WEB GIS AND REMOTE SENSING SOLUTIONS FOR MONITORING AND THEMATIC MAPPING IN THE MEKONG DELTA REGION

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Abstract. GIS and Remote Sensing technology had been widely applied in Viet Nam. However, research orientation and development of Web GIS and Remote Sensing solutions for regional management approach also indicates many difficulties and challenges. This paper aims to introduce Web GIS and Remote sensing solutions that can be used in monitoring salinity intrusion and land cover mapping to support the implementation of sustainable development strategy of the Mekong Delta region. The experimental results show the online mapping applications based on Landsat images open a new way that can be effectively applied in monitoring salinity intrusion in river network, updating the status of land cover changes and analysing the trend of forest-cover changes in this region. Results of this study also illustrate the suitable technology available to support regional organizations to create thematic maps in monitoring and managing the natural resources and environment of provinces/cities that can achieve high accuracy and save time.

1. Introduction
The Mekong Delta region comprises 13 provinces with total land area about 39,000 km² that plays an important role to the sustainable socio-economic development of Viet Nam. The environment in this region faces severe problems (wet season floods, dry season saline intrusion) resulting from global climate change and the surging economic development in the country [2, 4]. In order to assess past land cover (LC) changes, to undertake comprehensive and coordinated land planning based on the state of the environment and natural resources and future development needs,… Some ministries and provinces has been undertaking projects on specific purposes, related to the applications on the integrity of remote sensing and GIS technologies for regional management. The choice of an appropriate GIS solution for
giving valuable information to environment and natural resources managers plays an important role and many local agencies have deployed GIS as a tool to modernize their management and to strengthen their administrative machinery. However, the biggest difficulty is the lack of GIS data, due to the spontaneity of agencies in deploying GIS technology and it turns up some problems: duplication in data collection effort among organizations, different geographic data themes for an area, and difficulties in sharing information among organizations because of both mechanisms of management and technology. Web GIS solution thus is proposed for sharing spatial data among administrative agencies and developing a web-based GIS application in natural resources management that aims to achieve sustainable development in this region.

Recent experimental studies show that this solution can provide a way to allow the staff of agencies to easily manage the data using open source Web GIS platform enabling users to access, visualize and interact with the data online [8] Remote sensing image processing enable mapping, monitoring, and assessment of land cover changes at a range of spatial and temporal scales [6, 9] or Remote sensing and GIS are used in water quality parameters estimation [5]… This paper introduces Web GIS and Remote sensing solutions that can be used in managing natural resources and environment at different levels, in order to provide fully integrated information of updated on the status of land cover changes and analyzing the trend of salinity intrusion in river network of Mekong Delta region.

2. Study area
Data of 13 provinces (Long An, Tien Giang, Ben Tre, Vinh Long, Can Tho, An Giang, Dong Thap, Tra Vinh, Hau Giang, Soc Trang, Kien Giang, Bac Lieu and Ca Mau) is collected from a variety of sources such as topographic, cadastral, land use maps,… The development a web-based GIS solution comprises the choice of an appropriate database management model that allow multiple users using the same base map for creating thematic maps based on the national standard. This paper introduces Web GIS solution that can be used in sharing data at different levels: base maps with scale 1:250,000 for regional level and the provincial level at 1:50,000. Landsat image data for the different dates (from year 1997 to 2016) are also selected to create land cover maps for monitoring and analyzing the trend of land cover change, as well as to examine the relationship between the spectral bands of images and values of salinity in river network of this region.

Figure 1. Location of this study area

3. The proposed solution
Database management system of Mekong Delta region is established to provide integrated solutions for monitoring salinity intrusion in river network; analysing the status of land cover changes and the trend of forest-cover changes that aims to contribute to sustainable development for the region and each province. Therefore, Web GIS and Remote sensing solution is created mainly for sharing data and...
providing online tools that allow users to display in the form of thematic maps, to edit data and to create solutions for mapping and monitoring changes in order to support management. Fig. 2 shows a client-server architecture is applied for online mapping applications. The Web GIS application model of Mekong Delta region was designed and developed based on a three-tier architecture to serve different user requests in which the user interface is on the 1st tier that data and maps can be presented on a web browser (website: https://mgis.vn), all web-based GIS applications lie on the 2nd tier implements the functionality of Web GIS and GIS database lies on the 3rd tier and is managed by the current open source software (PostgreSQL software) that users can download or upload data to contribute content of GIS database.

**Figure 2.** Web GIS application model for the study area

GIS Database includes various data sources and satellite images to support for monitoring salinity intrusion, land cover change and analysing the trend of forest-cover changes that allows users to use the same base map for creating thematic data. Base map of Mekong Delta region has been generated from topographic map includes 7 basic layers: Mathematical basis, Boundary, Elevation, Transportation, Hydrology, Urban areas, Vegetation. Web GIS can facilitate the users to find appropriate statistical data and thematic maps quickly and conveniently as well as remote sensing data are available can be used in different applications. The application of this research is to use database of the Web GIS to develop the methodologies focusing on monitoring salinity intrusion, land cover change and analysing the trend these problems in future work.

4. Results and discussion

Rapid socio-economic development and urbanization of 13 provinces have a considerable impact on land cover (LC) change and the flow regime of river network that these changes have potentially large effects in the sustainable development of Mekong Delta region. This study introduces a Web GIS and remote sensing solution for monitoring, assessment the past changes and analyses the trend these impacts in future.

- **Monitoring and mapping salinity intrusion:** topographic map is used in the geometric correction between the map and Landsat images as well as to register the images were acquired at the same time of data that were collected at 11 salinity measurement stations. Statistical data and thematic maps are used to support for developing the model for monitoring salinity distribution in river network. In addition, spatial analyst tools in Web GIS are effectively applied to develop the solution for monitoring, analysing the trend and impacts of salinity intrusion.
In this study, the correlation coefficient between the spectral bands of images and values of salinity at measurement stations is used in choosing regression model in order to convert pixel values of image into salinity values. Figure 3 shows the salinity ground measured values (S) at eleven sampling locations that are used in developing the model for monitoring salinity distribution in river network.

The analysis results show a significant correlation between the observed salinity data (S) and (PC1) the first principal component image and conversion of pixel values of image into salinity values by using the exponential regression model: \( S = 0.0014 e^{0.0006(PC1)} \)

This model is applied in mapping salinity intrusion with the salinity values divided into 4 classes: (1) Low salinity (blue colour): < 4 g/l, (2) Moderate (yellow): 4 – 7 g/l; (3) High (pink): 7 – 10 g/l and (4) Severe salinity (red colour): > 10 g/l.

From this results, Web GIS is used to edit data and overlay boundary layer that allow to create solution for mapping and analysing impacts of salinity intrusion in Mekong Delta region.

- **Monitoring the forest cover changes**: Web GIS and remote sensing solution is for investigating the spatial distribution of forest-cover change in the period from the year 1997 to 2016. Supervised classification with the same training data for each Landsat image was carried out by using maximum likelihood classifier (MLC). In order to provide information quickly for monitoring and analysing the trend of forest-cover change, training sample data includes 4 classes (1) forest, (2) mangrove forest, (3) flooded forest and (4) non forest that is used to classify images and to create forest-cover thematic maps. The results show that the area of the forest-cover in Mekong Delta region has decreased with the average cover rate from 10% of the natural area at the year 1997 to 4% of the area in 2016. In this period, the
The forest-cover area of An Giang province has been changed from 18.922 ha to 7.209 ha due to fire damage and human impacts.

- **Monitoring the land cover changes**: Figure 5 shows that the spatial distribution of forest does not cover Can Tho city. In order to analyse the land cover change and the trend of the urban expansion of this city, MLC classification method and post-classification change detection techniques were applied to create land cover maps for 4 Landsat images (year 1997, 2005, 2009 and 2016). The training sample data includes 5 classes, as follows: (1) impervious surface, (2) bare soil, (3) vegetation, (4) water surface (river, lake) and (5) wetlands. Cross-tabulation and tools for analysing for the classification results of 1997 and 2016 images are developed that is mainly composed of the spatial distribution of different land cover changes and non-change areas. The results show the area of the impervious surface has increased with the average growth rate of 14% per year and the trend of the urban expansion movement along Hau River that occurs from the center district of Ninh Kieu to districts of Binh Thuy and O Mon.

![Figure 5a. Forest-cover map in the region](image1)

![Figure 5b. Forest-cover map in An Giang province](image2)

**Figure 5a.** Forest-cover map in the region

**Figure 5b.** Forest-cover map in An Giang province

![Figure 6. Land cover maps of Can Tho City](image3)

(a) Land cover map of Can tho city, 1997  
(b) Land cover map of Can tho city, 2005  
(c) Land cover map of Can tho city, 2009  
(d) Land cover map of Can tho city, 2016

- **Figure 6.** Land cover maps of Can Tho City  
  (a) Using Landsat year 1997 (b), Landsat 2005 (c) Landsat 2009 (d) Landsat 2016
5. Conclusions
The monitoring land cover change and the trend of salinity intrusion in river network play an important role in the environment and natural resources management that aims to achieve sustainable development in the Mekong Delta region. This paper introduces a Web GIS and remote sensing solution that can be applied to analyze the impacts of salinity intrusion and to extract the trend of the 20-year forest-cover change for regional level as well as land cover change at the provincial level by using Landsat images. These proposed solutions aim to open new ways that GIS database is managed by the open source software (PostgreSQL software) that users can integrate with remote sensing images (Landsat can be download free at website: http://earthexplorer.usgs.gov) to undertake further analysis regarding the environment and natural resources management. The results also show that the first principal component band of Landsat image can be used to develop the suitable model in simulation of the salinity distribution along the river. In addition, MLC classification method is quite reliable and can be effectively applied in investigating the spatial distribution of forest-cover change and monitoring land cover change of each province. Therefore, the proposed solution contributes to create a good opportunity for administrative agencies that can speed up the process of updating data, to provide information quickly for state management. Thematic maps can be frequently established to the Mekong Delta region that can bring more value on understanding situation of salinity intrusion at the regional level and analyzing the trend of land cover changes of each province.

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