CHANGE DETECTION OF HYDROLOGIC NETWORKS USING LANDSAT IMAGERIES FROM 1972 TO 2013 IN MEKONG DELTA

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ABSTRACT: The hydrologic networks play a paramount significance in paddy rice cultivation. The aerial photographs and satellite images, the latter were acquired from the Multispectral Scanner (MSS), Thematic Mapper (TM), Enhanced Thematic Mapper Plus (ETM+), and Operational Land Imager (OLI) were utilized to extract the fundamental information about the natural rivers and manmade canals over the past forty years from late 1972 to early 2013 in three districts which belong to Long An Province in Mekong Delta, Vietnam. The optimal threshold method was used to extract the hydrologic networks from Landsats 1, 5, 7 and 8 images. It was found that the total length of l canals had an obvious increase from 116 km to 2306.8 km through 1972 to 2013. The increment rate was faster from 1990 to 2000 than other ages, which was consistent with the national economic development in Vietnam.

1. INTRODUCTION

The hydrologic networks mainly consist of rivers and canals, which is one essential part of inland surfaces and play s a key role in paddy rice cultivation. The change of total number and length of rivers and canals over space and time is not only a result of natural conversion, human practice, but strong indicators of agricultural, environmental and ecological problems (Jiang et al., 2014). Surface water mapping to describe its tempo-spatial distribution is very important for studying global change and global, local policy-making.

Remote sensing approach in object recognition of water body including river and canals has been intensively studied. As an useful information source for water extraction, remotely sensed image data at the space platform (e.g., Landsats images) has been widely used (Nguyen, 2012). Generally, methodologies of water body extraction can be summarized to three categories: classification, spectral band, and spectral water index (Nguyen, 2012; Jiang et al., 2014). The first method which includes supervised and unsupervised techniques is widely used to extract water bodies from airborne or space-borne images. The supervised classification is on the basis of appropriate training samples selected by analyst, its extraction accuracy is higher than others at the cost of numerous time (Jensen, 2011). The iterative self-organization data analysis (ISODAT) and K-means are the most common methods for unsupervised classification (Lu et al., 2007; Otukei and Blaschke, 2010). The spectral band method is easy to conduct for extracting water body by applying thresholds to special reflective bands, its physical basis is the spectral difference between water body and other objects (e.g., vegetation, soil, build-up, etc). The spectral water index is an combination of two or more reflective bands for enhancing the discrepancy between water body and other objects (Jensen, 2011; Jiang et al., 2014). The most common water index for water extraction is the normalized-difference water index (NDWI) proposed by McFeeters (1996).

Mekong Delta is the most important rice production area in Vietnam, and it is called as the "rice bow" of Vietnam. Both the rice planting area and yield occupy over half of whole Vietnam. The rice production in Mekong Delta depends on rainfall and irrigation. A complex hydrologic network consisting of natural rivers and manmade canals has been formed in the past forty years. More than 10, 000 km of irrigation canals were constructed to deliver water throughout the region for agricultural production and transportation (Nguyen et al., 2014). The hydrologic network provide a basis for paddy rice cultivation in Mekong Delta, which played an huge contribution in quick increment of rice area and yield in Vietnam. The rice area increased over fifty percent and rice yield had 2.5 folder increase from 1972 to 2013. The change detection of hydrologic network in the study will open an door to study the relationship between natural landscape conversion and socioeconomic development in developing countries.

In this study, we applied the optimal threshold method to extract the amount of hydrologic networks from four Landsat NDWI images through 1972 to 2013. Specially, this study focused on the length change of rivers and canals based on the determination of optimal threshold value. In addition, one object of this study was to stimulate the application of free Landsats imageries in the Earth's environment field.

2. MATERIALS AND METHODS

2.1 Site Description

The study site comprises three adjacent districts (i.e., Moc Hoa, Tan Thanh, and Thanh Hoa) of Long An Province in the Mekong Delta region of Vietnam, and ranges from 105°30′E to 106°50′E and 10°20′N to 11°5′N (Figure 1). It has about 1364 km^2 and occupies over one tenth of Plain of Reeds encompassing most parts of north-western Mekong Delta, viz. Dong Thap, Tien Giang, and Long An in Vietnam and parts of Svay Rieng in Cambodia.

The study site, like the whole Plain of Reeds, was originally covered in dense vegetation with small natural rivers. However, massive agricultural expansion over the past 40 years has led to most natural areas being converted to paddy rice fields after gradually constructing a dense and complex hydrologic network of man-made canals, dykes and sluices.

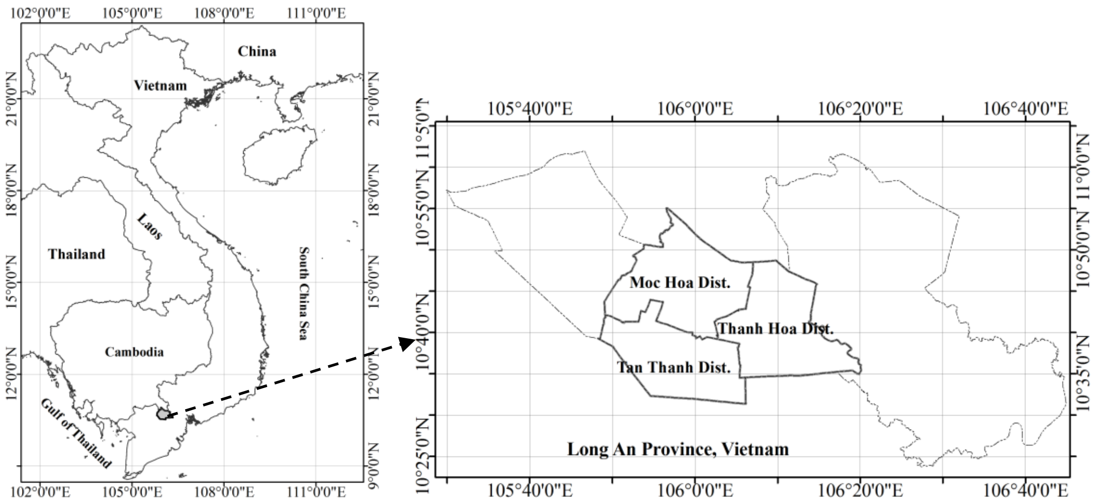

Figure 1. Location Of The Study Area With Reference To The National Map.

2.2 Data Preparation and Processing

2.2.1 Satellite Image Acquisition: All in all, four Orthorectified Landsat imageries through the end of 1972 to 2013 were selected to study the change of hydrologic networks (Table 1; Figure 2). Those data are some of the most geometrically and radiometrically corrected data available, which were acquired with primary sensors evolving nearly forty years: MSS (Multi-spectral Scanner), TM (Thematic Mapper), and ETM+ (Enhanced Thematic Mapper Plus) and one superior sensor operated on 11th February 2013: OLI (Operational Land Imager).

High resolution visible and infrared imageries are supplied by all Landsats, and higher resolution panchromatic images are also available from the ETM+ sensor and OLI sensor. The panchromatic wavebands were displayed in bold in the third column of Table 1. Images applied in this study were free, and downloaded from the official Landsat organization website, namely http://www.landsat.org/ortho/index.php.

Table 1. Image Acquisition Date, Worldwide Reference System, Solar Zenith Angle And Pixel Size For Landsat Satellites In The Study Area

Satellite	Sensor	Band#s	Imaging Date	Path/Row	Sun Zenith	Resolution
Landsat 1	MSS	4-7	1972-12-15	134/053	44.50°	60m
Landsat 5	TM	1-5,7	1989-01-16	125/053	46.00°	30 m
Landsat 7	ETM+	1-5,7,**8**	2000-11-06	125/053	35.21°	15 m-PAN/30 m-REF
Landsat 8	OLI	1-7,**8**	2013-11-02	125/053	32.33°	15 m-PAN/30 m-REF

* PAN and REF denote panchromatic and reflective bands, respectively.

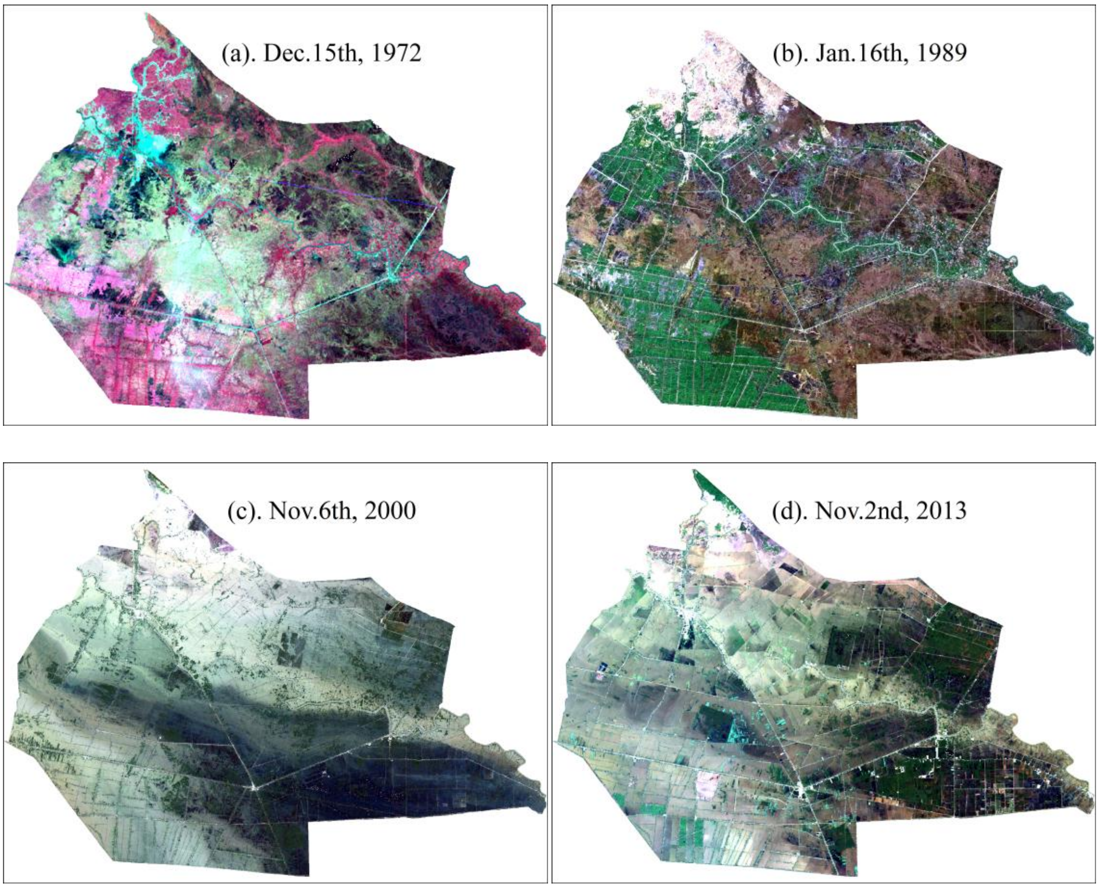

Figure 2. Satellite Images Of The Study Area In Long An Province, Vietnam. (A) MSS 754 Band False-Color Image; (B) TM 321 True Color Image; (C) ETM+ 321 True Color Image; And (D) OLI 421 True Color Image.

2.2.2 Calculation Of Spectral Index: The ability to detect and quantify changes for land use and land cover on Earth depends on sensors that can provide accurate, precise and consistent measurements of the Earth's surface features through time (Chander et al., 2009). The correct interpretation of scientific information from long-term series of remote-sensing products requires the ability to discriminate between product artifacts and changes in the Earth processes (Roy et al., 2002). It is necessary to conduct radiometric calibration for creating high quality science data. The radiometric calibration procedure of Landsat imagery include two steps in the study. The first is to convert digital number (Q) to at-sensor spectral radiance (L_λ), and the second is to convert L_λ to exoatmospheric

Top-Of-Atmosphere (TOA) reflectance (ρ_λ). The detailed calibration procedure referred to classical literature reported by Chander et al. (2009).

The Normalized Difference Water Index (NDWI) has more adequate to improve the separability of water from vegetation and soil in multispectral images than other indices (McFeeters et al., 1996). The NDWI is then calculated by the ratio of reflectance difference between green light band and NIR band to sum of green and NIR bands. For Landsat 1-MSS , the second NIR band (0.8-1.1μm) was selected to calculate NDWI in this study.

2.2.3 Reference Data Of Hydrologic Network: To provide a basis for comparison, the "true" river and canal were manually digitized from the Landsats image by visual interpretation technique in ArcGIS®, the Geographic Coordinate System and Datum are WGS 1984. During the digitalization procedure, background noise (e.g., road, house) had been excluded to avoid confusing with linear water objects.

2.2.4 Determination Of Optimal Threshold Values: Optimal threshold method was used to extract the hydrologic network in this study. To obtain the optimal threshold value, 50 samples and 200 samples were selected to represent the river and canal, respectively from the entire scene for the four satellite imageries listed in Table 1. We found that all the NDWI values of river and canal pixels were less than -0.15 for MSS and TM sensors, -0.10 for ETM+ and OLI sensors. Then -0.15 and -0.10 would be the optimal threshold values to extract the hydrologic network pixels.

2.2.5 Accuracy Assessment Parameter: Metrics that are based on feature length are often used to assess the results of extracting linear features, viz., roads or narrow rivers, instead of a pixel-by-pixel comparison (Jiang et al., 2014). Total accuracy metric (TMM) was chosen to evaluate the extraction performance of threshold method for the narrow river extraction results. TMM is the ratio of the total length of the extracted river (Le) to the total length of the reference river (Lr).

3. RESULTS AND DISCUSSION

The overall hydrologic network extraction performance with optimal threshold method was first tested with the reference data via visual inspection and a pixel-by-pixel assessment of the images (Figure. 3). There is one wide river and some narrow rivers in the study area throughout the past forty years. Only several major canals were constructed by the end of year 1972, most parts of the study area were natural wetland forty years ago (Figure 3a). The density of canal was low until early of 1989. The constructed canals mainly located in Moc Hoa District and Tan Thanh District, seldom in Thanh Hoa District (Figure 3b). The canals were popular, and the canal density were very high by the end of new millennium. Some agricultural fields were identified into water body because the typhoon "Xangsane" brought too much rainfall which nearly flooded all the agricultural fields (Figure 3c). The canal density on November 2nd 2013 was higher than year of 2000. Although the hydrologic network feature has obvious characteristics, some pixels covered by flooding water were identified into water body (Figure 3d). The reason was still typhoon, the troublemaker name was Yolanda.

Subsequently, detailed evaluation of the extracted data of hydrologic network results was conducted using accuracy metric (TMM) to assess the performance of the optimal threshold method in identifying river and canal pixels. The extracted data of hydrologic network was conversed to vector file (i.e., *.shp) for obtaining the length of river and canal in ArcGIS®. The small river and canal lacked coherence due to existence of mixed pixel. So the linear objects would be unified if the interval pixel number was less than five and elongation directions were consistent. Table 2. summarizes the TMM values which were used to assessment the extraction performance of optimal threshold method through simple comparison of extracted length of river with canal and the reference data.

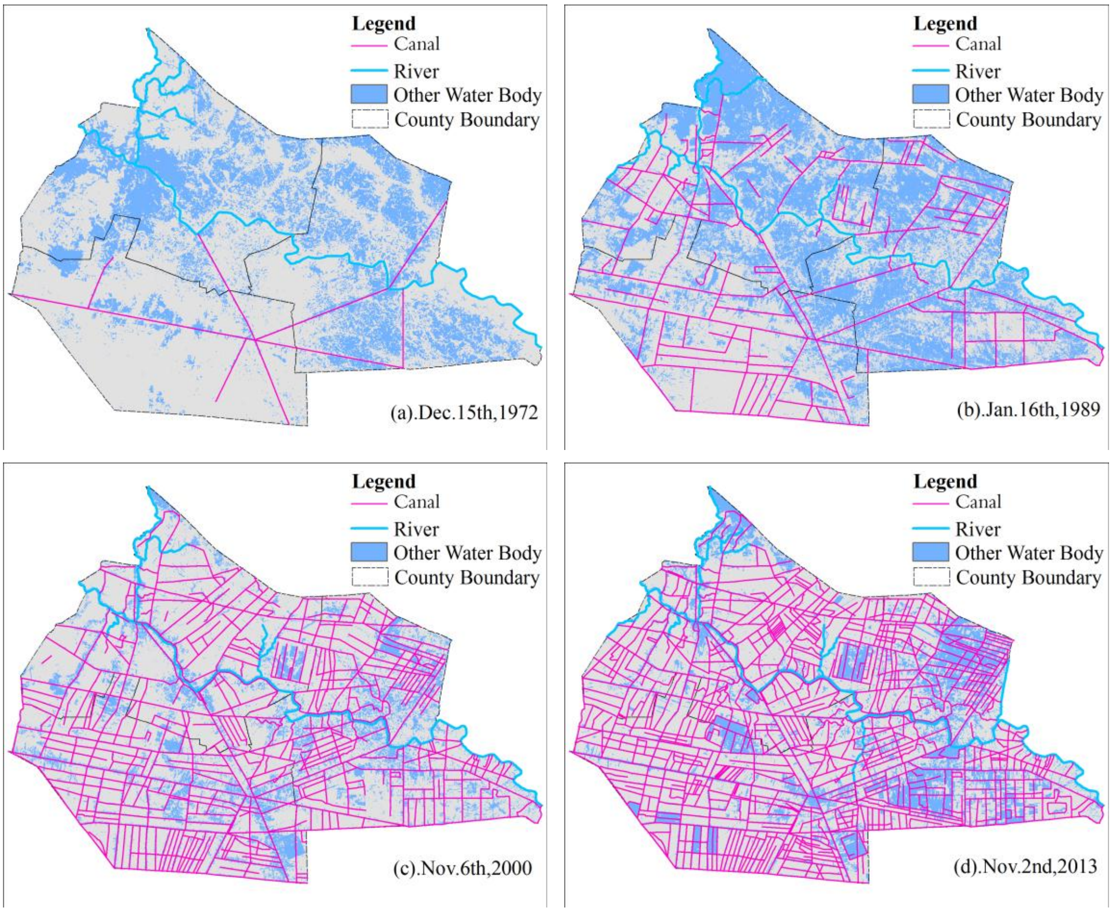

Figure 3. Hydrologic Network Extraction Result With Threshold Values In The Study Area From 1972 To 2013.

Table 2. Evaluation Of The Optimal Threshold Method Result.

Imaging Date		1972	1989	2000	2013
River	Extracted (km)	123	127	121	147
	Reference (km)	140	148	150	149
	TMM (%)	88.3	86.1	80.9	98.4
Canal	Extracted (km)	116	718	1673	2307
	Reference (km)	206	957	2480	2644
	TMM (%)	56.2	75.0	67.4	87.2

The four TMM values for rivers were higher than canals over the past forty years, the reason might be most pars of rivers were wider than canals. Then the mixed water pixel number for rivers was smaller than canals. For satellite imagery acquired on December 15th 1972, the extracted total length of canals occupied only 56.2% of reference data. The calibrated pixel size of MSS sensor for Landsat 1 is 60 m (Table 1). The original pixel size of MSS sensor for Landsat 1 is 80 m, this size is ten folders of physical width for most of canals. Although linear feature of canals were obvious, the MSS reflective sensor couldn't efficiently extract the small canals in the study. The image pixel size for ETM+ reflective sensor was 30 m, enormous flooding field pixels because of the typhoon Xangsane embarrassed the extraction accuracy on November 6th 2000. Because the radiance resolution (2^{32} bit) of OLI sensor loaded on Landsat 8 is higher than that (2^{6} bit)of ETM+ sensor loaded on Landsat 7, then the texture feature of OLI is better than ETM+. Even the pixel size of OLI and ETM+ are same, the extraction accuracy (TMM=87.2%) on November 2nd 2013 is superior to on November 6th 2000.

4. CONCLUSION

There are several difficulties associated with hydrologic network extraction from satellite imagery using water indices that are based on the threshold method. First is to exclude flooding rice paddy field, second is to identify mixed water pixels with build-up and plant; and final is to determine the optimal water extraction threshold that depend on the characteristics of an individual scene. An ongoing problem is that the hydrologic extraction result for narrow river and canal is not very good. The future research might focus on more efficient automatic extraction techniques of narrow river and canal, for example, isolation method, rule-based method and so forth by considering spectral and spatial characteristics and texture feature of satellite images.

Although there are some errors between the agricultural hydrologic network (i.e., river and canal) extraction result and reference data, the length of canal has an obvious increase over the past forty years through 1972 to 2013. This phenomena is general in Mekong Delta and Plain of Reeds according to the current literatures (Nguyen et al., 2014). The development of agricultural hydrologic network is a prerequisite for transforming natural wetland into agricultural field, especially for rice production. This conversion, however, has changed the natural landscape of Mekong Delta and Plain of Reeds and decreased the biodiversity for input of enormous agrochemical fertilization.

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