A Wise Use of Flood Water Resource at The Mekong Delta of Vietnam

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Overview Paper Spate Irrigation

Spate Irrigation Network

Abstract

This Spate Irrigation Overview Paper introduces the reader into the mighty living waters of the Mekong and the multiple natural richnesses it provides annually to people living in its arms. From ancient times the rhythm of the floods, providing fresh water and new nutrients, form the secure foundation generating income for its inhabitants, making use of the rich aquatic life, consisting of aquatic crops (e.g. Aquatic Caltrop, Lotus and Neptunia) and water animals (fish, snails and crabs). Last decade, however, the area used for rice production is increasing. The authors, also living in the flood plain, analyzed potential impacts of this changing land pattern on income sustainability of the poorer households. An Giang province was used as case study area, involving farmers, community associations and local authorities.

In each study site, 50 farmers per community were selected for in-depth interviews using formatted questionnaires and applied participated rapid appraisals (PRA). At the end of each field survey on-farm workshops were organized, inviting also the other stakeholders: community associations, press and local authorities The research showed that farmers and communities still profit most of fisheries (catching snails, crabs and fishes) annually generating 79 million VND (3854 US$) for an household. Production of aquatic crops and rice are good additional sources of income, bringing profits of respectively 9.1 and 10 million VND per adult household member. The aquatic crop production is regarded as most lucrative second alternative, especially for smallholder farmers, as it requires only a third of the land required for rice production (0.12 vs. 0.3 ha) to produce the same profit. Further pre-investments showed to be remarkably lower for aquatic crop production as compared to rice (4.2 vs. 16.6 million VND) creating another incentive for the poorer farmers to remain mainy involved in aquatic crop production.

These analysis prove that fisheries is still the dominant source of income for the people living in the Mekong delta. However, aquatic crop production is still a good second source of income, especially for the poorer farmers in the Mekong, as it requires a relative small land size and low pre-investment of capital. Therefore the current continues expansion of the rice area, requiring more land to generate the same profit, should be regarded with concern.

Key words: Mekong Delta, Water Resources, Flood Zone

Geography of the Delta

The Mekong, one of the world's great rivers (4,350 km), flows from the Tibetan Plateau of China through, or along the borders of, Myanmar, Lao PDR, Thailand, Cambodia and Vietnam. Before reaching the boundary of Vietnam, it splits into two arms (Tien Giang and Hau Giang) and reaches the East Sea by nine mouths. Its delta covers over 5 million hectares (51,176 km^2), of which 80 % is situated within Vietnam[1]. The delta, according to Chiem (1993), can be divided into five landform units:

(1) floodplains which include natural levees (up to 1 m high) along the two main arms of the Mekong river;
(2) a coastal complex of sand ridges and mangroves;
(3) a broad depression covering most of the Ca Mau peninsula, which does not receive floodwater from the Mekong river;
(4) an old alluvial terrace in the far north-east; and
(5) a small area of mountains (up to 780 m).

The average elevation of the whole delta is 2 m, with floodplains and the broad depression of Ca Mau covering most of the Delta (Ibid.). Still 70 % of the people live in a scattered pattern of villages and hamlets throughout the plain, cultivating 83 % of the delta with agriculture or aquaculture production systems (National Statistical Yearbook 2012). Another 7 % of the plains constitute of natural wetland ecosystems (Nhan, 1997). Only 30 % of the population lives in the small area left over for urban conglomerations, resulting in high population densities of over 800 pp km^{-2} (National statistical year book 2012).

Wetlands distribution in the Mekong Delta

In most of the Delta, sediments rich in pyrite (FeS_2) were deposited under a tidal, brackish water mangrove swamp in the Holocence period. Later, fertile alluvial sediments were deposited on top of these sediments (Chiem 1993). Still the floods of the Mekong River seasonally overtop the levees, usually during the flood of the wet period in September and October. The annual discharge of the Mekong River is 500 km^3 having an average discharge of 50,000 m^3s^{-1} and a peak flow of 100,000 m^3s^{-1}. The whole delta is influenced by a monsoon climate zone, inducing high rainfall between June and October. Up to the 20th century the wetlands situated at the lower-lying depressions further from the Mekong River were permanently submerged, the water level only gradually lowering during the dry season (Beilfuss and Barzen 1994). Such areas of wetlands were very rich in biological resources (Duc 1991), dominated by wetland forests and grassland. From the 1900's however, artificial drainage of these zones has altered these zones for agricultural and aquaculture production.

Processes in changing wetlands to paddy rice field and associated problems

The construction of canals and drainage has however resulted in a few unforeseen changes in soil properties. The pyrite containing sediment layer (pyritic layer) was oxidized to form a sulphuric layer, which transformed potentially acidic condition into actual acidic condition. The process is simplified represented in formula [1] (Bloomfield et al. 1973, van Breemen 1976, Dent 1992).

$$FeS_{2(s)} + 3\,{}^{1}/_{2}O_{2(aq.,g)} + H_2O_{(l)} \rightarrow Fe^{2+}_{(aq.)} + 2SO_4^{2-}{}_{(aq.)} + 2H^{+}_{(aq.)} \qquad [1]$$

The reaction of ferrous iron (Fe^{2+}) with sulfate ions leads to further acidification of the soil layers following the reactions [2] and [3]:

$$Fe^{2+} + SO_4^{2-} + {}^{1}/_{4}O_2 + 2\,{}^{1}/_{2}H_2O \rightarrow Fe(OH)_3 + 2H^+ + SO_4^{2-} \qquad [2]$$

$$Fe^{2+} + SO_4^{2-} + {}^{1}/_{4}O_2 + {}^{3}/_{2}H_2O + {}^{1}/_{3}K^+ \rightarrow {}^{1}/_{3}KFe_3(SO_4)(OH)_6 + H^+ + {}^{1}/_{3}SO_4^{2-} \qquad [3]$$

The former neutral reduced "pyritic layer" (grey color) changes suddenly into a mottled "oxidized-layer" (strongly bright yellow) having a pH value of 3.5 or lower. Depending on the pH and Eh (redox potential) of the soil, the yellow mineral Jarosite ($KFe_3(SO_4)_2(OH)_6$), a clear characteristic of the oxidized "pyritic layer", may be formed (van Breemen, 1980).

1) *The sole focus of this paper is on the delta of the Mekong river, as situated in Vietnam. All definitions, like Delta and Mekong river, used in this paper, refer therefore only to the river and flood plains located within Vietnam*

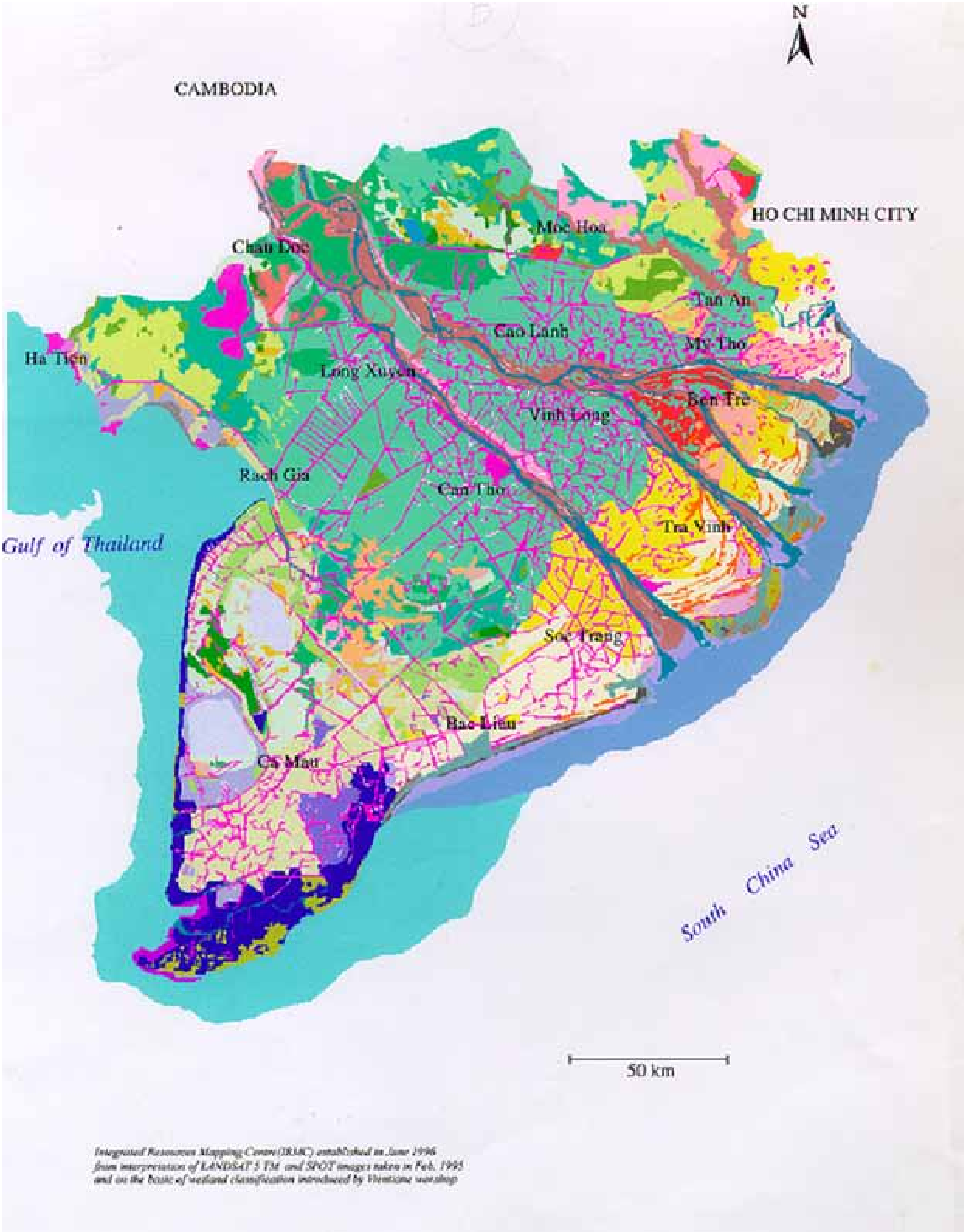

Figure 1. Wetland map of the Mekong Delta of Vietnam produce by applied Ramsar wetland definition and classification introduced at a workshop in Vientian (Lao PRD) in April 1993 (Nhan 1997).

The hydrogen ions formed in the reactions [1] to [3], continue to break down the clay mineral resulting in the liberation of Al^{3+} ions [4]. In reaction [4] the clay-mineral is represented by $Al(OH)_3$.

$$Al(OH)_3 + 3H_+ \rightarrow Al^{3+} + 3H_2O \qquad [4]$$

In the course of the rainy season the soil becomes wet and regularly flooded after heavy rains and therefore the soil layers are depleted of oxygen. In the presence of a high amount of organic matter from former vegetation, nitrates, manganese and ferric-iron compounds are reduced to ammonium, Mn^{2+} and ferrous-iron (Ponnamperuma, 1972). After every inundation ferrous iron reaches a peak concentration, which is often toxic to crops, including rice plants. This is mostly due to the reduction of ferric- to ferrous-iron, acidity is reduced and the pH increases [5] to [8]:

$CH_2O + H_2O \rightarrow CO_2 + 4H^+ + 4e^-$ [5]
Oxidation of organic matter

$NO_3^- + 10H^+ + 8e^- \rightarrow NH_4^+ + 3H_2O$ [6]
Reduction of nitrate to ammonium

$MnO_2 + 4H^+ + 2e^- \rightarrow Mn^{2+} + 2H_2O$ [7]
Reduction of manganese

$Fe(OH)_3 + 3H^+ + e^- \rightarrow Fe^{2+} + 3H_2O$ [8]
Reduction of ferric to ferrous iron

Due to the increase in the pH the concentration of Al^{3+} decreases, and changes to its di- or mono-valent forms. The risk of Al-toxicity therefore occurs mainly during the dry and the onset of the rainy season. In the presence of surface water and the subsequent increase of the soil pH due to reduction processes, Al-toxicity is prevented throughout the rainy season.

After some weeks of continuous submergence, reduction of sulfate to hydrogen sulfide occurs, and continuing submergence leads even to reduction of carbon dioxide to methane gas [9] and [10].

$SO_4^{2-} + 10H^+ + 8e^- \rightarrow H_2S + 4H_2O$ [9]
Reduction of sulfate to sulfide

$CO_2 + 12H^+ + 12e^- \rightarrow CH_4 + 4H_2O$ [10]
Reduction of carbon dioxide to methane gas

Reduction of sulfate to sulfide is catalyzed by anaerobic bacteria, which use the reduction of sulphates for their metabolism. These bacteria function best in the pH range between 5.5 and 9.0 (Ponnamperuma, 1972). H_2S production therefore only occurs in soils in which the pH, during the rainy season, rises above 5.5.

Young reclaimed wetlands that have not undergone years of drainage and leaching are generally well supplied with nitrogen and potassium. Phosphorus is, however, deficient due to the precipitation of phosphorus with soluble Al^{3+} and Iron.

Leaching toxicities out of the root zone and away from the field, are the first pre-requisite of wetlands reclamation. Leaching occurs by rain, irrigation or flooding, transferring substances from the soil to the water (Mormann and van Breemen 1978, Dent 1986, Klepper *et al.* 1990, Minh *et al.* 1997, Tuong *et al.* 1998). The amount of substances released depends on the volume of water drained and the crop grown. It is for instance known that leachate from raised beds of yam and pineapple fields have a lower pH (2.3 - 3.5) and higher Al^{3+} concentrations than leachate from rice fields (7-15 vs 4-5 mmol/l^{-1}) (Minh *et al.* 1997 and Tuong *et al.* 1998). All acid drainage water from reclaimed lands reduce however the water quality for productive lands and aquatic life. This relation is discussed in Hanhart and Ni (1992) who observed a pH drop in the canals surrounding a one hectare reclaimed land (ASS) for rice cultivation. The release of at least 154 mm drainage water reduced the pH of surrounding canals to around pH 4. In total 500,000 hectares of productive land deal acidity problem (Kham, 1988).

Acidification of canal water reaches a yearly peak at the onset of the rainy season (June to July), resulting in dramatic decreases in fauna and especially invertebrates (Smith 1990). Acidic toxicity, especially aluminum, is hazardous for fish (Breemen 1993). The tolerance limit of aluminum for most fish is 0.2 to 0.5 ppm (Singh *et al.* 1988), and a strong reduction of fish population at high aluminum content has been reported (Brown *et al.* 1983, Baker *et al.* 1993, Xuan 1997). Klepper *et al.* (1990) reported that fish yield was reduced by ten-fold in reclaimed wetlands areas compared with other areas. Dat (1991) and Willet *et al.* (1993) also reported serious environmental impacts of wetlands reclamation projects, in offshore ecosystems in West Africa. As earlier mentioned, also the impacts on rice are negative. A concentration of 1 - 2 ppm aluminum in a culture solution can be toxic for rice (Cate and Sukhai 1964, Mensvoort *et al.* 1985). At 60 ppm aluminum severely affects even tolerant rice varieties. Aluminum can directly affect cell division; disrupt the activities of the proteinaceous enzymes located in the cell wall; or decreasing phosphorus absorption and other essential cations including calcium and potassium (Rorison 1982).

The discussion above showed the detrimental impact of reclaiming wetlands for agricultural land (especially rice production) on soil properties and in the end also water quality. Besides reducing the number of fish, also the rice production itself is affected by the acidic water. The central issue to be emphasized is that land reclamation, and water management, for rice production should be carefully studied to prevent degradation of the environment and drop of income for the majority of the households, who are still depending on fisheries and aquaculture for their livelihoods.

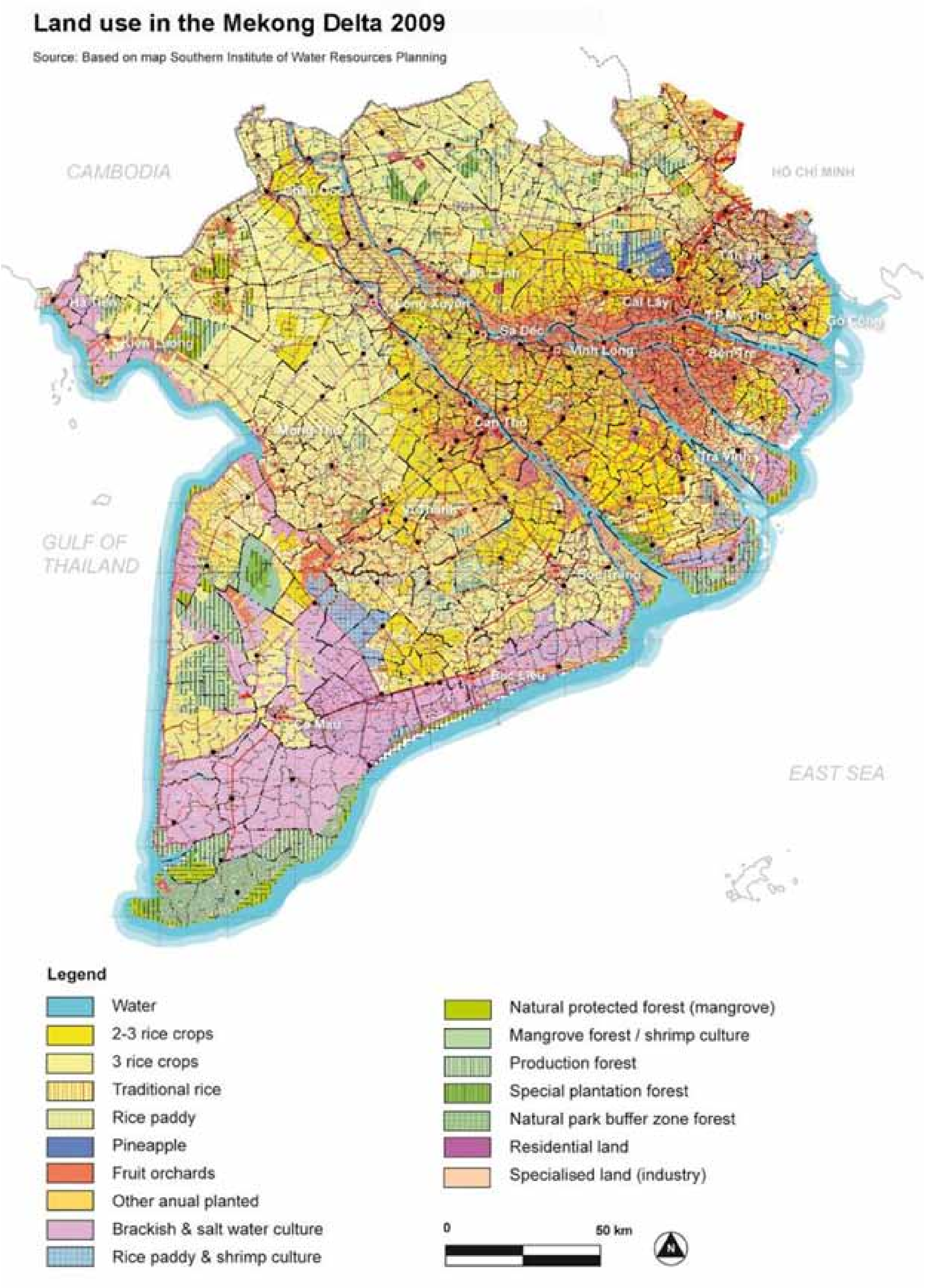

Figure 2 Land uses of the Mekong Delta on 2009 (Southern Institute of Water Resource Planning)

Historical development of paddy rice fields

The historical development of the delta is chronological to the paddy rice development. The arrival of rice production was earmarked by the construction of canals and new villages, starting from early 18th century. First the canals served to connect central provinces and districts (e.g. Quan Lo Phung Hiep Canal connected Phung Hiep district to Phuoc Long district, and Ca Mau province). Later the canals served to open new land for settlers, creating more villages and hamlets (e.g. Plain of Reed, Ca Mau peninsular and Long Xuyen rectangular). Canals are still the major routes of the Delta. The digging of canals has continued until the present time.

The canals dramatically changed the shape and nature of the Delta. At first, the canals, draining the excess surface water from the wetlands, reduced the period of flooding in the wetlands from 12 months to 4 to 6 months (Hanhart & Ni 1993). Only the lowest area's remained submerged all year round. Over the years, the lower water and groundwater level started to dry out the soils forming acidic sulphate soils by the oxidation of pyrite containing sediment. Nowadays, acid sulphate soils cover 2 million hectares of the Mekong Delta, and was used for paddy rice cultivation.

The Delta is an important food bowl of the country, mainly in providing paddy rice. Rice is planted at the onset of the rainy season and harvested after the recession of the flood in the dry season, locally referred to as the "Mua" system. With the introduction of the short duration dwarf varieties in the Delta in the 1960's, the farmers changed to the cultivation of an early rainy season crop (He-Thu crop) which is harvested before the flood. Further, the presence of canals carrying fresh irrigation water, allow farmers also to cultivate a winter-spring crop (Dong-Xuan crop), being planted after flood recession and harvested at the end of the dry season. This crop is followed directly by a short duration variety during the dry season (Summer-Autumn crop), which is harvested at the beginning of the flood. In the 1990's, with the construction of dikes to safeguard Summer-Autumn crops and the regional closed dikes, a triple rice cropping in the deep flooding area was applied.

Over 4 million hectares of paddy rice, cultivated by 18 million people, in the Mekong Delta produces nowadays more than 25 million ton rice per year. It contributes over 80 % to the national rice earnings and produces 90 % of all exported rice. Thus, rice production continues to play a vital role in the socio-economic development strategies of Vietnam. Therefore, potential impacts in variation of water resources (in quantity by climate change and quality, by reclamation) need to be managed to secure rice production activities and livelihoods of millions of inhabitants. On the other side also the impact of reclamation itself need to be managed and controlled for sustainability.

The surveyed areas in An Giang Province

An Giang province (see figure 3) was selected for an in-depth study how the current population uses land and water resources for their income, and if, and how, the current changing trends in land use dynamics can sustain their livelihoods. Also, the earlier studies (e.g. Tri *et al*. 2011) in An Giang made the area more suitable, having richer data and allowing comparison with earlier researches. Furthermore, An Giang having deep flooded areas, and so rich fish resources, is most vulnerable for future changes in management land and water resources. The survey of Tri et al. (2011) allowed a better understanding on the key roles of whitefish and sediments for the rice production activities and so livelihoods of inhabitants in An Giang province. Reduced water quantity and quality by habitat alteration (for rice production) could create a large loss of the fish population (70 % of the catches being migratory fish species) in this area. Other threats to aquatic life are over-exploitation, pollution, main stream dams, invasive species and climate change. The challenge of using water resources for rice production would be higher pressure in the deep flooded areas than the others.

Two surveys were done in the selected areas: one in the peak of the flood season (September 2012) and another in the dry season (April 2013).

Data collection

The literature study provided a broad understanding of the socio-economic conditions and livelihood activities of the households in the selected sites. The Strategic Environmental Assessment report of MRC on 12 hydropower dam projects on the Mekong mainstream was also of value for this study.
For each selected commune, the following research methods were applied:

- *Household surveys*: The surveys focused on the income distribution of the households, being composed of either fishing, farming aquatic crops, rice production or other activities.

About 50 households in each of the 5 communes were interviewed.

- *Key stakeholder surveys*: Interviews with government officials at provincial, district and communal level were held to explore the current conditions of local incomes and water resources. The respondents included officials of the Departments of Agriculture and Rural Development, Natural Resource and Environment, Agency of Aquaculture, Agency of Water Resources and Irrigation. The interviews aimed to understand water resource management, irrigation infrastructure developments and the operation of dams and sluice gates.
- *Group survey*: Three groups sessions per commune, with 5 to 10 members per group, were organized. These sessions aimed to create a better understanding of available indigenous knowledge, the threats on agriculture production and livelihoods, especially in the context of water resources variation.

The collected data were synthesized and analyzed by using Microsoft Excel. While qualitative data was documented into graphs and tables; quantitative data was entered and processed accordingly by the use of Microsoft Excel and SPSS. As such, descriptive data on frequency, mean, min, max, standard error of mean were documented.

The Results and Discussion

All data collected on the income distribution of the households is presented in table 1. It shows that the profitability fishing is by far the highest (79 million VND $hh^{-1}yr^{-1}$) and constitute the larger part of households income. The two other sources of income are rice cultivation and aquatic crop production; generating annually respectively 10 and 9.1 million VND per adult household member, owning on average 0.3 and 0.12 hectares for rice and aquatic crop production.

It is notable that pre-production costs for aquatic crops are much lower for aquatic crops than for rice, respectively 35 and 55 Million VND per hectare per season, making it attractive for the smaller and poorer farmers

Further it was observed that production - and benefits - of aquatic crops and animals (fish, snails and crabs) are highly interrelated. This confirms a study by Eric Barran (2010), who mentioned that fish yields are closely connected with inundation level and retention of floods and abundance of aquatic vegetation.

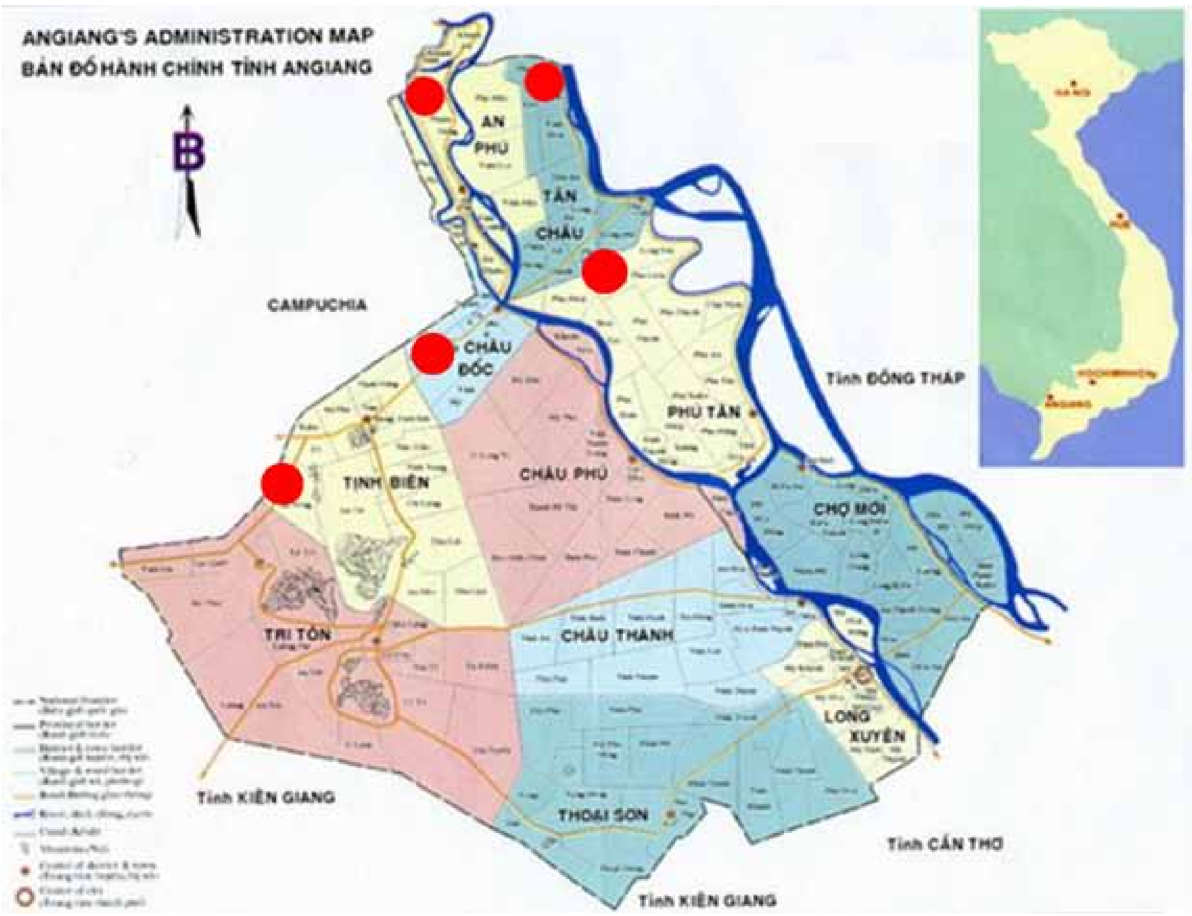

Figure 3 The surveyed areas and location of interviewed farmers (circles with red colors)

Table 1. Incomes of the people dependent on water resources in the surveyed areas. A comparative between irrigated rice crops and the aquatic crops and natural resources (catching)

Crops	Interviewed number(s)	Investment(s)		Return(s)		Profit(s)	
Rice crops		x 10^6 VND per hectare					
December - March	247	60	± 5.3	137	± 22.1	77	± 1.8
April - July	225	59	± 3.7	61	± 6.3	2	± 0.4
August - November	194	45	± 6.4	59	± 1.5	14	± 2.1
Average		55	± 8.8	89	± 12.8	33	± 2.9
Aquatic crop(s)							
Water-caltrop	65	40	± 4.3	110	± 9.5	70	± 12.4
Lotus	58	60	± 1.9	135	± 17.3	75	± 0.5
Neptunia	125	20	± 21.0	100	± 6.9	80	± 1.9
Average		35	± 9.2	111	± 23.7	76	± 9.5
		Investment(s) per household		**Return(s)/year**		**Profit(s)/year**	
Catching		x 10^6 VND*					
Fish	245	18	± 0.3	73	± 1.6	55	± 0.7
Mud crab	145	40	± 1.8	160	± 23.5	120	± 1.9
Average		26	± 8.2	105	± 8.4	79	± 6.5

* ($1USD=20,500 VND, Dec. 2012). The rice crop profit in April - July so low due to cost production for fuel irrigation, fertilizers and insecticides were very high

The change of fish habitats in rice production zones continues however, also in this area. The Statistic Bureau of An Giang (2011) reported rice production has increased significantly in terms of area and productivity. Was the rice area in 2006 still a meager 500,000 hectares, it increased to almost 600,000 hectare; the expansion of regional closed dyke systems and arrival of triple rice crop systems contribute to this growth. New production technologies have also contributed significantly to increased rice yields. The increasing rice production reduces fish population and fish grounds for the population

Other threats

Also the reduction of floodwater and suitable areas for aquatic crops contributed to reduced fish yields in An Giang. Fish catches have substantially declined over time, witnessing significant drops from 96,570 tons in 2001 to 51,329 tons in 2005 and 37,209 tons in 2010 (Statistic Bureau of An Giang, 2010). The observed problem is not restricted to An Giang, the Ministry of Finance reported in 2005 that total fish catch in whole The Mekong declined.

With more than 4,000 fishing tools, catching fish creates a significant job for the inhabitants living in the flooded areas. For the whole An Giang province it employs 23,389 households or 41,000 laborers. On average 67 % of the households in the flood-prone areas of The Mekong rely on fishing for their food and income. Among them 7 % do fishing whole year round and 57.2 % do it for additional earnings and 35% do it several times a year for consumption. Also the fisheries promote all kind of related income generating activities like the making of fermented fish, dried fish, fish sauces and production of fishing tools (Tri *et al.*, 2011).

The aquatic crop production and catching of fish provides 75 % of the total income for the local households. Interviews revealed that 90 % of them agreed that fish is their main protein source and 42 % regarded fish protein as irreplaceable. In total 94 % of the households eat fish for 5 to 7 days per week in the flood seasons and even 46 % of the households consume fish for 5 to 7 days in the dry season.

Most common fish species catched during flood seasons are Mud Carp (*Cirrihinus juillinni* and

Cirrhinus molitorella), Silver Barb (*Barbonymus gonionotus*) and Tinfoil Barb (*Barbonymus schwanenfeldii*).

Catching fish also provides feed sources for the aquaculture systems in the area. Two common species used in fish-farming are Snakehead fish (*Ophiocephalus striatus*) and Catfish (*Pangasius sp.*). During flood seasons, 100 % of the households apply this fish-farming model. This production model, produces annually 1.5 million ton fish, contributing significantly to the annual exported fish.

The decline of the fish population can be attributed to multiple causes. Firstly, 80 % of the interviewees identified reduced and irregular flood water levels as the primary driver. Secondly, the intensification of rice production, using chemicals (76 %) and over-exploitation (90 %) were also frequently listed. Thirdly, construction of embankments destroying wetland habitats was mentioned by 60 % of the interviewees. Lastly, 40 % considered the development of hydropower dams in the Mekong main stream and its tributaries as reason for the decline of the fish population.

The rural poor households are the most affected by the decline of fish resources, as they lack land, capital to invest and have a low adaptive capacity. It was found that the households relying totally on the catchment of fish are the landless groups. Secondly, also the smaller land owners were affected, as they use to growth to aquatic crops, requiring more labor but less capital investment. The farmers profiting from rice production were only those with large lands, some households accumulating over 100 hectares or more.

Predicted implications in case of further loss of land and water resources

Natural fish provides nutrition for 60 million people in the Mekong basin, especially for Thailand, Lao PDR, Cambodia and Vietnam. The further loss of land and water resources (and so fish) would deprive the nutrition source of 18 million people living in the Mekong Delta of Vietnam. It is synonymous to the loss of 28.108 tons/year (28,108,000 Kg X 2.88 USD/Kg = 81 million) represents 81 million USD yr^{-1} (if the price of natural fish stayed 2.88 USD/kg). The loss of these "free-of-charge" nutrition sources would require them to increase expenditures on substituted foods, which worsens their natural fish-based livelihoods.

Further the decrease of natural fish sources would lead to the un-employment of 23,389 households (Tri *et al.*, 2011). Also those who live on subsidiary occupations such as making fermented fish, dried fish, and fish sauce would be seriously affected. Their income would be reduced by 84 % in flood seasons and 21 % in the dry seasons (Tri *et al.*, 2011). Additionally, the further loss of natural resources would also cause multiple constraints to rural households' livelihood strategies: 78.6 % of the interviewees in the research of Tri *et al.* (2011) mentioned to seek work as hired laborers, do livestock husbandry or migrate to urban areas in search of work (Tri *et al.*, 2011).

Solutions for wetland restoration in the Mekong Delta

This study showed that the current change of land use, from aquatic crop production and fisheries towards rice production, shift the benefits of the natural resources toward the richer farmers, depriving the poorer farmer, who lack the financial resources for the pre-production investments, hiring laborers and technical machinery.

However, the sale of labor to the rich farmers during the rice production has become an important source of income for the poor and landless at the moment. So, solutions focusing on restricting land size for the richer farmers, fail to integrate the current income earned by the poorer farmers as laborers. The incomes earned by them are however still too low urging them to remain involved as well in fisheries and aquatic crop production. Unfortunately, the fish population remains decreasing and there has not been any signal for its recovery yet. As consequence farmers also start over-exploiting protected areas to produce aquatic crops or catch water animals. This has brought another major issue, confronting the environmental protection agencies last decade.

As shown, the challenges of a sustainable and inclusive development of the Mekong delta are not simply created by limited land or water resources. Rather, it was shown that the early channelization of the delta in the 18th century and the gradually entitling and allocation of the delta as the national rice bowl, for food sustainability and export, rearranged the allocation of land resources, and attached benefits, to the richer rice growing farmers. Therewith, the larger group of poor and landless farmers are deprived of their historical income sources, as the habitats of the fish population and area for aquatic cultivation are on the decline, on the expenses of rice production.

An integrated wetland ecology restoration program will be essential, to achieve inclusive development and socio-economic growth in the future. Integrating indigenous knowledge of farmer group on fisheries and aquatic crop production in national agricultural (rice) development strategies is essential for this. Such a sustainable development model includes as well the adaptive capacity of the poor farmers, as well as the economic importance of the delta for national rice production. In addition, richer farmers could think of integrating CSR strategies in their business, calculating as well the benefits over a short-term (rice production) and long-term period (aquatic crop and environmental conservation). When adopting these approaches a more sustainable use of natural resources and maintenance of environmental quality can occur.

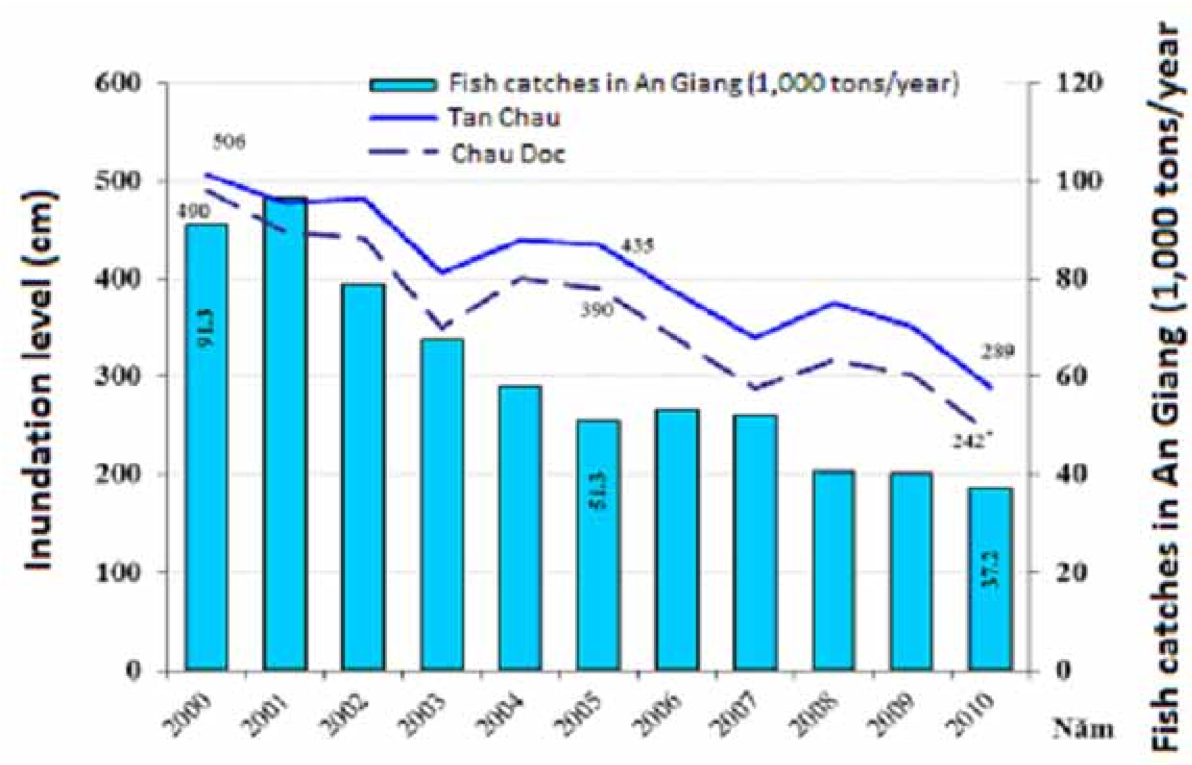

Figure 4. The progress of floodwater levels and wild fish catches in An Giang 2000 – 2010. (Source: Department of Agriculture and Rural development and Statistic Bureau of An Giang, 2010)

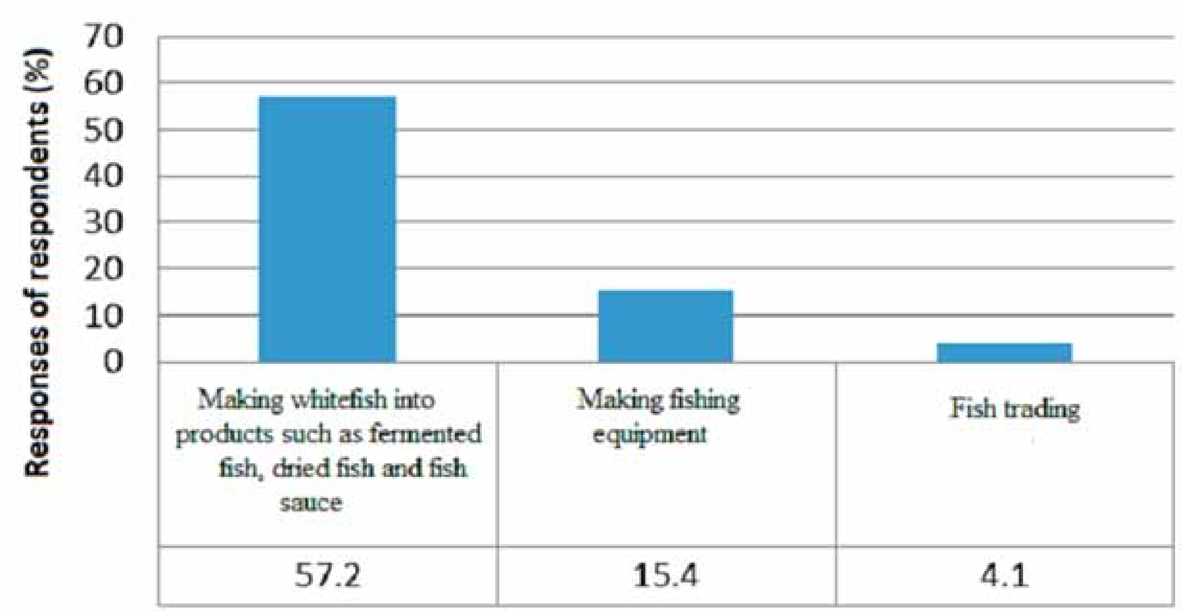

Figure 5 Diversification of rural occupations from catching fish resources (Tri et al. 2011)

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Spate Irrigation in Vietnam

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The sole focus of this paper is on the delta of the Mekong river, as situated in Vietnam. All definitions, like Delta and Mekong river, used in this paper, refer therefore only to the river and flood plains located within Vietnam

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