Land Use Transition and Possibility of Climate Change Adaptation by Rice Farmers around the Industrial Estate in Bangkok’s Urban Fringe

Shigehiro Yokota*, Yuhei Aihara**, Danai Thaitakoo***

Abstract
Rapid urbanization has taken place in Southeast Asian megacities located in the lower river delta basins, and a mixed urban-rural land use is being adopted in the urban fringes. Industrial land uses in particular are being mixed with farmlands, including paddy fields and orchards. Urban suburbs, 30-35 km east of central Bangkok, now face the risk of floods and droughts. Therefore, adaptive land and water management is urgently needed. This research focuses on paddy fields as spaces for water regulation and local water management activities against floods and droughts around Lat Krabang industrial estate.

The research consists of two parts: 1) spatial analysis using GIS to analyze the appropriate land use arrangement of wetlands that have high resilience to floods and droughts, and 2) hearing survey of rice farmers and other stakeholders on their awareness of future land development and collaborative water management scenarios. We digitized the land use change in the area that had paddy fields to the west of the industrial estate. In this region, adjustment ponds and abandoned areas increased as parts of the waterway disappeared. It is assumed that the farming type changed because of the fragmentation of the waterway and the increase in adjustment ponds. We also interviewed 39 rice farmers, the site managers of the water management company “GUSCO,” and the person in charge at the local government’s agricultural office. The awareness analysis concerning future scenarios indicated that most rice farmers recognize the importance of paddy field conservation, and many of them who were affected by floods and droughts tend to view the large-scale adjustment pond scenario as meaningless. Furthermore, there is a possibility of GUSCO playing the role of a coordinator for cooperative water management among stakeholders.

Based on the spatial analysis, it can be assumed that the current scenario of rice farming is affected by natural land use change and the inner structure of paddy fields. Analyses of the relationship between area ratios of paddy fields and adjustment ponds by current drainage types indicated that both ratios are low in the areas with nature drainage than in the areas with only pump drainage. Furthermore, it can be assumed that rice farmers find it easy to control water intake and drainage with small-scale paddy fields. The rice farmers who have been affected by floods are converged in areas with a higher ratio of adjustment ponds, which can be an adaptation measure against drought. It is suggested that a sufficient number of small-scale adjustment ponds connected to paddy fields can be an important protection measure against floods and droughts.

Keywords: urbanization, land use, rice farmers, climate change adaptation, water management

* Faculty of Environmental Studies, Tokyo City University
** IWATSUKA CONFECTIONERY CO.,LTD.
*** Department of Landscape Architecture, Chulalongkorn University
E-mail: yokotas@tcu.ac.jp

(c) 2020 City Planning Institute of Japan
http://dx.doi.org/10.14398/urpr.7.22
1. Background & Purpose

In Southeast Asia, rapid economic growth has led to the development of megacities, with urban sprawl leading to expansion of city areas (Klinmalai & Kanki, 2003; McGee, 2008). Many Southeast Asian megacities are located on the alluvial plains of the lower river basins, which make them prone to floods caused by climate change (Ishiwatari, 2016; The World Bank, 2017). Moreover, despite the rainy season, dry season often occurs. There are also differences in precipitation rates between the rainy seasons. Farmers are thus forced to farm under unstable weather conditions (Fig. 1).

In addition, mixed land use in urban and rural areas is a problem because of the fragmentation of water environment and the difficulties in water management for suburban farmlands. Therefore, we need to implement the concept of adaptive land use in which water environment is compatibly conserved along with urban sprawl (Hara et al., 2002).

Bangkok, Thailand’s capital, has the typical needs for adapting to changing water balance as any other Southeast Asian megacity. Bangkok Metropolitan Administration has built an arterial road called “King’s Dike” to prevent spreading of flood to central Bangkok, thus reducing flood risk. However, fragmentation of canals and wetlands has led to an increase in flood risk in the suburbs (Interrisk Asia, 2015). Farmlands in the suburbs can be expected to provide resilience against floods as they perform the high-level function of water storage and regulation of floodwater (Shinya et al., 2013). Paddy fields, the typical farmland in the flood plain, in particular perform the function of water storage and provide a habitat for wetland birds such as Asian Openbills (Hara et al., 2015).

Regarding the history of Thai agriculture, Rama IX conducted agricultural reforms from 1960 to 1990 and developed an agricultural reformation method called “New Theory.” New Theory involves the spread of the idea of recommended farmland use to get a stable income rather than using old agricultural methods. Under this method, the recommended individual farmland size is 2.4 ha, of which 30% area is reserved for a pond, 30% for paddy fields, 30% for useful trees or crops, and 10% for roads, banks/moats, or grass. It simulates measures against water shortage and excessive water supply to build a reservoir pond. Along with mixed farming, earning income during the off-season from the orchards on the dike and from fish ponds is recommended (Koganemaru, 2010). This vision of national-level reformation concerns farmers’ land use, which can help in effective utilization of the wetlands’ water balancing property in the mixed land uses of suburban areas. Amid continuous suburbanization, there is a need to focus on adaptive land use and water management to maintain the balance between wetland conservation and urban development. To this end, paddy field’s water storage service is of great importance.

Prior studies such as Hara et al. (2005) assessed land use change from agricultural land uses to urban land use by focusing on urban rural fringe, while Hara et al. (2014) assessed land use transition after serious floods in 2011, but did not discuss the future land use from the aspect of the utilization of paddy field’s environmental function. Suzuki et al. (2005) also assessed the relationship between paddy field and small adjustment pond by focusing on paddy field structure, but adaptability of farming against floods/droughts was not evaluated. Moreover, regarding the social aspects, rice farmers’ and other stakeholders’ consciousness of the adaptation measures against floods and droughts has not been evaluated yet.

Therefore, we aimed to clarify the spatial configuration of land use transition around paddy fields, together with the consciousness of rice farmers about the future land use in the region. Moreover, we
examined rice farmers’ and other stakeholders’ awareness and measures of future cooperative activities against regional floods and droughts.

In this research, we focused on paddy fields, rice farmers, and stakeholders in the area surrounding Lat Krabang industrial estate in suburban Bangkok. We particularly focused on the urbanization trends surrounding paddy fields, and rice farmers’ consciousness of adaptation measures against flood/drought, together with their understanding of water management. We examined the land use transition by spatial analysis to grasp the rice farming conditions and water environment around paddy fields, and evaluated the acceptability of water management in future land use scenarios by conducting a hearing survey of rice farmers and other stakeholders.

Fig. 1. Monthly precipitation in BANGNA agrometeorological station in Bangkok during 2012-2016 (Thai Meteorological Department)

2. Methods

2.1 Study area

The study area is located to the east of central Bangkok at a distance of 35 km. It covers three administrative districts: Min Buri, Nong Chok, and Lat Krabang which also include Lat Krabang industrial estate established in 1978 (Fig. 2).

Fig. 2. Study area around Lat Krabang industrial estate
The industrial estate intakes water from a surrounding canal and drains waste water to another surrounding canal, which is also the main water source for paddy fields, through wastewater treatment facility. Land use in the area is mixed with farmlands including paddy fields, orchards, unused land (mainly grassland), temple, and housing areas such as the Muban (a block of detached houses) and shop houses.

### 2.2 Land use transition and water use around paddy fields

#### 2.2.1 Data sources

To evaluate the spatial relationship between paddy fields and development type of surrounding land use, we analyzed the land use transition using land cover data of 1973 (before the establishment of industrial estate), 2002 (during the increase in urbanization), and 2015 (near to the present land use). In preparing the digital maps of our study area, we obtained the black-and-white aerial photographs taken in 1973 and color aerial photographs taken in 2002 from the Royal Thai Survey. These photos were geo-referenced at WGS1984-UTM47N. For the land use in 2015, we used Google Satellite Maps 2015 supported by ESRI ArcMap version 10.5.1.

#### 2.2.2 Creating land use maps from the aerial photos and satellite images

For the quantitative evaluation of land use transition, we created a land use polygon from aerial photos taken in 1973 and 2002 and satellite images taken in 2015 using ESRI ArcMap version 10.5.1. We classified the land use types as shown in Table 1, referring to previous research (Hara et al., 2005, 2014). We divided paddy fields into smaller plots to analyze the relationship between each plot and surrounding urbanized land uses. Paddy fields contained adjustment ponds, footpaths (only in 2002, 2015), footpath-waterways (only in 1973), dikes, roads, and wood areas. In the classification of adjustment pond and waterway in inner paddy field, we regarded the land not connected to paddy field as adjustment pond, and the land connected to paddy field as waterway. Paddy field and fish pond looked similar in the photos, but we were able to classify paddy field and fish pond as paddy field also had an adjustment pond nearby or inside it. We considered fish pond and adjustment pond to be the same.

In the classification of dikes and roads, we regarded linear land use along paddy fields without car

| Cultivation area                | Traditional cultivation area except paddy field |
|---------------------------------|-------------------------------------------------|
| Bare land                       | No vegetation or soil cover                      |
| Wood area                       | Tree cover with canopies                         |
| House                           | Single house or a group of single houses         |
| Artificial land                 | Apartment building for commercial use or small industrial building |
| Adjustment pond                 | Fish ponds or ponds in paddy field to pool water from the canal |
| Water way                       | Connects multiple paddy fields                   |
| Road                            | Road with car passage                            |
| Abandoned area                  | Abandoned paddy fields or other cultivation area, contains grassland and unused land |
| Industrial estate               | Lat Krabang industrial estate                   |
| Big road                        | Six-lane road                                    |
| Canal                           | Tributary stream of Chao Phraya River            |
| Paddy field                     | Large rectangular rice field                     |
| Diike                           | Road by tone in aerial photo, but not connected with road and surrounding paddy fields or adjustment ponds |
| Muban developing                | Open space before the construction of Muban      |
| Muban                           | Block of detached houses                         |
| Footpath-waterway               | Splits the paddy field, used as both footpath and waterway |
| Footpath                        | Walkway in paddy field (2002, 2015)              |
passage as a dike, and linear land use with connection to other roads or car passage as road. Footpath-waterway was present only in 1973, as a small linear part of paddy fields, and seemed to be used as both waterways and footpaths. Footpath was present in 2002 and 2015, also as a linear part of the paddy field, and seemed to be used only as a walkway.

2.2.3 Section analysis of land use transition around paddy fields

We sampled 39 paddy fields in the ground survey by referring to the aerial and satellite images, and divided paddy fields and surrounding land into sections (Fig. 3). Each section was extracted by using satellite images taken in 2015.

The model of the extracted section is shown in Figure 4. Traditional rice farmers’ houses and paddy fields are facing the canal to use it as water source and transport medium. Their paddy fields are surrounded by new roads and land for other uses. Therefore, the borders of sections are drawn along canals, roads, and borders of adjacent plots. The section consists of a plot with mixed land use by rice farmers, and contains paddy fields, farmlands, orchids, adjustment ponds, woods, dikes, and houses. Adjacent plots with other land uses on both sides of the plot are also included in the section.

Using the above definition, 29 sections of the sampled farmers' paddy fields were extracted from the research area. The total area of all the sections was 10.29 km², which covered 18.3% of the research area. The total area of paddy fields in the sections was 4.03 km², which covered 34.5% of the study area.

After extracting the sections, we calculated their areas and analyzed the land use transition. To observe change amount of each land use area per section area, we calculated area ratios of land uses in 29 sections, and analyzed the change amount during 1973-2002 (subtracting polygon area ratio per section in 1973 from that in 2002) and 2002-2015 (subtracting polygon area ratio per section in 2002 from that in 2015). Considering the inner structure of paddy fields, we calculated the polygon area ratio inside each paddy field.

![Fig. 3. Target section and farmers’ points in hearing survey](image_url)
2.3 Hearing Survey of rice farmers on their consciousness of adaptation measures against flood and drought

2.3.1 Hearing survey of rice farmers

To grasp the possibility of adaptive rice farming amid floods and droughts, and cooperative activity among rice farmers and other stakeholders, we examined the situation of present rice farmers, such as their awareness of the impact of floods/droughts and type of water intake and drainage system, and their willingness to adopt changing land use measures in future scenarios. We conducted a hearing survey of 39 sampled rice farmers during September 17-24, 2017. Hearing method involves face-to-face interactions in which farmers had to answer questions set in advance. We also asked the reasons behind their answers and summarized them. The 39 sampled rice farmers were either the owners or rental farmers of the paddy fields analyzed in the ground survey. The hearing survey content and farmers’ points are explained in Table 2 and Figure 3. According to the scenario questionnaire, four types of future scenarios were chosen (Table 3). We defined future land use change trend of each scenario, and asked the farmers to rate the meaningfulness of each scenario on a scale of 1 to 5 (5 being the most meaningful, and 1 being the most meaningless). The words “meaningful” and “meaningless” were introduced to express the strength of the impact of land use scenario and rice farmer’s agricultural business on the paddy field, with “most meaningful” expressing the strongest impact on rice farming. Scenario I (Wetland conservation) involves conserving the current status of paddy fields and abandoned land as much as possible. It has possibilities of protecting paddy fields or unused wetlands to maintain their regulation function as a buffer area against floods/droughts. Scenario II (Development compatibility) involves transforming abandoned land and bare land into urbanized land, with parallel construction of reservoir ponds. Scenario III (large-scale reservoir construction) involves construction of large-scale reservoirs to counter floods/droughts and limit the expansion of urban areas. Scenario IV (Urbanization, Development) involves accelerating
development in abandoned land and bare land, leading to increase in industrial land and housing land. Based on the responses of rice farmers, we analyzed the contents of farming tendency, current situation of floods/droughts, requirements of farming continuity, and the awareness of future scenarios.

Table 2. Rice farmers’ hearing survey content

| No. | Name                                           | detail                                                                 |
|-----|------------------------------------------------|----------------------------------------------------------------------|
| 1.  | About the current state of personal water use | Annual Harvest frequency, Seasonal water intake and drainage method, Prevention against floods and droughts, Concrete impacts of floods and droughts |
| 2.  | About the current situation of community in water management | Belonging to the communities concerning farming or environmental conservation, Communicating with others in advance about the prevention measures against floods/droughts |
| 3.  | Adaptation awareness to future scenarios      | Evaluation of four future scenarios, I : Wetland conservation, II : Development compatibility, III : Large-scale reservoir construction, IV : Urbanization, Development |

Table 3. Scenario details

| No. | Name                               | Detail                                                                 |
|-----|------------------------------------|------------------------------------------------------------------------|
| Scenario I  | Wetland conservation             | Conserving the current status of paddy fields and abandoned land as much as possible |
| Scenario II | Development compatibility        | Developing the urban areas (mainly housing or town housing) and reservoir ponds in parallel (clustered) |
| Scenario III | Large-scale reservoir construction | Constructing large-scale reservoirs in abandoned lands, limiting the expansion of urban areas |
| Scenario IV   | Urbanization, Development        | Accelerate urbanization while limiting the size of paddy fields |

2.3.2 Relationship between rice farmers’ adaptation measures and land utilization

We combined the spatial analysis data and hearing survey results to analyze the relationship between rice farmers’ current situation in terms of floods/droughts and the surrounding land use structure of paddy fields. We focused on the relationships between the type of drainage system and land use composition of the section (especially area ratio of paddy field or adjustment pond per section), and the impact of floods/droughts and paddy field structure.

We dealt with the data on the 29 sections, which contained the respondent farmers’ paddy fields and examined the relationship between the sections’ paddy field area ratio and adjustment pond, according to farmers’ consciousness about the impact of flood/drought.

2.4 Hearing Survey on the possibility of cooperative activities by the industrial estate and local government

2.4.1 Hearing survey at Lat Krabang industrial estate’s water management company “GUSCO”

We aimed to examine the situation of measures against floods/droughts and awareness of future cooperative activities among rice farmers and local community living near the industrial estate. We
Table 4. Content of hearing survey at GUSCO

| 1. Current intake and drainage environment | Ordinary communication with the local community about intake and drainage of industrial water  
Communication with local stakeholders about intake/drainage of industrial water  
The current local initiatives |
| 2. Cooperation with local communities concerning flood / drought | Awareness of the relationship with the local communities concerning flood and drought  
1) Before flood and drought  
2) During flood and drought  
3) After flood and drought |
| 3. Adaptation to climate change in this region | A significant impact of climate change on the industrial estate from a viewpoint of water resources  
Adapting to flood or drought jointly with the local communities through water intake and drainage  
About vacant lands and unused lands  
Requesting to the local government about water supply or adjustment measures |

Table 5. Content of hearing survey at BMA Lat Krabang district office and AEO Lat Krabang

| 1. About paddy field farmers | Information on the distribution of rice farmers  
Guidance on the diversion and the abandonment of paddy fields  
Information on the situation of abandoned land |
| 2. About canal water use | Information on farmer’s water use  
Regular advice to the farmers about the drainage in rainy season or the water intake in dry season  
Prevention measures for farmers in flood/drought |
| 3. About local community | Information about local community among farmers |

conducted hearing survey at a water management company “GUSCO (Global Utilities Services Co., Ltd.)” in Lat Krabang industrial estate through its site managers (Mr. Weerapong Wongtho, Mr. Tittwas Nawasith,) on May 29, 2017. The content of the hearing survey is presented in Table 4.

2.4.2 Hearing survey at BMA district office and AEO

We aimed to examine the support provided by the BMA (Bangkok Metropolitan Administration) district office and AEO (Agricultural Extension Office 2, Lat Krabang, in Ministry of Agriculture and Cooperatives, Thailand) to rice farmers and the situation of rice farmers’ water use. We conducted a hearing survey at the BMA Lat Krabang district office and Agricultural Extension Lat Krabang in September 2017 through the persons in charge of the support to farmers. The survey content is presented in Table 5.

3. Results
3.1 Land use transition around paddy fields between 1973 and 2015

3.1.1 Relationship between urban and agricultural land use

Area of land use categories composing the 39 sections in 2015 is detailed in Table 6. To observe the process of land use transition from the remaining paddy fields, we calculated the agricultural land use ratio (agricultural land use area / section area) and urban land use ratio (urban land use / section area) of each section by digitized Arc GIS polygon, and calculated the change from 1973 to 2002, and 2002 to 2015. In terms of urban land use, we focused on the total area of houses, artificial land, and Muban development. In terms of agricultural land use, we focused on paddy fields, woods, and abandoned areas (mainly grasslands) (Fig. 5).

By analyzing the relationship between the change in urban land use area ratio and paddy field area ratio, it was found that paddy field ratio markedly decreased with the increase in urban land use ratio from 1973 to 2002. This change gradually converged from 2002 to 2015.

Regarding the relationship between the change in urban land use area ratio and woods area ratio, woods area ratio showed little change with the increase in urban land use ratio from 1973 to 2002 and 2002 to 2015. There was a slight decrease in woods area ratio from 2002 to 2015.

Regarding the difference between the change in urban land use area ratio and abandoned area ratio, abandoned area ratio increased with the increase in urban land use ratio from 1973 to 2002. From 2002 to 2015, although there was no change in urban land use area, some sections’ change amount of abandoned area ratio decreased from 1973 to 2002.

3.1.2 Land use transition of water intake/drainage system

To observe the change in paddy fields and water intake/drainage system land use, we calculated the water intake/drainage system land use ratio (water intake and drainage system land use area / paddy field area) by ArcGIS polygon, and calculated the change from 1973 to 2002, and 2002 to 2015. In terms of water intake and drainage system land use, we focused on adjustment pond, dike, waterway, footpath, and footpath-waterway. For this analysis, footpath and footpath-waterway are treated as the same land use.

Table. 6 Area of land use categories of sections in 2015 (unit: m²)
Regarding the relationship between change in paddy field area ratio and adjustment pond area ratio, adjustment ponds had increased with the decreasing trend of paddy fields during 1973-2002 as compared to 2002-2015 (Fig. 6).

Regarding the relationship among change in area ratio of waterway, dike, and footpath-waterway, the footpath-waterway ratio decreased with an increase in dike and waterway area, while it increased with a decrease in dike area ratio. The number of sections that showed an increasing ratio of waterway was higher than those that showed a decreasing ratio (Fig. 7). Comparison between the change in road area ratio and footpath-waterway and footpath area ratios showed that road area ratio increased with the decrease in footpath-waterway and footpath area ratios from 1973 to 2002, and the decreasing tendency converged from 2002 to 2015 (Fig. 8, left). Furthermore, to observe the conversion of footpaths to dikes, we calculated footpath area ratio (footpath area / paddy field area) and dike area ratio (dike area / paddy field area). Regarding the relationship between the change in footpath area ratio and dike area ratio, footpath area ratio decreased with an increase in dike area ratio mainly during 1973-2002, while dike area ratio constantly increased during 2002-2015 (Fig. 8, right).
Fig. 6. Relationship between the change in paddy field area ratio and adjustment pond area ratio per section area from 1973 to 2015.

Fig. 7. Change in the area ratio of waterway, dike, and footpath-waterway in the paddy field area of section from 1973 to 2015.
3.2 Awareness analysis of rice farmers

3.2.1 Rice farmers’ current water use

We conducted a hearing survey of 39 rice farmers in the area surrounding Lat Krabang industrial estate (Fig. 3, farmers’ points). We analyzed the questionnaire results about the current state of personal water use and farming (Figures 9-12), and cooperation with local communities concerning floods/droughts (Figs. 13-14).

Most rice farmers were tenant farmers since their grandparents’ generation. Among these farmers, 20 were using only pump drainage system, while 16 farmers were using pump drainage as well as gravity drainage systems (Fig. 10).

The farmers’ data showed differences in the harvest season. All farmers were using multiple cropping systems, with farming divided in two types. In the first, farmers did not cultivate rice in the rainy season because of water overflow, while in the other, no cultivation was done during the dry season because of water shortage (Fig. 11).

Regarding impact of flood and drought, flood impact seemed more severe with 29 out of 39 farmers reporting getting affected, while in case of droughts, 19 farmers were affected and 19 were not. However, most farmers answered that the impact of floods/droughts did not affect their decision to continue farming (Fig. 12). The reasons included having no skills to perform other jobs or inability to farm during severe seasons.

Many rice farmers belonged to local community groups (Fig. 13), with 19 belonging to rice farmer groups, 11 to the Bank for Agriculture and Agricultural Cooperatives (BAAC), and 3 to the Canal Conservation Network (CCN). Many rice farmers did not communicate with others in advance about floods and droughts, while some communicated about the ordinary water use especially during dry season (Fig. 14). They dealt with floods and droughts by catching up with daily news, and communicated with others regarding compensation after floods and droughts as key topic (Table 7).
Fig. 9. Farming situation of rice farmers

- Area of paddy field (1 rai = 1,600 m²)
  - Over 30 rai: 21%, 15 - 30 rai: 9%, Under 15 rai: 4%, Unknown: 5%

- Land ownership
  - Land owner: 8%, Land owner + Rental farmer: 3%, Rental farmer: 28%

- Harvesting frequency
  - Once a year: 33%, Twice a year: 2%, More than 3 times a year: 4%

- Water source for paddy field
  - Canal: 37%, Fish pond: 4%

Fig. 10. Intake/drainage method and the chance to change intake method in rainy or dry season

- Intake method
  - Pump only: 30%, Pump + gravity: 6%, Pump + irrigation: 2%, Pump + gravity + irrigation: 2%

- Drainage method
  - Pump only: 20%, Pump + gravity: 16%, Gravity: 3%

- Change of intake method in rainy season
  - Change: 11%, Do not change: 28%

- Change of intake method in dry season
  - Change: 33%, Do not change: 6%

Fig. 11. Rice farmers’ harvest season

- Number of respondents
  - April: 12, May: 8, June: 4, July: 2, August: 1, September: 1, October: 8, November: 10, December: 4, January: 7, February: 2, March: 1, No answer: 1
Fig. 12. Impact of Flood and Drought on rice farming (left), Flood and Drought affecting continuation of farming (right)

Fig. 13. Number of rice farmers in a community

Fig. 14. Communication with others on ordinary water use and floods or droughts
3.2.2 Awareness of future scenario

Regarding adaptation awareness in future scenarios by rice farmers, significance of land use for rainy season and dry season was almost same (Fig. 15). About Scenario I, most rice farmers thought of it as meaningful or slightly meaningful. About Scenarios II and III, many rice farmers thought of them as meaningless, with few considering them as meaningful or slightly meaningful. There was a division of opinion on the evaluation of Scenario IV.

Regarding scenario evaluation according to the impact of floods and droughts (Fig. 16), almost half of the rice farmers considered Scenario I (Wetland conservation) as meaningful regardless the impact of floods and droughts. About Scenario II (Development compatibility), almost half of the rice farmers thought of it as meaningful or slightly meaningful regardless the impact of floods; more than half of the those affected by droughts considered it meaningful or slightly meaningful, while more than half of those who were not affected by droughts considered this scenario meaningless. About Scenario III (Large-scale reservoir construction), more than half of the farmers considered it as meaningless or slightly meaningless regardless the impact of floods and droughts. Those who were impacted by flood chose the answer “meaningless” the most. About Scenario IV (Urbanization, Development), more than half of the rice farmers who were not impacted by floods or droughts considered it meaningful or slightly meaningful, while more than half the farmers who were impacted considered it meaningless or slightly meaningless.

We also asked the rice farmers about their reasons of choosing a scenario. About Scenario I (Wetland conservation), there were comments against water use and water quality. About rainy season, some rice farmers who suffered because of wastewater were worried about the increase in water quality degradation by floods every year during the rainy season, while those who did not suffer thought wetland conservation contributes in supplying sufficient water. About dry season, some rice farmers who suffered from water shortage expected to have water sources from wetlands for farming, while others who did not suffer thought wetlands cause flow of rotten water during the dry season. About Scenario II (Development compatibility), some rice farmers expected that wetland mitigation of development contributes in providing good quality water and conserving ecosystem by creating small adjustment ponds, while others thought it was meaningless because these ponds do not have enough function in rainy season as they have difficulty preventing flood. About Scenario III (Large-scale reservoir construction), most rice farmers who considered it meaningful thought that the reservoir and retention area can reduce floods, while most who considered it meaningless thought it does not
Fig. 15. Evaluation of scenarios by rice farmers

Fig. 16. Scenario evaluation according to the impact of floods (top) and droughts (bottom)
have any affect in rainy season. The comments for Scenario III on dry season are the same as those on rainy season, which expected water control. About Scenario IV (Urbanization, Development), most rice farmers thought that wastewater will increase from housing and industry and there will be damage from floods during the rainy season. They also thought that water quality degradation would be caused by water shortage in dry season.

3.2.3 Relationship between land use and rice farmers’ awareness

Regarding the relationship between drainage type and farmland use (paddy field and adjustment pond), rice farmers who used natural drainage system had about 40% paddy field area per section area. Rice farmers who used pump drainage had higher ratio of adjustment pond area (Fig. 17).

Regarding the relationship between flood impact and farm land use, rice farmers who were not affected by floods had lower ratio of adjustment pond area regardless the paddy field area per section. On the contrary, the rice farmers who were not affected by droughts had higher ratio of adjustment pond area and had wider range of paddy field area ratio (Fig. 18).

Fig. 17. Relationship between drainage type and farmland use

Fig. 18. Relationship between flood impact and farmland use (left), drought impact and farmland use (right)

3.3 Current relationship among stakeholders

3.3.1 Current relationship between “GUSCO” and rice farmers, and other organizations
The Lat Krabang industrial estate has a water plant for drought emergencies. Local residents have requested the GUSCO to adjust the water quantity during rainy season, but overflow often occurs. GUSCO wants to adjust water quantity for district office, but it is difficult in the current situation. Some water gates are controlled by the Department of Drainage and Sewerage (DDS) of BMA (the water gates were built mainly for flood protection). The water gate will be open to let the water flow in to flush polluted water out of the area, so that GUSCO needed to communicate with BMA Lat Krabang district office to manage water gates for managing water flow. Some water gates are controlled by RID (Royal Irrigation Department in Ministry of Agriculture and Cooperatives, Thailand), and those water gates were built mainly for irrigation. In some cases, GUSCO might need to get RID involved to get the water flow from water gates controlled by RID, so GUSCO needed to communicate with RID district office to manage water gates for managing water flow.

GUSCO communicates with CCN and CI (Canal Improvements), which is organized by local residents, including farmers. GUSCO and CCN discuss problems such as local floods and droughts twice a year, but do not take actions. GUSCO considers it important to discuss water management with local community. Water shortage is a serious problem for GUSCO and local farmers. GUSCO cannot provide support to deal with water shortage during droughts because it cannot take care of each local farmer’s water shortage issues. There is a possibility of GUSCO playing the role of a coordinator between local farmers and government, however, there is a limit of GUSCO taking an initiative in cooperation activities. It can also provide information and knowledge of risk management against floods and droughts, by utilizing the monitored climate data and canal data.

3.3.2 Current relationship among BMA district office, AEO and rice farmers

BMA Lat Krabang district office has general information about rice farmers. Majority (about 70%) of the farmers in the area are residents who rent their farms. In the management of water for farming, BMA Lat Krabang district office provides advice to farmers about drainage during the rainy season and water intake in the dry season, collaborating with AEO (Agricultural Extension office), which is responsible for irrigation, promotion of farming and development of farmers and cooperative systems, including agricultural manufacturing and products. They are engaged in 1. adjustment of the timing in terms of water inundation/availability, 2. advising rice farming schedule according to water seasonality, 3. sharing information on rice farms twice a year among districts, 4. registering farming practices and types in May and public hearings, and 5. arranging harvesting schedule. BMA Lat Krabang district office has information about the rice farming network and leaders, and collaborates with CCN in canal management activities such as removal of weeds for the recovery of water flow.

4. Discussion

Spatial analysis results suggest that paddy field areas are still changing due to other land use, as is evident from the comparison of the relationship between the change in paddy field area ratio and urban land use ratio from 1972 to 2015. Furthermore, ratio of unused area where cultivation had been abandoned tended to increase with an increase in urban land use ratio from 1973 to 2002, while it increased or decreased with an increase in urban land use ratio from 2002 to 2015. It can be assumed that abandoned area has the potential of an open space for adjusting the flood water or for storing
water in case of droughts. There was a change in water areas in and around paddy fields, such as the
decrease in footpath-waterway area ratio and increase in waterway and dike area ratios. This increase
in waterway and dike areas seems to be because of the filling of footpath and division of water area
and constructing artificial road around paddy field. From 1973 to 2015, there was a remarkable change
in terms of disappearance of footpath-waterway, decrease of waterway, and integration of paddy fields
because of the appearance of adjustment ponds. It can be assumed that the farming type in paddy fields
changed because of the fragmentation of waterway and an increase in adjustment ponds inside the
plots, and the current rice farming practices are affected by natural land use change or inner structure
of paddy fields.

There was no significant variation in the intake form, but there was variation in the type of drainage.
Almost all farmers used the pump for intake or drainage, but if the farmland was at a sufficient height,
they used natural drainage system. In addition, there are significant variations in the harvest season
according to the impact of floods and droughts, and it was found that rice farmers’ land could be
adapted against floods and droughts.

Regarding future scenarios, Scenarios I and IV were found to be important for rice farmers. It can be
assumed that rice farmers are concerned about water intake in Scenario I and are wastewater from
industrial estate or urban land use in Scenario IV. About Scenario II, many rice farmers answered that
it is meaningless in the rainy and dry seasons, but some think it is meaningful as it helps sustain water
intake. Regarding Scenario III, many rice farmers think it is meaningless, but some consider it
meaningful in terms of having adjustment space. This result is the same in the rainy and dry seasons.
It can be assumed that adjustment spaces such as adjustment ponds as surrounding land use are useful
for rice farmers to sustain water quality or get a water resource.

It was also clarified that GUSCO and CCN consult each other regarding these matters, but GUSCO
cannot take initiative in implementing any activity and can only provide support. In addition, GUSCO
can manage water intake from the canal against floods, but it cannot develop countermeasures against
droughts. It needs to consider measures regarding intake quantity during the dry season.

Analyzing the relationship between paddy field and adjustment pond area ratios concerning current
drainage types, it was found that natural drainage could be done on a smaller scale than pump drainage
on farmlands. Regarding the relationship between paddy fields, adjustment pond area ratio per section
area, and the possibility of being affected by floods and droughts, it was found that small-scale
farmlands tend not to be affected by floods. It can be assumed that rice farmers find it easy to control
water intake and drainage on small-scale farmlands. These results suggest that small-scale farmlands
and sufficient adjustment ponds are effective protective measures against floods and droughts.

From the spatial analysis and hearing survey results, it was thought that social agreement for the
future land uses by integrating appropriate land use pattern and cooperative water management
framework which utilize regulation functions of wetland in and around paddy fields is important. In
the arrangement of the mixed land uses in the future suburbanization, it was thought to be important
to distribute the small-scale reservoirs or adjustment ponds networked with the conserved farmland
by canals and waterways. At the same time, residential development connected with the water network
will be important to utilize surface water and maintain good water condition by social awareness. In
such a land mosaic which realizes water adjustment and good water circulation, the utilization of
wetlands in unused grassland, together with the conservation of large-scale paddy fields, is also
important, and the collaborative development and management of the local water flow should be
discussed by the stakeholders. In addition to the environment management activities such as CCN, the
cooperative organization by various stakeholders and the opportunities to share the monitored
information on water environment and make an arrangement of the intake/drainage needs for collaborative water use and disaster risk reduction will be important.

We would like to take the lead in research from the perspective of floods and droughts to examine the arrangement in surrounding areas and a suitable paddy field structure in the suburb of Bangkok. In the future, we would like to consider better ways of co-establishment of wetland conservation and urbanization with the models of concrete landscape design, and would also like to propose the concrete supporting method of social communication for collaboration among stakeholders in local water management.

Acknowledgements
This research was supported by the Obayashi Foundation. We wish to express our deep appreciation to the students of Dr. Thaitakoo’s laboratory in Chulalongkorn University for their help in our field survey. We are grateful to GUSCO, BMA Lat Krabang district office, Agricultural Extension Office 2 (Lat Krabang), and all the farmers who kindly cooperated with us on our survey.

References
1) Hara, Y., Haruyama, S., Okubo, S., Takeuchi, K. 2002. Flood hazard response to the urbanized bank up areas of Laguna Lacustrine Plain, Metro-Manila. *Journal of Rural Planning Association*. 21(21), 19-21. (in Japanese)
2) Hara, Y., Takeuchi, K., Okubo, S. 2005. Urbanization linked with past agricultural landuse patterns in the urban fringe of a deltaic Asian mega-city: A case study in Bangkok. *Landscape and Urban Planning*. 73, 16-28.
3) Hara, Y., Yukimatsu, H., Thaitakoo, D., Tsuchiya, K. 2014. Agricultural landscape changes and its resilience in response to the 2011 serious floods in the urban fringe of Bangkok. *Rural Planning Association*. 33, 191-196. (in Japanese)
4) Hara, Y., Yamaji, K., Yokota, S., Thaitakoo, D., Sampei, Y. 2015. Dynamic wetland mosaic environments and Asian openbill habitat creation in peri-urban Bangkok. *Urban Ecosystems*. 21, 305-322.
5) Suzuki, K., Yamamoto, Y., Ando, M., Ogura, C. 2005. Evaluation of land and water resources in rainfed agricultural area using high resolution satellite data and GIS. *Journal of the Japanese Agricultural Systems Society*. 21 (3), 209-216.
6) Koganemaru, U. (ed). 2010. Thailand agriculture overview. Tokyo University of Agriculture, Tokyo, pp. 17-64. (in Japanese)
7) McGee, T. G. 2008. Managing the rural-urban transformation in East Asia in the 21st century. *Sustainability Science*. 3, 155-167.
8) Klinmalai, S., Kanki, K. 2013. Urban sprawl classification and composition analysis of land use including gated housing development in Bangkok Metropolitan Region, Thailand. *Journal of Architecture and Building Science* (Architectural Institute of Japan). 78(694), 2537-2546.
9) Ishiwatari, M. 2016. What are crucial issues in promoting an integrated approach for flood risk management in urban areas? *Japan Social Innovation Journal*. 6(1), 15-26.
10) Shinya, M., Tsuchiya, K., Hara, Y., Thaitakoo, D. 2013. Effects of urban development with landform transformation on flooding patterns in peri-urban Bangkok: Case of flood in 2011. *Journal of the City Planning Institute of Japan*. 48(3), 783-788. (in Japanese)
11) The World Bank. 2017. Climate Change Knowledge Portal.
https://climateknowledgeportal.worldbank.org/
12) Thai Meteorological Department: https://www.tmd.go.th/index.php
13) Interrisk Asia. 2015. King’s Dike and Chaophraya Dike in 2015.
    https://www.irric.co.jp/pdf/risk_info/thailand/2015_03.pdf (in Japanese)