Establishing sustainable, resource efficient agri-food supply chains

Resource efficiency and ecosystem services in rice production in Thailand's central plain: Baseline Research

UNEP, IIED and AIDEnvironment Project (IRRI coordination)

Sub-study III: Inventory of ecosystem services

Research done by the Asian Institute of Technology and CIRAD (UMR G-Eau)

Authors: S.R. Perret, M.S. Babel, S.D. Rahatwal, R. Yarnsiri

Executive summary

This study delivers a brief inventory of ecosystem services offered in Central Plain of Thailand, and related considerations on economic value. It partakes to a broader baseline study on resource efficiency and ecosystem services in rice production in Thailand's central plain. The overall purpose of the baseline study is to contribute to a UNEP research and development project targeting the establishment of sustainable, resource efficient agri-food supply chains.

Lowland paddy rice ecosystems in central plain of Thailand offer several ecosystem goods and services and include functions and values related to regulation, support, culture, and contribution to the economy. However, being mostly irrigated, and designed and operated for intensive production towards export and agro-industry sectors, some functions have limited positive effects (support), and some negative externalities are significant (GHG emissions and high contribution to climate change as the main negative externality of paddy rice). Among ecosystem services, regulatory functions seems to be the most important, as paddy rice ecosystems contribute significantly to water resource management and conservation, erosion control, preservation of biodiversity and aquatic habitats, and, more importantly in central plains, flood mitigation and prevention. Paddy rice systems also contribute to the economy (local and national), to development, and bear very significant cultural value all over South East Asia. In terms of support functions, paddy fields contribute to nutrient cycling, water purification (denitrification), air purification, and photosynthesis.

The case study in Ayutthaya Province in central plain reveals that the concept of ecosystem services is widely unknown among all stakeholders in the rice production sector. Further, few research have been carried out, and limited information is actually available on ecosystem services in the area. Discussions with local experts show that some ecosystem functions and services are fulfilled by paddy rice fields, with regards to culture, provision of goods, and contribution to the economy. However, intensification of cropping systems and the intensive use of pesticides hinders most possibilities on support and regulation. Local stakeholders, officials, most public and private sector agents, and the general public seem to largely ignore both the concept of ecosystem services, and the implications thereof. More specifically, farmers as primary producers and custodians of such goods are not aware of the role they play and that benefits the whole society. There are two notable exceptions to this general lack of awareness: the role played by paddy fields in flood mitigation and in wildlife conservation. Also, the Royal Irrigation Department of Thailand's Ministry of Agriculture and Cooperatives has develop Good Agricultural Practices recommendations in order to sustain and enhance ecosystem services, especially those related to environmental conservation, soil quality, sustainable use of pesticides and fertilizers. Concrete application and impact of GAP recommendations remain few at this point in time. The economic values of the different rice ecosystems services and goods have not been assessed in Thailand, while methodologies do exist. No compensation, incentive or payment mechanism related to ecosystem services has been developed so far in Thailand.

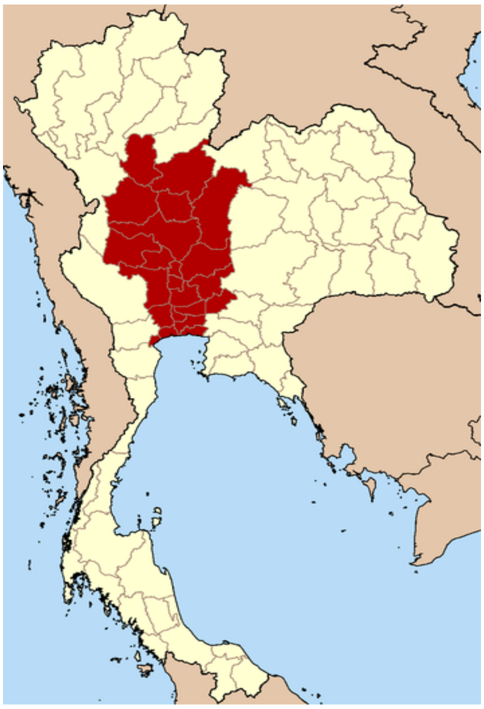
In view of such results, two sets of recommendations may be made, one for further research, the other towards role-players for implementation. More research should be carried out on certain biophysical and ecological processes that are poorly documented at this stage, i.e. hydrology, water and soil chemistry, ecology. The outcomes of such background research would be to better define the quantity and quality of ecosystems services provided, to back up further investigations on their economic value. Research should also be carried out in economics, first assessing the value of all identified ecosystems goods and services, second investigating and testing economic instruments towards sustainability of such provision. Research agencies should team up with public and private interested stakeholders in order to redress the observed lack of knowledge and awareness on ecosystem services. Communication and information has to take place, towards the general public, and more specific stakeholders. It is suggested that some pilot projects are set up, based upon existing farmer groups and/or delineated irrigation systems in order to experiment mechanisms potentially leading to sustainable provision of ecosystem services: farmer certification mechanisms, area certification

mechanisms, labeling of products. Such pilot projects could ultimately be used to experiment PES mechanisms.

Table of content

1 Demarcation of central plain of Thailand and rice cultivation

1.1 Demarcation of Central Plain of Thailand



(Source: http://en.wikipedia.org/wiki/Regions_of_Thailand)

Figure 1: Demarcation of the Central Plain of Thailand

There are three ways to define Thailand regions. One is based on geography, hydrology and geomorphology; a second is based upon socio-economic characteristics; and a third one is based on administration, policy and conventions. In this study, the Central Plain of Thailand is defined according to geographic reference.

Central Plain is a region of Thailand covering the broad alluvial plain of the Chao Phraya River. It is separated from North-East Thailand (Isan) by the Phetchabun mountain range, and another mountain range separates it from Myanmar to the west. In the north it gently changes into the hilly terrain in Northern Thailand. The area was the heartland of the Ayutthaya kingdom, and is still the dominant area of Thailand. Central Thailand contains the Thai capital of Bangkok. Central Thailand is the most populated region in the country.

The following provinces form parts of central plain of Thailand

1. Ang Thong
2. Phra Nakhon Si Ayutthaya
3. Bangkok (Krung Thep Maha Nakhon)
4. Kamphaeng Phet
5. Lop Buri
6. Nakhon Nayok
7. Nakhon Pathom
8. Nakhon Sawan
9. Nonthaburi
10. Pathum Thani
11. Phetchabun

12. Phichit
13. Phitsanulok
14. Sukhothai
15. Samut Prakan
16. Samut Sakhon
17. Samut Songkhram
18. Saraburi
19. Sing Buri
20. Suphan Buri
21. Uthai Thani

1.2 Land Use Map of Thailand

Type of Land Use	Area	
	Rai	%
Residential and building Area	15,111,800	4.71
Residential and building area	15,111,800	4.71
Agricultural Area	171,585,556	53.51
Abandoned paddy field	1,340,914	0.42
Paddy field	78,619,362	24.52
Crop field	38,679,371	12.06
Permanent crop	32,464,276	10.12
Fruit farm	12,526,963	3.91
Rotation farm	3,607,916	1.12
Fresh water culture	2,694,372	0.84
Other agricultural areas	1,652,382	0.52
Forest Area	113,170,136	35.29
Rich forest	102,983,513	32.11
Recovering forest	10,186,623	3.18
Water Resources Area	8,812,352	2.75
Water resources	8,812,352	2.75
Others	12,017,043	3.74
Abandoned land	9,179,624	2.86
Basin area	1,833,783	0.57
Other areas	1,003,636	0.31
Total	**320,696,887**	**100**

Source: www.ldd.go.th
Land Development Department, Thailand

Figure 2: Land use map of Thailand

From land use map of Thailand (figure 2), it can be noted that maximum amount of rice cultivation area is in central plain and northeast of Thailand. The main Chao Phraya river basin and many other sub basins are found in central plain of Thailand; hence the maximum area is under rice cultivation and many other agricultural purposes. The main city (Capital city) Bangkok is also located in central plain of Thailand, which captures large number of tourists and industrial sites.

1.3 Rice cultivation in Thailand and in central plain

The following figures (3-4) provide general information on the dynamics of rice cropping in Thailand then in central plain of Thailand (area planted, area harvested, production over time, dry season / wet season coverage) (Source: Office of Agricultural Economics, Ministry of Agriculture and Cooperatives, Statistical Forecasting Bureau, National Statistical Office).

NB: "Major Rice" sometimes refers to as primary rice or wet season rice or rainfed rice; "Second Rice" sometimes refers to as irrigated rice or dry season rice. 1 Rai = 0.16 ha

Figure 3a. Thailand: Major Rice Cultivation (wet season)

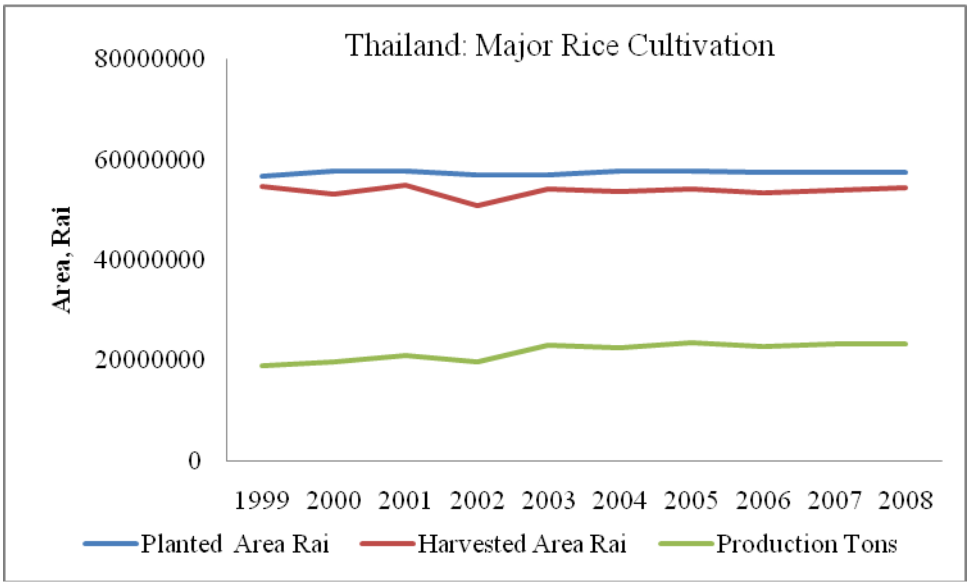


Figure 3b. Thailand: Second Rice Cultivation (dry season)

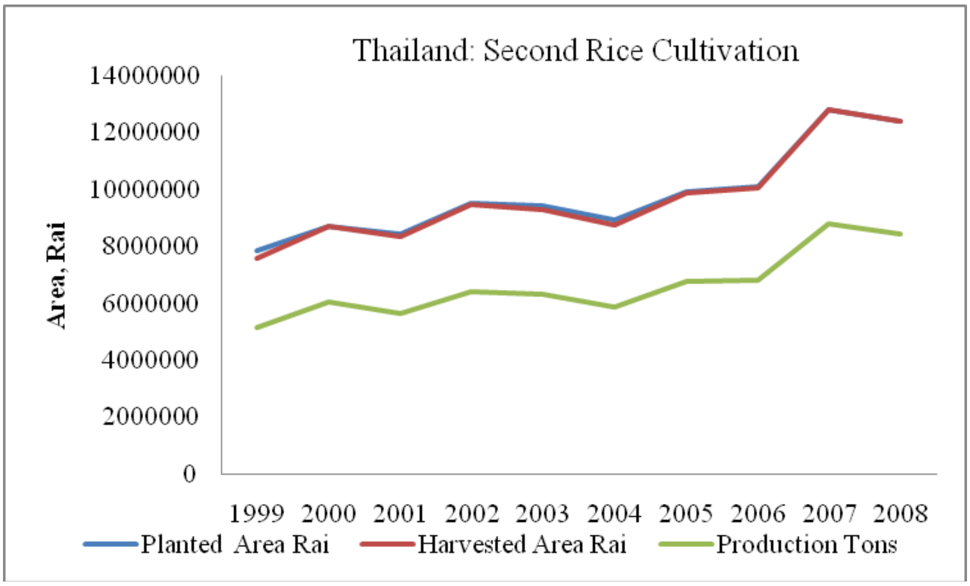


Figure 3c. Central Plain of Thailand: Major Rice Cultivation (wet season rice, mostly rainfed)

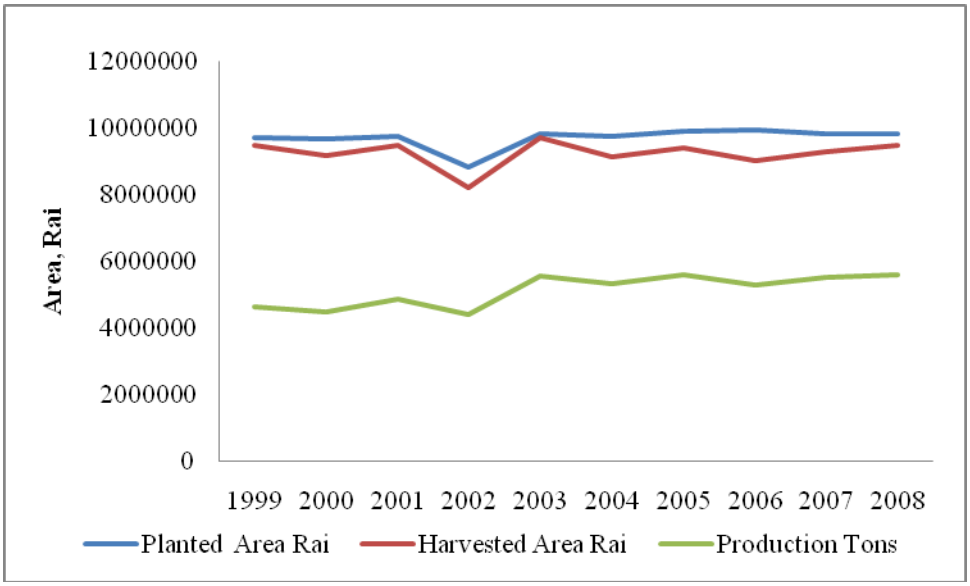
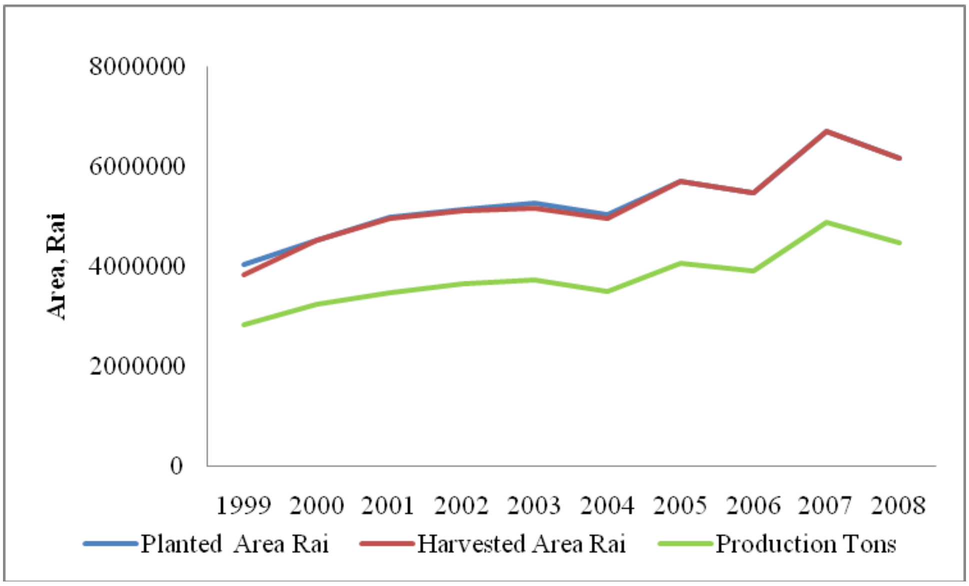


Figure 3d. Central Plain of Thailand: Second Rice Cultivation (dry season rice, mostly irrigated)



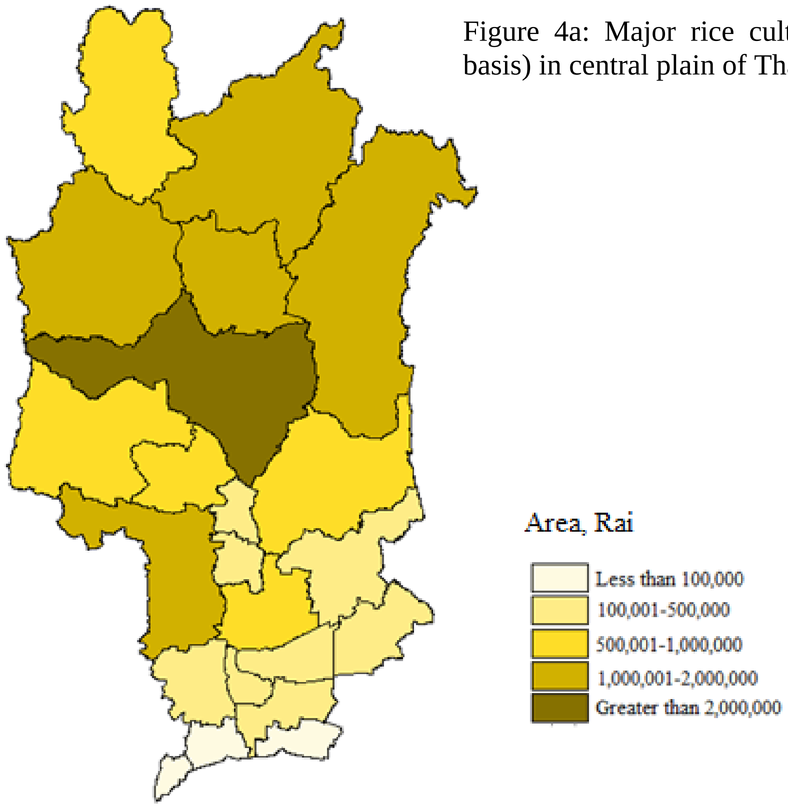


Figure 4a: Major rice cultivation area (Provincial basis) in central plain of Thailand

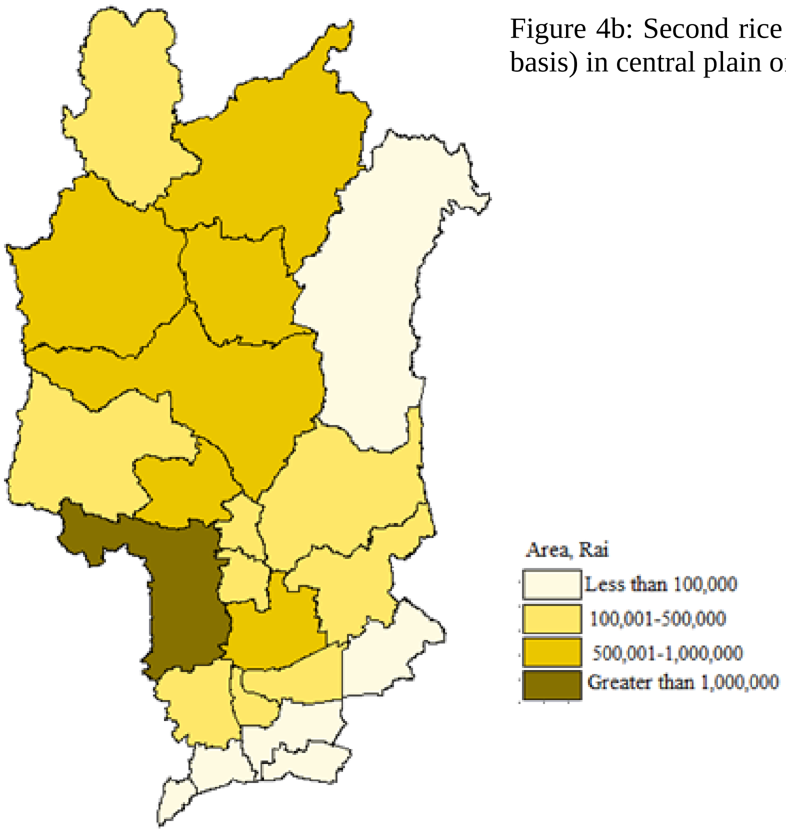


Figure 4b: Second rice cultivation area (Provincial basis) in central plain of Thailand

1.4 Meteorological Data

Meteorological information of central plain of Thailand is presented in table 1 and figure 5, e.g. temperature, rainfall, evaporation, humidity. All meteorological data are average data from 1980-2009. Maximum rainfall is observed between May to Oct. (monsoonal rainy season) and other months refer to the dry season. Rice cultivation performed during rainy days is called wet season rice, which is highly dependent on rain, except in areas with irrigation facilities.

Table 1: Meteorological Data: Central Plain of Thailand (Average data: 1980-2009)

Month	Mean Max Temp (°C)	Mean Min Temp (°C)	Mean Air Temp (°C)	Avg Rain mm	Avg Rainy Day	Mean Sunshine, hr	Mean Evap mm	Mean RH %
Jan	32.08	20.37	26.15	5.97	0.90	7.85	4.26	64.50
Feb	33.74	22.43	27.98	13.53	1.60	8.19	5.04	65.25
Mar	35.47	24.79	30.02	46.18	4.11	8.09	6.09	66.45
Apr	35.68	25.11	30.27	61.73	5.26	7.85	6.08	66.90
May	34.74	25.52	30.00	164.32	13.65	6.58	5.59	71.70
Jun	33.64	25.30	29.37	136.18	14.56	5.22	5.00	72.85
Jul	33.15	25.00	28.97	144.19	15.75	4.78	4.80	73.40
Aug	32.90	24.91	28.79	164.09	17.10	4.40	4.54	74.30
Sep	32.61	24.55	28.46	255.78	18.95	4.83	4.21	76.75
Oct	32.11	24.19	28.04	191.08	14.67	5.38	3.91	76.05
Nov	31.56	22.55	26.98	40.46	4.24	7.26	4.15	69.85
Dec	30.99	20.21	25.54	5.22	0.91	7.83	4.28	64.95

(Source: Thai Meteorological Department, 2010)

Figure 5 provides a comparison of climatic profiles between Central Plain region and Northeast (Isan) region of Thailand.

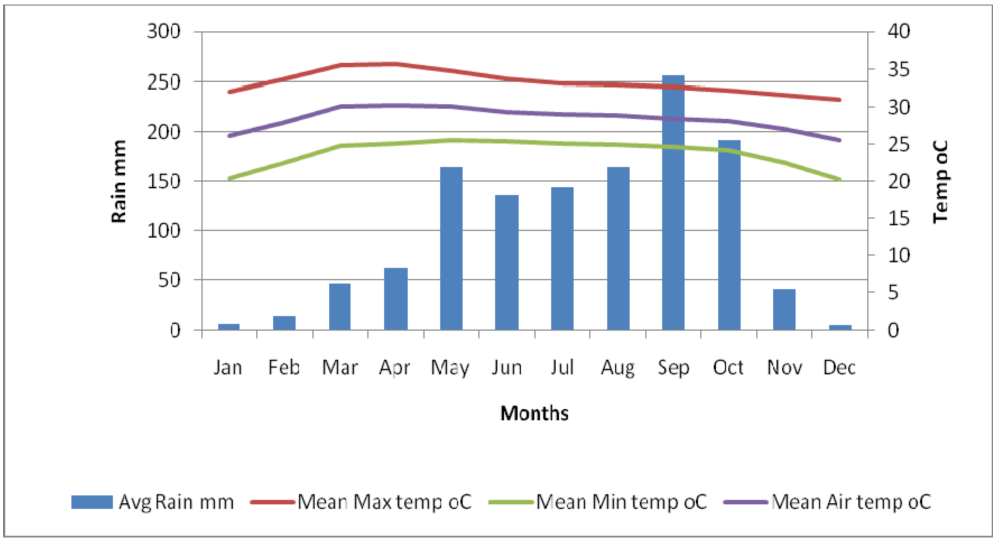


Figure 5a: Meteorological Data: Central Plain of Thailand

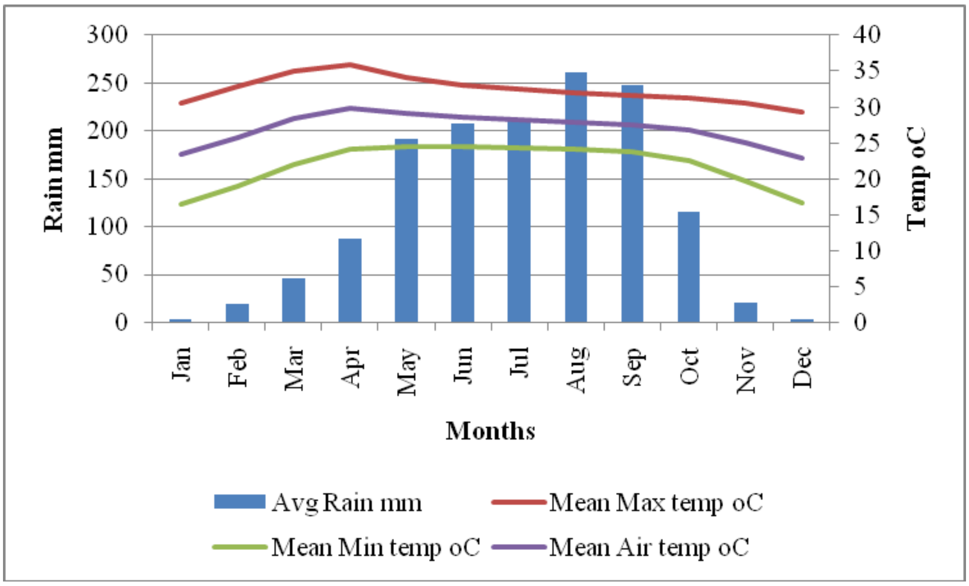


Figure 5b: Meteorological data: Northeast Thailand

1.5 Rice production in Thailand: main features

While China and India produce more than half of all global rice (600Mt overall annually), Thailand contributes (exports) about a third of all rice traded globally (8 Mt of 25Mt on average). Global trading of rice is therefore very limited, as compared to its global production and consumption features; to a large extent, producing countries have been self-consuming their production so far. However, increasing demand from Africa, declining home consumption in exporting transition countries, and GATT agreements tend to alter that situation towards intensification of global rice trading. Rice, as the typical Asian staple food crop, is characterized by price volatility, monsoon-dependency and erratic yields, and a large diversity of production systems. Thailand is only the fifth world largest rice producers (27Mt), but has long been the largest exporter with almost 8Mt exported in 2009. Thailand mostly exports white rice, mainly produced in central plain region (5.4Mt in 2009; by Government and private exporters) and Hom Mali Jasmine Fragrant rice (2.4Mt in 2009; only by private exporters). Shrinking rice farmers' population, due to rural outmigration and aging, is an immediate threat to Thailand rice industry.

Over the last 30 years, Thai rice production and export has remained fairly stable. Cropping area increased by only 10%. Production is still fraught with low land productivity (2.9t/ha as compared to a global average of about 4.2 t/ha). Typical rice plots are usually small (less than one ha per family) and cropped by poor, small-scale peasant farmers. Yet, production systems and cropping practices vary significantly. Some irrigation systems along main rivers in the central plain of the country show intensive production, mechanization, high use of pesticides and fertilizers while North-Eastern areas are much poorer, with more traditional, manual, cropping systems (some being only based upon wet season / rainfed rice).

1.6 Summary

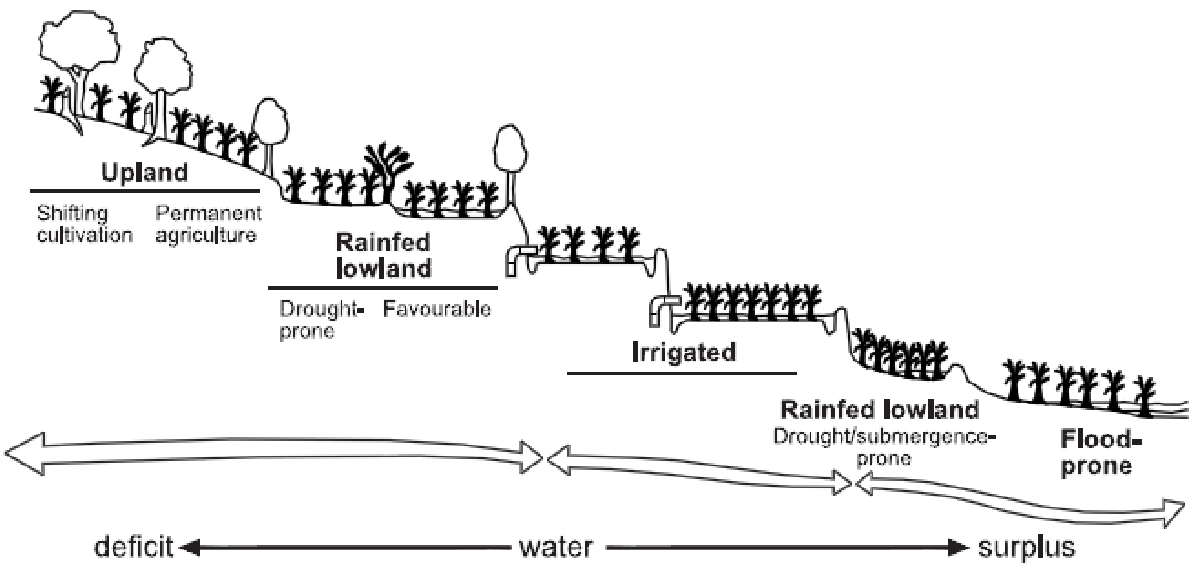
The central plain region of Thailand, as the lower part of Chao Phraya river basin, forms a geographic and hydrological entity that features relatively flat landscapes, bi-seasonal climate with monsoonal high precipitations, and flooded paddy rice cropping as the largely predominant cropping system. Central plain is the "rice bowl" of Thailand. White rice and co-products are the main productions. One of the region's peculiar traits is that it includes deeply agrarian and rural countryside settings (north and upstream) and highly developed urban, residential and industrialized environment (Bangkok city area) (south and downstream).

2 Rice ecosystems: functions and services

2.1 Defining rice ecosystems and ecosystem services

According to Floresca (2009), ecosystem services are benefits which people obtain from ecosystems. Similarly, Brown (2006) explained that ecosystem goods and services are the flows from an ecosystem which are of relatively immediate benefit to humans and occur naturally.

Paddy fields comprise an artificial environment that operates in concert with the natural environment. Rather than having an “impact” on the environment, paddy fields become part of a new environment with ecological processes that reflect the influences of both man and nature (Groenfeldt, 2006). The rice agro-ecosystems are typically categorized into five major types: 1. Irrigated rice fields, 2. Rain fed rice fields, 3. Deepwater rice fields, 4. Upland rice fields and 5. Tidal rice fields (Edirisinghe, 2006). Figure 6 proposes another, yet similar, classification, based upon location and water use. Rice production in central plain region of Thailand is predominantly irrigated (dry and wet seasons). Only highland plots and areas with no irrigation facilities are rainfed (e.g. in Isaan / Northeast Thailand).



Upland	Rainfed lowland	Irrigated	Flood-prone
Level to steeply sloping fields; rarely flooded, aerobic soil; rice direct seeded on plowed dry soil or dibbled in wet, non-puddled soil	Level to slightly sloping, bunded fields; non-continuous flooding of variable depth and duration; submergence not exceeding 50 cm for more than 10 consecutive days; rice transplanted in puddle soil or direct seeded on puddle or plowed dry soil; alternating aerobic to anaerobic soil of variable frequency and duration	Leveled, bunded fields with water control; rice transplanted or direct seeded in puddle soil; shallow flooded with anaerobic soil during crop growth	Level to slightly sloping or depressed fields; more than 10 consecutive days of medium to very deep flooding (50 to more than 300 cm) during crop growth; rice transplanted in puddle soil or direct seeded on plowed dry soil; aerobic or anaerobic soil; soil salinity or toxicity in tidal areas

Figure 6: Rice Ecosystems (Greenland 1997, adapted from IRRI 1993)

2.2 Regulation functions

2.2.1 Paddy fields affecting local climate

Due to the effect of evaporation from paddy fields covered in water, paddy fields can have a cooling effect on ambient environment. In this way, paddy fields contribute to the climatic mitigation (1.3 °C on average) of surrounding areas, particularly in summertime (Yoshida, 2001). In South Korea, it is estimated that about 6mm of water in paddy fields evaporates every day. This brings down the air temperature during Korea's hot summer. The value of the energy which would otherwise be needed for cooling amounts to about 346 million kL of crude oil. The value of this function is about US$ 1,175 million (Dong-Kyun, 2002). In winter, paddy fields may cause an increase in temperature (Wu and Lee, 2004). This function has been recognized in peri-urban areas where paddy and urban land are scattered. The temperature effect is higher where the paddy area is larger and is applicable up to 150 to 200m downwind of paddy areas (Yokohari et al., 1998). No research has been carried out on such regulatory function in central plain of Thailand. The approach used by Dong-Kyun (2002) could be applied.

2.2.2 Paddy fields interacting with global climate

While rice production is affected by climate change and related extreme events. According to ADB, Thailand suffered more than $1.75 billion in economic losses related to floods, storms, and droughts from 1989 to 2002. The main share of that ($1.25 billion) was from crop yield losses.

Irrigated rice production is in turn contributing to climate change, and is harmful to the environment (Roger et al., 1998; Tilman et al., 2001; Wenjun et al., 2006). Flooded rice grows under anaerobic conditions, which favor methane formation and release (CH_4 is 21 times more potent than CO_2 as a GHG). About 120g of CH_4 is released in the atmosphere for each kg of rice produced. Overall, world's rice cropping under flooded conditions contributes 60 million tons CH_4 per year (or 13% of all anthropogenic CH_4 emissions). In 2005, Thailand's methane emissions equaled 91.6 million tons of carbon dioxide equivalents, 51% of which were due to rice cultivation - a statistic that is drawing international attention to the climate effects of rice paddies (Corinne Kisner, 2008).

Alternative cropping practices, including alternate wetting and drying conditions, sparing water use, well-drained, non-puddled soils, may significantly reduce CH_4 emission. However, such conditions may result in increased nitrous oxide emission if N fertilization is ill-managed or in excess. N_2O is 300 time more potent than CO_2 as a GHG. All in all, research show that about 60 to 90% of global warming impact of rice relates to production at field level.

Thailand's climate change action plan (Office of Environmental Policy and Planning, 2000) includes specific measures in order to reduce GHG emissions from rice fields: low-methane rice cultivars, direct seeding, soil aeration in conjunction with water management, organic matter and fertilizer management, methane production inhibitors. All measures are captured within the concept of Good Agricultural Practices (GAP) as promoted by the Royal Irrigation Department of Thailand's Ministry of Agriculture. Yet, the large diversity of cropping systems and water management practices, and prevailing socioeconomic constraints faced by farmers hampers concrete implementation of GAP. Unlike other crops which environmental focus is set on reducing carbon dioxide and nitrous oxide emissions from deforestation, mechanization, and chemical fertilizer use, rice production's greatest impact is through methane. In the context of flooded ecosystems, organic fertilizers may not help in the way they can with other cereals because methane is emitted through the anaerobic fermentation of organic matter in flooded rice plots.

Table 2 features possible measures for mitigating greenhouse emission from agricultural ecosystems, their apparent effects on reducing emission of individual gases where adopted (mitigative effect), and an estimate scientific confidence that the proposed practice can reduce overall net emission at the size of adoption. It highlights that, among other more efficient measures, rice management and water management show uncertainty in effects, with weak agreement and confidence on their capacity to mitigate GHGs emissions.

Table 2. An evaluation of possible measures for mitigating Greenhouse Gases (GHG) emissions

		Mitigative effects			Net mitigation	(confidence)
Measure	Examples	CO_2	CH_4	N_2O	Agreement	Evidence
Cropland management	Agronomy	+		+/-	***	**
	Nutrient management	+		+	***	**
	Tillage/residue management	+		+/-	**	**
	Water management	+/-		+	*	*
	Rice management	+/-	+	+/-	**	**
	Agro-forestry	+		+/-	***	*
	Set-aside, Land use change	+	+	+	***	***

Notes:

+ denotes reduces emissions or enhanced removal (positive mitigative effect);

- denotes increased emissions or suppressed removal (negative mitigative effect);

+/-denotes uncertain or variable response

A qualitative estimate of the confidence in describing the proposed practice as a measure for reducing net emission of greenhouse gases, express as CO_2-eq

Agreement refers to the relative degree of consensus in the literature (the more asterisks, the higher the agreement);

Evidence refers to the relative amount of data in support of the proposed effect (the more asterisks, the more evidence).

(Source: adapted from Smith et al., 2007a., IPCC Fourth Assessment Report: Climate Change, 2007)

The most prominent options for mitigation of GHG emission in rice cultivation are:

Cropland management

Using an appropriate amount of nitrogen fertilizer by avoiding applications in excess of immediate plant requirements, by applying it at the right time, and by placing it more precisely in the soil. Reducing the reliance on fertilizers by adopting cropping systems such as use of rotations with legume crops has a high mitigation potential.

No burning of crop residues in the field.

Reducing tillage: No-till agriculture can increase carbon in the soil, but in industrial farming settings this may be offset by increasing reliance on herbicides and machinery. However, for organic systems some preliminary study results showed that reduced tillage without the use of herbicides has positive benefits for carbon sequestration in the soil.

Improved water and rice cropping patterns

In the off-rice season, methane emissions can be reduced by improved water management, especially by keeping the soil as dry as possible and avoiding water logging.

Table 3: Data methane emission from paddy field in Thailand

Location	Range of CH4 flux mg/m2/hr	Season total g/m2	Experimental Treatment	References
Ayutthaya	3.3-7.9	13.0-20.0	CU,OM,WM	Siriratpiraya, 1990
Bang Khen	4.3-21.7	16.0-55.0	SE	Minami, 1994;Yagi et al., 1994b
ChaiNat	1.6	4.0		Minami, 1994,Yagi et al., 1994b
Chaing Mai	3.7-5.5	9.0-13.0	MF,OM	Jermsawatdipong et al.,1994
Chaing Mai	9.0-9.5	20.0-21.0	CU	Siriratpiriya et al 1995
Khlong Luang	3.8	8.0		Minami, 1994;Yagi et al., 1994b
Khon Kaen	23.0	76.0		Minami, 1994;Yagi et al., 1994b
Nakompathom	9.4-12.0	25.0-32.0	SE	Tomprayoon et al., 1991
Pathumthani	1.9 - 4.6	5.0 - 11.0	MF	Jermsawatdipong et al., 1994
Phitsanulok	6.6 - 7.2	17.0 - 18.0	SE	Katoh et al, 1995
Phrae	16.6 - 22.2	51.0-69.0	SE	Minami, 1994; Yagi et al., 1994b
Ratchaburi	3.2-42.5	9.0-117.0	MF,OM	Jermsawatdipong et al., 1994
San Pa Tong	10.4 - 16.1	25.0-40.0	SE	Minami, 1994; Yagi et al., 1994b
Surin	15.0 - 24.5	41.0 - 66.0	MF,OM	Jermsawatdipong et al., 1994
Surin	13.3	41.0		Jermsawatdipong et al., 1994
Suphan Buri	19.5 - 32.2	51.0 - 75.0	SE	Minami, 1994; Yagi et al., 1994b

(Source: adapted from Minami, 1995)

Experimental treatment: CU – cultivars, MF – fertilizers, OM – organic matter, SE – seasons (early and late rice, or dry and rainy seasons), SO – soil types, WM – water management

2.2.3 Function of conserving water resources

Water drawn from rivers to irrigate paddy fields penetrates into the soil. The water that does not evaporate eventually drains away and returns to the rivers. Some of this water contributes to the stabilization of flow regimes, while some of the rest penetrates deep into the ground and becomes part of the groundwater resources. The soil of paddy fields and similar areas also absorbs rainwater at times when they are not being irrigated. This reusable water in the soil and subsoil is evaluated as the function of conserving the water resources of fields used for paddy and crop fields (Yoshida, 2001).

Rice production contributes to water management. Paddy fields are under water during the rice crop, and have the function of contributing to the underground water. Dong-Kyun (2002) estimated that, in South Korea, 55% of the water stored by paddy fields goes to rivers, while the other 45% is stored as underground water, accounting for 5,420 million cubic-meters annually. The value of this function is about US$ 1,224 million each year.

In Japan, groundwater recharge, which was estimated based on saturated hydraulic conductivity and growing period with standing irrigation water in the paddy, was 2,421.7 m^3 ha^{-1} $cropping^{-1}$ (Yoshida, 2001). Groundwater recharge this is an important hydrologic feature of rice irrigation. In Kumamoto area of Japan, 85% of all groundwater recharge is accounted for from paddy fields (Ichikawa, 2002; Chen, 2005). In Taiwan, it is estimated that 21-23% of paddy irrigation water in the highland areas infiltrate into the groundwater, while 4-8 % of upland irrigation water is accounted for groundwater recharge (Liu et al., 200; Chen, 2005). The magnitude of recharge depends on soil texture, soil structure, thickness of the layer, soil and water temperature, ponding depth, groundwater level and topographic features (Liu et al, 2004; Chen, 2005). No research has been performed on such regulatory function in central plain of Thailand per se. However, many local studies on basin hydrology and irrigation systems do exist and could be exploited.

2.2.4 Function of prevention of soil erosion

In the process of crop cultivation, levees are repaired and organic materials are added to the soil. This leads to an increase in the bulk density of soil, while the ground surface is gradually smoothed and flattened. Both these effects reduce loss of soil by water and wind erosion. However, if cultivated fields are abandoned and left fallow, soil is likely to be eroded. Soil erosion can be prevented by paddy rice cultivation (Yoshida, 2001). Paddy fields also contribute to soil conservation. Annual soil losses in South Korea amount to about 1.17 million metric tons. A significant amount of cultivated soil is protected by the fact that it is used for paddy rice. The value of paddy fields in reducing soil erosion is estimated at US$ 713 million (Dong-Kyun, 2002). No research has been carried out on such regulatory function of rice ecosystem in central plain of Thailand per se. However, many local studies on basin hydrology (rainfall and runoff) do exist and could be exploited.

2.2.5 Functions of preservation of biodiversity and habitat for wildlife

An important aspect of preserving biodiversity is to conserve the native species and indigenous varieties of each region and ecosystems. Substituting imported products for domestic ones may destroy native flora (Dong-Kyun, 2002). Flooded rice ecosystems whenever established, are located in wetlands, water-rich or even aquatic environments. Also, owing to dependency upon irrigation infrastructures, paddy plots are fairly perennial, not being dismantled or subject to land use shifts frequently. So they usually and quite naturally host aquatic fauna and flora. Rich biodiversity has become associated with rice fields. It is an ecosystem that sustains not only the people whose staple diet is rice but also a diverse assemblage of plants and animals that have made rice fields this niche. The rice fields offer shelter, food, breeding and nesting grounds to the various kinds of animals, birds, and insects. The flooded rice fields are an ideal habitat for a variety of aquatic invertebrate communities comprising neuston, zooplankton, nekton, periphyton and benthos. Aquatic vertebrates such as freshwater fish and amphibians colonize the fields during the aquatic phase for breeding, and these in turn attract numerous species of predatory birds. Rice plant growth stages vegetative and reproductive growth stages attracts variety phytophagous insects and promote growth weeds. The arthropod community found in rice abundantly. Proper weeds growth in the rice field and the surrounding bunds add another advantage to this ecosystem (Edirisinghe and Bambaradeniya, 2006). In Fukuoka prefecture of Japan, 30% of animal rare species live in the paddy environment. These habitats have importance for ecosystem health and biodiversity both locally and for the global ecosystem through migratory birds (e.g., cranes) and insects (Chen, 2005).

Paddy rice farming contributes indirectly to the production of forests and wildlife habitats. Rice straw and rice husk, the byproducts of the rice harvest, serve as a source of organic fertilizer and as a feedstuff for livestock, especially cattle. This not only helps prevent woods and forests from being overexploited, but also contributes to the protection of wildlife habitats (Dong-Kyun, 2002).

The biological function of the paddy landscape lies in the wetland habitat it provides to animal and plant forms. These habitats have importance for ecosystem health and biodiversity both locally and for the global ecosystem through migratory birds (e.g. cranes) and insects (Groenfeldt, 2006).

The following animal and insects commonly live in rice fields in Central Plain of Thailand: spotted munia (*Lochura punctulata)*, ricefield crab *(Esanthelphusa spp*.), roof rat, ship rat (*Rattus rattus)*, ricefield rat *(Rattus argentiventer)*, great bandicoot *(Bandicota indica)*, lesser bandicoot *(Bandicota savilei)*, golden apple snail *(Pomacea canaliculata*).

Also, extremely rare and endangered fish species are also found in deeper river systems: *Himantura chaopraya* (Giant freshwater stingray) and *Himantura signifer* (edged-freshwater white stingray) (both from Dasyatidae family).

Many different birds species are found in central plain of Thailand, which actually forms the largest wetland bird sanctuary of the country (an Important Bird Area –IBA- as shown in figure 7) while remaining officially largely unprotected. The IBA comprises the Lower Central Plain of the Chao Phraya River, which extends inland from the Gulf of Thailand and encompasses the environs of Bangkok. The Lower Central Plain was formerly a vast area of natural and semi-natural swamps, well-watered throughout the year by four major rivers: the Chao Phraya, Bang Pakong, Pasak and Mae Klong. However, the area was the focus of massive irrigation system developments in the early 20th Century, and current land-use is dominated by intensive rice cultivation, with only small remnant patches of wetland habitats and extensive agriculture. Due to high human population density and levels of use, it is unrealistic for anything but a small fraction of the area to be placed under strict conservation management. However, the Lower Central Plain was designated as a single IBA because conservation actions aimed at controlling hunting and promoting compatible forms of land-use are required across the whole area. Sites within the IBA currently afforded some protection include Wat Phai Lom (11 ha), Wat Tan En (16 ha), Bung Chawak (320 ha) and Wat Ratsattha Krayaram (7 ha) Non-hunting Areas.

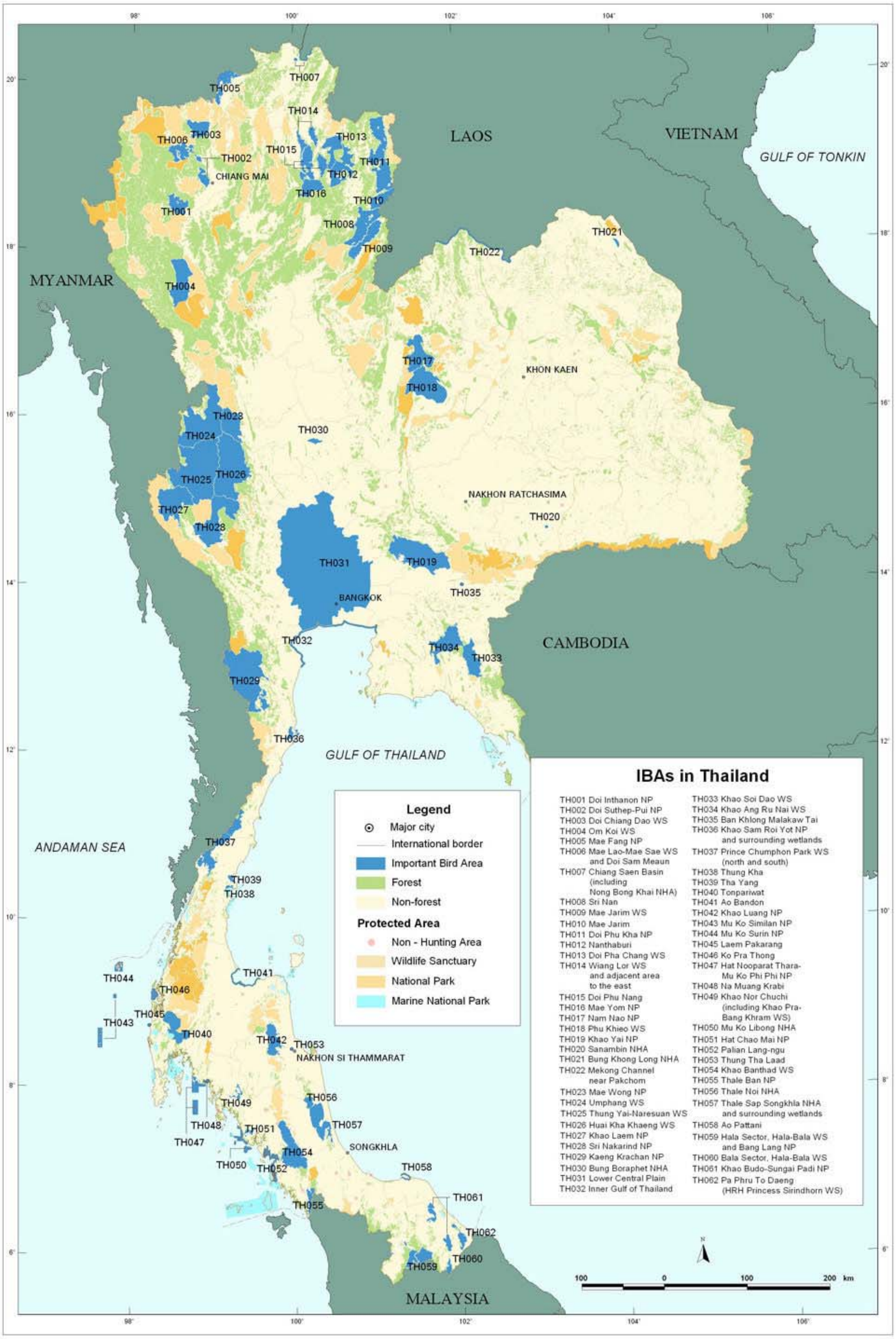
Several globally threatened species occur in the Lower Central Plain and the area regularly supports well in excess of 20,000 waterbirds. A number of globally threatened species regularly occur at the site, some of them in significant numbers. The site regularly supports *Aythya baeri* and Imperial Eagle *Aquila heliaca*. Spot-billed Pelican *Pelecanus philippensis* is an occasional non-breeding visitor, while Baikal Teal *Anas formosa* and Greater Adjutant *Leptoptilos dubius* are vagrants. In addition, there are historical records of the globally vulnerable Lesser Adjutant *Leptoptilos javanicus*.

In recent years, the site has supported over 1% of the Asian biogeographic population of Grey-headed Lapwing *Vanellus cinereus*, Intermediate Egret *Mesophoyx intermedia* and the globally near-threatened Painted Stork *Mycteria leucocephala*. Other globally near-threatened species to occur at the site in significant numbers are Asian Golden Weaver *Ploceus hypoxanthus* and Black-headed Ibis *Threskiornis melanocephalus*, while Oriental Darter *Anhinga melanogaster* and Band-bellied Crake *Porzana paykullii* have also been recorded, although not in significant numbers.

Table 4. Rare and endangered birds of the central plain region

Species	Notes
†Greater Adjutant *Leptoptilos dubius*	Formerly widespread in Thailand, the species is now on the verge of national extinction, and occurs at the IBA only as a vagrant. Singles have been recorded at three different localities, in mid-June 1995, January 1986 and November 2002; the latter was among a flock of 16 Black-headed Ibises at Wat Kusarot, Ayutthaya.
†Baer's Pochard *Aythya baeri*	The species is a rare winter visitor to the site. Two birds were seen at Rangsit marsh in January 1991 and two were seen at Kasetsart University (undated).
†Baikal Teal *Anas formosa*	The species is a vagrant to the site. There is a single record of two females and two males among 12,000 Garganey (*Anas querquedula)* at Kasetsart University in January 1992.
Greater Spotted Eagle *Aquila clanga*	At least 8 to 10 individuals winter annually at the site, the most important known wintering population of the species in Thailand. Birds wintering at the site also use the Inner Gulf of Thailand (IBA TH032).
†Imperial Eagle *Aquila heliaca*	The species is an annual winter visitor in very low numbers. Birds wintering at the site also use the Inner Gulf of Thailand (IBA TH032).
Spot-billed Pelican *Pelecanus philippensis*	The species was formerly more numerous but is currently an occasional non-breeding visitor.
Manchurian Reed Warbler *Acrocephalus tangorum*	The species was recorded at Rangsit marsh in march 2001. The species is a winter visitor as passage migrant perhaps.
Grey-headed Lapwing *Vanellus cinereus*	The maximum count of the species at the site is 368 birds between Sena and Band Sai districts, Ayutthaya province, in January 2003.
Intermediate Egret *Mesophoyx intermedia*	A count of 1,000 birds was made in Maharaj district, Ayutthaya province, in January 1999.
Painted Stork *Mycteria leucocephala*	A count of 200 to 250 birds was made in December 1995.

Notes: † = not confirmed to regularly occur in significant numbers.



Figu

Figure 7: Map of Important Bird Areas for Conservation in Thailand

(Source: Bird Conservation Society of Thailand (2010))

2.2.6 Function of pest suppression

Table 5 features the main diseases occurring in rice cropping systems.

Table 5: Rice diseases according to region and cropping system

Rainfed	**Area**	**Irrigation**	**Area**
Rice Blast	N, NE	**Dirty Panicle Disease**	C, W, N, NE, S
Bacterial Leaf Blight	N, NE, C	**Sheath Blight**	C, N, S
Bacterial Leaf Streak	NE, C, S	**Brown Spot**	C, W, N, NE, S
Root Knot Nematodes	N, NE	**Sheath Rot**	C
Sheath Rot	C	**Ragged Stunt Disease**	C
Sheath Blight	C, N, S	**Orange Leaf Diseases**	C
Dirty Panicle Disease	C, W, N, NE, S	**Red Strip Diseases**	C
Bakanae	N, W, NE	**Leaf Scald**	C
		Bakanae	N, W, NE
		Yellow Orange Leaf	C
		Yellow Dwarf Diseases	C
		Grassy Stunt Disease	C
		Gall Dwarf Disease	C
		Akiochi	C
		Narrow Brown Spot	C, W, N, NE, S

C - Central
N - North
NE - North East
W - West
S - South

Source: Rice Knowledge Bank, Thailand, available at: http://www.brrd.in.th/rkb/

Being mostly irrigated, with 2 cropping seasons par year, rice in central plain area is most exposed and sensitive to various diseases. No research has been performed as yet on pest suppression or mitigation by rice ecosystems in central plain.

2.2.7 Function of flood prevention

Paddy fields surrounded by ridges temporarily store water at times of heavy rain, and discharge it gradually into downstream rivers and surrounding areas. In this way, they prevent or mitigate the damage which might otherwise be caused by floods. This role played by agricultural land is called the water retention function (Yoshida, 2001). In central plain of Thailand, paddy rice fields are used for that purpose in many occasions and play a major role in preventing flooding of urban areas downstream (Ayuttaya, Bangkok).

In Korea's monsoon climate, more that 60% of the year's precipitation falls during the three summer months (June, July and August). This is also the rice-growing season. Hence, many dams are required to manage surface water. However, flood damage occurs every year, as the result of sudden downpours. Paddy fields help control flooding because they contain water over the wet season and release it over the dry season. They are estimated to store a total of 2,733 million m^3 of water, valued at US$ 1,208 million (Dong-Kyun, 2002). It was estimated that 20% of flooded water in the lower Mekong River Basin during 1999 and 2000 was temporally stored in paddy fields that were later used in the further downstream paddy fields (Masumoto et al, 2004; Chen, 2005). Floating-rice farming in the delta has played important roles. It can be summarized as having low input and low yield but sustainable farming. Cultivated floating-rice area decreased from 228,000 ha in 1987 to 114,000 ha in 1997 (CTI et al., 1999). Floating rice can grow flexibly according to irregular increases in water level.

Problems of flooding in Chao Phraya Delta often occur in October and November. Paddy field cultivating with high yield variety can't receive too much water during flood. However floating rice area has great possibility to receive surplus water which contributes to flood mitigation at regional level. At Chao Phraya delta floating rice area can be estimated at 2280 million m^3 assuming area 114000 ha water depth 2 m. The volume would be almost same as the storage in the remaining paddy fields in the water management wet season, assuming water depth 0.2 m. If we could convey surplus water to the floating-rice area to decrease the peak flood discharge with a depth of 25 cm (5 cm day^{-1} for 5 days), also act as a buffer function. Water released from the floating-rice area can be used in downstream areas and it contributes to decreasing the salinity concentration at the beginning of the water management dry season.

Table 6. Rice systems and flood mitigation: management methods and impacts

Preferential enhancement function		Flood mitigation	Development of water resources	Food production
Method (how)		Preliminary release of standing water from floating-rice area Conveyance of floodwater into floating-rice area Insurance contract between government and farmer for receiving surplus floodwater Heightening of embankment Advanced operation of drainage regulator Development of decision support system of infrastructure for information and communication technology	Release of standing water considering the timing of water use downstream Change of drainage point to use water resources more effectively Arrangement of new facility such as pump, regulator, and regulating pond Modification of cultivation pattern in downstream fields Development of a decision support system	Introduction of new farming technology for dry-season cultivation Drainage improvement Arrangement of irrigation facility New water allocation
Induced positive impact	What	Peak period of flood discharge	Provision of new water resources	New farm products
	When	Flooding period (October, November)	From middle of December to end of January	From February to May
	Where	Downstream delta, especially Bangkok	Downstream fields Whole basin	Floating-rice field
	For whom	People in downstream delta	Farmers of downstream fields People in the basin	Farmers Consumers
Induced negative impact or remarks		Increase in risk in farming and harvest yield	Increase in salinity in the Chao Phraya River Decrease in water level in the downstream Chao Phraya River (it is sometimes unsuitable for navigation and intake for tap water)	Deterioration of water quality and soil Increase in water demand New water conflict might occur Change in ecological environment

(Source: Rice is Life: Scientific perspective for 21st century, 2004)

Paddy farming has an ability to filter sediment in landscape and contribute to flood mitigation. Agus, F. et al., 2004; flood mitigation by paddy farming it can be assessed by the following guideline: (TPS – FC). AZ + PC + IC

TPS: Total Soil Pores (%)

FC: Water Content at Field Capacity (%)

AZ: Depth of Water Absorption Zone (not applicable as paddy field is saturated during most of planting seasons)

PC: Surface Ponding Capacity, $PC_{\text{paddy filed}}$ = Dike Height – Normal Water Level

IC: Interception Capacity, base on vegetation, $IC_{\text{paddy filed}} = 0.003$

Flood mitigation → Water Retention Capacity, WRC

↑

Watershed or field area capacity to absorb water and hold rain

↑

Water hold in soil pores and as well stored by paddy fields

While contribution to flood mitigation, and even to flood control and damage avoidance, by paddy fields is probably very significant in central plain area, no quantitative economic valuation of such service has been performed as yet on a large scale basis.

2.3 Provision and contribution to economy and development

Rice farming also maintains the economic viability of rural communities, through the revenue from rice. As a result, rural people are more likely to remain on their farms, thereby avoiding excessive concentrations of the population in urban areas (Dong-Kyun, 2002).

In Sri Lanka, agriculture provides employment to 30% of country population and it helps to keep control of migration to cities for employment. Therefore, Sri Lanka Government keeps investing on irrigation sector not only for food security but also for balanced territorial development (INWEPF, 2007).

Another opportunity offered by irrigated rice landscapes is eco-tourism. In Bali, rural hotels located in the midst of paddy lands use this as a feature to attract tourists, and arrange farm visits for the guests (Groenfeldt, 2006). In industrialized countries, such as Japan and Republic of Korea, urban dwellers are willing to travel to paddy fields for sightseeing and recreation. In Bali, paddy fields are light spots of local ecotourism (Chen, 2005).

Local rice systems may also be hotspots of social capital and decentralized governance. Traditionally, small-scale paddy-based irrigation systems were built and managed by the farmers themselves. Today, participatory management of local irrigation systems is an important trend as a way of improving management and reducing operating costs. A multi-functional aspect of this approach is the strengthening of social capital that participatory irrigation management stimulates. The skills and experience that farmers gain through the cooperative management of their irrigation system can be applied to other entrepreneurial endeavors and thereby contribute to broad-based rural development. Multifunctional water user associations: Water user associations – whether traditional (e.g., Balinese subaks, noth Thailand), or newly established through government programs (as in Vietnam and the Philippines) serve functions of local governance, and can themselves serve multiple functions.

While traditional self-management and local governance do exist in Northern Thailand, rice schemes in central plain are much larger and de-facto under Royal Irrigation Department management, with little actual active participation in collective decision-making processes by farmers.

While rice systems support many livelihoods, directly and indirectly (multiplier effects), no research has been performed as yet on the economic and socioeconomic contribution of rice ecosystems in central plain.

2.4 Support

2.4.1 Function of soil nutrient cycling

Nutrient cycling estimated base on the rice straw yield and its nutrient content consisted of 16.9 kg N ha^{-1}, 12.0 kg P_2O_5 ha^{-1} and 55.8 kg K_2O ha^{-1} (Floresca, 2009). Sandy soils, which have low water holding capacity and less plant nutrients, are mostly found in Northeastern Thailand. Clay soils, which have high water holding capacity and high plant nutrients, are mostly found in the Central Thailand and are more suitable for rice plantation.

Figure 8 features N inputs and outputs in paddy rice fields according to experiments in Japan (Feng et al., 2003). Only 60% of N inputs are actually taken up by rice. However, results differ significantly between studies, according to fertilizer types, application method and scheduling, soil pH, meteorological conditions and the like.

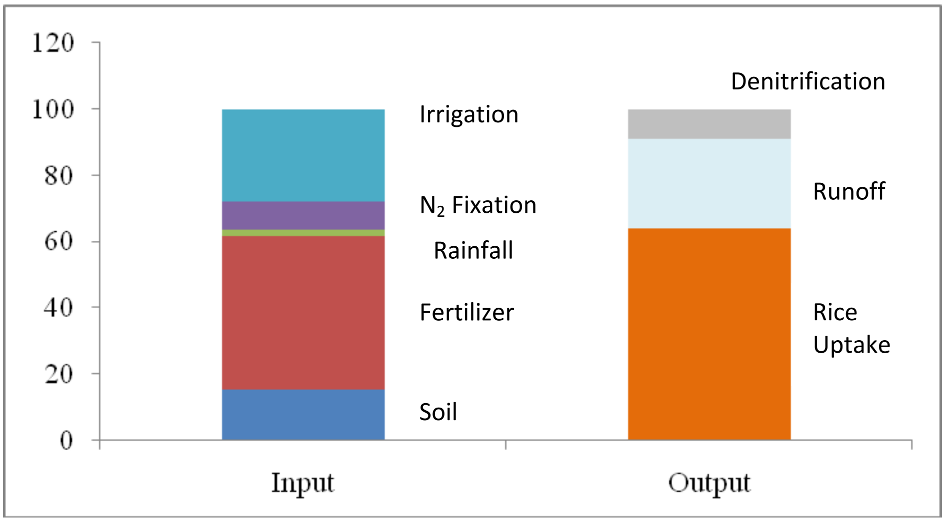


Figure 8. Nitrogen balancing in paddy fields

Experimentations in Japan showed that inputs to phosphorus balance in paddy fields include chemical fertilizer (about 90% of P input), rainfall (1%) and irrigation water (9%). Outputs include drainage water (14% of P output), and rice uptake (86%). The soil compartment absorbs and retains 56% of P fertilizer and creates the difference in P input-output balance (Feng et al., 2003).

From these results, it must be highlighted that under intensification practices (high fertilization) drainage water and runoff contain large amounts of N and P, leading to potential eutrophication and pollution, unless recycling takes place. Experiments demonstrate the benefits of recycling drainage water in further reuse as irrigation water, for water saving, nutrient saving, and pollution control purposes (Feng et al., 2003).

No research has been performed as yet on nutrient cycling and recycling in rice ecosystems in central plain, on a large scale basis.

2.4.2 Function of water purification

As long as chemical fertilization remains reasonable, paddy fields behave as artificial wetlands as their capacity to remove nitrogen and phosphorus. Ponding condition of paddy fields causes an increase in denitrification (Yamaoka et al., 2003; Chen, 2005), which process refers to the microorganism-led reduction of nitrates (fertilizing yet polluting) into gaseous N_2 through various stages and components. The total amount of contaminated water which is purified in paddy fields each year is estimated at 704 million mt. This value from rice production of purifying polluted water is about US$ 1,651 million in South Korea (Dong-Kyun, 2002).

Seasonal organic nitrogen loss by denitrification may be calculated with the following equation (Tabushi et al., 1993):

$D = (0.000011 * T^2 + 0.005) * N$

D is the amount of denitrification in $kg.ha^{-1}$

T is the average seasonal water temperature (degree Celsius, between 10-40)

N is total N concentration in paddy water in $mg.l^{-1}$

2.4.3 Function of air purification

Vegetation growing on cultivated farmland purifies air by absorbing gases which are air pollutants, such as SO2 and NO2. The volume of these gases absorbed by crop may be calculated and given a monetary value (Yoshida, 2001). Owing to photosynthesis, rice production helps clean the atmosphere by absorbing 14 million mt of CO2, and emitting 10 million tons of O2 annually. According to Dong-

Kyun (2002, research in South Korea), the value of rice crops in purifying air is about US$ 1,613 million.

2.4.4 Function for photosynthesis

Both rice crop itself and aquatic micro-organisms (algae, aquatic weeds) living in the paddy field do photosynthesize. Shading by rice field can limit photosynthetic activity of algae in the rice fields. High and low temperature depresses phytoplankton productivity and photosynthesis. High temperature is favorable for blue green algae and low temperature for eukaryotic.

2.5 Culture

2.5.1 Function of supporting cultural identity

Throughout the rice producing regions of Southeast Asia, the integration of paddy cultivation and local cultures has been evolving for thousands of years. Religious rituals and cultural identity are tied to the rice cycle (Groenfeldt, 2006). Paddy cultivation is a living heritage which refers to tradition and reaffirms that heritage in the present. The significant components of that heritage may include the visual landscape, the architecture of rural buildings, the irregular bunds marking the borders of the paddy fields, the irrigation channels themselves, and the fields themselves with paddy growing, or the empty fields between crops. Culture heritage also has less visible and invisible components: particular varieties of rice which have cultural meaning, as well as nutritional and culinary significance, the knowledge of the consumer that the rice has been cultivated in a particular way, and in a particular place that has meaning (and may be reflected very directly in the price of that variety), even the consumers' knowledge that by purchasing this particular rice, they are supporting farmers who are maintaining agricultural traditions (Groenfeldt, 2006).

2.5.2 Function of preserving amenities for recreation and relaxation

Lowland paddy fields and upland fields not only constitute a beautiful rural landscape, but also create unique natural, cultural, and social environments. Many of those living in urban areas like to visit the countryside, seeking the landscape and natural amenities that cannot be found in cities, as well as for leisure and relaxation (Yoshida, 2001; Dong-Kyun, 2002).

Rice ecosystems also bear landscape value. Many people, both urban and rural, enjoy the scenery of paddy fields (and other forms of agriculture) and may be willing to pay for this experience. The visual benefits of the landscape are easy to experience (by driving or in the compact urban setting of Japan, even by walking) into the countryside (Groenfeldt, 2006).

Aesthetic values can overlie the values of cultural heritage, landscape, and even religion. As artists and art critics can attest, there is an aesthetic aspect to viewing not only art, but the world at large. The human appreciation of the spacious, tranquil verdant landscape is an expression of aesthetic values. So too is the appreciation of the particular flavor or aroma, or appearance of a particular rice variety, or rice preparation made from that variety. The pleasure that an urban-dwelling Japanese businessman experiences upon viewing a traditional farmhouse derives from a combination of cultural and aesthetic values. The appreciation that underlies a consumer's willingness to pay a high price for a particular variety of rice may derive partly from an appreciation of the aesthetics of the cultivation process – knowing that it was produced on a small farm without using pesticides and in harmony with nature, etc (Groenfeldt, 2006).

2.6 Summary

Rice ecosystems offer a number of ecosystem services and amenities. However, being mostly irrigated, and designed and operated for intensive production towards export and agro-industry sectors, some functions have limited positive effects (support), and some negative externalities are significant (GHG emissions and high contribution to climate change as the main negative externality of paddy rice). Among ecosystem services, regulation functions seems to be the most important, as paddy rice ecosystems contribute significantly to water resource management and conservation, erosion control, preservation of biodiversity and aquatic habitats, and, more importantly in central plains, flood mitigation and prevention. Paddy rice systems also contribute to the economy (local and national), to development, and bear very significant cultural value all over South East Asia. In terms of support functions, paddy fields contribute to nutrient cycling, water purification (denitrification), air purification, and photosynthesis.

3 Case Study in Central Plain of Thailand: Ayutthaya Province

3.1 General Information

Ayutthaya, Thailand's former capital city, is located in the flat river plain of the Chao Phraya river valley in Central Plain of Thailand. Ayutthaya Province is subdivided into 16 districts, 209 sub-districts and 1,328 villages. Its administrative boundaries are adjoining Ang Thong and Lopburi provinces in the North, Nakhonpathom, Nonthaburi and Pathumthani provinces in the South, Saraburi Province in the East, and Suphanburi province in the West.

Total rice crop area covers 1,596,875 rai, and irrigated area is 1,364,710 rai. There are 4 main rivers namely Chao Phraya, Pasak, Noi and Lopburi rivers flow through Ayutthaya but two rivers significantly influence rice plantation in Ayutthaya as follows:

1. Chao Phraya River

Chao Phraya Dam which is located in Chainat province is the main dam for storing and releasing water into main canals. There are 2 main canals under Chao Phraya Dam which are beneficial for agricultural use specifically rice plantation in Ayutthaya as follows: Chainat-Ayutthaya Canal, Chainat-Pasak Canal

2. Pasak River

Pasak Jolasit Dam which is located in between Lopburi and Saraburi provice is the main dam for storing and releasing water for agricultural use in three provinces consisting of Lopburi, Saraburi and Ayutthaya.

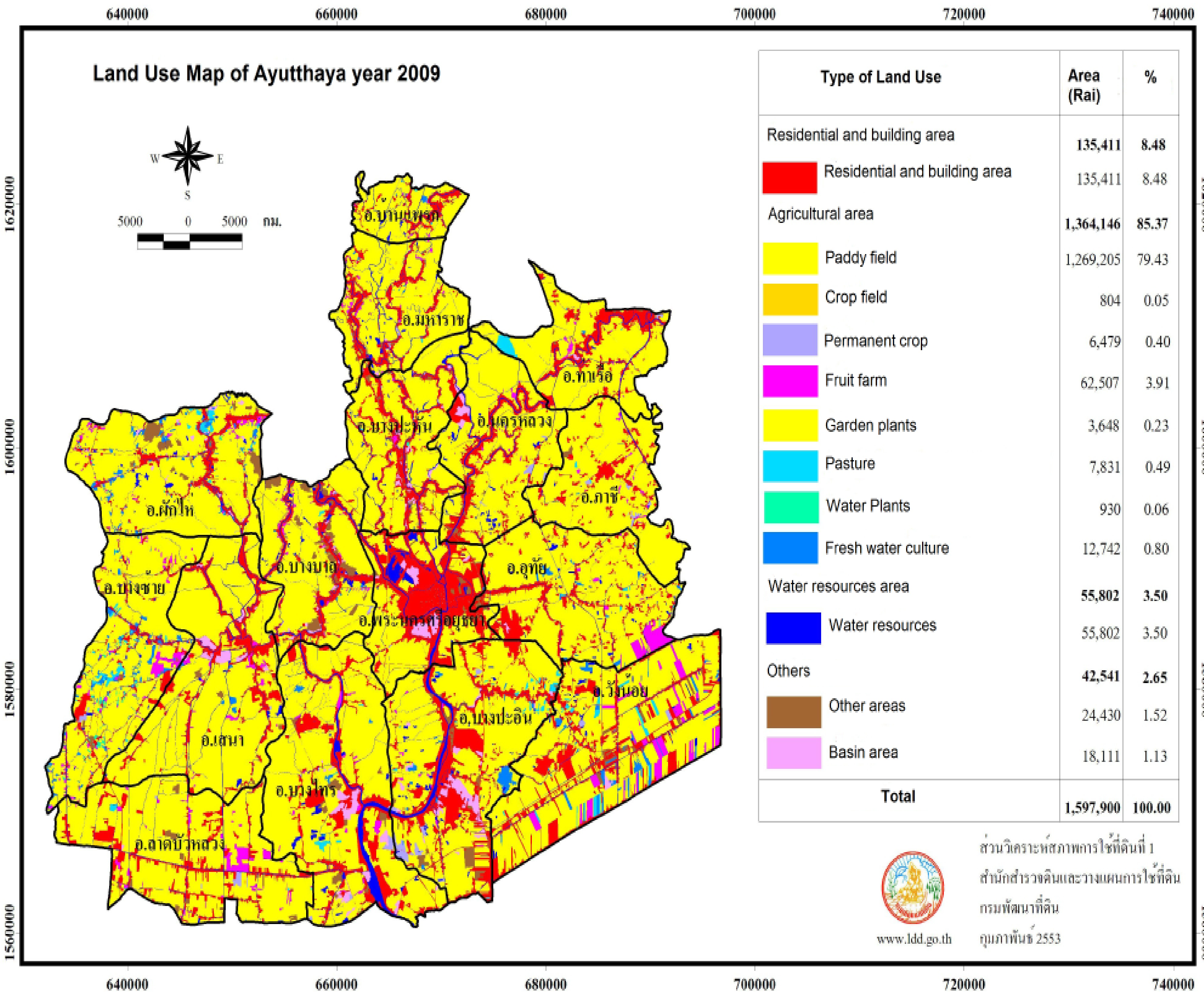
3.1.1 Meteorological Data (1993-2009)

Table 6 and figure 10 recap average meteorological data in Ayutthaya Province. Figure 9 features land use types.

Table 6: Meteorological Data, Ayutthaya Province

Month	Mean Max Temp,°C	Mean Min Temp,°C	Avg Rain mm	Avg Rainy Day	Mean Sunshine hr	Mean Evap mm	Mean RH %	Mean Air Temp,°C
Jan	33.10	19.70	5.70	0.65	7.70	4.60	62.00	26.30
Feb	34.50	21.80	6.90	1.29	7.90	5.10	64.00	28.00
Mar	35.60	23.80	38.10	4.41	7.30	5.60	67.00	29.50
Apr	36.20	24.80	71.70	6.82	7.90	5.80	69.00	30.40
May	34.70	24.80	137.70	13.41	6.50	5.10	73.00	29.60
Jun	34.00	24.50	124.80	13.71	5.60	4.70	73.00	29.10
Jul	33.60	24.40	122.30	14.29	4.50	4.70	73.00	28.90
Aug	33.10	24.30	169.80	15.41	4.30	4.30	74.00	28.60
Sep	32.60	24.00	252.10	17.63	4.60	3.90	77.00	28.20
Oct	32.70	23.60	107.20	12.00	6.30	3.90	74.00	28.10
Nov	32.20	21.80	35.10	3.41	7.70	4.50	69.00	26.90
Dec	31.80	19.90	9.90	0.88	7.90	4.90	63.00	25.70

Figure 9: Land Use Map of Ayutthaya, Source: Land Development Department, www.ldd.go.th



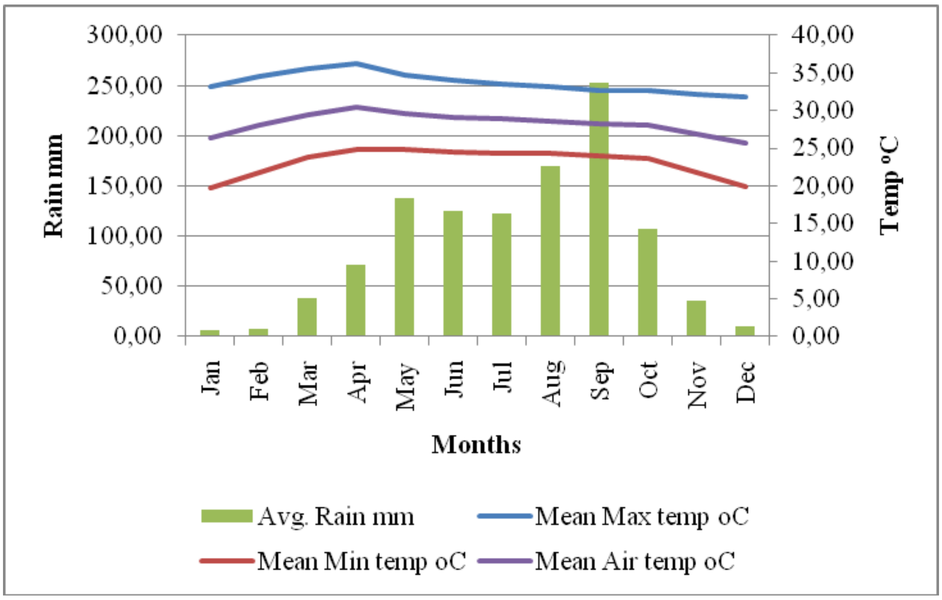


Figure 10. Meteorological Data, Ayutthaya Province

3.1.2 Soil characteristics

The following tables summarize the physical and chemical characteristics of soils in Ayutthaya Province.

Table 7a and 7b. Soil characteristics in Ayutthaya Province (Pak Hai district and Tha Ruea district)

Soil group: Ay
Identification: Very fine, mixed, active, acid, isohyperthermic, Vertic Endoaquepts
Land use: Rice Farming
Site: Phak Hai District, Ayutthaya Province

Soil depth cm	Texture	pH (1:1)	EC dS m-1	Available P mg kg-1	Available K mg kg-1	C %	N %	Exchangable Ca mg kg-1	Exchangable Mg mg kg-1	CEC cmol (+) kg-1
0-25	Clay	4.95	0.26	4.97	205.40	1.43	0.18	3064.00	52.51	36.46
25-50	Clay	4.56	0.48	2.33	111.10	0.39	0.09	2748.00	75.36	34.98

Sample 2:
Soil group: Ay
Identification: Very fine, mixed, active, nonacid, isohyperthermic, Vertic (Aeric) Endoaquepts
Land use: Rice Farming
Site: Tha Ruea District, Ayutthaya Province

Soil depth cm	Texture	pH (1:1)	EC dS m-1	Available P mg kg-1	Available K mg kg-1	C %	N %	Exchangable Ca mg kg-1	Exchangable Mg mg kg-1	CEC cmol (+) kg-1
0-25	Clay	5.20	0.03	6.69	119.04	0.52	0.10	2654.00	1069.64	26.73
25-50	Clay	5.60	0.03	5.80	102.00	0.20	0.10	2600.00	1239.81	29.20

Source: Land Development Department, 2007

3.2 Rice and rice ecosystem services in Ayutthaya

As per Land Development Department, 85 per cent area is under agricultural and remaining is residential and building area. Most of the agricultural area is under paddy fields (80 %).

3.2.1 Rice cultivation

Most of the rice in Ayutthaya is grown in lowland areas paddy fields (ponding: 5-20cm). Deepwater rice ("floating rice") (50-100cm ponding) can be found in some limited areas. Rice is cultivated during wet season and dry season. Rice cropping calendar is different in each area depending on water availability and rice plantation practice. Cropping calendar can be divided into two main groups depending on rice plantation practice as follows:

<u>Wet-season rice</u>

June: land preparation including tillage practices
July: sowing rice seed
October: generating ear of rice
December or January: cultivating rice

<u>Dry-season rice</u> (taking around 105-110 days to get yield)

January or February: land preparation including tillage and sowing rice seed
March or April: generating ear of rice
April or May: cultivating rice

Rice growing in Ayutthaya follows different in each district, number of times rice cultivation in each district is defined as follows:

It is different in each area depending on characteristics of specific area in Ayutthaya.

- 1 time per 1 year: wet-season rice

Three districts namely Pak Hai, Bang Sai and Sena are under this practice. These three districts are located outside of irrigated area and farmers in these three districts can only plant wet-season rice (drought).

- 2 times per 1 year: wet-season rice and dry-season rice

Ten districts namely Bang Ban, Pranakornsri Ayutthaya, Ban Phraek, Maharat, Bang Pahan, Nakorn Laung, Ta Rau, Phachi, Uthai and Wang Noi are under this practice.

- 2 times per 1 year: only irrigated rice (second rice) (or 5 times in 2 years)

Three districts namely Lat Bua Luang, Bang Sai and Bang Pa In are under this practice. These three districts are located inside of irrigated area so farmers can access water throughout the year. As a result, farmers grow only irrigated rice practices because they can get higher yields within shorter time. Some farmers increase land crop density and plant rice up to 5 times over 2 years under irrigation.

Rice varieties planted during dry season and wet season are different, and listed as follows:

Dry season rice varieties: Suphanburi 1, Suphanburi 3, RD 31, Phitsanulok 2

Wet season rice varieties: Ayutthaya 1, Prachinburi 1, Prachinburi 2, Laung Patiew, Khao Dawk Mali 105

A majority of farmers choose rice varieties by themselves by considering following factors: high yield, strong stem, fine seed, insect and disease resistance. Few farmers, specifically among the new generation of farmers, prefer to follow government recommendation through various departments such as Ayutthaya Rice Research Center and Ayutthaya Provincial Agricultural Extension Office. Availability of seeds is often an issue though. Choice of rice varieties depends on season (temperature and daylight time), area characteristics and seasonal rainfall patterns.

3.2.2 Ecosystem services

Regulation

Paddy rice systems in Ayutthaya area are intensive and use much pesticides and herbicides. In Ayutthaya rice fields, weeds such as barnyard grass, morning glory, sprangletop and wrinkle duce-beak are normally found. Farmers use pesticides for controlling weeds after 10-15 days of growing rice. After that, it depends on the numbers of weed found in rice field. Also farmers do control weeds not only for space and nutrient competition with rice, but also because weeds tend to offer a shield for rodents against their natural predators (owls and hawks).

Pests and insects are quite systematically eliminated from rice fields as some are seriously detrimental to yields. Brown plant hopper destroys rice by sucking nutrients from the rice stem above water level. This causes rice having yellow leaf which syndrome is called “hopper burn”. In addition, brown plant hopper is a virus-carrier causing rice having shorter stem, slow-growing leaf and indented leaf which is called “rice ragged stunt”.

Rodents are widely spread and common in rice fields of Ayutthaya province. They eat rice grains and sometimes stem and leave. Various kinds of rats found include great bandicoot, lesser bandicoot, ricefield rat, lesser ricefield rat, fawn-colored mouse and ryukyu mouse. Most farmers in Ayutthaya use raticides to get rid of them. Also, weed control indirectly supports rodent control (as seen above).

The golden apple snail destroys rice specifically during seedling stage and early rice by eating rice stem under water level then up to leaf above water level.

Natural predators can potentially contribute to pest control in paddy fields. Insect predators comprise dragonfly, tortoise beetle, ant lion and earwig. Other predators include spiders, birds and snakes. Predators can be the part of biological control measures. However, in Ayutthaya, above-mentioned predators are found in small numbers in rice fields because of the intensive use of pesticides and chemicals. This depletes the potential preys (pests) and also creates unhealthy environment for their survival.

Provision

Paddy areas accommodate a number of side productions. Small-size fruit trees such as papaya or banana are commonly planted along the ridges and dikes of the rice fields. Fruits crops are mostly used by farmers for self-consumption. Rice remains the major crop, and main livelihood. Some weeds are edible (e.g. morning glory) but most farmers in Ayutthaya do not collect them. All weeds (edible or not) are eliminated with chemical herbicides.

Contribution to economy

Paddy rice cropping entails many operation, most labor-intensive (land preparation, transplanting or broadcasting, harvesting, spraying). Most farmers hire non-family laborers. This creates employment for the poorest, landless people in local communities. Payment is usually based on working hours.

Support

Officials report issues about nutrient balance to rice cultivation. In Ayutthaya area, farmers usually take only a month after harvesting before doing next dry-season rice plantation. This is considered a too-short time for the soil to recover, causing soil problem such as nutrient loss in long term.

Most farmers in Ayutthaya use only chemical fertilizer as they target high yield without considering the negative effect to land and the environment. However, some farmers, especially new generation who are educated, informed and trained tend to combine chemical fertilization with organic matter application. They understand the negative effect of exclusive and intensive use of chemical fertilizer, and the local benefits of organic fertilizers. However, the issue of methane emission from organic matter decomposition remains.

Culture

Rice farmers believe that there is "goddess of grain" who is protecting and helping farmers to get plentiful yield. Farmers gather and arrange ceremony in rice fields to worship the goddess and offer different foods and fruits especially sour fruits such as star gooseberry, tamarind and betel. However compared to the past, the number of farmers participating has decreased.

Interestingly, there are some indirect benefits from such gatherings as in some occasions government officials from local divisions also join the ceremonies. Government officials and farmers have then a chance to interact face to face and enhance communication.

3.3 Summary

The case study in Ayutthaya Province reveals that the concept of ecosystem services is widely unknown among the stakeholders in the rice production sector. Further, few research have been carried out, and few information are actually available on ecosystem services in the area. Discussions with local experts show that some ecosystem functions and services are fulfilled by paddy rice fields, with regards to culture, provision of goods, and contribution to the economy. However, intensification of cropping systems and the general use of pesticides hinders most possibilities on support and regulation.

4. Economic valuation

4.1 The economic values of aquatic ecosystems

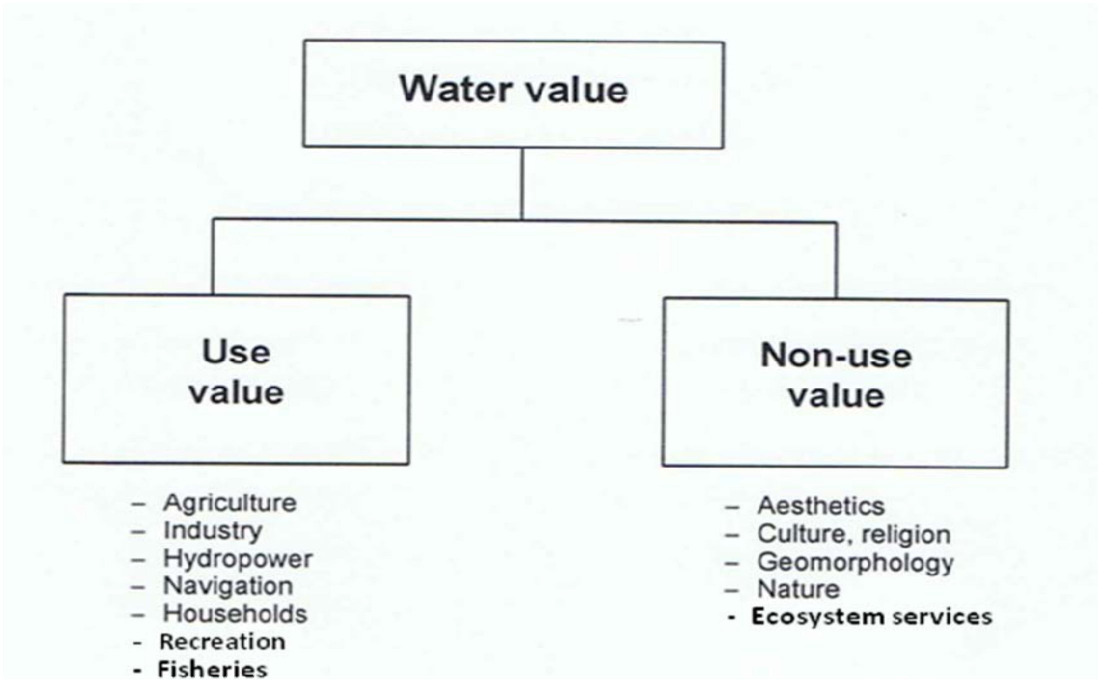
Ecosystems do not belong to anybody; they are not divided nor shared by people, although some may have property rights over parts of them (e.g. rice growers owing land). Ecosystem outcomes (services) are shared and benefit different individual and collective agents in society, beyond the agricultural and rural sectors (INWEPF, 2007). In general, ecosystems fulfill multifunctional roles beyond agriculture in rural areas. These multifunctional roles are often considered as by products from an agricultural viewpoint. Yet, farmers and their families are often both the custodians and the suppliers of those multiple functions. Moreover, these functions have the characteristics of a public good, i.e. they may be accessed and used by anyone without excluding who does not pay. Most of the time, the beneficiaries of these functions pay little attention to the farmers who provide them (Yoshida, 2001).

Ecosystems services, as multifunctional roles of ecosystems, are fraught with market failures, i.e. they do not depend on, nor obey to market mechanism or efficient resource allocation. Market failures occur when markets do not reflect the full social costs or benefits of a good. Market failures related to ecosystems include the facts that (i) many ecosystems provide services that are public goods; (ii) many ecosystem services are affected by externalities (costs or benefits borne by an external agent); and (iii) property rights related to ecosystems and their services are often not clearly defined (King and Mazzotta, 2000).

As a result, these services and functions may not be supplied as and when they are needed. Policy intervention is therefore required in order to maintain these multifunctional roles. However, as these functions are not traded in any market, they do not have a market price, while they might bear a high value from user's viewpoint. It is therefore necessary to evaluate the values and benefits of the multifunctional roles of agriculture and rural areas in monetary terms, to present these monetary benefits as one of the important reasons for maintaining such functions (Yoshida, 2001), and possibly to investigate mechanisms allowing for a transfer of benefits into compensation or incentives towards those who offer and sustain the services.

Figure 11 clarifies use and non-use values attached to water resources. Use values refer here to activities that directly require and utilize water (as an input or a medium to the production of a marketable good or service). Non-use values refer to activities that do not extract or utilize water as such but rather the aquatic ecosystem as a whole.

Figure 11. Use and non-use values of water resources: examples



In other words, direct use value is the benefit obtained from actual use (e.g. rice grain from paddy fields) whereas indirect, non-use use value is the benefit obtained from an ecosystem function (e.g. flood mitigation by paddy fields). Non-use also comprise bequest value (potential future use and patrimony) and existence value (e.g. culture, aesthetics) (Brown et al., 2006).

Figure 12. Different values attached to wetland ecosystems

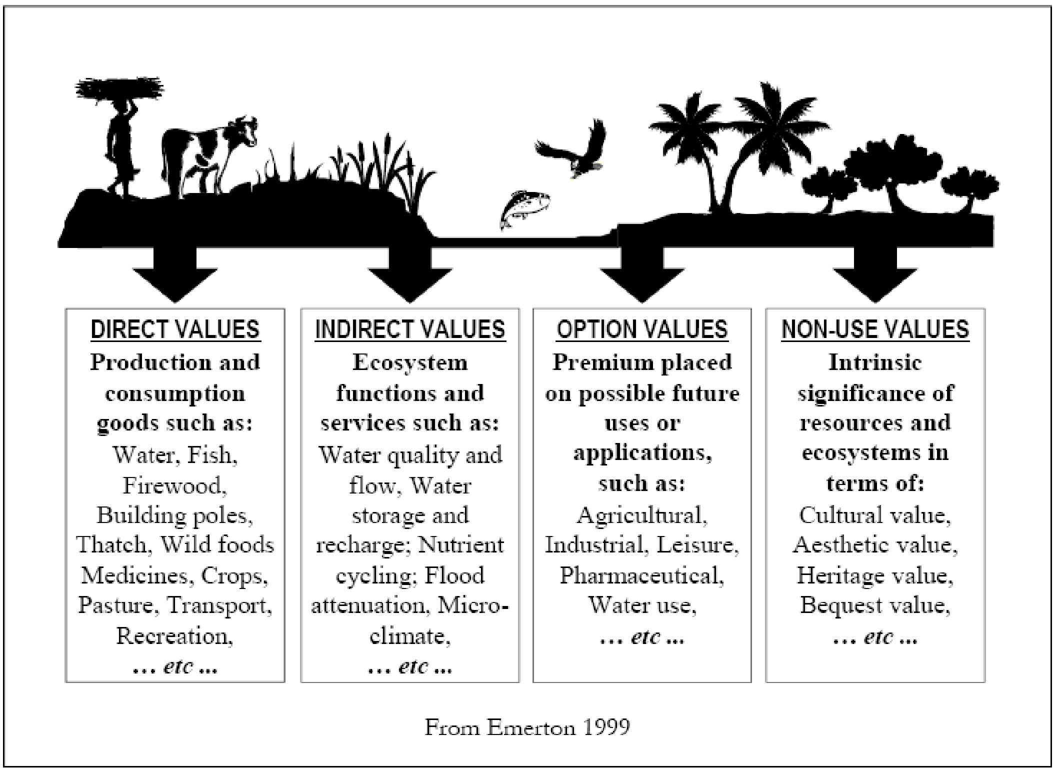
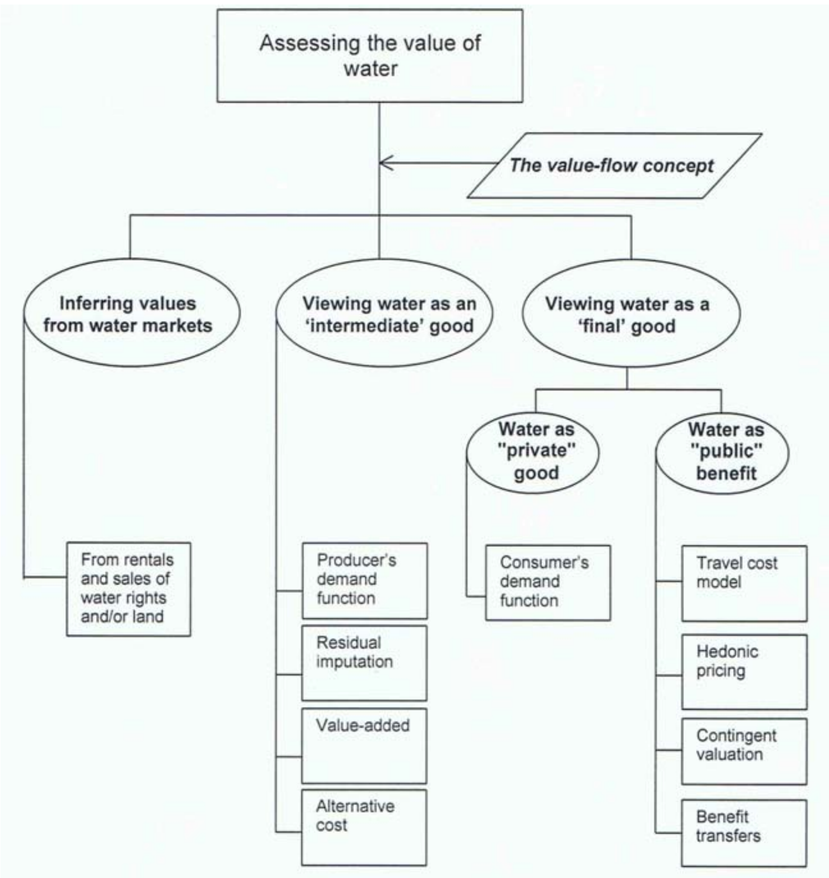


Figure 12 provides examples of such values in the case of wetland ecosystems. It shows that environmental economists tend to group the benefits attached to ecosystem functions and services as indirect values, while ecosystem services are also attached to use values and non-use values in other schools of thought, as seen earlier (e.g. culture, support, regulation)

The ecosystem services of lowland rice agro-ecosystems need to be assessed to enhance productivity, food safety, environmental protection, protection and sustainability. The assessment of the ecosystem services should be in the context of change in sources and levels of inputs, outputs and environmental burdens brought about by variations in season and cultural practices (Floresca, 2009).

Regarding ecosystem values, some functions and services may refer to a market mechanism (use value), whereby a price do exist (e.g. fish being caught then sold at local market, rice production); many other ecosystem services, mostly non-use type, are not traded in markets (e.g. enjoying wildlife sight, or a view over beautiful landscapes, cultural value). Thus, people benefiting such services do not pay for them. Additionally, because people are not familiar with purchasing such goods, their willingness to pay may not be defined. However, this does not mean that ecosystems or their services have no value, or cannot be valued in monetary terms (King and Mazzotta, 2000).

Figure 12. Valuation methods as per utilization-status of water resources (traded good, intermediate good, public or private final good)



As exemplified in figure 12, water is an intermediate good when it is the input or medium generating another product (e.g. crops, fish, pottery, navigation, recreation, hydropower); it is a final good when the resource itself is the good or service to be valued (e.g. drinking water, aesthetic value, waste dilution). Such final good may be a private good (e.g. drinking water) or a public good.

Economic valuation methods are based upon the categories established here above. Different methods of economic valuation for non-use values have been used and recommended by various authors. King and Mazzotta (2000), and Yoshida (2001) suggested different methods for valuating multifunctional roles of ecosystem services, i.e. the replacement cost method, the travel cost method (TCM), the hedonic pricing method, and contingent valuation method (CVM). From a different viewpoint, Heal et al. (2005) recommended four main categories of economic valuation methods for ecosystem goods and services. The four main categories of methods comprise revealed preference methods (including the travel cost, hedonic pricing and averting behavior methods), stated preference methods (including contingent valuation and attribute-based methods), production function method and replacement cost method. For further details on evaluation methodologies, readers may refer to Agudelo, 2001; Young, 2005; Briscoe, 2005; Griffin, 2006.

In the frame of this sub-study III focus on "inventory of ecosystem services" offered by rice ecosystems, a brief outlook of possible valuation methodologies is provided, with regards to ecosystem services in central plain of Thailand. Very few studies have been done so far in that area of research.

4.2 Actual and potential valuation studies

4.2.1 Function of provision of food and aquaculture

Rice production is the primary function of paddy cultivation, and the primary user of irrigation water. Thailand produces rice for itself and for much of the world as about 30% of rice traded globally comes from Thailand. However, central plain produces mostly lower quality rice, which is mostly used for domestic and agro-industrial purposes. The economic value of paddy fields is not always limited to rice production, or to off-season dry land crops, but is also due to the raising of fish and ducks. Fish living in the paddies eat rice pests (algae and insects), while producing nutrients for the rice, and protein (or cash) for the farm family. Ducks have a similar function and produce enough meat to compensate for any fish that they might eat as well (Groenfeldt, 2006).

Food products have market prices, so value may be inferred from it. **Residual imputation method** is use, based upon an analysis of the market prices of all inputs and outputs (except water, which market price is unknown). The value of the final product less the value of all inputs except water (residue) forms the contribution of water, hence its value. One remaining and biggest difficulty in applying the RI method is that the amount of water used as per unit of final product must be known, which is not an easy task in paddy ecosystems. Sometimes, the most relevant base unit for valuation may not be water but land, depending on which one is the scarcest resource.

4.2.2 Regulation functions

<u>Habitat for wildlife and biodiversity</u>

Contingent valuation methods should be used to assess the stated value people ascribe to the existence of a given species, or whole ecosystem. The concepts of willingness to pay (WTP, for protecting the ecosystem or the species) is exploited in surveys. Often, indirect payment scenarios (such as conservation tax) yield more realistic results than hypothetical direct WTP options.

<u>Function of preserving amenities for recreation and relaxation</u>

The recreational value of a given ecosystem may be equaled to the cost of traveling to this site incurred by people who wish to visit. **Travel cost method** reckons all costs incurred by travelling, leaving expenditures, accommodation, access fee if any, etc., and related to visiting the site and enjoying its recreational amenities.

<u>Function of flood prevention</u>

Economic evaluation of flood prevention may be based on **damage avoidance approach**: the value of the service equals the cost of fixing the damages caused by floods. Another option is **alternative cost approach**: the value of the service equals the cost of constructing an alternative infrastructure (e.g. flood control dam or dyke) which would play the same regulatory role. Basic financial approach based upon depreciation and discounting principles, maintenance and replacement costs, is to be followed here (Yoshida, 2001).

Function of conserving water resources

An **opportunity cost approach** may apply here. Any quantity of water saved for any other use may be valued based upon the highest price or value of most valuable use (highest opportunity). On that vein, Yoshida (2001) assessed the value of the function of groundwater conservation in irrigation systems as the difference in price between irrigation and domestic uses of that groundwater.

Function of prevention of soil erosion

Economic valuation of soil conservation may be based on the volume of soil conserved, i.e. the difference between the volume of soil lost from cultivated farmland (or good practice) and the volume of soil lost from abandoned farmland (or bad practice) during a given period. Monetary value then refers to the cost of constructing a sedimentation dam that would filter and retain a similar volume of sediments, over a similar timeframe (Yoshida, 2001). Such approach refers to **substitute cost method**. Alternatively, analysis of land transactions may be performed, comparing the **market prices** of preserved land vs. degraded land .

Function of climatic mitigation

The effect of a drop in temperature in the areas surrounding paddy fields during a given period is given a monetary value, based on the saving of air conditioning costs during the same period (**alternative cost approach**) (Yoshida, 2001).

4.2.3 Culture, recreation

Cultural value

Contingent valuation methods should be used to assess the stated value people ascribe to a given cultural good or service referring to cultural value. The concepts of willingness to pay (WTP, for benefiting the service) and willingness to accept compensation (WTA, for losing the service) are exploited in surveys targeting samples including people with and without cultural attraction and interest in a given resource.

Function of preserving amenities for recreation and relaxation

The recreational value of a given ecosystem may be equaled to the cost of traveling to this site incurred by people who wish to visit. **Travel cost method** reckons all costs incurred by travelling, leaving expenditures, accommodation, access fee if any, etc., and related to visiting the site and enjoying its recreational amenities.

4.2.4 Support functions

Function of air purification

The volume of air pollutant gases absorbed by agricultural fields is calculated, and given a monetary value based on the replacement cost of flue gas desulfurization and denitrification (**alternative cost approach**). Basic financial approach based upon depreciation and discounting principles, maintenance and replacement costs of desulfurization and denitrification equipment is to be followed here (Yoshida, 2001). Similar approach may be used regarding water purification, photosynthesis, nutrient cycling and the like.

Section 4.2 only provides examples of methods, and the most commonly used ones. Many other combinations and alternative methodologies may also be used, depending on context and research limitations (time, budget).

4.3 Summary

Methodologies to assess the economic value of ecosystem services are readily available. They have not been mobilized in Thailand so far for evaluation of rice ecosystem services.

5 GAP (Good Agricultural Practices) and impacts on improving ecosystem services

5.1 GAP for rice production

The increase in rice production in Thailand over recent years was largely due to the expansion of cultivated areas, while land productivity remained relatively stable and low (as compared to Vietnam for instance, as the other main rice exporter). Therefore, increasing land productivity is one of the main objectives of the sector.

For that aim, Thailand has adopted the Good Agricultural Practices (GAP) framework and has developed its own Thai-GAP, promoted by the Royal Irrigation Department of Thailand's Ministry of Agriculture and Cooperatives. The establishment of standards is important to significantly promote and encourage the quality and safety development of rice production in order to be accepted for both domestic and international trade sectors. This entails standards in production and post-production which consider both local and global effects of rice production.

National Bureau of Agricultural Commodity and Food Standard has established standard Good Agricultural Practices for cropping. This standard serves as a guideline to farmers in their rice cultivation and postharvest practices, and also applies as criteria to certify production process at farm level for safety and promoting rice exportation.

Thailand's climate change action plan (Office of Environmental Policy and Planning, 2000) includes specific measures in order to reduce GHG emissions from rice fields: low-methane rice cultivars, direct seeding, soil aeration in conjunction with water management, organic matter and fertilizer management, methane production inhibitors. Yet, the large diversity of cropping systems and water management practices, and prevailing socioeconomic constraints faced by farmers hampers concrete implementation of GAP.

As seen in figure 13 here below, different hydrological tools can be used to develop Good Agricultural Practices. Those hydrological tools are listed as (Satya Priya and Shibasaki, R. (2001)): (i) CREAMS and GLEAMS; (ii) AGNPS; (iii) ANSWERS; (iv) SWRRB; (v) DSSAT and (vi) EPIC. CREAMS and GLEAMS are field scale continuous models. They do not possess a robust crop growth model (Ramanarayam 1994; Satya Priya and Shibasaki, R. (2001)). SWRRB and EPIC are almost synonymous, except for the fact that SWRRB is a basin scale simulation model. EPIC (Williams and Sharpley, 1989) has improved residue-handling capabilities over SWRRB, and better nutrient cycling.

To further narrow down the yield gaps, several programs have also been set up in Thailand rice sector over past two decades, i.e. Rice Varietal Improvement Programme, Seed Production and Seed Exchange Programme, Production Technology Improvement Programme, Rainfed Rice Improvement Programme, Upland Rice Production Improvement Programme, Land Consolidation, Dike and Ditch Construction Programme and Irrigation Pumps for Rice Cultivation Programme.

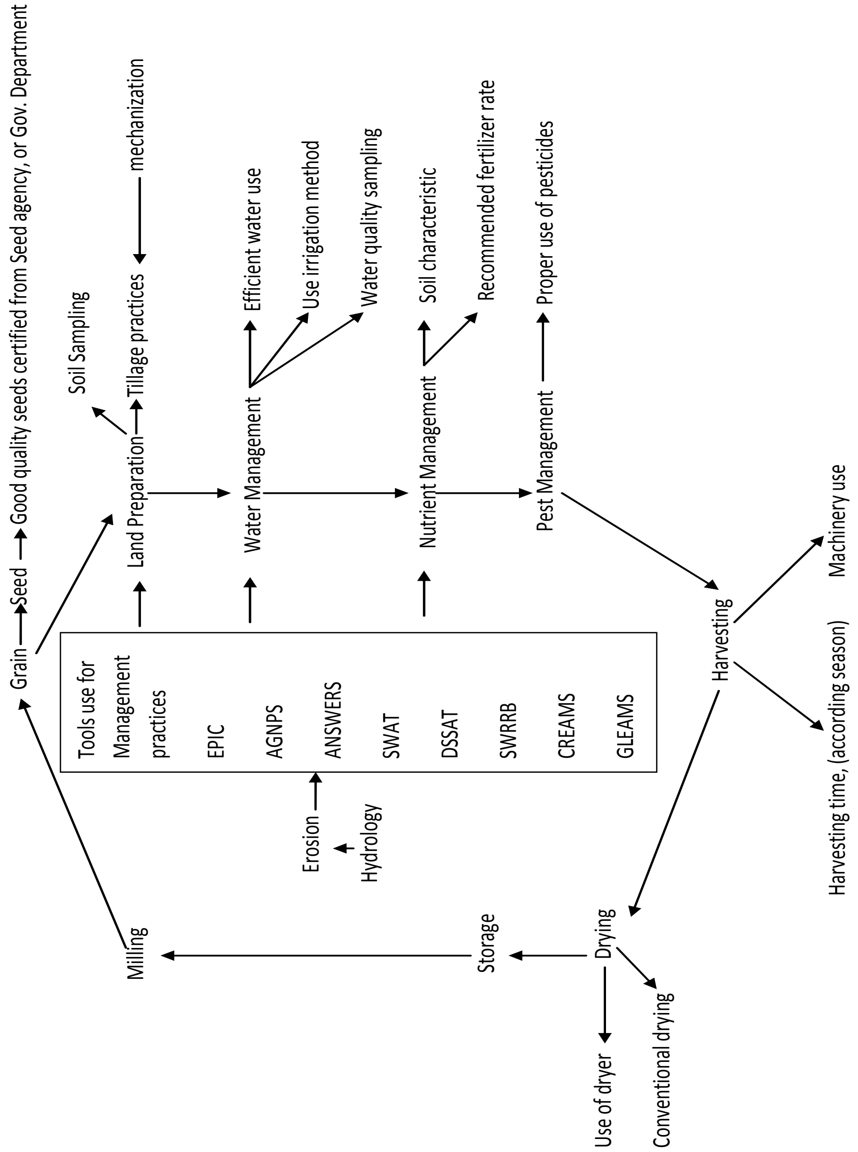


Figure 13: GAP framework and Management tools

Table 8. Identification of GAP for rice and practices follows for the rice cultivation at Central Plain of Thailand (Base on Ayutthaya case study) and relevant ecosystem services.

Practices	
Water Sources	About 70% of farmers use water for rice farming from surface water sources like small canal and swamp. About 30% of farmers use water for rice farming from irrigation water source. Farmers have to pay money for government based on the farming area.
Water quality testing	Only few farmers, new generation farmers (and educated) send water samples to the Irrigation Office to check water quality (water contaminant). While, a majority of farmers don't send the water sample to check contamination; even government is doing free for them
Field, Soil sampling to check hazardous contamination (before cultivation)	It is the same as water quality testing

Pesticide use Insecticide Herbicides	
1. Do farmer use application rate as per labeled on bottle?	Yes, most of farmers follow the application rate as per labeled on bottle
2. Do farmer use any protection while application pesticide (mask, clothes)?	Yes, most of farmers hire the labour to spray chemical pesticide in their farms. Regarding the labour who is spraying chemical pesticide, they wear proper mask and clothes as they know how to protect themselves when they use chemical pesticide.
3. Pesticide application done at morning or evening?	Most of farmers prefer to spray chemical pesticide in the morning as there is no high wind speed that affect to nearby environment including people who stay in this area and also it is not hot in the morning for farmers who spray chemical pesticide.
4. Do they keep pesticides at proper place (store room)?	They keep pesticides in the proper place. Most of them keep pesticides in store room which is separated from the place to sleep or cook food.
Seed use	
1. Do farmer use qualified seed from any agency or government seed department?	A majority of farmers choose rice variety to plant in farm by themselves by considering following factors; high yield, strong stem, fine seed, insect and disease resistance. While some (few number) of farmers specifically educated farmers prefer to follow Government recommendation through various departments such as Ayutthaya Rice Research Center and Ayutthaya Provincial Agricultural Extension Office.
2. Do farmer use seed produced from his own farm?	A majority of farmers buy seed from agricultural shops in local market. While, only few of farmer produce own seed.
Rice planting Variety:	Rice species planted during dry season in Ayutthaya are shown below: Suphanburi 1 Suphanburi 3 RD 31 Phitsanulok 2 Rice species planted during dry season in Ayutthaya are shown below: Ayutthaya 1 Prachinburi 1 Prachinburi 2 Laung Patiew Khao Dawk Mali 105
Cropping calendar:	Wet-season rice June: land preparation including tillage July: sowing rice seed October: generating ear of rice

<table>
<tr><td></td><td>December or January: cultivating rice

Dry-season rice (taking around 105-110 days to get yield)
January or February: land preparation including tillage and sowing rice seed
March or April: generating ear of rice
April or May: cultivating rice</td></tr>
<tr><td>Seed rate
1. 5 to 7 kg per rai for transplanting.
2. 10 to 20 kg per rai for wet seeded.
3. 10 to 20 kg per rai for dry seeded.</td><td>
5-7 kg. per rai
20 kg. per rai
20-25 kg. per rai</td></tr>
<tr><td>Fertilizer application
1. Do farmer use organic fertilizer?</td><td>
Yes, some of farmers who understand the benefit of organic fertilizer. However, they still use chemical fertilizer along with organic fertilizer because in short term chemical fertilizer can provide all necessary nutrients rice need while organic fertilizer cannot cover all kinds and amount of nutrients required for rice plantation.</td></tr>
<tr><td>2. Do farmer use fertilizer application based on soil sampling?</td><td>Yes</td></tr>
<tr><td>3. Do they follow following application rate?
<table>
<tr><th>Soil</th><th>Application rate, kg/rai</th><th>Fertilizer</th></tr>
<tr><td>Clay</td><td>20-25</td><td>16-20-0/
18-22-0/
20-20-0</td></tr>
<tr><td></td><td>5-10 Top dressing application
Or</td><td>Urea</td></tr>
<tr><td></td><td>10-20 Top dressing application</td><td>Sulphate
or ammonium
sulphate</td></tr>
</table></td><td>Wet season rice
• 16-20-0 (20-25 kg/rai)
Dry season rice
• 16-20-0 (25-30 kg/rai)
Wet season rice
• Urea (10-15 kg/rai)
Dry season rice
• Urea (20-25 kg/rai)</td></tr>
<tr><td>Do farmer water management practices?</td><td>Farmers excavate small canal (water flow channel) in their rice fields so as to have enough water for rice. Also, they have good system of water drainage to let water in and out of their rice fields.</td></tr>
</table>

Keeping water depth in the field?	Seedling stage - 5-10 cm. (the water level is half of seedling stem) Tillering stage - 10-15 cm. Flowering stage - 10-15 cm. Around one to two weeks before harvesting - 0 cm. (the water is released out of rice field)
Harvesting Do farmer do harvesting 25 to 35 days after flowering? Is there harvesting period different for dry and wet season and what it is? Do farmer use combine harvester?	Around 30 days It is not different for dry and wet season. Yes.
What kind of storage use to store rice? Is it safety from insects or any contamination?	Generally, most of farmers do not have rice storage as there are middle men going to their farms directly to buy rice after harvesting. However, some of farmers keep small amount of unmilled rice for themselves in proper places which are far from contamination.

6 Policy and Stakeholders

In general, multifunctional roles are formed by the external economies of agriculture. They have the characteristics of public goods. However, the general public that benefits from these multifunctional roles does not place a proper value on them. If these functions are not traded in the market, policy intervention may be required in order to maintain them (Dong-Kyun, 2002). It cannot be claimed that rice paddy farming is always friendly to the environment. On the contrary, the agricultural chemicals used can adversely affect the environment. However, these negative effects can be reduced by following Low Input Sustainable Agriculture (LISA). Examples are organic farming, integrated pest management and integrated nutrition management systems. Some indirect benefits, such as flood control and water resource management, are not directly linked with rice production itself. Those outputs can be maintained if paddy fields are preserved, regardless of whether rice is being grown.

The first step in designing policies to support the multiple functions of agriculture is to establish the policy intent to do so. This step implies a policy debate not only within the government, but within the larger civil society, as to the desirable role of agriculture within that society (Groenfeldt, 2006).

The multifunctionality concept serves as a guide to agricultural policies that are in the long-term interest of society. Basically the concept offers a broader context, besides economic profitability or crop productivity, for selecting among agricultural options. When the logic is followed, the result is likely to be a more eco-oriented agriculture that has long-term sustainability, and supports the social and cultural values of society (Groenfeldt, 2006).

Once the policy decision is taken to promote multiple functions of agriculture, what practical measures can accomplish this? Conventional market mechanisms are not adequate. In order to support the multifunctional services of agriculture, either the markets need to change, or governments must intervene. Interventions are needed at four basic levels (Groenfeldt, 2006):

1. Support to Individual Farmers: Incentives can be directed to farmers to pursue certain types of production regimes that will enhance multifunctional objectives. In Japan and Korea, farmers receive direct payments to maintain paddy terraces in mountainous areas, where flood control is of particular concern.

2. Support to Rural Communities: Regional plans promoting multifunctional agriculture blend participatory process of community involvement with outcomes that create rural amenities as well as jobs.

3. Support to Rural Area: Conventional rural development has emphasized a range of infrastructure (roads, markets, communications, storage facilities, etc.) and services (water supply, schools, medical clinics) aimed at agricultural growth and stable populations. The education system is perhaps the most critical component of the rural amenities. Providing local students the knowledge and skills needed for multifunctional agriculture requires more practical curricula and perhaps novel teaching methods.

4. Support to the Agriculture Sector: Conventional mono-functional agriculture is supported by a vast research and extension network that would need to be reformed to meet the needs of ecologically-oriented agriculture. Decentralized, location-specific, farmer-led research would become relatively more important for multifunctional approaches.

Rice cultivation is not related to only farmers but also other stakeholders from different groups. Those different groups are from various agencies, such as government, private sector, NGOs etc. Stakeholders from mentioned groups or agencies are contributing their work direct or indirect to the rice ecosystem through GAP. List of stakeholders who involves in rice ecosystem is mentioned as below.

Table 9 lists the different stakeholders concerned with ecosystem services and related issues in central plain of Thailand.

Table 9. Stakeholders related to GAP, ecosystem services and related issues in central plain of Thailand

Sr. No.	Stakeholders	Function or contribution to improve rice ecosystem
1	Producers	
	i. Farmers	Follow the agricultural practices recommended by Government or GAP
	ii. Labour	Follow the agricultural practices recommended by Government or GAP
	iii. Land Owner (may be farmer or business man)	if he or she is farmer then do same as (i) but if he or she is business man then, he or she should give land in cheaper rate to the farmers who follow GAP for the cultivation Government should give some incentives (e.g. lower down tax) and support to land owner (e.g. free organic fertilizers).
	iv. Farmers' Group	Hub of knowledge/sharing ideas understanding the cultivation practices in terms of externalities to the environment specifically adjacent area
	v. Learning Center	Basic knowledge (e.g. literacy), e-Learning center
2	Government Agencies	
	i. Local Administration	Cooperation between local government and farmers
	ii. Cooperatives	Support (e.g. loans, buying rice etc.)
	iii. Provincial Rice Research Center	Providing knowledge (e.g. technology)
	iv. Royal Irrigation Department	improvement in rice varieties
	Regional Irrigation Office	Water management (e.g. regulation)
	Water User Group	
	v. Land Development Department	Soil suitability, recommendation on fertilizer use and organic fertilizers
	vi. Ministry of Natural Resources and Environment	Environmental policies and research
3	NGO and Institutes	
	i. I-NGOs	Research
	IRRI	Support (e.g. New technologies, rice varieties)
	UNEP	Coordination among different level stakeholders
	Green Peace	
	ii. Local NGOs	
	iii. Institutes and Universities	
4	Private sectors/agencies	
	i. Buyer Group	Buying rice based on cultivation practices (e.g. organice rice getting higher price than non organic rice)
	ii. Chemical Agencies	Training to the farmers for how to use chemicals properly

7 Conclusion, recommendations

7.1 Conclusions

This short study includes only partial results, and therefore demands follow-up research for confirmation and proper documentation and evidence (see recommendations section). However, a number of conclusions may be drawn.

Lowland paddy rice ecosystems in central plain of Thailand offer many ecosystem goods and services and include functions and values related to regulation, support, culture, and contribution to the economy. However, being mostly irrigated, and designed and operated for intensive production towards export and agro-industry sectors, some functions have limited positive effects (support), and some negative externalities are significant (GHG emissions and high contribution to climate change as the main negative externality of paddy rice). Among ecosystem services, regulation functions seems to be the most important, as paddy rice ecosystems contribute significantly to water resource management and conservation, erosion control, preservation of biodiversity and aquatic habitats, and, more importantly in central plains, flood mitigation and prevention. Paddy rice systems also contribute to the economy (local and national), to development, and bear very significant cultural value all over South East Asia. In terms of support functions, paddy fields contribute to nutrient cycling, water purification (denitrification), air purification, photosynthesis.

The case study in Ayutthaya Province reveals that the concept of ecosystem services is widely unknown among all stakeholders in the rice production sector. Further, few research have been carried out, and few information are actually available on ecosystem services in the area. Discussions with local experts show that some ecosystem functions and services are fulfilled by paddy rice fields, with regards to culture, provision of goods, and contribution to the economy. However, intensification of cropping systems and the intensive use of pesticides hinders most possibilities on support and regulation. Local stakeholders, officials, most public and private sector agents, and the general public seem to largely ignore both the concept of ecosystem services, and the implications thereof. More specifically, farmers as primary producers and custodians of such goods are not aware of the role they play and that benefits the whole society. There are two notable exceptions to this general lack of awareness: the role played by paddy fields in flood mitigation and in wildlife conservation. Both are generally known. Also, the Royal Irrigation Department of Thailand's Ministry of Agriculture has develop GAP recommendations in order to sustain and enhance ecosystem services, especially those related to environmental conservation, soil quality, sustainable use of pesticides and the like. Concrete application and impact of GAP recommendations remain few at this point in time.

Furthermore, the economic values of the different rice ecosystems services and goods have not been assessed in Thailand, while methodologies do exist. No compensation, incentive or payment mechanism related to ecosystem services has been developed so far in Thailand. As said, the only measure in place is actually a set of recommendations based on Good Agricultural Practices.

7.2 Recommendations

In view of such results, two sets of recommendations may be suggested, one for further research, the other towards role-players for implementation.

7.2.1 Research

More research should be carried out, investigating in deeper details the different ecosystem services, goods and amenities offered by paddy rice ecosystems in Central Plain. This specifically concerns certain **biophysical and ecological processes** that are poorly documented at this stage:

- hydrology (e.g. groundwater recharge, flood protection, erosion control),
- water and soil chemistry (nutrient balance and cycling, water filtration and purification),
- ecology (effects of pesticides on fauna and flora, biodiversity indicators).

The outcomes of such background research would be to better define the quantity and quality of ecosystems services provided, to back up further investigations on their economic value (see below).

Research should also be carried out in **economics**, first assessing the value of all identified ecosystems goods and services, second investigating and testing economic instruments towards sustainability of such provision, based upon previous economic evaluation (e.g. payment for ecosystem services, incentives).

7.2.2 Implementation

Research agencies should team up with public and private interested stakeholders in order to redress the observed lack of knowledge and awareness on ecosystem services in central plain of Thailand, then to implement some specific activities.

First, **communication and information** has to take place, towards the general public, and more specific stakeholders in rice ecosystems and rice supply chain. Second, it is suggested that some **pilot projects** are set up, based upon existing farmer groups and/or delineated irrigation systems in order to experiment mechanisms potentially leading to sustainable provision of ecosystem services: farmer certification mechanisms, area certification mechanisms (geographic indications of quality), labeling of products (e.g organic, sustainable pesticide use, sustainable chemical use, GAP-based). Such pilot projects could ultimately be used to experiment PES mechanisms.

References

Agus, F., Wahyunto, Tala'ohu S. and Watung R. (2004), Environmental Consequences of Land Use changes in Indonesia, ISCO 2004 - 13th International Soil Conservation Organisation Conference – Brisbane, July 2004.

Bird Conservation Society of Thailand Bulletin 18(7): 13-14 (July 2001).

Bird Conservation Society of Thailand. (2010). Important Bird Areas in Thailand. http://www.bcst.or.th/back_up_2009/project/IBA/iba_map.htm (accessed on July 8, 2010).)

BirdLife International (1998) *Proceedings of the Thailand IBA workshop, Bangkok, November 1998.* Unpublished report.

BirdLife International (2001) *Threatened birds of Asia: the Bird Life International Red Data Book.* Cambridge, UK: Bird Life International.

Brown, T.C., Bergstrom, J.C. and Loomis, J.B. (2006). Ecosystem goods and services: Definition, valuation and provision. RMRS-RWU-4851 Discussion Paper.

Chen, Z., (2005). Multiple roles of Agriculture Water Management Systems: Implications for Irrigation System Management and Integrated Water Resources Management in Rural Watersheds. Sub-session C , Reconciling Agriculture Water Services, Management and Protection of Rural and Coastal Ecosystem in Rural Watersheds Second South East Asia Water Forum, August-September 2005, Bali, Indonesia.

Corinne Kisner (2008). Climate change in Thailand : Impacts and adaptation strategies.

CTI Engineering Co. Ltd. And INA Corporation 1999, The study on integrated plan for mitigation Chao Phraya River Basin Final Main Report, RID, JICA.

Dixon, J.A. and Sherman, P.B. (1990). *Economics of protected areas: a new look at benefits and costs*. Island Press, Washington, USA.

Dong-Kyun, S. (2002). Social and economic evaluation of the multifunctional roles of paddy farming. Rural Development Administration, Korea.

Edirisinghe, J.P.; Bambaradeniya, (2006). Rice Fields:An ecosystem rich in Biodiversity. *Journal of the National Science Foundation of Sri Lanka* 34: pp. 57 -59

Feng, Y.W. et al (2003), Nutrient Balance in a Paddy Field With Recycling Irrigation System, Diffuse Pollution Conference, Dublin 2003, Poster Paper, pp. 14-38.

Floresca, J.P., et al. (2009). Assessment of Ecosystem Services of Lowland Rice Agroecosystems in Echague, Isabela, Philippines. *Journal of Environmental Science and Management*, 12(1):pp. 25-41.

Groenfeldt, D. (2006). Multifunctionality of Agricultural Water: Looking Beyond Food Production and Ecosystem Services. *Journal of Irrigation and Drainage*, 55(1): pp. 73-83.

Halwart, M. (2006). Biodiversity and nutrition in rice-based aquatic ecosystems. *Journal of Food Composition and Analysis,* 19 (2006). pp. 747–751

Hazrat Ali M et al (2004). Influences of various of water depth on rice growth in rice-fish culture under wetland ecosystem. *The Journal of Geo-Environment* Vol. 4, 2004, pp. 23-30.

Heal, G.M., et al. (2005). Valuing ecosystem services: toward better environmental decision-making. National Academy Press, Washington, D.C., USA.

INWEPF. (2007). Sustainability of Paddy Fields and Ecosystems towards Society. The Fourth Steering Meeting and Symposium. Ministry of Agricultural Development and Agrarian Services, Sri Lanka.

IPCC, IPCC Fourth Assessment Report: Climate Change 2007; Climate Change 2007: Working Group III: Mitigation of Climate Change.

Jessica, B. et al (2008). Cool Farming: Climate impacts of agriculture and mitigation potential, available at: www.greenpeace.org

King, D.M. and Mazzotta, M.J. (2000). Ecosystem Valuation. US Department of Agriculture Natural Resources Conservation Service, USA. http://www.ecosystemvaluation.org (accessed on June 25, 2010).

Lopez, A. and Mundkur, T. (1997) *The Asian Waterfowl Census 1994-1997: results of the coordinated water bird census and an overview of the status of wetlands in Asia*. Kuala Lumpur: Wetlands International.

Office of Environmental Policy and Planning (1999) *Directory of internationally important wetlands in Thailand*. Bangkok: Ministry of Science, Technology and Environment. (In Thai.)

Pearce, D. and Morgan, D. (1994). The economic value of biodiversity. Earthscan Publications, London, UK.

Rice Department, Thailand available at, http://www.ricethailand.go.th/gap.htm (accessed at 26th Jun, 2010)

Satya Priya and Shibasaki, R. (2001). National spatial crop yield simulation using GIS-based crop production model, *Ecological Modelling*, Vol 136, Issue 2-3, jan 2001, pp. 113-129.

Toriyama, T., Heong, K. L. and Hardy, B. (2004). Rice Life: scientific perspective for 21st century, Session 11: Enhancing the multifunctionality of floating rice farming in Chao Phraya delta of Thailand, pp. 340 -343.

Teo S. S. (2001). Evaluation of different duck varieties for the control of the golden apple snail (*Pomacea canaliculata*) in transplanted and direct seeded rice. *Journal of Crop Production* 20 (2001) pp. 599-604.

Teo S. S. (2006). Evaluation of different species of fish for biological control of golden apple snail *Pomacea canaliculata* (Lamarck) in rice. *Journal of Crop Production* 25 (2006) pp. 1004-1012.

Thai Agricultural Standard, TAS 4401-2008, Good Agricultural Practices for Rice, National Bureau of Agricultural Commodity and Food Standards, Ministry of Agriculture Cooperatives, ICS 67.060.20 ISBN 978-974-403-560-8.

Weimin M. (2009). Recent developments in paddy–field fish culture in China: A holistic approach for livelihood improvement in rural areas, Success Stories in Asian Aquaculture, available at http://www.idrc.ca/en/ev-147117-201-1-DO_TOPIC.html

Xia, L. and Guangcan, Z. (2002). Ecosystem Services and Assessment of Water Protection Forests. The twelth ISCO Conference. Department of Soil and Water Conservation, Shandong Agricultural University, Beijing, China.

Yoshida, K. (2001). An economic evaluation of the multifunctional roles of agriculture and rural areas in Japan. Policy Research Institute, Ministry of Agriculture, Forestry and Fisheries, Tokyo, Japan.

Zhang Qi-chun and Wang Guang-huo (2005), Studies on nutrient uptake of rice and characteristics of soil microorganisms in a long-term fertilization experiments for irrigated rice, *Journal of Zhejiang University* Science ISSN 1009-3095, 2005 6B(2):pp.147-154.

Personal Communications:

Dr. Patchanee Chaiyawat, Agricultural Scientist, Ayutthaya Rice Research Center, Tel. 035-241-680 (Email-ID: patchanee@ricethailand.go.th).

Appendix 1: Rice–fish and rice-duck ecosystems

Combined and purposive production of rice and fish, or rice and duck in paddy fields may lead to increased provision of ecosystem services, as indicated by literature, as reported here after.

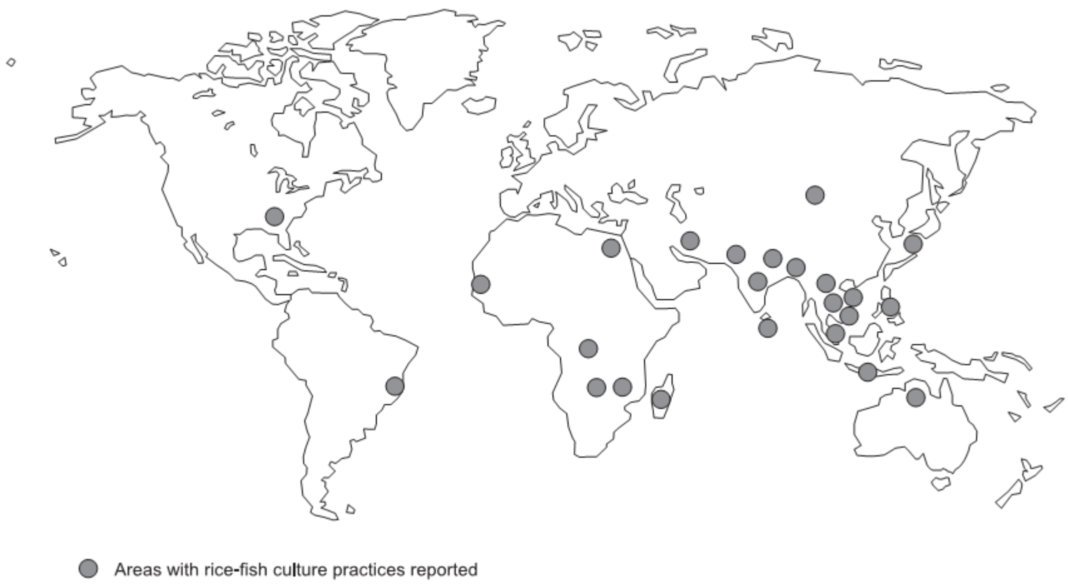


Figure A1.1: Areas with rice fish culture reported, (Halwart M. and Gupta M., 2004)

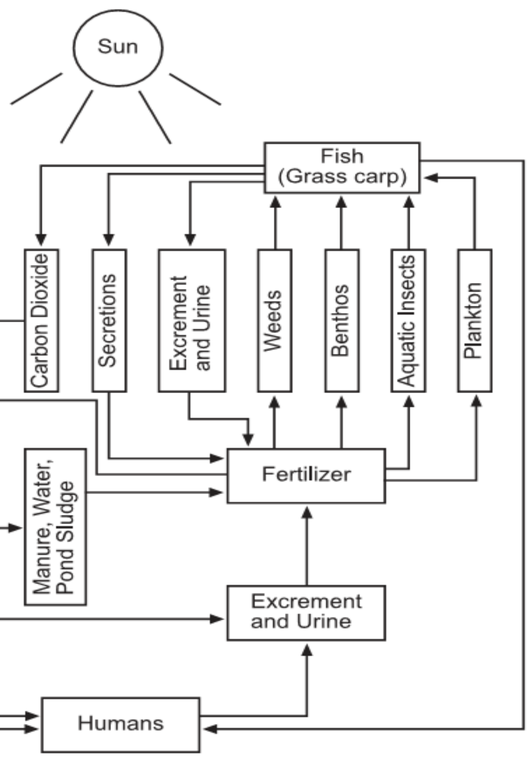


Figure A1.2: Rice – fish culture and rice ecosystem

Integrated rice-fish farming is believed to have been practiced for more than 200 years in Thailand, particularly in the Northeast where it was dependent upon capturing wild fish for stocking the rice fields. It was later promoted by the Department of Fisheries (DOF) and expanded into the Central Plains. However, during the 1970s, Thailand, like the rest of Asia, introduced the HYVs of rice and with it the increased use of chemical pesticides. This resulted in the near collapse of rice-fish farming in the Central Plains as farmers either separated their rice and fish operations or stopped growing fish altogether. Fedoruk and Leelapatra (1992) attributed the recovery to more discriminate use of HYV; the emergence of pesticides that when properly applied are not toxic to fish; the growing perception of the economic benefits of rice-fish farming, and its promotion in special projects assisting disadvantaged farmers, among other factors. The increasing frequency of directly broadcasting rice seeds and using machines for field preparation are signs of the growing labor shortage. The shortage may favor the development of more easily managed pond culture rather than the more laborious rice-fish system. On the other hand, adoption of rice-fish systems in the Northeast Region may be biased towards those who are better off and have access to labor and other resources (Halwart M. and Gupta M., 2004).

Table A1.1: Rice yield with fish and without fish in Thailand (fish e.g. *Trichogaster* sp. (Snakeskin gourami) and *Clarias batrachus*)

	Rice Yield (kg·ha^{-1})			Reference
System/Location/Year	With fish	W/out fish	More (Less)	
ns, Dom Noi, wet 1985	1890	1790	100	Thongpan et al. 1992
ns, Khoo Khad, wet 1985	1630	1510	120	
ns, Amnart Charoen 1987	2537	2014	523	
ns, Kheuang Nai 1987	2574	2372	202	
ns, Det Udom 1987	2651	2427	224	

Policy to follow rice fish culture**,** since IPM is now an accepted approach to pest control this is a logical entry point for raising fish in rice fields. However, suitable curricula for the Farmer Field Schools still need to be developed.

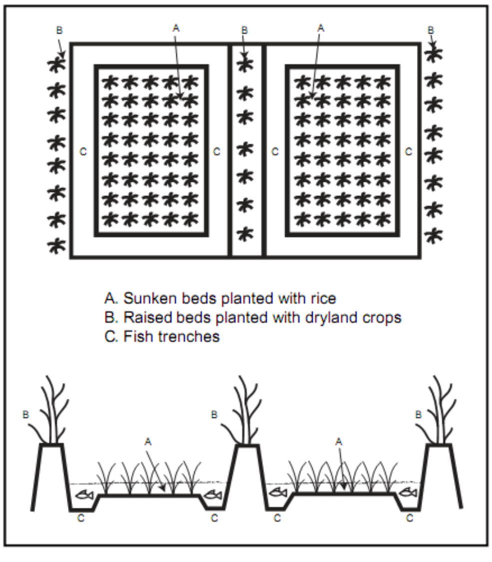


Figure A1.3: Rice fish farming, farm layout

(Halwart M. and Gupta M., 2004)

Previous studies related rice fish ecosystem:

Rice-Fish Culture: In the rice fish culture cultivation practice additional nutrients are supplied by fish in the form of faces excretion and decomposition of dead fish. Nutrients supply to crops when they swims, released fixed nutrients. Recycling of nutrients is when fish graze on photosynthesis. But this culture may affect phosphors cycle.

Hazrat Ali M. et al (2005), study was undertaken at the experimental farm of Philippine Rice Research Institute, Maligaya, Science City of Muñoz Nueva Ecija, Philippines to *determine the effect of various level of water depth on rice growth under rice-fish culture in wetland rice ecosystems.* The treatment with rice-fish at 16-20 cm water depth produced significantly the tallest plants whereas the treatments with rice-fish at 5 -10 cm and 11-15 cm water depth and the control produced the shorter plants. The leaf area was increased progressively with plant age reaching its maximum value at 72 days after transplanting (DAT) and beyond 72 DAT leaf area declined because of leaf senescence. The values of LAI (Leaf area index) were maximum at 72 DAT for all the treatments except the treatment of rice + fish with 21-25 cm water depth and the control. The values of DM (Dry matter) were statistically similar among the treatments throughout the growing period but at harvest, consistently higher dry matter production was observed for the treatment of rice + fish with 11-15 cm water depth. This was lower in the treatment of rice + fish with 16-20 cm and the control. Plant population at 17 DAT differed significantly among the treatments possibly due to uneven distribution of seedlings at planting and also damaged by Golden nails. Maximum tiller production was observed at 45 DAT for all the treatments and the highest number of productive tillers per hill as well as in unit area was obtained from the treatment with water depth of 16-20 cm followed by 21-25 cm. Rice plants were found lodged which was observed more importantly when they were grown beyond 15 cm of water depth

Teo S. S., (2006) has defined the concept of *rice–fish farming was employed to evaluate five species of fish for biological control of golden apple snail in rice.* Aquaria trials were initially used to observe the predation potential of the individual fish species, followed by replicated field trials. In the aquaria studies all the fish species preyed upon the hatchlings of the golden apple snail, but *at the field level only common carp and African catfish consumed snails significantly more than the other species.* Common carp, which attained a recovery rate of 90%, was the only fish species suitable for biological control of snail in rice. African catfish was not adaptable to the rice field conditions; the fish suffered a low recovery rate of 17% even when the plots were covered with nets to protect the fish from natural predators. *The density of common carp recommended for biological control of snail in rice was 2041 fish/ha.* However, it was essential to set up a pond refuge to improve survival rate and to enhance fish production. The study revealed that under direct seeding planting method, the increase in plant density restricted the foraging activities of the fish. Consequently, the number of snail sampled in direct seeded plots was significantly greater than in transplanted plots. *Throughout the studies, the fish neither caused a significant increase in rice yields nor a reduction in stem borer, case worm and stink bug infestations. Common carp was however, an effective predator of the golden apple snail in rice.*

Rice-Fish culture in China, Weimin M. (2009):

Rice field-fish culture, also popularly referred to as rice cum fish culture, is a traditional integrated fish-rice production system. The earliest practices can be traced back to more than 2,000 years ago. China is the largest producer of fish and rice in the world. Rice-fish culture has achieved significant development in China in the past three decades, in spite of the major socioeconomic changes that have occurred during this period. There are some 1.55 million ha of rice-fish culture in China now, which produces approximately 1.16 million tons of fish products (2007), in addition to about 11 million tons of high quality rice. Fish production from rice–fish culture has increased by 13-fold during the last two decades in China. Rice-fish culture is now one of the most important aquaculture systems in

China. While making significant contribution to rural livelihood and food security, development of rice-fish culture is an important approach for environment friendly holistic rural development, and epitomizes an ecosystems approach to aquaculture. Rice-fish culture in China utilizes a range of production systems and practices, but all contribute to eco-environmental benefits and sustainable development. Many factors have contributed to these developments, but equally and still, there are challenges that need to be addressed for up-scaling these production systems and practices. It is estimated that the area under rice cultivation in Asia approximates 140.3 million ha, accounting for 89.4% of the world total. The potential for development of rice-fish culture is very high in the region. The successful experiences and lessons of rice-fish culture development drawn from China can be a good reference for sustainable rice-fish culture development in the region as well as other parts of the world, thereby contributing further to food security and poverty alleviation.

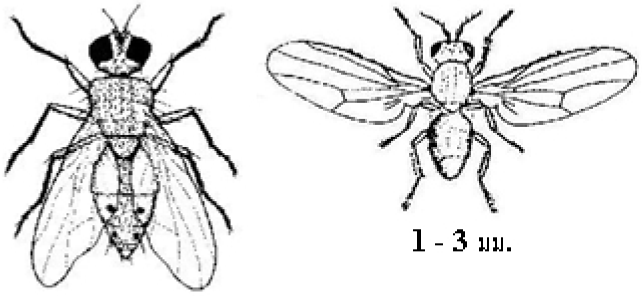
Rice–duck ecosystems:

Teo S. S. (2001) investigated the potential of *ducks for the control of the golden apple snail in irrigated rice.* The varieties of duck recommended for the biological control of snail in decreasing preference were William Siam > Taiwan > Mallard> Peking> Muscovy. Cherry Valley, a variety with a bigger body size was not suitable for snail control because of its poor adaptation to rice field conditions. *A density of 5-10 ducks ha^{-1} in continuous grazing for a period of 1-2 months significantly reduced the pest density from 5 snails m^{-2} to less than 1 snail m^{-2}.* This density of ducks was recommended for biological control of snails in rice. Timely release of ducks was crucial as they damaged young rice seedlings. In transplanted rice, it was appropriate to release the ducks when the seedlings were 4 weeks old. For direct seeded rice, a longer waiting period of 6 weeks was necessary. Numerically, ducks preyed on more snails in transplanted than in direct seeded rice, but the difference was not statistically significant. The increase in plant density under direct seeding probably reduced the browsing efficiency of the ducks. This difference would be expected to diminish under prolonged grazing. It is suggested that ducks were an effective biological control agent against the golden apple snail.

Appendix 2: Insects and pests found in rice farm (photos)

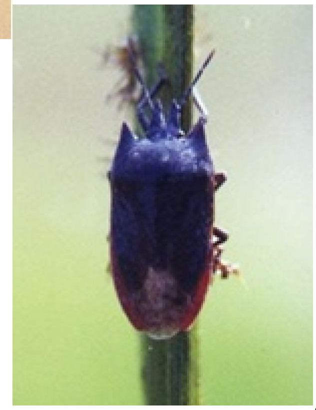
Rice thrips (*Stenchaetohrips biformis)*

Rice whorl maggot (*Hydrellia spp*.)



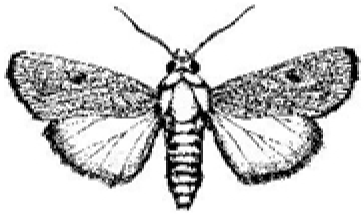
1 - 3 มม.

Stink bug (*Tetroda denticulifera*)



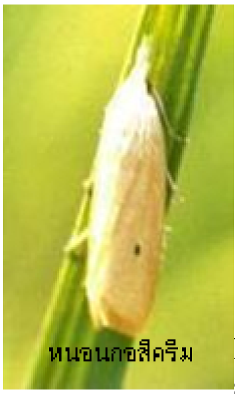
Rice armyworm (*Spodoptera mauritia*)

35 - 40



35 - 40

Rice stems borers, SB
Yellow stem borer (*Scirpophaga)*
Dark-headed stem borer *(Chilo* *polychrysus*)



Pink stem borer (*Sessamia inferens)*
Striped stem borer (*Chilo suppressalis*)

Brown planthopper, BPH (*Nilaparvata lugens*) **Rice gall midge, RGM *(Orseolia oryzae*)**

Green rice leafhopper (*Nephotettix virescens)*

Rice black bug Malayan black bug
Rice leaffolder, LF
(*Scotinophara coarctata*) (*Cnaphalocrocis medinalis*)

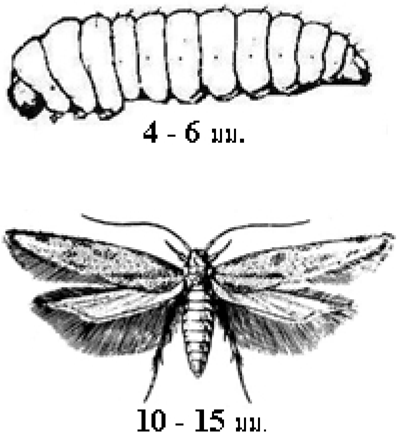
Rice caseworm (*Nymphula depunctalis Guenee*) **Rice hispa (*Dicladispa armigera)***

Scarab Beetle (*Alissonotum cribratellum)*
Rice bug, stink bug (Leptocorisa acuta)

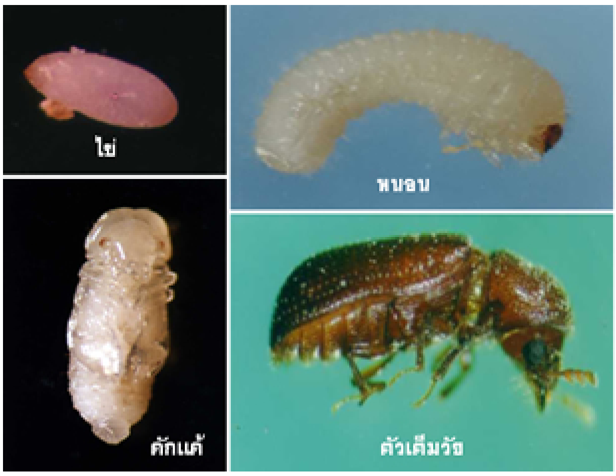
Insects and pests in stored rice

Angoumois grain moth
(*Sitotroga cerealella)*

Rice weevil (*Sitophilus oryzae*)



Lesser grain borer (*Rhyzopertha dominica*) **Red flour beetle *(Tribolium castaneum)***



Siamese grain beetle (*Lophocateres pusillus)*

Animal and insects

1. **Spoted munia (***Lochura punctulata)*
2. **Ricefield crab** *(Esanthelphusa spp*.)
3. **Roof rat, ship rat (***Rattus rattus)*
4. **Ricefield rat** *(Rattus argentiventer)*
5. **Great bandicoot** *(Bandicota indica)*
6. **Lesser bandicoot** *(Bandicota savilei)*
7. **Golden apple snail** *(Pomacea canaliculata*)

Appendix 3: Rice varieties in Thailand

Rice varieties recommended by Bureau of Rice Research and Development for rice farmers in Thailand

Since 1999, Rice Research Institute has continued improving rice varieties in order to increase rice yield and have good quality of rice seed which can resist disease and pest as well as can easily adjust to different environments. Rice Research Institute makes a recommendation of rice varieties which are from both local rice species and from breeding rice varieties for farmers to plant in their farms. *The recommendation of rice varieties can be divided into 3 categories based on ecosystem characteristics in each area consisting of irrigated rice farming, rainfed rice farming and floating rice farming.* The rice varieties in each category is shown below (Bureau of Rice Research and Development, 2010).

1) <u>Rice varieties recommended for irrigated rice farming area</u>

Rice Varieties	Type	Period	Yield (kg/rai)	Region
RD 7	Rice	125 days	672	All regions which are in irrigated areas or where there is good water management practice
RD 10	Sticky Rice	130 days	660	North and Northeast in irrigated rice farming area
RD 23	Rice	125 days	800	All regions which are in irrigated areas or where there is good water management practice
Suphanburi 60	Rice	120-122 days	700	Central, West and East in irrigated areas
Suphanburi 90	Rice	120 days	600	Central specifically the area where there is the spread of brown plant hopper, ragged stunt disease, yellow orange leaf disease and rice blast disease
Chainat 1	Rice	121-130 days (if planted in dry season) 119 days (if planted in rainy season)	740	Central and lower part of North specifically the area where there is the spread of brown plant hopper, ragged stunt disease and rice blast disease
Phrae 1	Sticky Rice	130 days	685	Northeast and upper part of North specifically the area where there is the spread of brown plant hopper, ragged stunt disease and rice blast disease in the area where RD 10 rice species is planted
Suphanburi 1	Rice	120 days	806	Central in irrigated rice farming area. This rice species should be planted along with Suphanburi 90 rice species

				for solving the problem of brown plant hopper spread
Suphanburi 2	Rice	115 days	700	Central, East and West in irrigated rice farming area
Khao Jow Hawm Khlong Luang 1	Rice	118 days (if planted in dry season rice) 125 days (if planted in wet season rice)	591 (in dry season rice) 650 (in wet season rice)	Central in irrigated rice farming area
Khao Jow Hawm Suphanburi	Rice	120 days	582 (in dry season rice) 673 (in dry season rice)	Suphanburi, Angthong, Kanchanaburi and nearby provinces
Pathumthani 1	Rice	104-126 days	650-774	Central in irrigated rice farming area
Sakonnakhon	Rice	128 days	467	Northeast in highland area or irrigated rice farming area
Surin 1	Rice	138 days	620	Northeast in rainfed rice farming area as well as irrigated rice farming area

2) Rice varieties recommended for rainfed rice farming area

Rice Varieties	Type	Date of harvesting	Yield (kg/rai)	Region
Khao Dawk Mali 105	Rice	20 Nov	363	All regions but Northeast is the significant source in terms of both quality and quantity
RD 6	Sticky Rice	21 Nov	666	North and Northeast
Niaw Ubon 1	Sticky Rice	20 Nov	660	Northeast (specifically in the area which has water level in the paddy field not over 80 cm)
Niaw Ubon 2	Sticky Rice	15 Nov	463	Northeast (specifically in highland area)
Leuang Pratew 123	Rice	19 Dec	414	Central in lowland rice system
Nam Sa-gui 19	Rice	4 Nov	499	Northeast in lowland rice system
Phitsanulok 60-1	Rice	10 Dec	550	Upper part of Central in rainfed rice farming area which has water level in the paddy field not over 75 cm specifically the area where there is the spread of rice gall midge

Chumphae 60	Rice	13 Feb	467	Northeast in rainfed lowland area
Phitsanulok 1	Rice	25 Nov	579	Central and Lower part of North in rainfed rice farming area
RD 15	Rice	10 Nov	560	Northeast specifically in dry area
Khao Tah Haeng 17	Rice	20 Dec	473	Central in lowland rice system
RD 27	Rice	10 Dec	600	Central in lowland rice system
Pathumthani 60	Rice	25 Nov	517	Central in lowland rice system

3) Rice varieties recommended for floating rice farming area

Pin Gaew 56	Rice	20 Dec	362	Central in floating rice system
Leb Meu Nahng 111	Rice	19 Dec	328	Central in floating rice system
Hantra 60	Rice	25 Dec	425	Central in lowland area which has water level in the paddy field not over 100 cm
Plai Ngahm Prachinburi	Rice	25 Dec	380	Central and Lower part of North in lowland area which has water level in the paddy field over 100 cm
Prachinburi 1	Rice	25 Nov	450	Central, East and lower part of North in lowland area which has water level in the paddy field not over 100 cm
Prachinburi 2	Rice	18-25 Dec	846 (if planted in the paddy field with 25 cm of water level) 590 (if planted in the paddy field with 100 cm of water level)	Central and East in lowland area which has water level in the paddy field not over 100 cm

Appendix 3: Values of ecosystem services

(Source: Yoshida, 2001)

Unit: Billion US$

	Valuation for whole of Japan	Hilly and mountainous areas	Abstract of evaluation
Flood prevention	28.789	11.496	Water retention capacity of paddy fields and upland fields (paddy field: 5.2 billion m^3, upland fields: 0.8 billion m^3) is evaluated based on depreciation costs and annual maintenance costs of a dam controlling the water supply
Conservation of water resources	12.887	6.023	Water capability (638 m^3/S) contributing to the stabilization of water flow and the reuse of irrigation water in paddy fields by returning it to rivers is evaluated based on depreciation costs and annual maintenance costs of an irrigation dam. Also, the volume of groundwater supplied from paddy fields and upland fields (3.7 billion m^3) is evaluated by the difference in price between groundwater and tap water.
Soil erosion prevention	2.851	1.745	The estimated volume of eroded soil (53 million mt) prevented by cultivation of farmland is given monetary value, based on the construction costs of a dam to arrest sediments.
Landslide prevention	1.428	0.839	The estimated number of landslides (1,700 cases) prevented by cultivation of paddy fields is evaluated based on average losses incurred.
Organic waste disposal	0.064	0.026	The value of organic wastes applied to farmland (municipal waste: 60,000 mt, human waste: 860,000 kg, sewage sludge: 230,000 mt) is based on the final disposal costs.
Air purification	0.099	0.042	The estimated volume of exhaust fumes (SO^2:49,000 mt, NO^2: 69,000 mt) absorbed by paddy fields and upland fields is evaluated based on depreciation costs and annual maintenance costs of desulfuri-zation and denitrification equipment.
Climatic mitigation	0.105	0.02	Capability of paddy fields to reduce temperatures in summertime (1.3°C on average) is evaluated based on cost otherwise required for air conditioning.
Recreation and relaxation	22.565	10.128	Functions of recreation and relaxation provided by agriculture and rural areas are evaluated by travelling costs for tourists and homecoming people to rural areas.
Total	68.788	30.319	

Appendix 4: Use of aquatic organisms from rice fields

Indicative list of uses of various aquatic organisms from rice fields (Halwart, M. 2006)

The cultivation of most rice crops in irrigated, rainfed and deepwater systems offers a suitable environment for fish and other aquatic organisms. Wild and gathered foods, from the aquatic habitat, provide important diversity, nutrition and food security as food resources from ricefield environments supply essential nutrients that are not adequately found in the diet.

Taxon	Image	Scientific name	Uses
Fish		*Cyclocheilichthys* sp.	As food (consumed fresh, fermented into fish paste and fish pieces, dried salted fish, fish sauce)
Reptile		*Erpeton tentaculatum*	As medicine
Amphibian		*Bufo melanostictus*	As food and medicine (anthelmintic properties)
Crustacean		*Somanniathelphusa* sp.	As food, feed, bait
Mollusc		*Pila* sp.	As food, feed, bait; for trade on market
Plant		*Nelumbo nucifera*	As food (flowers, leaves, seeds, rhizomes) for trade on market, for decoration and as wrapper for food
Insect		*Lethocerus* sp.	As food and medicine