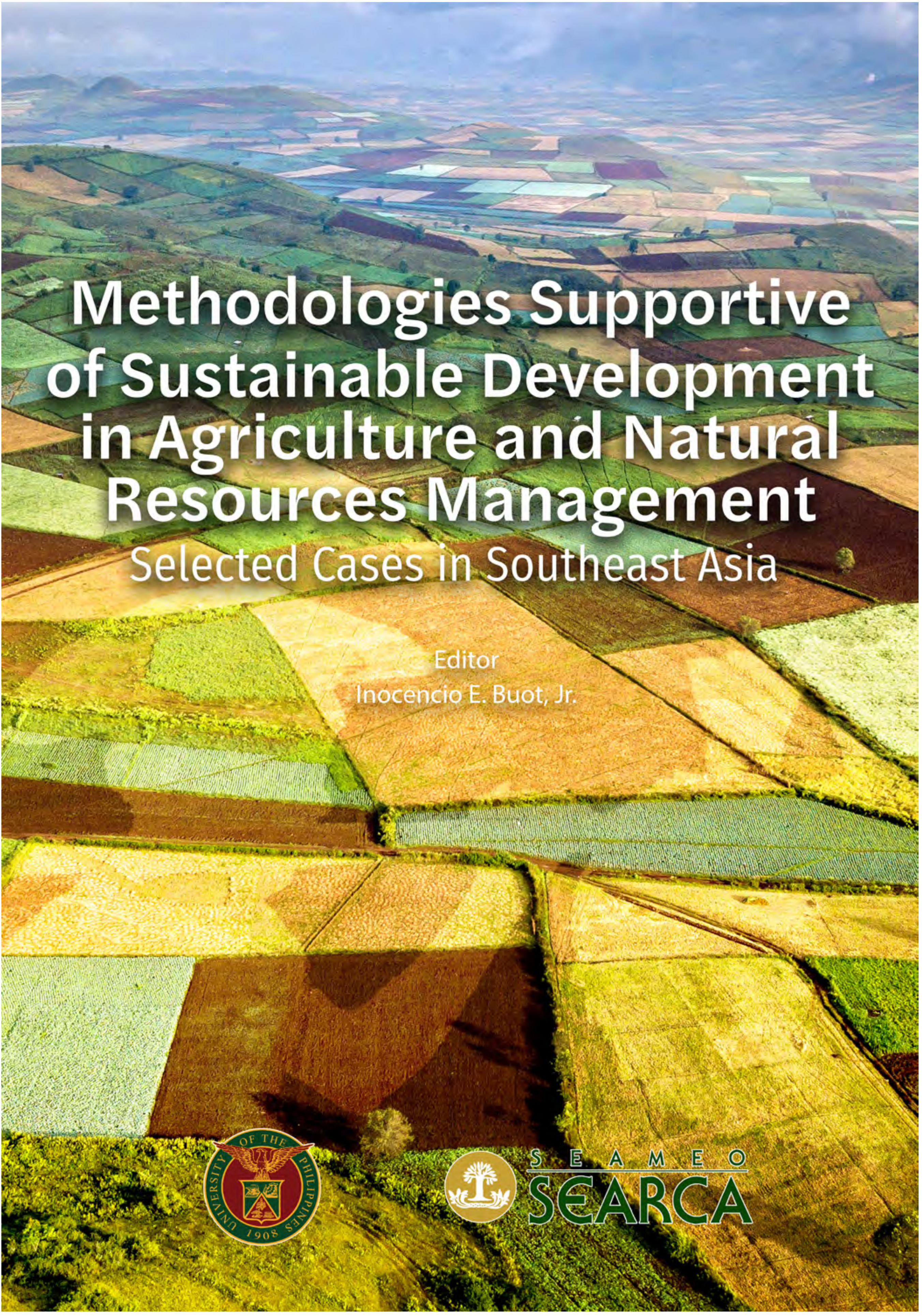

Methodologies Supportive of Sustainable Development in Agriculture and Natural Resources Management

Selected Cases in Southeast Asia

Editor

Inocencio E. Buot, Jr.

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Foreword

Methodologies Supportive of Sustainable Development in Agriculture and Natural Resources Management: Selected Cases in Southeast Asia is the maiden book writing project of the Regional SEARCA Alumni Association (RSAA), authored by selected SEARCA alumni from the Philippines, Thailand, Vietnam, Indonesia, and Lao PDR. The RSAA (formerly known as the Regional SEARCA Fellows Association or RSFA) is SEARCA's valuable network of alumni that works toward sustainable agricultural and rural development through conferences, seminars, and collaborative research projects that bring together experts in the region.

This publication presents a compendium of relevant methodologies used by the authors for their research in select Southeast Asian countries to tackle the challenges that impinge on sustainable development. It illustrates the practical application of various research methodologies and evidence-based decision making to enhance the rigor of studies in the field of agriculture and natural resources management. As the region confronts the dynamic nature and magnitude of competition for dwindling resources caused by climate change and biodiversity loss, the publication pushes for research methodologies that are supportive of sustainable development and grounded on local realities.

The book is divided in two categories: (a) "Methodologies Supportive of Sustainable Development in Agriculture Management" and (b) "Methodologies Supportive of Sustainable Development in Natural Resources Management." Impetus to this publication has been given by the continuous support of SEARCA to its alumni and in harnessing the capacity of individuals and institutions as effective catalysts of agricultural and rural development in the region.

The book is a timely publication of RSAA as SEARCA enters its eleventh Five Year Plan that banners **Accelerating Transformation Through Agricultural Innovation or ATTAIN.** The authors' contribution to realizing sustainable development through research that impacts people's lives aligns well with the center's priority area on sustainable farming systems and natural resources management.

GLENN B. GREGORIO
Director, SEARCA

Preface

This book, *Methodologies Supportive of Sustainable Development in Agriculture and Natural Resources Management: Selected Cases in Southeast Asia,* presents customized methodologies tested by Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA) alumni as well as thesis and dissertation grantees in their independent research works. It highlights and celebrates some commendable research and development (R&D) breakthroughs of SEARCA. Thereby, the book is a good reference volume for undergraduate and graduate students and essential for Southeast Asian university researchers and scientists, local government units, and nongovernment organizations concerned with available materials on theory, practice, and R&D for evidence-based decision making. It showcases the impact of SEARCA's graduate scholarship program to Southeast Asia.

I am thankful foremost to SEARCA for the funding of the book through the kind endorsement of Dr. Josefina T. Dizon, Professor of the College of Public Affairs and Development, University of the Philippines Los Baños (UPLB), who is also the President of the Regional SEARCA Alumni Association. The constant encouragement of Dr. Maria Cristeta N. Cuaresma, Head of the SEARCA Education and Collective Learning Department, is also gratefully acknowledged. SEARCA Program Specialist Ms. Zacyl R. Jalotjot was guiding me all the way from accounting to reporting.

I thank all the authors for their perseverance, the technical and language reviewers for their expertise and diplomatic criticism. I commend the SEARCA staff who collated the documents, including the book layout, for the patience. Finally, I thank the Plant Systematics Laboratory, Institute of Biological Sciences, UPLB for the office facilities and equipment, providing and enhancing an ideal environment for work.

INOCENCIO E. BUOT, JR.
Editor

CHAPTER 11

Change Detection of Land Cover and Land Use Using Remote Sensing and GIS Techniques in Nong Han Wetland in Thailand

Puvadol Doydee[1]

ABSTRACT

This paper describes the changes in the different land covers and land uses in the Nong Han wetland, Sakon Nakhon province, Thailand during the ecotourism project called the *Lotus and Water Lily Development Project* in 2009. These changes were detected through the use of remote sensing and Geographic Information System (GIS) techniques. The results indicated that there were four major types of land cover and land use changes, namely in the: (1) lotus and water lily area (112,156 m^2); (2) aquatic vegetation zone (20,970 m^2); (3) paddy field (34,498 m^2); and (4) landfill area (52,368 m^2). Land cover and land use change (LCLUC) is a key driver resulting in climate change and climate variability. Change detection was recommended to be an approach for remote sensing and GIS. Raster to raster images rectification process must be conducted using the same Geodetic Datum and Map Project. Good evenness and distribution of at least 25 ground control points (GCPs) have to be performed associated with the values of root mean square errors that must be <1.00 in all GCPs. *In situ* data from actual field survey using GPS receivers with <5 m accuracy, while the number of global navigation satellite system for receiving the signal from outer space must be greater than eight satellites. Then, the LCLUC in the form of rater dataset is converted into binary image files, band interleaved by line, and imported to GIS for map annotation. Remote sensing and GIS are good and quick techniques to determine the LCLUC, with low cost compared to conventional surveying methods. The analysis of the results showed that most of Nong Han wetland had been significantly, adversely affected by the different classes of land cover and land use changes due to anthropogenic activities.

Keywords: remote sensing, GIS, change detection, land cover change, land use change

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INTRODUCTION

Spatial patterns of the land cover and land use in Thailand have been changing due to natural disturbances such as fire, storm, tsunami, floods, as well as human activities (e.g., timber harvesting, farming, livestock grazing, land use, and land cover conversion). Changes in these patterns as measured by land cover and land use change (LCLUC) are dynamic and must be assessed appropriately. This chapter describes landscape changes in patches of the Nong Han wetland, Sakon Nakhon province, Thailand. Wetland ecosystem offers diverse environmental conditions and habitat types providing food, shelter, and breeding grounds for terrestrial and aquatic organisms (Wang 2010).

An ecotourism project was implemented from 2008 to 2009 in Nong Han wetland to establish the Lotus and Water Lily Natural Museum for which a portion of the wetland ecosystem was converted. This wetland was the breeding ground of freshwater fishes that migrated from the Mekong River. Freshwater wetlands served as spawning and nursery for various species of aquatic fauna during the rainy season (May–August). Thus, landscape change in this area had been the main cause of biodiversity decline (Myers et al. 2000; Sims 2010; Vitousek et al. 1997; Wang 2010), particularly, for freshwater fish species. Hence, LCLUC was investigated to generate a thematic map to inform efforts to balance any ecotourism development project and wetland conservation (Doydee 2014).

Remote sensing and Geographic Information System (GIS) provide spatial information for monitoring the LCLUC, and can be used in rescue and rehabilitation plans. Kelmelis et al. (2006) reported that satellite images were applied to monitor and evaluate the damages over several devastated spots, while Doydee and Chaturabul (2018) recommended that remote sensing and GIS applications in disaster prevention and mitigation had become critically important approaches to support preparedness programs (Wang 2010; Doydee 2011). Remote sensing, on the other hand, is a crucial tool for mapping and monitoring land use and land cover changes (Richards 1993; Lillesand and Kiefer 1994; Liu et al. 2001; Kennedy et al. 2009). A change detection method (Doydee and Siregar 2006; Anongponyoskun et al. 2011) using multitemporal Geo-link was performed to determine the LCLUC in the Nong Han wetland.

The main objective of the study was to monitor the changes in land cover and land use using remote sensing and GIS techniques.

METHODS

Dataset and System Requirement

Satellite change detection required at least two different dates of remotely sensed data. In this study, the Thailand Earth Observation System (THEOS) images were used to monitor land cover and land use change (LCLUC) in Nong Han wetland, the case study for ecotourism of the *Lotus and Water Lily Development Project*. Images were supported by the Geo-Informatics and Space Technology Development Agency (GISTDA), Bangkok, Thailand.

The acquisition date of the first dataset was 21 December 2008 (before the project), while the second image was on 7 October 2009 (after the project). Both images were selected with the same sensor (panchromatic), associated with spatial resolution of 2 m × 2 m. Topographical map sheet 5843 III Sakon Nakhon was used as base map, serving as reference to the THEOS image, together with field survey using global positioning system (GPS) receiver in order to validate the type of LCLUC. The map sheet had a scale of 1:50,000 and was published in 1999 by the Royal Thai Survey Department.

Remote sensing and GIS software required ER Mapper and QGIS (i.e., Open Source Geographic Information System) for image processing (ER Mapper 1997) and spatial annotation and attribute data management. Computer hardware with Microsoft Windows XP, Intel Core 2 Quad CPU or better, GPS version eTrex handheld with Universal Transverse Mercator (UTM) coordinate system, performing at an accuracy of 5 m or better (Doydee and Siregar 2006), were also necessary for digital image processing.

Image Processing

Radiometric correction was performed to reduce errors in the digital numbers of satellite images. This process improved the interpretability and quality of remotely sensed data. Geometric distortions were corrected by linking the image coordinate system and the geographic coordinate system using data calibration of the sensor, measured data of position, and altitude. Ground control points (GCPs) had been embedded for both images with even distribution. The georeferencing had been performed for setting up the main objects in multitemporal images to be the same geodetic datum (WGS84), map projection (NUTM48), and azimuth angle. Areas of Interest (AOI), where the researcher should notice the landscape change by comparing two image datasets, were identified and rechecked with a topographic map and the GPS localities record.

Change Detection

Before performing the multitemporal geo-link technique or other change detection methods (e.g., red-green method, ratio method, subtract method), apply at least 25 Ground Control Points (GCPs) for all GCPs (i.e., Root Mean Square error <1.00). This aims to improve geometric accuracy of images obtained on different periods. This aims to improve geometric accuracy of images obtained on different periods. Pixel-based statistics calculation in each LCLUC was done using screen digitizing method with support from QGIS software. The images of each patch were compared and were validated with field survey or *in situ* data. Then, land cover and land use types, patch size, shape, and habitat types were identified and described in attribute data of the LCLUC. The satellite images of THEOS, acquired 7 October 2009 on raster format, were converted into binary image files—Band Interleaved by Line (BIL), and imported to QGIS software for map annotation. The LCLUC was overlaid with object change on THEOS imagery with acquisition date of 21 December 2008. There was a year difference but the landscape was changed evidently due to the ecotourism activities for the Lotus and Water Lily Development Project. GIS spatial data were added as vector feature type in the form of polygon themes and the area of change was quantified using pixel-size calculation.

RESULTS AND DISCUSSION

Human activities, particularly the establishment of aquatic ecotourism for lotus and water lily, were mainly responsible for the LCLUC in the Nong Han wetland. There were four major types of LCLUC, namely: (1) lotus and water lily area (112,156 m^2); (2) aquatic vegetation (20,970 m^2); (3) paddy field (34,498 m^2); and (4) landfill area (52,368 m^2) (Table 11.1 and Figure 11.1).

Each LCLUC type (Table 11.1) was validated in its respective locality using GPS coordinates from actual field survey. Among LCLUC types, the lotus and water lily area was the largest patch (112,156 m^2) (Figure 11.2 and Table 11.1). Most aquatic plants in this patch were emergent vegetation growing in shallow water and this was

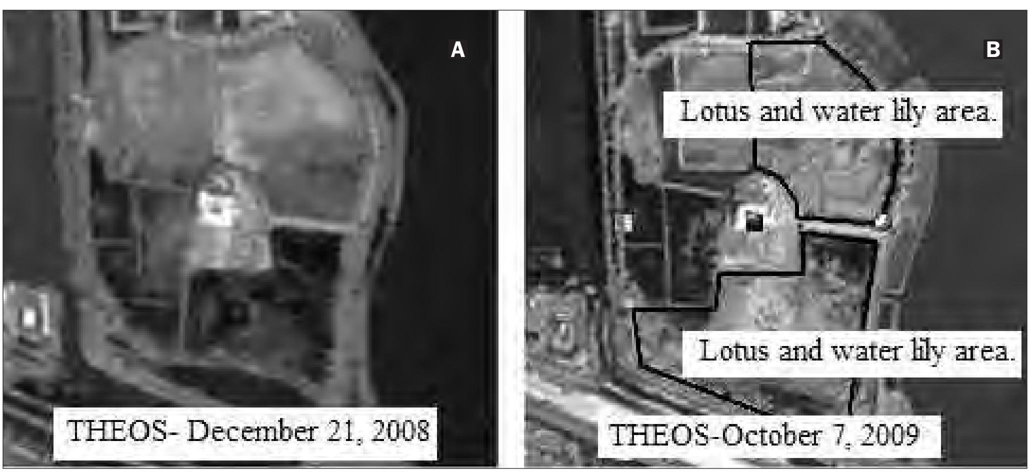
Table 11.1. Land cover and land use change types in Nong Han Wetland

LCLUC Types	Area (m^2)	Patch Shape	Habitat Types
Lotus and water lily area	112,156	Polygon	Emergent aquatic vegetation, shallow water
Aquatic vegetation	20,970	Elongate	Marginal plants, flooding area, littoral zone
Paddy field	34,498	Elongate	Agricultural crop area
Landfill area	52,368	Polygon	Bare soils, marginal vegetation
Total	**219,992**		

Figure 11.1. LCLUC habitat types in Nong Han Wetland, Sakon Nakhon Province, Thailand

Note: (A) lotus and water lily area; (B) aquatic vegetation; (C) paddy field; (D) landfill area

Figure 11. 2. THEOS imageries showing lotus and water lily areas



Note: Imageries were acquired on 21 December 2008 and on 7 October 2009.

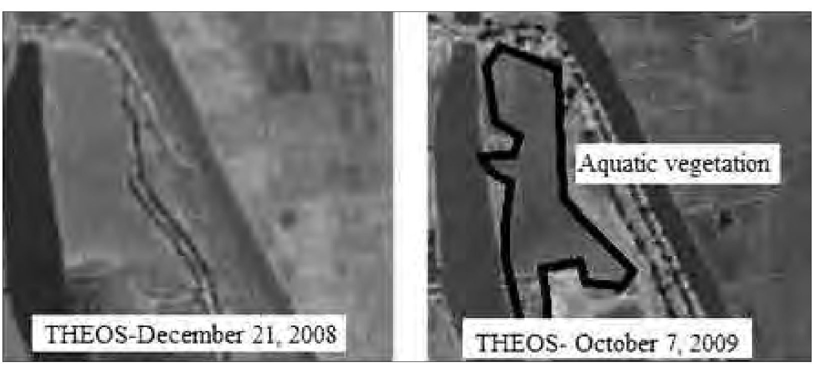
also the habitat and niche for invertebrates, such as snail, bivalves, aquatic insects, and benthos, which sustain the food chain and food web in the aquatic ecosystem.

Area size was quantified using pixel-based calculation from remote sensing, while the shape of landscape change was derived from the GIS. Habitat types with GPS data recorded were obtained from field methods and the bird's-eye view of lotus and water lily areas using an unmanned aerial vehicle (UAV) is shown in Figure 11.3.

The aquatic vegetation zone showed the smallest change in area (20,970 m^2). The change was due to human activities like land leveling and bush slashing for agricultural purposes, such as oil palm and sugarcane plantation. The shape was

Figure 11.3. Bird's eye view of landscape taken using an UAV at Nong Han wetland

Figure 11.4. THEOS imageries showing aquatic vegetation



elongated (Table 11.1) and since this land use type was located near the upper tip of the water body (Figure 11.4), with diverse marginal plants, it served as the favorable habitat for spawning and egg laying of freshwater fishes during the rainy season.

Paddy field landscape has an elongated shape with an area of 34,498 m^2. In 2008, this patch was a rainfed agricultural area and now had been changed into paddy field due to the request from local communities who used to dwell in this area, for their livelihood (Figure 11.5). The paddy field for growing glutinous rice and Thai Jasmine rice used water pump and small-scale irrigation for crop production.

As ecotourism progressed, more land conversion occurred, which paved the development of the adventure zone project. Related activities like game fishing,

Figure 11.5. THEOS imageries showing paddy field

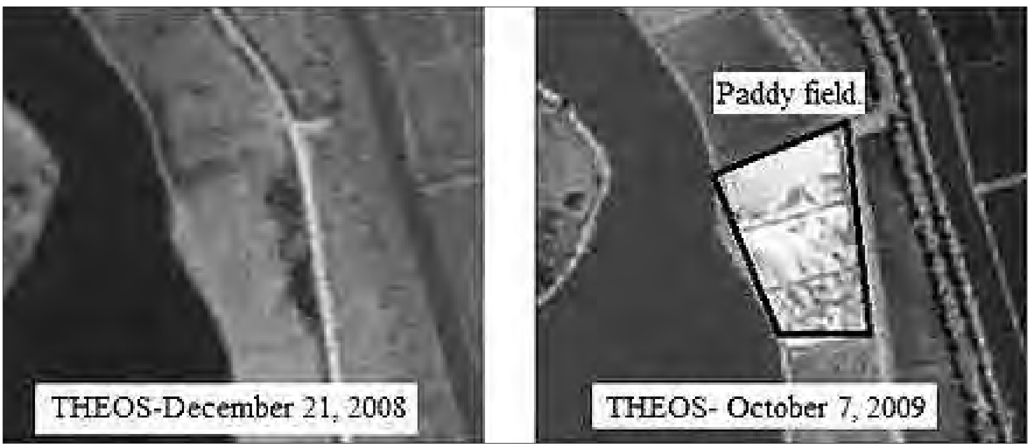


Figure 11.6. THEOS imageries showing landfill area

camping, canoeing, bicycling, and pseudo-mountain climbing commenced. Adventure patch preparation as landfill area (Figure 11.6) had a polygon shape and was located at the lower right corner of the study area. Their habitat types were bare soils with marginal vegetation (Table 11.1).

While ecotourism is one of the attractive activities for tourists, there is a need to understand the impact of human activities on nature. Thus, the balance between ecotourism and natural resources conservation must be taken into account (Nash 2009; Karanth and DeFries 2011; Yu, Hendrickson, and Castillo 1997).

In working with the Nong Han wetland ecosystem, many scientists lacked the skill in the use of remote sensing and GIS technology in aquatic environmental management. This is similar to the findings of Wiens, Sutter, and Anderson (2009) that many scientists rarely use remote sensing in ecosystem studies, or collaborate with scientists and conservation groups, which are all very crucial. Effective geoinformatics tools, such as remote sensing and GIS, should be used in monitoring programs (Skidmore, Bikjer, and Schmidt 1998) for greater efficiency, especially in terms of communicating the results.

CONCLUSION

This study illustrated the importance of remote sensing and GIS technology in change detection as part of monitoring and management of LCLUC in the Nong Han wetland ecotourism project, involving the planting of lotus and water lily in Sakon Nakhon Province, Thailand. Change detection methods are useful for monitoring uniform, irregular, and continuous aquatic ecological dynamics for on-the-ground applications, such as land use conversion, natural disturbance, and anthropogenic expansion. Remote sensing and GIS have advantages in detecting LCLUC with low cost compared to conventional surveying methods. The map of the LCLUC is useful for landscape development and supports biodiversity conservation planning and management. This is a vital step towards enhancing conservation in freshwater wetland biodiversity.

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