Hydrologic image interpretation on small-scale on farm pond using high resolution satellite imagery

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Abstract

This paper describes the use of satellite image interpretation for analysis of small-scale on-farm ponds in northeastern Thailand based on field knowledge of hydrology and water use. Image interpretation on high-resolution QuickBird satellite imagery revealed that 1) the type of pond can be categorized visually from the viewpoint of its location, 2) the catchment location in relation to the pond can be estimated from the intake point of water and the layout of the pond. Through a series of image interpretations, the effectiveness of high-resolution satellite imagery for field sciences and investigations was confirmed.

Keywords: Field sciences, Image interpretation, Northeastern Thailand, QuickBird

1. Introduction

In field science, which focuses on the survey of actual sites, a technique of juxtaposing field study observations with interpretations of aerial photography or high-resolution satellite imagery is effective in the investigation of area-specific phenomena. For example, in a study of river engineering, aerial photographs of the area around the channel taken immediately after flooding provided invaluable information when combined with the site survey and hydraulic model tests (Miwa *et al*., 2003).

High-resolution imagery produced typically by IKONOS or QuickBird satellites provide images that are as detailed as aerial photographs, with a resolution of up to 1 m. Since these satellite images became available, some researchers have been testing them for use in surveys of relatively small areas in so-called site-based field studies (Suzuki *et al*., 2005a).

This paper describes an example of image interpretation regarding the hydrological location of small-scale ponds using field knowledge and high-resolution satellite imagery.

2. Overview of the study area and data used

For this study, we selected the village of NS in Ban Haet District, Khon Kaen Province, in northeastern Thailand. The village is located about 30 km south of the city center of Khon Kaen. The area is characterized by a gently undulating terrain. Paddy fields dominate the lower site, the valley, while the upper site features sugar cane and cassava farms.

The soil is sandy with poor water retention capacity and nutrient content, and is susceptible to erosion. Heavy rain often causes soil erosion in the upper site, where the lands are practically bare. The wet seasons and dry seasons are distinct in northeastern Thailand. Precipitation is minimal in the dry season. In the wet season, the precipitation is variable because the timing of seasonal onset and the amount of rainfall are unstable. The rain generally comes in the form of localized squalls, contributing to the uneven temporal and spatial distribution of water resources. As a result, agricultural productivity has remained low and unstable.

Under such circumstances, there have been many small-scale water resources developments. Small ponds adjacent to cultivated fields, such as paddy fields and farmlands, and irrigation weirs built in small rivers are typical examples of such measures. The study site, the village of NS, has already had more than 260 ponds developed in the area, and is known to have more ponds than other areas (Suzuki *et al*., 2005b).

This study used panchromatic images (60 cm/pixel) and multispectral images (2.4 m/pixel) taken by QuickBird in the dry seasons of April 2002 and January 2004 for visual interpretation. In addition, we conducted field surveys in the subject area over the period from 2002 to 2005 to facilitate the observation of precipitation and water levels.

3. Examples of interpretation and application

3.1 Identification of types of ponds

Farmers own small-scale ponds adjacent to their farms, and take water primarily by pump for a variety of uses, including rice planting and drought relief, as well as for fish farming and vegetable growing. The ponds in the study area are roughly divided into 2 categories according to their location and construction methods.

The most common ponds in the lower site are made of earth bunds built in the lowest part in the valley bottom (Photo 1). The bunds run for lengths of some 60 to 80 m. Water levels available for storage are less than 1.5 m, although some ponds have their upstream side dug down somewhat deeper. Since there is little precipitation during the 6-month dry season, the water level keeps falling during this time due to an evaporation rate of about 5 mm/day. These ponds usually remain wet even without stored water because they are situated in the valley. However, their water budget suggests that water may not be available year-round because of their inherently shallow storage depth.

Contrastingly, the ponds in the upper site are predominantly dug into the ground by heavy machinery. One side of the pond runs about 20 to 30 m in length. The total height of the surrounding embankment and the depth of the dug-out pond provide the storage depth, which can be as high as 3 m (Photo 2). Many of these ponds have water available for use year-round because sinking them into the ground ensures a sufficient storage depth. Some of these ponds are replenished by shallow subsurface water.

On the images, the bunds of the ponds that dominate the lower site are visually identifiable. The images taken in the dry season in particular often present the ponds in an irregular shape that reflect falling water levels (Fig. 1). On the other hand, the in-ground ponds in the upper site retain their rectangular shape, and do not change even when their water level falls. The embankments surrounding these ponds are also recognizable in the images (Fig. 2). These differences presented by high-resolution satellite imagery provide the possibility of identifying the type of pond from the images. For convenience, this study refers to these respective types of ponds as the “lower ponds” and the “upper ponds”.

Many of these ponds are of a rectangular shape, with the short sides normally running parallel to the direction of the grade. The paddy fields are also rectangular and laid out in a similar orientation. This layout reduces the difference in water levels in ponds (and in paddy fields) when the water is stored on a sloped terrain. Nevertheless, even this layout may cause unevenness, especially in paddy fields, if the land is not leveled sufficiently. Accordingly, the layout of ponds and paddy fields (the orientation of the short sides) provides clues which make it possible to estimate the direction of the surface grade at the site.

Photo 1 Typical pond in the lower site

Photo 2 Typical pond in the upper site

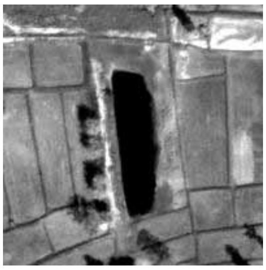


Fig. 1 Typical pond in the lower site
(QuickBird, Panchromatic, 0.6 m/pixel)

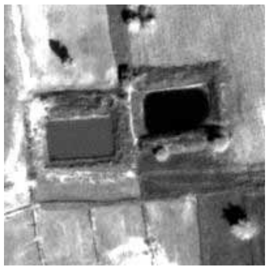


Fig. 2 Typical pond in the upper site
(QuickBird, Panchromatic, 0.6 m/pixel)

3.2 Identification of intake points in the upper ponds

The water level may vary among a number of ponds present within a small watershed even with the same usage of water. What factors regulate the difference in the water levels of the upper ponds? Figure 3 illustrates the concept of the water budget of a pond. Because there is little difference between the ponds in terms of their surface area, factors such as precipitation and evaporation are virtually the same. On the other hand, factors such as surface flow, lateral inflow (and outflow), and seepage loss of the ponds may vary depending on their location. The lateral inflow (and outflow) and seepage loss are relatively small. Consequently, the inflow of surface water from the catchment area regulates the water budget of the ponds, and is the biggest factor causing locational differences.

Substantial rainfall in the wet season causes a rapid rise in the water level (Fig. 4). Especially, a daily rainfall of more than 100 mm raised the water level by more than 55 cm in a day in mid-September. Subtracting the 10 cm of direct rainfall on the pond surface, the water level rose by 45 cm. Assuming that 40 cm of this rise was due to surface inflow from the catchment area, and that the runoff ratio was 0.4, a calculation-based water budget estimates the size of the catchment area to be 10 times as large as the surface area of the pond.

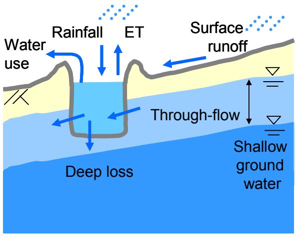


Fig. 3 Concept of water budget of upper ponds

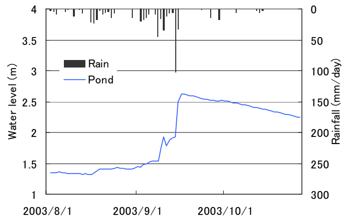


Fig. 4 Observed changes in water level of an upper pond

If the inflow of water depends on the size of the catchment area, farmers will be motivated to secure the catchment area. Many of the upper ponds are equipped with an intake point or a small channel to secure an inflow of water from their catchment area. The passage of water, however, makes the ground around the intake point prone to erosion. If the volume of water passing is too high, there is a risk that the embankment near the intake point may collapse. Furthermore, if farmlands or bare lands occupy a large portion of the catchment area, and these lands are adjacent to a pond directly, sedimentation from the inflow of sediment-laden surface water becomes a problem.

An examination of images identified some ponds with recognizable sedimentation indicating the location of their intake points. Figure 5 is a satellite image that provides a relatively clear view of the area near the intake point. The area marked by the dotted line indicates the extent of the sedimentation, presented as a triangle with its apex at the intake point in the upper right corner. Photo 3 is a photograph of the intake point of this pond and the actual condition of the sedimentation, confirming how well the satellite image corroborated them.

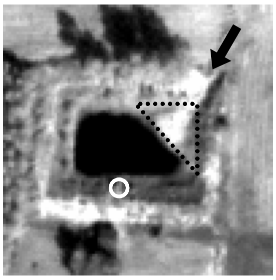
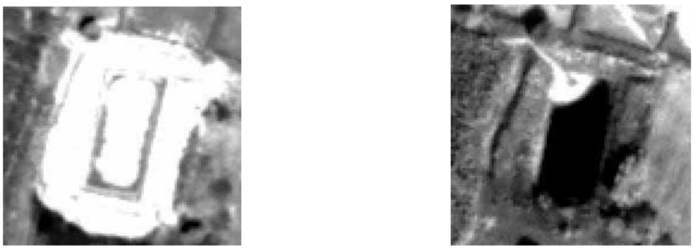


Fig. 5 Sedimentation around intake point of water (QuickBird, Panchromatic, Jan. 2004, Arrow: intake point, Dotted line: sedimentation, Photograph taken from position marked ○)

Photo 3 Sedimentation around intake point of water (Photograph taken from position marked ○ in Fig. 5 in July 2005; Arrow: intake point, Dotted line: sedimentation)

A comparison of images taken at 2 different times also confirms the process of sedimentation over time. The white area in Fig. 6a is a newly constructed pond. The embankment and the periphery of the new pond are presented as a bright white area in contrast to the surroundings as it is bare land covered by dry soil. Another image of the same pond taken 2 years later (Fig. 6b), however, shows a clear sign of sedimentation due to the inflow of sediment.



(a) 2002 (b) 2004

Fig. 6 Process of sedimentation in a pond (QuickBird, Panchromatic, 0.6 m/pixel)

Figure 7a shows an upper pond in a rare dried-up condition, which provides us an opportunity to make close observation of the condition of its bottom. Examining the bottom surface of the pond indicates that its intake point is located at the lower right corner. The sediment-laden water flowed into the pond from this point, but has since dried, appearing in white in the image. The 2004 image of the same pond (Fig. 7b) shows a higher water level than is shown in the 2002 image (Fig. 7a). The shape of the water surface clearly confirms the area of sedimentation in the lower right corner of the pond. The intake point itself is not very clear in Fig. 7b. If the water level were slightly higher, the sedimentation would have been hidden beneath the water surface, making it difficult to identify the intake point. In other words, the presence of sedimentation provides convincing evidence of the location of the intake point. Accordingly, the sedimentation on the bottom of a pond exposed by low water level supports the identification of the location of the intake point.

(a) 2002 (b) 2004

Fig. 7 Observed sedimentation at low water levels (QuickBird, Panchromatic, 0.6 m/pixel)

4. Conclusion

This study examined hydrological information that can be extracted from visual interpretation of high-resolution satellite images of small-scale ponds in northeastern Thailand. It was found that (1) it was possible to classify the ponds according to their location or their type (ponds in the upper site, and in the lower site); (2) for some of the ponds, it was possible to estimate the location of the main catchment from the layout of the ponds and the location of the intake point. These interpretation techniques are believed to provide valid information when conducting an investigation of suitable locations for irrigation ponds.

With respect to the collection of hydrological information using remote sensing methods, the role of visual interpretation is very important from the point of view of region-specific information (Kondo, 2003). To this end, a researcher must possess sufficient understanding of local conditions and expert knowledge of the visual interpretation of satellite imagery. A future task is to accumulate examples to further develop and refine the analytical techniques that utilize field knowledge.

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