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Synergistic using medium-resolution and high-resolution remote sensing imagery to extract impervious surface for Dianci Basin

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Abstract. The knowledge of impervious surfaces, especially the magnitude, location, geometry, spatial pattern of impervious surfaces, is significant to urban ecosystem studies, including urban hydrology, urban climate, land use planning and resource management.Impervious surface area (ISA) is considered a key indicator of environmental quality and can be used to address complex urban environmental issues, particularly those related to the health of urban watersheds. ISA is also an indicator of non-point source pollution or polluted runoff. Remote sensing offers a consistent framework for representing spatial patterns and rates of urbanization over time through accurate observations of impervious surface area. Most of the existing methods of extracting impervious surface based on remote sensing concentrate on an urban scale, but the rapid and accurate methods of extracting impervious surfaces in a basin scale are nearly nonexistent in China and abroad.In recent years,with the rapid urbanization especially surrounding the Dianchi water body, the impervious surface coverage rate also grows rapidly and results in severe degradation of basin water environment within Dianchi watershed. In this study,we developed an approach to extract impervious surface for Dianci Basin by synergistic using medium-resolution and high-resolution remote sensing imagery. Subpixel percent impervious surfaces at Thematic Mapper (TM) images were mapped using the classification and regression tree(CART) algorithm. Sub-pixel impervious surfaces at 30m resolution were mapped in this study area through regression tree models. The estimated ISA results were evaluated through independent ISA reference data derived from high resolution QuickBird. The results prove the suitability of the approach for a widely automated and mapping of impervious surfaces in a basin scale.

Keywords: impervious surface area(ISA); the classification and regression tree (CART); Dianci Lake basin; high resolution remote sensing imagery; TM;

1. Introduction

Impervious surfaces are anthropogenic features through which water cannot infiltrate into the soil, such as roads, driveways, sidewalks, parking lots, rooftops, and so on. In recent years, impervious surface has emerged not only as an indicator of the degree of urbanization, but also a major indicator

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of environmental quality[4]. Therefore, estimating and mapping impervious surface is significant to a range of issues and themes in environmental science central to global environmental change and human-environment interactions. The datasets of impervious surfaces are valuable not only for environmental management, e.g., water quality assessment and storm water taxation, but also for urban planning, e.g., building infrastructure and sustainable urban development.In recently years, Remote sensing data have been widely used to detect and quantify impervious surfaces due to their vast geographic coverage and the temporal frequency of data collection, and thus have provided a range of inputs such as land cover for hydrological and environmental models. A range of satellite sensor data has been utilized for impervious surface mapping, including moderate spatial resolution[7] Landsat TM/ETM+, SPOT, and ASTER imagery, and higher spatial resolution IKONOS and QuickBird data[5]. The approaches of extracting impervious surfaces based on remote sensing mainly include: (1) pixel-oriented image classification, (2) multiple regression, (3) subpixel classification, (4) artificial neural network, (5) object-oriented image classification[5],(6) classification and regression tree (CART) algorithm,(7) integration of remote sensing data with geographic information systems ,and so on.

Although many methods of extracting impervious surfaces have emerged in China and abroad, almost all of the studies are limited to the urban scale[3], and methods for a fast and accurate extraction of impervious surfaces in a basin scale have not been established[2]. However, many water resource exploitation and utilization, river management and planning, and water cycle process research are conducted in a basin scale. The basin is the basic unit of hydrological cycle study because it is closed. Therefore, extraction of impervious surface distribution in a whole basin using remote sensing has significant meaning for hydrological cycle and water resource assessment .In recent years, with the rapid urbanization especially surrounding the Dianchi Lake water body, the impervious surface coverage rate also grows rapidly and results in severe degradation of lake basin water environment within Dianchi watershed. In this study, we developed an approach to extract impervious surface for Dianci Basin by synergistic using medium-resolution and high-resolution remote sensing imagery. We obtained the exact impervious surface distribution of the entire Dianci Lake River Basin.

2. Study area and data

The study area is Dianci Basin, which is located within the city of Kunming, Yunnan, China (Figure 1). The Dianci Basin areas are about 2920 square km. The study area was selected because it is located about Kunming. Kunming is one of the most rapidly growing cities in the china. In recent years, with the rapid urbanization especially surrounding the Dianchi, the impervious surface coverage rate also grows rapidly and results in severe degradation of basin water environment within Dianchi watershed.

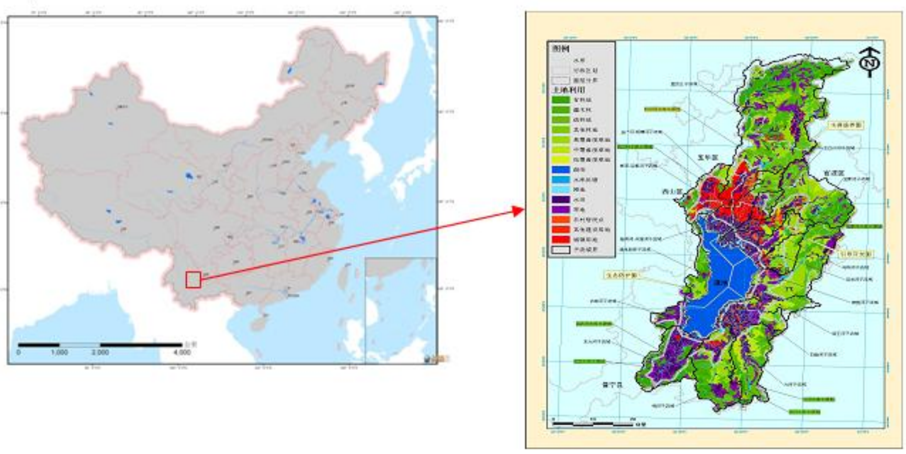
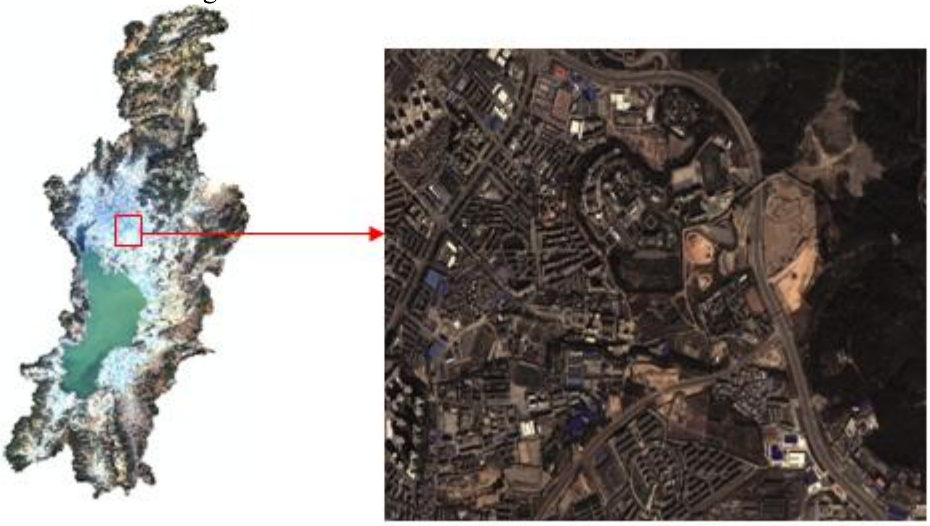


Figure1. The study area-Dianci Basin

One high (Quick Bird) and one medium (Landsat TM) spatial resolution remote sensing datasets were used in this study (Figure 2). The Landsat TM images (bands 1-5and 7,30m spatial resolution) obtained in June 2010.The Quick Bird images were obtained in March 2010. For Quick Bird data the 0.61-m panchromatic data was fused with 2.44-m multispectral bands, resulting in an image of four bands (blue, green, red and NIR) with "sharpened" spatial resolution of 0.61-m. The Landsat TM images were the primary data source for mapping impervious surfaces. The Quick Bird images were utilized for derivation of training/test data.



a. The landsat TM image b. The Quick Bird image
Figure 2. Remote sensing images of the study area

3. Methods and procedures

The proposed method in this paper was adopted to map impervious surfaces Synergistic using medium-resolution and high-resolution remote sensing imagery. This approach used high-resolution remote sensing imagery to obtain impervious surfaces training/test datasets, and medium-resolution satellite imagery to obtain impervious surface over basin scale through regression tree models. The proposed methodology for impervious surface mapping consists of several steps:1) Regression Tree Algorithm description ,2)development of training/test data based on object-oriented classification from 0.61 m resolution Quick Bird images,3)impervious surface modelling and mapping based on the CART regression tree algorithm, and4)accuracy assessment of impervious surfaces. The general process for impervious surface mapping is as shown in Figure 3.

3.1. Classification and regression tree(CART)

The general classification and regression tree (CART)algorithm conducts a binary recursive partitioning process[1]. The process splits each parent node into two child nodes and the process is repeated, treating each child node as a potential parent node. The regression tree algorithm produces rule-based models for prediction of continuous variables based on training data. Each rule set defines the conditions under which a multivariate linear regression model is established. Regression tree models can account for non-linear relationship between predictive and target variables and allow both continuous and discrete variables as input variables. It has been reported that accuracy and predictability of the regression tree models were better than those[2]. The regression tree algorithm we used to model impervious surfaces is commercial software called Cubist, which is one type of the regression tree algorithm.

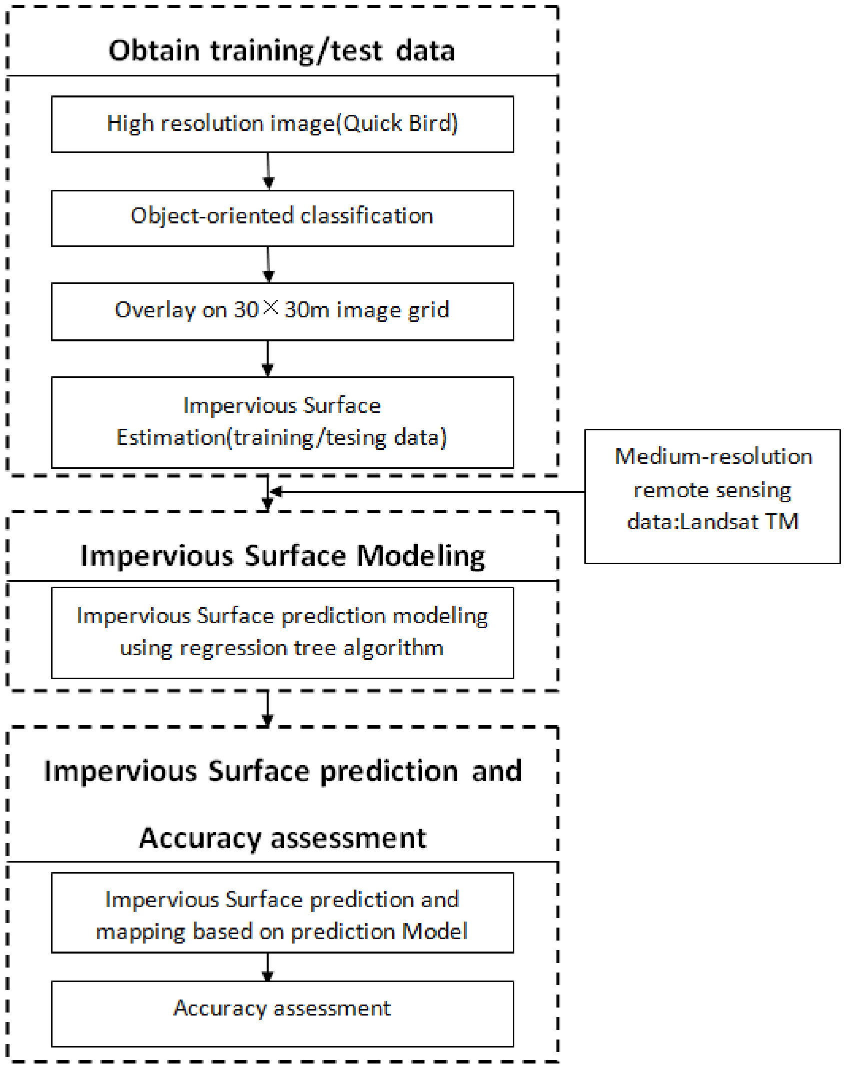


Figure 3. Scheme of impervious surface modelling and mapping synergistic using medium-resolution and high-resolution remote sensing imagery based on the CART

3.2. Obtainment of impervious surface training/test data based on object-oriented classification

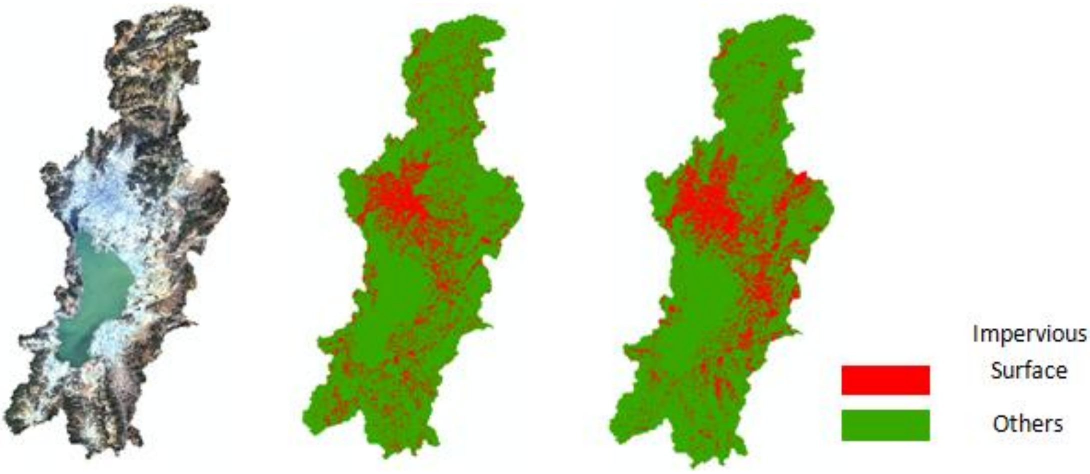
Successful impervious surface modelling with CART algorithm relies on the quality of training/test data. In this study, training/test data were derived form one subset of the 0.61m resolution Quick Bird remote sensing image. The subset area was approximately 8000m by 8000m.Training and test data of impervious surfaces were obtained based on object-oriented classification. Object-oriented classification involves two successive steps[6]: image segmentation and image object classification. The segmentation process in used software eCongnition is a bottom up region merging technique starting with randomly selected one-pixel object. Throughout the segmentation process, some non overlap image objects were created. Each image object was attributed to one of five land cover classes (water, vegetated areas, bare soil, impervious surfaces and shadow).

3.3. Impervious surface modelling and mapping

Impervious surface prediction models were developed based on the CART regression tree algorithm. These impervious surface models used the training data obtained from the high-resolution Quick Bird image as the target variable, and the medium-resolution remote sensing image (Landsat TM image) as predictor variables. The regression tree algorithm produced the final rule-based models to predict impervious surfaces with the most relevant predictor variables and all available training data. Each rule set defined the conditions under which a multivariate linear regression model was established and can account for a nonlinear relationship between predictive and target variables. A regression tree model involved two tasks, feature selection for most relevant input variables and preliminary regression tree modelling. Once the final impervious surfaces prediction models were built, they were applied to all pixels of the medium-resolution remote sensing dataset (Landsat TM) to map basin scale large-area impervious surfaces. In this paper, the regression tress modelling task was accomplished using the Cubist Software.

4. Experimental results and analysis

In this paper, the impervious surfaces prediction models based on the CART algorithm Synergistic using medium-resolution and high-resolution remote sensing imagery. The impervious surfaces prediction models were used to obtain Dianci Basin impervious surfaces. The two algorithms are used in the compared experiment: 1) Maximum Likelihood (ML) algorithm, 2) the classification and regression tree (CART) algorithm. Experiment results are shown in Figure 4. The impervious surfaces classification accuracy of ML and CART are separately 74.25%, 85.6%, the classification accuracy of CART improve 11.35%.



a. Landsat TM image b. ML c. CART

Figure 4. Experiment results

5. Conclusions

In this paper, the impervious surface extraction method of remote sensing in a basin scale is proposed Synergistic using medium-resolution and high-resolution remote sensing imagery. The impervious surfaces prediction models were used to obtain Dianci Basin impervious surfaces. We have obtained imperious surface coverage distributions in the Dianci Basin in the 2010.the experiment results indicate that the CART algorithm has the capability to obtain better result than ML algorithm. The modelling procedure was mostly automated and took only limited computing, we believe that the method is cost-effective and suitable for basin scale large-area imperviousness mapping. Next, we will compare the CART algorithm to other approaches of extracting impervious surfaces (multiple regression, artificial neural network, object-oriented, linear spectral mixture analysis etc). Together with other land surface parameters, such as land use, soil types, and vegetation coverage, we will analyze the spatial and temporal pattern of the land surfaces. Then, combining this data with rainfall, field infiltration, and other relevant data, we will explore the reasons why the water resource in the Dianci Basin changes.

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