

URBAN IMPERVIOUS SURFACE EXTRACTION BASED ON REMOTE SENSING IMAGES

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ABSTRACT:

Urban planning and constructions affect spatial patterns of urban impervious surfaces, which in turn modify the urban environment and affect human-environment interactions. Impervious surfaces can redistribute precipitation patterns, and the perviousness–imperviousness ratio is considered as one important indicator for assessing the degree of urbanization and the quality of urban environment. The spatial distribution and dynamics of impervious surfaces contribute to better understand urbanization and its impacts on regional or urban hydrological environment, surface temperature balance and biodiversity, etc. Hengqin new area is located in Hengqin island, south of Zhuhai city, adjacent to Hong Kong and Macao. It was officially established as a free trade zone in 2009. Due to the rapid development of Hengqin in recent years, this paper discusses Landsat8 imagery of time series in mapping impervious surfaces, and analysis the changes of impervious surface in Hengqin from 2013 to 2018. Support vector machine (SVM) is a classical classifier that is supervised learning models and that use related learning algorithms to analyze data for classification and regression analysis (Vapnik, 1995). In this paper, we obtain the impervious surface distribution via SVM and get good accuracy. The impervious surface distribution of Hengqin in six years show that the quickly improve of urbanization level. However, with the development of urbanization, the impervious surface has not changed dramatically, which shows that the decision-making of urban managers is correct. After the urbanization construction in Hengqin, it is still an ecological island.

1. INTRODUCTION

The urbanization process has led to changes in the natural landscape and climate of the city. With the acceleration of urbanization, the land use types such as farmland, vegetation and water in the city have gradually been replaced by artificial surface (Wenhui et al. 2013). Impervious surface, defined as any surface which water cannot infiltrate, such as highways, parking lots and building rooftops, and so on. As the most significant artificial surface feature of urbanization, impervious surface is the product of the formation and continuous development of human activities in the process of transforming nature (Liu et al, 2014). It has become the most intuitive indicator for studying the degree of urbanization and its development intensity. The large-scale expansion of impervious surfaces has affected the material cycle of urban ecosystems, which has led to a series of ecological problems.

The increase of impervious surface area often takes the cost of reducing vegetation coverage area, which seriously affects the green ecological environment of the city and reduces the restraint of vegetation on urban heat island effect (Coseo and Larsen 2014). Also, the increase of urban surface runoff caused by impervious surface leads to the increase of the frequency of flood disasters and urban waterlogging (Shao et al. 2019). The point source pollution spreads along surface runoff to rivers and lakes, causing water quality to decrease and endangering human health. Moreover, impervious surface materials absorb heat quickly, but have small heat capacity, so under the same solar radiation, the surface temperature of impervious surface is higher than that of natural surface (Ward 2018). In this way, the surface atmospheric conditions will change, leading to the aggravation of urban heat island. Therefore, the change of impervious surface is the main factor that causes the change of ecological environment, such as biogeochemical cycle, landscape dynamics, and heat island effect, etc.

Remote sensing has the advantages of less cost, large coverage, and high temporal resolution. Therefore, remote sensing data has become the basic data source for studying impervious surface extraction and dynamic change monitoring. The dynamic change information of impervious surface has become the basic data needed by urban planning, land resource management, ecological environment monitoring and other industries. This study utilized the Landsat 8 imagery to extract and estimate the percentage of the impervious surface area across the Hengqin new area, Zhuhai City.

2. STUDY AREA

Hengqin new area is located in Hengqin island, south of Zhuhai city, adjacent to Hong Kong and Macao. Hengqin new area is in the south of the tropic of cancer, which belongs to the south subtropical monsoon climate zone. It has abundant sunshine and rainfall. The average annual temperature is 22-23°C, the average annual precipitation is 2,015.9 mm, and the annual water storage is 36.54 million cubic meters. The Hengqin island economy was originally based on traditional agriculture and fishery. It was officially established as a free trade zone in 2009, and its economic scale has gradually grown, forming a development pattern dominated by foreign capital and private economy. With the development of the Hengqin Free Trade Zone, the impervious surface changes have also undergone important changes as an important manifestation of urban development.

In this paper, Landsat images with a cloud coverage of less than 10% and a time span of 2013 to 2018 are used for impervious surface extraction studies. These images were downloaded from the USGS Earth Explorer with a strip number of 122, 45. The location of the study area is shown in the figure below. The map in the figure is a false color synthesis of the Landsat 5 image band 5, Band 4 and Band 3 on February 22, 2018.

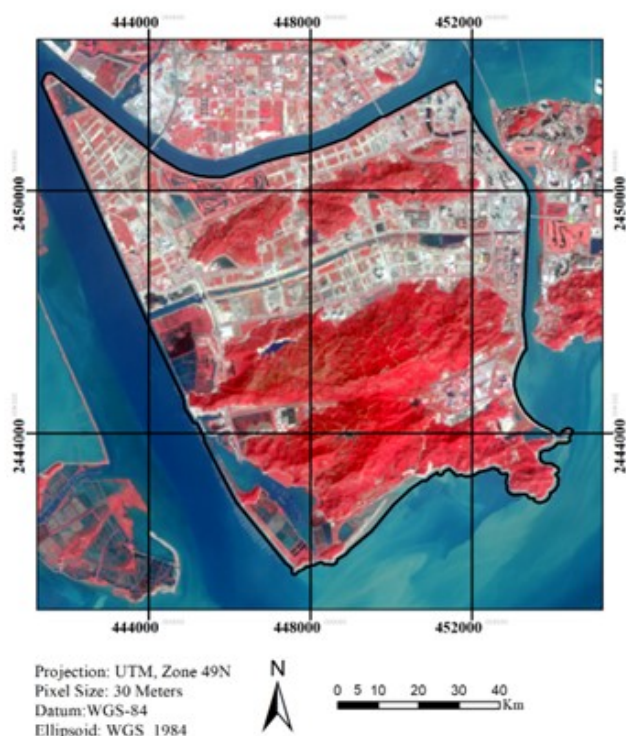


Figure 1. Landsat image of Hengqin area

The imagery are acquired from USGS Earth Explorer for impervious surface extraction as follows: November 29, 2013; November 16, 2014; January 3, 2015; September 18, 2016; October 23, 2017; February 22, 2018.



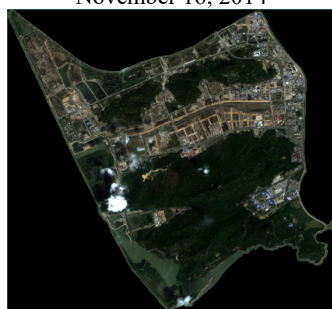
November 29, 2013



November 16, 2014



January 3, 2015



September 18, 2016



October 23, 2017



February 22, 2018

Fig 2. Landsat image of Hengqin new area from 2013 to 2018

3. METHODOLOGY

The Landsat imagery spatial resolution is 30 meters and was rectified to the UTM projection system (ellipsoid WGS84, datum WGS84, zone 49) using ENVI 5.3 software.

In machine learning, SVMs are supervised learning models that use related learning algorithms to analyze data for classification and regression analysis (Vapnik, 1995). Given a set of training examples, each of which is marked as belonging to one or the other of the two categories, the SVM training algorithm builds a model, assigning a new example to one category or another, making it non-probabilistic Binary linear classifiers (although there are methods such as platt scaling that use SVM in probabilistic classification settings). The SVM model is to represent the examples as points in space and map them to divide the example of the individual categories by the widest possible gap (Vapnik, 1995). The new examples are then mapped into the same space and predicted to belong to a category based on the margins they were in when they were dropped. In addition to performing linear classification, SVMs can efficiently perform nonlinear classification using so-called kernel techniques, implicitly mapping inputs to high-dimensional feature spaces.

The emphasis and objective of this paper is on classification of impervious surfaces from Landsat8 imagery of Hengqin new area. In this study, because of the medium spatial resolution of imagery, there are only three land cover types to classify: impervious surface, non-impervious surface and water. The classification use supervised classifier: support vector machine to extract the impervious surface in Landsat imagery.

Results and discussion

In the classification, we use radical basis function as the kernel type, with parameter $\gamma = 0.250$, penalty parameter is 100. The overall classification accuracies and kappa coefficients are shown in the table 1.

Year	2013	2014	2015	2016	2017	2018
OA	99.4%	99.2%	97.4%	93.9%	99.9%	96.7%
Kappa	0.991	0.987	0.959	0.906	0.998	0.950
	0	6	0	1	0	0

Table 1. The overall accuracies and kappa coefficients of SVM classification from 2013 to 2018.

Figure.3 shows the variation of the spatial distribution of impervious surface in Hengqin new area from 2013 to 2018.

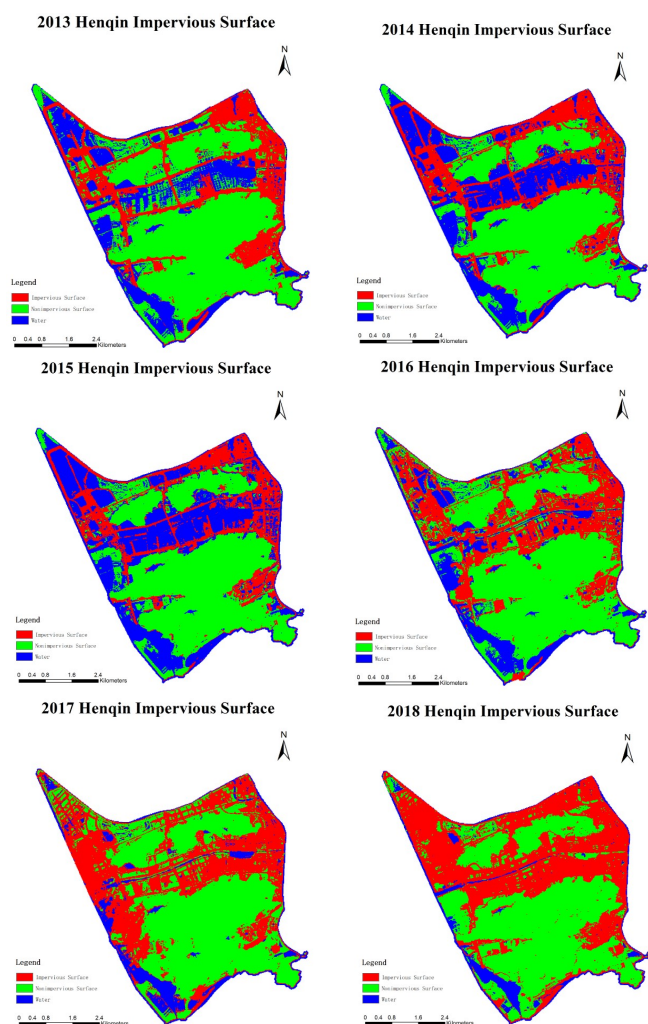


Figure 3. Variation of the spatial distribution of impervious surface in Hengqin new area from 2013 to 2018

As can be seen from the figure, the proportion of impervious surface in Hengqin area has increased year by year, from 26.5% in 2013 to 44.8% in 2018, an increase of 18.3%. Since the establishment of the Hengqin island in 2009 as a free trade zone, urbanization has developed rapidly. With the successive opening of the Hengqin Bridge and the Lotus Bridge, Hengqin island has been integrated with Zhuhai City and Macau, becoming the second land route to the mainland. Hengqin new area is the intersection of Guangzhou and Jiangzhu Expressway. These trunk lines will be connected to Macao through Hengqin new area, and the distribution of impervious surfaces will gradually expand.

The development of Hengqin new area is aimed at building an “ecological island”. Accelerate the transformation of economic growth mode and promote sustainable development. In addition, the government built Hengqin new area into an “eco-island” with resource conservation and environmental friendliness; strengthen resource intensive use, shape livable space, and build Hengqin new area into ecologically superior and smart growth. Therefore, while the impervious surface is growing, the proportion of non-impermeable surfaces has only decreased by 3.9% from 52.3% in 2013 to 48.4% in 2018. However, as can be seen from figure 3, the paddy fields in the central part of Hengqin new area have been transformed into various parks, and the ecological and environmental protection are also emphasized in the transformation.

From the impervious surface extraction results, we can see that the paddy field between the size and the Hengqin Mountain was gradually filled in 2016. Combining the development policy of Hengqin, the filled area was for construction of the science and technology research and development zone, the cultural and creative zone and the comprehensive service zone. From figure2 and figure3, the tidal flat wetland in the northwest corner is protected while the development. The wetland was built as a wetland park, and the paddy field is partially filled into a high-tech industrial zone. Develop environmentally friendly tourism services, strictly control the scale of development, and protect and restore the diverse ecological landscape around the central ditch. Urban construction in the ecological construction area should emphasize the principle of “unified planning, rational distribution, fragmentation development, and distribution implementation” to maintain the coordinated development of the city and the natural environment. Due to the development from 2013 to 2018, while the proportion of impervious surface in Hengqin new area increased while non-impervious surface did not decrease sharply. The results indicate that, environmental protection was emphasized while the urban development. It is mainly to landfill and utilize the paddy fields on the island to protect the original vegetation and wetlands as much as possible, and to carry out urban development planning. As can be seen from Table 2, from 2013 to 2018, water decreased from 21.2% to 6.8%, and the impervious surface increased from 26.5% to 44.8%.

Percentage	2013	2014	2015	2016	2017	2018
Impervious Surface	26.5 %	26.2 %	22.0 %	30.4 %	39.5 %	44.8 %
Non-Impervious Surface	52.3 %	46.7 %	44.9 %	52.8 %	50.7 %	48.4 %
Water	21.2 %	27.1 %	33.1 %	16.8 %	9.8 %	6.8 %

Table 2. The percentage of land cover in Hengqin area from 2013 to 2018

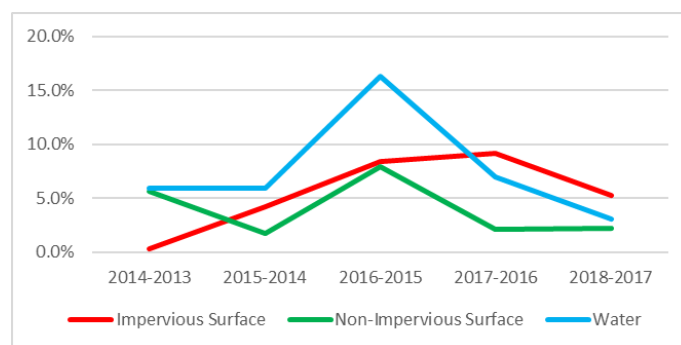


Figure 4. The change rate of land use percentage in Hengqin New Area 2013-2018

As can be seen from Figure 4, in 2015-2016, the percentage of water reduction was the largest, and the corresponding non-impervious surface and impervious surface increased accordingly. It shows that while the Hengqin new area is filling the construction of the “sea” land, the ecological protection of the city is also vigorously carried out. The impervious growth rate of 2017-2018 is 5.3% compared to the growth rate of 9.1% in 2016-2017, and the growth rate of 8.4% in 2015-2016 has decreased. The construction of the basic city of Hengqin new area has been completed.

4. CONCLUSION

In this paper, we use the Landsat 8 30-meter spatial resolution image from 2013 to 2018 to obtain the spatial distribution of impervious surface based on SVM classification, and then obtain the change information of the impervious surface distribution from 2013 to 2018 through comparative analysis. According to the impervious surface extraction results, we analyze the relationship between the urbanization process and the change of land cover types since the establishment of the free trade zone in Hengqin new area. In the two years from 2015 to 2017, the Hengqin new area was built rapidly, and the proportion of impervious surfaces increased sharply. At the same time, the proportion of water is correspondingly reduced due to the transformation of the internal paddy field of Hengqin island into commercial land. However, in the development of the past two years, the proportion of non-impervious surface has not decreased due to the construction of the city, which shows that the government carried out the environmentally friendly development in Hengqin new area.

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