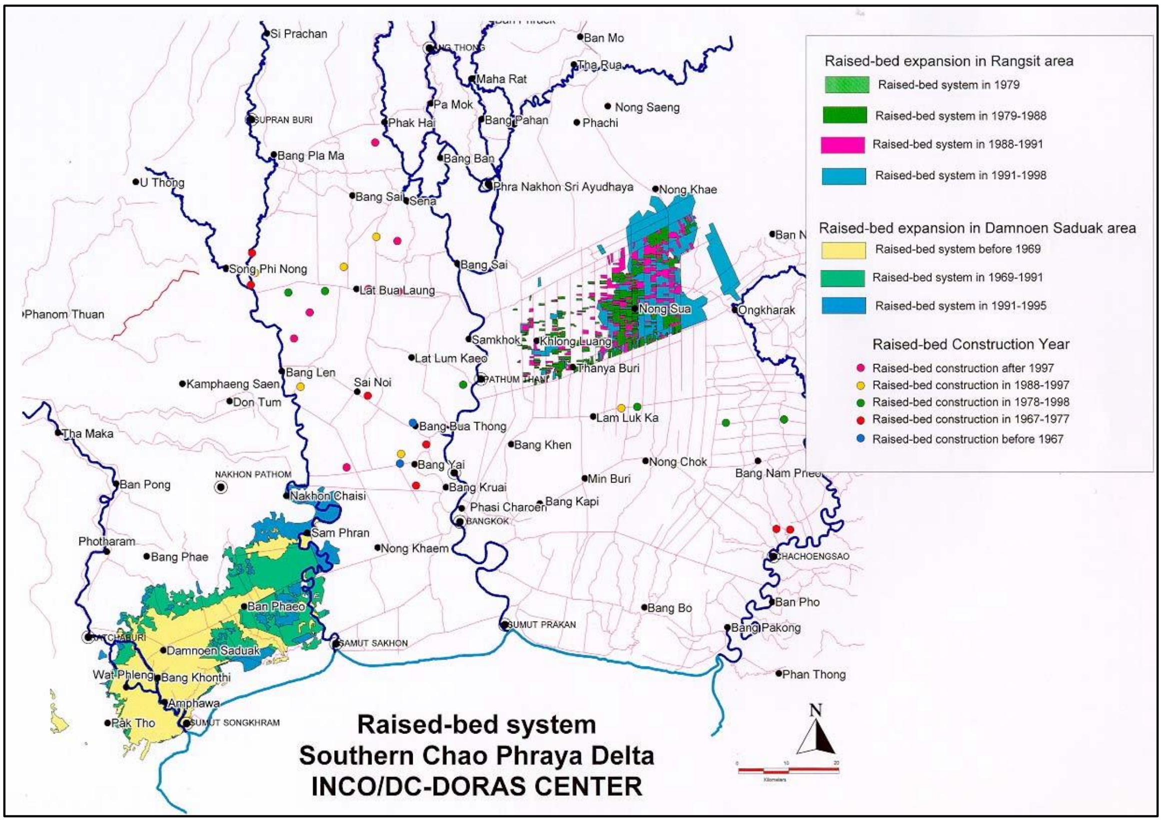


FIGURE 3: LOCATION OF MAIN RAISED BED AREAS IN THE DELTA



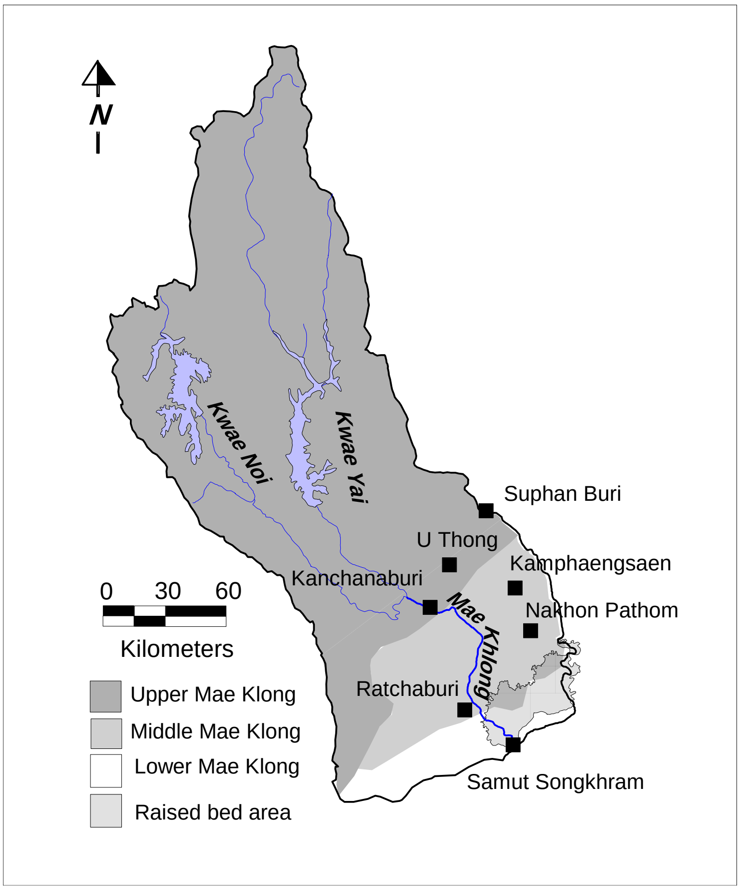
2.2.1 Land development in Damnoen Saduak

The Damnoen Saduak Area is the lower part of the Mae Klong Basin and forms the western extremity of the "young delta" (Figure 1). Covered by the sea during the Holocene, the area received marine deposits. Later, the area was still swept by the tide and corresponded to part of the former tidal plain of the Chao Phraya Delta.

Stretching from the Mae Klong River to the Tha Chin River, the raised bed area of the lower Mae Klong Basin is crossed by the main canal of Damnoen Saduak (Figure 3). In the south, the area is limited by a dike running parallel to the coast, 9 km away from it, which aims at preventing saline intrusions. The northern limit is still shifting, as the raised bed area expands at the expense of rice fields.

Moreover, being located in the lower Mae Klong Basin (Figure 4), the area was affected by the hydrological regime of the Mae Klong River. This regime is characterised by a sharp contrast between the rainy season, when floods can spread and accumulate in the region, and the dry season, during which water is progressively drained out to the sea and soils dry up. At this time, when the discharge of the stream decreases, the region under tidal influence is affected by saline intrusions. Dried out a short period of the year, soils are little developed, with a clay to heavy clay texture.

FIGURE 4: MAE KLONG BASIN

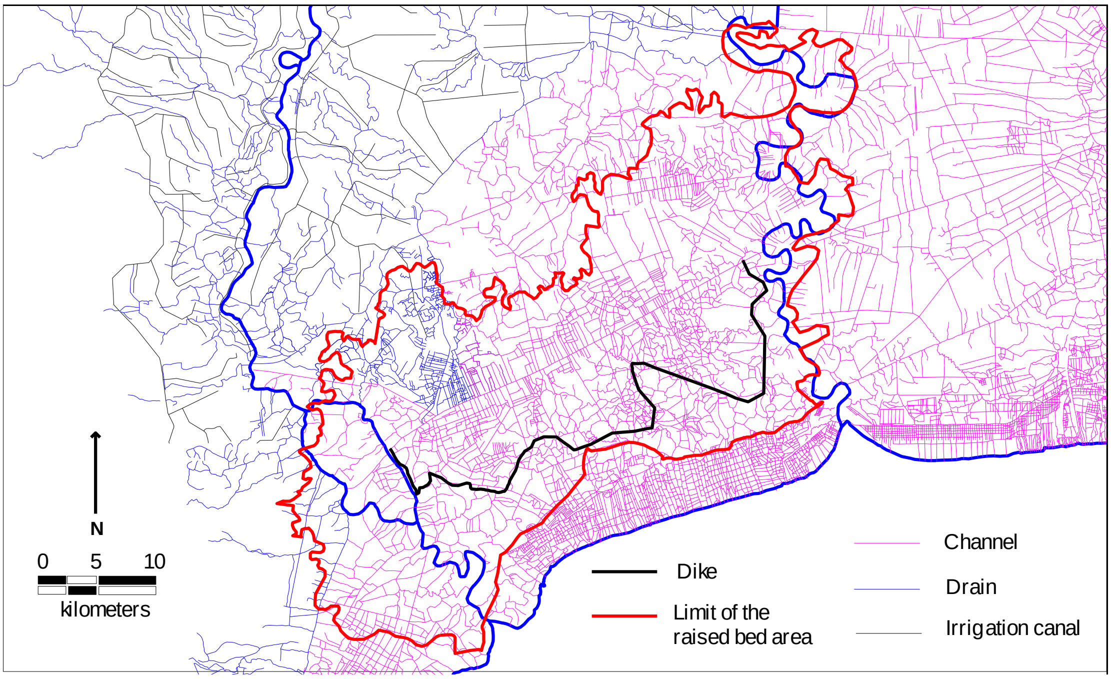


Until the 19th century, when land development and human settlement started, the region was covered by swamps penetrated by salt water and home to mangroves.

2.2.1.1 *Improvement of drainage conditions*

In the reign of Rama V, at the end of the 19th century, several canals - among which the main canal of Damnoen Saduak - were excavated in order to improve transportation between the Mae Klong, Tha Chin and Chao Phraya rivers. The expansion of channels permitted the settlement of the uncultivated tidal plain. However the development of the region was highly dependent on further water control investments which were undertaken partly by the farmers themselves. Because of the extreme flatness of the area (slope less than 1%), gravity irrigation was not possible. Additional channels were consequently dug in order to expand the reach of water to the whole area (but a water elevating device was necessary, when the tidal effect did not allow the water level to reach the plots). The Damnoen Saduak area is nowadays crossed by a very dense network of channels. (Figure 5)

FIGURE 5: NETWORK OF CHANNELS IN THE RAISED BED AREA



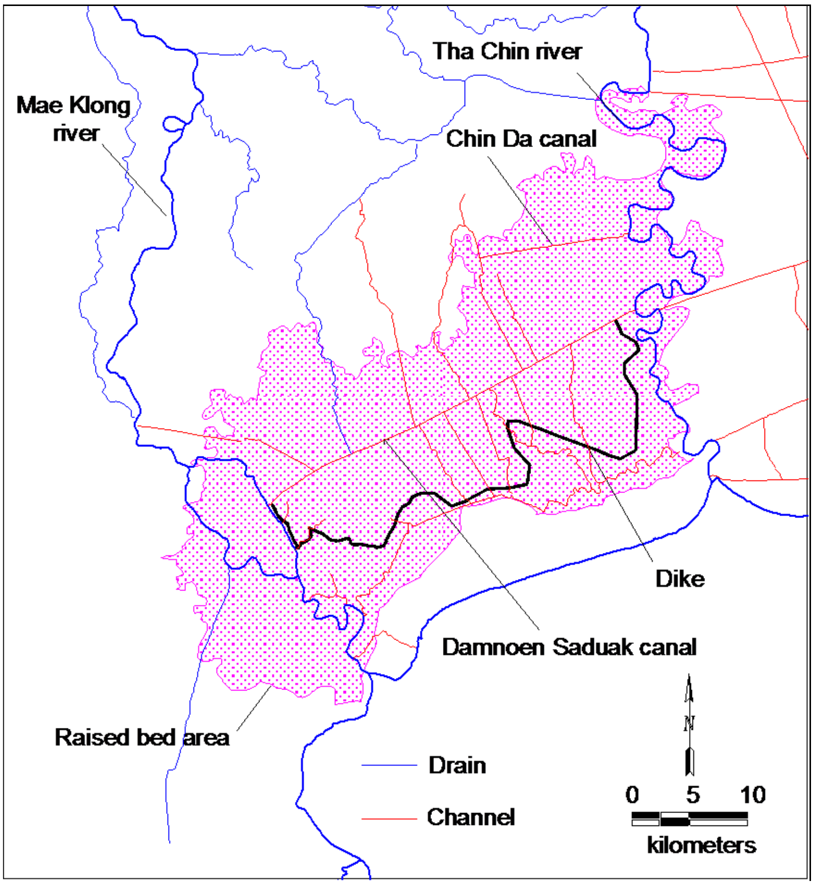
2.2.1.2 *Improvement of water control in quantity and quality*

Three main problems remained. Settlers had to deal with (fresh) water shortage and saline water intrusion in the dry season, and with water excess in the rainy season. In order to turn the area fully suitable for agriculture, regulators were constructed on the main canals so as to better control the water level in the area and to limit saline intrusion. Most of the streams flowing to the Mae Klong and Tha Chin rivers are now gated except:

- 2 or 3 canals south-west of the Damnoen Saduak Canal
- the Chin Da Canal and some minor outlets flowing into the Tha Chin in the north-east of the area (Figure 6)

Finally, a permanent dike (Figure 6) was raised in the southern part of the area to impede saline intrusions.

FIGURE 6: MAIN CHANNELS OF THE STUDY AREA



In the dry season, gates are closed in order to retain fresh water in the area. If the streams are ungated, temporary dams may be built with sand bags to obstruct outlets. In the rainy season, the main regulators located at the end of the Damnoen Saduak Canal and of the seven main channels are opened in order to drain excess water.

Due to this specific regulation associated with the extreme flatness of the area, water is "trapped" in the dense network of channels. That is why this area is often referred to as a conservation area, as opposed to the gravity area north of it, respectively in purple and blue on Figure 5.

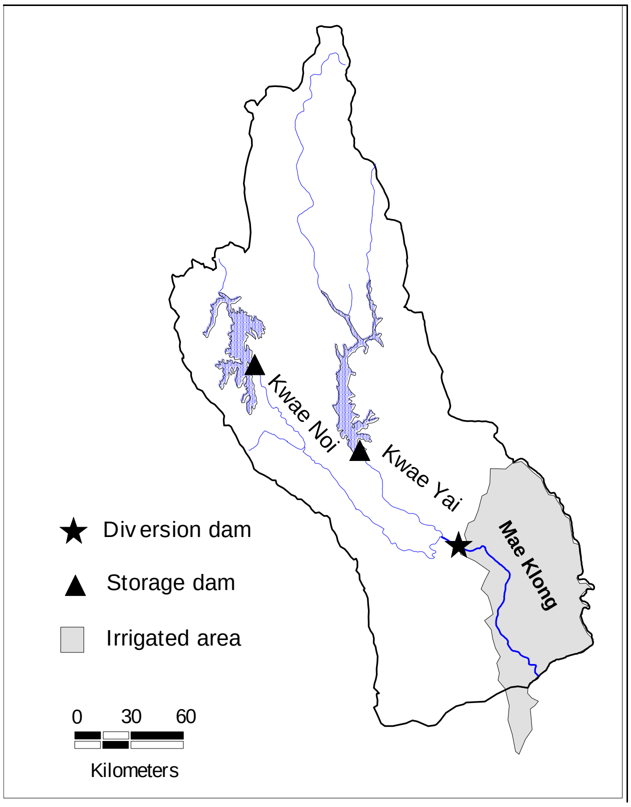
2.2.1.3 The regulation of the Mae Klong River floods

The annual rise of the Mae Klong River, which flooded the lower basin from the beginning of August to the end of September, was considerably limited by the development of the Greater Mae Klong Project initiated in 1972. A water diversion dam - the Vajiralongkorn Dam - located a few kilometres downstream of Kanchanaburi, was constructed and now allows the irrigation by gravity of the lower part of the Mae Klong Basin. The regime of the Mae Klong River has further been fully regulated thanks to the construction of two large storage dams on its main tributaries: the Srinakarin dam on the Kwae Yay River (1980) and the Khao Laem dam on the Kwae Noi river (1984). (Figure 7)

All these steps in land and water development have allowed a good control of the water regime, including of the flood. However, the dramatic flood of the year 1996, which resulted in severe damages, has shown that exceptional events can still occur.

The further expansion of the raised beds is contingent upon the supply of enough good quality water all year round. This is at present ensured by water channelled through the irrigation canals and released to the drainage system which flows down to the Damnoen Saduak area. Water quality can be impacted by refuse from industries or pig farms. Recently, drainage water from shrimp farms has also altered water quality.

FIGURE 7: DAMS IN THE MAE KLONG BASIN



2.2.2 Land development in Rangsit[1]

Fruit tree orchards appeared as early as the 1950s in the Rangsit area, but on a limited scale and in specific locations, most particularly in the area with good drainage and rather fertile soils. Following the development of supporting infrastructure and the government campaigns in the 1960s, fruit production expanded gradually, with a sharp increase in fruit tree plantation during the years 1977-1985. The poldered raised-bed systems have allowed the cultivation fruit trees, mainly tangerine oranges, with both the ground water and soil acidity being controlled. The poldered raised-bed systems are usually located along the main irrigation canals, mostly in irrigation canals Klong 9, klong 10, klong 13 and klong 14. A recent trend of orange orchard expansion from the original area toward the eastern rice areas and moving up to the northern parts can be noticed. Two to three meter dikes have been constructed around the plots for flood protection. Some soil improvement materials, especially lime and marl, have been applied in order to reduce the high acidity of acid sulphate soils. Water can be pumped in the dry season, thus the vegetable and orange productions are produced and marketed throughout the year.

The expansion of raised bed areas has followed three stages namely, a slow introduction stage (between years 1966-1977), a rapid expansion stage (between years 1977-1985), and a smooth expansion stage (after year 1985). The annual growth rate during the rapid and smooth expansion stages was 14 and 4 times higher than that of the introduction stage.

2.2.2.1 <u>Factors affecting land use change from rice to raised-bed orchard systems.</u>

Gardeners from Damnoen Saduak and Bangmod areas, which are the most popular raised bed orchard areas in the central plain, migrated to the area after selling their own plot. The area was attractive because a) the potentiality of the soils in the previous areas was deteriorating due to sea water intrusion, b) of the pollution of the environment, c) of land price differential (e.g. it is known that by selling 1 rai land in the earlier locations it was possible to buy 10 rai of land in the Rangsit area, d) of the quality of water (better than in previous areas where polluted water affected production due to the proximity of both the sea and urban areas.

Good canal and road network, and the wholesale agricultural market located near Rangsit area (and others which are very close to Bangkok), made it possible for wholesalers and middlemen to access to the farm easily.

The soils are out of tidal influence in this area. Moreover, they are acid sulphate soils but not severely and can be improved to be made suitable for oranges which need neutral pH for optimal production.

[1] This section mostly draws on the work by Saha (1993)

Land price and land availability: During the introduction period, the land price in this area was very cheap compared to Bangkok vicinity and Damnoen Saduak, and it was very easy to get a plot either by renting or by purchasing depending upon the location in Rangsit area. Even in the last 1970s land prices were still not so high.

Labour availability: Since, North Rangsit Irrigation area was one of the dominant rice production areas in the Central plain of Thailand and was mostly farmed by tenant farmers, it was easy to find labour at a reasonable rate.

Low yield and price of rice: the rice yield in acid sulphate soils is very low and needs more fertiliser input compared to non acid soils. At the same time, the farm price of rice remained depressed, making a shift out of rice all the more desirable.

Experience and inspiration from orchard farms: in the off-season of rice cultivation, many tenant farmers worked as labourers in orchard farms and could witness the profitability of raised bed systems as well as acquire skill and experience. Some initiated orchards while still continuing rice cultivation as a way to wait for the period of production of the fruit trees. After establishment of orchards, more loans could be obtained from the banks, allowing the expansion of the gardens.

3 Some features of raised bed systems in the delta

3.1 Raised bed plots

Raised beds are not uniform in dimensions and management, which depend on several factors. In general terms, plots are generally located along a perennial canal and surrounded by a 1.5 meter high dike which protects fields from the flood. Inside the plot, raised beds alternate with ditches (Figure 8 and Figure 9). Raised beds are usually 3 to 6 meters large and their length depends on the plot lay out (30 to 100 m). Ditches are partly flooded along the year and, for an average water level in the plot, the water body represents about 40% of the total surface of the poldered raised bed plot (Molle et al, 1998).

FIGURE 8: LAYOUT OF A RAISED BED PLOT

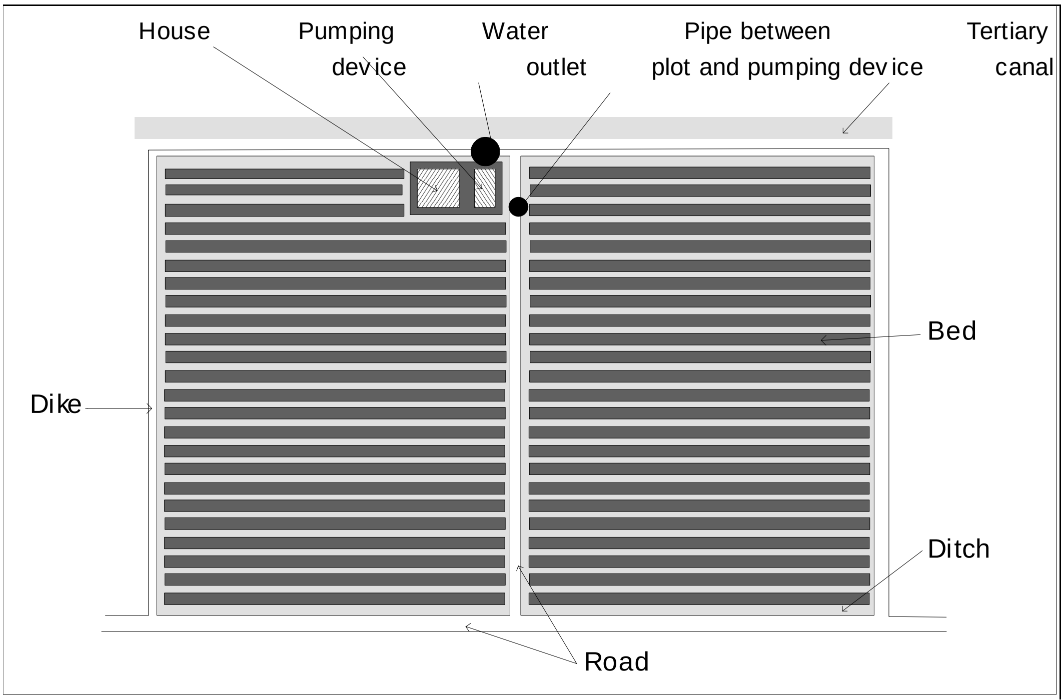
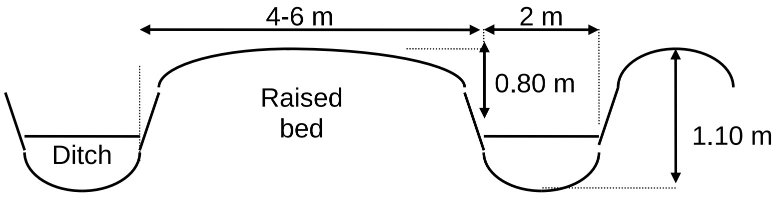


FIGURE 9: TYPICAL CROSS SECTION OF A RAISED BED



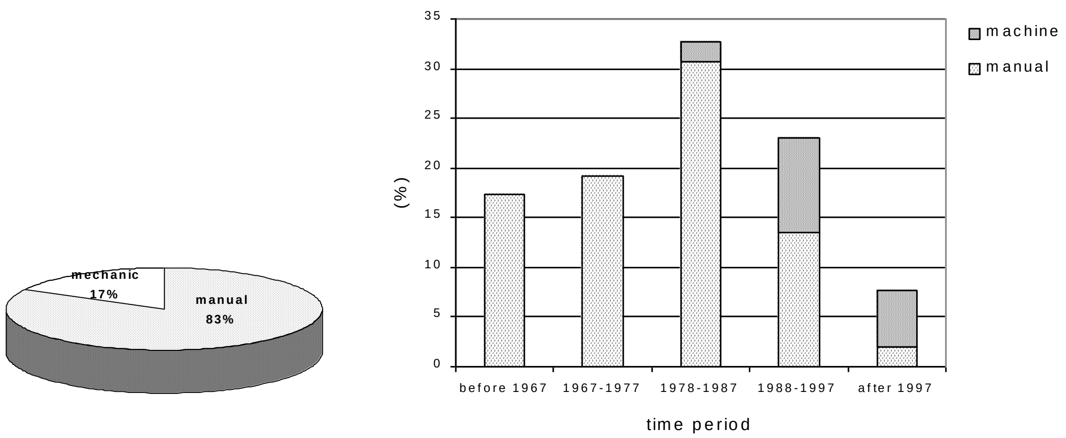
3.2 Construction techniques

The raised beds are nowadays mostly constructed with mechanical diggers. After digging the ditches and raising the beds, but before they cultivate the beds, farmers flood the plot from two to four weeks and then let it dry from 2 to 6 months, so that water drains out. The main reasons put forward by the farmers are to break up and level the soil on the raised beds but also to get rid of possible pests and weeds.

The frequency of reconstruction of the raised beds (generally every 10 to 15 years) depends on the farmer, on his capital and on the crops he grows. There are two main techniques. The first and the most expensive one consists in destroying the raised beds, levelling the plot and elevating new raised beds in the location of the former ditches. Sometimes farmers prefer to only "refresh" the raised beds by dredging the ditches with a mechanical digger, reshaping the beds, carrying out soil preparation with a two-wheel tractor and applying organic manure. Afterwards, they flood the plot for 2 weeks and let it dry between one (even less for vegetables) and three months (for fruit trees).

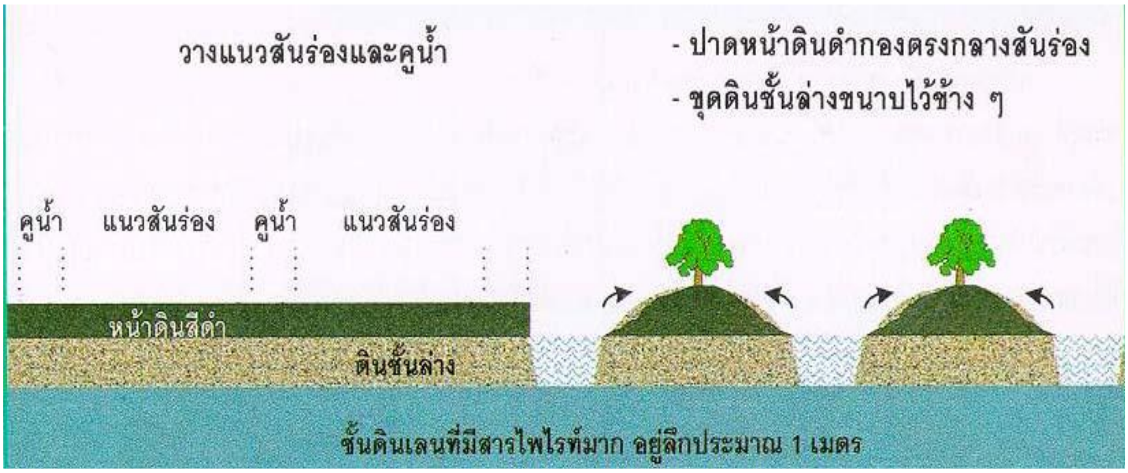
The variations of the physical characteristics of raised beds was studied through the survey of 167 different gardens. Figure 10 shows the proportion of construction techniques (mechanical or manual) according to the time period. A total of 83% of the raised beds surveyed were constructed manually while the remaining were constructed by machine. Regarding the manual technique, the gardener would hire labour for ditch digging. The price in 1967-1977 was approximately 300 baht/sen (1 sen = 1.5 m. wide, 1 m. depth and 40 m. long). In 1978-1987, about 300-450 baht/sen (1,800-2,700 baht/rai). In 1988-1997 about 1,600-3,900 baht/rai. Mechanical excavation started after 1977 and increased during the 1988-1997 because of labour shortage. However, areas with difficulties of access may still use manual labour, even nowadays. The work is calculated in working time hours. The price for the 1978-1987 period was 2,700 baht/rai, and approximately 3,000-6,000 baht/*rai* from 1988 to present times.

FIGURE 10: CONSTRUCTION TECHNIQUES OF RAISED BED SYSTEMS



By constructing raised beds, farmers completely modify soil profiles. With this technique, indeed, they considerably increase the depth of the surface horizon by keeping it at the surface as much as possible. In some cases, when soils are turned over, the original organisation of the profile disappears altogether.

FIGURE 11: CONSTRUCTION TECHNIQUES FOR RAISED-BED IN ACID SULPHATE SOILS IN RANGSIT AREA

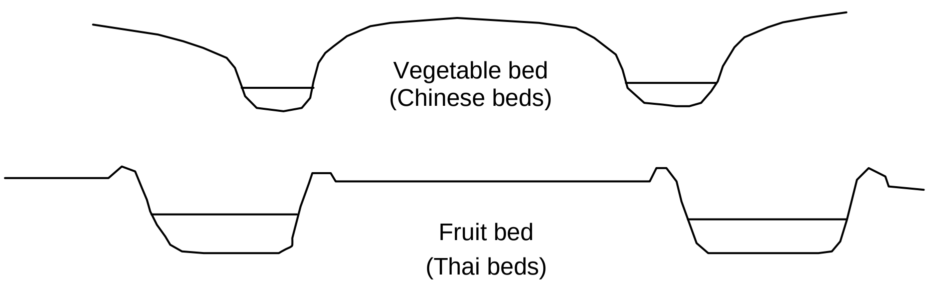


3.3 Geometry of the beds

Raised beds are an alternation of beds and ditches, but their width and depth vary significantly. In addition, they evolve over time, as beds tend to erode and to get narrower.

Farmer sometimes refer to two types of beds, distinguishing 'Thai beds' and 'Chinese beds'. Although the terms are not common, they will be used here to describe two main shapes of beds. The first one ('Chinese beds') are constructed for vegetable and are made with a convex shape, in order to avoid water retention. The second ones ('Thai beds') are constructed for fruit trees. They are levelled and bounded with a small levee in order to retain irrigation water and facilitate its infiltration in the beds.

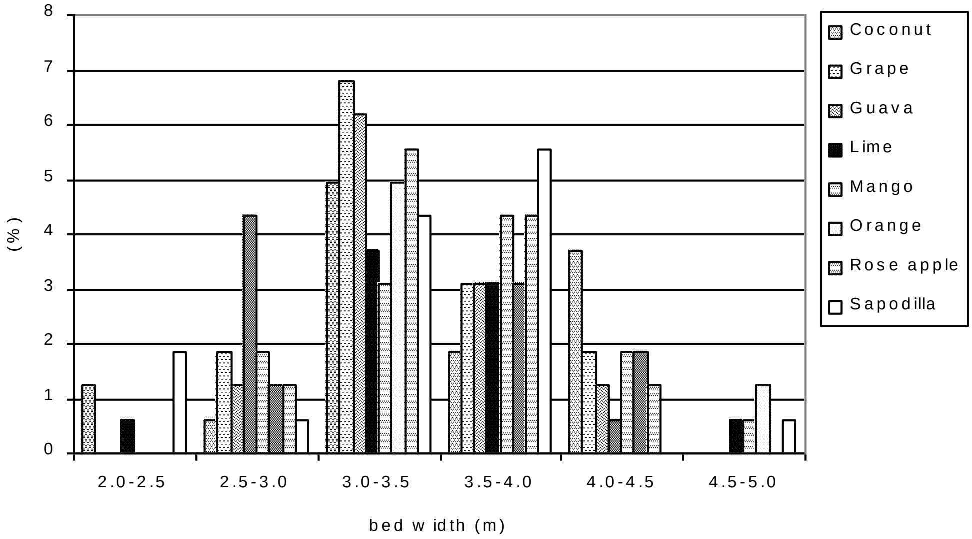
FIGURE 12: TWO MAIN TYPES OF RAISED BEDS



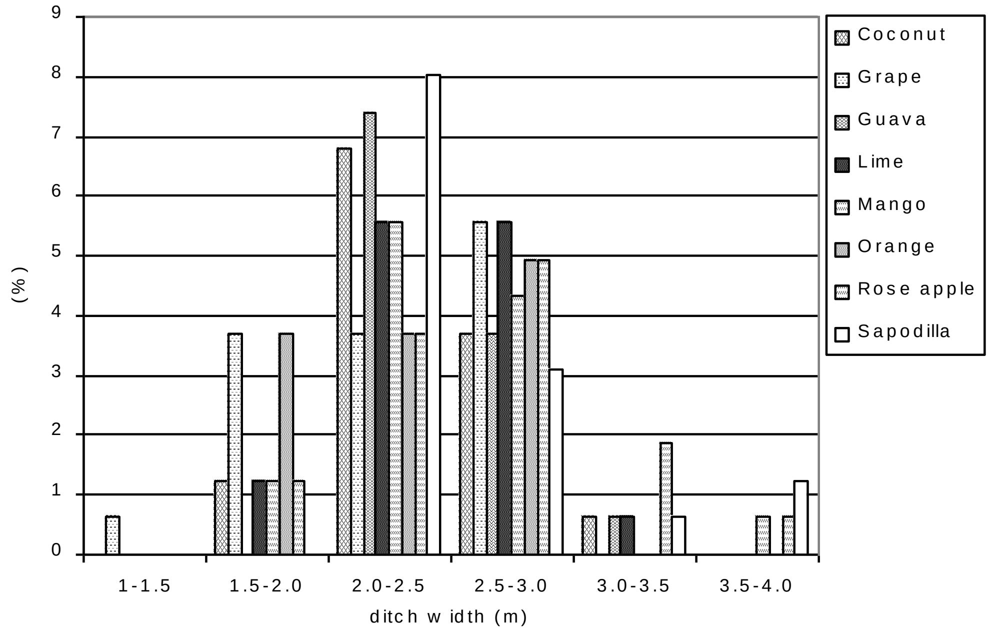
The distribution of the beds according to the beds and ditch widths (sample of 167 gardens) is shown in Figure 13. It can be seen that 40% of the beds are in the 3.0-3.5 m bracket, while 44% of the ditches were found in the 2.0-2.5 m range. We found 4% of old raised beds, which had narrow beds and large ditches, and which farmers will soon reconstruct.

It is likely that the initial bed width has evolved over time. The width is poorly correlated to the type of crop and the corresponding root system[2], as commonly believed, but is rather a consequence of practical considerations and time erosion. When irrigation had to be done manually, large beds increase drudgery. With plot irrigation by sprinkler, things have changed but bed width is commonly limited to 6 m (a wider ditch would not receive water in its central part).

FIGURE 13: BED WIDTH IN RAISED BED SYSTEM



[2] The fact that farmers often change of crops on the same plot is also in contradiction with this hypothesis.

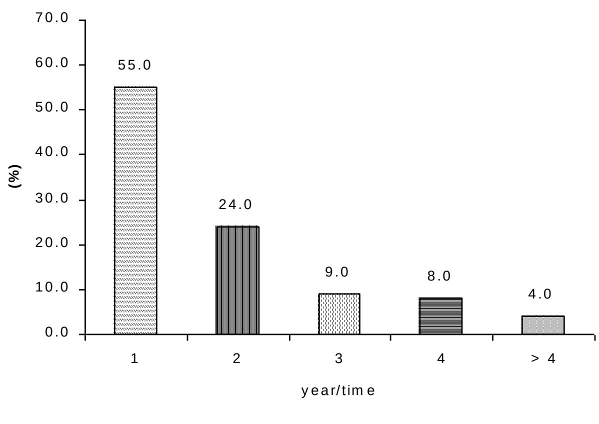


3.4 Maintenance of raised bed system

Once a year, in most cases, farmers dredge the ditches by hand to improve the capacity of drainage of the ditches in the rainy season and the 'navigability' of the boats. They use the mud to reshape the raised beds, which erode easily because of heavy rain and frequent irrigation, and also to renew the fertility of the soil. Farmers also take advantage of the dredging of the ditches to make bunds around the beds in order to retain irrigation water on the beds and to limit run-off.

Figure 14 shows that most farmers do some maintenance work in their beds once a year. They do so in intensive fruit gardens such as grape, guava, orange, pomelo, lime, mango and rose apple gardens. For associated fruit gardens and old gardens with little care, maintenance is done with a lower frequency.

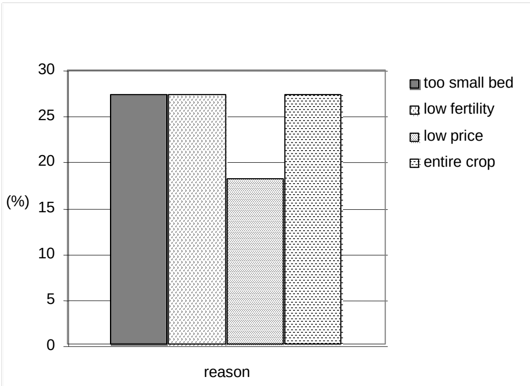
FIGURE 14: PERCENTAGE OF MAINTENANCE FREQUENCY IN RAISED BED SYSTEM



3.5 Raised bed reconstruction

A total of 19% of the beds surveyed have been reconstructed. All these gardens are over 20 years of age. Figure 15 shows the reasons for reconstruction. Farmers report that too small beds, a low fertility of soils, and entire crop are the main reasons for reconstruction, followed with low price. Old plantations tend to have less fertile and narrower beds, which impacts on productivity. Crop change also often implies reconstruction: gardeners reconstruct the beds when they change from fruit to vegetables gardens. As mentioned earlier, two reconstruction techniques were found in the survey. In the first technique, the beds are broken and ploughed as a paddy field. New raised beds are then constructed. In the second technique, the beds are transformed in ditches and vice versa.

FIGURE 15: RECONSTRUCTION OF RAISED BED SYSTEMS



3.6 Chemical fertiliser application

Figure 16 shows the frequency of chemical fertiliser application on raised beds in the Southern central plain. Many farmers do not use much chemical fertiliser, but this dependes on the crop grown. 13% of the farms surveyed do not use chemical fertiliser, 41 % use only 1-6 time/year, and 17 % use 7-12 time/year. Only 10 % (4 %, 6%) of the farms surveyed use chemical fertiliser more than 25 time/year on high value crops as orange, guava, grape, rose apple, jujube and lemon raised beds. Farmers do not apply much fertiliser on crops that have low price because fertilisers are judged too expensive.

FIGURE 16: CHEMICAL APPLICATION ON RAISED BED SYSTEM

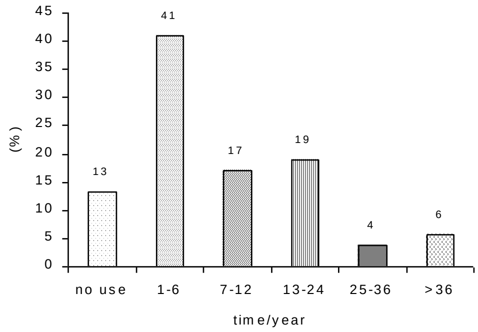
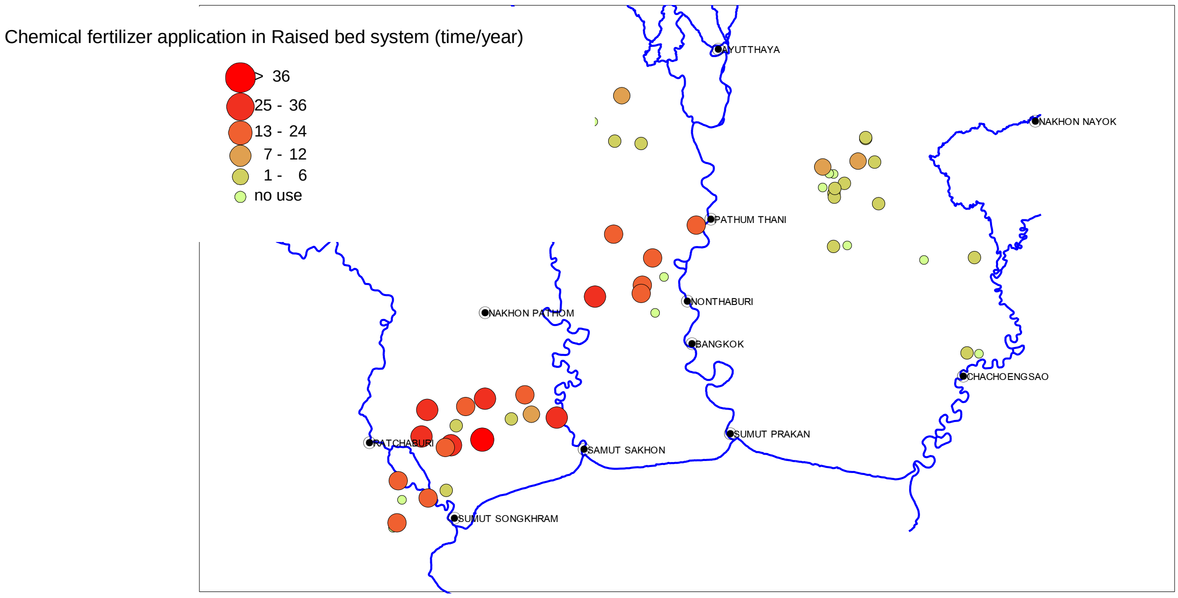


Figure 17 shows chemical fertiliser application on the raised beds surveyed. Song Pi Nong and Damnoen Saduak areas, where annual crops such as vegetable, pomelo, guava, grape, jujube and rose apple are grown, use high levels of fertiliser. On the other hand, less fertiliser is used on raised beds with associated crops and old raised bed with litchi, coconut and mango.

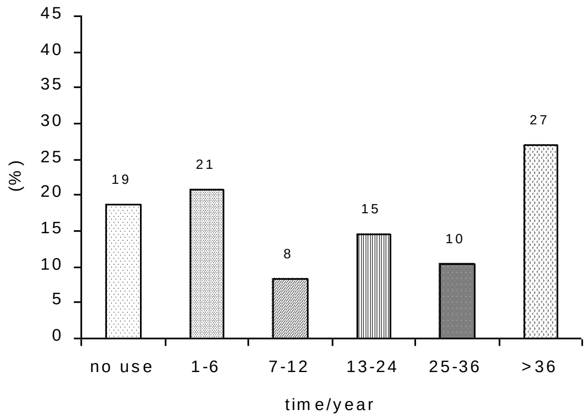
FIGURE 17: MAP OF CHEMICAL FERTILISER DISTRIBUTION ON RAISED BED SYSTEM



3.7 Pesticide application

Pesticide application in raised bed systems is shown in Figure 18. We classified pesticide application by time/year. We found that 18% of the farms surveyed do not use pesticide in plots cropped with litchi, coconut and association of crops which do not need intensive care. 21% of farmers apply pesticide 1-6 times/year, 8% apply 7-12 time/year, and 15% apply 13-24 time/year. All these lower levels of application were found in gardens with crops that give 1-2 products/year and do not give high value products such as coconut, mango and associated crops. 10% of the farms surveyed spray 25-36 time/year and 27% more than 36 time/year. High levels of pesticide application were found on gardens with crops that need intensive care, such as vegetables, grapes and oranges.

FIGURE 18: PESTICIDE APPLICATION ON RAISED BED SYSTEMS



4 Soil conditions and soil management

All raised beds are not alike, neither are their management. Depending on the kind of soil and on the crops that are intended, their construction will vary. The exchanges of water between the orchard and the nearby canal will also depend on local conditions, including the water regime in the canal, the bed elevation, the crop planted, etc. This section reviews some aspects of soil and water management in the raised beds.

The lower Chao Phraya Delta is a very extremely broad flat land, which is well shown by the elevation of the northern point (Ayutthaya province) is only 2 meters, although it is located about 100 kilometres inland. This deltaic plain mostly consists of marine and brackish water deposits, which occurrence of acid and saline soils. They are so called young delta zones, therefore, that constitutes a large flooding area when flood can spread and water accumulated in each rainy season. Its western part, between the Chao Phraya and Tha Chin rivers is often referred to as the "*West Bank*" where the vegetables and fruit trees raised-bed systems are well developed since at least last century. Its eastern side can be divided into the Rangsit area where the commercial orchards raised-bed system is well developed, and the Bang Pakong coastal zones. Around these deltaic plains, we can find the coalescing alluvial fan terraces. Alluvial deposits of the Mae Klong river constitute the main alluvial fans, which are made of fertile soils. Most of its higher parts are covered with sugarcane and vegetables, where the lower areas are planted with paddy rice.

Regarding stratigraphy, two main units can be found in the Southern Chao Phraya Delta: Pleistocene marine deposits and Holocene marine deposits. The Holocene marine sediments are constituted of marine and brackish clays, which are potential sources of salt and acid sulphate soils. The Pleistocene marine and brackish sediments are also potential salt and acid sulphate suppliers, but they are not as strong as the Holocene clays because they have been weathered and leached out, as indicated by the presence of spherical concretion of iron and manganese oxides, "*pisoliths*".

4.1 Distribution and types of major soils in the Chao Phraya Delta

According to the Soil Taxonomy (1998 Editions), we can distinguish 26 great groups in 6 soil orders of the Chao Phraya Delta, namely Entisols, Inceptisols, Vertisols, Mollisols, Alfisols, and Ultisols.

The main lowland area of the Chao Phraya deltaic plain mostly consists of Vertisols, Inceptisols and Entisols, which means that the young soils have black heavy clay, high in organic matter and rich in montmorillonite. Its southern parts consist of marine clay deposits and its northern parts of brackish sediments, although both have later received surface fresh water sediments from four main rivers as Chao Phraya, Tha Chin, Mae Klong and Bang

Pakong. Along the levees of Chao Phraya, Tha Chin, and Mae Klong Rivers, and together in the tidal marshes and mangrove areas, we find the soils known as Entisols. They are most recent deposits favoured with high fertility, however these soils are offset by brackish condition and salinity constraints. Mollisols are soils with very high content of organic matter and often correspond to the vegetables and fruit tree orchard areas. They are predominant in the Damnoen Saduak area.

4.1.1 Soils on active tidal flats

These soils occur along the coast in the active tidal area. They are very young clay or silty clay soils with little profile development. New sediments are still received by regular flooding by sea water. Most soils are flooded only at spring tides but some of the low lying areas are flooded daily at high tide. Three different soils have been distinguished, depending on their degree of ripening and potential acidity: *Tha Chin series, Bang Pakong series and Samut Prakarn series*. On somewhat higher elevations occur soils that have been ridged by digging very wide shallow ditches separating beds (*Samut Songkhram series*), which have been planted to coconuts that are used for the production of sugar.

Large areas of the tidal swamps are in use for salt making and fish breeding. The area where fish ponds have been excavated has expanded considerably in the last decades. The salt pans are mostly constructed on the lower areas close to the sea in order to warrant a regular supply of salt water.

4.1.2 Soils on former tidal flats with recent marine and brackish sediments

Most of these soils are nonacid clay or silty clay having a dark grey surface over a mottled grey B horizon. The C horizon is a greenish grey, soft mud clay occurring at depths of 100 to 180 cm. These soils have a well developed profile and the B horizon is well structured and mottled with yellowish brown and brown mottles of iron oxide. Large, black, soft manganese concretions are also very common. Many of the soils have slickensides, but cracks, though rather wide at the end of the dry season, do not extend very deep. The soil reaction is variable alkaline in the subsoil. They are also distinguished by the presence of fine gypsum crystals in the lower part of surface horizon: *Bangkok series, Bang Len series, Bang Phae series, Phan Thong series*. At various part of the marine plain occur acid sulphate soils. Most of these soils are not extremely acid, though the occurrence of yellow or pale yellow jarosite mottles in the B-horizon is typical for acid sulphate soils: *Cha-am series, Bang Nam Prieo series.* In certain areas, along the large rivers and in Damnoen Saduak area, the marine clays have been ridged for the cultivation of vegetables and fruit trees orchards: *Damnoen Saduak series, Thon Buri series*.

4.1.3 Soils on former tidal flats with older brackish sediments

Most soils on older brackish water deposits are acid sulphate soils with a thick, black to very dark grey A horizon that is probably mainly a river deposit. They occur in a wide zone stretching from east to west. The acidity varies with the depth of the so-called *“**catclay**”* horizon, which is the horizon containing characteristic yellow or pale yellow mottles of the mineral jarosite ($KFe_3(So_4)_{2(}OH)_6$). This horizon is extremely acid. The *Ayutthaya series and Maha Phot series* have a catclay horizon starting below 100 cm, while the *Sena series, Rangsit series and Thanyaburi series,* have cat clay below 40 cm but within 100 cm. Only the *Ongkharak series* has yellow mottles of jarosite within 40 cm, which makes this soil very acid and unproductive. Most of the older acid sulphate soils have strong red mottling in the upper part of the B horizon. These red mottles consist of dehydrated, more or less amorphous iron oxides that are typical in monsoon climates for poorly drained mature soils with low pH. The soils are underlain with marine deposits below 150 or 200 cm. These soils have a red mottled upper B horizon but generally lack the yellow mottled catclay horizon. They may have a low pH in the surface but the reaction increases with depth to moderately acid: *Bang Khen series, Chachoengsao series*.

Nearly all soils are used for paddy rice. In a few small areas near Chachoengsao on the Bang Pakong river and near Rangsit, north of Bangkok, acid sulphate soils have been ridged and raised-beds systems have been prepared for growing vegetables and fruit trees.

FIGURE 19: MAIN SOIL TYPES IN THE LOWER DELTA

4.2 Soil characteristics of the southern central plain

The soils of the southern central plain are formed of river alluvial deposits, brackish sediments, and marine sediments. Brackish water deposits is a biggest area that occurs in the middle part of the Southern central plain that are medium to strong acid soils. Soils in the western part of the delta were affected by nearby limestone mountains that raised the pH of soils in this area. Marine deposits occur along the shoreline. These soils are neutral to alkaline and have high salt content. However, these brackish and marine deposits consist in clay to silty clay. High percentage of clay in these area allows a high cation exchange capacity. The northern part of the Mae Klong River alluvial fan is made of sandy loam to silty clay: these area have a lower percentage of clay and only medium cation exchange capacity (Figure 20).

Organic matter in the soil induces a higher cation exchange capacity. Figure 22 shows that most areas have moderate to very high organic matter percentages. The levels of cation exchange capacity, base saturation and organic matter are fair to good in the Southern Central Plain. This promotes soil fertility as most soils can be considered of medium and high fertility.

FIGURE 20: CATION EXCHANGE CAPACITY (CEC) IN SOUTHERN CENTRAL PLAIN

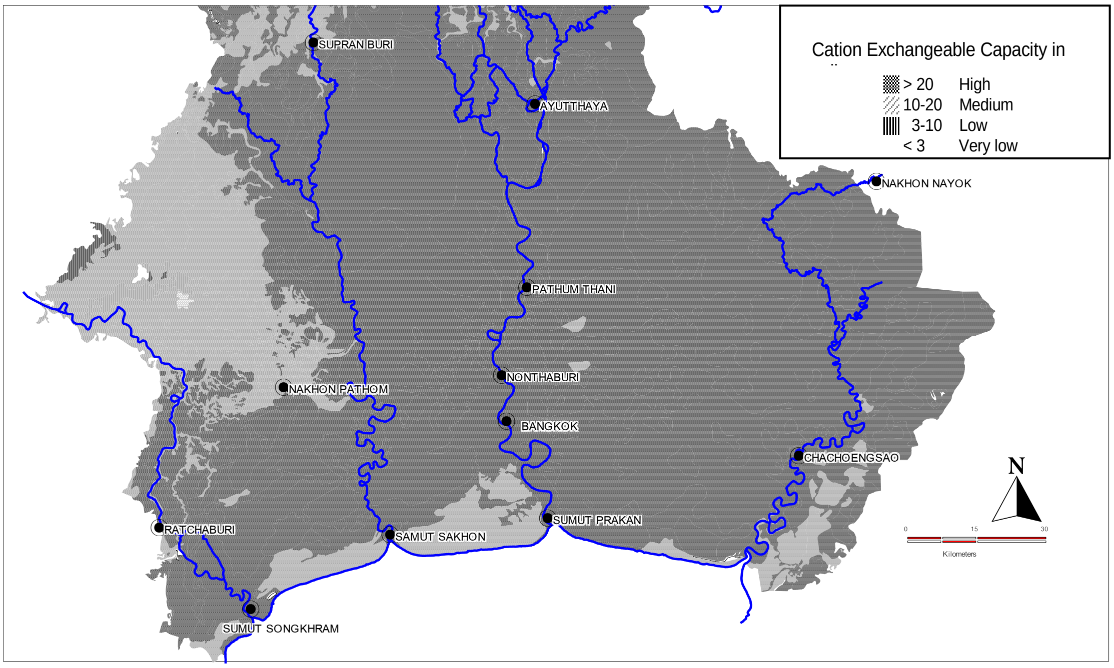


FIGURE 21 MAP OF BASE SATURATION (%) IN SOUTHERN CENTRAL PLAIN

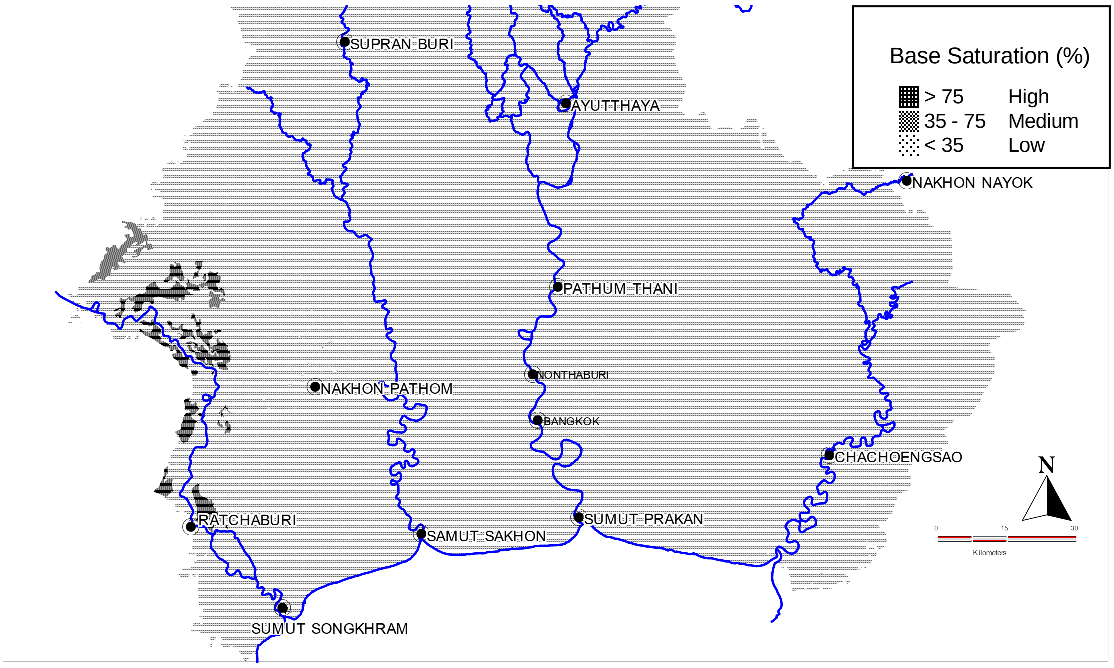


FIGURE 22 MAP OF ORGANIC MATTER IN SOUTHERN CENTRAL PLAIN

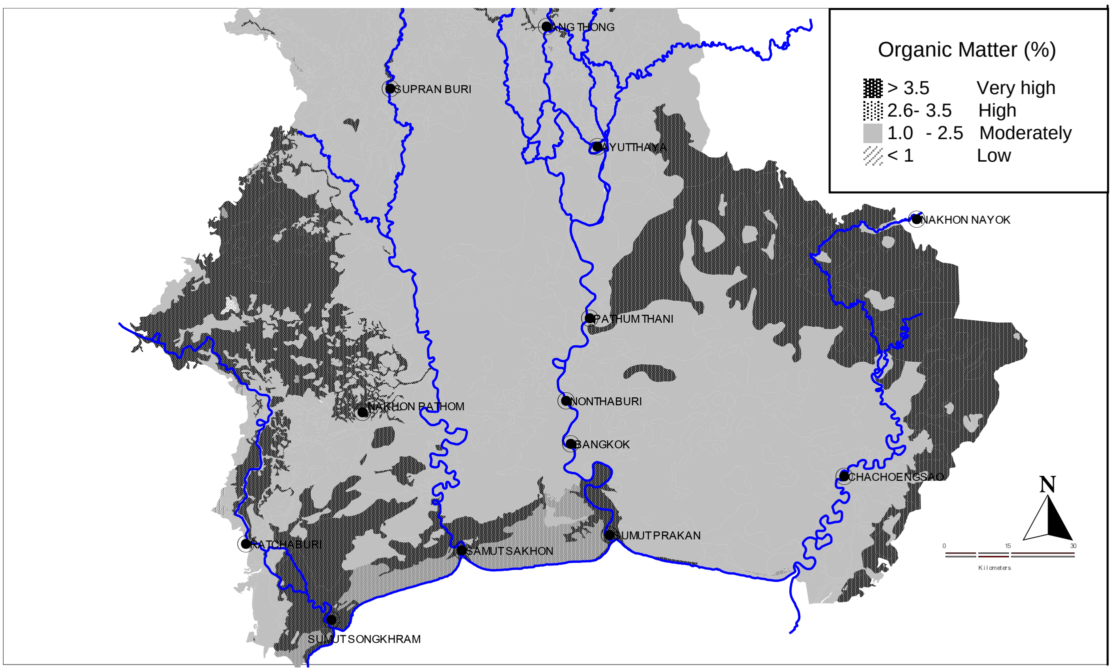


FIGURE 23 MAP OF SOIL REACTION (PH)

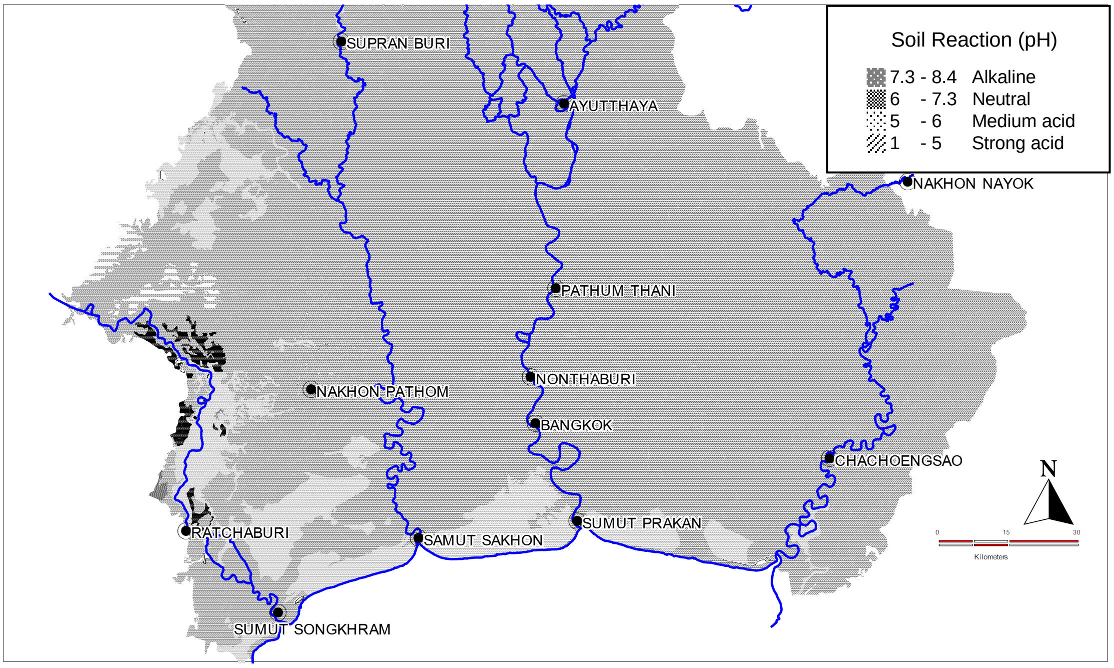
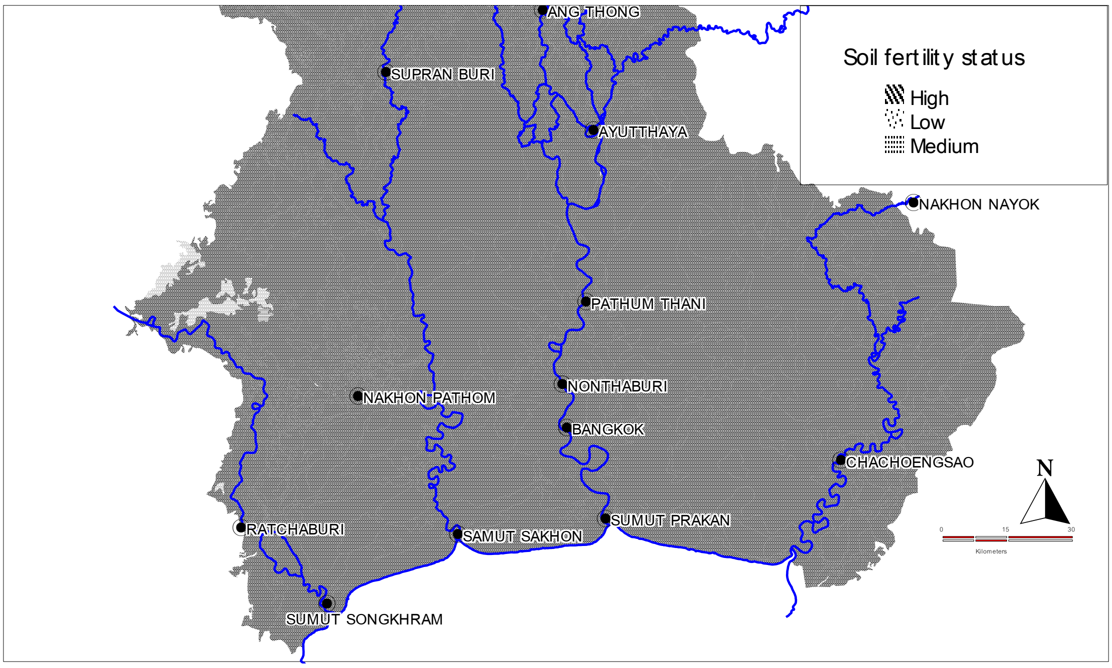


FIGURE 24 MAP OF SOIL FERTILITY STATUS



4.3 Soil problems in the raised-bed systems of the Chao Phraya Delta

There are two main generic soil problems: acid sulphate soils and saline soils.

Acid sulphate soils: with pH as low as 3, occur on the upper part of the Chao Phraya young delta where brackish sediments and poorly drainage conditions. These soils extend along an east-west belt between Ayutthaya and Bangkok with particular occurrence in the Rangsit area and the north of west bank. They can be divided into two major groups: potential acid sulphate soils and true (active) acid sulphate soils. The potential acid sulphate soils are classified as *Typic Sulfaquents*, such as the *Bang Pakong series*. They are common along coastal areas, very poorly drained, with a fine clayey texture, high pH (mild soils), greenish or bluish colors, high salinity and pyrite (FeS_2) content. The drainage of these unripe soils results in the formation of true acid sulphate soils. Some parts of these potential acid soils covered with marsh and mangrove forest have been cleared for salt pans or fish and shrimp aquaculture. These soils have a low potential for agricultural production and require heavy investment in soil improvement.

The true acid sulphate soils are mainly *Sulfaqueptic Dystraquerts*, such as Bang Nam Prieo series, Thanyaburi series, Rangsit series, Sena series ; *Typic Sulfaquepts*, such as Cha-am series, and *Sulfic Endoaquerts*, such as Don Muang series. They are also included *Ustic Dystraquerts*, such as, Bang Khen series, Ayuthaya series, Maha Phot series, Tha Khwang series, Chachoengsao series, and Bang Pa-in series. These acid sulphate soils present a very low pH, that is caused by the oxidation of iron sulphides into sulfuric acid and complexes of iron-aluminum sulphates, namely jarosite minerals: pale straw yellow mottles of jarosite mark the end of the oxidation reaction. They are poorly drained soils of fine clayey texture with about 35-60% of montmorillonitic clay minerals. The degree of acidity depends on the amount and depth of jarosite minerals in the root zone layer. The main limitations of true acid sulphate soils for agricultural productions are high acidity, phosphorus deficiency and the toxicity of soluble Fe and Mn ions. A high water table should be maintained in order to prevent pyrite oxidation. Generally, the management of acid sulphate soils use of lime and the application of nitrogen and phosphorus fertilizers. Most of these soils are normal used for paddy rice cultivation. Following the development of supporting infrastructure such as irrigation systems, roads and the government campaigns, the diversification agriculture toward fruit and vegetable production increased continuously the raised-bed systems for vegetable and orchards plantation in acid sulphate paddy fields in northern and eastern parts of the Southern Chao Phraya delta (Rangsit area).

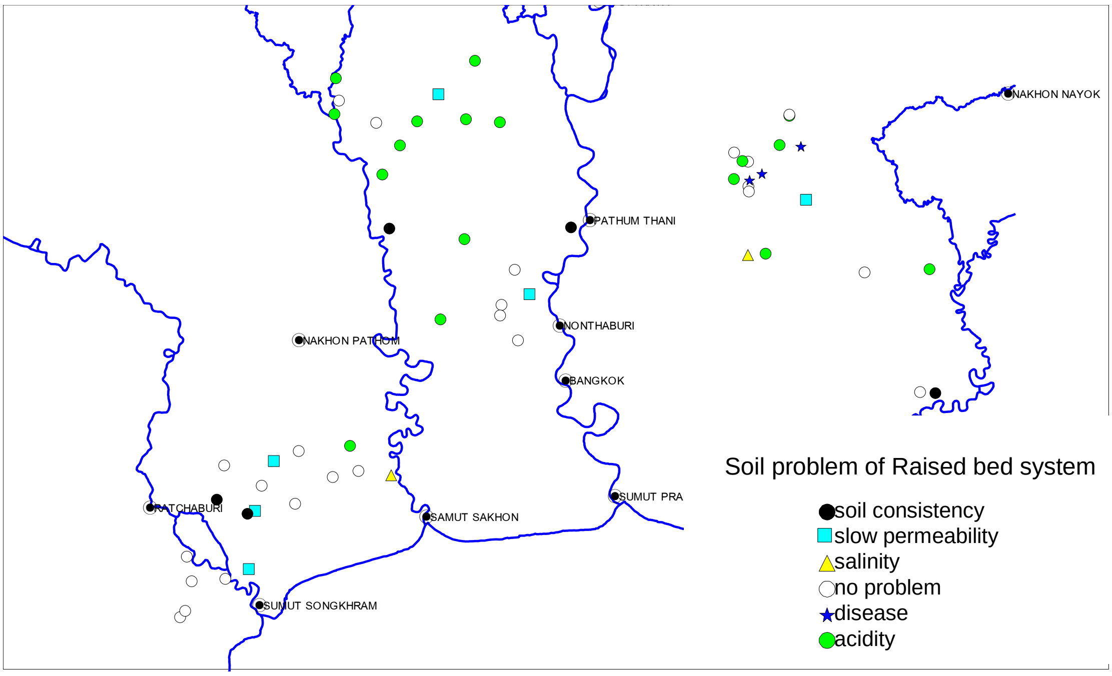
Saline soils: the salinity problems occur because of seawater intrusion in the main estuarine areas. Normally, maintaining an appropriate discharge in the main river controls intrusion of marine water. This is possible only in the mainstreams regulated by dams in the upper basin. In the past, the fruit orchards situated along the Chao Phraya, Tha Chin and Mae Klong rivers have suffered important loss because of salt water intrusion when there have a period of long dry season. Other problems with saline soils also occur when digging marine sediments too deep in the area near the seashore, such as Nakhon Chaisi and Damnoen Saduak areas. There are three different soils as depending on their degree of ripening: *Tha Chin series* (*Sodic Hydraquents*), *Bang Pakong series* (*Typic Sulfaqents*), and *Samut Prakarn series* (*Fluvaquentic Endoaquepts*).

FIGURE 25: SOIL PROBLEMS: ACIDITY AND SALINITY

Acid Sulphate soils in Rangsit area *Marine Saline soils in Damnoen Saduak area*

Figure 26 shows some soil problems on raised bed systems in the Southern central plain, as revealed by the field survey. Most soil problems in the southern central plain come from acidity and were found in Rangsit and Song Pi Nong areas. Liming is the solution for farmers who are affected by soil acidity problems. There are few soil texture, permeability and salinity problems. Grapes, orange and pomelo raised beds in Damnoen Saduak, which have to be sprinkled with water often, have problems of low permeability and hydraulic conductivity. We found disease problems in old orange tree raised beds of the Rangsit area.

FIGURE 26: MAP OF SOIL PROBLEMS IN RAISED BED SYSTEMS



Soil salinity is dealt with by adopting fruit and vegetable varieties which are resistant. We can classified all the crops found in our survey by their level of tolerance to salt (Table 1). We found that varieties with varied levels of salt tolerance were often mixed up in the study area. There were only two gardens near the coastal area where serious salinity problem where reported. Coconut is the main varieties of that area. But there are a lot of non salt tolerance like pomelo and litchi gardens in Samut Songkhram where the parent material is marine sediments. We can therefore assume that salinity is not a serious problem in the southern central plain, but for the restrictions on crop choice that it may entail.

The choice of crops appear neatly in the lower Damnoen Saduak Project. In the most saline area, only coconut trees are found; when we move upward we then find some jujube, then some mango trees, then all types of crops.

TABLE 1: TOLERANCE TO SALINITY OF SEVERAL CROPS

Non-tolerant	Medium tolerant	High tolerant
Orange	Rose apple	Asparagus
Lime	Pome granate	Chinese kale
Banana	Hog plum	Morning glory
Lychee	Chili	Basil
Mango	Onion	Sapodilla
Grape	Sweet corn	Jujube
	Water melon	Coconut
	Tomato	Guava
	Cassava	
	Roses	

5 Water management in raised bed systems

5.1 Tidal effect in the rivers

Because of the influence of the tide, which tends to bring saline water into the network of channels, the lower parts of the delta must be 'closed' by a dike provided with gates constructed at the outlet of all waterway which flow either to the sea or, laterally, to the lower reaches of the main rivers. These gates are generally closed only during the dry-season, when they contribute to keeping freshwater in the so called 'conservation area', while they are left open in the wet season to allow drainage of excess water to the sea.

In practice, things are a bit more complex. Because of the influence of the sea tidal movement onto the lower reach of the main rivers, the water levels downstream of the regulators located along the dike will fluctuate constantly. This means that in the dry-season the water level in the river at high tide is still likely to be higher than the level upstream of the regulator (in the conservation area). By opening the gate at that moment some inflow can be obtained during a few hours. Conversely, in the wet season, it will sometimes be necessary to close the gate to prevent high water levels in the river to back up inland, limiting the possibility to drain to only the few hours of low tide.

Figure 27 shows the dike systems which closes the Chao Phraya Delta. It can be observed that there are still three mains river reaches which are not fully gated and which therefore allow some permanent inflow and outflow between the canal network and the river system. The main reason for not totally closing the corresponding waterways is to allow free navigation transportation without the hindrance of locks. This probably results in a limited loss of water in the dry season but also, consequently, allows the transmission of the tidal effect further inland. As long as the discharge in the rivers is maintained above the minimum value allowing the control of salinity control (50 cms in the Mae Klong and Chao Phraya Rivers, 35 cms in the Tha Chin River) this inflow will not be saline and the tidal effect will be much beneficial: in fact it allows farmers to drain their plot during the hours of low tide, while, most of the time, they can also fill up the ditches of their orchards at high tide by gravity. A significant share of the farms in the lower Red River and Mekong deltas, where the tidal effect is much stronger, are able to manage a large part of the irrigation and drainage flows between their plot and the canal system by using the tidal effect.

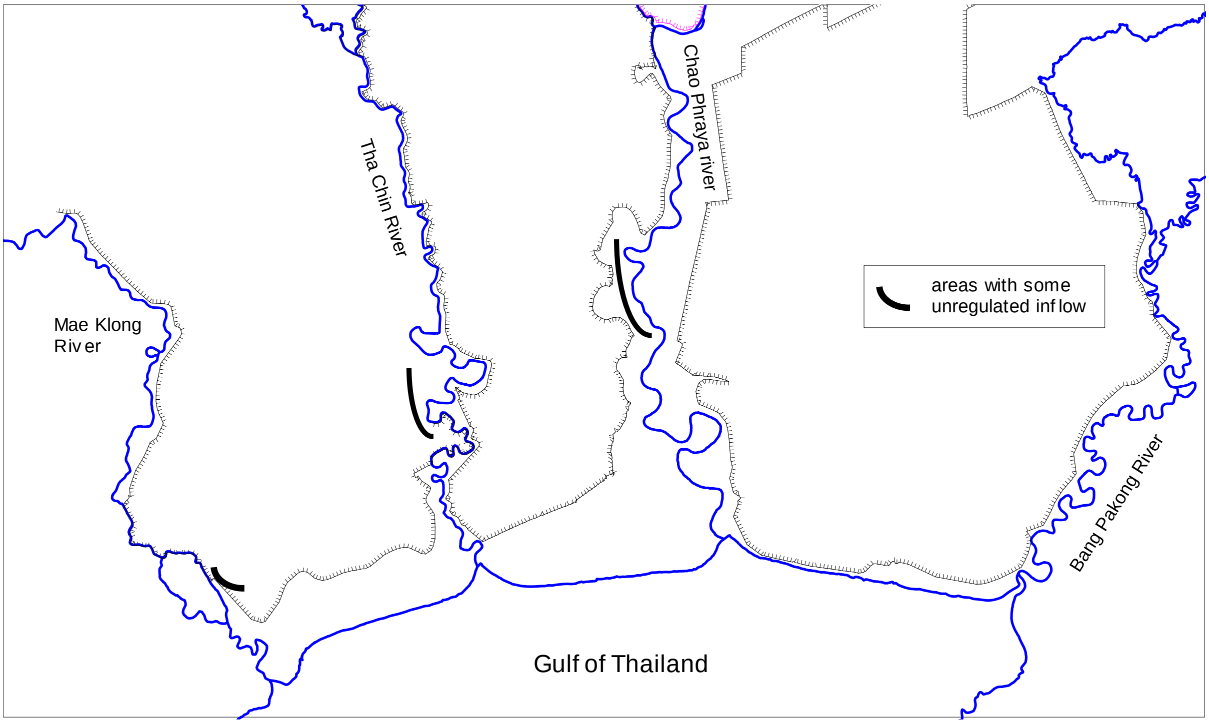
A semi-closure therefore brings several advantages:

- Areas near the river benefit from the tidal effect and pumping costs are significantly decreased.
- Transportation by boat is eased or allowed.

- Polluted water will be diluted (in the Chao Phraya Delta, this constraint entails that some regulators are left partly open in order to mitigate pollution and allow some constant flushing out).
- Even in case of waterways which bring salinity inland, this effect may be desirable if shrimp farms are using brackish water.

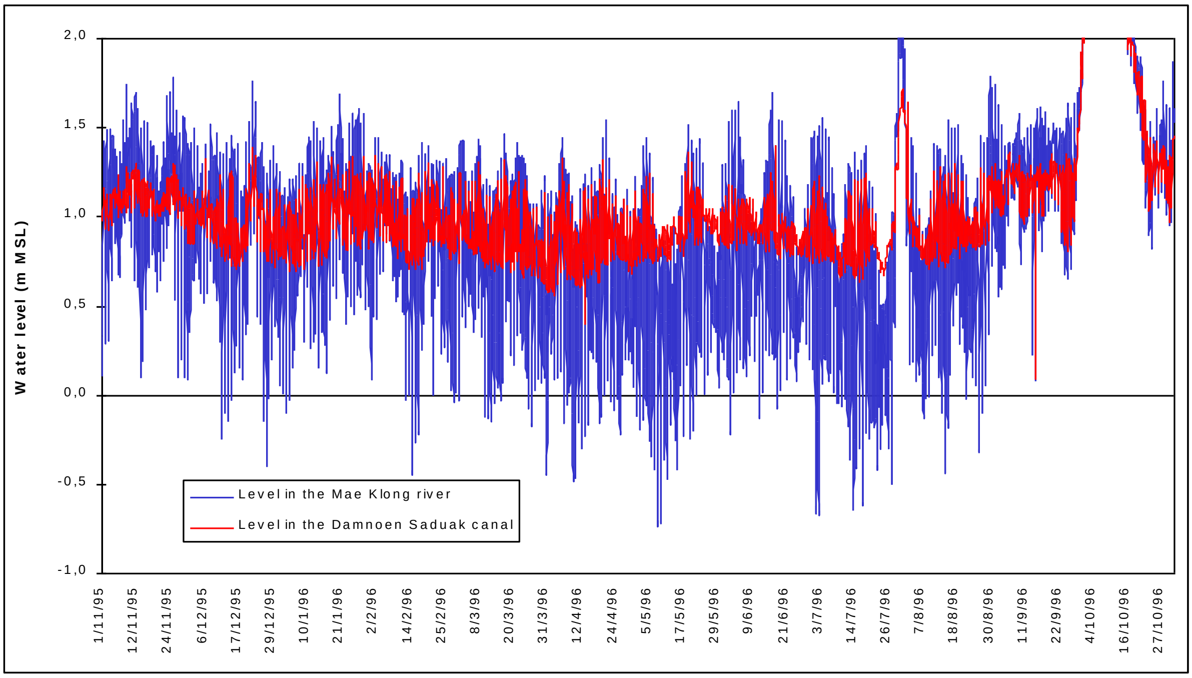
Therefore, it appears that the full closure may not always be the most desirable option and that some daily management of the water gates are necessary to adapt to the tidal effect and to the evolution of water quality both inland and in the rivers.

FIGURE 27: CLOSURE OF THE LOWER DELTA AND RIVER REACHES WITH UNGATED EMBANKMENTS



The impact of the closure on inland water levels is illustrated in Figure 28 which shows the evolution of the water level in the Mae Klong River as well as upstream of the watergate located at the extremity of the Damnoen Saduak canal. It can be seen that while the water level in the river can decrease down to the 0 level or even lower, the inland water level is roughly stabilised around an average level of 1 m MSL. (the exceptional flood of 1996 also appears on the chart).

FIGURE 28: EXAMPLE OF REGULATED WATER LEVEL (DAMNOEN SADUAK CANAL)



5.2 Water management at the plot level

Throughout the year, farmers manage the water level in the plot by controlling water flows between the plot and the canal. A raised bed plot has one or two gates which communicate with the canal next to the field. Outflows or inflows can be obtained either by pumping or by gravity depending on the need (irrigation, drainage, renewal of poor quality water) and on the relative water levels inside and outside the plots. The level in the canals relates to water management at the regional level. As seen earlier, the semi-closed nature of the lower delta implies that the tidal influence is still to be felt near where ungated waterways remain, but this influence will be greatly dampened. Figure 29 illustrates this point by showing the evolution of the water levels in the Mae Klong River, inside the Damnoen Saduak Canal and near a plot located a few kilometres away from the river. It can be seen that while the amplitude of the fluctuations is over 1.2 m in the river, it is dampened down to 20 cm at most in the canal near the plot.

Controlling flows between the canal and the plots is in general done by a pumping installation, as shown in Figure 30. It allows the farmer, with the same fixed pump, to pump water from the canal into the orchard and vice versa. Pipes also allow flows by gravity. The four different situations (inflow/outflow vs. gravity/pumping) are shown in Figure 31.

The respective frequency of these four types of flow will depend on several factors. These include: 1) the seepage through the dike between the canal and the plot; 2) the kind of crop and the water level desired; 3) the evolution of water quality; 4) the respective water levels inside and outside the plot; 5) agronomic stages (for example, the water level is lowered at the time of flowering); 6) plot irrigation operation (the water level is raised to ease the use of small boats equipped with sprinklers); 7) rainfall. Figure 32 shows the distribution of the four types of flows, as observed during 10 months in three adjacent plots. It can be seen that there are significant differences according to the type of crop (for example the lower level maintained in the mango plot allowed gravity inflow and translated into higher seepage from the canal, therefore into fewer inflow operations.

FIGURE 29: DAMPENING OF WATER LEVEL FLUCTUATIONS

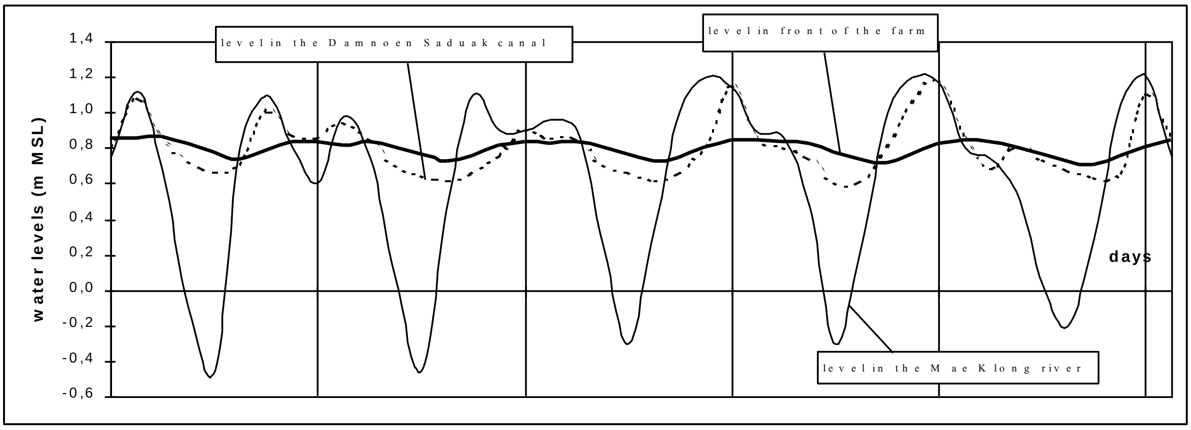


FIGURE 30: TYPICAL DUAL-PURPOSE PUMPING EQUIPMENT USED FOR TWO ADJACENT PLOTS

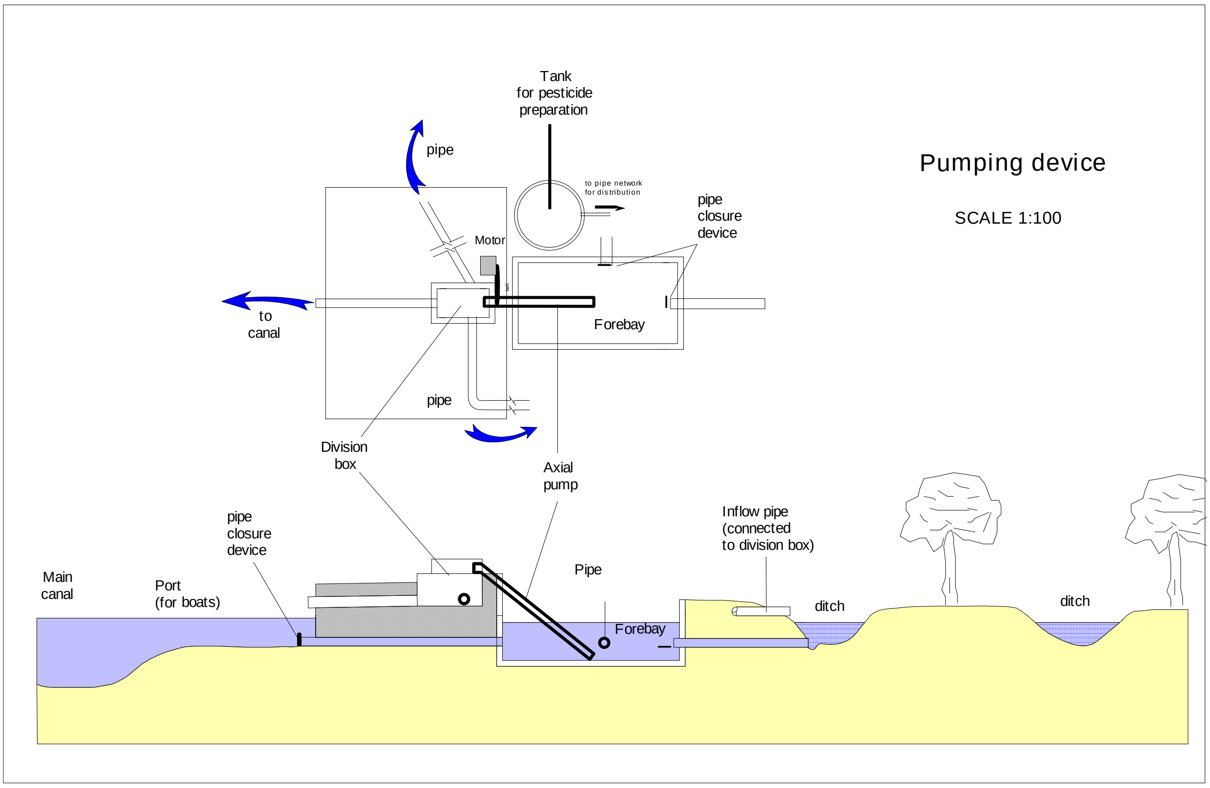
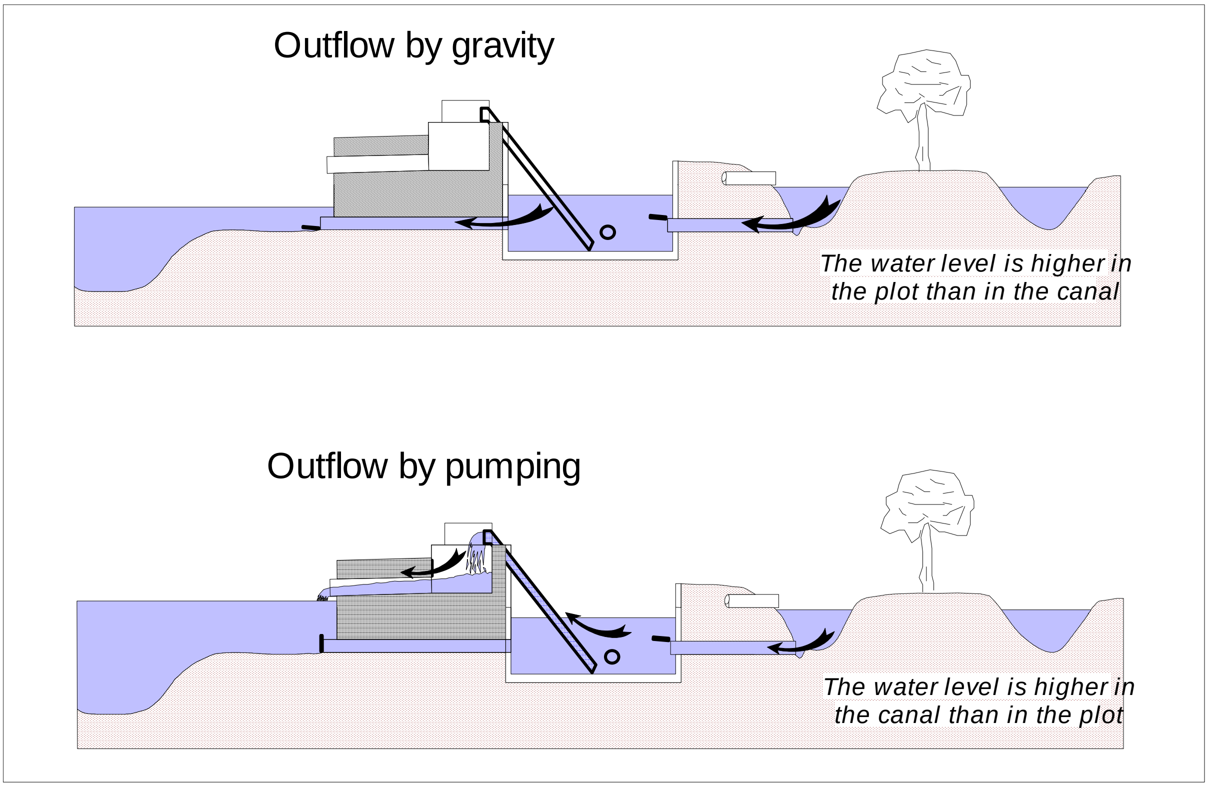


FIGURE 31: WATER MANAGEMENT AT THE PLOT LEVEL: INFLOWS AND OUTFLOWS IN RAISED BEDS



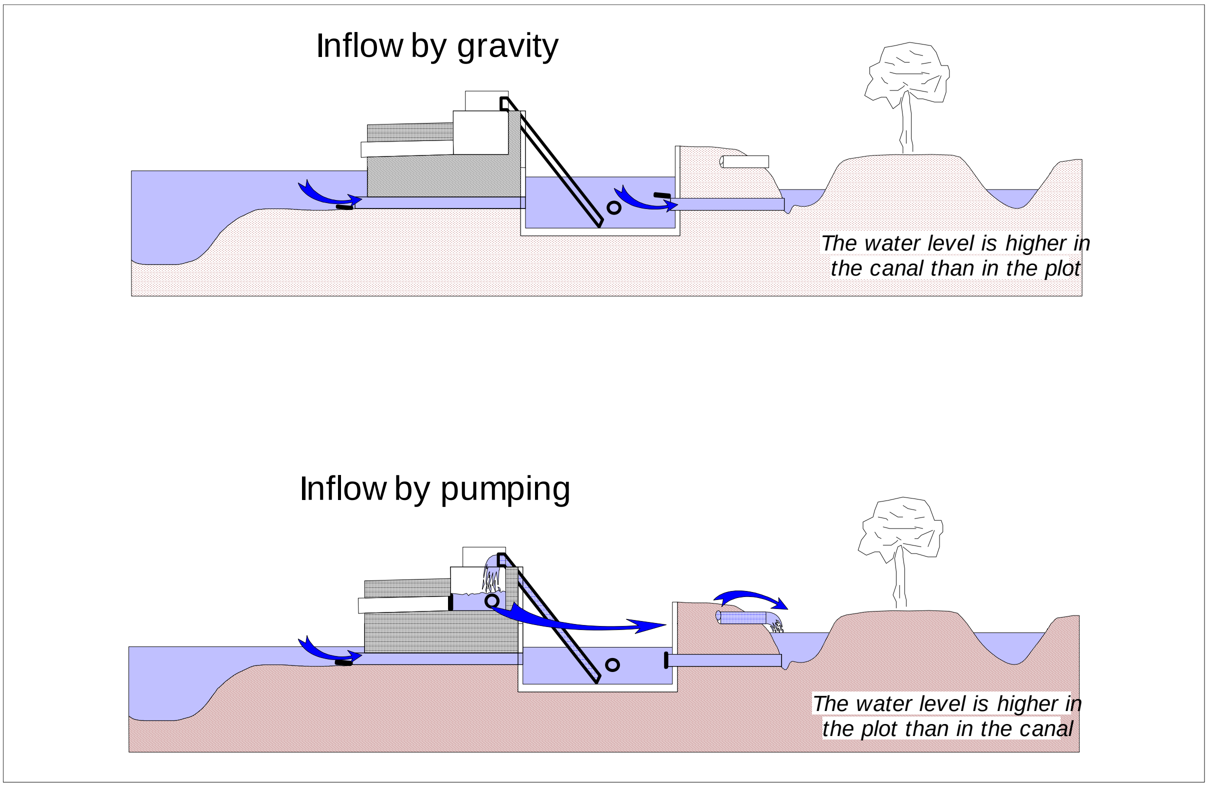
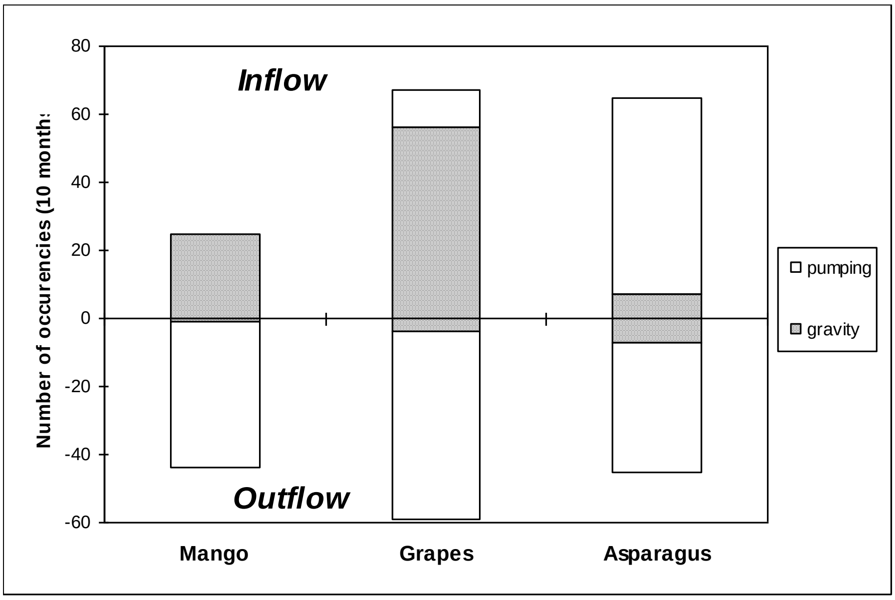


FIGURE 32: EXAMPLE OF FREQUENCIES OF INFLOWS AND OUTFLOWS FOR THREE TYPES OF CROP



5.3 Irrigation at the plot level

In this 'artificialised' environment, farmers had to develop very specific devices to make their work in the field easier: double-purpose pump, small boat equipped with sprinklers used to irrigate the beds or pipe network to distribute pesticides or liquid fertilisers under pressure. Plot irrigation and pesticide application are indeed tasks to be carried out constantly. While in the past most plot irrigation was done manually (bucket), the most common device is now a small boat equipped with sprinklers which goes along the beds. There are three different types of boats. The most simple one carries the pump and the sprinklers and is simply pushed by the farmer along the beds (this requires that the farmer walk within the ditches). The second type allows the farmer to sit within the boat and to guide and power its movements with a pole. The most sophisticated model allows the farmers to sit in and the motor both powers the pump and propels the boat.

The frequency and duration of bed irrigation are shown in Table 2. High discrepancies between crop types are evident, with asparagus receiving water 2.6 times a week, grapes 1.3 and mango as little as 0.4. Requirements, of course, vary greatly between seasons: in the dry season, asparagus is irrigated every two days and grapes almost every three days, whereas weekly frequencies are as low as 1.4 and 0.5 in the rainy season.

Durations of water applications are quite regular: 1.4 hour for grapes and 1.6 for asparagus, with plot sizes of approximately 1 *rai.* These durations are proportional to the pump discharge, to the total ditch length and to the water depth to be applied: this explains the longer time of the irrigation in the mango plot, which beds are watered with an older and less powerful pump and for which a higher amount of water must be brought, demanding a slower pace of boat movements.

However, the last line of the table shows that the irrigation doses are quite small (between 5,2 and 9 mm, on the average), let alone the percentage of water which does not infiltrate into the soil and flows back directly to the ditch. This contributes to explaining why irrigation frequency is rather high.

TABLE 2: Characteristics of plot irrigation

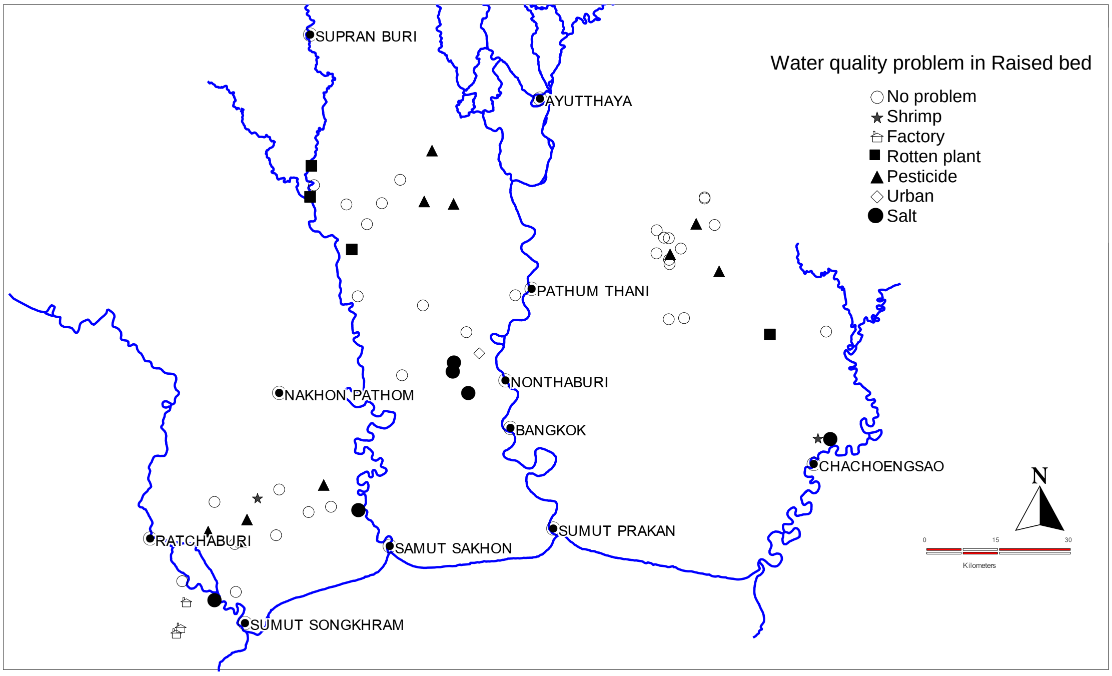
Season		Grapes	Asparagus	Mango
Frequency of Irrigation (times / week)	Rainy season	0.5	1.4	0.1
	Dry season	2.1	3.8	0.7
	Whole year	1.3	2.6	0.4
Average duration of bed irrigation (hours)	Rainy season	1.2	1.6	3.4
	Dry season	1.5	1.6	2.6
	Whole year	1.5	1.6	2.7
Average volume by irrigation:	m^3	38	37	63
	mm/soil area	5,5	5,2	9
	water depletion in ditch	9,3 mm	7,5 mm	13 mm

5.4 Water quality problems

Water quality is also a very important aspect of raised bed cultivation. Many vegetable growers of Nonthaburi, for example, have sold their land and bought new plots more distant from the city. Salinity in the river lower reaches is also a problem if the RID fails to ensure the adequate discharge necessary to control saline water intrusion (50 cms for Mae Klong and Chao Phraya River, 35 cms for Tha Chin River).

Our field survey allowed the identification of several problems related to water quality (Figure 33). Pesticide residues is the main problem, especially when farmers apply a lot of pesticides, as in orange and grapes gardens. There was salty water problem in some areas near the mouth of the rivers. This problem just happened in some years of water shortage. Raised beds which had water quality problem because of rotten plants were sweet potato raised beds, because roots rote in case of excess water.

FIGURE 33 MAP OF WATER QUALITY PROBLEMS IN RAISED BED SYSTEMS



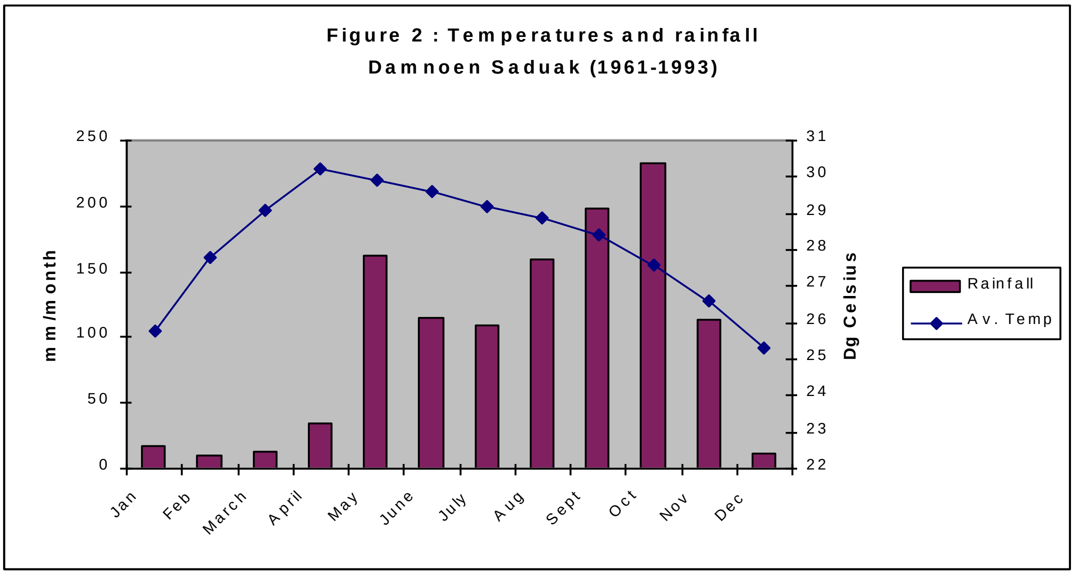
6 Climatic conditions

6.1 Three seasons

This section provides a few general data on the climate of the lower delta, most especially the Damnoen Saduak Area, which will be the object of Part II.

Dominated by a monsoon regime, the climate is marked by 3 seasons (Figure 34).

FIGURE 34: TEMPERATURES AND RAINFALL DAMNOEN SADUAK (1961-1993)



- <u>the cold season</u> (November to February): Thailand undergoes the north-eastern monsoon which brings fresh and dry air from China. Across China sea, this monsoon gains humidity and brings few rains in January near the southern coast of Thailand where Damnoen Saduak is situated. Temperatures are higher than 15C and can increase up to 30C.

- <u>the hot season</u> (February to May): during the inter-monsoon period, temperatures are the highest of the year (30-40C). At this period of the year, rainfall are scarce.

- <u>the rainy season</u> (May to October): the region is subject to the south-western monsoon which brings humidity from Indian Ocean. Temperatures remain high, between 25 and 35C.

6.2 Main features

The characteristics of this climate are:

- Negative soil water balance for three fourth of the year: Average rainfall is only higher than ET in the August-September-October period.

- High temperatures the whole year: The average temperature in the Central plain ranges from 25C to 33C. Minimum average temperatures are seldom lower than 20C.

- Heavy rain: a feature of tropical climates such that of Thailand is that rainfall events are short and intense. In 1998, we observed a few rains of 60-70 mm per day.

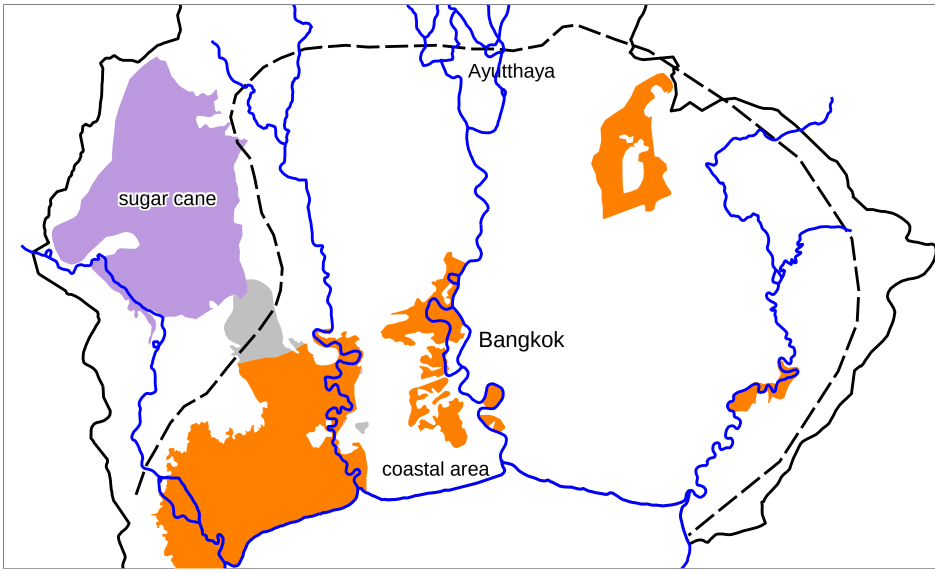
- Common flood risk: In October and November, and commonly well into December, excess of water occurs in saturated areas and the environment is globally flooded.

- High humidity: average humidity is fairly high along the year: between 65 and 80%.

7 Constraints to the expansion of raised beds

The preceding sections have alluded to several parameters which favour or constrain the establishment of raised beds in the gross potential area indicated in Figure 35. They can be recapitulated as follows:

FIGURE 35: GROSS POTENTIAL AREA FOR RAISED BEDS IN THE SOUTHERN DELTA



Part II

Environmental aspects of raised bed intensive farming

Gwenaelle Joannon

Roongnapa Korparditskul

Roland Poss

Pratueng Treepetch

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1 Introduction

The association of favourable environmental conditions in the delta (high water availability, strong sunshine all year round, fertile clayey soils) and socio-economic conditions (proximity of Bangkok, development of urban and export markets, reliable transport infrastructures) encouraged farmers to increase their production and to intensify their cropping systems, particularly fertiliser and pesticide use.

In this context, new crops have been introduced in the delta to create new markets. Grapes has been introduced in the 1960s. Its cultivation is so intensified nowadays that farmers can get five crops in 2 years. Native to South-western Europe, grapes is not well adapted to tropical climate. It is so sensitive to fungus and insect attacks that farmers have to spray pesticides every other day.

In raised bed environments, water makes up a significant part of the total area. Inside agricultural fields water covers around 40% of the total area (Molle *et al*, 1998). In particular, the Damnoen Saduak area is crossed by a very dense network of waterways and this environment is very sensitive to pollution, particularly by diffusion in the water. This section attempts to assess the impact of agricultural practices on the environment, focusing on grapes cultivation in the Damnoen Saduak area, because this crop requires the highest doses of pesticides (Cheyroux, 1997).

In a first part, the agricultural practices used in vineyards are assessed, based on a field survey. The second part addresses the issue of water quality in the canals at different time and space scales in order to understand whether agricultural practices have an impact at the regional level. The third part deals with the on-site and off-site effects of grapes cultivation considering water, soil and fruit quality. The fourth part reports the results of a field experiment where phosphorus and potassium fertilisations have been interrupted.

1.1 Development of a commercial agriculture on raised beds

At the end of the 19th century, the Chinese migrants who resorted to raised beds techniques to rid the natural milieu of its main constraints have fuelled the agricultural development of the region. Protected from the flood regime and provided with fresh and perennial water throughout the year and also with fertile sedimentary soils (Mollisols), the region presented favourable conditions for large scale land development. Farmers have developed an intensive agriculture on raised beds characterised by its large diversity of crops and its high requirements in labour force and capital.

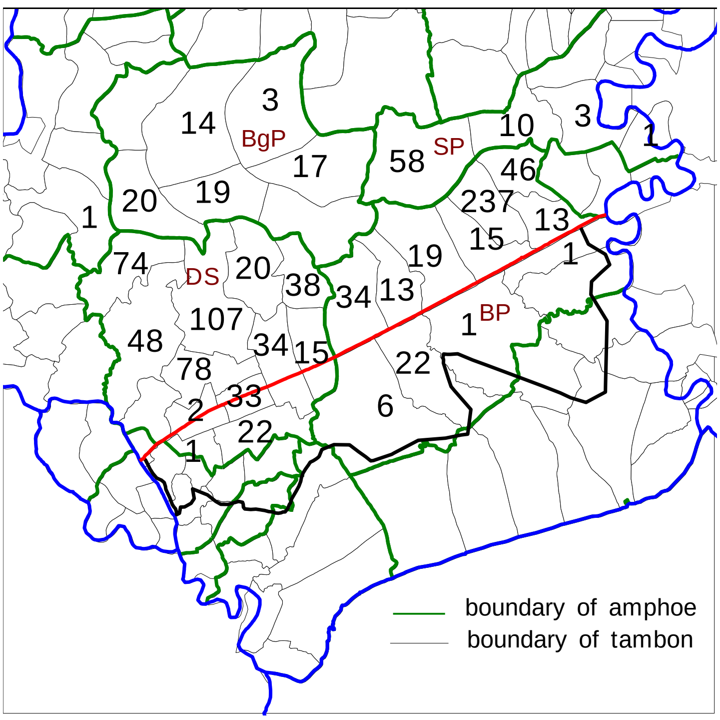
Benefiting from reliable transport and market infrastructures due to the proximity of Bangkok and also from good connections between farmers and the marketing systems, farmers produce high added value fruits and vegetables aimed at urban and export markets. Showing a high reactivity in response to the changing economic situation, the raised bed area of Damnoen Saduak has become a centre of innovation: farmers regularly try to grow new crops to gain new markets and to remain competitive.

1.2 Introduction and expansion of the grapes cultivation

Aware of the capacity of farmers to innovate, the Department of Agriculture of Damnoen Saduak district introduced grapes in the sixties. As a result of research works of Dr. Pavinpunsri (Horticulture Department of Kasetsart University), two varieties (White Malacca and Cardinal) and specific cultivation techniques were developed, adapting this crop to a tropical humid environment. Grown primarily in *amphoe* Damnoen Saduak, vineyards expanded simultaneously to the whole raised bed area.

According to the land use survey of 1997 carried out by each *kaset amphoe*, grapes was grown by 1,039 farmers on a total area of 12,782 rai (2045 ha). It is mainly cultivated in four *amphoe*: Damnoen Saduak (DS) with 472 grapes growers, Ban Phaeo (BP) with 407, Bang Phae (BgP) with 73 and Sam Phran (SP) with 76 (Figure 36). Grapes vineyards are mostly concentrated in *amphoe* Damnoen Saduak and in Ban Phaeo. In Ban Phaeo, grapes is concentrated mainly in one *tambon* (Djet Riew) which totalled 237 grapes farms in 1997.

FIGURE 36: DISTRIBUTION OF GRAPES FARMS PER *TAMBON*

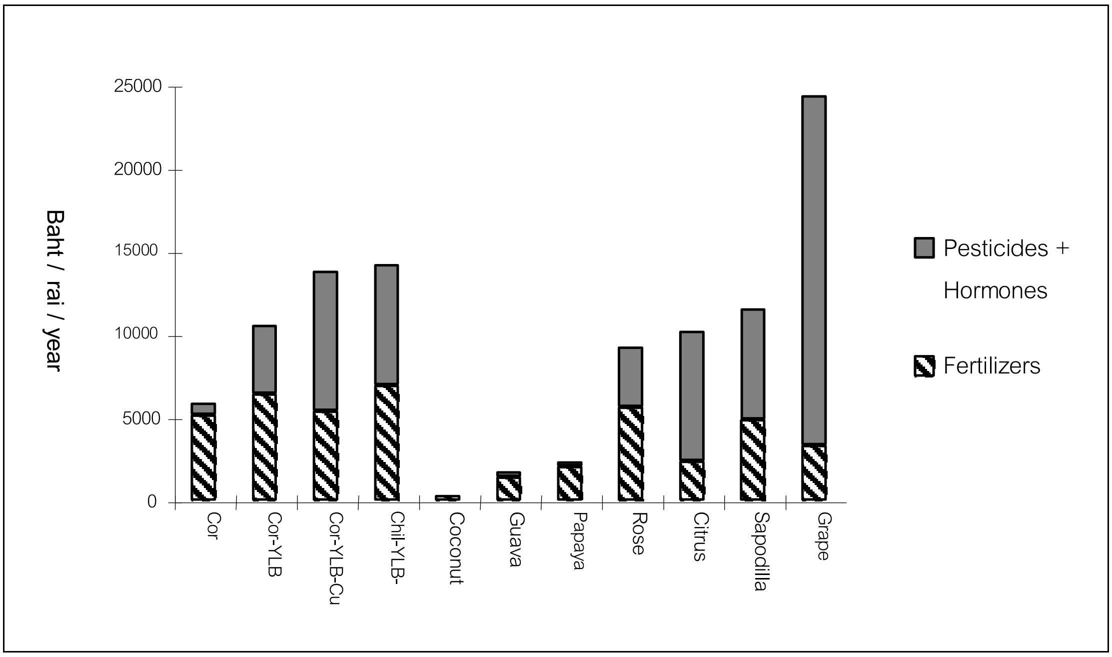


1.3 Main characteristics of grapes cultivation in Damnoen Saduak

With five harvests in two years, grapes growers can make high profits even if this crop requires a high investment for crop establishment, much labour force and also high amounts of chemicals. Farmers have to fight pests throughout the year, which constitutes a great threat for the yield. In order to face invasions of worms and insects and also the development of fungi favoured by humid conditions, farmers adopt highly intensified pesticides uses: 1 to 2 treatments per week on average.

Compared with the main crops cultivated in the area, grapes is on the whole the most intensive crop regarding chemical use (Figure 37). That is the main reason why we chose to focus on this crop to assess the impact of agricultural practices on the environment.

FIGURE 37: COMPARISON OF INTERMEDIATE COSTS OF CHEMICALS FOR VETGETABLES AND FRUITS IN *AMPHOE* DAMNOEN SADUAK



Cor: Coriander; YLB: Yard Long Bean; CU: cucumber: Source: Cheyroux (1997)

2 Grapes cultivation and agricultural practices

2.1 Assessment of agricultural practices

In order to assess agricultural practices in vineyards, two levels of study were considered. At the plot level, we studied the use of chemicals and at the regional level, the diversity of cultivation techniques and particularly of pest management strategies. As a result of a pre-survey we had actually noticed that it is very difficult to get accurate answers about the amount of pesticides sprayed in one year. Farmers buy chemicals little by little and do not take any notes either of their purchases or of the spraying operations. An assessment at the plot level was therefore absolutely necessary.

2.1.1 Case studies

In *amphoe* Damnoen Saduak, we selected three farms where we decided to take water samples regularly and also to record all the fertilisers and pesticides applications, for 8 months, from May 1998 to January 1999. Farmers helped us recording all the treatments on a board: date, trademark of type of chemical, amount. As we came to visit farmers once or twice a month we asked some more questions about the crop, the stage of the trees and the different farming practices (pruning, attach of branches, harvest, etc.)

One of the farmers, khun Bamrung, had already worked 2 years with Kasetsart researchers. The same kind of data had been recorded in 1996 and this gave us the opportunity to compare chemical use in 1996 and in 1998. Accustomed to participate in such studies, khun Bamrung turned out to be the most receptive to our requests.

2.1.2 Regional surveys

Fertilisation practices and pest management were the subject of two different surveys.

2.1.2.1 Fertilisation practices

Preliminary to the project, a limited survey of grapes growers had been carried out in order to set up the future objectives. Thirteen farmers in Amphoe Damnoen Saduak have been interviewed, mainly about fertilisation. We compared the results with the data collected in the cases studied.

2.1.2.2 Pest management practices

- Collaboration with another research team

A research team at King Mongkut Institute in Bangkok was found to be working on the same topic. In the framework of a master thesis, a student and her adviser were preparing a survey among grapes growers in the *amphoe* of Damnoen Saduak. Their main objective was to understand the pest management techniques in order to bring out appropriate strategies which could be adopted for the Integrated Pest Management program, set up recently in the *amphoe* Damnoen Saduak. The student interviewed 122 farmers in the *amphoe*, the fourth of the grapes farmers in August 1998.

We joint our efforts, deciding to design a common questionnaire (cf. Appendix 2). Despite working separately for the questionnaire, we decided for our part to survey grapes farmers in the other *amphoe*s (Ban Phaeo, Sam Phran and Bang Phae). Afterwards, the student shared with us some of her data which allowed us to cross-check our main conclusions.

- <u>Objectives of the questionnaire</u>

The one hour questionnaire dealt with different topics: the main characteristics of the farm (e.g. age of the farmer, farm area, cropping system, labour), the grapes cultivation in the farm (duration, grapes orchard nowadays, area), the opinion of the farmer about water pollution (in the canal, in the plot), pest management practices (choice of chemicals, spraying, storage, toxicity), alternatives to pesticides (the other methods developed by the farmer).

For each farm, we wanted to answer the following questions:

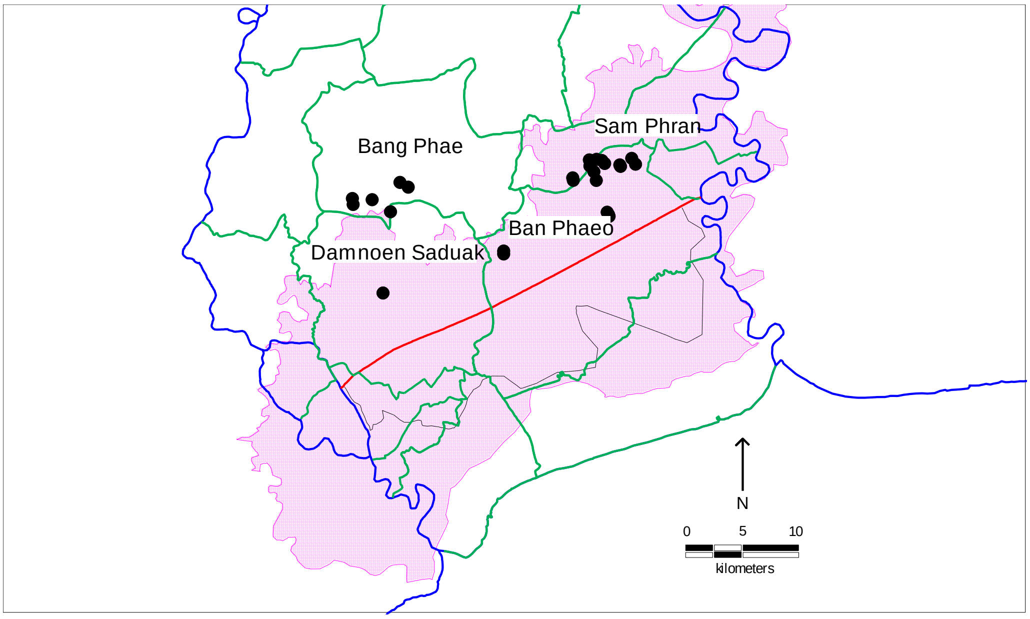
- How intensive is the crop management of this farmer?
- What is the behaviour of the farmer when he uses pesticides?
- Is the farmer aware of the toxicity of pesticides?
- What are the main active ingredients the farmer uses?
- What is the opinion of the farmer about pesticides?

- <u>The sample of farmers</u>

Based on the agricultural census (per *tambon*) of 1997 (data of the Extension department in Bangkok), a sample based on grapes area and *tambon* was prepared. However, it became soon obvious than the lists were not valid: many farmers mentioned in the list had quit the activity. As the lists proved of little use, farms were chosen randomly along the field visits and through discussions with government officers or with village heads.

Limited by the difficulties to meet farmers, especially in the *amphoe* where grapes cultivation had decreased, 25 farmers were finally surveyed (Figure 38). The supplementary data shared with the student of King Mongkut and discussions with Blandine Cheyroux complemented the information and limited the risk that our sample would not be representative of the grapes growers population.

FIGURE 38: LOCATION OF SURVEYED GRAPES FARMS



2.1.2.3 <u>Survey of government officers</u>

Government officers were also interviewed in each *kaset amphoe* to get their opinion on the different topics addressed with the farmers. These interviews provided, for example, some information about the recent evolution of the grapes area. We got, by this way, an overview on grapes cultivation in the raised bed area.

2.2 Agricultural practices developed in grapes cultivation

2.2.1 Crop calendar

Grapes plants are bought from a graftman which uses the technique of layering and budding. Grapes trees are planted with a density of 130 plants per rai on average (between 80 and 170 trees/*rai*). Plants growth is supported by a trellis made with strings, bamboo sticks and concrete poles. This system of trellis generates a ventilation of the vine and contributes to fungi management and also maximises photosynthesis.

The first harvest of a grapes plot can be done between 15 to 20 months after the plantation. A grapes crop lasts approximately 110 days (from pruning to harvesting) and so 5 harvests are feasible in 2 years. Production decreases with time and generally farmers renew the plot after 6-7 years, somewhat more frequently in Ban Phaeo (about 3-4 years).

Grapes is often grown in rotation with vegetables or other fruit trees. The advantage of vegetables is their short cycle which allows to produce quicker than grapes. When farmers own two plots, they seldom grow grapes on both plots because grapes is a risky crop, but they often do on one plot: from one plantation to another, he changes of plot to grow grapes. However, in our survey, a few farmers had grown grapes in monocrop for 20 years, mainly in Ban Phaeo, whereas in Damnoen Saduak farmers rotate the crops most of the time.

FIGURE 39: CROP CALENDAR OF GRAPES CROP

(P) (1) (2) (3) (4) (H1) (1^{bis}) (2) (H2)

|-------------|----|--------|-------|-----------|-------|----|--…….--|-----→

1 year 15d 30d 20d 45d 20d 15d 100d

(P) Planting
(1) Pruning the vine stock(1^{bis}) Pruning the trees and cutting the leaves
(2) Pruning the vine shoots: pruning of the shoots without flower
(3) Tying the shoots to the trellis
(4) Pruning the grapes bunches: it deals with cutting the smallest and latest fruits of each bunch in order to let place to the grapes left to grow to a maximum.
(H1) First harvest
(H2) Second harvest

Source: Cheyroux (1997)

Most farmers only grow grapes in one plot as the trellis generates a lot of shade and as it receives a lot of pesticides that young plants grown under the grapes would not tolerate. However, a few farmers were found to grow coriander, Chinese cabbage, Chinese onions and even peanuts under grapes. Coriander is indeed sensitive to too much sunshine. Some farmers also grow other trees on the same row: they were actually preparing the next crop of lime or longan.

2.2.2 Irrigation and water management

Thanks to small boats, grapes growers irrigate raised beds in grapes orchards every 3 days for 9 months except the first 20 days after harvesting. The rest of the year, rain provides natural irrigation.

Like in other raised bed plots (see Part I), farmers control the water level in their plot according to tasks to be done in the plot and crop development stage. Before pruning, farmers leave only little water in the ditches for approximately 3 weeks in order to induce a water stress: vegetative growth of leaves and buds is temporarily stopped. A water stress is also sometimes provoked in order to induce flowering.

To evacuate water excess or renew the water in the ditches, about 90% of the outflows are created by pumping (Molle *et al.*, 1998). Before they let water flow into the plot, farmers wait for 2 days: poor quality water pumped out from the field has time to flow downstream and above all, farmers let vine roots out of water for two days. Soils as well as roots get dryer and get oxygen. Water is renewed around the roots: by this way farmers bring water richer in dissolved oxygen. If the level of water is high all the time in the raised beds, roots will get easily rotten because of saturated conditions insofar as grapes roots grow within the water table (Molle *et al.*, 1998).

2.2.3 Fertilisation practices

2.2.3.1 Fertilisers used

In vineyards, farmers use both inorganic and organic fertilisers during one crop. The applications are numerous (about 6 applications for inorganic fertilisers) and are done according to the development of the plant. Farmers follow a very precise fertilisation calendar.

Before the first pruning, farmers apply mainly urea from the 6^{th} month after the plantation with a frequency of 1 or 2 times per month. Then a typical fertilisation for one crop (Table 3) consists in applying a balanced formula of chemical fertiliser such as 16-16-16 before and after pruning every 15-20 days. At this time they also apply formula enriched in nitrogen (20-10-10) or simply urea, which is cheaper, to stimulate the growth of branches, leaves and buds. Then at the flowering time and later when fruits appear, farmers apply more phosphorus (formula such as 12-24-12). At this period also, they add animal manure: cow manure or bat dirt, approximately 50-60 days after pruning. Finally when fruits are nearly mature (15 days before harvest), potassium is applied through a formula such as 13-13-21. Potassium contributes to the sweet taste of fruits.

TABLE 3: EXAMPLE OF THE WINTER CROP OF KHUN PRA THUANG (PRUNING: 10/10/98 – HARVEST: 11/02/99)

Date	Crop calendar	Kind of fertiliser	kg N/ha	kg P/ha	kg K/ha
30/09/98	Pruning - 10 days	8-24-24	13.3	17.6	33.2
15/10/98	Pruning + 5 days	18-46-0	30.0	33.7	0
22/11/98	Pruning + 44 days	46-0-0	31.9	0	0
		20-10-10	20.8	4.6	8.6
8/12/98	Pruning + 60 days	46-0-0	38.3	0	0
		16-16-16	13.3	5.8	11.0
15/12/98	Pruning + 67 days	16-16-16	22.2	9.7	18.4
22/12/98	Pruning + 74 days	17-17-17	23.6	10.4	19.6
28/12/98	Pruning + 80 days	8-24-24	8.3	11	20.7
		13-21-21	13.5	9.6	18.2
01/02/98	Pruning + 115 days	16-18-46	26.6	13.2	63.6
		Total	241.8	115.6	193.3

TABLE 4: COMPARISON BETWEEN BAT MANURE AND INORGANIC FERTILISERS

	C %	N %	P %		K %		Ca %	Mg %	Na %
Bat manure	10.5	0.9	Total (XRF) 0.24	Bray II 0.18	Total (XRF) 2.2	Exch. 0.8	Exch. 0.72	Exch. 0.18	Exch. 0.25
Fertilisers	-	46 Urea	6 (16-16-16)		12 (15-15-15)		-	-	-

The choice of cow or bat manure depends on the capital of the farmer more than on their availability. Bat dirt is produced in caves of Ratchaburi Province and cow manure comes from the province of Nakhon Pathom up north. Bat dirt represents a high investment for farmers but it is supposed to be rich in phosphorus. In relity bat manure is much poorer than inorganic fertilisers for each element (Table 4). Farmers probably use it because the nutrients are released more slowly than from inorganic fertilisers. Cow manure is cheap, so farmers can use a lot. They use cow manure to improve the soil structure. Finally grapes leaves fallen on the ground during pruning are kept on the raised beds and are used as bio-fertilisers.

Added to the basic standard fertilisation, farmers use liquid fertilisers which they mix together with pesticides and spray at the same time. We can wonder about the efficiency of such liquid fertilisers applied on the plants. It represents only a few units each time. For example, khun Bamrung applied a liquid fertiliser 9-27-9 in November 1998: the five litres sprayed in the plot brought 0.45/1.35/0.45 units of N/P/K!

2.2.3.2 Quantity of fertilisers

TABLE 5: AMOUNT OF MINERAL FERTILIZERS APPLIED DURING THE PERIOD OF STUDY

Farm	Duration	UN/ha	UP/ha	UK/ha	KgN/ha	kgP/ha	kgK/ha
khun Bamrung	9 months	89	158	161	89	69.5	133.6
khun Pra Thuang	8.5 months	364.6	389	451.6	364.6	171.2	374.8
Khun Somchai	7 months	306	346	277	306	152.2	229.1

The amount of fertilisers applied in the three farms chosen as case studies was assessed (Table 3 and Table 5). Fertilisation was quite similar at khun Pra Thuang and khun Somchai's farms and was close to 400/400/400 Units of N/P/K/ha/year, equivalent to 400/176/332 kg of N/P/K/ha/year (it does not include organic fertiliser). This represents a very high amount of nutrients brought each year. Moreover, if we now consider the real soil area of the plot which receives fertilisation (the water body represents about 40% of the total plot surface), we find out that fertilisation is in fact closer to 670/670/670 Units of N/P/K/ha of soil/year, or about 670/300/560 kg of N/P/K/ha/year. This represents considerable amounts of fertiliser in one year.

It is worth noting that we could do the computation about fertilisation only for mineral fertilisers because we did not get samples of cow manure or bat dirt.

2.2.3.3 Modification of the fertilisation

Most farmers apply the same fertilisation as it is transmitted by word of mouth and it seems that farmers have not modified it since the cultivation techniques were introduced. Because they want to make this crop the most profitable and because they want to limit the risks of loss, they seldom adjust the fertilisation to the conditions of the plant and of the plot. They do not take time to test different fertilisations or to lower the amount of fertilisers. Moreover farmers seldom analyse their soil.

Nevertheless, when farmers see that the next harvest will not produce so much profit, they try to reduce the amount of fertilisers. That was the case of khun Bamrung in 1998. Because of poor climatic conditions at the flowering period especially, plants gave only few fruits. Anticipating this, khun Bamrung decided to reduce fertilisation: he only applied 147/178/232 Units of N/P/K from May to December 1998 (9 months), whereas he applied 586/784/440 Units of N/P/K in 10 months in 1996 (Molle *et al.*, 1998).

2.2.4 Pest management practices

2.2.5 Pests in vineyards

The main pests farmers have to fight in grapes orchards are insects (beet armyworm, american ballworm, red mite, thrip) and fungi. Fungi easily develop in humid conditions and not only in the rainy season, as humidity remains fairly high all year round. Insects show more and more resistance to insecticides. Farmers also have to control weeds although they do not represent a major problem in grapes orchards.

2.2.5.1 Frequency of pesticide use

Grapes growers facing along the year the attacks of insects and fungi spray high amounts of pesticides with a frequency of 2-3 times a week. The frequency actually depends on the season, farmers tend to intensify pesticide use during the rainy season because of the development of fungi in high humidity conditions: they spray fungicide after each rain. Attacks of insects are usually worse during the cold and the hot seasons. The frequency of pesticide use also depend on the development stage of the vine. Worms and insects attack easily the shoots and the leaves but not the fruits contrary to fungi and antracnot worms. On Figure 40 and Figure 41, we clearly notice the high frequency of treatments at the fruiting stage, about two months after pruning. That is why farmers intensify pesticide use when fruits are small. Whereas a farmer can spray up to every 2 days at the fruiting stage, he can decrease the frequency of application and spray every 5 or 7 days at other stages.

FIGURE 40: TREATMENTS OF FUNGICIDES AND INSECTICIDES AT KHUN BAMRUNG'S FARM (1995-96)

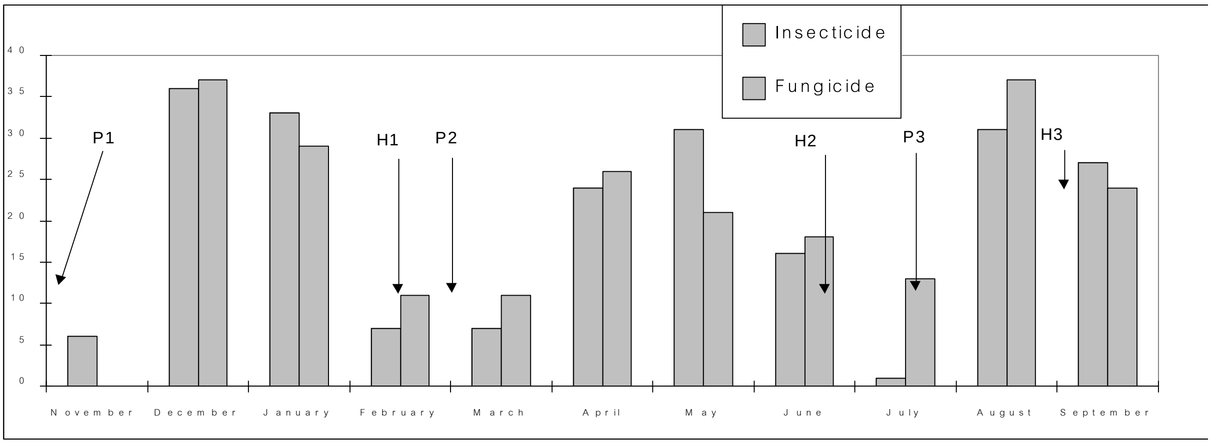
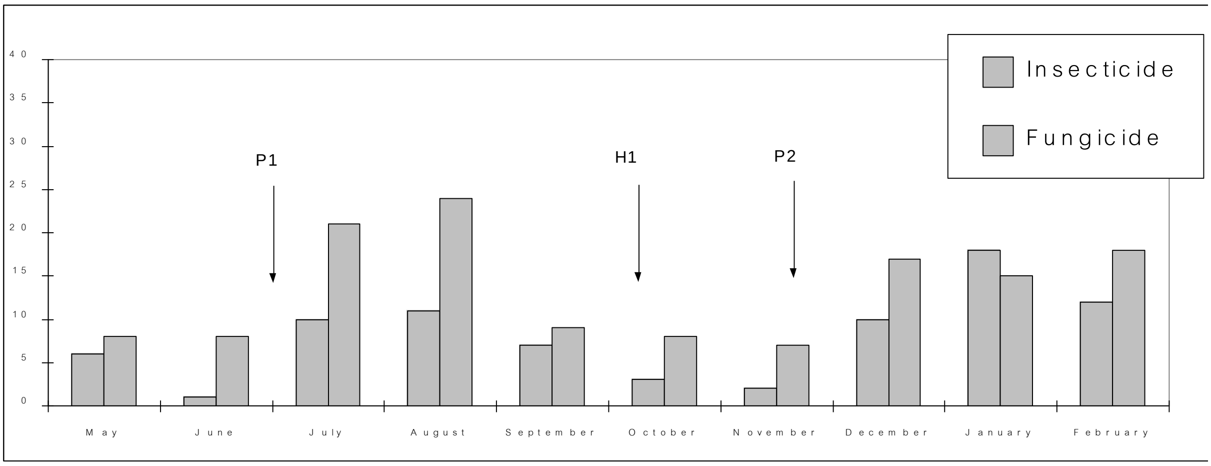


FIGURE 41: TREATMENTS OF FUNGICIDES AND INSECTICIDES AT KHUN BAMRUNG'S FARM (1989-99)



In 1998, khun Bamrung carried out 78 applications of fertilisers in 10 months and 135 applications for the same duration in 1996. Farmers manage sometimes their field in two parts and therefore do not spray pesticides on both parts on the same day. In 1996, khun Bamrung sprayed 135 times in 10 months but the whole field received actually 85 applications. Spraying does not mean one treatment insofar as farmer mix and spray together different pesticides (at least 3 or 4, in one time). For example in 1998, this farmer made 232 treatments (for 78 spraying) in 10 months (from 13/05/98 to 08/03/99): 135 fungicides and 97 insecticides treatments were achieved.

Before harvest, farmers stop spraying pesticides. They first stop spraying insecticides 2 or 3 weeks before harvesting but still continue to apply fungicides (often *captan* or *carbendazim*) as mature fruits are sensitive to fungi but not to insects. There is actually no treatment for 3 to 7 days before the harvest.

Grapes farmers rarely use herbicides and prefer to control weeds by hand every 10 days, except in large farms where it would require too much labour force. Some farmers lay rice straw on the top of the raised bed to limit the development of weeds. Rice straws also constitute a biofertiliser.

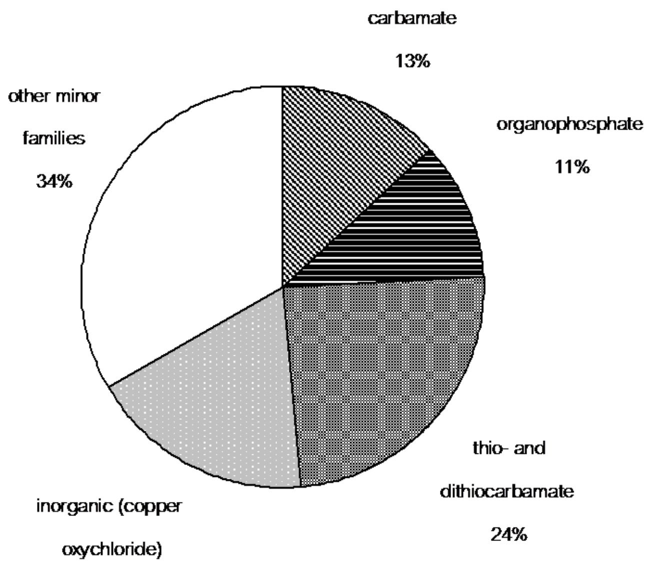
It is worth noting that calculating a global amount of pesticides does not mean much, except for the economic cost based on an average price per litre or per kg for example. That is why we prefer to stress the frequency of application.

2.2.5.2 Active ingredients

Farmers spray preventive and curative pesticides: preventive above all for fungicides and curative for insecticides. Farmers often do preventive treatments because of the risks to loose benefits and also because of the very high price of curative treatments (the price is sometimes tenfold the price of a preventive treatment).

The main pesticides used in grapes orchards are (from the most to the least used): *methomyl, chlorfenapyr, methamidophos, amitraz, copper oxychloride, monocrotophos, dimethoate, dicofol, tebufenozide, malathion, mevinphos, EPN, methylparathion*. Farmers use mainly in vineyards carbamate and thiocarbamate, organophosphate and inorganic pesticides. (Figure 42)

FIGURE 42: MAIN CHEMICAL FAMILIES OF PESTICIDES USED IN KHUN BAMRUNG'S VINEYARD (1998-99)



In one year, grapes growers use a large diversity of active ingredients: khun Bamrung used 23 different molecules in 1996 and 22 in 1998 (Table 6) and only 12 were used in both years. However this does not mean that farmers misuse pesticides and mix the same active ingredients at the same time: between 1996 and 1998 we only found one occurrence when khun Bamrung used two products with cypermethrin as main active ingredient.

TABLE 6: APPLICATIONS OF PESTICIDES IN KHUN BAMRUNG'S VINEYARD (1998-99)

	Kind	June	July	August	September	October	November	December	January	February	Total (9 months)	Systemic
amitraz	Insect.	1	6	3	2			3	6	1	22	NS
azoxystrobin	Fung.				1						1	
carbosulfan	Insect.		1								1	
cardendazim	Fung.			4							4	S
cartap	Fung.		1								1	
chlorfenapyr	Insect.								1	1	2	
chlorothalonyl	Fung.			1							1	
copper oxychloride	Fung.	3	7	4	2	3	3	7	4	5	38	NS
cyfluthrin	Insect.								3		3	
cypermethrin	Insect.		1	4				4	11	1	21	NS
difenoconazole	Fung.			1		1		1	2		5	
dimethoate	Insect.		1	1						4	6	S
EPN	Insect.			2							2	NS
fipronil	Insect.						1	2		2	5	
flusilazol	Fung.	1	2	1			1				5	
formetanate	Insect.				2						2	
mancozeb	Fung.	4	8	9	4	4	3	8	4	7	51	NS
methamidophos	Insect.					1			4	1	6	S
methomyl	Insect.		1	1					3		5	NS
monocrotophos	Insect.				3	2	1	1	1	2	10	S
propineb	Fung.		3	4	1			1	7	5	21	NS
tebufenozide	Insect.								1		1	
triadimifon	Fung.				1						1	
tridemorph	Fung.									1	1	S
Total (/month)		9	31	35	16	11	9	27	47	30	215	

Insect.: Insecticide Fung.: fungicide

By applying some pesticides, farmers apply in the same time heavy metals such as Cu (in copper oxychloride), Mn (in mancozeb), Zn (in mancozeb or propineb). There is 50% of inorganic Cu in copper oxychloride, 16% of Mn in mancozeb, 2% of Zn in mancozeb. Khun Bamrung applied in 1996 153 kg/ha of copper oxychloride, therefore 77kg/ha of Cu and in 1998 41 kg/ha of copper oxychloride therefore 20.5kg/ha of Cu. Concerning Mn and Zn, we could not calculate so accurately the quantity applied. They are indeed contained in different pesticides and for some of them, we could not find the composition. If we consider only mancozeb, khun Bamrung brought 9.2kg/ha of Mn and 1.2kg/ha of Zn in 1998, 26kg/ha of Mn and 3.4kg/ha of Zn in 1996.

Farmers apply also sometimes products containing trace elements such as East Plus® which contains the following microelements: Ca, B, M, Mn, Fe, Cu, Zn, Mo, Ca. Some trace elements are well-known to improve the plant growth or the quality of the production (e.g.: Boron would make fruit skin thicker).

2.2.5.3 Behaviour of farmers using pesticides

- Choice of pesticides

Most farmers (18 among 25 in the survey) choose chemicals on the advice of the representative sellers who come to their farms and organise from time to time meetings with other farmers and also on the advice of the sellers of chemicals in the towns. They also rely on their experience (12 among 25) and pay attention to the decisions of their neighbours. In the survey, farmers rarely mentioned the government officers, except when we were accompanied by officials. Officers of the kaset *amphoe* are not allowed to give advice about trademarks and it sounds like farmers do not have so much confidence in government officers. Farmers complain that they do not carry out field trials, as salesmen from companies do. Another reason is that extensionists do not have business relationships with farmers, contrary to chemical sellers who until now gave credits to farmers. Chemical dealers have developed close relationships with farmers: they not only sell them chemicals but they also bring them other knowledge about how to grow grapes. One farmer also told us that he had chosen to grow grapes on the advice of a chemical seller!

Only 2 farmers among 25 mentioned that they read books to diagnose pests and choose the kind of pesticides. It seems that the educated children rarely come back to work in the farm and prefer to work in the city. Like their parents, the children who stay in the farm lack knowledge to choose pesticides.

The first criteria for the choice of pesticides is of course the kind of plant pests. If farmers do not recognise the pests by themselves (which is rare because grapes is attacked by a limited number of insects), the farmers ask for information from the chemicals shop or sometimes from the kaset *amphoe*. To select the products, farmers seem to be sensitive to commercial arguments, like the trademark (for 14 farmers among 25). They also look at the chemical components. However during the interviews, we noticed that farmers generally know better the brandname than the active ingredients. To help them in their choice, sellers give them information about the “quality” and the “power” of the pesticides. Many farmers told us also that they do not care about the price but about the efficiency of chemicals which sounds like a commercial slogan.

Farmers buy pesticides little by little because of the cost and because of the variety of pests along the crop cycle. Farmers can thus buy different pesticides according to the pest situation. This does not mean however that farmers do curative treatments according to the attacks of insects and fungi. Most treatments are actually preventive. A consequence of the regular purchases along the year is that farmers try different chemicals and can change quickly when they are not satisfied with it, particularly in case of resistance of the insects.

- Use of pesticides

In grapes farms, at least three family members work permanently in the farms whatever the area. Grapes cultivation requires much labour force. If for some works farmers need absolutely to hire workers because of the peaks of work (like tying the shoots to the trellis), family members usually take care of spraying pesticides (except in very big farms) as it is a strong constraint even if it does not require so much labour at the same time.

Most of the time, the farmer handle himself the pesticides and mix them in the tank equipped with a motorised stirrer, mixing different products at the same time. One or two persons at the most in the farm know how to select pesticides for spraying and how to prepare them.

The other members of the family are in charge of spraying only. Among 25 farmers interviewed, 20 told that they use graduated containers to measure the quantity of pesticides. However 7 among 25 admitted that they measure approximately the rate of pesticides knowing the volume of the pack or even by guesswork.

Farmers do not always apply pesticides at the same rate. They look first at the rate indicated on the label and then adapt according to their constraints, to the pest situation and to their experience. Some apply less than the label rate in order to save money (a few farmers think that the rate is too high as companies want to encourage farmers to use high amount of pesticides) or sometimes because of the toxicity for human health and for the plants. Some other farmers apply always more than the label rate insofar as they do not want to take any risk. If the rate is not given for grape, farmers compare with other crops such as mango.

Farmers use two kinds of equipment to spray pesticides depending on their capacity to invest: they can either spray pesticides from a boat equipped with lateral sprinklers (the boat has a mini-tank in which they also mix the pesticides) or use a network of pipes laid on the trellis. In this case, agrochemicals are diluted and mixed in a large tank (around 25 m^3) from which the liquid is distributed under pressure in the pipes. Workers plug their sprayers to the pipes outlets and spray the products without having to carry it (Molle *et al.*, 1998). After spraying, some farmers rinse their pipes. While rinsing water, farmers may spray the trees or the soil as we have seen in one farm!

Farmers usually spray in the early morning and sometimes in the evening. Some spray different chemicals according to the period of the day, fungicides in the morning and insecticides (against worms) in the evening. They spend approximately 1h/2 persons/4 rai.

While spraying, farmers protect themselves mainly with clothes (usual working clothes with long shirt and pants), hiding so their skin, but also with mask (sometimes out of cloth) and hat. The protection is quite rudimentary. Farmers do not wear special waterproof protective clothing. Because they spray pesticides on the trellis above them, they usually get all wet. Among the 25 interviewed farmers, 8 do not protect themselves at all and just pay attention to the direction of the wind!

Empty packages are collected and sold (2 to 5 baht/bottle). Boxes are often burnt by farmers or thrown to the garbage. Agrochemicals are kept in a store house (54.1% of 122 farmers interviewed in *amphoe* Damnoen Saduak). They are often gathered near the reservoir where the farmer mixes the pesticides. In some farms, they are merely kept outside under a roof or even in the house. On the other hand, if there are young children in farms, owners pay attention to keep chemicals in a locked store house.

- About toxicity

Farmers usually admit that pesticides may be dangerous for human health (however less than in the past) but seem not be aware of what it means. Although 64% complained that they were regularly sick while or after spraying pesticides on grapes, they do not protect themselves carefully. The most frequent symptoms are headaches, unconsciousness, allergic reactions on skin (e.g.: with methomyl) and eyes, difficulty to breathe. While farmers know that pesticides may be toxic for their health, they do not admit that pesticides residues in fruits may affect consumer health. The best reason is that farmers and workers are used to eating unwashed grapes during the harvest and that they never get sick. Moreover farmers are convinced that one week without treatment is enough to limit pesticides residues on the fruits.

There are often fishes in the ditches, sometimes bred by farmers to control water weeds. Fishes are victims of the toxicity of pesticides: after farmers use highly toxic pesticides, fishes sometimes die. It is especially the case with cypermethrin, alpha-cypermethrin, chlorfenapyr, EPN and methamidophos. This kind of accident make farmers more aware of the toxicity of pesticides but not always. In some cases, farmers renew water very quickly in the ditches after spraying strong chemicals. Regarding the impact of pesticides on the global environment, farmers do not feel so concerned because it does not have any colour or any smell.

Even if farmers are aware of the toxicity of the bottle of agrochemicals (they are for example very careful when they have young children and with their pets), it seems that they are not so worried when the product is diluted for spraying.

2.2.5.4 <u>Alternative methods of pest management</u>

As alternative methods of pesticides use, farmers mainly:

- traditional methods (that farmers used before pesticides exist)
    - ♦ water the trees to make worms fall down and put therefore plastic papers on the trees to prevent worms from climbing on the vine,
    - ♦ catch the insects by hand (they most of the time beat the canopy to make worms fall in the water or on special plastic cover that the farmer maintain under the trellis as they beat it. It requires 2 persons need 10 days to do it for 9 rai of grapes),
    - ♦ use lights to repel insects (black lights) or to attract insects in a basin filled with water,

- high tech methods
    - ♦ use virus (NPV),
    - ♦ use plant extracts.

Most farmers are not so enthusiastic about trying other methods than pesticides because they are afraid it would not be as efficient as pesticides and if it is the case they would compensate by a higher amount of pesticides. In both cases a loss of benefits will result. The majority of farmers think that pesticides is the best method to get rid of insects and fungi. Farmers hesitate to try alternative methods to pesticides: representative sellers often discredit them, weakening the efforts from the kaset *amphoe*. Moreover the price of high tech methods like plant extract is often too high and is not really attractive to farmers. Because few farmers try new methods of pest management, farmers have no guaranty of success. For example, in *tambon* Djet Riew (*amphoe* Ban Phaeo), the kaset *amphoe* had done a demonstration with plant extracts. Farmers were disappointed because it can give results after a long time and because the government officers only tried on two raised beds. Farmers thought that this test was not a real field test as it concerned only two raised beds and were reluctant to try at the field scale.

Sometimes farmers use other pest management methods but still use pesticides! They however sometimes the amount of pesticides applied. That is why they do not really the efficiency of the other methods as compared with pesticides.

The resistance of insects to pesticides make often farmers try to use other methods. They often increase first the concentration of the insecticide usually applied, then if it does not work they change of chemical or mix different chemical together and finally in last solution, use pesticide together with another method like watering the trees.

Conclusion:

In the interviews, we were not able to find out if farmers had more intensive pest management practices than others. The total cost of agrochemicals would have helped us but unfortunately because farmers do not register their purchases, the figure they gave were most of the time unreliable. Nevertheless we got the feeling that farmers behave in a very similar fashion. Farmers are really worried by pesticide use in vineyards mainly because of the increasing price of pesticides but not so much because of the health concerns. Insofar as farmers are nowadays much influenced by chemical sellers, it would be a hard job raising their awareness about the dangers of pesticides. Kaset *amphoe* officers are now launching an Integrated Pest Management program but farmers are until now reluctant to adopt this program which is discredited by chemical salesmen because of the risks of failure.

2.3 Effects of the decrease in potassium and phosphorus fertilisation

2.3.1 Introduction

The investigation of the potassium and phosphorus content in three soil profiles and 13 surface horizons in long-term vineyards has shown that the continuous addition of P and K fertilisers had led to very high levels of these nutrients in the topsoil. They are well above the recommended levels for grapes cultivation. It thus seemed possible to stop the application of these fertilisers without provoking any yield decrease. This change in fertiliser application was tested in Khun Pratueng's vineyard for one year.

2.3.2 Material and methods

In July 1999, Khun Pratueng stopped applying P and K fertilisers to the fourth bed from the canal. He continued to apply nitrogen as urea at the same rate as before.

In January 2000 grapevine petioles were sampled to check for any nutrient deficiency or toxicity. Around 160 petioles were taken at flowering stage from the basal leaf opposite bunch clusters, according to the method described by Reuter and Robinson (1997). The third (fertilised) and the fourth (without P and K) bed were sampled. The petioles were air-dried, then ground and analysed for N, P, K, Pb and Cu.

The field was harvested in November 1999. Measuring the yield in each experimental plot was not possible. However the farmer said that the yield on bed 4 was similar to the yield of the other beds (the total yield was 17 tons). Therefore, the experiment was carried on to get the results of the following harvest.

2.3.3 Results and interpretation

2.3.3.1 Nutrient content in the petioles at flowering stage

The results of the analysis of the petioles 5 months after P and K fertilisation was stopped showed no difference between the two treatments (Table 8).

TABLE 7:NUTRIENT CONTENT IN VINE PETIOLES AT FLOWERING STAGE WITH AND WITHOUT P AND K FERTILISATION

	Nitrogen %	Phosph. %	Potassium %	Lead mg kg-1	Copper mg kg-1
Without P and K fertilisation	1.46	0.39	3.42	8	26
With N, P and K fertilisation	1.55	0.40	3.25	9	24

Thus the lack of P and K fertilisers for 5 months had no effect on nutrient concentration in the petioles.

According to Reuter and Robinson (1997) phosphorus was adequate, potassium and copper were very high. No data were available for lead. The results for potassium and phosphorus were in agreement with the very high values found in the topsoil. The very high level of potassium in the petioles is probably related to so-called “luxury consumption” of potassium in plant grown on soils rich in exchangeable K (Marschner, 1995; Saragoni and Poss, 1992). As a result of P and K content in the petioles, the farmer should be able to grow grapes in his field for several years without P and K addition.

According to the same authors nitrogen in the petioles was high. Unlike P and K, interrupting N fertilisation is however risky. In the raised beds system the plants are watered regularly using the water of the ditches. This watering and the natural rains induce a downward movement of soil water. This drainage is likely to induce a strong leaching of solutes, especially nitrate. It is thus probable that N fertilisation could be reduced, but field trials should be carried out to diagnose the optimal level.

The high level of copper in the petioles is probably the result of the many applications of copper oxychloride to the leaves to prevent fungi development. Reuter and Robinson (1997) stress that values higher than 15 mg kg^{-1} are indicative of surface contamination with copper sprays. It is certainly not related to copper uptake from the soil.

2.3.3.2 Grapes yield

Grapes was harvested in early April 2000. Total yield was 5 tons and the yield of each bed were as mentioned in Table 8. The results showed no difference between the two treatments, indicating that P and K were sufficient in the soil. However yield was 3 times lower than usual, as expected by the farmer, because of unusually high temperatures.

TABLE 8: YIELD OF GRAPES (KG PER PLOT) ON THE FERTILISED AND NON-FERTILISED BEDS

Fertilisers	Rep 1	Rep 2	Rep 3	Rep 4
P and K	12.0	22.3	15.8	16.7
No P and no K	12.5	15.8	18.2	15.5

2.4Evolution of grapes cultivation

2.4.1 Dynamic of grapes cultivation in the raised bed area

During the survey, 4 areas of grapes farmers characterised by different dynamics could be distinguished in the raised bed area. Grapes areas correspond in fact to the four *amphoe*s where grapes was introduced at different periods.

- Amphoe Damnoen Saduak: grapes has been first introduced in this *amphoe* in the 1960s. A lot of farmers have adopted this profitable crop. The children of these farmers have kept growing grapes: they had the know-how and also enough capital to invest in this crop. Thus grapes cultivation is a long tradition in this *amphoe*.

- Amphoe Ban Phaeo: grapes came a little bit later than in Damnoen Saduak, about 20-25 years ago. Migrants of Damnoen Saduak came probably here to rent land, more available in this area than in Damnoen Saduak. Grapes growers were and still are concentrated mainly in one *tambon* (Djet Riew). This concentration may be due to the fact that Mon people settled here preferably and adopted this original crop: Mon people traditionally made different choices than Thai people who usually grew orange or mango after they settled the area. Recently the area cultivated in grapes in this *amphoe* decreased seriously.

- Amphoe Sam Phran: Influenced by farmers of Ban Phaeo (south of Sam Phran), the first farmers start growing grapes 20 years ago. However in this *amphoe*, because raised beds were developed in a limited area, grapes has not been able to expand so far. The area cultivated in grapes is still quite limited in *amphoe* Sam Phran: about 500 rai whereas two years ago it was approximately three times larger.

- Amphoe Bang Phae: Migrants from Damnoen Saduak came to Bang Phae less than 10 years ago to find fertile soil, still cultivated in rice field and areas with less pest pressure. Children of rich farmers of Damnoen Saduak have rented rice fields, often located in favourable zones: close to the irrigation canal, benefiting from a road along the canal, with no shade from neighbouring orchards and from the trees grown on the dikes, more wind (the absence of any vegetal barrier around the plot allows a better ventilation of the trellis and so far a better control of the fungi) and a higher rate of organic matter in the soil. Immediately they reshaped the rice fields and developed raised beds to grow grapes. This is why nowadays most farmers in Bang Phae who grow grapes are young and usually rent the land.

2.4.2 Present difficulties of grapes cultivation

Whereas 15 years ago grapes cultivation was adopted by many farmers in the raised bed area ("grapes boom"), a recent decrease of the cropping area is observed in the different *amphoe*s. Different reasons can be mentioned:

2.4.2.1 Pest resistance

Most of the surveyed grapes farmers have the feeling that there are more and more insects in the area and that they consequently have to increase the amounts of pesticides. It seems that it is not completely true but these remarks may result from the fact that farmers have to face more and more resistance of insects to insecticides. Often concentrated, grapes farmers must fight strong pest pressure. Fields are invaded quickly by insects coming from neighbouring plots and farmers have many problems to control these invasions. The increasing resistance of insects to pesticides results in the frequent and heavy treatments all year round on grapes.

2.4.2.2 Impact of the recent economic crisis

If farmers are convinced that they use higher amounts of pesticides, it may be linked with the increasing price of chemicals. Because of the economic crisis which started in July 1997, prices of imported products have considerably increased, sometimes by 100%.

For the time being farmers remain quite optimistic. Grapes growers can be classified in two main groups:

- the ones who have accumulated capital in the past, often thanks to grapes cultivation,

- the ones who have little capital but who hope to gain much money in a short time by growing grapes like in the past.

Farmers who own more capital seem to wait for the evolution of the economic situation before they take new decisions. For the moment they can afford the cost of the economic crisis. They can, for example, afford some losses due to a bad harvest if of course it does not occur too often.

The second category corresponds to more vulnerable farmers. A lot of them have already quited the activity because they could not afford costs and risks resulting from grapes cultivation. Farmers do not have easy access to credit anymore. Chemical sellers stopped giving credits. Those who are indebted can not afford investment in grapes cultivation, chemical costs along the year, labour costs without credit. Moreover farmers benefit less and less from family loan and labour exchange. Sometimes, if farmers want to change of crop, it is not always possible: if plants are young, the plantation has to pay by itself.

After the flooding that happened in the raised bed area in November 1996, a lot of trees were destroyed. Sometimes farmers decided to change of crop because in the case of a young plantation, which had not yet given benefit, farmers could not afford the losses and also because of the difficult economic situation.

2.4.2.3 A very risky crop

Grapes can provide a very high income. In a village of *amphoe* Damnoen Saduak in 1997, Cheyroux assessed a net product of 217,500 baht/*rai*/year on average. However this figure may hide large variations between the different harvests. Sensitive to climate and pests, grapes is a very risky crop. If 5 harvests are possible in 2 years, they indeed do not provide the same income each time. Generally the harvest in the cold season is better than in the hot season. Yield is very dependant also on the climatic conditions at the flowering stage but also during all the cropping season.

Yield variations can be impressive. Yields at khun Pra Thuang's farm are quite characteristic of this phenomenon (Table 9).

TABLE 9: THE 4 LAST YIELDS AT KHUN PRA THUANG'S FARM

Date	December 97	May 98	September 98	February 99
Yield (t/ha)	31	2	1	12

If the farmer can once make a large benefit, he can also lose a lot of money the next harvest. In uncertain economic situations like nowadays, farmers are careful with such a risky crop. Farmers who plan to quit the activity or have already stopped, change for less risky but still profitable crop like lime.

Given the high capital farmers have to invest in grapes crop and the potential risks, farmers make their best to limit pests and diseases and fertilise a lot the plots. Farmers often say that they have no other choice than using pesticides: in fact, they are afraid of losing a lot of money if they reduce the amount of pesticides. This is also the reason why farmers do not adjust fertilisation to plant and plot conditions. It sounds like farmers barely modified the fertilisation introduced in the sixties by the Department of Agriculture of Damnoen Saduak.

Farmers often complain about the sensitivity of the variety White Malacca. Although its price is higher on the market, some farmers have changed recently for black varieties, more resistant to pests. Sometimes, farmers decided to test black varieties in one part of the field and keep growing White Malacca otherwise.

Some farmers have diversified their crops to limit the losses that may result from grapes cultivation. This is true above all for large farms (more than 15 rai). Anyway a raised bed farm is never totally specialised: along the road, on the dikes and near the house, farmers grow fruit trees such as rose apple, banana, jackfruit, mango. They often sell these commercial crops on the local market when the production is not high enough.

2.4.2.4 Strategies of farmers to limit expenses

Grapes cultivation is a very labour intensive crop. Labour is required for the different works along the crop: planting, pruning, spraying pesticides, harvesting, etc. This results in high cost for grapes farmers, above all since the price of labour force has increased. Moreover the Kaset Amphoe of Ban Phaeo mentioned the difficulties for farmers to find workers. Recently farmers had to hire people from Isaan to work in raised bed plots.

Because labour force represents a strong constraint, farmers find out tricks to limit their expenses. For example, khun Bamrung manages his field in two parts with a delay of 10 days in order to stagger the labour peaks in both parts: he harvests the field in two times with 10 days of difference. He also manages the field in two parts for the pesticides application, so that family labour can handle it.

Although most of the 25 surveyed farmers stated that they could not reduce the amounts of pesticides, we noticed that khun Bamrung did so considerably between 1996 and 1998: he decreased the treatments by 45%. It seems that generally farmers try to develop strategies to reduce the amount of pesticides. They use again old methods: they catch insects by hand, water the trees in the evening, use trap lights, etc.

2.5 Conclusion

The favourable natural environment, the 'artificialisation' of the environment through the raised bed technique and the water management developed at the regional level have permitted far-reaching land development and the intensification of cultivation practices like in grapes orchards. Farmers apply huge amount of fertilisers and pesticides and we can wonder about the fate of nutrients and pesticides in the environment.

Covering approximately 20 to 30% of the total raised bed area, water is an essential element in people's life. Benefiting from a direct access to water all year round, numerous human activities are related to the canals which represent potential sources of pollution: detergent, litter, wastewater from domestic use, chemicals and nutrients from agricultural use, wastewater from sewage outlets or industries, etc. The large surface of water increases considerably the risks of water pollution which can easily spread through the dense network of interconnected channels.

Farmers themselves complain about the degradation of the water quality. 54 among 122 in *amphoe* Damnoen Saduak and 10 among 25 in the other *amphoe*s have to renew water in their plot because of its poor quality. According to them, water is polluted in the canal next to their plot (71% in Damnoen Saduak and 18/25 in the other *amphoe*s). Depending on the location of the farm, the main pollution sources they mentioned were: litter, shrimp farms, rotten plants, pig farms (for farmers in Sam Phran and Ban Phaeo) and also sometimes pesticides. In Bang Phae, farmers did not complain about water pollution insofar as they are located near an irrigation canal. Finally, 41% of the sample surveyed in Damnoen Saduak stressed that water quality is worse in the dry season than in the rainy season.

By analysing the topsoil of 13 vineyards spread over the Damnoen Saduak area we have proved that in vineyard the levels of P (extracted by the Bray 2 method), exchangeable K and total Cu and Zn were high and sometimes above the safety level. By investigating the fate of nutrient at the scale of three vineyards we have shown that most nutrient of the applied fertilisers remained in the soil. Phosphorus and potassium accumulated in the soil down to 40 cm and heavy metals such as Cu and Zn (contained in some fungicides) mainly in the surface horizon. Peak concentrations were found in the first two centimetres of the topsoil.

Unlike P, K, Cu and Zn, N did not accumulate in the soil. As very little is released into the canals, we can wonder about the fate of this nutrient. One hypothesis is that N is taken up by the phytoplankton. We know from the increase in alkalinity that the activity of the phytoplankton changes the composition of the water in the ditches. It could be worth investigating about the fate of nitrogen in a cultivated raised bed plot and the role of phytoplankton in nutrient cycling.

A farmer has stopped applying P and K fertilisation in one bed of his field. After 5 months P was still adequate and K very high in vine petioles. After one year the yield was still not lower in the bed where P and K have not been added. Thus it appears that P and K could be interrupted altogether for at least several years. More caution should be given to N fertilisation. Although a decrease in N fertilisation seems possible, the risk of rapid nitrate leaching related to drainage requires field trials before any recommendation can be given.

Finally, as we know that the soil contains substantial amount of heavy metals, we can wonder whether these elements are absorbed by the plants and transferred to the aerial biomass and the fruits. If they are absorbed, are the contents in plants and fruits dangerous for human health or detrimental to plant growth? This is an area worth investigation for the future.

In order to assess the impact of agricultural practices on the environment, we will look in the following part of this section at the water composition in the canals.

3 Water quality

3.1 Set-up of water sampling in the canals

3.1.1 Canals and agricultural fields

In the study area, between Mae Klong and Tha Chin rivers, cultivated fields are tightly linked with water, as a large number of crops are grown on raised beds, while numerous farmers also breed intensively fishes and shrimps in ponds. The presence of water all year round inside the poldered raised bed plots has allowed farmers to intensify the cultivation of fruit and vegetable crops: drought during the fresh and hot season is not a limiting factor, flooding is not one either during the rainy season, thanks to the dikes surrounding the plots.

Nevertheless water which stagnates in the ditches may become in some conditions the worst enemy of the crops: in case of excess water, roots which expand in the 50 cm above the water table (cf. Molle *et al.*, 1998) can rapidly asphyxiate and cause the death of the trees. If water quality in the ditches gets poor (for example, increase in salinity), plants also may be affected. That is why specific water management practices were developed at the plots and also at the regional level. Farmers control carefully the level of water in their plots. The canal also constitutes a reservoir from which they can access fresh water to renew the water in the ditches. On the other hand, farmers discharge poor quality water or excess water into the canal in the rainy season, depending on the amount of rain, on the crop development stage and on the water quality in the canal.

3.1.2 A sensitive environment

This specific environment seems to be highly sensitive to the degradation of the water quality. We can indeed assume that fertilisers and pesticides applied by farmers may be leached to the water table and later to the ditches or flushed by runoff to the ditches after a heavy rain or the irrigation of the raised beds. The transfer of agricultural pollutants to the canal is then simple: nutrients, heavy metals and pesticides are dispersed in the outflow to the canal and then later to the network of canals.

Moreover because of climatic conditions, high evaporation in dry season, high precipitation in rainy season, we can foresee the high magnitude of changes in the water composition occurring in one year. Given that in the dry season evaporation is about 5 mm/day, we can hypothesise that water quality is worst during the dry season, especially in March-April before the first rains. At this time, the water level is the lowest in the khlongs, water gets concentrated by evaporation and farmers keep applying fertilisers and pesticides. It may result in high concentrations of dissolved elements.

3.1.3 Water sampling at different scales

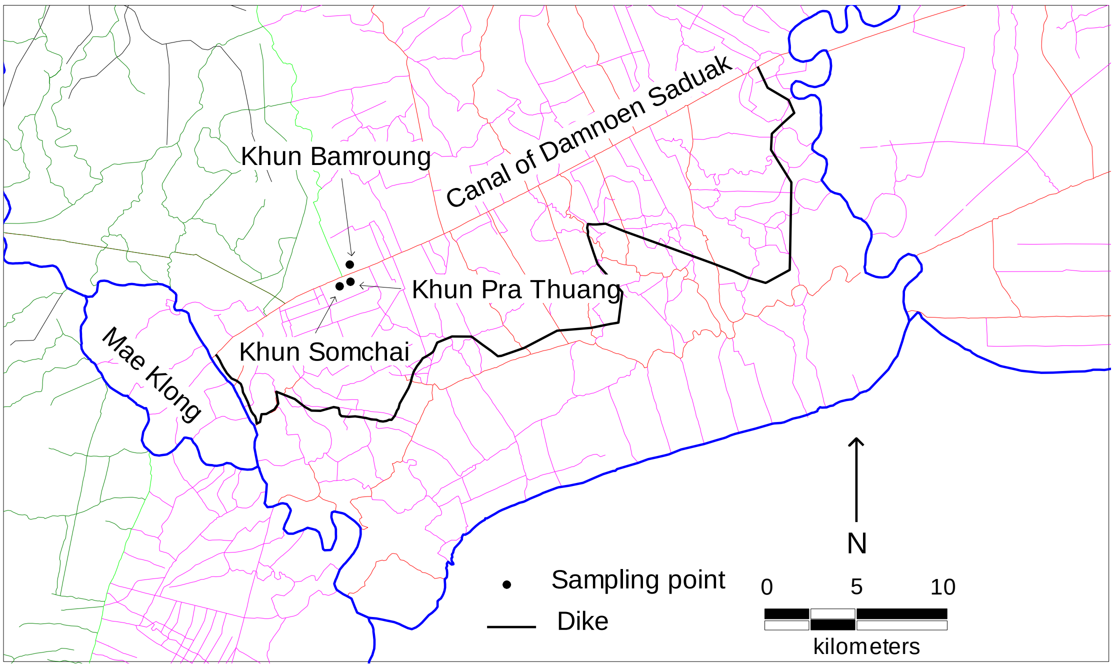
3.1.3.1 *<u>Sampling sites and sampling time</u>*

In order to check the water composition in the canals temporally and spatially, three different sampling were organised to check daily and annual changes in the water composition in the canals and to assess the regional water quality in order to highlight polluted areas and main sources of pollution.

- <u>Sampling along a day</u>: Samples were taken in the canal next to khun Bamrung's farm on a hourly basis on the 12th of March 1998 from 6 am to 6 pm. These two parameters were checked in the field every 30 minutes with portable EC and pH meters.

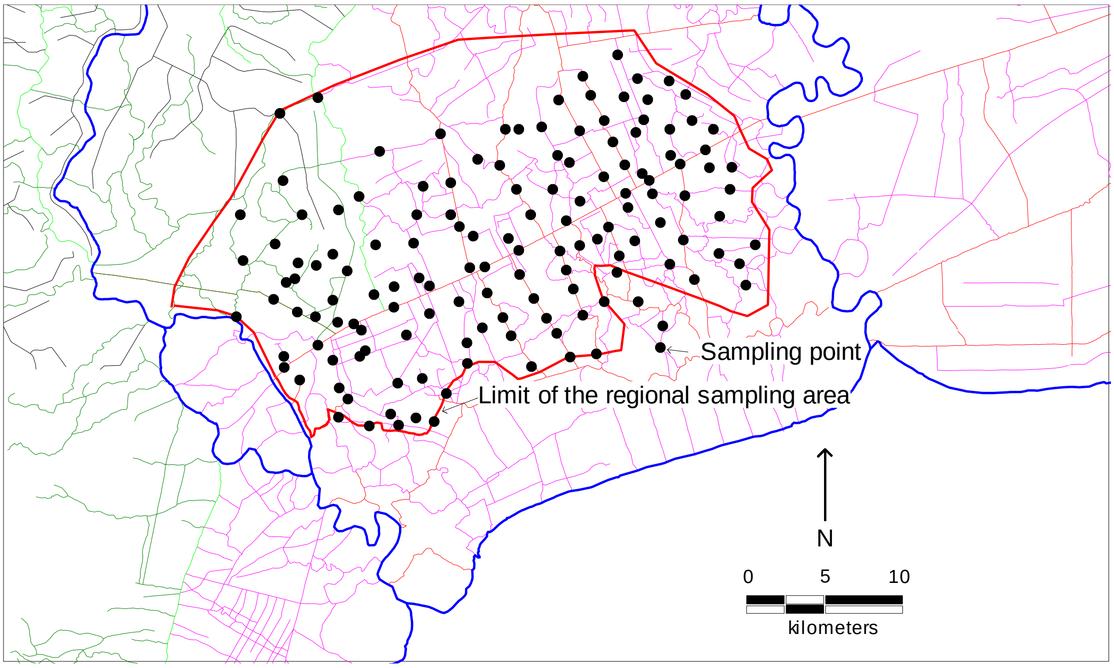
- <u>Sampling along the year</u>: From the 5th of March 1998 to the 14th December 1998, we took water samples on a monthly basis in three canals: 2 south of the main canal of Damnoen Saduak (next to khun Pra Thuang's and khun Somchai's plots, 1 north of it (Figure 43).

FIGURE 43: LOCATION OF THE SAMPLING POINTS FOR THE STUDY OF DAILY AND ANNUAL CHANGES



- <u>Sampling at the regional scale</u>: 142 samples were taken between the 30th of March and the 10th of April 1998, between Mae Klong and Tha Chin rivers and north of the main dike built to impede saline intrusion. We limited our survey a few kilometres above the raised beds area (Figure 44), in order to check the composition of the water before it enters the intensive agricultural area. We determined the sites of the sampling points so as to get a homogeneous sampling all over the area. Two means of transportation were used: car for 6 days and boat for 2 days.

FIGURE 44: COVERAGE OF THE REGIONAL SAMPLING



3.1.3.2 <u>Parameters</u>

According to the objectives of our study and to our budget, we chose to analyse a limited number of parameters:

- general criteria about physico-chemical characteristics of the water: Electrical conductivity, pH, Total Solids, Suspended Solids, Alkalinity, Sodium. Calcium and Magnesium were also analysed in the regional sampling.

- parameters which may reveal agricultural pollution: nitrates, ammonium, phosphorus, potassium and copper (except in the regional sampling). Copper oxychloride is indeed a fungicide frequently used in grapes orchards (cf. paragraph 1.2.). We also checked the presence of organophosphate and carbamate pesticides.

Methods of analysis are indicated in Appendix 3. Given the prohibitive price of pesticide analysis by chromatography, we decided to use a qualitative screening method, far cheaper: the "pesticide test kit" delivered by the division of food of the Thai Ministry of Public Health (cf. Appendix 3). This method based on the cholinesterase inhibition is usually used for checking carbamate and organophosphate pesticides residues in fruits and vegetables. Organophosphate and carbamate are two predominant families of pesticides used in horticulture. In 1996 and 1998, they represented 53% and 48% of the insecticides recommended by the Thai Ministry of Agriculture and Cooperative in its annual publication *Plant protection and* insects (see Appendix 4) for the 14 main crops cultivated on raised beds in the Damnoen Saduak area listed by Cheyroux (1997).

3.1.4 Analysis of the results

3.1.4.1 Change in water composition with time

To study the temporal evolution of the parameters, we computed the results in tables or graphs and tried to interpret the evolution of parameters along the day or along the year. Facing a large number of graphs for the annual changes study, we compared the results for the three canals, highlighting their common characteristics and also identifying the particular events that occurred in the different channels. We found the explanation for the variations observed in the survey about agricultural practices but also in the different conversations held with the three farmers chosen for the case studies: for the monthly sampling, we monitored the canals next to their plot.

3.1.4.2 The regional distribution

All the data gathered during this survey (co-ordinates of the points, results of analysis) were keyed in the GIS (Mapinfo®). We also considered data from a previous regional sampling carried out by DORAS in 1996 in the same area. After achieving the thematic maps for each parameter, we studied the distribution of the values and then tried to compare the different maps in order to highlight polluted areas.

In order to make a diagnosis of the regional water quality and at a smaller scale an analysis of the delimited polluted areas, we compared the thematic maps with land use. We got land use data at the end of 1997 at the Extension service in Bangkok: each Kaset Amphoe is in charge of surveying land use per *tambon* and adding it to a national database.

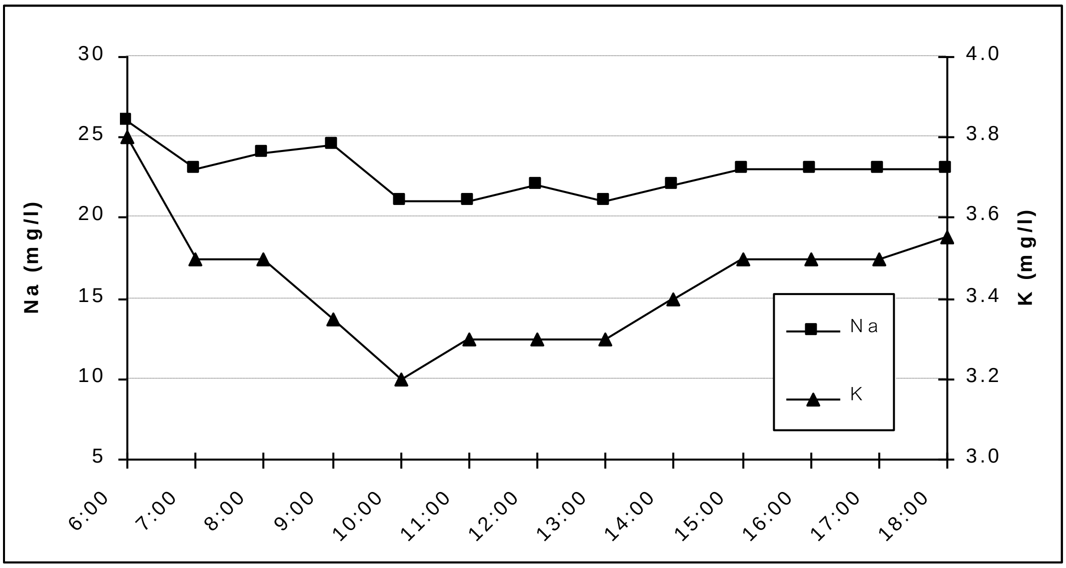
3.2 Daily changes of the water composition: the case of a secondary canal

The table of results appear in Appendix 5.

Most parameters varied little along the day. Slightly acid, pH fluctuated between 6.2 and 6.5. Na and K presented low changes respectively of 23.8% and 18.8%. Likewise, TS values ranged from 230 et 284 mg/l.

If some parameters, like Alkalinity or SS, fluctuated irregularly along the day (with a standard deviation of 11% and 61% respectively), we notice that the fluctuations of Na (consequently EC) and K were quite similar (Figure 45). Water was slightly saline in the early morning and seemed to become again at the end of the day. Na and K concentrations indeed decreased from 6 am to 10 pm (time of respectively the highest and lowest concentrations in Na and K) and then increased again after 1 pm. This can be attributed to the remote influence of the tide which still affects the sides of the area.

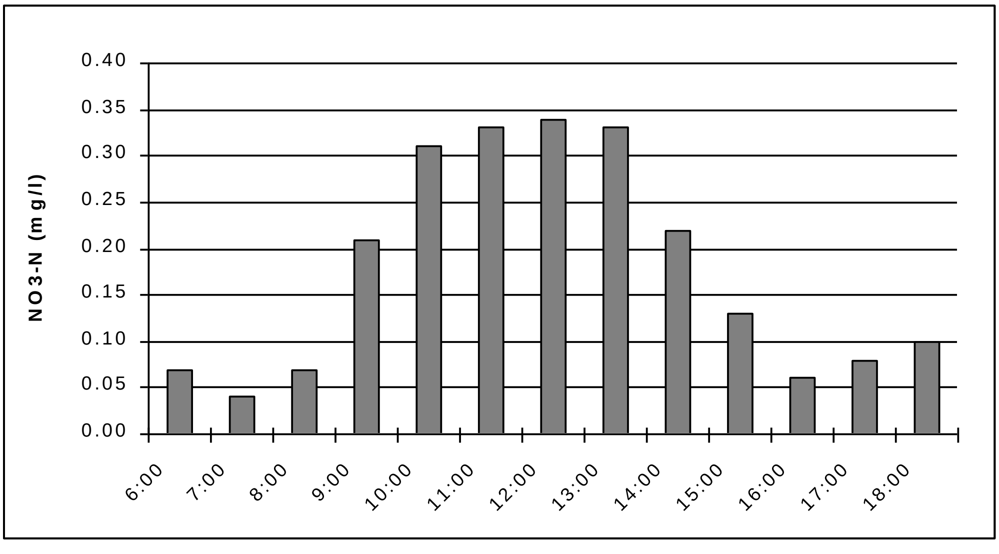
FIGURE 45: DAILY CHANGES OF NA AND K IN THE CANAL NEXT TO KHUN BAMRUNG'S FARM



Contrary to other parameters, values of concentrations of NO_3 varied greatly along the day (Figure 46). Nitrate concentrations evolved following a parable with a peak at noon with 0.34 mg/l NO_3-N, 6 times the value measured at 7 am.

Finally, copper and phosphorus could hardly be detected in the canal at this date.

FIGURE 46: DAILY CHANGES OF NO3-N AND K IN THE CANAL NEXT TO KHUN BAMRUNG'S FARM



The water composition appears relatively stable along the day in the canal. However the discharge of water from agricultural plots upstream may create disturbance, like the increase of the nitrate concentration which remains very low anyway. Because of the interconnected canals, a point source pollution affecting a tertiary channel will become progressively a non point source pollution in larger canal, like the nearby main canal of Damnoen Saduak which plays a buffer role. We can assume that variations are quite low in larger canals because of the dilution and of the different streams connected to them.

3.3 Annual changes of the water composition in the canals

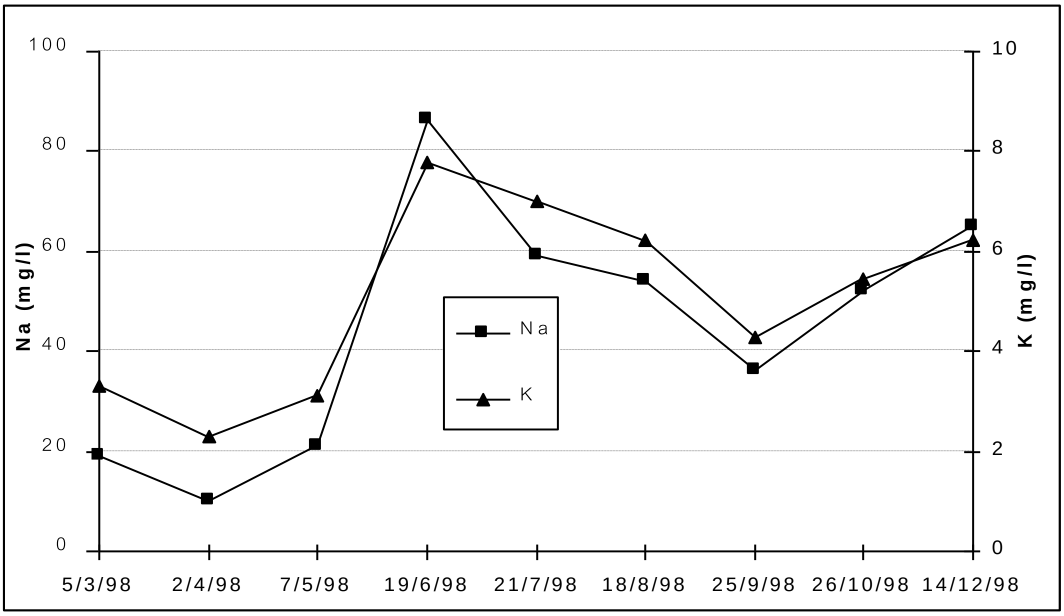
The values of measured parameters for the monthly sampling from March 1998 to December 1998 are shown in Appendix 6.

3.3.1 Features of the water composition along the year

In the three canals, pH ranged from 6 to 7.5 and fluctuations seemed quite irregular. Likewise, alkalinity was fairly stable along the study period (between 200 and 250 mg/l). However the three graphs indicate a sudden peak in October around 450 mg/l.

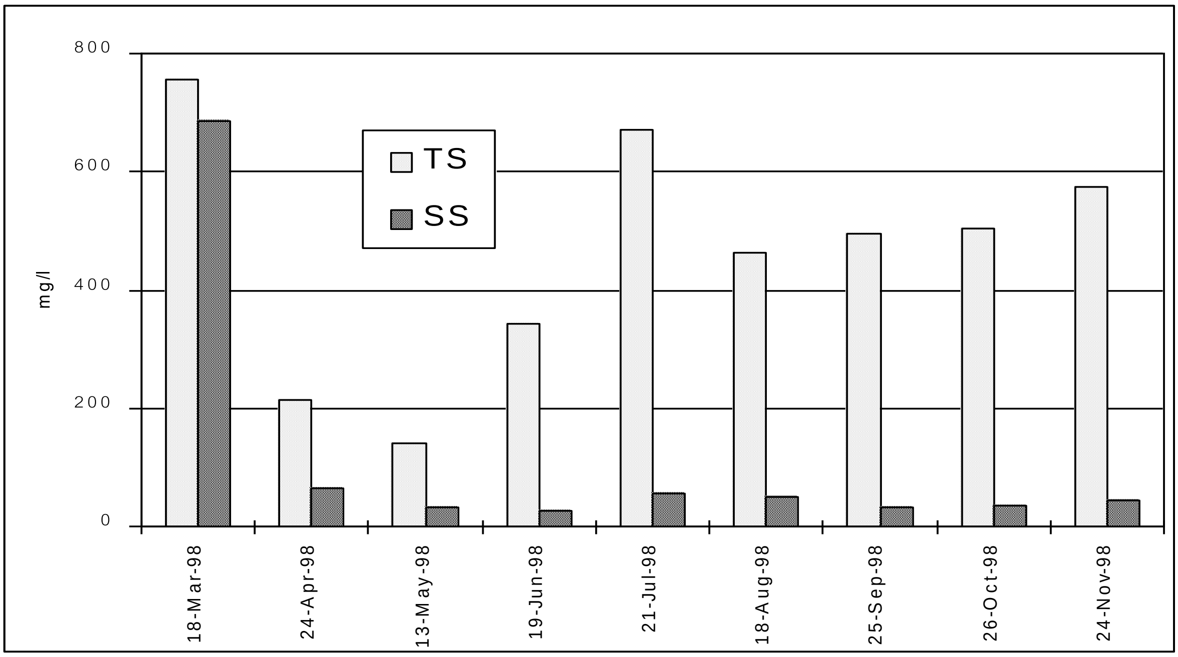
EC values ranged from 0.3 to 1.2 mS/cm but in contrast to pH, EC graph shows a clear difference between values in the dry season (below 4 mS/cm) and in the rainy season when EC was higher than 0.6 mS/cm. Peaks of EC were noticeable in June near khun Bamrung's farm and in July in the two other channels. Similar changes were observed for Na and K (Figure 47). The concentration of sodium was lower than 20 mg/l during the dry season but could reach 60 mg/l in the rainy season or even 90 mg/l in the canal next to khun Bamrung's plot (value on 19/06/98). Concerning potassium, concentrations were close to 3 mg/l in the dry season whereas we measured 7-8 mg/l in June-July.

FIGURE 47: ANNUAL CHANGES OF NA AND K IN THE CANAL NEXT TO KHUN BAMRUNG'S FARM



In March, TS showed a particularly high value, reaching 800-1000 mg/l in the three canals before dropping in April and May to 200-300 mg/l. TS was higher in the rainy season and stabilised around 500 mg/l. In fact, except in March when high values of TS seemed to be due to high SS levels (Figure 48), SS was generally around 40-50 mg/l. This means that TS resulted essentially from the dissolved elements.

FIGURE 48: ANNUAL CHANGES OF TOTAL SOLIDS AND SUSPENDED SOLIDS IN THE CANAL NEXT TO KHUN BAMRUNG'S FARM



Nitrate concentrations were very low, below 0.50 ppm NO_3-N for the whole year showing little increase in July and August. As for NH_4, values ranged from 0 to 0.15 mg/l NH_4-N for the study period and appeared like nitrates higher in July and August. Like nitrogen, phosphorus was also in low concentration (generally below 0.15 mg/l of H2PO4-P), never exceeding 0.7 mg/l H2PO4-P (highest value near khun Bamrung's farm on 21/07/98). In front of khun Somchai's plot, phosphorus was always lower than 0.2 mg/l H_2PO_4-P whereas at khun Pra Thuang's farm, we observed a peak at 0.45 mg/l H_2PO_4-P in October.

Copper content varied much from one month to another but given that levels are very low (0-0.050 mg/l), we should be careful with these fluctuations.

We also checked the presence of organophosphate and carbamate pesticides in water samples from 05/03/98 to 01/02/98. Among 11 samples taken in each canal, 3 were positive at khun Bamrung's canal, 4 at khun Pra Thuang's and 0 at khun Somchai's.

3.3.2 Initial hypothesis and observations

From the previous observations, we can deduce that:

- Measured parameters showed very similar variations in the three channels. The canal next to khun Bamrung's farm seemed sometimes a bit apart. This may be linked to its location north of the main canal of Damnoen Saduak.

- Levels of nutrients were quite low all along the year, far lower than was expected. For example, $N\text{-}NO_3$ never exceeded 0.5 ppm, whereas the standard for drinking standard decided by the Thai Ministry of Public Health is 10 ppm.

- Pesticides could be detected in almost one third of the samples at khun Bamrung's and khun Pra Thuang's farm. However in front of khun Somchai's house, no sample was positive.

- Concentrations of dissolved elements were lower in dry season and got higher in rainy season although we had expected the opposite.

3.3.3 Interpretation of the main trends

3.3.3.1 Discrepancies of salinity levels

The evolution of EC, Na and K reveals that, in the rainy season, water is slightly more saline than in the dry season. Different explanations can be put forward: intrusions of saline water from the sea through the streams and rivers, water outflow from shrimp ponds managed with seawater, the desalinisation of the soils. The latter hypothesis is little probable insofar as soils are very little salted. The first one seems to contradict the hydrologic regime (a higher flow in the west season prevents salinity intrusion from the lower Mae Klong reach). The impact of shrimp ponds is therefore the most probable.

If we now draw the graph of the Na/K ratio in the three canals (Figure 49 and Figure 50), we notice that in the dry season the ratio is around 4-6 whereas in the rainy season it is closer to 8-10. In contrast with the two canals south of the main canal of Damnoen Saduak, the ratio at khun Bamrung's farm exceeds 10 in two instances (June and December). The difference in the Na/K ratio between the two seasons suggest two influences on the water.

FIGURE 49: ANNUAL CHANGES OF THE RATIO NS/K IN THE CANAL NEXT TO KHUN PRA THUANG'S FARM

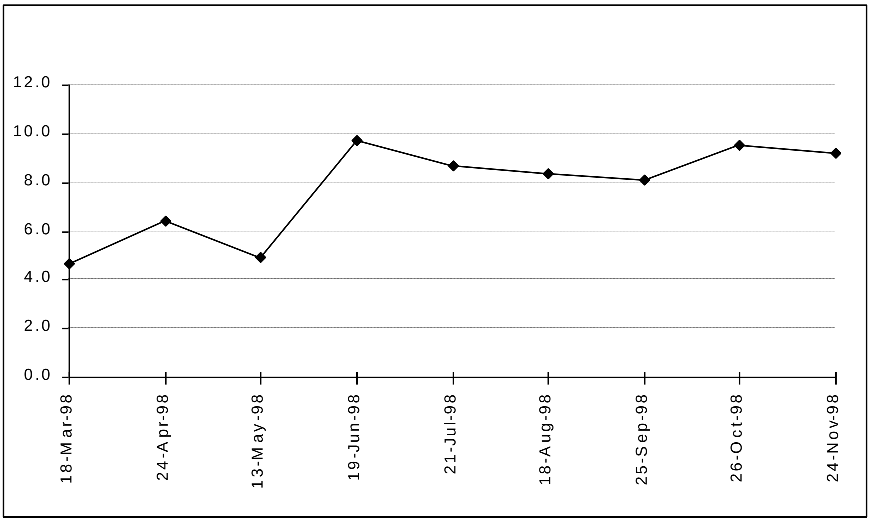
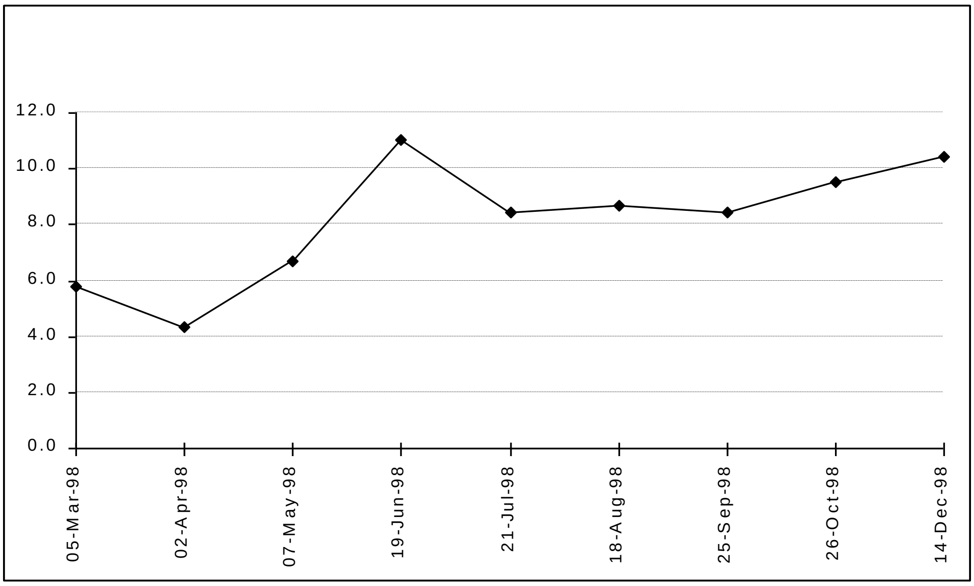


FIGURE 50: ANNUAL CHANGES OF THE RATIO NS/K IN THE CANAL NEXT TO KHUN BAMRUNG'S FARM



During the dry season, gates on the main channels and temporary dams obstruct the outlets on the river in order to prevent intrusions of saline water which may occur at this season because of the lower discharge of the rivers. On the contrary, in the rainy season, gates are opened to evacuate excess water. Although there still may be tidal influence and probably little saline intrusion even if attenuated during the rainy season, the Royal Irrigation Department does not close the gate daily because of the strong constraints of this task. In these conditions when gates are open, we can assume chemical diffusion of salinity which progressively comes in with the tide.

Regarding the peak of salinity in the canal next to khun Bamrung's in June, one explanation may be the pollution from tiger shrimp ponds upstream. South of the main canal of Damnoen

Saduak, this pollution is not observed probably because of the main canal itself, which would play a buffer role and limit the extension of this pollution to the south.

The two sources of salinity would be: saline intrusions from the sea through the river and the shrimp ponds.

3.3.3.2 High values of SS in March

March corresponds to the period in which farmers destroy raised beds before the change of crops. Most of them build new raised beds, flood their plot for 1 or 2 months and then drain it before letting the soil dry for 2 other months. The high peak in SS may be due to the outflow from upstream plots of water loaded with soil particles.

3.3.3.3 Nitrogen and phosphorus concentrations

Mineralisation of the organic matter starts simultaneously with the rainy season: soil moisture increases and boosts the soil micro-organisms. In heavy clayey soils, nitrate may leach slowly and take one or two months to reach the water table and then the ditches. This may be the main explanation for the slight increase in the nitrate concentration in July and August. Concerning ammonium ions, they result mainly from the transformation of urea applied as fertiliser before they are converted to nitrate by microbiological activity. After application, if a heavy rain occurs, run-off washes out the ions ammonium to the ditches. Concentrations of N-NH4 are actually a bit higher in July and August.

The rainy season corresponds to the growth period of many crops. Farmers may be obliged to compensate the runoff of ammonium and leaching of nitrates by more frequent fertiliser applications.

Variations in phosphorus evolution can not be explained as easily as that of nitrogen. Different reasons may cause these irregular peaks: detergent in the water, run-off after fertilisers application. However levels remained low to moderate most of the year, below 0.2 mg/l. Phosphorus is highly fixed on the soil exchange complex in clayey soils.

3.3.3.4 Copper levels

TABLE 10: AVERAGE COPPER CONCENTRATION IN WATER

Water	Average concentration of copper (μg/l)	
Underground water	48[(1)]	(1) Page et al (1983)
River water	2[(2)] –7[(3)]	(2) Merian (1991)
Seawater	0.25[(2)]	(3) Lester (1987)

The levels of copper in the canals, between 0 and 45 μg/l, are quite high compared with the average concentration in surface water (Table 10). However, levels of Cu remain safe, lower than the recommended rate of the European Community for drinking water (100 μg/l) or the admissible rate in France (1000 μg/l). In Thailand, it is mentioned that copper concentration in superficial water should not exceed 0.1 mg/l for the classes 2,3,4 which correspond to water resource except drinking water and water suitable for ecosystem conservation.

Conclusion:

The results of the hourly and monthly sampling have not confirmed our hypothesis concerning the high concentrations of dissolved elements in the dry season. Even if in the rainy season water quality seemed a bit poorer for the measured parameters, and concentrations were not really worrying either. With the regional sampling, we will try to assess if results obtained in the previous sampling during the dry season are valid for the whole area.

3.4 Regional distribution of the water composition

3.4.1 Basis of the analysis

We noticed earlier that the water composition was relatively stable all along a dry day except for nitrate. Given that we took most of the water samples in the main channels, we neglected the disturbances which occur in tertiary canals. We assumed that in large channels variations are attenuated and that concentrations do not fluctuate much during a day. These hypotheses were the basis of the interpretation of our regional sampling: we considered that values measured in channels were representative of the average levels from 30/03/98 to 10/04/98.

3.4.2 General features of the water quality over the study area

TABLE 11: STATISTICS ABOUT THE WATER COMPOSITION OVER THE STUDY AREA

	PH	EC	TS	SS	ALK	NO_3-N	NH_4-N	K	Ca	Mg	Na
Unit	-	mS/cm	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	Mg/l	mg/l	mg/l
MEAN	6.7	0.86	608.1	121	290	0.08	0.05	7.4	36.5	34.6	141.6
MIN	6.0	0.07	100.0	4.0	180	0.00	0.00	1.0	3.8	1.3	2.0
MAX	7.8	12.20	5840.0	660	599	0.73	0.44	225	300	1071	6503
Q1	6.5	0.28	254.5	31.3	233	0.00	0.00	2.1	24.9	10.1	10.5
Q2	6.6	0.35	372.0	76.0	268	0.04	0.00	2.7	29.5	13.6	19.6
Q3	6.8	0.69	628.0	140	325	0.12	0.08	5.3	37	26.4	57.4

Note:

- Q1, Q2 and Q3 mean the three first quartiles.
- MIN is the minimum, MAX the maximum.

- Alk means Alkalinity.

Water in the study area was characterised by a neutral pH (6.7 on average) and a low Electric Conductivity ranging most of the time from 0.2 to 1mS/cm, indicating low salinity (Table 11). This observation was reinforced by the low concentrations in sodium (50% of the values range from 10 to 25 mg/l). The low results of EC in 1998 confirmed quite well the results of the dry season 1996 sampling: 80% of the samples were found in the 0 to 1 mS/cm bracket.

Furthermore, water was rather alkaline: alkalinity values ranged from 180 to 599 mg/l. Alkalinity, which measures naturally available bicarbonate, carbonate and hydroxide ions in the water is often linked with ions associated with carbonates like Ca and Mg. Water was fairly rich in calcium (60% of the values range from 25 to 50 mg/l) and magnesium (50% between 10 and 25 mg/l).

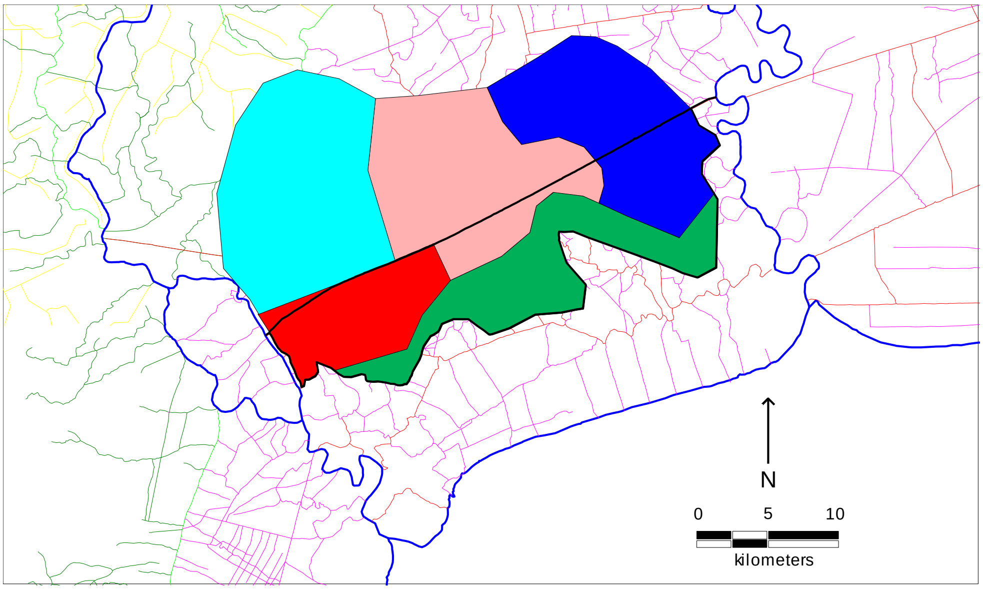
Although we expected rather high concentrations in nutrients because of intensive agricultural practices (in particular intensive use of fertilisers), results were not so significant and were close to the values measured in the two other sampling in the dry season. Nitrate concentrations were low: 140 points showed a concentration below 0.4 mg/l NO_3-N. Concentrations in ions ammonium were also very low, with an average level of 0.1 mg/l. Levels of phosphorus were also low: 96% of the values showed a concentration of H_2PO_4 below 0.1 mgP/l.

As concerns organophosphate and carbamate pesticides, 23% of the samples were positive with the enzyme technique. The “positive” points were scattered all over the tract.

3.4.3 Spatial variability of the parameters

Studying the thematic maps drawn for each parameter, we observed that despite water quality being quite heterogeneous over the study area, we could identify five different zones (Figure 51):

FIGURE 51: MAP OF THE MAIN AREAS IDENTIFIED ACCORDING TO THE WATER COMPOSITION



- <u>where water was little loaded in dissolved elements</u>:
  - the northern and central part of the sampling area mostly above the main canal of Damnoen Saduak,
  - the south-west, south of the DS canal and close to the Mae Klong river.

- <u>where concentrations in dissolved elements appeared higher</u>:
  - the south of the tract: at the end of the canals all along the dike,
  - in the eastern part, near the Tha Chin river, a crescent-shaped area,
  - finally, the north-western area.

The two last zones did not appear so clearly: the values of parameters were not so homogeneous. We will try, however, to describe the trend of the water composition in these zones.

3.4.3.1 <u>The central part of the study area</u>

The main characteristics of this zone were:

- pH between 6.4 and 7
- low EC values ranging from 0.07 to 0.46 mS/cm, confirmed by low concentrations of Na (11.93 mg/l on average)
- little loaded in soil particles: SS was on average about 70.89 mg/l
- not so rich in dissolved elements compared with the global average: on average calcium concentrations were about 26.95, magnesium 11.20, potassium 2.27 mg/l

- concentrations of nitrates were low: on average 0.13 mg/l of NO3-N. It is worth noting that nitrate concentrations were somewhat higher in the main canal of Damnoen Saduak and in the channels close to it.
- phosphorus could hardly be found.

3.4.3.2 South-west of the main canal of Damnoen Saduak

Except near the dike, points in this zone showed very low concentrations of dissolved solids, among the lowest of the whole area.

- close to the values measured in the previously mentioned area, EC was low (between 0.22 and 0.43 mS/cm) which indicates a low salinity. 75% of the samples showed a concentration of Na below 13.4 mg/l.
- water was little concentrated in solids, either suspended nor dissolved (respectively 55.6 and 150.6 mg/l)
- contrary to magnesium (average of 9.7 mg/l), calcium levels were quite high with an average of 26.7 mg/l.

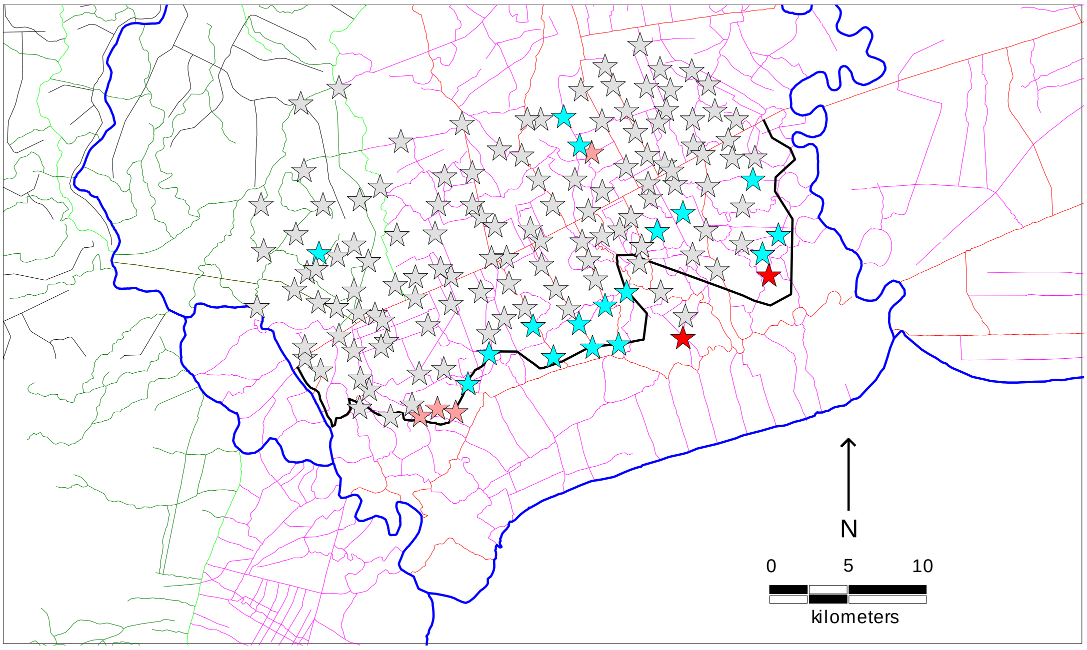
Although SS and TS presented lower values in this zone, characteristics were very similar to the central part of the study area.

3.4.3.3 Along the southern dike

Contrary to the zone considered just before, most of the samples taken along the dike showed a poorer water quality according to the parameters checked in the survey.

- Electrical conductivity was higher than 1mS/cm and reached next to the dike 12.2 mS/cm. (Figure 52). In 1996, Doras Project found similar results. In 1998, at one site, we measured a very high value for EC. The ECmeter indicated that the value was above 20 mS/cm. However this sample must be considered separately insofar as it was taken like three other samples beyond the dike, which means in the area under tidal influence.

FIGURE 52: REGIONAL DISTRIBUTION OF ELECTRICAL CONDUCTIVITY(MS/CM)



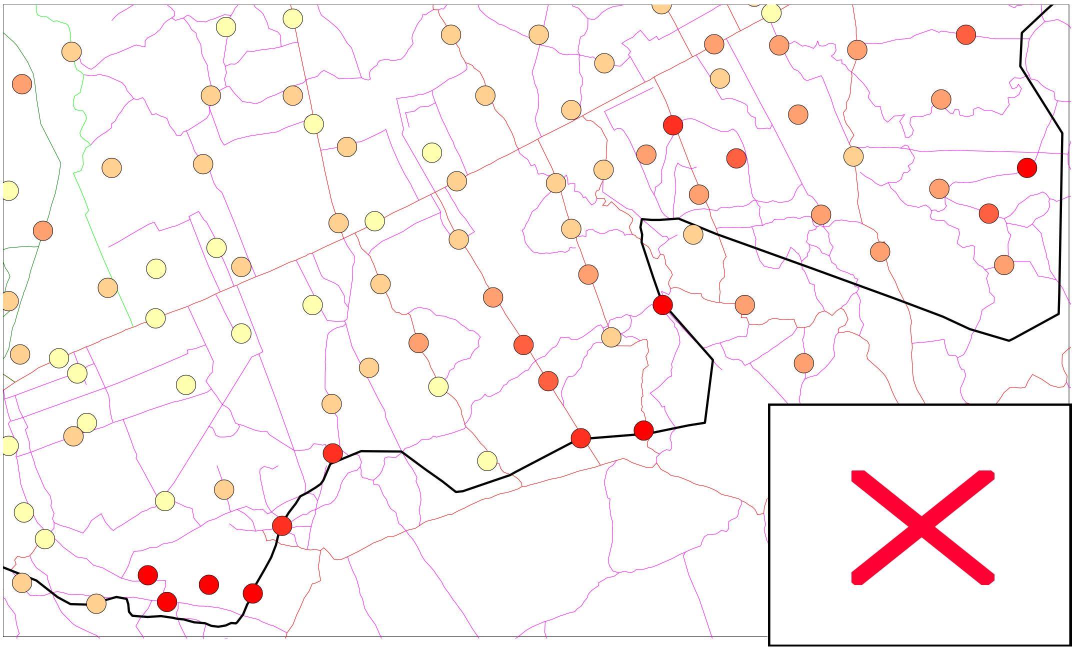
- Water was very rich in suspended and dissolved solids. At the end of channels, just before the dike, TS reached very high values up to 5840 mg/l. Alkalinity was also high: 355 mg/l +/- 22%. Concentrations of nutrients were definitely higher than in the rest of the sampling area except for N and P which levels were very low (Table 12).

TABLE 12: NUTRIENTS LEVELS ALONG THE SOUTHERN DIKE

	NO3-N	NH4-N	P2O4	Ca	Mg	K	Na
Unit	Mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Mean	0.07	0.04	0.04	45	68	15	328
Min	0.00	0.00	0.00	20	10.5	2.2	9.2
Max	0.27	0.35	0.57	122	326	75	2201

Sometimes, in the same canal, several samples were taken at different sites. It appeared that there was a grading of the concentrations, particularly noticeable from the main canal of Damnoen Saduak down to the dike. We made this observation for at least two or three canals above all for the following parameters: TS, Alkalinity, Mg, K, Na. (cf. Figure 53). However this phenomenon could not be observed for all the channels.

FIGURE 53: GRADATION OF THE TS VALUES ALONG THE CANAL, DOWN TO SOUTH



3.4.3.4 East of the study area

The area near the Tha Chin river was characterised by

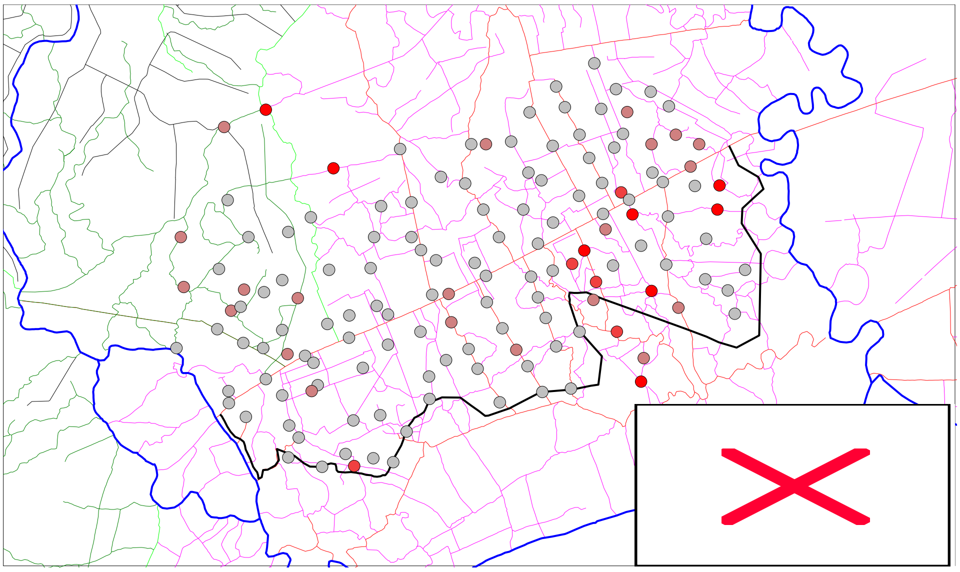
- a rather low pH (between 6 and 6.5 for 50% of the samples),
- high values of EC (up to 6.4 mS/cm),
- and rather high values of dissolved elements like calcium (up to 99.7 mg/l), magnesium, potassium and sodium. This justifies the higher Alkalinity (50% of the values range from 305.5 to 582.0 mg/l) and EC. Because water composition was not homogeneous in all this sector, we preferred to consider quartiles to analyse the results. (Table 13)

TABLE 13: WATER COMPOSITION NEAR THE THA CHIN RIVER

	pH	EC	TS	SS	Alk	NO3-N	NH4-N	Ca	Mg	K	Na
Unit	-	mS/cm	Mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
MIN	6.0	0.28	186.0	4.0	204.0	0.00	0.00	22.8	10.0	2.1	10.0
Q2	6.6	0.50	358.0	84.0	284.0	0.04	0.00	31.2	16.9	4.7	37.5
Q3	6.8	0.77	581.5	146.5	305.5	0.14	0.07	36.5	29.1	5.4	58.5
MAX	6.9	6.40	1922.0	595.0	582.0	0.42	0.40	99.7	54.9	14.0	160.1

In this area, we measured also higher levels of SS than the average (Figure 54).

FIGURE 54: REGIONAL DISTRIBUTION OF SS

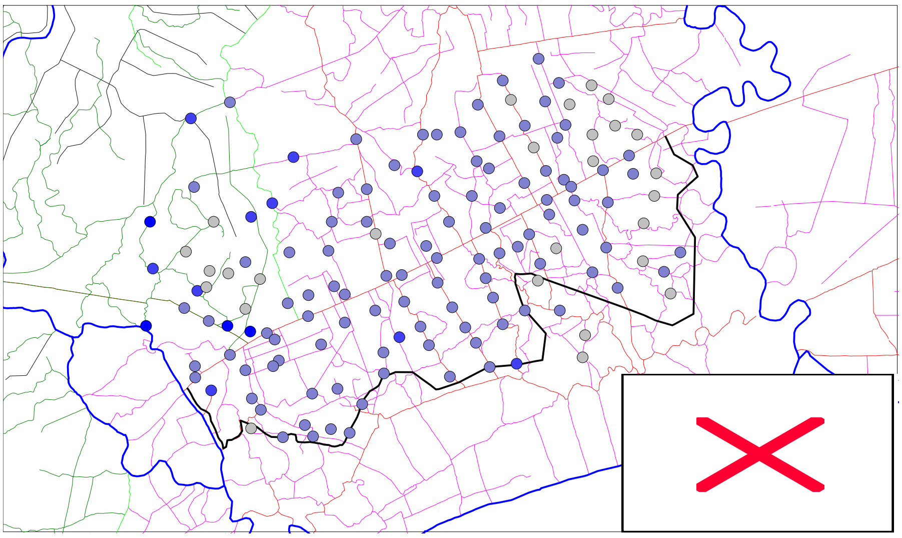


3.4.3.5 *Northwest of the canal of Damnoen Saduak*

This area corresponds to the western part of the Amphoe Damnoen Saduak and also to the extreme south of the Amphoe Bang Phae. Here also values of parameters were not homogeneous over the area but we could describe a few trends.

We found here a few points in the centre, distinct from the rest of the area. When the pH seemed higher all round the area (up to 7.8), 7 in the middle points showed a lower pH, between 6 and 6.5 (cf. Figure 55). EC was low in all the zone, below 1 mS/cm, with an average of 0.42 mS/cm). TS was somewhat higher than the average: for 50% of the sampling points, TS ranged from 440 to 1320 mg/l. In the north, three points showed high values of TS and SS. (up to 1320 mg/l for TS and 595 mg/l for SS).

FIGURE 55: REGIONAL DISTRIBUTION OF PH



Except for four points, Alkalinity was quite low (75% of the values were under 264 mg/l) and that could be understood insofar as concentrations of mineral ions were also low except for several points in the middle where concentrations were higher, the same points for which we found a lower pH.

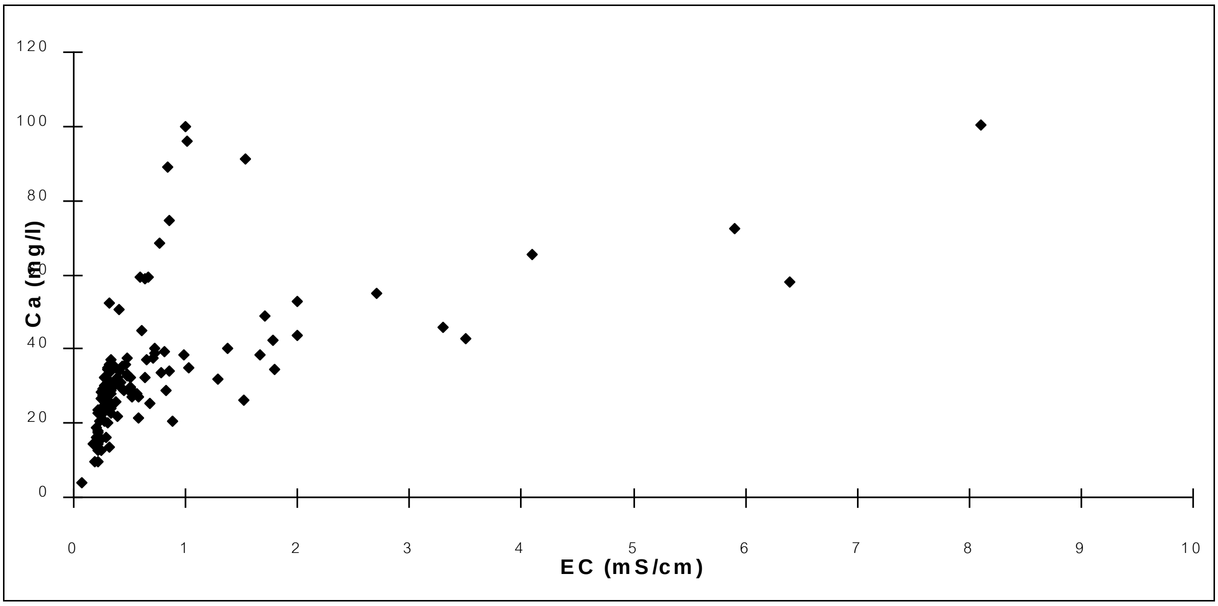
Although it was difficult to determine a zoning of pesticides concentrations, we could however notice the largest number of positive values in this area, about 36% of the samples taken here.

3.4.4 Interpretation of the results

3.4.4.1 <u>High concentrations in Calcium</u>

Figure 56 plots EC against Ca. If we set apart the points of high EC which corresponds to high salinity values, and consequently to high concentrations of Ca due to the richness of the seawater in mineral ions, we observe that water flowing in the network of the conservation area is fairly rich in calcium. Samples taken in the central and south-western parts indicate 26.85 mg/l of calcium on average whereas stream water is usually characterised by a concentration of calcium around 13 mg/l (Michard, 1989).

FIGURE 56: REGRESSION GRAPH BETWEEN EC AND CA FOR THE REGIONAL SAMPLING



The Mae Klong River has its source in the calcareous relief above Kanchanaburi at the boundary with Myanmar. Draining this calcareous area, the river gets enriched in calcium and flows then by gravity through the irrigated area of the middle Mae Klong basin. That is why water coming from the gravity area into the conservation area is rich in calcium.

Moreover, as mentioned earlier, calcium is the dominant nutrient in soil profiles even before the intensification of environment use. Calcium in the soils may come from the marine deposits rich in shells and therefore in calcium carbonate. High concentrations of calcium may result from the drainage of these sedimentary soils. Farmers, as they use fertilisers, especially P_2O_5, apply at the same time high amounts of calcium (14% of calcium in phosphate fertilisers) and enrich even more the soil in calcium. Calcium may leach from soils saturated in this element to the ditches and then to the canals.

3.4.4.2 Salinity

3.4.4.2.1 SEA WATER COMING FROM THE RIVERS AND FROM THE SOUTH

Most of the points in the sampling area showed low EC values. This proves the efficiency of the southern dike and of the regulators in limiting saline intrusions in the raised bed area. However in some areas, high EC values were detected.

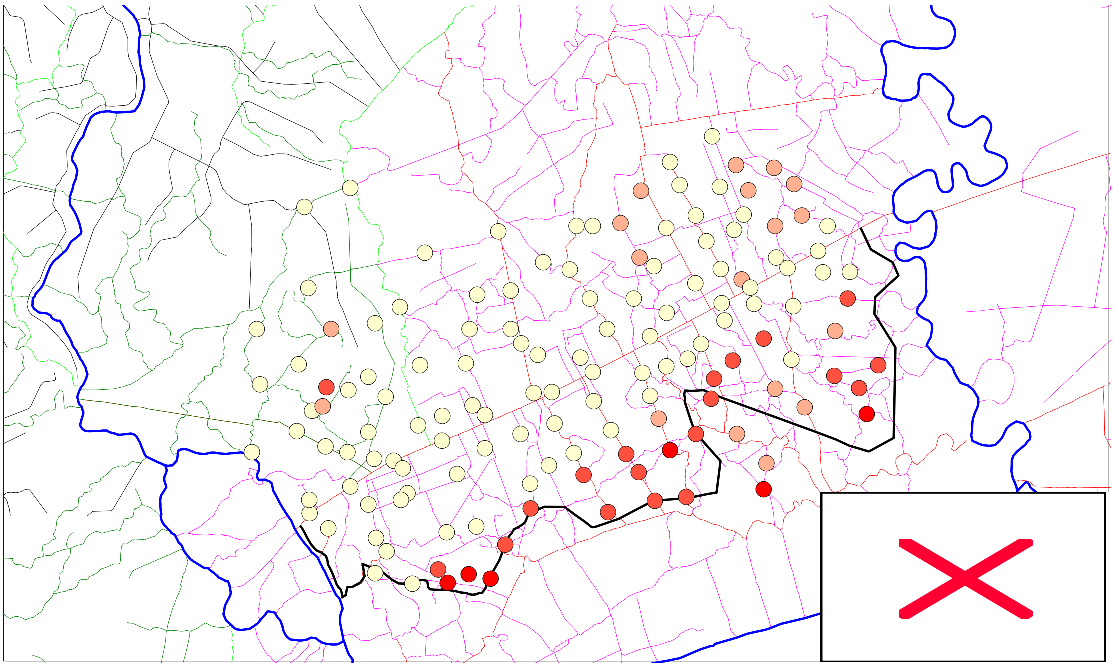
Along the dike, most of the canals and gates are closed to impede saline intrusions. During the dry season, indeed, discharges of the streams are not sufficient enough to prevent seawater from coming up north. High EC values related to high concentration in sodium all along the dike proves that gates are not tightly closed and saline water can still intrude. It may also be that the gate had been opened a few years to flush out poor quality water and that salinity increased in the operation. However, they never spread further than 3 km north of the dike.

Some points indicated EC values higher than 0.75 mS/cm, limit above which water is not suitable for irrigation, in the north-eastern part of the raised bed area. This may be linked with the water management in this zone. Near the Tha Chin River, north of the main canal of Damnoen Saduak, the Chin Da Canal indeed is ungated as well as some minor outlets. When the tide comes in, the flow is reversed in the Tha Chin River. Tidal influence is noticed in the Tha Chin River up to km182 from the river mouth (PCD, 1997). But this does not mean that saline water can come in so far. Nevertheless, saline water can intrude lands through the Chin Da Canal which is only 50 km far from the river mouth. Although this saline intrusions may affect agriculture in the area, farmers do not want to close these outlets. With the daily variation of the water level in the canal due to the tidal influence, farmers maximise flows by gravity between plot and canal. During the dry season, they pay attention not to let saline water enter the plot and irrigate at low tide.

3.4.4.2.2 POLLUTION FROM SHRIMP PONDS

If the last explanation seems to be the most reliable about salinity in the North-Eastern part of the study area, we can however wonder if it also holds for 4 points situated in the west, separated by sampling points which do not indicate problems of salinity (Figure 57). Likewise, we find water more saline within the north-western part although canals and streams linked with the Mae Klong river are all gated. These gates seem moreover efficient as we look at the points near the river which present low values of EC and Na.

FIGURE 57: REGIONAL DISTRIBUTION OF NA (MG/L)



Concerning this group of points, we can think about another source of salinity: the discharge from the shrimp ponds provided with saline water for breeding Tiger shrimps and located in the north of the raised bed zone.

As we look at the figure 30, we observe two distinct pools of points.

- points with high values of EC and high values of Calcium: that corresponds to diluted sea water
- points with moderate EC and high values of Ca

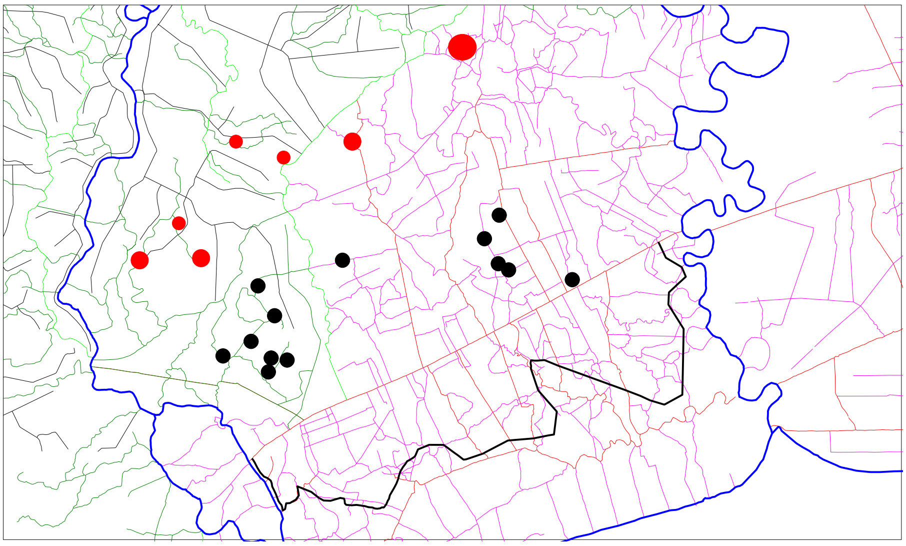
If we now select calcium values higher than 40 mg/l, we isolate a few points on two delimited areas (Figure 58). If we now compare, their location with the location of the shrimp ponds, these ones are exactly upstream (Figure 58). Water discharged from the ponds flows down to the south and raises the salinity along the canals downstream. It seems that these shrimp ponds load water with calcium.

There are also Tiger shrimp ponds in the south-eastern part of the raised bed area but we could not observe this signature in Calcium. It is may be due to the more extensive farming system developed in the south. Calcium, additive element of the food given to shrimps, is brought in higher quantity in intensive farming system.

3.4.4.3 <u>Nitrogen and phosphorus</u>

Whatever zone of the area we consider, concentrations in nitrogen and phosphorus were very low as compared to what we expected in an intensive agricultural area.

FIGURE 58: POINTS CHARACTERISED BY HIGH VALUE OF NA AND CA AND LOCATION OF TIGER SHRIMP PONDS NORTH OF THE STUDY AREA



First it appeared that water coming from the north was not polluted in nitrogen and phosphorus. Before arriving in the conservation area, water drains actually extensive agricultural areas even if the area of Nakhon Pathom and south-west of Nakhon Pathom to the Mae Klong river intensifies progressively developing mixed cropping patterns (sugarcane, asparagus, babycorn, vegetable, etc.).

Even through the intensive agricultural area of Damnoen Saduak, water does not seem to get much polluted from the discharge of raised bed plots. During the dry season, it seems that no nutrient pollution comes from the field except maybe for calcium. We can make two assumptions:

- Given that lots of fertilisers are applied in raised beds plots, we can suppose that most of the nutrients are accumulated in the plot, adsorbed in the soil.
- The dry season is not the worst season as for nutrient concentration. Run-off during the rainy season may cause more pollution than the increase of concentration by evaporation in the dry season.

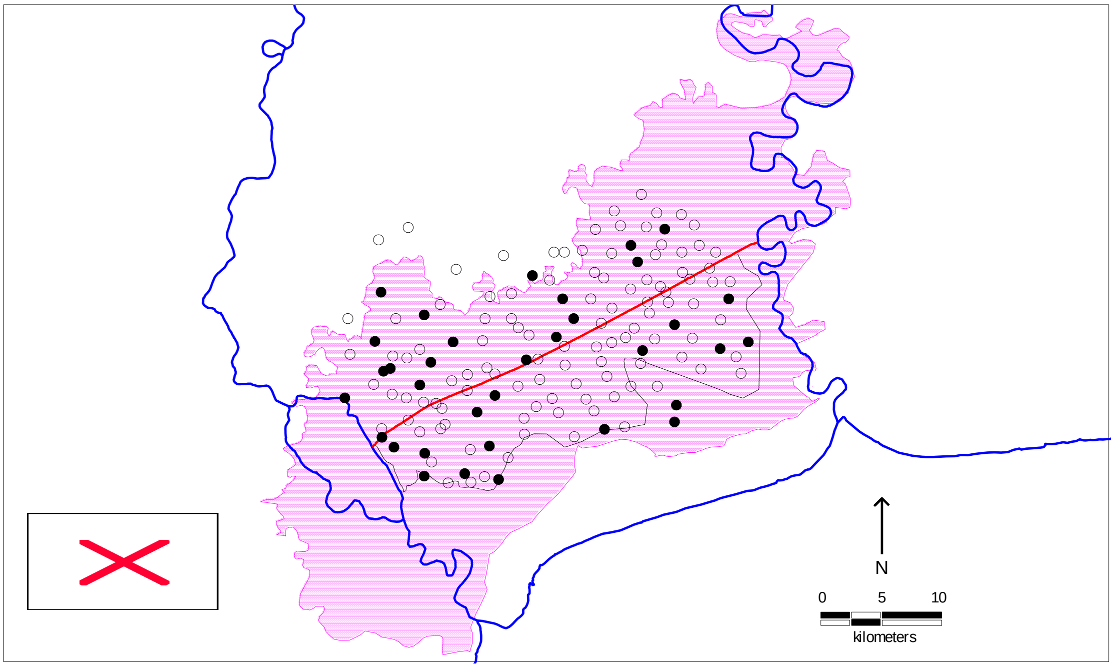
If we refer now to our monthly sampling in canals, it seems that run-off exists but is limited. Water in rainy season, except for the slight increase of the salinity, is barely polluted by nutrients.

A little higher concentration of nitrate could be found in the central part of the main canal of Damnoen Saduak. It may be due to population contribution which is clearly noticed when this canal discharges in the Tha Chin river. (PCD, 1997)

3.4.4.4 Pesticides

Scattered all over the tract of raised beds, 23% of the samples were positive (Figure 59). Used commonly on fruits and vegetable, organophosphate and carbamate are used in the whole raised bed area of Damnoen Saduak.

FIGURE 59: RESULTS OF PESTICIDES CHECKING



This presence of pesticides in the channels raises a real problem of pesticides overuse insofar as organophosphates and carbamates are characterised by short half-life, that is to say a rather quick degradation in the local conditions (strong sunlight and high temperatures). The rate of 24% is thus considerably high if we take in account the short half-life of these two families of pesticides.

This may be an indicator of severe water pollution by pesticides. However it would be worth confirming these observations by analysing the exact concentration of pesticides in water.

3.4.4.5 Increase of concentrations along the canals

As mentioned earlier, we could observe in a few canals a gradation in Total solids down to the sea. This slight increase is natural and corresponds to the concentration in cations and anions which increases along waterways resulting from the erosion of drained land. However it is difficult to distinguish if the increase of concentration results from the drainage of land upstream or from pollution.

Although seldom observed, higher values of SS and TS are probably due to the intrusion of saline water near the dike. Moreover because of the flatness of the conservation area and therefore of the low discharge of the canals, we can assume that water takes a long time to drain in the dry season and that elements either sediment or precipitate. That is maybe why water does not get more and more loaded along waterways.

We can also hypothesise that at the end of the canal, when the gates are closed in the dry season, there are favourable conditions for the development of plancton (higher values of SS) insofar as there is less turbulence.

Conclusion:

The regional sampling confirmed quite well the results of the monthly sampling for the dry season. During the dry season, contrary to what we expected, water is little loaded in nutrients. Moreover we could find out that:

- Saline intrusions in the raised bed area are efficiently limited by the southern dike, regulators and temporary dams. Some small intrusions are nevertheless possible through the gates, which induces high EC along the dike over approximately 2 km north of the dike. This limits the landuse south of the main canal of Damnoen Saduak where farmers grow mainly coconut trees or jujube which can tolerate salinity or develop fish and shrimp ponds like in the south-eastern part.

- Tiger shrimp ponds filled with seawater, which were still in activity in April 1998, were shown to have a significant impact on the water quality inside the raised bed area. Because of the environmental consequences, these ponds have been officially banned on the 25th of January 1999.

- Water in Damnoen Saduak is fairly rich in calcium, naturally because of the quality of soils in the basin but maybe also because of the use of phosphate fertilisers applied by farmers in their raised bed plots.

- Water in the canals is highly polluted by pesticides, especially by those used on fruit trees and vegetables. This results directly from the pesticides overuse in raised bed plots, that we studied in the previous chapter.

- Given the low concentrations in nutrients, it seems that agricultural plots do not contribute so much to water pollution, except for pesticides. We can thus wonder about the fate of the high amounts of fertilisers applied farmers in raised bed plots. We can assume an accumulation of elements in the soil at least for phosphorus. The third part will help us understand the fate of the nutrients.

4 On and off-site effects of grapes cultivation

4.1 On-site effects

4.1.1 Water in the ditches

4.1.1.1 Monthly changes in water composition

4.1.1.1.1 INTRODUCTION

Some of the pesticides and fertilisers applied to the fields can end up in the water of the ditches and later be released into the main canals. The objective of this section is to investigate the evolution of the composition of the ditch water in plots equipped with only one outlet, and to discriminate between those resulting from the farming practices and those of other origins.

4.1.1.1.2 MATERIAL AND METHODS

Water samples were taken every month in the ditches near the outlet and far from it in Bamrung's, Nipat's and Pratueng's fields, as well as in the canal next to them. The samples were analysed for potassium, sodium, pH and alkalinity (see methods in appendix 3).

4.1.1.1.3 RESULTS

For both sodium and potassium, the content was higher in the ditches than in the canal during the dry season (October to June) and lower during the rainy season (Figure 60 and Figure 61 for Pratueng's field, other data in appendix 6). The sodium content in the ditches followed closely the changes in the canal.

FIGURE 60: CHANGE IN NA CONTENT WITH TIME IN THE CANAL AND IN THE DITCHES(PRATHUENG'S FIELD)

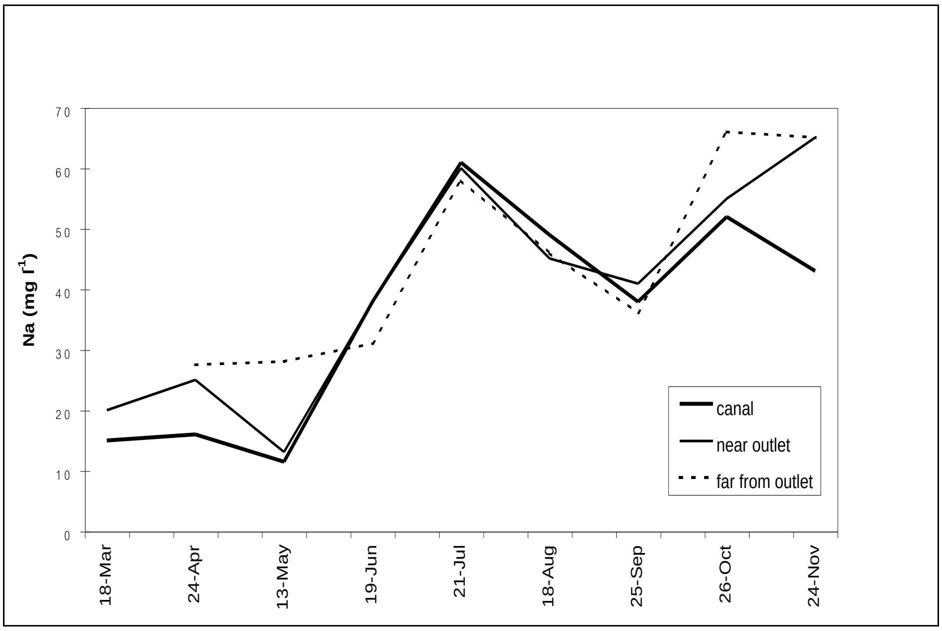
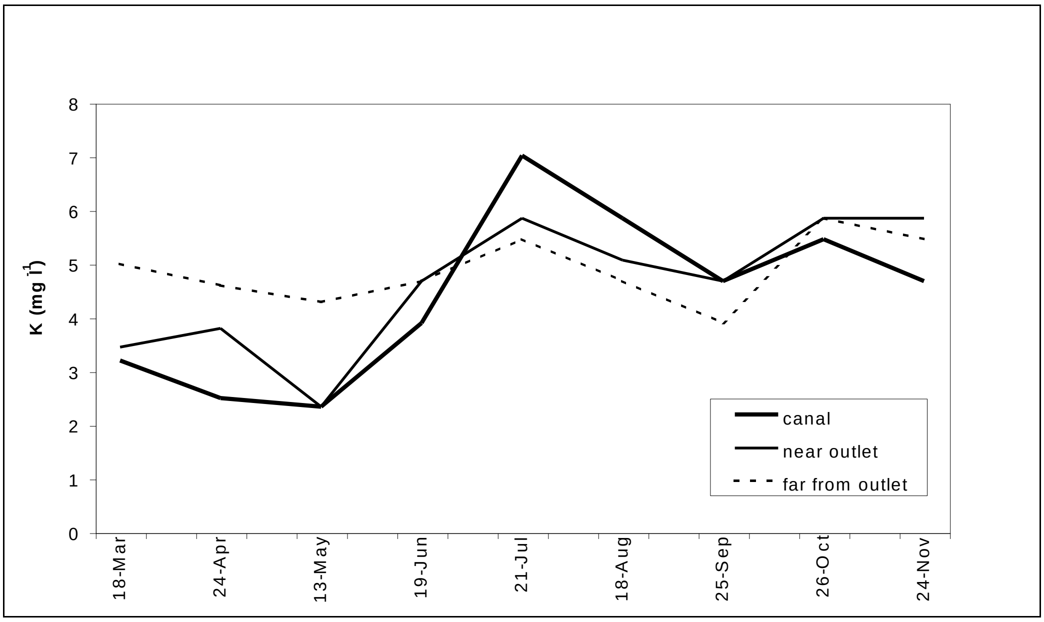


FIGURE 61: CHANGE IN K CONTENT WITH TIME IN THE CANAL AND IN THE DITCHES (PRATHUENG'S FIELD)



Alkalinity and pH (determined in the field) were higher in the ditches than in the canal (Figure 62 and Figure 63). Other determinations done in 1997 showed that dissolved oxygen was also higher in the ditches than in the canal (Molle *et al*., 1998).

FIGURE 62: CHANGE IN PH WITH TIME IN THE CANAL AND IN THE DITCHES (PRATUENG'S FIELD)

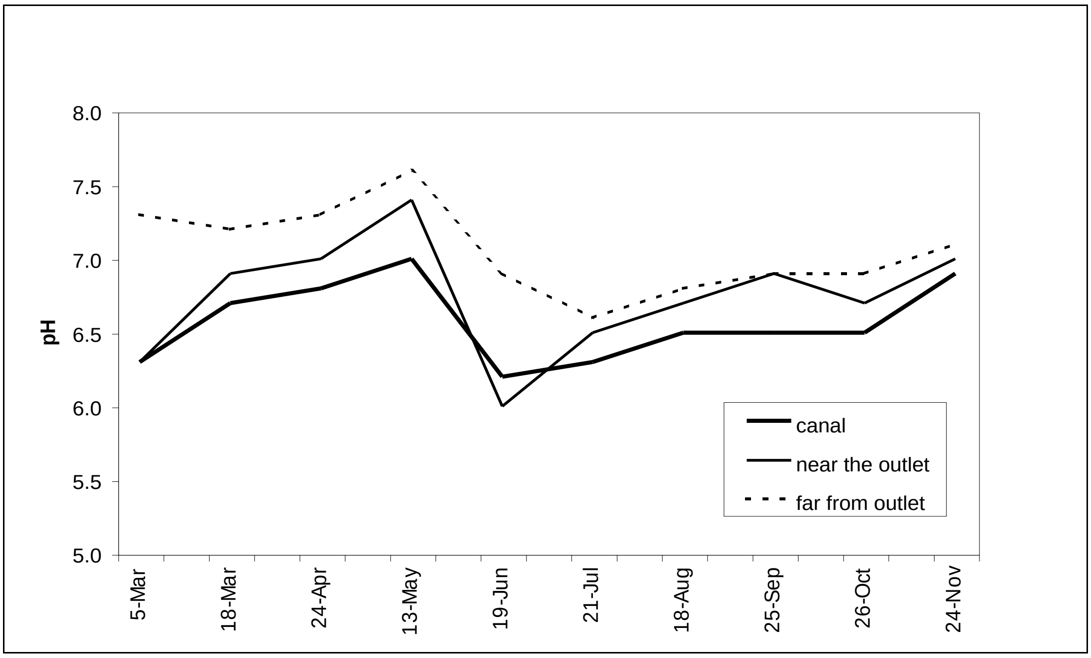
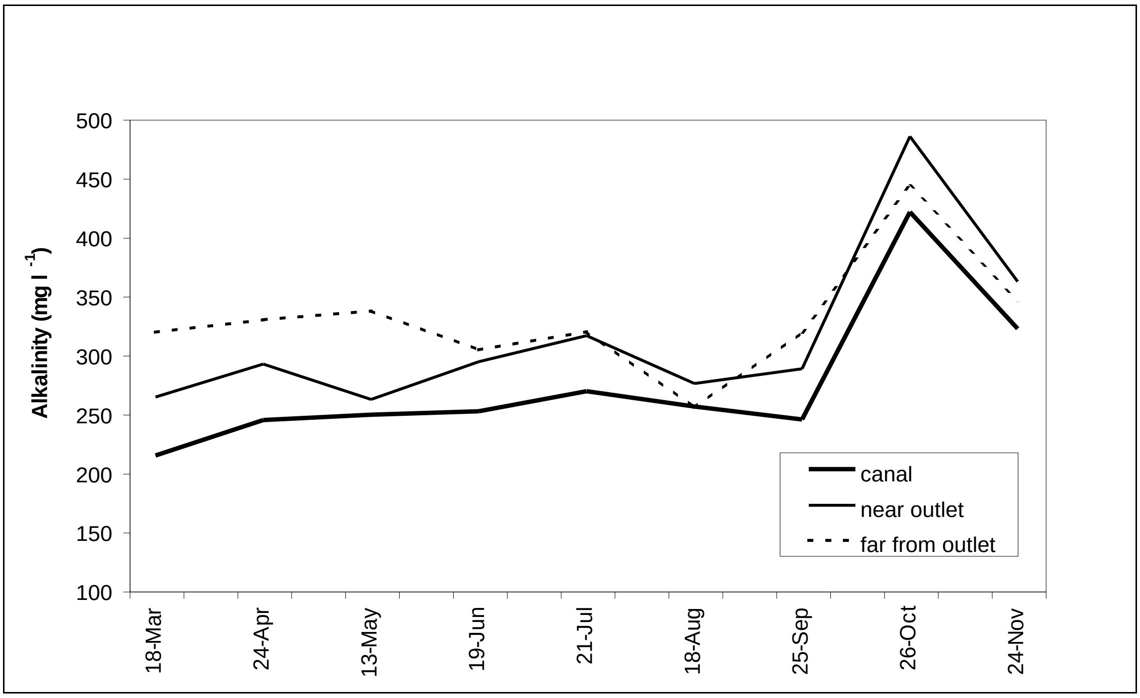


FIGURE 63: CHANGE IN ALKALINITY WITH TIME IN THE CANAL AND IN THE DITCHES (PRATUENG'S FIELD)



4.1.1.1.4 INTERPRETATION

As sodium is the most abundant anion in the water, the close relationship between sodium in the ditches and in the canal during the rainy season proves that the composition of the ditch water is mainly determined by the one in the canal.

During the rainy season the sodium and potassium contents are lower in the ditches than in the canal, and the potassium concentration is lower far from the outlet than near to it. During the dry season the concentrations are higher in the ditches than in the canal, but they decrease with time from high initial values. These results suggest that the renewal of water is not perfect within the field, particularly far from the outlet.

Unlike sodium and potassium, water pH and alkalinity remained higher in the ditches than in the canal throughout the year. During the dry season, the farther from the canal the higher the values. Together with the high values of dissolved oxygen measured in 1997, these results suggest that the phytoplancton has a major effect on the water quality of the ditches.

4.1.1.2 Short-term changes in water composition

4.1.1.2.1 INTRODUCTION

By studying the monthly changes in water composition, it appeared that the sodium and potassium concentrations were higher in the ditches than in the canal during the dry season and lower during the rainy season, which could be due to an imperfect renewal of water when the farmer changes the water of the ditches. But the increase in Na and K during the dry season could also stem from an accumulation of sodium and potassium in the ditch water by evaporation from the ditches and from the soil, and by plant transpiration.

4.1.1.2.2 MATERIAL AND METHODS

The first experiment was designed to determine whether of not the water is imperfectly renewed when the farmers pump the water out of their fields and then refill the ditches. Water samples were taken from the canal and from the ditches at three locations (near the outlet, in the middle of the field and far from the outlet) just after or shortly after the water had been renewed in the ditches. These samplings were made in the three fields equipped with only one outlet.

The second experiment was designed to determine whether or not the ions concentrate in the ditch water by evaporation and transpiration. Water samples were taken twice a week from three locations in the ditches of Bamrung’s field. The experiment began the day Bamrung had changed the water of the ditches and lasted for 26 days. As this experiment was carried out at the end of the dry season (late April and May), Bamrung had to pump some water into the field every 5 days or so.

4.1.1.2.3 RESULTS

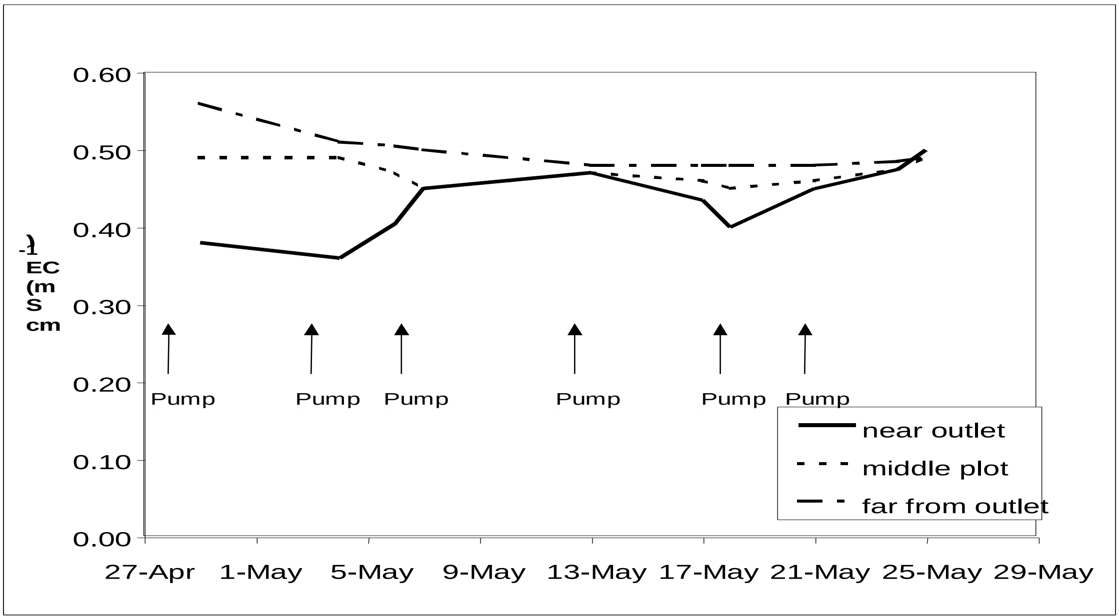
For the samples collected just after the water was pumped into the field, the different chemical parameters were higher far from the outlet than near to it for the three cases studied (Table 14). There was a gradient of values from the canal to the ditches located far from the outlet.

TABLE 14: PARAMETERS OF THE WATER IN THE CANAL AND IN THE DITCHES AFTER WATER WAS PUMPED IN TO THE FIELD

		Canal	Ditches		
			Near outlet	Middle field	Far from outlet
Nipat	PH	6.4	6.7	6.9	6.9
Just after pump in	EC (mS cm^{-1})	0.29	0.36	0.58	0.70
Pra Thuang	PH	6.3	6.3	6.9	7.3
4 days after pump in	EC (mS cm^{-1})	0.45	0.46	0.54	0.57
Bamrung	EC (mS cm^{-1})	-	0.38	0.49	0.56
Just after pump in	Na	-	15.0	22.1	29.0
	K	-	2.7	3.1	3.9
	Suspended solids (mg l^{-1})	-	24	30	35
	Alkalinity	-	280	325	348

For the samples collected in Bamrung's field for 26 days after water had been changed, the electrical conductivity of the ditch water near the outlet was modified every time the farmers added water from the canal (other data in appendix 7). But the electrical conductivity in the ditch far from the outlet decreased slowly with time to become close to the value near the outlet after 26 days.

FIGURE 64: CHANGE IN ELECTRICAL CONDUCTIVITY WITH TIME IN THE DITCHES AFTER PUMPING OUT (BAMRUNG'S FIELD)



4.1.1.2.4 INTERPRETATION

We know from the monthly changes in water composition that most chemical parameters of the water of the ditches are higher far from the outlet than close to it during the dry season. The gradient of values from the canal to the farthest ditch proves that the water was imperfectly renewed when the farmers changed the water.

As the electrical conductivity is directly related to the total amount of ions in solution, the fact that electrical conductivity did not increase during the 26 days of the second experiment proves that there was no increase in ion concentration by soil and water evaporation and plant transpiration.

4.1.1.2.5 GENERAL INTERPRETATION OF THE COMPOSITION OF THE WATER OF THE DITCHES

The composition of the water of the ditches seems to be related to two main factors. The composition of the water of the canal determines the sodium content in the ditch water and, to a lesser extend, the potassium content. The variations in these concentrations with time are dampened by the imperfect renewal of water when the fields are equipped with only one outlet.

The activity of the phytoplancton increases water pH, alkalinity and dissolved oxygen in the ditches, and more so far from the outlet where the water in not as well renewed as near to it.

4.1.2 Soil of the raised beds

4.1.2.1 Spatial variability of the soil properties in the field

4.1.2.1.1 INTRODUCTION

In the case the fields have only one outlet, some farmers complain that the yield is lower far from the outlet than next to it.

The difference in yield far and near the outlet was investigated in two fields where farmers had noted a difference in yield. Nipat measured the yield on 12 April 1998 by dividing his field into two equal parts and weighing the total amount of grapes harvested on each half. He found 1,500 kg on the half near the outlet and 900 kg on the other half.

The yield was measured in Pratueng's field on 4 February 1999. Three plots made of 5 vines in good condition were chosen near the outlet and three other at the furthest extremity of the field. Grapes were weighed immediately after harvest.

TABLE 15: GRAPES WEIGHT NEAR AND FAR FROM THE OUTLET IN PRATUENG'S FIELD (4 FEBRUARY 1999)

	Near the outlet	Far from the outlet
Replicate 1	67.6	40.1
Replicate 2	62.8	44.4

Replicate 3	57.2	37.5

The yield was 40% lower in Nipat's field and 35% lower in Pratueng's field far from the outlet, compared to near to it (Table 15). As the difference in yield can reflect a difference in soil properties, the spatial variability of chemical soil properties was investigated fields where the farmers had noted a difference in yield.

4.1.2.1.2 MATERIAL AND METHODS

Soil was sampled on the beds closest to and furthest from the outlet in three fields (Nipat, Bamrung and Pratueng). The soil samples were taken from the surface to 50 cm depth by 10 cm depth increments using a 8 cm diameter auger. On each bed five holes were drilled five meters apart of a line located in the middle of the bed. The samples from the same depth were bulked together to form a composite sample.

Soil samples were air-dried, then analysed for pH, particle size distribution and exchangeable cations (analytical methods in appendix 3).

4.1.2.1.3 RESULTS

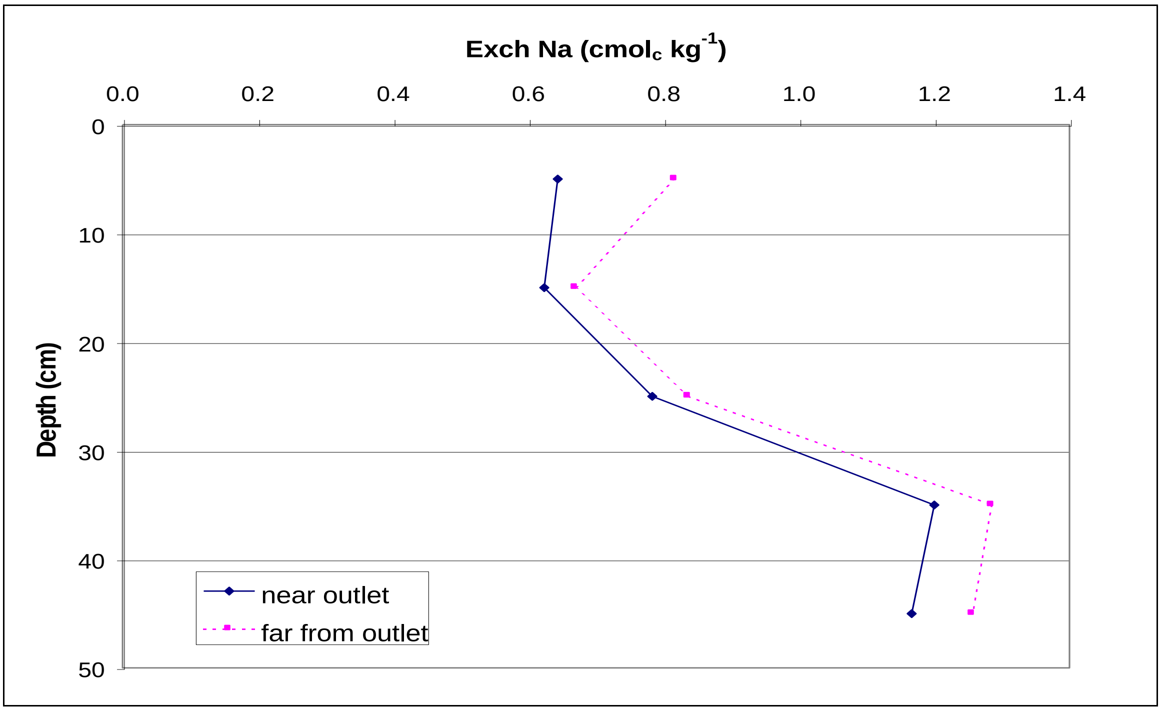
The three soils are heavy clay soils (around 50% clay and 45% silt), with little difference between depths and between profiles (Appendix 8). The exchangeable bases near and far the outlet did not show any systematic difference (Table 16). The only difference was in the pH $CaCl_2$ values, always higher far from the outlet than near to it.

TABLE 16: SELECTED SOIL PROPERTIES NEAR AND FAR FROM THE OUTLET (0-10CM LAYER)

	PH H_2O		PH $CaCl_2$		Exch Ca		Exch Mg		Exch K		Exch Na	
	Near	far	near	far	near	far	near	far	near	far	near	Far
Nipat	6.2	6.9	5.9	6.4	27	24	7.2	7.0	2.8	2.3	0.6	0.7
Bamrung	5.8	6.2	5.0	5.7	18	21	4.6	6.2	1.9	1.8	0.6	1.0
Pra Thuang	6.2	5.3	4.7	4.9	24	22	5.8	5.5	3.0	3.0	0.8	0.7

The distribution of elements within the profile was the same near the outlet as far from it (Figure 65 and appendix 8).

FIGURE 65: EXCHANGEABLE NA IN THE SOIL NEAR AND FAR FROM THE OUTLET (AVERAGE 3 FIELDS)



4.1.2.1.4 INTERPRETATION

The only difference in soil properties between the profiles near the outlets and the profiles far from it is a higher soil pH far from the outlet. As the lowest soil pH is 5.8, a lower pH does not seem sufficient to explain the drop in yield.

A difference in yield related to the position of the outlet is not frequent in the region. Only 1 out of the 25 farmers surveyed (paragraph 1.2.) has noted such a problem. Thus spatial variability is not a major issue for grapes cultivation in the Damoen Saduak region.

The three profiles studied provide however some insight on the present processes of soil evolution. As some elements are more abundant in the ditch water far from the outlet during the dry season, part of them could accumulate in the soil as a consequence of transpiration of the plant and the evaporation form the soil surface. As sodium is the most abundant anion in the water and as sodium is easily displaced in solution, sodium should be the first to accumulate in the soil. Figure 39 proves that there was no such accumulation.

The main explanation is that the farmers irrigate the soil several times a week during the dry season. This irrigation must prevent any capillary rise and accumulation of salts within the soil profile.

According to soil samples collected in the region in 1971, topsoil pH H_2O was then 7.4 on average (Department of Land Development, analysis of the Damnoen Saduak soil series). Thus the soils have been acidified in the last 27 years as a consequence of agricultural activities (probably mainly by leaching of nitrate). As the alkalinity of the water is higher far from the outlet than near to it by 27 mg/l as $CaCO_3$, the use of the ditch water to irrigate the beds has added more alkalinity to the soil far from the outlets, which can explain the spatial distribution of soil pH.

4.1.2.2 Distribution of the chemicals within the soil profile

4.1.2.2.1 INTRODUCTION

The intensive systems developed on the raised bed systems require a large use of pesticides and chemical fertilisers. We made the assumption that some elements accumulate in the soil profile as a result of addition of fertilisers and pesticides.

4.1.2.2.2 MATERIAL AND METHODS

Two sets of soil data were used. The first one is made of the results of the soil samples analysed to determine the spatial variability of the soil properties. As we have seen that there was no spatial variability in the plots studied (except for pH in calcium chloride), we used the average of the data obtained near the outlet and far from the outlet. As a result, the values obtained for each depth are an average of 10 different soil profiles.

The second set of data is made of the results of soil profiles analysed in 1971, when the region was first surveyed (Department of Land Development, unpublished data). This set of data is made of 5 different profiles. The data available are from soil samples from the 0-30 and 40-45 cm layers. We made the assumption that the average values from these five profiles give a rough estimate of the situation 27 years before the other soil samples were taken.

For Nipat's and Pratueng's fields the amount of phosphorus and potassium accumulated in the soil profiles was calculated by difference between the two sets of data, using a bulk density of 1.3 t m^{-3}. As copper and zinc had not been analysed in 1971, the amount of copper and zinc accumulated in the soil profiles was calculated making the assumption that the initial content was the value found in the 40-50 cm layer in 1998.

Bamrung's field was turned over 10 years ago, which explains nearly constant values for most soil parameters below 10 cm. Phosphorus, potassium, copper and zinc accumulation in this field was calculated in the 0–10 cm layer using the average content in the 10-50 cm as a reference and a bulk density of 1.3 t m^{-3}.

4.1.2.2.3 RESULTS

Total phosphorus and Bray II extractable phosphorus were extremely high in all three fields (Table 17 and Appendix 8). Such high values are usually found only in soils that have been irrigated with sewage sludge.

TABLE 17: AVERAGE SOIL CONTENT IN P, K, CU, ZN AND CD IN 1998 (0-10 CM LAYER)

	P Bray II mg kg^{-1}	Total P mg kg^{-1}	Exch. K cmolc kg-1	Cu EDTA mg kg^{-1}	Total Cu mg kg^{-1}	Total Zn mg kg^{-1}	Total Cd mg kg^{-1}
Nipat	2264	3213	2.5	34	115	163	0.3
Bamrung	1046	1773	1.8	98	238	158	0.2
Pratueng	1410	2908	3.0	52	158	180	0.4

If most phosphorus has accumulated in the surface horizon, some has migrated down to 40 cm depth (Figure 66). A close relationship appeared for each field between total phosphorus and Bray II extractable P (Figure 67 for Nipat's field, other relationships not shown). These relationships were used to calculate the accumulation of total phosphorus from the Bray II extractable P values (Table 18).

FIGURE 66: TOTAL P AND BRAY II EXTRACTABLE P IN THE SOIL (PRATUENG'S FIELD)

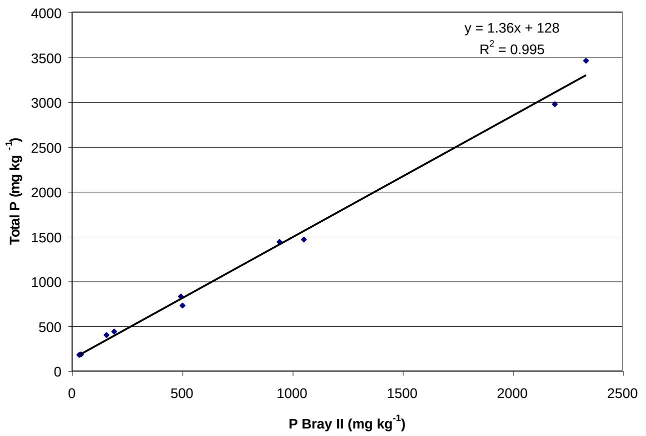


FIGURE 67: RELATIONSHIP BETWEEN TOTAL P AND BRAY II EXTRACTABLE P (NIPAT'S FIELD)

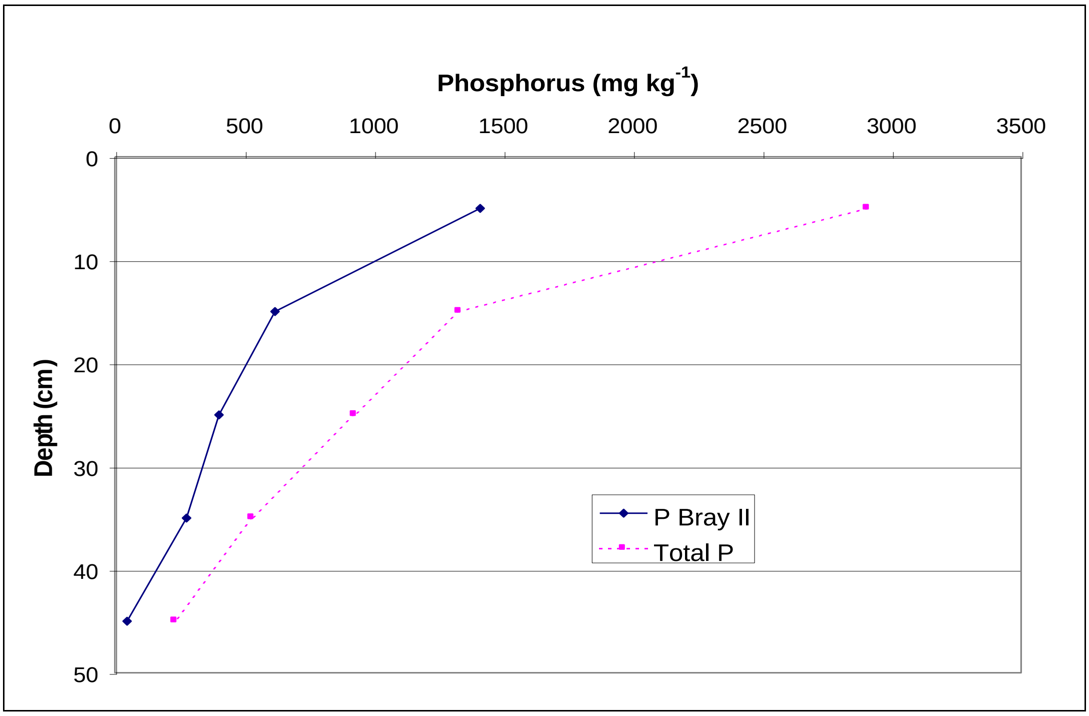


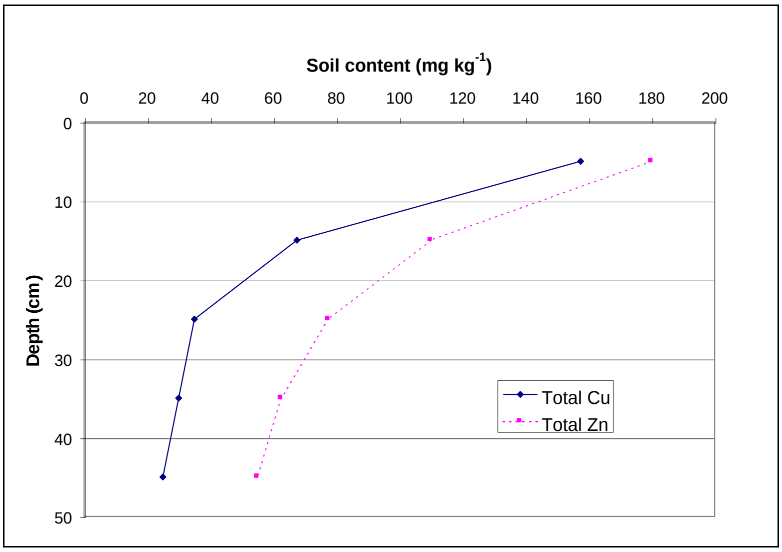
TABLE 18: INITIAL CONTENT AND ACCUMULATION OF PHOSPHORUS, POTASSIUM, COPPER AND ZINC IN THE SOIL (KG HA –1)

	Depth	Initial content	Accumulation		
			Nipat	Pratueng	Bamrung
	(cm)	(1971)	(27 years)	(27 years)	(10 years)
Total P	0-30	341	2272	1814	(0-10cm) 722
	30-50	128	241	563	
	0-50	470	2512	2377	
	Increase per year		**93**	**88**	**72**
Exch. K	0-30	1095	1798	2186	(0-10cm) 64
	Increase per year		**26**	**40**	**7**
Total Cu	0-30	-	94	138	(0-10cm) 103
Total Zn	0-30	-	119	150	(0-10cm) 42

In Nipat's and Pratueng's fields the accumulation of phosphorus was around 2.4 t ha-1 over 27 years, or 90 kg P ha^{-1} $year^{-1}$ in the 0-50 cm layer. Potassium also accumulated to very high values of exchangeable potassium (1.8 to 3.0 $cmol_c$ kg^{-1}, Table 13), which represents an accumulation of around 30 kg K ha^{-1} $year^{-1}$ in the 0-30 cm layer.

Zinc and copper increased in the soil profile to 40 cm depth (Figure 68). The accumulation was 116 kg Cu ha^{-1} and 135 kg Zn ha^{-1} over 27 years on average. In the topsoil the amount of total Cu was above the values permissible in most developed countries (50 to 100 mg kg^{-1}) and the amount of Cu extracted by EDTA was near the critical value (100 mg kg^{-1}). The amount of Zn in the topsoil was near 150 mg kg^{-1}, the permissible value in most developed countries (ADEME, 1995).

FIGURE 68: TOTAL CU AND ZN IN THE SOIL (PRATUENG'S FIELD)



The cadmium concentration in the topsoil remained much lower than the permissible values of 1 to 3 mg kg^{-1} (ADEME, 1995).

4.1.2.3 <u>Distribution of the chemicals in the topsoil</u>

4.1.2.3.1 INTRODUCTION

We have seen that the concentrations of the different elements increased in the surface horizon. As pesticides and fertilisers are applied to or fall on the soil surface, and as the soil surface is not tilled during the time the plot remains cultivated in grapes, we can expect the concentrations to be even higher in the first centimetres below soil surface.

4.1.2.3.2 MATERIAL AND METHODS

Two fields under grapes for more than 20 years were chosen. Khun Samran's field (SAN) was a 12 rai plot in Ampheu Baan Pheo, Tambon Djetriu. Khun Buunlom's field (BUL) was a 8 rai plot in Ampheu Samphran, Tambon Talart Chinda. Khun Samran destroys the old beds and build new ones every 5 to 10 years to keep a good growth. Khun Buunlom does the same every 3 to 4 years.

The soil of the two fields was sampled to 10 cm depth by 2 cm increments. The samples were taken on eight locations along a diagonal using a spade in Khun Samran's field, in six locations only in Khun Buunlom's field because the second field was smaller. For each field the samples were bulked by 2 cm depth increment to form 5 composite samples.

The samples were dried at 105°C, sieved and analysed for P Bray II, total Cu and total Zn according the methods described in appendix 3.

4.1.2.3.3 Results

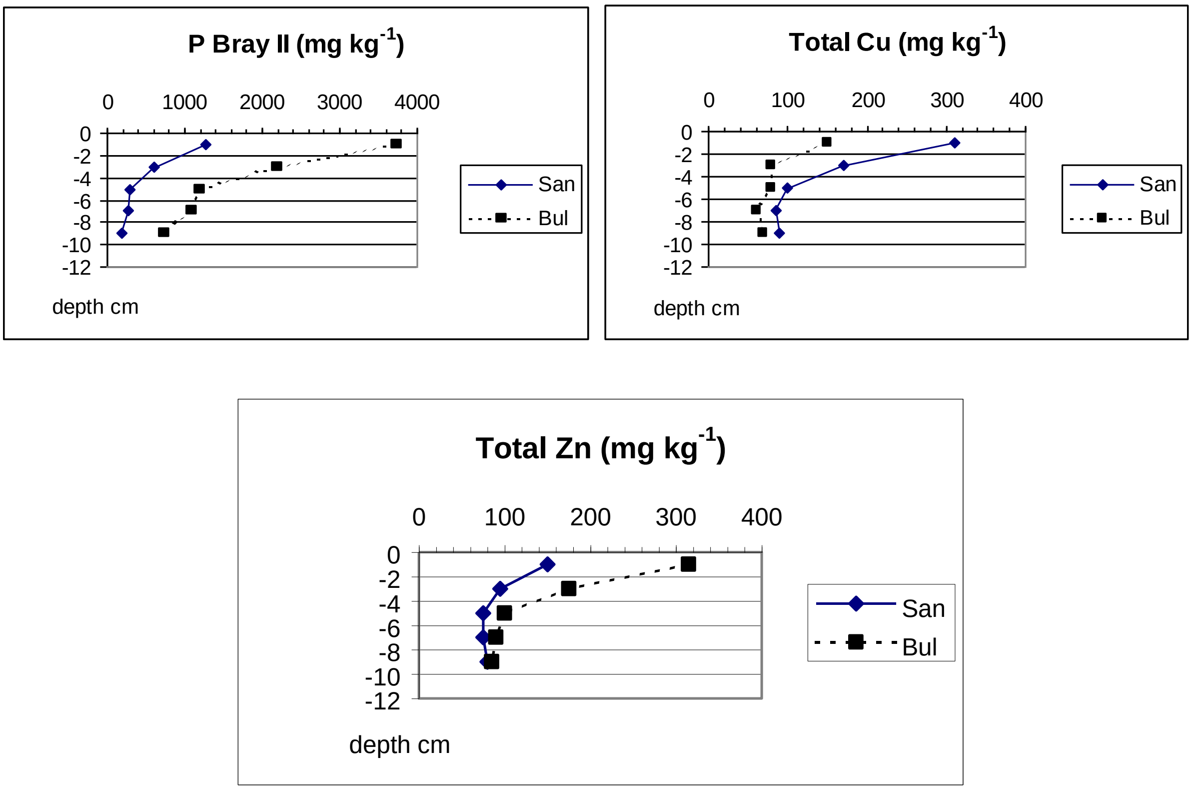
The contents in P Bray II, total Cu and total Zn were two to four folds higher in the first 2 cm than below 5 cm (Figure 69). For Cu and Zn the values in the top 2 cm were higher than the permissible values (ADEME 1995). Thus some chemicals accumulated to unsafe values in the surface horizon in 4 to 10 years of grapes cultivation.

4.1.2.4 Distribution of the chemicals under grapes cultivation in the raised bed area

4.1.2.4.1 Introduction

The concentration of chemicals near the soil surface has been found to occur in the five fields studied previously. However, all these fields were located in the small area around Damnoen Saduak where grapes has been cultivated for around 30 years. It was thus interesting to know whether the same phenomena occurred everywhere grapes was cultivated.

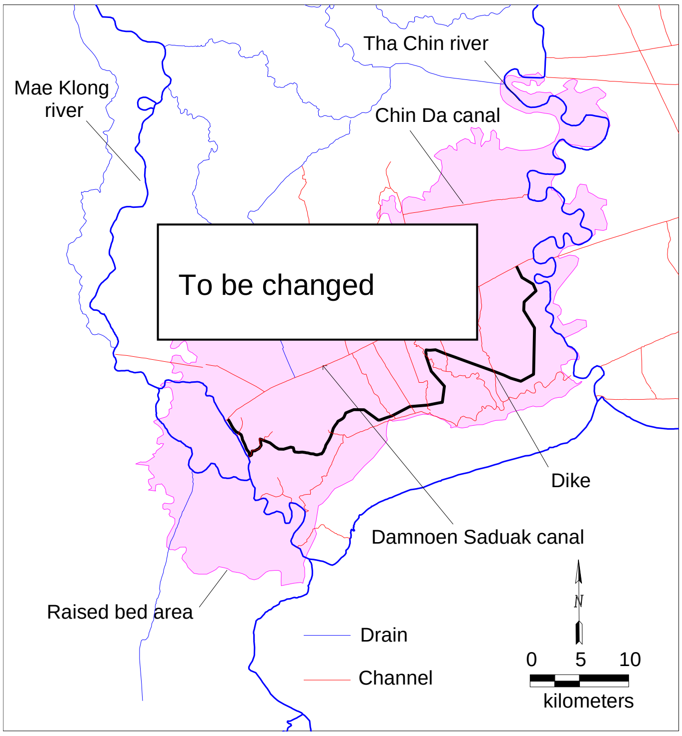
Figure 69: P Bray II, total Cu and total Zn in the topsoil (Samran's field SAN and Khun Buunlom's BUL)



4.1.2.4.2 MATERIAL AND METHODS

Ten fields were chosen across the raised-beds area to cover all the region where grapes is cultivated (Figure 70). In each field 10 soil samples were taken from the 0-10 cm layer using an auger along the two diagonals. All the samples of each field were bulked together to form a composite sample.

FIGURE 70: LOCATION OF THE VINEYARDS SAMPLED FOR SOIL REGIONAL VARIABILITY



4.1.2.4.3 RESULTS

In order to get a general overview of the topsoil properties, the three sites previously studied (Nipat, Bamrung and Pratueng) appear in the same Table as the 10 new sites (Table 13 bis). The soils of the region where grapes is grown appeared to be quite homogeneous for their particle size distribution, clay to silty clay. If on average the topsoil was slightly acidic (pH in water 5.8), they could be strongly acid (pH water 4.2), probably as the result of the excessive addition on ammonium as nitrogen fertiliser. The organic carbon content was quite low for such clayey soils (2.2 % on average, but lower than 1.5 % in 30% on the cases). Calcium was always the major exchangeable cation, and sodium remained low, showing that salinity was not a problem in these soils.

P Bray 2 was above 600 mg kg^{-1} and topped at 2860 mg kg^{-1}, with an average total P of 2733 mg kg^{-1}. Exchangeable potassium was between 1.8 and 3.9 $cmol_c$ kg^{-1}. Total copper was variable from field to field, but reached 345 mg kg^{-1}, well above the permissible levels (50 to 100 mg kg^{-1}). Zinc concentration was less variable than copper concentration, but was near 200 mg kg^{-1}, when the permissible level is 150 mg kg^{-1}.

4.1.2.4.4 INTERPRETATION

The phosphorus content in the soils studied was extremely high for agricultural soils. Such high values may be responsible for unbalances between nutrients. Phosphorus is usually strongly fixed on soil particles and applied P remains in the topsoil. However P becomes mobile above a certain concentration. The migration of P to 40 cm depth was probably the consequence of the very high concentrations on P in the surface horizons.

TABLE 19: MAIN SOIL CHEMICAL PROPERTIES OF 13 VINEYARDS IN THE RAISED-BEDS AREA OF THE CHAO PRAYA DELTA

Location	Sand	Silt	Clay	Texture	pH 1/5	pH 1/5	C	P Bray 2	Exch. Ca	Exch.Mg	Exch. K	Exch. Na	total P	total Cu	total Zn
	%	%	%		H2O	CaCl2	%	mg kg-1	cmolc kg-1				mg kg-1		
Nipat	4	42	54	SiC	6.6	6.1	2.1	2264	25.3	7.1	2.5	0.7	3213	115	163
Bamrung	4	46	50	SiC	6.0	5.3	1.8	1046	19.5	5.4	1.8	0.8	1773	238	158
Pratuang	11	48	41	SiC	5.3	4.8	5.7	1411	22.9	5.6	3.0	0.7	2908	158	180
Bua M1	4	45	51	SiC	6.6	6.2	2.7	1700	26.5	11.5	2.6	1.0	3030	345	88
Bua M2	3	44	52	SiC	4.2	4.0	1.2	1460	17.5	10.9	3.6	0.9	2650	75	110
Donkrouy M3	8	44	48	SiC	6.1	6.0	1.5	1340	23.4	6.9	2.3	0.7	2660	75	100
Donkrouy M4	4	41	55	SiC	5.6	5.4	1.4	980	22.6	8.9	2.6	0.8	1895	60	110
Chet M2	8	36	56	C	5.7	5.5	4.0	2480	22.0	9.3	3.9	1.4	6185	125	195
Chet M3	2	33	65	C	6.4	6.3	1.8	620	27.5	13.8	2.3	1.5	1265	65	85
Somchai	9	41	50	SiC	4.9	4.7	2.3	2860	16.5	7.9	2.0	0.7	3355	305	105
SRI	6	52	42	SiC	4.9	4.6	1.4	1080	14.9	6.5	2.6	0.7	2365	100	95
Thanat M5	3	39	58	C	6.9	6.8	1.0	880	26.8	9.7	2.6	1.0	1565	55	110
Donphai 2	3	40	57	C	6.0	5.9	2.0	1380	24.0	9.5	2.6	0.9	2660	130	175
Minimum	3	33	41	-	4.2	4.0	1.0	620	14.9	5.4	1.8	0.7	1265	55	85
Maximum	11	52	58	-	6.9	6.8	5.7	2860	27.5	13.8	3.9	1.5	6185	345	195
Average	5	41	53	SiC	5.8	5.5	2.2	1500	22.3	8.7	2.6	0.9	2733	142	129

Exchangeable potassium was very high in the topsoil. The increase in exchangeable K with time was much lower than the increase in total P, whilst K applied as fertiliser was higher (560 kg K ha^{-1} $year^{-1}$ on average) than P fertilisation. This difference suggests that K is strongly leached through the soil.

At present the concentrations in copper and zinc in the topsoil are usually critical but not toxic. But if the farmers keep applying the same amount of pesticides rich in Cu and Zn, toxic levels could be reached in a few years.

Cadmium is not a problem in the fields investigated, although high doses of P fertiliser have been applied. This result suggests that the farmers were supplied with fertilisers low in cadmium. In case P fertilisers high in cadmium have been used in these intensive systems, cadmium is certainly a problem.

4.1.2.5 Microbiological properties: plant pathogens and beneficial microbes

For the sustainable agriculture, it is necessary to know the environment and situation of soil-born plant pathogens and the beneficial micro-organisms in the soils in order to manage the practice properly. Therefore, the study was conducted in both field site and in laboratory to count the number of soil fungi i.e., soil-born plant pathogens and its antagonists as well as the number of nitrifying bacteria including the nitrification in soil after manure amendment to soils.

4.1.2.5.1 THE PLANT PATHOGENS AND ANTAGONIST

The causal agent of disease of grapes was mainly fungal disease. There were reports of diseases i.e. anthracnose (caused by *Colletotrichum gleosporioides* infected young and ripen fruit. The disease can either infect the young leaves or tendril resulting the dryness of stem and died after.). The fungicide commonly use to protect the infection are the chemical containing copper *i.e*., Captan, copperoxide, Cupravit etc. The disease disseminate easily under the optimum condition like rainy season (May-August). The frequency and type of fungicide used in grapes cultivated soils had been reported (Molle *et al*., 1998. Not only the causal agents on the leaves or fruits were affected but also the micro-organisms dwelling in the soils. Therefore, soils from the 4 fields *i.e.* Khun Nipat's, Khun Bamrung's, Khun Somchai's and Khun Pratueng's farm were taken and enumerated the population of soil-born plant-pathogen and antagonists in order to compare between the repeatedly-used fungicide application and seldom-used fungicide practices ones.

Soil samples were randomised collected and composite to represent the soil in the fields. The soils were transferred to the laboratory for preparation as follows: The soil sample were air dried and sieved (2mm). Ten grams of soil sample (dry basis) were put in a sterile Erlenmeyer flask with 90 sterile water and shaken with rotary shaker for 30 min. Soil suspension were serially diluted three folds. Half ml of suspension was transferred onto peptone dextrose rose-bengal agar (Martin's medium) which then spread with a flamed "L-shaped glass rod". Plates were incubated at room temperature for 2-4 day for total population, soil-borne plant pathogens and antagonist counts.

The description of the studied farms was shown in Table 14. Khun Nipat adopted the idea of biocontrol and tried avoiding pesticide application in the grapes field.

TABLE 20: DESCRIPTION OF THE 4 GRAPES FIELDS

Description	Khun Bamrung	Khun Pratueng	Khun Nipat	Somchai
Age of grapes field	7 years	3 years	6 years	8 years
prior to grape	vegetable (miscellaneous)	Sapodilla	Papaya	Mango & Banana
type of practices	Conventional	Conventional	Biocontrol	conventional

The highest population of fungi was found in Khun Nipat's field at the number of 2.45 $x10^4$ cfu.(Table 20). The soil-borned plant pathogens was not found in the grapes soils. However, the antagonist was found in some soils as shown in Table 21. The number of antagonist was found relatively high compared to those found in the soil in Rangsit (Korpraditskul et al, 1998). For agricultural practices to control the air-born disease which one stage in the life cycle are in the debris in soils, this study should be worth to cut this stage of the pathogen by the soil-habited antagonist in grapes field.

TABLE 21: THE SURVEY OF THE SOILS IN 4 CULTIVATED FIELDS (SAMPLES COLLECTED IN MARCH 1988)

Properties	Khun Bamrung	Khun Pratueng	Khun Nipat	Somchai
Pop. of soil fungi (x103)	**12.25**	**3.1**	**24.5**	**6.65**
Soil-born pathogens	**nf**	**Nf**	**Nf**	**nf**
Antagonists (x103)				
Aspergillus sp.	**6.26**	**0.875**	**14.89**	**3.64**
Penilcillium sp.	**2.39**	**1.04**	**2.845**	**1.955**
Trichoderma sp	**2.80**	**1.1**	**7.0**	**0.585**
pH	**5.3**	**6.74**	**6.55**	**na**
EC	**0.44**	**0.56**	**0.31**	**na**

***note**: Soils from near and far from the outlet were mixed thoroughly and analysed for the soil microorganisms and chemical properties*

na = not analysed

4.1.2.5.2 NITRIFICATION AND NITRIFYING BACTERIA

Practically, the grapes farmer amended nutrients various time at various rates in the field. The amount and frequency of fertiliser application in the grapes field was extremely high (Molle *et al.*, 1998). The case study of Khun Bamrung grapes field showed that nitrogen was applied at the rate of 586 kg/9 rai (ca. 65 kg per rai) of which the application frequency of 20 times in 2 cuttings. From our survey, most of the grapes farmers applied manure twice a year at the rate of 1,000 kg*/rai*. Hence, It can be indicated that the nitrogen was input into soil at the amount of 30 kg*/rai*.

Nitrification refers the reactions involved in inorganic nitrogen mineralisation when ammonium is formed in soils. When nitrogen in the manure was introduced to soils, organic nitrogen can not directly be converted to nitrate, and ammonium generally first be liberated as a consequence of the mineralisation process. Previous study showed that ammonium and nitrate at the top soil level were found in the range of 0-3.0 mgN/100 g soil and 2-18.0 mgN/100 g soil, respectively(Molle. et al, 1998). In order to know the nitrification in the soil and the change of the nitrification after fertiliser amendment, ammonium and nitrate in the soils of Khun Bamrung, Khun Nipat and Khun Pratuang was analysed by steam distillation (Page, 1982). Nitrification activity was measured by the bottle-incubation method (Kimura 1986). Figure 71 shows that ammonium was highest in Khun Pratueng's field *i.e*. 14.32 mg/100 g soil whereas the ammonium content found in Khun Bamrung and Khun Nipat's soils were 2.01 and 2.60 mg/100 g soil, respectively. The nitrate content in the three fields are as follows 6.55, 7.51 and 9.23 mg/100 g soil. The nitrifications were in the same range as those found in previous year. Fertiliser application prior to soil sampling differed field to field. The relatively high concentration of ammonium found in Khun Pratueng's field than those other two farms probably due to that Khun Pratueng just applied cow manure and fertilisers a few days prior to sampling date or nitrification of Khun Pratueng soils probably be suppressed. From the three studied soils, the highest amount of nitrate in Khun Nipat's soils indicating slightly higher nitrification activity than those in the other two soils.

To obtain more information for nitrification process after manure application, the same soil from Khun Pratueng field was analysed again 3 months after. Fig. 43 shows that ammonium content decreased rapidly to the amount similar to those found in Khun Nipat and Khun Bamrung's soils while nitrate was not much changed. The nitrifying bacteria was enumerated under the treatments of high rate and low rate of cow manure application in the laboratory conditions. The soils from Khun Pratueng's field were collected and transferred to the laboratory for preparation. Ten grams of fresh soil (dry weight basis) was put into a glass bottle. Moisture content was adjusted to 50% of the maximum water holding capacity (MWHC). Cow manure was amended into soil sample at the high and low rates (2.75 and 0.18 g. into 10 g soil equal to N content of 8 and 1.5% N in soil) Control was carried without putting cow manure. Soil sample was incubated for 0, 15, 30, 45 and 60 days at 30^o under dark condition. The whole soil sample was extracted with 100 ml. of NaCl solution (0.7%) to obtain soil solution. The numbers of ammonium oxidiser and nitrite oxidiser in soil were estimated by the most probable numbers (MPN) method using NH^{+}_{4} and NO^{-}_{2} ions as sole nitrogen source.

FIGURE 71: AMMONIUM AND NITRATE CONTENT IN GRAPES CULTIVATION SOIL

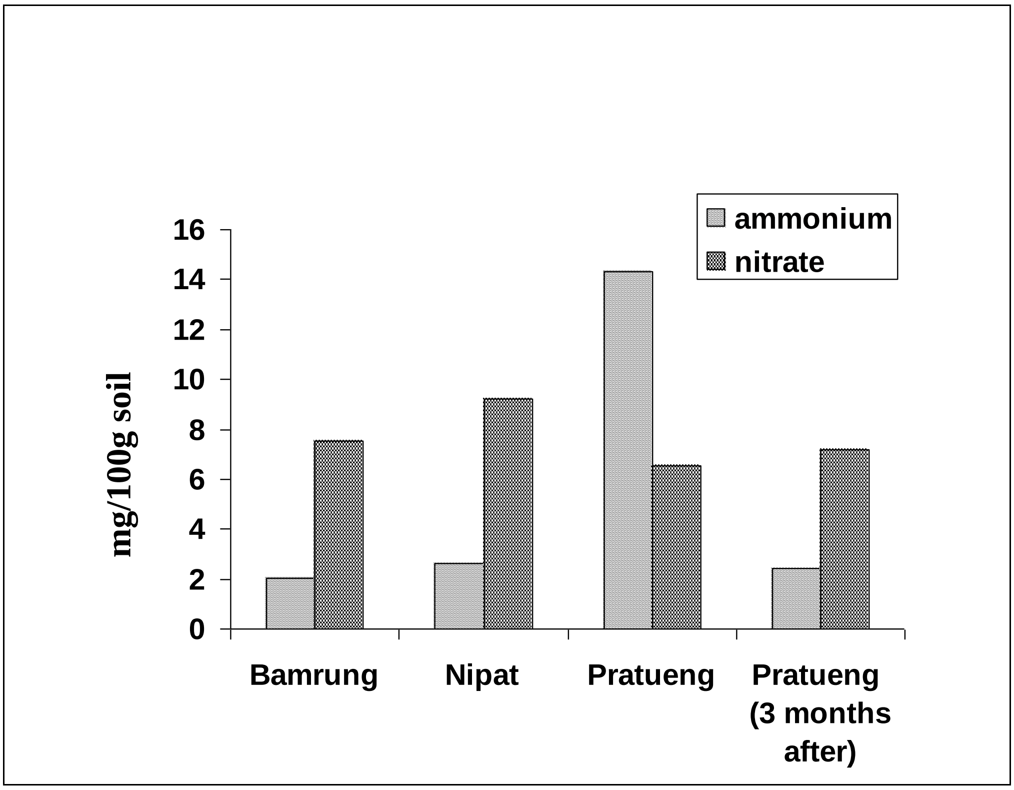


Figure 70 and Figure 71 shows the number of ammonium oxidisers and nitrite oxidisers during incubation period. The number of ammonium-oxidiser occurred in a relatively higher in the low and high rate application compare to the treatment with no manure application after 45 days of incubation. The number of nitrite oxidiser was always higher in the treatment of high rate application than the low rate application except at 45 days after incubation. This indicated that the high amount of cow manure amended into soils did not increase the number of nitrifying bacteria. Figure 72 and Figure 73 shows ammonium and nitrate contents during the incubation period. Ammonium content in the soils did not show the respective amount corresponded to the high or low input of cow manure. In consequence, the ammonium content in the treated soils was never exceeded 10 mg/100 g soil whereas nitrate was found slightly higher in the same soils.

FIGURE 72: THE MOST PROBABLE NUMBER OF AMMONIUM OXIDIZERS IN THE SOIL AMENDED WITH COW MANURE

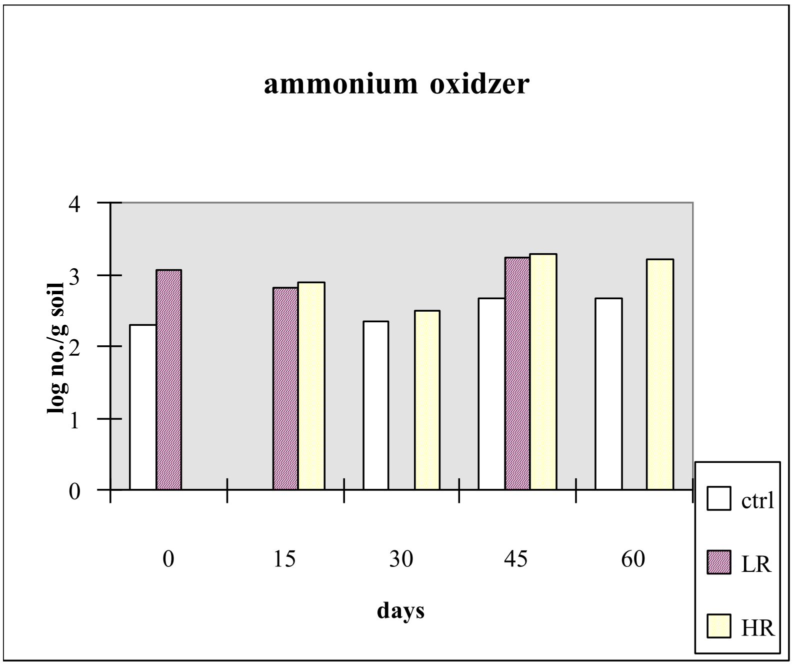


FIGURE 73: THE MOST PROBABLE NUMBER OF NITRITE OXIDIZERS IN THE SOIL AMENDED WITH COW MANURE

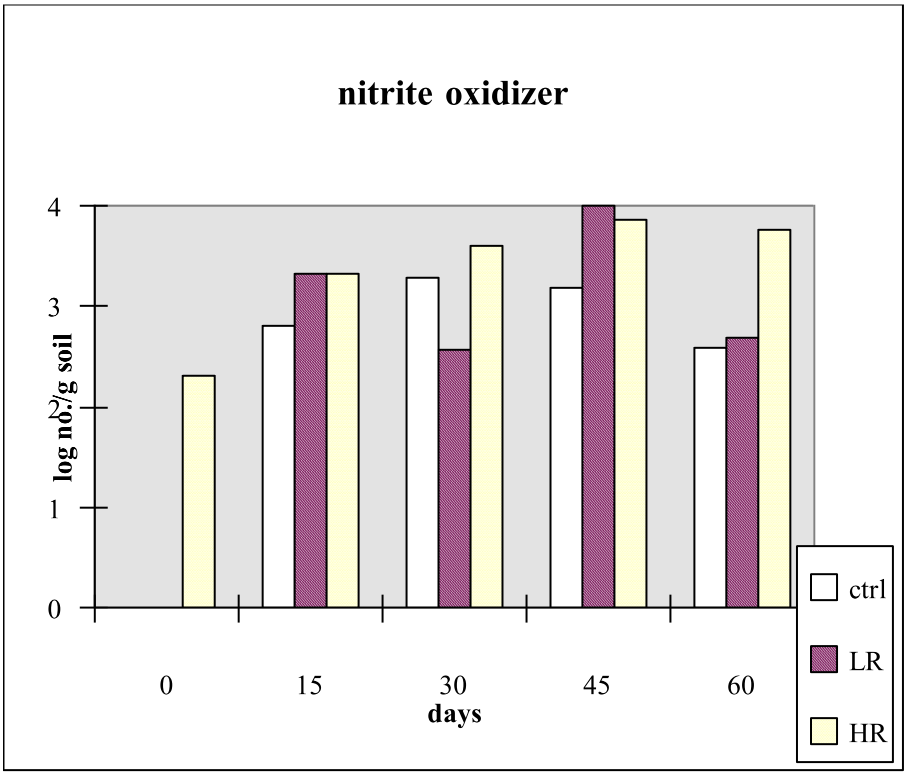


FIGURE 74: AMMONIUM IN THE COW MANURE AMENDED SOIL

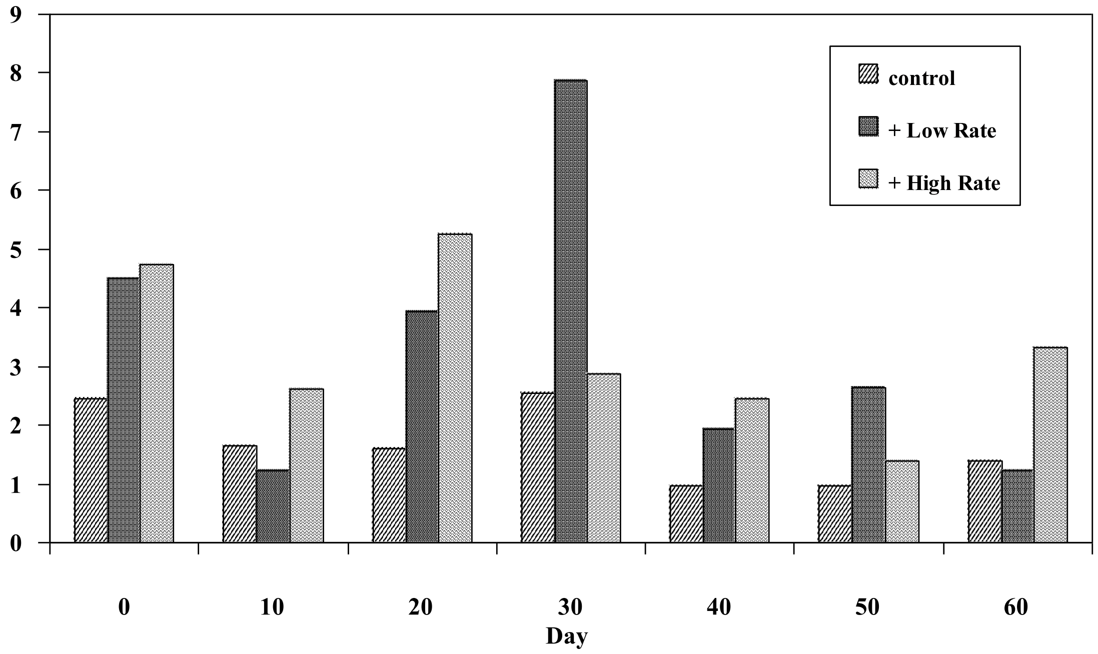
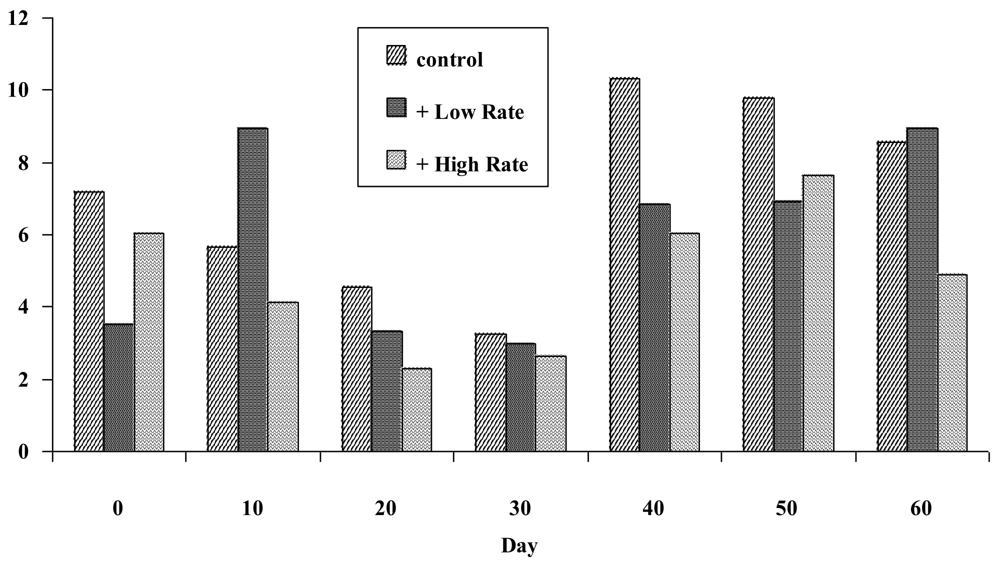


FIGURE 75: NITRATE IN THE COW MANURE AMENDED SOIL



Although cow manure increased the number of ammonium oxidiser but in a negligible number compared to their effect to nitrite oxidiser (higher than one order). Low rate and high rate of cow manure application apparently showed no effect to nitrification activities probably due to less effect to the nitrifying bacteria. The studies of nitrification in saline soils of Khon Kaen region suggested the low activities of nitrification due to the high salinity (Murase *et al.*, 1994). In our study, the number of nitrifying bacteria was more than one order higher than those found in saline soils.

4.1.3 Soil-water relationships

4.1.3.1.1 INTRODUCTION

The transfer of elements through soil profile can be monitored by studying the composition of the soil solution and its transfer. Moutonnet e*t al.* (1993) have suggested the use of a soil solution sampler called Tensionic made of a ceramic cup of small diameter (volume 12 ml) full of water that equilibrates with the soil solution by diffusion through the cup wall. This sampler was tested in 1998 to investigate the transfer of elements and pesticides through the soil profile.

4.1.3.1.2 MATERIAL AND METHODS

Five Tensionic instruments were installed at 20 cm and 50 cm in the bed near the outlet in Bamrung's field, each couple of instruments being 5 meters apart from the next one. The soil solution was collected every month. The solution from each depth was bulked to form a composite sample, as 25 ml were needed to determine the pesticide content. The samples were analysed for pH, electrical conductivity, sodium, nitrate, potassium, phosphorus and copper (see analytical methods in appendix 3), and for pesticide content (carbamates and organophosphates) by the enzymatic method (appendix 3).

4.1.3.1.3 RESULTS

Soil solution samples could be collected at 50 cm (capillary fringe) for each date, unlike 20 cm because of a drier soil (Table 20).

The pH was about the same at 20 cm as at 50 cm. The pH measured in the Tensionic instruments in the field was less than 0.5 pH unit different from the pH of the water in the ditches. The pH measured in the laboratory was always higher than the pH measured in the field, the difference being sometimes as high as 1.3 units.

The electrical conductivity was lower at 20 cm than at 50 cm, and the electrical conductivity of the soil solution at 50 cm was around three times higher than the electrical conductivity of the water in the nearby ditch (0.6 to 0.9 mS cm^{-1}, see earlier section).

Pesticides were detected at 50 cm in half of the samples.

Large changes in nitrate concentrations were recorded at both 20 cm and 50 cm, with a sharp drop in August at 20 cm and in October at 50 cm. The concentrations at 50 cm were much higher in the bed than in the nearby ditch (0.3 to 1.0 mg N l^{-1}).

Large changes in ammonium concentrations were recorded at both levels. At 20 cm the highest value was measured in September shortly after N fertiliser had been applied. The concentrations at 50 cm were much higher than the concentrations in the nearby ditch (0.03 to 0.10 mg N l^{-1}).

Some phosphorus was found at 20 cm, but none at 50 cm. Potassium was higher at 20 cm than at 50 cm, and the concentration was lower in the soil than in the ditch (4 to 7 mg K l^{-1}). Sodium was lower at 20 cm than at 50 cm, and the concentration was much higher in the soil than in the ditch (36 to 65 mg Na l^{-1}). Copper was detected at both depths at comparable concentrations with those measured in the ditch (10 to 57 ?g l^{-1}).

TABLE 22: COMPOSITION OF THE SOIL SOLUTION COLLECTED WITH THE TENSIONIC INSTRUMENTS (BAMRUNG'S FIELD)

Depth	Parameter	Unit	02/07	28/07	27/08	25/09	29/10	24/11
20 cm	pH (field)		7.1	6.8	6.3	6.4	6.8	Ns
	pH (lab.)		7.8	8.0	7.8	-(1)	7.3	Ns
	EC (lab.)	mS cm-1	2.03	1.44	1.25	ns	1.20	Ns
	Pesticides		no	No	ns	ns	ns	Ns
	NO3-N	mg N l-1	ns	17.3	4.7	0.83	0.20	Ns
	NH4-N	mg N l-1	ns	0.90	0.84	2.24	0.03	Ns
	P	mg H2PO4 l-1	ns	0.27	0.57	ns	0.42	Ns
	K	mg K l-1	ns	14.4	10.5	ns	10.1	Ns
	Na	mg Na l-1	ns	109	89	ns	85	Ns
	Cu	?g Cu l-1	21	29	9	52	42	Ns
50 cm	pH (field)		7.0	6.9	6.3	6.7	7.2	6.9
	pH (lab.)		8.1	8.0	7.6	8.0	7.6	7.4
	EC (lab.)	mS cm-1	2.89	2.53	2.25	2.19	2.30	1.50
	Pesticides		no	yes	no	yes	yes	No
	NO3-N	mg N l-1	8.43	18.42	19.40	12.46	0.42	0.46
	NH4-N	mg N l-1	0.84	1.57	0.71	0.62	0.64	0.56
	P	mg H2PO4 l-1	0.00	0.00	0.00	0.00	0.01	0.00
	K	mg K l-1	3.12	3.51	2.34	2.34	2.34	2.34
	Na	mg Na l-1	310	270	240	235	230	205
	Cu	?g Cu l-1	12	29	4	15	23	29

(1) not measured Ns: no sample

4.1.3.1.4 INTERPRETATION

The large increase in pH between the field and the laboratory suggests a high concentration in bicarbonate (probably related to microbiological respiration) that transforms to carbon dioxide when the soil solution gets in contact with the atmosphere.

As nitrate, ammonium and sodium concentrations were higher in the soil solution than in the ditch, and as leaching is large in the system (irrigation several times a week), these ions move from the soil to the ditch by both diffusion and mass flow. As a result the sodium initially contained in the soil is progressively released into the ditches, and some of the nitrogen applied in large quantities as fertiliser escapes from the soil.

As potassium content was lower in the soil than in the ditch, potassium tends to migrate from the ditch to the soil by diffusion and from the soil to the ditch by mass flow.

Phosphorus is transferred from the soil surface to 20 cm, but does not reach 50 cm depth. This result is in agreement with the sharp decrease in soil phosphorus with depth and the fact that P does not migrate in clayey soils when soil P is low.

The fact that pesticides and copper were found at both depths proves that they can migrate trough 50 cm of soil and that they can end up in the water of the ditches by mass flow. This result is somehow surprising, as pesticides and copper fix strongly on soil particles.

Finally the Tensionic instruments have proved to be suitable to follow the changes in concentrations in the soil solution with time for several elements and particularly pesticides, the main limitation to their use being the dry soil near the surface.

4.2 Pesticide application and impact on water quality

4.2.1 Pesticide residues in water

The objective of the study was to investigate the fate of pesticides applied to the fields. Therefore, the amount of nutrients and pesticides discharged from the fields into the canal were studied. Water samples were collected and analyzed for physico-chemical properties, including pesticide contamination. The accumulation of elements in the soil profile was investigated in three different fields by taking soil samples to 50 cm depth.

Insecticides and fungicides are usually applied in combination every 4 days. The most commonly used pesticides are methomyl, chlorphenapyr, methamidophos, amitraz and copper oxychloride.

A regional survey showed that 28% of the water samples were contaminated, out of 148 samples taken along the canals. Further studies proved that monochrotophos and dimethoate, two widespread insecticides were present at a concentration between 0.6 to 13.4 ug L^{-1}. At these concentrations the pesticide are not a hazard to aquatic life and human health.

4.2.2 Some organophosphate residues in water

Pesticide in the canal, ditch as well as along the channels were detectable by choline esterase inhibition techniques. Sixty water samples from the ditch in vineyard were analyses during May 1998-February 1999. It was found that 10 water samples were contaminated by pesticides. As this techniques was qualitatively shown the contamination by organophosphorus and carbamate chemical compound. Therefore, it is important to know what they are and the concentration of those compounds.

Objectives: 1. To study the limit of detection by enzyme choline esterase
2. To analyze the concentration of the pesticide in water

Therefore, quantitative analysis of organophosphate pesticide residues in water samples were intensively undertaken. Sixty samples from the ditch in the raised bed were collected during May 1998-February 1999 to be checked for pesticide residues by enzyme techniques. Monocrotophos and dimethoate, the most region-wide insecticide in the vineyard were analyzed by Acetylcholine esterase inhibition techniques. Nineteen samples from sixty water samples were found contaminated or 31.7 percent of total samples were positive. Further analysis by Gas Chromatograph were carried out in Environmental Science Lab. The results of dimethoate and monocrotophos residues are shown in Table 23 and Table 24. Dimetoate and monocrotophos were detected in the range of 0.54-11.63 and 1.19-113.37 μg/l, respectively. This concentration was not acutely toxic to fish (Hartley and Kidd, 1991). To compare the level of residue to the Maximum Allowable Concentration, it was found that monocrotophos residues were slightly higher.

4.2.3 Conclusions

1. Agricultural practices *i.e.*, fertilizer application, did not deteriorate quality of water in the ditch compare to water quality in the contiguous canal.
2. From 88 water samples, 29 water samples from both canal and ditches were contaminated.
3. Some organophosphate, *i.e.* dimetoate and monocrotophos were detected in the range of 0.54-11.63 and 1.19-13.37 μg/l, respectively. This concentration was not severely toxic to fish.

TABLE 23: DIMETHOATE RESIDUES IN WATER FROM FIELD 1 AND 2

Month 1998-99	Field 1 (Khun Bamrung)		Field 2 (Khun Pratueng)	
	Range (ppm)	Average	Range (ppm)	Average
May	-	-	6.66-7.05	6.85
June	-	-	-	-
July	-	-	-	-
August	1.55-5.07	2.96	0.94	0.94
September	0.93-1.51	1.22	-	-
October	-	-	-	-
November	-	-	-	-
December	0.54-0.91	0.68	-	-
January	8.42-11.63	10.02	3.64	3.64
February	2.14	2.14	0.96-1.511	1.23

Range	0.54-11.63	0.68-10.02	0.94-7.05	0.94-6.85

TABLE 24: MONOCROTOPHOS RESIDUES IN WATER FROM FIELD 1 AND 2

Month 1998-99	Field 1 (Khun Bamrung)		Field 2 (Khun Pratueng)	
	Range (ppm)	Average	Range (ppm)	Average
May	-	-	-	-
June	-	-	-	-
July	-	-	-	-
August	1.19-4.63	3.2	6.80-7.11	6.91
September	7.28-13.37	110.32	-	-
October	-	-	-	-
November	-	-	-	-
December	2.41-5.83	4.18	-	-
January	-	-	7.73	7.73
February	9.72	9.72	2.16-3.47	2.82
Range	1.19-13.37	3.20-10.32	2.16-7.73	2.82-7.73

4.3 Off-site effects of grapes cultivation

4.3.1 Discharge from the plot to the canal

4.3.1.1 Hypothesis and methodology

4.3.1.1.1 WATER OUTFLOW AND DISPERSION OF POLLUTANTS

Farmers who cultivate raised bed plots are used to controlling the level of water in the ditches all along the year. The main reason are the renewal of the poor quality water in the plot and the removal of excess water induced by rain, inflow by seepage through the dikes or due to a bad closure of the pipe (Molle *et al.*, 1998). Finally, independently of the farmer, outflow of water from the field to the canal happens sometimes because of seepage through the dike.

Given that a large volume of water is discharged from the plot to the canal next to it (24540 m3 from December 1995 to September 1996), we assumed that in the same time the plot pollutants were flushed out to the canal. Water which stagnates in the plot between two outflows provoked by the farmer may be enriched in nutrients, heavy metals and pesticides because of the application of input in-between or the leaching of elements from the raised beds.

4.3.1.1.2 SURVEY OF THE OUTFLOWS BY PUMPING

Given that the outflow by pumping represent more than 90% of the total outflow (Molle *et al.*, 1998), we decided to survey only the outflows by pumping. In agreement with the farmer, we recorded each time the duration of pumping. In order to assess the volume of the outflow by pumping, we checked the flow rate of the farmer's pump by measuring the time needed to fill a 200l container.

Moreover we noted also the number of occurrences of outflow by gravity and we compared with the volume measured by Molle *et al.* (1998). We used also their data concerning the volume of seepage (2.70% of the total outflow).

4.3.1.1.3 ASSESSMENT OF THE QUALITY OF THE WATER DISCHARGED TO THE CANAL

With the farmer's help, we took a water sample each time he pumped out. Samples were analysed at the Environmental sciences laboratory at Kasetsart University and also at the Department of land development. Methods of analysis are listed in Appendix 3.

♦ Parameters

Different parameters were analysed related to the physico-chemical characteristics of the water (pH, Alkalinity, Electrical conductivity, sodium, Total solids and Suspended solids) and the impact of agricultural practices on water. We measured the content in nutrients (nitrates, ammonium, Total phosphorus and potassium) and checked the presence of organophosphate and carbamate pesticides with the "pesticide test kit" (Appendix 3). We also determined the copper concentration because copper oxychloride is frequently used in grapes orchards as fungicide. Finally we analysed BOD_5 which, in assessing the activity of the micro-organisms, can reveal organic pollution.

♦ Sampling time

There were two possibilities to take water samples:

- take a composite sample, which would consist in taking 3-4 samples (1 sample every 30 minutes) bulked together (the average pumping is 1.8 h for grapes plot, Molle *et al.* 1998)
- take only one sample but at the time the water composition is representative of the water in the plot.

We chose the second method which was the most simple to set up and which required less time insofar as the farmer helped us to take samples. Before the first sampling in March 1998, we checked twice in December 1997 and January 1998 the evolution of the water quality of the outflow with time, comparing it with the water quality in the ditches.

Figure 74 and Figure 75 show the evolution with time of EC and of N, P, K concentrations in the water pumped out. Like for most of the other parameters, we observe that concentrations increase progressively for 30-40 minutes and then tend to stabilise around the concentration measured in the middle of the plot, as if it could be considered as the average water quality of the plot. From this observation resulted that samples were generally taken 30 to 45 min after the beginning of the pumping.

FIGURE 76: EVOLUTION OF EC IN WATER PUMPED OUT FROM THE GRAPES FIELD OF BAMRUNG, 23/12/97

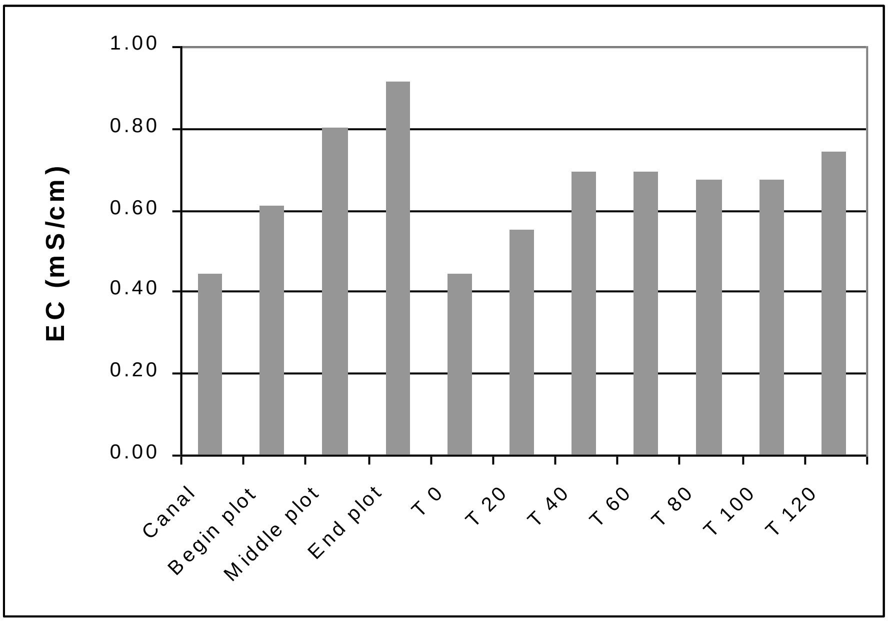
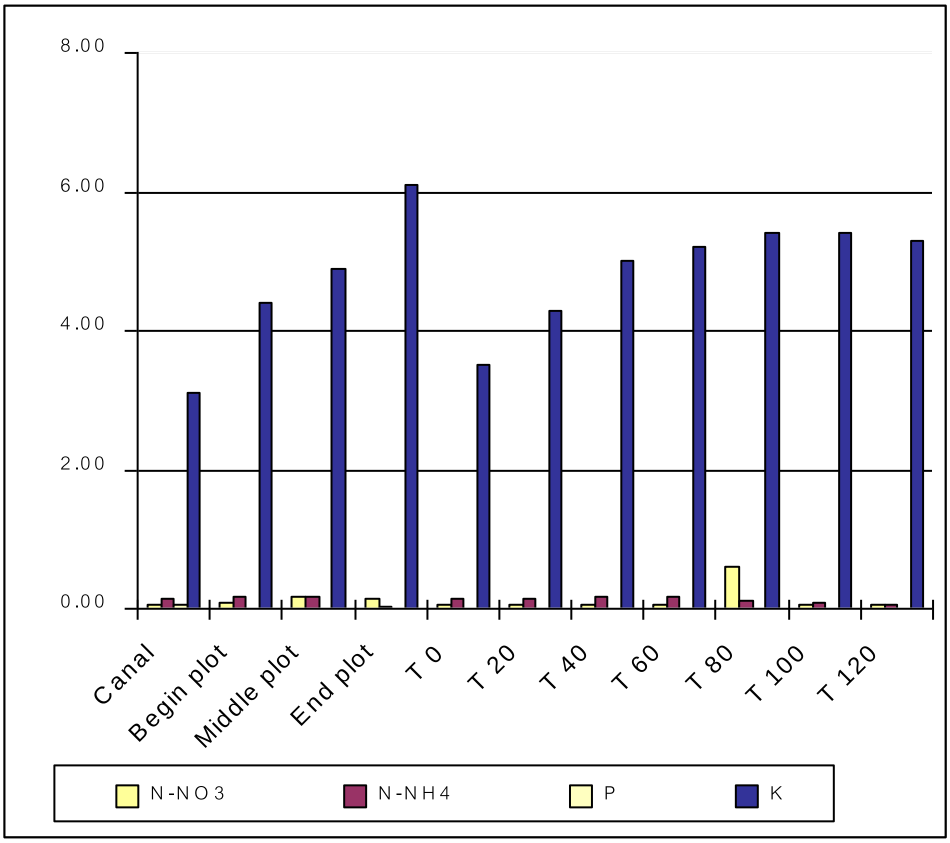


FIGURE 77: EVOLUTION OF N, P,K IN WATER PUMPED OUT FROM THE GRAPES FIELD OF BAMRUNG, 23/12/97



♦ <u>Analysis of the results</u>

Results of analysis were displayed in graphs and compared to the data of water quality in the canal next to khun Bamrung's farm (monthly basis sampling). We studied separately:

- the elements in suspension: particles of soil are pulled out of the raised beds by erosion and may export nutrients, heavy metals and pesticides. In the case of the elements highly retained in the soil indeed, the main way of exportation is the transport on the soil particles.
- and the elements in solution.

We estimated then the maximum discharge of elements in one time considering the highest peak of concentration as if the water in the canal was not loaded at all. Then we assessed the amount of elements discharged to the canal considering the difference of the average concentrations in the outflow and in the canal for 9 months.

4.3.1.2 *Preliminary results*

4.3.1.2.1 THE OUTFLOW FROM THE GRAPES PLOT TO THE CANAL

We recorded 37 occurrences of pump out in one year (Appendix 2). The average duration was about 95 minutes each time. In the case of missing data, we took the average duration. The flow rate of khun Bamrung's pump was estimated at 80 l/s. It results an annual outflow by pumping of 16848 m^3. However because all our water samples were not analysed on time, we had to limit our study to a period of 9 months, from the 14th of March to the 8th of December 1998 (Table 17).

TABLE 25: ESTIMATION OF THE OUTFLOW (14/03/98-08/12/98)

	Data	Volume (m3)
Outflow by pumping	27 recorded occurrences Average duration: 95 min	12240
Outflow by gravity	4 recorded occurrences (April and August)	1501
Outflow by seepage and leakage	2.70% of the total outflow	381
Total Outflow		14122

It is worth noting that Molle *et al.* (1998) recorded the frequency of outflow by pumping and the corresponding duration as we did. Afterwards, they compared the results with the values obtained after computation of the water levels recorded by the data logger. It appeared that the first volume was lower than the second one by 30%. Although we can not correct our values in the same way, we should be aware that the outflow we assessed may be underestimated. The exact volume of pump out may be between 12,240 m^3 and 17,486 m^3.

In our further computations about the discharge of pollutants into the canal, we will consider the outflow by pumping and by gravity (13,741 m^3). In fact, we suppose that water flowing out from the ditches to the canal by seepage is filtered in the soil and its contribution to the total discharge is negligible.

4.3.1.2.2 EVAPORATION AND DILUTION

In order to compare the concentrations in the outflow and in the canal, we corrected the values concerning the canal. After the water of the canal enters the plot, it gets indeed concentrated because of evaporation or gets diluted because of rainfall. We used the water balance done by Molle *et al.* (1998) for a whole year to establish a coefficient of concentration taking into account evaporation and rainfall.

If we neglect the inflow by seepage from the neighbouring plot, water in the plot comes for 80% from the canal and for 20% from the rainfall. Concerning the outflow, 61% of the water of the ditches is exported to the canal. The evaporation and the plant consumption represent 39% of the total outflow. The coefficient of concentration is: 1.6/1.2=1.4.

4.3.1.3 Assessment of the discharge

For most parameters, we can observe that the evolution of the water composition in the plot is close and parallel to the one in the canal. But generally concentrations are higher in the water pumped out than in the water in the canal what can be interpreted as a discharge from the plot, even if it is quite low (values are close). All the results of analysis are shown in Appendix 10.

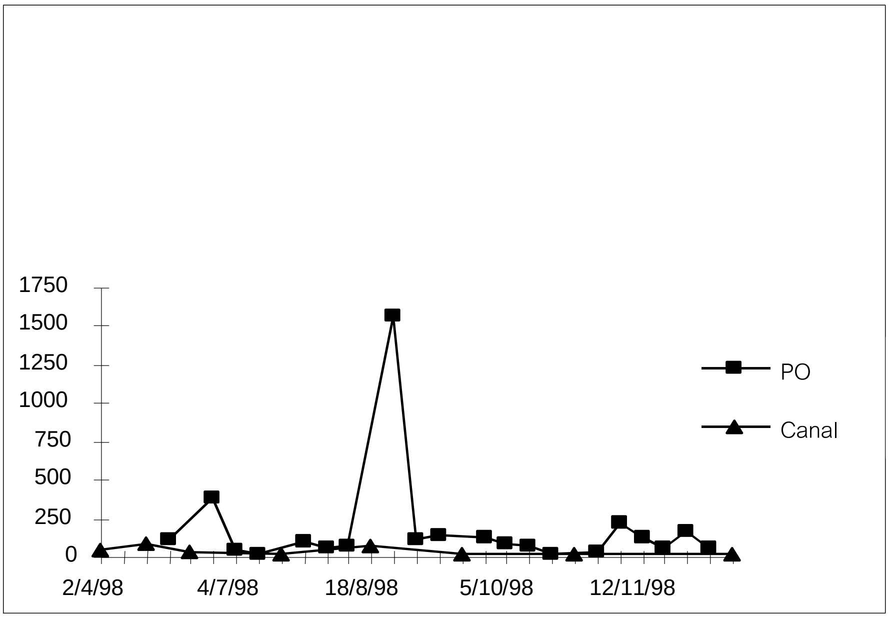
4.3.1.3.1 DISCHARGE IN SUSPENSION

The load of soil exported out of the field can be estimated with using the value of SS (suspended solids). But SS consist generally in soil particles and also in phytoplancton. So looking only at soil particles in first and then at phytoplancton only will be for us extreme hypotheses: we calculate each time the maximum values of discharge through the soil particles and then through the phytoplancton.

- Hypothesis 1: Suspended solids as soil particles

SS in the canal is on average 56.4 mg/l (Figure 76) and after concentration-dilution about 79 mg/l. With the exception of a peculiar point in August (1558 mg/l), the average suspended solids content in the outflow is 102 mg/l. The field exports in 9 months 316 kg of soil. This shows that only 22.6% of the suspended solids come from the field. An explanation for the very high value measured on 18/08/98 is that regularly the farmer dredges the ditches and spreads the mud on the raised beds sides in order to give them a regular slope.

FIGURE 78: SUSPENDED SOIL (MG/L) IN WATER PUMPED OUT FROM THE GRAPES FIELD OF BAMRUNG AND IN THE CANAL.



If we look now at the soil content in nutrients, salts and heavy metals, we can calculate the load of nutrients exported with the soil particles. We will lay the accent mostly on phosphorus and copper which are highly retained in the Damnoen Saduak soil. We found that 597g of phosphorus (0.8% of the total phosphorus applied in the plot in 9 months) and 80 g of copper would be maximum discharged by this way (0.4% of total copper in 9 months). Even if there is no contribution of the canal to the suspended solids in the outflow, the discharge would be only 2.6 kg of P (3.3% of the total Phosphorus) and 357.4 g of Cu (1.9% of the total).

- <u>Hypothesis 2: Suspended solids as plancton</u>

We now consider plankton as a way of export. If assumed that the plankton contents a maximum of 0.5% of phosphorus (phytoplancton contains Phosphrus in the chlorophyll A), a maximum of 1.5 kg of phosphorus could have been maximum discharged.

With these two extreme approaches, we can deduce that little is removed from the field as suspension. Most of the phosphorus as well as copper applied by the farmer remains in the soil, fixed on the exchange complex.

4.3.1.3.2 DISCHARGE IN SOLUTION

- <u>Dynamics of elements</u>

  - *Nitrates*

On Figure 77, we notice 3 peaks of respectively 3.93, 2.32 and 1.61 mg/l. The Table 22 shows the rains which occurred before the peaks of nitrate and the applications of nitrogen.

Peaks occurred after the heaviest rains of the year. On the contrary, applications of nitrogen by the farmer do not seem to be linked with these peaks.

FIGURE 79: NO3 (MG N/L) IN WATER PUMPED OUT FROM THE GRAPES FIELD OF BAMRUNG AND IN THE CANAL

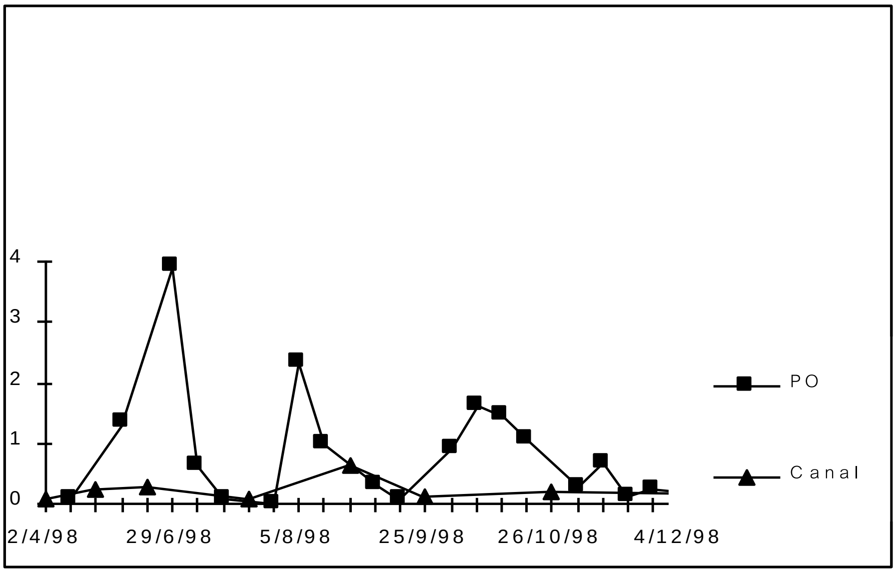


TABLE 26: RAINS AND FERTILISERS APPLICATIONS OBSERVED BEFORE THE PEAKS OF NITRATE

Date of very high nitrate concentration	Rains happened the week before		Fertiliser application the month before	
	Date	mm	Date	kg of N/ha
29/6/98	26/06/98 28/06/98	74 28	-	-
5/8/98	30/07/98 02/08/98	74 15.5	-	-
5/10/98	27/09/98 02/10/98	41.5 41	21/09/98 September	19 cow manure

The highest peak occurred one month and a half after the beginning of the rainy season. Mineralisation of organic matter and fertilisers were boosted by the first rains because of the increase of the soil moisture. When an unusual heavy rain appeared, nitrate resulting from the mineralisation process leached through the soil profile before reaching the water table. We could not detect flush of nitrates by run-off.

- *Ammonium*

In the case of the ions ammonium, we note four peaks (Figure 78). If we look at the rains and the applications of fertilisers (Table 25), it seems that unlike nitrate, fertilisers inputs are responsible for the flush of ammonium to the ditches. After nitrogen application on the raised beds, ammonium ions are washed out from the soil surface by run-off. Run-off can be induced by rain or by the frequent irrigation of the raised beds.

FIGURE 80: NH4 (MG N/I) IN WATER PUMPED OUT FROM THE GRAPES FIELD OF BAMRUNG AND IN THE CANAL

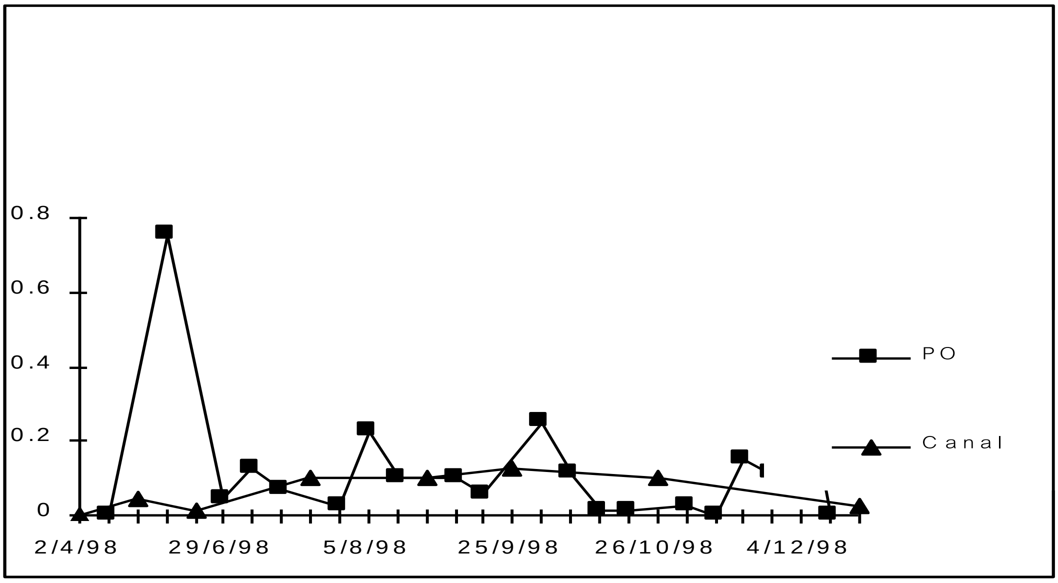


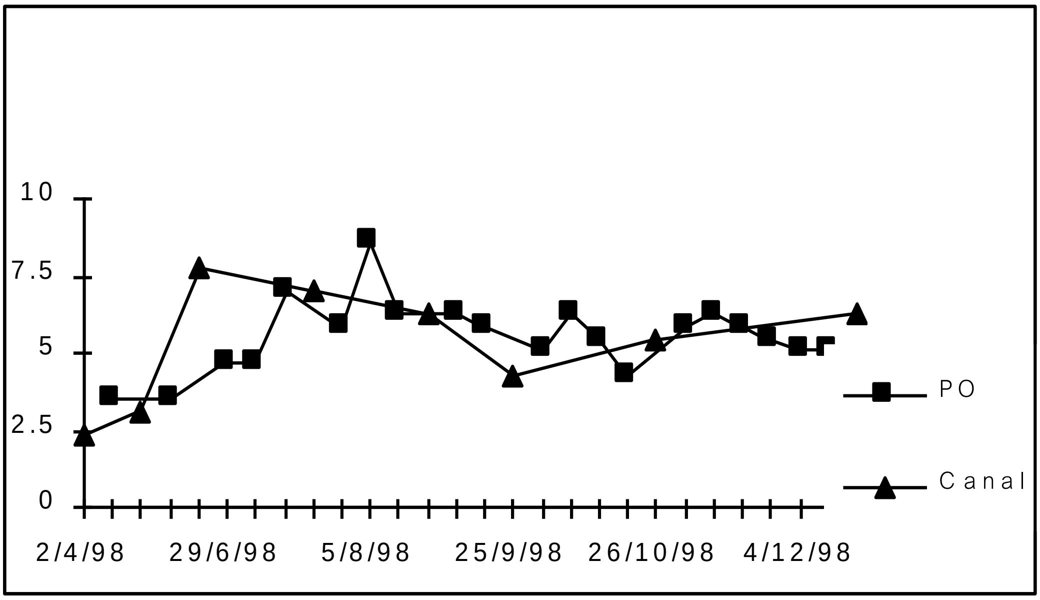
TABLE 27: RAINS AND FERTILISERS APPLICATION OBSERVED BEFORE THE PEAKS OF AMMONIUM

Date of very high NH4 concentration	Mineral fertiliser application the month before		Rains happened the week before	
	Date	kg of N/ha	Date	mm
25/05/98	23/05/98	25.2	24/05/98	5.3
05/0898	-	-	02/08/98	15.5
28/09/98	21/09/98	19.3	24/09/98 25/09/98 27/09/98	4.4 4.2 41.5
04/12/98	30/11/98	29.4	-	-

- *Potassium*

Concentrations of potassium in the canal and in the outflow are very close and vary much along the year (cf. Figure 79). There is no real peak of potassium. Potassium is retained by the soil of the raised beds which is characterised by a high cationic exchange capacity (around 25-30 $cmol_c/kg$).

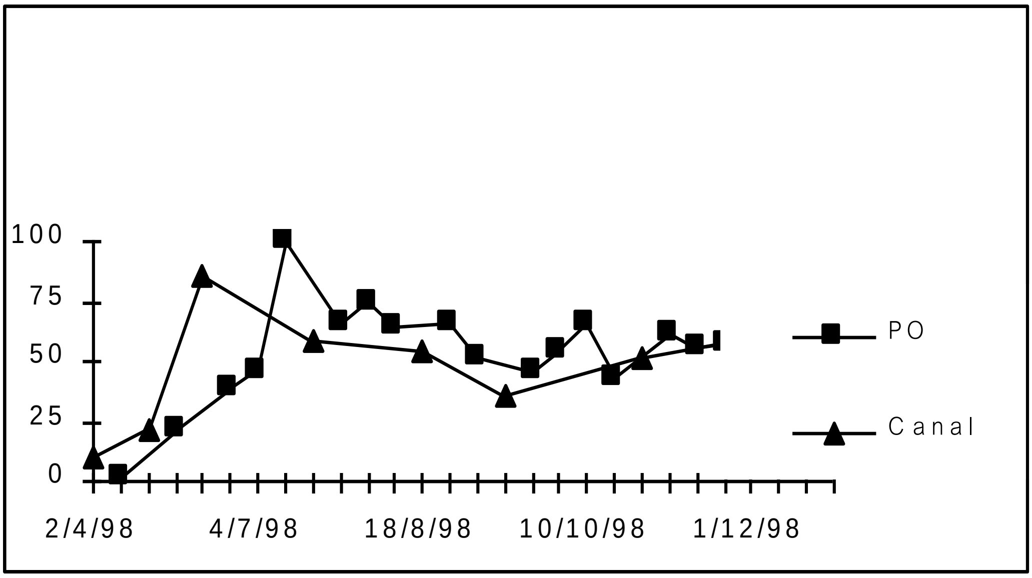
FIGURE 81: K (MG/L) IN WATER PUMPED OUT FROM THE GRAPES FIELD OF BAMRUNG AND IN THE CANAL



- *Sodium*

For sodium, the concentration in the canal and in the outflow are very close except on 19/06/98 when there was a peak of sodium in the canal (see Figure 80). The main reason may be a discharge from saline shrimp ponds upstream. We notice that if the coefficient of concentration-dilution we established for the computation (cf. paragraph III.2.1.2.b.) varies a little bit, the plot got enriched or impoverished in sodium.

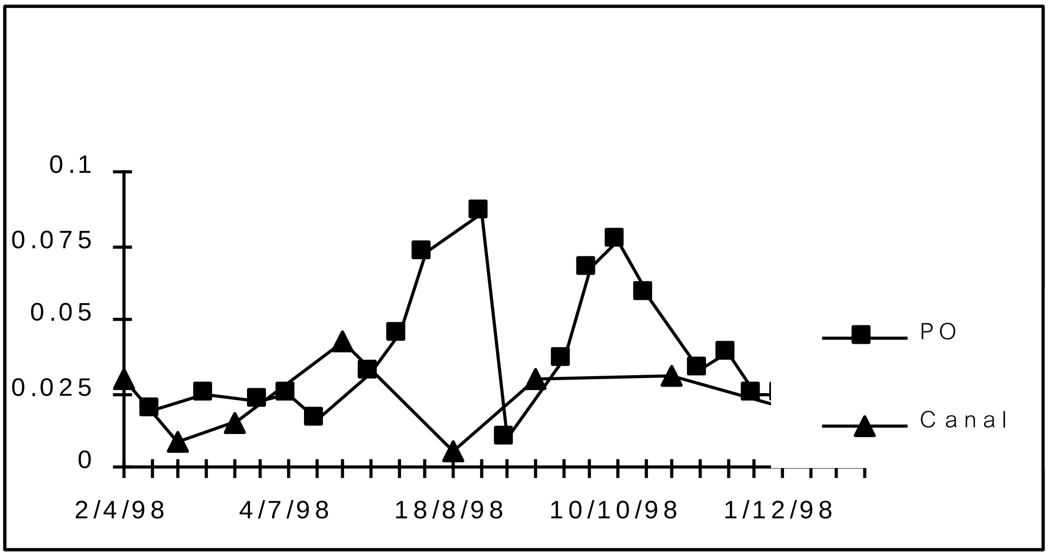
FIGURE 82: NA (MG/L) IN WATER PUMPED OUT FROM THE GRAPES FIELD OF BAMRUNG AND IN THE CANAL



- *Copper*

The graph of the copper concentrations (Figure 81) present two peaks (on 25/08/98 and 10/10/98) for which we could not find any explanation because data of pesticides application did not show any intensification at this period: copper oxychloride is sprayed regularly all along the year. However concentrations of copper in the water are very low, never exceeding 0.1 mg/l.

FIGURE 83: CU (MG/L) IN WATER PUMPED OUT FROM THE GRAPES FIELD OF BAMRUNG AND IN THE CANAL



- <u>Discharge of elements in solution</u>

In table 20 are displayed the values about the maximum discharge of N, K, Cu for one pumping and the estimated discharge for 9 months.

TABLE 28: RESULTS ABOUT DISCHARGE IN SOLUTION

Element	Maximum discharge in one time (kg)	Average concentration in the outflow (mg/l)	Average concentration in the canal (corrected) (mg/l)	Estimated discharge in 9 months (kg)	Estimated discharge in 9 months (% of the input)
N-NO3	2.26	0.82	0.28	7.42	5.0
N-NH4	0.33	0.13	0.08	0.69	0.5
K	4.94	5.54	7.43	(*)	(*)
Cu	0.025	0.037	0.028	0.12	0.6

(*) in the case of potassium, we can not calculate a discharge for 9 months: the average concentration in the canal is higher than in the plot.

From these results we can deduce that whether in suspension or in solution, discharged elements from the plot are negligible when compared with applications. From this test, we can state that most of the nutrients and heavy metals brought by the farmer on the raised beds remain in the plot, mainly in the soil. If this remark may be true for phosphorus and copper, soil analysis show that nitrate is not accumulated in the soil. According to our results, it seems that our system is quite sensitive: if a high amount of nitrogen had been exported by the outflow to the canal we would have detected it. The fate of the nitrate seems to be inside the plot.

4.3.2 Checking pesticides residues in fruits

4.3.2.1 Objectives

As we were checking the dispersion of pesticides used in grapes orchards in water and in soil, we decided to check it also in the plants, particularly in the fruits. We analysed pesticides residues that may remain on the fruit skin but also inside the fruits as farmers spray sometimes systemic pesticides.

With this experiment, we tackled the topic of the toxicity of pesticides for consumers and the impact of intensive agricultural practices on the quality of agricultural products.

4.3.2.2 Methodology

To check the pesticides residues in fruits, we used the pesticide test kit developed by the Division of Food of the Ministry of Public Health of Thailand. This simplified test kit is based on the human plasma cholinesterase and acetyl choline testing method for checking the presence of organophosphate and carbamate pesticides residues in food.

The quality of this test kit was assessed by the Division of Food and Drug (Thoophom et al, 1998). The efficiency of the test for different molecules was checked in some vegetable (kale, yard long bean and Chinese cabbage). Among others, methomyl and monocrotophos, pesticides frequently used in grapes cultivation were studied. Used in comparison with the standard method, the test showed good results with a sensitivity of 92.3%, a specificity of 85.1%, an accuracy of 87.1% and predictive values of 70.6% for positive and 96.6% for negative. These results prove the good quality of the test which can be used for screening pesticide residues. Detection limit for methomyl and monocrotophos are respectively 0.5 μg/g and 0.05 μg/g which are fairly low. The detection limit for monocrotophos is quite low if we consider that maximum allowance level for monocrotophos in vegetables and fruits is in the range of 0.1-1 mg/kg.

TABLE 29: CHECKING ORGANOPHOSPHATE AND CARBONATE PESTICIDES RESIDUES IN GRAPES FRUITS KHUN PRATHUENG PLOT 27/04/98

Treatment	Replication1	replication2	replication3
Peeling	ns (1)	1	2
no wash	2	2	2
wash 15 sec under running tap water	2	2	2
soak 1 min in tap water	2	2	2
soak 5 min in tap water	2	2	2
soak 10 min in tap water	ns	2	2
soak 15 min in tap water	ns	2	2
soak 20 min in tap water	ns	2	2
soak 25 min in tap water	ns	2	2
soak 30 min in tap water	ns	2	2

	khun Bamrung's plot		khun Pra Thuang's plot	
	19/10/98	26/10/98	11/02/99	
Treatment	rep.1 and 2	rep.1 and 2	replication1	replication2
Peeling	1	0	1	0
no wash	1	0	1	2
wash 1 min under running tap water	1	0	1	1
wash 15 min under running tap water	1	0	1	1
soak with saline water (2 tbsp. of salt/4 l of water)	1	0	1	1
soak with a solution of polished rice rinse water	1	0	1	0
soak in a solution of vinegar 0.5% (750 ml/ 4 lit of water)	1	0	1	1
soak in a solution of sodium bicarbonate (1 tbsp./20 l of warm water)	1	0	1	1

(1) no sample1: detected at a safety level; 0: non detected2: detected at an unsafety level

Pesticides residues in fruits were analysed twice on fruits harvested respectively at khun Pra Thuang's farm on 27/04/98 and at khun Bamrung's farm on 19/10/98. We analysed residues in grapes fruits before and after cleaning but we did not apply the same methodology the two times.

- First sample:

We checked the efficiency of washing and peeling fruits to remove pesticide residues. We considered three replications with 10 treatments: peeling, no wash, wash 15 seconds, soak 1, 5, 10, 15, 20, 25 and 30 minutes.

- Second and third samples:

We used this time different treatments, usually recommended to wash fruits and vegetables. We considered two replications with 8 treatments: pealing, no washing, wash 1 min, 15 min under running tap water, soak 15 min in rice washing water, wash with sodium bicarbonate solution (1 tablespoon/20 l of warm water), soak in saline water (2 tablespoons of salt/ 4 l of water), soak in solution of vinegar (750 ml of vinegar of 0.5%/ 4 l of water).

4.3.2.3 Results

Results are displayed in Table 30 which compares the levels of pesticides for unwashed fruits and peeled off fruits at the four harvest times.

TABLE 30: COMPARISON OF ENZYME TECHNIQUE RESULTS IN UNWASHED AND PEELED OFF FRUITS AT THE FOUR HARVEST TIMES

Site	Khun Pra Thuang		Khun Bamrung	Khun Bamrung	Khun Pra Thuang	
Date	27/06/98		19/10/98	26/10/98	11/02/98	
Replication	Rep. 1	Rep. 2	Rep. 1 and 2	Rep. 1 and 2	Rep. 1	Rep. 2
Unwashed	1	2	1	0	2	2
Peeled off	1	0	1	0	1	2

0: not detected1: detected at a safety level2: detected at an unsafety level

The unwashed fruits were free from pesticides in the grapes harvested on 26/10/98. This might be due to the law yield so that the farmer decided to limit the investment in chemicals and therefore apply less pesticides. Moreover the last application of organophosphate or carbamate was done 18 days before on 08/10/98 with a spraying of monocrotophos. 11 days after the application of monocrotophos, the test kit could still detect pesticides in the first fruits harvested. Pesticides may have been degraded in the following week.

The different procedures of cleaning were generally not able to remove pesticides but seemed to decrease the rate as compared with unwashed samples. Although removing the skin of fruits by peeling seems to decrease the probability of pesticide presence in fruits, pesticides are still detected in 62.5% of fruits samples after peeling. This may be due to systemic pesticides which have been used regularly. Palakul (1995) reports that monocrotophos which is a systemic insecticide contributes at a level of 75% to detected pesticides. In his experiment, he showed that pesticides residues are often found in grapes fruits: 139 samples of grapes fruits could be organophosphate pesticide detectable from a total of 156 samples. A high rate comparable to ours: 7 among 9 unwashed samples were positive.

Even though the enzyme technique could not detect organophosphate and carbamate in some fruit samples, the farmer should be aware of the impact of pesticides on fruits, particularly from systemic pesticides like monocrotophos. Farmers should be encouraged to adopt integrated methods of pest management rather than pesticides, especially before harvest. Application of pesticides should be controlled: farmers should stop spraying a long time before harvesting. In addition systemic pesticides should be obviously labelled with specification of half-life or degradation.

5 Conclusion

5.1 Water quality and agricultural practices

We have never detected high levels of nutrients and heavy metals due to the discharge of poor-quality water from the agricultural plots in the water samples taken from the canals. We were able to show that shrimp ponds filled with saline water in the northern part of the area to polluted the water of nearby canals. Downstream, the water was indeed enriched in sodium (from sea water) and in calcium (from the food used to grow Tiger shrimps). At the plot level, the discharge of nutrients and heavy metals from a vineyard was minimal, both in solution and in suspension. Given the results at the regional level, we can assume that in the other cropping systems the discharge from the agricultural plots to the canals is not higher than the discharge from vineyards.

Farmers regularly change the water in the ditches because of its “low quality” in the ditches. We found that this water was rich in oxygen and low in most nutrients. We were unable to determine what 'bad water quality' meant to the farmers. Insofar as we checked a limited number of parameters, the answer to the question of water quality may lie in the measurement of other parameters.

5.2 Water composition and water management at the regional level

We noticed large changes within the year in the composition of water in the canals. Water became slightly salted during the rainy season, probably because the water gates along the dike downstream remained open. The salinity seems to spread to the north of the delta by diffusion. This phenomenon was unexpected because we anticipated that the flux of water coming from the dams in the north would be sufficient to flush the salt out. This is an area where more research is needed to determine the origin of the salt, the extent of the saline intrusions in the raised bed area and the changes in salinity with time.

5.3 Pesticides

While the heavy metals used in fungicides (Cu, Zn) remain mainly in the soil, the organic molecules present in the pesticides seem to spread in the canals, in the soil solution, in the ditches and in the fruits. However these results must be used with caution because organic molecules were tracked down with a qualitative method based on cholinesterase inhibition. The results are worrying but need to be confirmed. In particular the nature of the molecules and their concentrations in the fruits and in the environment should be determined.

Part III

Socio-economic and marketing aspects of raised bed intensive farming

Blandine Cheyroux

1 Agricultural diversification and study area presentation

The Chao Phraya Delta is predominantly cultivated with rice. However, aquaculture, animal husbandry, fruit tree cultivation and vegetable cropping constitute the most prominent aspects of an agricultural diversification process which stands out as the main feature of the current development in the delta (Kasetsart University and IRD, 1996).

In addition to the improvement of rice farming, agricultural diversification represents for farmers one of the many way to increase their income: in the Chao Phraya Delta, orchard and vegetable based farming systems provide high income but require particular conditions that will be discussed in this chapter, with regard to the case of Damnoen Saduak agriculture.

In the western part of the Chao Phraya Delta, the lower Mae Klong Basin stands out as the main fruit and vegetable cropping area. On the fringe of the rice-based systems that have dominated the agriculture of the Chao Phraya Delta, Chinese immigrants and their Sino-Thai descendants have developed a peculiar agrarian system in the lowlands of Damnoen Saduak area. They have resorted to a raised bed technique to polder this old tidal marsh, and they have built a huge canal network providing drainage and irrigation throughout the year. In these gardens between land and water, farmers are able to grow a large variety of vegetables and fruits.

The proximity of the Bangkok market, the development of transportation infrastructures and the efficient market connection through a network of middlemen constitute important socio-economic conditions for the development of this market-oriented agriculture.

In contrast with the extensive rice-based systems which provide a fairly low income by current standards, the agriculture in the poldered raised bed system is highly labour and capital intensive. It is extremely diversified (more than 20 main crops) and oriented towards crops with high added value, such as fruits and vegetables.

About 20 kilometres to the north of the coastline, the Damnoen Saduak area corresponds to an old tidal marsh: marine and brackish clays have been covered by deposits brought by the Mae Klong River in spate. Damnoen Saduak forms part of the Delta’s perennial wet zone (Takaya, 1987) and represents the transitional zone between the inland zone, governed by floods, and a coastal zone, governed by tides. The natural hydrological regime was marked by a sharp contrast between the rainy season (July to November) and the dry season

(December to June). During the rainy season, the marsh area was flooded by fresh water from the Mae Klong River in spate. During the dry season, the river discharge was dramatically reduced and the tidal effect brought the influence of saline water further inland.

Until the middle of the 19th century, the Damnoen Saduak area, like most of the lower Chao Phraya Delta, remained a wasteland. This lowland, alternately flooded by fresh and saline water, represented a hostile environment for humans: access was difficult and agriculture would not be implemented without important land development (Johnston, 1972).

2 1850-1870: historical background and Damnoen Saduak Canal excavation

During the 19th Century the main feature of the agricultural development in the Chao Phraya Delta was the shortage of a labour force relative to the abundance of available land[3]. Due to a high land/man ratio, a large part of the delta was still uncultivated: most of the population was settling in the upper delta where peasants developed rice based systems and the lower delta would not be fully exploited until the late 1920s. Farming systems were oriented towards subsistence (Douglas, 1984).

In 1856, the Bowring Treaty with England and similar treaties with other European nations resulted in free trade and in the inclusion of Siam into international trade, thus triggering the development of rice exportation. To supply the increasing demand for rice from French and British colonies in Asia, the wastelands of the lower delta were rapidly opened up for rice cultivation on a large scale (Ishi, 1975).

Major reforms like the abolition of slavery and corvée freed the labour force and contributed to the rapid expansion in paddy production and of the area under cultivation. Deprived of the corvée, the government resorted to using the numerous Chinese coolies who migrated to Siam[4] in order to dig several canals in the delta. The new canals were aimed at giving access to the new lands and allowed the collection and the transportation of marketable surplus from the production zone to the export port of Bangkok (Chiengkul,1983).

The digging of the Phasi Charoen Canal (1867) and the Damnoen Saduak Canal (1867-1868) formed a transversal line connecting the Chao Phraya River and the Mae Klong River.

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[33] The abundance of land and the shortage of an available labour force were closely reflected in the overall organisation of the Thai State. The major source of government revenue was the four-month corvée imposed on all the active freemen. Thus, if one considers the organisation of freemen corvée in conjunction with the high incidence of slavery, it is overwhelming that the primary source of wealth and power in Thai society was not land but the control of the labour force (Kemp, 1981; Akin, 1969).

[4] The Chinese have long been present in Siam, but Chinese immigration increased rapidly during the 19th century: Chinese arrivals were estimated at around 7000 immigrants per year in 1833 and around 15,000 per year in 1851 (Skinner, 1957). This immigration of numerous Chinese coolies provided the country with a labour force at a low cost.

The objective was to allow convenient transportation of rice, salt and sugarcane from the Mae Klong Basin to Bangkok (Takaya, 1987; Manarangsan, 1989). The main purpose of the Damnoen Saduak Canal excavation was the development of a communication route for trade, and the agricultural development of this area was considered of secondary importance (Brown, 1988; Zimmerman, 1931).

Wealthy Chinese traders rapidly dominated the trade activities in this area and took over the land located along the new canals (Ishii, 1975). They rented these lands to the numerous Chinese coolies who settled in Damnoen Saduak after the excavation work. In 1877, a large community of Chinese was living along the Damnoen Saduak canal (Skinner, 1957).

3 1870-1950: The first step of the Damnoen Saduak agricultural development

3.1 The hydraulic system and land development

To develop the swampy lowlands around the main canal of Damnoen Saduak, these numerous new farmers first had to drain this perennially flooded area and they resorted to the poldered raised bed technique[5]. They progressively developed a hydraulic system with 3 main levels:

1. To drain the swamp and to remove excess water, farmers dug several canals serving each plot;
2. To protect the plot from floods and the intrusion of saline water, a dike was built around it;
3. Because of seepage and of the rise of the water table, the plot was still flooded most of the year. That is why the third level of land development consisted in building raised beds separated by ditches inside the plot.

This land development allowed very good conditions of drainage but not all year round: the plots were still flooded during the rainy season (from July to November). Consequently, farmers could cultivate only annual crops (Boonma *et al.*, 1974).

3.2 Market-oriented farming systems

A large part of the market production from the Mae Klong Basin (mainly rice and sugar) transited through the Damnoen Saduak canal to reach Bangkok. The digging of the canal boosted trade development in this region and had a dramatic effect on the Damnoen Saduak agrarian economy: farmers from Damnoen Saduak had outlets for marketable production.

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[5] In the beginning of the 19th century, fruit and vegetables were already grown on such poldered raised bed plots around Bangkok. (Pallegoix, 1854)

They developed farming systems combining crops for family consumption, such as rice in the ditches and vegetables on the beds, and cash crops for sale. These cash crops, such as onions, shallot, garlic and chilli were dried to make them less perishable in order to withstand bad transportation conditions (by boat) and delays (Skinner, 1957). Most of the vegetable production was exchanged in floating markets that appeared in some main canals in the early morning. Thanks to the canal network, the farmers-sellers could transport their marketable products by boat from their plot to the floating markets. There, traders would buy their products, load them in their boats and would take 24 hours to reach Bangkok where the goods would be sold to retailers or directly to consumers. The floating market has provided an outlet for fragmented supplies from scattered farms.

3.3 An original agricultural development in the Chao Phraya Delta

At this time, most of the Chao Phraya farming systems consisted of a self-sufficient rice-based system, even if rice farmers sold some rice surplus. Marketable vegetable products concentrated around large towns. Nevertheless, the intensive production of vegetables found in some distant areas with favourable conditions represented an exception, since such advantages offset the disadvantage of the long distance to the market (Von Thünen, 1826, Moustier & Pages, 1997).

The vegetable production in Damnoen Saduak was one of these exceptions. The main advantage for farmers in Damnoen Saduak was the availability of a labour force for land development and intensive farming systems, but also a privileged access to markets: Damnoen Saduak farmers benefited from transportation infrastructures. They were of the same language community as the Chinese traders (*teochu*) who had dominated the trade sector in the Chao Phraya Delta[6] and had developed a monetary and market economy. Therefore, Damnoen Saduak agriculture was integrated into the market since its origin, and farmers adopted commercial strategies and developed cash crops.

4 1950-1975: transportation improvement and agricultural transformations

Before 1950, more than 24 hours were needed to go from Damnoen Saduak to Bangkok. In the 50’s and the 60’s, motorboats appeared and their number increased in Damnoen Saduak canal. Traders needed only 8 hours to reach Bangkok and could transport bigger quantities of goods at lower costs. Due to these transportation facilities and in order to satisfy an increasing urban demand, commercial exchange increased and extended to more perishable products like green vegetables. Farmers from Damnoen Saduak grew chilli, onion, garlic,

[6] By 1850, it appears that the Chinese, in particular the Teochu Chinese, controlled almost totally the trade in Siam (Fistié, 1967)

shallot and new crops such as cucumber, yard-long beans or cabbage, but the new crops required better irrigation conditions and pest control: Some farmers could invest in pumps and inputs in order to cultivate these more profitable products (Boonma et al., 1974).

Traders played an increasingly important role and, indeed, became middlemen: they collected products from the farms, transported them by motorboat to Bangkok where they resold them to retailers, and then carried commodities and basic agricultural inputs (pesticides, gasoline for pumps, etc.) back to Damnoen Saduak.

As production and trade increased and transportation costs decreased, Damnoen Saduak farmers could buy rice at a lower price. Therefore, they gave preference to a system concentrating their activities on more profitable products (dry and green vegetables) and progressively gave up growing rice in the ditches of the raised bed plots.

Agricultural diversification is a process accompanying trade development, characterised by a gradual shift out of self-sufficient production to products exclusively aimed for sale. The Damnoen Saduak agriculture was more and more integrated into the developing market economy, especially with the building of roads in the 70's and the 80's.

5 1975- 2000: new environmental and economic conditions and their consequences on the agrarian system

From 1960, the Royal Thai government began to implement policies and programs based on the idea that economic growth would be better stimulated by the infrastructures required by a modern economy. Increasing public expenditures were thus concentrated on the development of hydraulic systems and the construction of road networks.

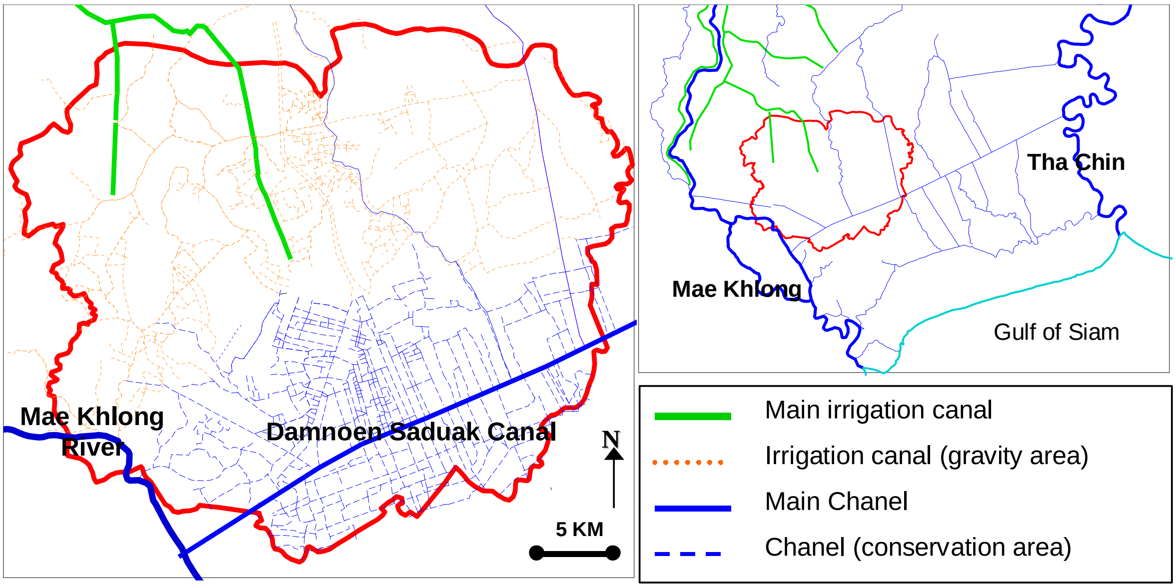
5.1 Consequences of the transformation of the water regime

The Greater Mae Klong Project (a public project) was initiated in 1964 with the objective to improve water control in the basin. In the 70's, the annual flood ceased to occur and an irrigation network was developed in the basin.

The transformation of the water regime had three main consequences on the Damnoen Saduak raised bed agriculture:

1. With the end of the annual flood and the possibility to have year-round irrigation, the farmers could thus cultivate on raised beds throughout the year, in particular, perennial crops.

Figure 1: Drainage and irrigation networks in Damnoen Saduak



2. Thanks to the development of the gravity irrigation system, the uplands in the northern part of Damnoen Saduak benefited from a regular water supply all year long; farmers were thus able to expand their raised bed cultivated area into this zone[7].
3. Before the development of the Mae Klong Project, the silt deposited by the annual flood constituted the main means of fertility repositioning and the flood was also a means to control pests. As the annual flood ended, it became necessary to resort to fertilisers and pesticides.

The new physical environment offered new constraints and new possibilities: farmers in Damnoen Saduak responded to them in the context of the transformation of the socio-economic environment.

5.2 New crop development and extension of the raised bed area

In spite of these new technical possibilities to increase the quantity and the diversity of production, farmers could take advantage of them only if they could find outlets for these additional products. Urbanisation and the increase in income resulted in increased demand for vegetables and fruits, especially in Bangkok. The food industry took off and export trade developed, creating new outlets for Damnoen Saduak products (Mubaric,1998). These new market conditions provided incentives for farmers to increase and diversify their production.

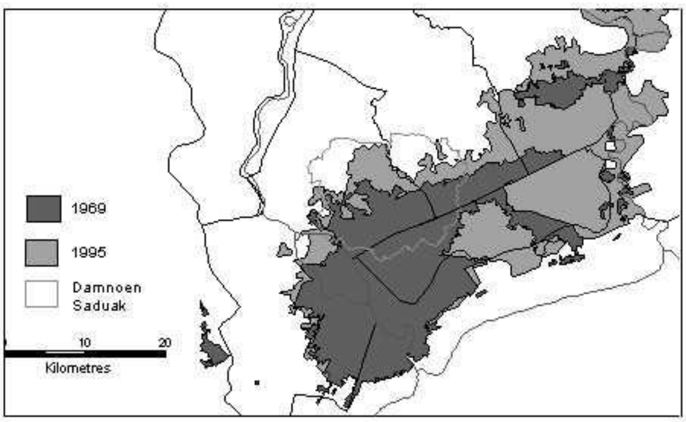
The gardeners in Damnoen Saduak lowlands now had good irrigation and drainage conditions all year long. They extended their cropping season of vegetables up to 3 or 4 crops per year (only 1 or 2 were possible before). From the end of the 1970s, some farmers

[7] Before, farmers grew only one rice crop in the rainy season.

began to develop orchards and vineyards; the area cultivated in perennial crops gradually increased and today represents more than 70% of the agricultural area of Damnoen Saduak.

The rice farmers in the northern part of Damnoen Saduak were faced with declining rice prices[8]. Because of the lower profitability of rice production, farmers progressively transformed rice fields into raised bed plots to grow orchards and vegetable gardens (Molle et al., 1998). The expansion of the raised beds zone (Figure 2) involved the extension of the garden area and an increase in vegetable and fruit production in Damnoen Saduak district.

Figure 2: Expansion of gardens on raised beds in Damnoen Saduak area (1969-1995)



The agricultural production from Damnoen Saduak has increased in volume and has been more and more diversified. Even if this agricultural development has brought about an increasing added value per farm, it has also induced increasing agricultural investments (input, plantation investments, etc.) and new needs in capital.

5.3 Marketing, Input supplies and credit

As the end of the annual flood in the 70’s resulted in increased difficulties controlling pests and recovering fertility, agriculture required more chemical fertilisers and pesticides. Middlemen developed their input supplying activities thanks to the new road network. But the use of fertilisers and pesticides created additional costs. Most farmers could not afford these costs and resorted to borrowing money on credit. In the 70’s, institutions of agricultural credit were not developed in Damnoen Saduak and sources of capital came from the trade sector (Dufumier & Srijantr, 1997). The middlemen became money lenders: a farmer could borrow money from a middleman only if he committed to sell his product to him at a pre-determined price. This price, given the fluctuations of the market, was usually underestimated regarding the value of the crop at harvest (Phonpaichit & Baker 1995). Because of the lack of credit

[8] This period marked the beginning of rice intensification in the Chao Phraya Delta. In the rice sector, productivity growth has been accompanied by declining real prices of rice and subsequently lower incentives for farmers to cultivate rice. In the north of Damnoen Saduak, the income of rice farmers has declined and they have developed alternative sources of income with off-farm activities or agricultural conversions.

institutions, the middlemen quickly began to give short-term credit with high interest rates. In this way, the middlemen supplied farmers with financial means to develop new cropping practices and new crops like orchards and vineyards In the 70's and the beginning of the 80's, the trade sector invested capital in the agricultural development of Damnoen Saduak.

Public and private banks were opened in Damnoen Saduak in the 80's and the 90's. Alternative sources of institutional credit became more accessible to a growing number of farmers (Siamwalla, 1993). Institutional interest rates fluctuated between 10 and 20% per year, while middlemen interest rates were around 10% per month. Nevertheless, some farmers who had been forced to borrow money from middlemen had previously been rejected by the institutional credit organisations. From one perspective, middlemen can be seen as fulfilling a role of risk-takers that the banks have been unwilling or unable to fill. But, while the usurer activities of middlemen declined in general, the profits generated by the input supply activities decreased too. Decreasing transportation costs allowed some traders to specialise in the sale of inputs. There was a differentiation between upstream and downstream activities: on the one hand, some middlemen were marketing products; on the other hand, others were selling farm inputs to farmers and, banks were giving credit. The bargaining power shifted in favour of the farmers.

With the end of the annual flood, it was possible to develop a permanent road network (before the roads were partly damaged every year by the flood) financed by the government. The progressive improvement of transportation allowed production areas to connect with consumption areas in a minimal amount of time; a prerequisite for perishable goods production. Moreover transport by road turned out to be less expensive than by boat (Hafner, 1970): in the 1980's, trucks spent only four hours to go from Damnoen Saduak to Bangkok, as opposed to 10 hours by motorboat. Farmers were less isolated and as a result had access to more middlemen and alternative marketing channels. They could travel more widely in order to sell their products at a better price; middlemen were able to broaden their marketing areas with increasing ease of transportation. These developments resulted in increased competition between middlemen. The possibilities to exploit farmers who benefited from a better marketing information were limited and, as a result, the profit margins of the middlemen were reduced.

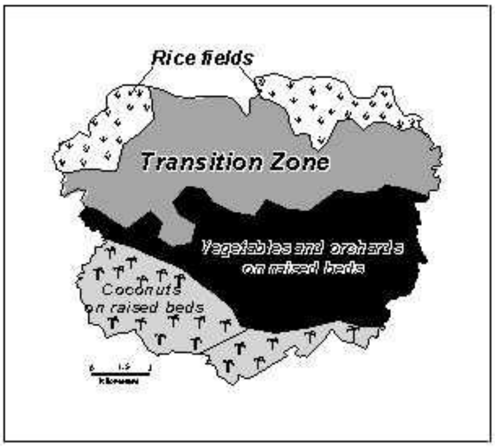
Today, in contrast with the traditional extensive rice based systems, which provide a fairly low income, the intensive and diversified agriculture on raised beds, oriented toward crops with high added value, uses a great amount of labour (Figure 3) and capital.

FIGURE 3: WORK IN THE RAISED BED PLOT (DAMNOEN SADUAK)

(Papaya harvest) (Vineyard pruning) (Aspergus plot plowing)

Agricultural diversification, cropping systems and socio-economic differentiation of the Damnoen Saduak farms

Figure 4: Landuse of Damnoen Saduak district (1998) Figure 5: Watering of vegetables



6 Agricultural diversification, cropping systems and socio-economic differentiation

6.1 Agricultural diversification

Agricultural diversification can be analysed at various levels:

- At the regional level (lower Mae Klong Basin), the diversification process is characterised by the expansion of raised bed areas at the expense of the rice field zones with single-crop farming.
- At the raised bed area level, there is a great diversity of cropping systems, especially in Damnoen Saduak district where more than 20 different crops are grown (chilli, coriander, kale, papaya, asparagus, rose apple, guava, coconut, sapodilla, grape, jujube, and lemon). In every Damnoen Saduak village, a vast number of different crops arefound[9].
- At the farm level, the gardeners develop diversified cropping systems to deal with economic constraints. They grow simultaneously different crops mainly to spread the needs of the labour force, to get regular income and to weather the risks of price and production fluctuations.
- At the plot level, there are crop associations and rotations. Annual crops are, in general, grown in association (for example, chilli with yard-long beans and cucumber). Perennial crops (such as orchards and vineyards) are mono-specific, even if some vegetables can be associated at the beginning of plantation (when trees are still small). Last, farmers make crop rotations in a given plot. They never successively grow the same crop in the same plot: they change every time to cope with soil fertility and phyto-sanitary problems.

In the raised bed zones, the highly 'artificialised' environment allows the growth of a large range of crops. The Damnoen Saduak farmers have privileged access to the marketing system and can easily find buyers for different kinds of fruits and vegetables. In this agro-ecological and marketing context, farmers can chose between different cropping systems, according to the means of production accessible to them.

6.2 Cropping systems

The different cropping systems require a varied level of capital (Graph 1) and labour force (Figure 6) and provide varied levels of income (Graph 2). Cropping systems cover a large range of more or less intensive systems (from highly intensive and profitable vineyards to lower intensive and profitable coconut plantations).

The flexibility of this agriculture can be partially explained by the limited capital invested in the different plantations. Because of the low cost of crop change, farmers are very responsive to the evolution of relative prices. For example, farmers do not hesitate to destroy guava orchards to grow rose apple orchards, if the price of guava becomes too low.

The fertiliser and pesticide costs represent the main part of the capital needs (especially in vineyards). To buy this input, farmers often have to resort to credit: 80% of Damnoen Saduak farmers are more or less in debt.

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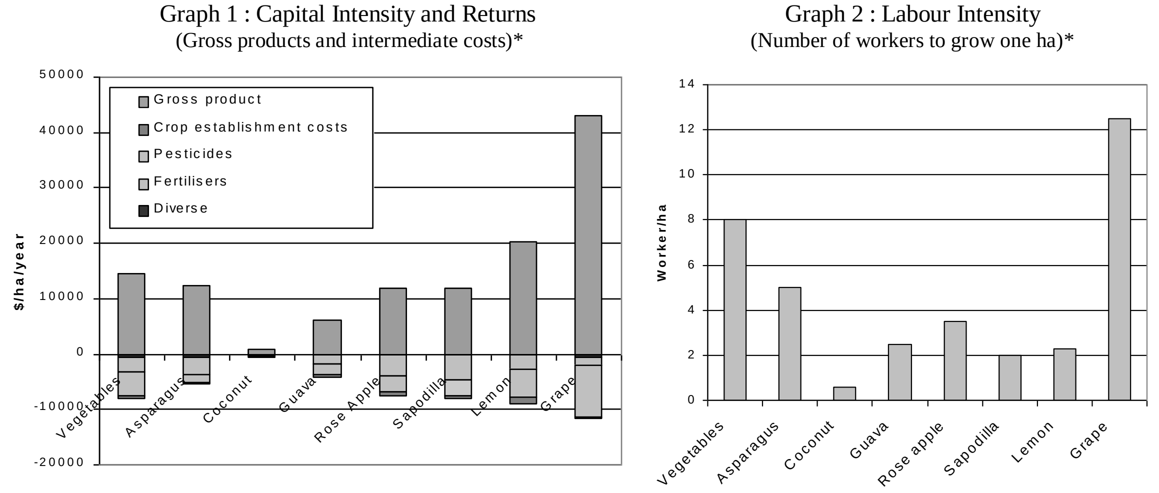
[9] We found an exception in the south-western part of Damnoen Saduak where coconut plantations dominate the landscape because of particular ecological constraints.

Figure 6



* We considered only the 8 main cropping system between the 20 different crops found in Damnoen Saduak : Vegetables associations (cucumber, chili, yard long bean, coriander, papaya), asparagus, coconut, guava, rose apple, sapodilla, lemon and grape. The calculations were made on 130 farmers surveys from 1997 to 1999.

In the case of very risky crops, like vineyards, a farmer, who has 2 or 3 bad harvests in succession, cannot pay back his credit and may be forced to sell his land. In fact, the most profitable cropping systems are also the most risky. Only the farmers, who have accumulate enough capital, can invest in this risky but profitable cropping system and deal with bad harvests. Rather than to resort to short-term credit, some farmer grow low risk crops harvested year round: these crops such as vegetables, guava, rose apple, coconut allow predicable and regular income.

In this labour intensive agriculture, most farmers resort to temporary hired labour to handle work peaks (harvest, pruning, etc.). Due to the increase in real agricultural wages over the last 20 years, farmers are trying to reduce this cost. The choice of a cropping system takes into account the availability of the family labour force. The spread and staggering of activities is also taken into consideration when choosing the combination of crops.

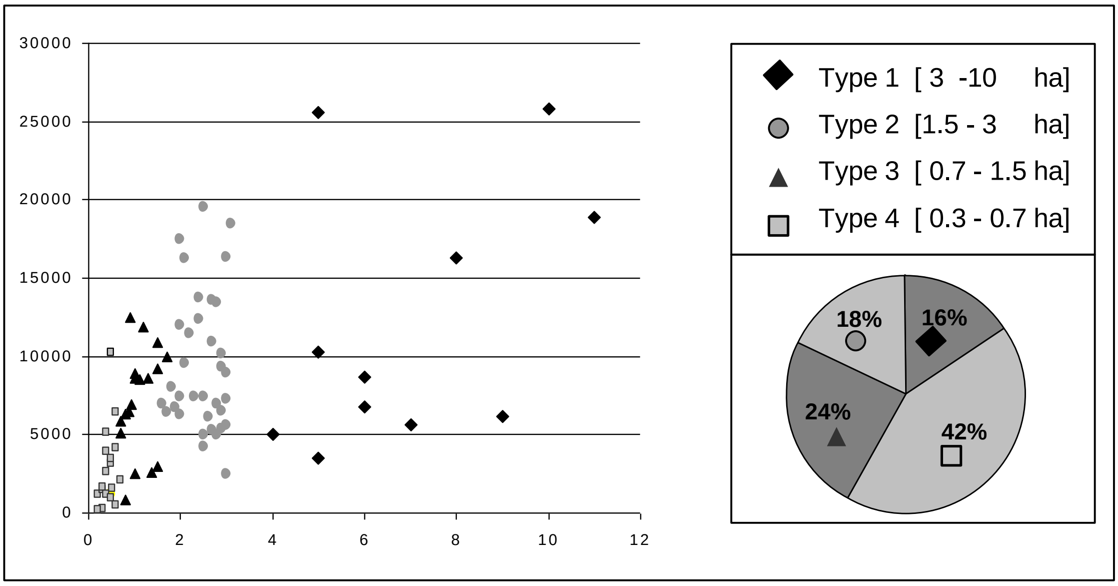
Depending on their individual situation (farm size, family labour force, capital accumulation and access to credit), farmers develop different cropping systems, more or less intensive in work and capital, more or less risky and profitable. The socio-economic differentiation of farms partly explains the cropping diversity in Damnoen Saduak.

6.3 Socio-economic farm differentiation

In Damnoen Saduak the average farm area is 2 ha, which is quite low compared to the average size of farms (4 ha) in the Chao Phraya Delta (Kasetsart University and IRD, 1996; Molle and Srijantr, 1999). In fact, Damnoen Saduak agriculture is mainly manual. It is nearly impossible to develop the mechanisation of the peak work operations, such as harvesting or pruning. In this labour intensive agriculture, the farm area is limited by the availability of the labour force.

Nevertheless, there is some differentiation of the average Damnoen Saduak farm size. The fragmentation of farms have produced a concentration of small farms (less than 1,5 ha), especially in the oldest raised bed villages, along the Damnoen Saduak Canal. Some farmers have succeeded to extend their area by buying rice fields in the northern part of Damnoen Saduak and by transforming them into raised plots.

Figure 7: Added values of the different farms (1999)



Farmers with similar areas can nevertheless produce variable levels of added value (Figure 7). In fact, the productivity and the profitability of a farming system depends more on the kind of cropping system developed by farmers than on the cultivated area[10]. Even if the capacity for capital accumulation is positively correlated with the area, small farmers, who have high availability of capital and labour force, can develop more intensive and profitable cropping systems than some bigger farmers who have a shortage of capital and family labour.

But, different types of farms develop different strategies, according to their access to means of production. They try to maximise the productivity of the scarce factors (labour force for the big farms, capital and labour force for the medium farms, land and capital for the small and very small farms).

- The labour force of the large farms (Type 1) is fully employed. These farmers have good access to credit because they have large land holdings which can be mortgaged. The farm durability depends of the availability of agricultural employees in the area and of the improvement of their salaries. But they have enough area to obtain sufficient agricultural income, even if they grow less intensive and less profitable crops.

[10] A farmer who grows vegetable on one ha generates more added value than a farmer who grows coconuts on ten ha.

- In medium size farms (Type 2), farmers use family labour force and employees to cope with labour peaks. They have a limitation for borrowing capital and tend to diversify their farming system to spread their capital and labour force needs.
- With small size farms (type 3) farmers cultivate labour intensive crops that allow them to receive high added value with small capital investment (vegetables). So, they succeed in having enough capital to continue their farming system. When there is insufficient working capacity in their small farms, a part of the family labour force can take temporary jobs in bigger farms and increase the family income.
- With an added value of under 4,000 $ per year[11], most of the farmers with very small farms (type 4) have off-farm activities to obtain supplementary income. Temporary job opportunities are numerous in Damnoen Saduak because many medium and big farms regularly need extra employees.

It is common to see situations of agricultural development where the small scale farmers get lower income, are progressively eliminated and go to the cities, increasing the number of workers in the expanding secondary or tertiary economic sectors. The medium and large scale farms can extend their areas at the expense of evicted small scale farmers, and accumulate capital to invest in the improvement of work productivity (mechanisation, inputs, etc.). In contrast, Damnoen Saduak has undergone limited out-migration. Smaller scale farmers develop intensive systems oriented toward high added value or/and have off-farm activities as agricultural employees; in this way they can continue their farming system and receive sufficient income to remain in Damnoen Saduak. The medium and large scale farms also need these small farmers, who as temporary employees supply them the necessary labour force; in this way, they can develop intensive and profitable crops. The different kinds of farmers are complementary in the development of this diversified and intensive agrarian system. This is quite similar to the situation described by Molle and Srijantr (2000) for rice areas, where land and labour markets have been found to operate rather flexibly, where smaller farms tend to diversify production and where the proportion of hired labourers in the agricultural population is neatly correlated with the demand for off-farm and on-farm hired labour.

7 The particular conditions of agricultural development in Damnoen Saduak

The raised bed farming system provides high profitability, and the question can be asked, *why this kind of system has not expanded on a larger scale in the Chao Phraya Delta*.

[11] The agricultural income is equal to the added value less salaries, land rent, tax and credit interest. With an added value about 4000$/year, farmers have an average income close to 1,500$. That is lower than in the industrial sector.

Through the description of the development of the Damnoen Saduak agrarian system, we have seen that it required particular agro-ecological and socio-economic conditions.

- This agricultural development has been possible in Damnoen Saduak due to favourable ecological conditions (high availability of water, fertile clayey soils) and a highly 'artificialised' environment[12] (very dense network of waterways and important land development).
- To develop this environment and this agriculture a huge labour force had to be mobilised. In the first historical stage of Damnoen Saduak, Chinese coolies provided this necessary labour force. Later, in spite of new opportunities and remunerative jobs in the developing industry, this agriculture was able to generate relatively high levels of on-farm incomes and to limit out-migration to the cities, retaining the labour force in Damnoen Saduak.
- Huge capital was also necessary to intensify cultivation practices, particularly fertiliser and pesticide use. The start-up money was provided by the trade sector. Today, farmers' capital accumulation and institutional credit has replaced middlemen credit.
- Agricultural development in Damnoen Saduak is a process accompanying the economic and trade growth and is boosted by improved rural infrastructures and marketing system development. The area has privileged access to markets due to the proximity of Bangkok, the development of the road network and an efficient marketing system. Therefore, Damnoen Saduak farmers could benefit from the emergence of new markets (vegetable and fruit) induced by national economic growth. They have also developed well-diversified market oriented production systems and have been able to gain sufficient flexibility to adjust smoothly to changing conditions of the market.

But the Thai economic crisis (1997-1998) has revealed weaknesses of agricultural development in Damnoen Saduak. This agriculture is very dependent on the market for the supply of a high level of inputs and for the sale of its market-oriented products. Farmers have developed diversified cropping systems to cope with the high fluctuations of fruit and vegetable prices; they largely resort to institutional credit to finance their inputs. But the agriculture in Damnoen Saduak proved to be vulnerable to the general decrease in vegetable and fruit prices, the increasing prices of input and the escalation of credit interest rates. Some farmers have changed their farming system to less intensive systems, others have gone bankrupt[13].

New threats to the agricultural development in Damnoen Saduak are looming. Agricultural practices (for example, high level of fertiliser and pesticide use) have an impact on the environment (Joannon *et al.*, 1999): the degradation of water quality and the accumulation of toxic elements in the soils might become an important problem which questions the

[12] The Damnoen Saduak landscape has been built and shaped by man: almost any lump of earth has been dug to make canals, ditches, dikes and raised beds.

[13] Today, it is too soon to evaluate the number of farmers who have gone bankrupt; a few years are needed to allow sufficient data collection.

ecological sustainability of this agricultural development. New producers have developed fruit and vegetable products for Asian markets, such as gardeners in the Mekong Delta (Vietnam) and will be able to compete with the farmers of Damnoen Saduak in national and international markets. This raises doubts about the economical sustainability of this type of agriculture.

The conditions for development of the poldered raised bed systems in the Chao Phraya Delta are all the more challenging because of the sprawl of urbanisation and industrialisation: the agricultural sector has to compete for land, water and labour and may be on the losing end if no coherent policy of regional development and planning are set to limit land speculation. Because the Mae Klong River Basin appears to have water surplus the poldered raised bed systems have so far been able to expand along with urbanisation and industrialisation. In the Chao Phraya Basin, however, the water deficit poses the problem of water allocation between rural and urban areas, between agricultural and non-agricultural sectors, and the expansion of raised beds in the lower Delta may be constrained. Above all, the expansion of the raised bed systems will depend on its capacity to remunerate and keep its labour force (which will depend on the growth of real wages in the industrial sector), something Damnoen Saduak area has hitherto been able to achieve due to the high added value of its products.

In the past the farmers of Damnoen Saduak area have shown their capacity to quickly change agricultural practices and cropping systems, and smoothly adapt their farming system to the rapid and in-depth transformations of the agro-ecological and socio-economic environment. This suggests that farmers of Damnoen Saduak will be able to successfully address future challenges and that fruits and vegetables will not disappear so soon from Thailand's rice bowl.

Marketing channels and contract farming of fruits and vegetables in the Damnoen Saduak area

In the Chao Phraya Delta, agricultural diversification from rice to orchards and vegetables appears as a key agrarian change, responding notably to new market opportunities. Such changes are conditioned by numerous factors, agro-ecologic and socio-economic factors (soil type, water regime, availability of labour, capital…). Marketing, however, appears as both a paramount driving force and a constraint of the development of vegetable and fruit cultivation.

In the lower Mae Klong Basin, Damnoen Saduak area stands out as the main fruit and vegetable production area of the Chao Phraya Delta. Since more than one century, farmers have developed an highly 'artificialised' environment, digging a huge canal network and resorting to raised bed technique, and they have been able to grow a large range of vegetables and fruits in their gardens: cucumber, chilli, yard long bean, coriander, asparagus, eggplant, jujube, coconut, rose apple, sapodilla, guava, grape…

Through the case study of the diversified and commercialised agriculture of Damnoen Saduak area, we intend here to understand the organisation of the marketing system which represents a pivotal element of this market-oriented agrarian system and an important conditions of its development[14].

1 Fruits and vegetables markets in Thailand

A major challenge for Thailand food and agricultural production is the transformation in the volume and pattern of demand brought about by population and economic growth, and by urbanization (Mubarik, 1998).

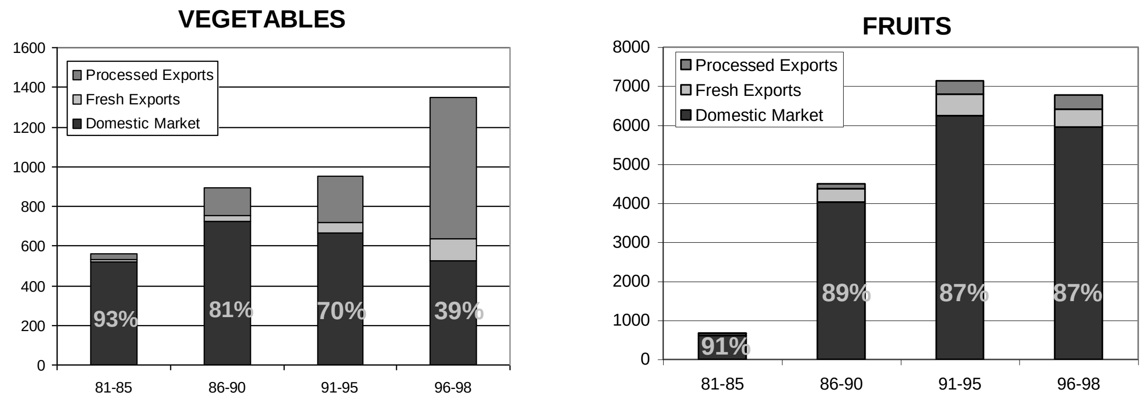
As incomes rise, people first increase consumption of traditional foods (rice) but after diversify their pattern of food consumption into higher value and higher quality foods (fruits and vegetables, animal products…). Per capita income rise has already caused an expansion and diversification of overall food consumption in Thailand, although the considerable disparity between income levels in urban areas (principally Bangkok and vicinity) and rural areas means that the transformation in diet has mainly taken place among urban consumers (E.A.A.U., 1994).

[14] All data and information used come from interviews with farmers, middlemen and related persons engaging in the fruits and vegetables marketing system.

Thailand consumers mainly buy fresh fruits and vegetables at the retail markets. Canned and processed fruits and vegetables sold in shops and supermarket still represent a small, albeit increasing, part of the domestic market. The increase in vegetables and fruit production is aimed at meeting the growing domestic demand and capturing export market opportunities, and is a means for raising rural incomes.

Thailand has clearly achieved considerable diversification into higher value vegetables and fruits in the last decades. Vegetables and fruits have expended from 6% of Thailand crops in 1950 to more than 22% since the 1980s (Siamwalla, 1990). Thailand has emerged as a sizeable producer of a wide range of vegetables and fruits, with the majority of production consumed domestically, but also gradually moved to exporting some high values products such asparagus, eggplants, etc. (Othman *et al.*, 1995).

FIGURE 1: FRUITS AND VEGETABLES PRODUCTION AND EXPORTS, ANNUAL AVERAGE (100 MILLION TONS)



Source: Statistics FAO & Agricultural Statistics of Thailand

The key feature of the supply side response is the expanding role of the private sector and agribusiness. Large-scale conglomerates and agribusiness, both local and foreign, play a growing role in agricultural production agro-processing and marketing (Pattakun and *al*, 1988). In response to both the changing domestic demand aimed at import substitution and to the opportunity to develop an area of higher value exports, they have increased the scale, scope and sophistication of their food processing industry in the 1980s. Thailand is producing frozen and dried, canned and pureed types of food and a whole range of good quality prepared and preserved vegetable and fruit products.

The new long distant transport facilities (plane, air conditioned boat) and processing industry development allow the exportation of an increased volume of this foodstuffs. For some fruits and vegetables, the production was pulled by a processing industry oriented to export, for example baby corn and asparagus. Contract farming is an important aspect of the Thai agribusiness (Naritom, 2000).

It appears that rising domestic demand and attractive potential profit will stimulate the expansion of the more capital-intensive gardening and horticultural sector, with good prospects for Thailand to both meet domestic demand and to develop as a significant export supplier in Asia.

2 Marketing channels of Damnoen Saduak fruits and vegetables

Agricultural development in Damnoen Saduak is a process accompanying economic and trade growth and is triggered by improved transport infrastructures and marketing system development.

The major function of any marketing system is to provide a link, continuous in time and space, between producers and consumers (Siamwalla, 1990). This link materialises by the setting up, the structuring and the organisation of marketing channels. These channels allow the transfer of the fruits and vegetables from the production areas to the consumption zones. As these products are very perishable, the flow through these channels must be rapid, in order to minimise post-harvest losses[15].

Damnoen Saduak fruit and vegetable products follow a great diversity of channels to reach their final consumers. Among the multiplicity of fruits and vegetables channels, we can identify two main organisational patterns:

- Markets channels, which are constituted by numerous vegetables and fruits traders (collectors, wholesalers, carriers, retailers) ; fresh products transit through wholesale markets and are mainly sold in domestic retail markets.

- Process industries and exporters develop integrated channels outside conventional markets. They associate producers, cooperatives or collectors, and industry or exporters.

We estimate that in 1997 92% (in volume) of the fruits and vegetables grown in Damnoen Saduak transit through market channels. Even if the current outlets are mainly the domestic fresh markets, the process industries and exports will be able to offer new significant opportunities for the future development of the Damnoen Saduak productions.

2.1 Markets channels

The first step of the marketing channels of Damnoen Saduak fruits and vegetables is generally the wholesale market of Ratchaburi (provincial market) or that of Bangkok (*Talaat Thai* market). The fragmented farming productions are concentrated there before being dispatched to the numerous retails markets of Thailand. The confrontation of supply and

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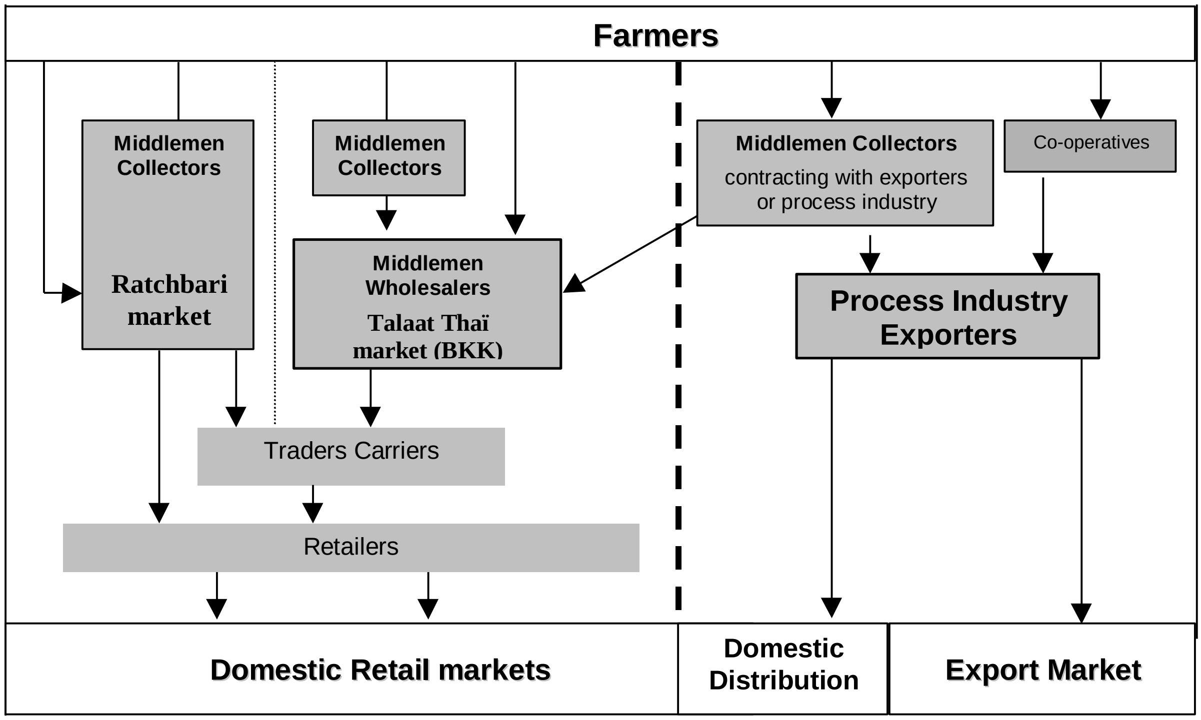
[15] The refresh transports and cold store involve huge investments in the channels. Today, they are virtually non-existent for fruits and vegetables in Thailand. The failure to deal effectively with fruit-ripening processes in hot and humid environments and the handling of product at the farm and markets level probably accounts for high post-harvest losses: 20 to 25% in average (Singh, 1993).

demand in the wholesale markets leads to the formation of a price system, which serves as a reference at the different levels of the channels.

FIGURE 2: SCHEMATIC VIEW OF THE FRUITS AND VEGETABLES MARKETING CHANNELS



Ratchaburi or *Taalat Thai* markets are managed by private companies and have admission fees[16]. But beyond these fees, the acquaintance network constituted an important entry barrier to the markets. The wholesalers, who rent some space by the year, collect deliveries from their employees, from some farmers or generally from middlemen-collectors. They resell their fruits and vegetables to traders and retailers from various provinces.

The daily morning exchange activities of Ratchaburi market concentrate on vegetables and there are few fruits, except guava and rose apple. This provincial market is the hub for vegetable exchanges between the central plain and the south of Thailand. In addition to middlemen-collectors stands, some Damnoen Saduak farmers also sell vegetables directly in Ratchaburi market.

In *Talaat Thai* market, the exchanged volumes are much more considerable. Open all the day, the activity is at its top during the night and early morning[17]. The fruits and vegetables exchanged in this huge wholesale market come from all the country. Here, there are no

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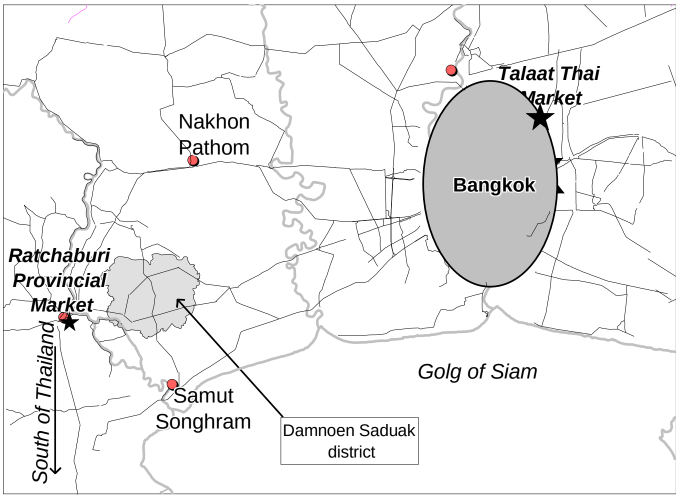
[16] In 1998, the sale space is rented for 5,000 baht/m²/year in Bangkok and 2000 baht/m²/year in Ratchaburi; the admission fee for the pick-up or trucks is 100 baht in Bangkok and 50 baht in Ratchaburi.

[17] Without refrigerated trucks, the fresh fruits and vegetables are transported during the night to avoid hot hours.

farmers. Wholesalers supplied by middlemen-collectors or by their employees rent the stands.

MAP 1: MAIN ROADS NETWORK AND MARKETS



PICTURE 1: FARMER AT RATCHABURI MARKET

2.2 Integrated channels

Capital concentration in the fruits and vegetables processing industry has a significant impact on the marketing structure. To get returns on investments, the process industry must ensure a regular flow of homogeneous products to supply production lines, what is particularly tricky because fruits and vegetables are perishable, non-stackable and non-standard products. The process industries therefore prefer to operate through some collectors than directly with the farmers: because of the huge volumes processed, they cannot collect a tiny amount of heterogeneous products at a large number of farms.

Industries make contracts with a small number of collectors. These collectors commit themselves to supply industries with the agreed amount of one standard kind of fruits or vegetables at a required time. They collect the products from a regular farmers clientele, select, grade, prepare, lorry the products according to the industries requirements and sell the non-standard products to wholesalers of the markets channels.

Bypassing the markets channels and its numerous merchant middlemen, the process industries try to avoid the competition for its raw material in the fresh domestic market and minimise the supply costs. Because the integrated channels are partly disconnected from the conventional marketing channels and present an oligopolistic structure, the corresponding price system is specific, less fluctuating and often specified in the middlemen contracts.

A limited part of the Damnoen Saduak production is directed to the process industries: some grapes, guava and papaya are processed by cannery and juice factories in Nakhon Pathom and Samut Songkram provinces[18]. Fresh vegetables and fruit exporters should be supplied by standardised and high quality products destined to markets in Japan, Singapore, Taiwan, USA or Canada[19]. Transportation from the farm gate to the packinghouse should be a short and quick process, and should minimise the percentage of the fruits and vegetables lost between the harvest, the various ports and the consumers. This is why the exporters have developed similar integrated channels: they conclude contracts with middlemen-collectors who collect, select, grade, and pack in ice according the specifications of the exporters.

Damnoen Saduak fresh export productions are concentrated on a few products: 10% of aromatic coconut production and 45% of the asparagus production. In some particular villages in Damnoen Saduak district, the producers' co-operatives are organised in order to better respond to exporters and process industries requirements. We can find nine co-operatives (7 asparagus co-operatives and 2 aromatic coconut co-operatives) in Damnoen Saduak that have the same function than the middlemen-collectors. This producers co-operative deal directly with the factory or the exporters and the producers are particularly interested by one advantage of this marketing system: the agreed price negotiated each year.

Asparagus has a particular marketing system organised by a Japanese firm (Taniyama Siam Co. Ltd) in order to promote asparagus production 20 years ago. The Japanese firm uses the co-operatives to manage asparagus production in Damnoen Saduak (supplying seed, disseminating cropping system techniques, etc.) and streamline the harvest collected by refrigerated pick-ups (Naritoom, 2000).

The fruit and vegetable productions of Damnoen Saduak go through different channels to reach final consumers: most of the vegetables and some fruits are marketed through the semi-wholesale Ratchaburi market channel, most of the fruits through the wholesale *Taalat Thai* market and a small, but increasing, part of the production through the integrated channels.

The different channels have an operator in common: the middlemen-collectors. These middlemen link the scattered producers to the upstream channels and pass on the market information, which orient farm production. Thus contract farming, as negotiated between the middleman and the farmers, appears as an important element to understand the fruits and vegetables marketing system.

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[18] According to our estimations, in1998 only 15% of the grapes production, 20% of the guava production and 30% of the papaya production are directed to this factory.

[19] The value should be high in order to make air or sea transport cost effective.

3 Contract farming in Damnoen Saduak area

In the raised bed zone, the highly 'artificialised' environment allow the cultivation of a large range of crops. Depending on their individual situation (farm size, family labour force, capital accumulation and access to credit), farmers can develop different cropping systems more or less intensive in labour and capital, more or less risky and profitable, insofar as they have market outlets to sell their productions.

The proximity of Bangkok market, the development of roads network in Damnoen Saduak and the efficient market connection via a middlemen's network constitute important socio-economic conditions for the development of this commercialised and diversified agriculture: more than 20 different crops are grown for sale (chilli, coriander, kale, papaya, asparagus, rose apple, guava, coconut, sapodilla, grape, jujube, lemon, pomelo…).

Most of the farmers sell their production to middlemen-collectors. Before harvest, the gardeners contact middlemen and negotiate a verbal agreement with the traders offering the best conditions. This contract farming between a middleman and a farmer differ according the channel organisation, the type of crops and the situation of the farmers. A few representative examples will provide a general view of the different contract farming present at Damnoen Saduak.

- Sapodilla, pomelo, orange, jujube, mango orchards and vineyards have a relative long juvenile period requiring great input use (particularly for vineyard) and the harvests are concentrated in the year. These cropping systems require a great capital investment and give irregular incomes along the year. Only farmers who have accumulated enough capital or have a good access to credit can develop this cropping system. These farmers have in general larger farms (3 to 10 ha).

The harvest period of these crops is concentrated in few weeks[20]. Growers should market large volumes in a short period. Before the harvest period, they contact different middlemen and make an agreement with the middleman who give the best price. They can change middlemen at every harvest period.

These middlemen deal huge volumes of different fruits according to the season: they have trucks, several employees and they are often wholesalers in *Talaat Thai* market. Because of the large volumes dealt each time, there are some scale economies, which explains the more concentrated structure of the market channels. These market channels are less competitive and the middlemen margins are higher. This is particularly true in the case of the grapes market. There are few wholesalers in Bangkok who have employees collecting

[20] For example, sapodilla orchards are harvest in November and February every 15 days (600 kg/rai/harvest). Or for grape, 2 harvest period per year (1,5ton/rai/harvest), each harvest 1or 2 days.

production in Damnoen Saduak. Farmers contact wholesalers before the harvest to make an agreement. The wholesalers come to observe the harvest quality and propose a price. If the farmer agrees, a verbal contract is concluded: the wholesaler promises to buy all the harvest at the fixed price. To face the expensive harvest costs[21], the wholesalers advance 20% of the amount agreed upon.

- Middle farmers (1,5 to 3 ha) have a limitation for borrowing capital and adopt cropping systems allowing to spread their capital and labour force needs: guava, rose apple or lemon are the most common. In fact, these kinds of orchard have a shorter juvenile period and the harvest periods are staggered over the year. As a result, the growers obtain a continuous flow of income but should sell their production on a regular basis, in relatively tiny amounts each time.

In this case, farmers prefer to trade continuously with one buyer for a full harvest cycle. But farmers regularly change of middleman between two harvest cycles. Before the harvest period, farmers contact different middlemen and make an agreement for all the production period with the middlemen who propose the best average price. Even if this price is often a break promise, farmers are ensured to have outlets for all their production, good or bad quality.

Because the market production at one time represents a small volume, there is no scale economy in this kind of marketing system: numerous small middlemen collect the production of 10 or 20 farmers with a pick-up and resell it at Ratchaburi market. The heightened competition between middlemen has the effect of reducing the potential for exploitation and of lowering marketing margins to an acceptable level.

- Small farmers (1,5-0,7ha) cultivate labour intensive crops that allow them to get a high added value with small capital investments; usually they grow an association of vegetables. Because of the tiny volume of each harvest, farmers can handle transportation with pick-ups[22] and find outlets in the Ratchaburi market. The farmers who choose this marketing system have enough labour force and capital to invest in the marketing of their production. The estimated profit of this marketing system is 10% to 20% of the gross product, compared with the middlemen-collectors marketing system.

- Some farmers need to borrow money to be able to grow some crop, in particular very small farmers (0.3-0.7 ha) or young farmers. Some middlemen accept to give credit in kind to these poorer farmers (seeds, fertiliser and pesticides). The middlemen are the risk-takers and determine the cropping system: low risk crops such as sweet potatoes, sweet or baby corn. As Damnoen Saduak farmers said: “corn and potatoes are the crops of poor farmers”.

The farmers in general avoid resorting to the middlemen credit and prefer alternative sources with lower interest (public or private banks, relatives, neighbours…). A farmer who obtains

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[21] Grapes farmer employees 7 persons for each harvested rai.

credit from a middleman must sell all his production to him until the debt is cleared. The moneylender middleman has a monopolistic position and can increase his margin at the cost of the farmers.

Marketing is characterised by a high degree of competitiveness because farmers have the choice between numerous alternative marketing channels, and the price received by farmers for their products compared to the retail prices is quite high (Figure 3).

A part of the middlemen profits are largely speculative, arising from price fluctuations. When the price is high, farmers receive little return of the larger middlemen profits. When the price is low, the middlemen pass the price decrease on to the farmers. We can observe this mechanism in all the market systems. So the farmers take the major part of the risk: the production risk and the market risk.

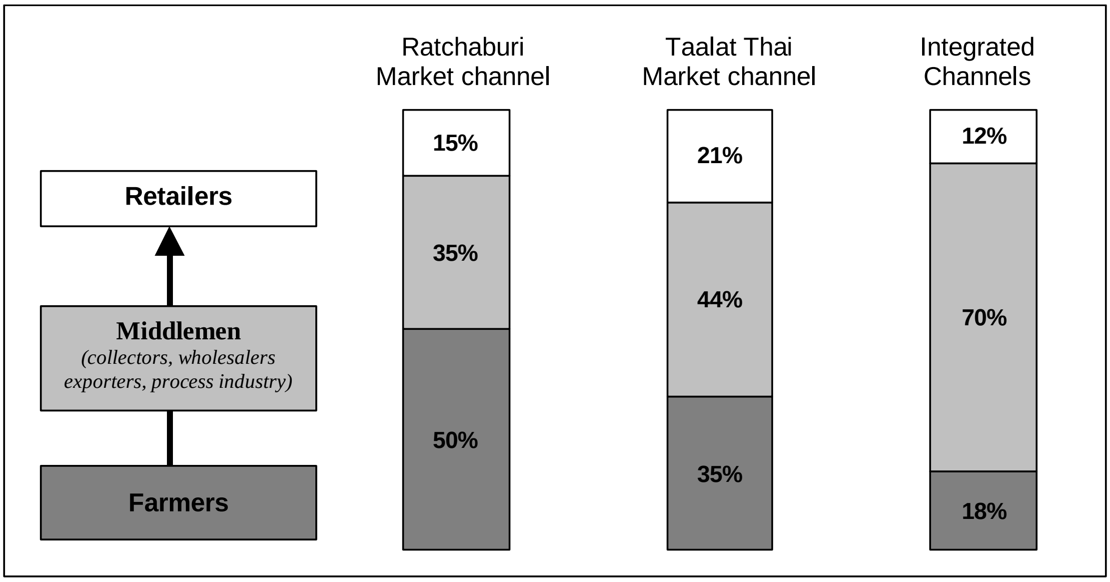
Under the present marketing structure, there is very little incentive for farmers to improve the quality of production. There exist no standards for any of these commodities. For transactions at the farm-gate level, the buyer will make his own subjective evaluation. It is the middleman who sets the standard and decides what the quality is. This is one of the main methods used by middlemen to exploit farmers.

4 The distribution of the added value and perspectives

The marketing systems for the major crop gives way to no exorbitant profits, are rather competitive, and there is therefore little room for improving economic efficiency. A more efficient system could theoretically be achieved by eliminating some middlemen, allowing them to expand to an optimum size and thus cutting down marketing costs. But the marketing channels would lose competition, flexibility and adaptativeness to the farmer's situation.

[22] Some farmers have theirs own pick-up, some farmers call carriers who rent the service of prick-up transport.

FIGURE 3: PERCENTAGE OF THE ADDED VALUE COMING TO THE DIFFERENT OPERATORS



The part of added value accruing to the middlemen is dependant upon their functions in the channel. In the case of Ratchaburi market channel, the middlemen only have a role in trading; in the case of the Talat Thai channel, they act as collectors, carriers and traders; in the integrated channels, the middlemen activities include the collect, the transport, the marketing and the process. Therefore the part of the added value accruing to them is in direct relation of the tasks they perform. But the distribution of the added value also reflects the channels competitiveness and the bargaining powers of the different actors. The benefit of the middlemen is also dependent upon the type of product, the quantity, the distance and the risk involved.

Until now, the increase in income triggered a quantitative increase of the fruits and vegetables demand in Thailand. The new requirements of the consumers would now be a better quality of products[23]. As new fruits and vegetables producers and exporters appear, the Asian market become more competitive, and Thailand processing industries and exporters place top priority on product quality. To respond to these new market trends, standards (grading, label) must be established and incentive on quality premium must appear through the prices system.

The main outlets of fruits and vegetables in Damnoen Saduak have been the numerous urban and rural retail markets, which represent the main mode of fresh food distribution in Thailand. More and more consumers, particularly in Bangkok, buy fruits and vegetables in the new supermarkets. If these distribution trends are confirmed, the integrated channels, which supply these supermarkets, would expend their role in the fruits and vegetables markets to the detriment of the market channels. The oligopolistic aspect of this type of channels would impact negatively on the farmers' position and on their share in the channel

[23] The development of « safety or organic products » market is an example of this market trends.

added value, which would tend to eliminate most small farmers. To be able to face this new challenge, farmers should consider establishing producers' co-operative organisations.

References

ADEME (1995) Les micro-polluants métalliques dans les boues résiduaires des stations d'épuration urbaines. ADEME/INRA eds., 209 p. French.

Akin, R. (1969) The Organization of the Thai Society in the Early Bangkok Period, 1872-1873, Cornell University, Departement of Asian Studies, Data paper n°74, Ithaca, p 42.

Boonma C., Issariyanukula A., Tugsinavisuitti S. (1974) Vegetable production in *amphoe* Damnoen Saduak, Changwat Ratchaburi, 1972-1973, Department of Agricultural Economics, Faculty of Economics and business Administration, Kasetsart University, p13, p41.

Brown, Ian (1988) The Elite and the Economy in Siam, 1890-1920, Oxford, University Press, p16.

Chatthip, Nartsupha & Suthy Prasartsert (1981) The political Economy of Siam, 1851-1910, Social Science Association of Thailand, Bangkok.

Cheyroux B. (1997) Analyse des systèmes agraires passes et actuels d'un village de la plaine centrale thaïlandaise. Mémoire de DEA. Institut national agronomique de Paris-Grignon. 155 pages. French.

Cheyroux, B. (1997) Analyse des systèmes agraires passés et actuels d'un village de la plaine centrale Thaïlandaise, DEA Géographie et Pratique du Développment, INA-PG.

Chiengkul, Witayakorn (1983) The effects of capitalist penetration on the transformation of the agrarian structure in the central region of Thailand (1960-1980), Social Research Institute, Chulalongkorn University, Bangkok, p33.

Donner, W. (1978) The five Faces of Thailand – An economic geography, Institute of Asian Affairs, Hamburg, p211.

Douglas, M. (1984) Regional Integration on the capitalist Periphery: The central plains of Thailand, Institute of Social Studies, The Hague, p35, p 47.

Dufumier M. & Srijantr Thippawal (1996) Agriculture Paysanne, Interventions de l'Etat et Limites de la « Révolution Verte» en Thaïlande, *Revue Tiers Monde*, pp 121-136.

E.A.A.U. (East Asia Analytical Unit) (1994) Subsistence to supermarket: food and agricultural transformation in South East Asia, Department of Foreign Affairs, Australia.

Fistié, P. (1967) L'évolution de la Thaïlande contemporaine, Armand Colon, Paris, p 48.

Hafner, J.A. (1970) The impact or road development in the Central Plain of Thailand, The University of Michigan, PH.D.

Hobson R.N., Robertson A.M. (1977) Waste treatment in Agriculture. Applied Sc. Publ. Co. Inc., London. 257 pages. English.

Ishii, Y. (1975) *Thailand: A Rice-Growing Society*, The university Press of Hawaii, Honolulu, 1975, p 30.

Joannon G. Poss R. Korparditskul, R. (1999) Impact of grapes cultivation on the environment – the case of Damnoen Saduak area, Kasetsart University, IRD

Kasetsart University and IRD (ex-ORSTOM) (1996) Agricultural and Irrigation Patterns in the Central Plain of Thailand, DORAS Project, Bangkok, 220 p.

Kemp, J. H. (1987) Legal and Informal Land Tenures in Thailand, *Modern Asian Studies*, V15, page 1-23, Cambridge University Press.

Kimura R. (1986) Nitrification activity. *In* Standard Methods of Soil analysis and Measurement, ed. Japan. Soc. Soil and Plant Nutr., p. 312-320, Hakayusha, Tokyo. Japanese

Korpraditskul V., Paradornuwat A., Korpraditskul R. and Polyangsong P. (1998) The effect of Fero on Citrus plantation in Rangsit. Final report submitted to Thai Foods International Co., LTD, Bangkok. Thai.

Lester J.N. (1987) Heavy Metals in wastewater and sludge treatment processes. Vol.1. Sources, Analysis, and Legislation (ISBN 0-8493-4668-1, 183 pages). Vol. 2. Treatment and disposal (ISBN 0-8493-4669-X, 155 pages), C.R.C. Press. English.

Manarangsan, Sompop (1989) Economic Development of Thailand, 1850-1950: Response to the Challenge of the World Economy, Institute of Asian Studies, Bangkok, p55.

Marschner H. (1995) Mineral nutrition of higher plants. Second edition. Academic Press, Harcourt Brace Jovanovitch Publishers, 674 p.

Merian E. (1991) Metals and their compounds in the environment. Occurrence, analysis, and biological relevance. VCH, ISBN 3-527-26521-X, 1438 pages. English.

Michard G. (1989) Équilibres chimiques dans les eaux naturelles. Publisud. Collection sciences et techniques. 357 pages. French.

Molle F., Sutthi C., Keawkulaya J., Korpraditskul R. (1998) Water management in poldered raised bed systems: a case study in the Chao Phraya Delta, DORAS-DELTA research project no. 4. Orstom, Kasetsart University, Bangkok. 68 p.

Molle, François; Srijantr, Thippawan (1999) Agrarian change and the land system in the Chao Phraya Delta, DORAS Project, Kasetsart University, Bangkok, Research Report n°6, 191 p.

Moustier P., Pages J. (1997) Le péri-urbain: une agriculture en Marge. *Economie Rurale* Vol 241 sept-oct 1997 pages 48-56

Moutonnet P., Pagenel J.F., Fardeau J.F. (1993) Simultaneous field measurement of nitrate-nitrogen and matric pressure head. *Soil Sci. Soc. Am. J.*, 57: p 1458-1462.

Mubarik, Ali (1998) La nouvelle problématique de la production de légumes en Asie, Revue Tiers Monde n°153, janvier-mars 1998.

Murase J., Topark-Ngarm B., Adachi T., Losirikul M. and Kimura M. (1994) Studies on saline soils in Khon Kaen Region, Northeast Thailand V. Nitrification and nitrifying bacteria. Soil Sci. Plant Nutr., 40(1), p 173-177. English.

Naritoom, Chatcharee (2000) Contract farming in Central Plain: a case of asparagus grower groups in Nakhon Pathom province, Proceedings of the international Conference: «The Chao

Phraya Delta: Historical Development, Dynamics and challenges of Thailand Rice Bowl », 12-14 December 2000, Kasetsart university, Bangkok

Othman Yaacob and Suranant Subhadrabandhun (1995) The production of economic fruits in South-East Asia, Oxford university press, Kuala Lumpur.

P. Phonppaichit & C. Baker (1995) *Thailand - Economy and Politics,* Oxford University Press, New York.

Page A.L. (1982) Methods of soil analysis. Part II: Chemical and microbiological properties. 2nd ed. American Society of Agronomy, Inc. and Soil Science Society of America, Inc. 1159 pages. English.

Page A.L., Gleason III T.L., Smith Jr. J.E., Iskandar I.K., Sommers L.E. (1983) Utilization of municipal wastewater and sludge on land. University of California, Riverside, CA 92521 (USA), 480 pages. English.

Palakul S., Sukmak S., Damrak B. (1995) Studies on toxic residues in vegetable and fruits. *In* First conference of toxic substance division, Ministry of agriculture and cooperative. P96-104.

Pallegoix (1854) Description du Royaume Thaï ou Siam, DK Book House, Bangkok 1976, p46.

Patmasiriwat, D. (1982) Credit expansion for rural poor areas, in the Thai University Research Association (cd.), A study of policies and programs for eradication of rural poverty in selected districts in Thailand, Bangkok.

Pattakun, Chandhanamutta and Hiran Hiranpradit (1988) Diversification process in Thailand, Department of agriculture, Kasetsart University, Bangkok.

Pignon M. (1997) Le delta du Chao Phraya en Thaïlande: diagnostic de la qualité de l'eau. Impact sur les activités agricoles. Mémoire de fin d'études. ESA d'Angers. 117 pages.

Pollution Control Department (1997) Development of an action plan to improve water quality in the central river basin. 24 volumes. Thai Ministry of science, technology and environment, Bangkok. English and Thai.

Reuter J. & Robinson J.B. (1997) Interpretation from plant analysis. An interpretation manual. Inkata press (Melbourne, Sydney), 2nd Edition.

Rigg, Jonathan D. (1986) The Chinese agricultural middleman in Thailand: Efficient or exploitative?, Singapore Journal of tropical Geography, vol. 7 n°1

Saha, Pradit Kumar (1993) Agricultural Development in The Tropical Delta : A Case Study in The North Rangsit Irrigation Project, Thailand. Asian Institute Of Technology. M.Sc. Master Degree. Bangkok, Thailand.

Saragoni H. & Poss R. (1992) Production de matière végétale et prélèvements minéraux du maïs au sud-Togo. *Agron. Trop.*, 46(3): 185-201.

Siamwalla Ammar (1990) Farmers and middlemen: aspect of agricultural marketing in Thailand, Thammasat University publication, Bangkok.

Siamwalla Ammar, Direk Patamasiriwat and Suthad Setboonsarng (1990) Public Policies towards agricultural diversification in Thailand, Thailand Development Research Institute Foundation, Bangkok.

Siamwalla, Ammar (1993) The Thai rural credit system and elements of a theory: public subsidies, private information and segmented markets, Oxford University Press

Siamwalla, Ammar (1999) Collection of articles, TDRI.

Silcock, T.H. (1970) The economic development of Thai agriculture, Australian National University Press, Canberra.

Singh K.G. (1993) Research and development of fruits and vegetables in Asia-pacific region, Food and Agriculture Organization, Bangkok.

Skinner, W. (1957) Chinese Society in Thailand, Cornell University Press, New York.

Srijantr P. (1996) Appui méthodologique a l'application d'une politique agricole: utilisation de la télédétection pour caractériser les sols en vue de la gestion des ressources en eau de la plaine centrale de Thaïlande. Ph.D. thesis. University of Bordeaux III. 233 pages. French.

Srijantr T. (1998) Transformations actuelles de l'agriculture thaïlandaise. Étude du système agraire de Thung Look Nok. PhD thesis. Institut national agronomique de Paris-Grignon. 353 pages.

Suranant Subhadrabandhun and Kasem Pibuk (1990) A look at Thai Horticulture, Chronica Horticulture, 30 (3): 39

Sutthi, Chusak. (1998) Management of water usage in areas using raised bed technique in Damnoen Saduak area. Master thesis. Kasetsart University, Bangkok. 138 pages. Thai.

Takaya Y. (1987) Agricultural development of a tropical delta: a study in the Chao Phraya delta. Monographs of the center of southeast Asian studies. University of Hawaii. 269 pages. English.

Takaya, Y. (1987) Agricultural Development of a Tropical Delta - Study of the Chao Phraya, University of Hawaii Press, Honolulu.

Thai Ministry of agriculture, entomology division (1996) Plant protection and insects 2539. Bangkok. 259 pages. Thai.

Thai Ministry of agriculture, entomology division (1998) Plant protection and insects 2541. Bangkok. 285 pages. Thai.

Thoophom G., Sungvaranond B., Jiragobchaiyapong G., Atisook K., Jongmevasana P. (1998) Test kit for rapid screening residues of pesticide in food. Bulletin of the Department of Medical Sciences, Bangkok, vol. 40, p 273-287. Thai.

Tomosugi, T. (1966) Historical Development of Irrigation and Drainage in the Chao Phraya Delta, Southeast Asian Studies, page 165-175.

Viessman W., Hammer M. (1993) Water supply and pollution control. Fifth edition. Harpercollins college publishers. English.

Abhakorn, R. (1984) Ratburi, an inner province: local and central politic in Siam 1868-1892, Ph.D. Political Science, Chulalongkorn University

Zimmerman, C.C. (1931) Siam – Rural Economic Survey 1930-1931, Harvard University Press, p167.