Land use/cover change and the urbanization process in the Wuhan city.

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Abstract

Urbanization has become a very common phenomenon, especially in the developing countries. Although urbanization brings economic development, rapid urban expansion will bring many environmental problems, including the occupation of vegetation, the area of arable land, the disruption of ecological balance and the potential impact on human health. China, as one of the biggest developing countries, has been rapidly urbanizing since 1980s. This study analyzed the land use/cover change and the urbanization process from 1990 to 2020 in Wuhan, the largest city in Central China. In this study, the ground features are classified into urban, water, bare and vegetation. The unsupervised classification and the supervised classification are both be used to the land cover/use detection. The results indicated that Wuhan has a high rate of urbanization with the urban area expanding 3-4 times during the 30 years, the change of water resources was the least during the 30 years. Due to the rapid development of urbanization, the area of bare and vegetation decreased. In addition, the trend of different ground features changes also are different in different time periods.

Key words: Land use/cover change; Urbanization;

Introduction

Background

With the quickly development of economic, China has witnessed rapid urbanization since the reform and opening-up in early 1980s (Han, Zhou, Li, & Li, 2014). Urbanization is the process of rural population moving towards the cities, which will cause some natural land cover types including forests, lakes, agriculture areas to shift to urban land (Sun, Chen, Niu, & Trinder, 2016). Urbanization has become a universal phenomenon all over the world. The United Nations predicts that global population growth will be concentrated in urban areas of developing countries through rural-urban migration. Since the 1980s, China’s urban population has grown from 140 million in

1970 to 710 million in 2012 (National Bureau of Statistics, 2013). While urbanization will bring economic development, it will also lead to a series of environmental issues (Wang, Ma, & Zhao, 2014). For instance, the high speed of urbanization may influence the regional climate, ecosystem balance and hydrological characteristics (Haregeweyn, Fikadu, Tsunekawa, Tsubo, & Meshesha, 2012). Furthermore, the highly concentrated urban areas will result in the urban heat island, which will not only affect the ecological environment, but also bring hidden dangers to human health (Macintyre et al., 2018). However, especially in developing countries, there is still a huge influx of rural people into cities, pushing urban sprawl. It has become a global concern to assess the ecological effects of urbanization and mitigate its negative effects (Zhang et al., 2018). Therefore, it is significant to monitor the urbanization process in the area of sustainable development.

One of the influences linked to man-made disturbances is cause the changes of land use/cover (Yin et al., 2011). The main characteristic of the land use/cover change during the last 300 years are the decrease of forest and the expansion of agricultural land (Yin et al., 2011). In the past ten years, the increase of the urban areas is the main form of land use/cover changes, especially in the developing countries (Yin et al., 2011). Therefore, it is an effective and timely way to monitor the urbanization process according to the land use/cover change. Remote sensing techniques have been widely used in monitoring changes in ground features (Chen, Wang, Li, & Li, 2015). Satellite remote sensing has the characteristics of wide coverage and fixed orbit period, which is an effective method to monitor the urban environment (Michishita, Jiang, & Xu, 2012).

Wuhan, as the biggest developing city in Central China and the seventh most populous city in China, is a very representative place in terms of the urbanization process (Sun, Chen, Niu, & Trinder, 2016). Urbanization in Wuhan began at a rapid pace about twenty years ago, the rapidly urban sprawl has made a significant change to Wuhan natural environment and caused widespread environmental degradation (Zhang et al., 2018). From 1991 to 2020, the population in Wuhan increased by 60.4%; in 2020, The urbanization rate of permanent resident population in Wuhan has reached 80.5% (data obtained from Wuhan Statistical Yearbook in 1991 and 2020), which means Wuhan is already a highly urbanized city. In addition, the urban distribution of Wuhan is also very characteristic. According to the statistical, Wuhan has a total of 166 natural lakes, as well as rivers, the Yangtze River, the Han River and other rivers. The water area of Wuhan accounts for one quarter of Wuhan's municipal area, and the per capita level of water resources in Wuhan is forty times the average of the whole China (data obtained from Master Plan for Lake Protection in Wuhan, 2018). However, due to the urban sprawl, more and more lakes in Wuhan are disappearing as people fill them up to get more urban land (Chen, Wang, Li, & Li, 2015). Urban lakes play an important role in maintaining urban ecosystem (Chen, Wang, Li, & Li, 2015). Wuhan's government has drawn up a number of plans to mitigate the adverse effects of urbanization (Zhang et al., 2018).

Due to the rapid urbanization process and the unique characteristics of the urban ecological environment in Wuhan, it is of great significance to study the urbanization development and ground features change in Wuhan. As a very representative city with many lakes, there are many researches focus on the process of Wuhan urbanization. For instance, some studies focus on the influence mechanism of human activities on lake changes in Wuhan, concluded that increasing population and urbanization are believed to be the main driving forces for the decline of lake ecosystems (Chen, Wang, Li, & Li, 2015). Furthermore, some studies focus on the urbanization process of Wuhan from the perspective of the urban lakes’ water ecological carrying capacity (Ding, Chen, Cheng, & Wang, 2015). However, although many studies have been conducted on the relationship between the lakes in Wuhan and urbanization, few of them have analyzed the influence of the combined action of other surface features except lakes on the urbanization of Wuhan.

Literature review

Wuhan city is the provincial capital of Hubei Province and the central megalopolis of China, it is situated in the east of the Hanjiang Plain and the geographical position is 29°58'-31°22' north latitude and 113°41'-115°05' east longitude. The terrain of Wuhan is low and flat in the middle, with hills and ridges in the north and south. The altitude ranges from 19.2 meters to 873.7 meters. Wuhan has a northern subtropical monsoon climate, which has the characteristics of abundant rainfall and sufficient heat; meanwhile, it is cold in winter and hot in summer. Its total area is is 8569.15 square kilometers and water area cover the quanter of the total. As the middle reaches of the Yangtze River run through Wuhan, its tributary consistituded a network which makes Wuhan developed into the biggest water transportation junction in the hinterland of China.

Due to Wuhan's superior geographical location, Wuhan city has developed rapidly in two decades, and its population and economy have increased substantially. The a plenty of population transformed form rural to urban and urban population increased. As a result, Wuhan's land use has changed greatly, the expansion of urban area replaced rural area. This change is closely related to Wuhan's urbanization and has a certain impact on Wuhan's ecosystem and urban development. Therefore, we will discuss the changes in land use and the process of urbanization in Wuhan.

In this study, urbanization procedure is evaluated according to the 17 United Nation's Sustainable Development Goals (SDGs). To achieve further city development, the planning of urbanization in Wuhan should be conducted under the framework of SDGs. Monitoring the land cover and land use has a significant meaning in achieving SDG goals. The goal 11 implemented in 2015, asking for "safe, resilient and sustainable" living surroundings for human beings (Sietchiping el al., 2016), is supposed to be the fundamental principal of the city construction of Wuhan with the process of urbanization. For example, one of the indicators 11.3.1 "Ratio of land consumption rate to population growth rate" intends to measure the urbanization appropriateness by analyzing census data and land cover and land use change (Mudau el at., 2020). Futhermore, Wuhan’s urbanization process contributes to SDG 11 and meets the targets. From 1991 to 2020, Wuhan has developed a habitable environment as a developing city. The expansion of urban area is used in building roads and commercial zone. It solved inaccessible transport issue, enhanced economy and improved employment rate for people who lives in Wuhan (Tan, 2016).

However, it is inevitable that urbanization will result in varying degree of deterioration of some land cover and land use. For instance, it is reported that Wuhan’s water area, which can regulate climate and provide fresh water, has reduced dramatically during the past 30 years (Sun et al., 2016). During the urbanization, Wuhan’s lake degrades partly, especially the small lake and the lake located in remote area (Zhiwen Liu et al., 2021). This deterioration causes a conflict between urbanization and the SDG target 6 “protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes”, and aggrevates the Urban Heat Island (UHI) phenomenon in Wuhan. In the light of these potential adverse impacts due to urbanization, it is significant for policy makers and the government to balance urbanization and sustainability in the long term based on SDGs (Al-Zu'bi, & Radovic, 2018). As the one of the object cities of the global sustainable development city, Wuhan is chosen by the United Nations Development Programme (UNDP) and the United Nations Environment Programme (UNEP) for the research of China landuse and land cover change (Xiangmei Li et al., 2016). Therefore, it is significant to monitor the land cover change and the urbanization process in the area of sustainable development.

In terms of types of analysis proposed by other researchers and justification of our analysis choice. The article “Analysis of urbanization dynamics in mainland China using pixel-based night-time light trajectories from 1992 to 2013” introduced the characteristic of Chinese urban development occurred recently. In the article “Characterization and spatial modeling of urban sprawl in the Wuhan Metropolitan Area, China”, in order to explore the relationship between urban sprawl and the loss of

cultivated land in China, Chen Zeng et al. used supervised classification to monitor the land cover/use changes (Zeng et al., 2015) t. Chen Zeng et al. chose Landsat data in this study and defined land cover/use into four land cover/use classes, “built-up land”, “vegetation”, “water”, and “forest”, by the maximum likelihood classifier (MLC) in supervised classification. Then they used the latest interpretation of the build-up land map as a reference to corrected the first classified images manually. At the same time, relatively new SPOT images are also used to rectify the classification result. Finally the Wuhan’s Metropolitan area and cultivated land area are confirmed.
J. Yin et al. studied the land cover/use changes in Shanghai, China, by using a maximum likelihood supervised classification algorithm (Yin et al., 2010). They used Landsat images as materials, and classified Shanghai’s land cover/use into five land cover/use classes, urban/built-up areas, water, farmland, green land, and bare land. Then they used Shanghai’s aerial photographs and field data to help with the assessment of accuracy of the classification. The final accuracy is acceptable according to the standards recommended (Lucas et al.,1994).

Supervised classification is also used in the research of land cover/use changes of Gilgit River Basin, which is conducted by K. Ali et al. in “Analyzing Land Cover Change Using Remote Sensing and GIS: A Case Study of Gilgit River Basin, North Pakistan” (K. Ali et al., 2019). For the purpose of monitoring the ecological vulnerability caused by the land cover/use changes, Ali et al. selected Landsat data and use a MLC classification in ERDAS. They eventually defined five land cover classes including range land, glacier/debris, water bodies, residential/agricultural and barren land, and the result achieved a standard Kappa statistic.

Some studies have adopted the method of unsupervised classification in image classification. The article “Analysis of urbanization dynamics in mainland China using pixel-based night-time light trajectories from 1992 to 2013” introduced the characteristic of Chinese urban development occurred recently. In this study, Ju. Y et al. extracted night-time light (NTL) trajectories based on pixels and time-series, then classified all the trajectories into finite classes by implementing the k-means unsupervised classification. Ju. Y et al. In the classification, the investigators tested the coefficient relevance in each number of classes. It showed when two classes coefficient performed best; however, the number of classes did not conform to the real land cover/use situation. Therefore, Ju. Y et al. chose the second highest coefficient classification, which had five classes in NTL trajectories, which are stable urban activity, high-level steady growth, acceleration, low-level steady growth, and fluctuation. After the first-time classification, to eliminate the dependence of results on the original mean center allocation and acquire an optimal classification result globally, Ju. Y et al. generated the classification tautologically in 10 times.

After studying the previous research methods and referring to the results obtained by the previous researchers, in this study, we chose the following methods. Supervised classification, Maximum Likelihood Algorithm, and unsupervised classification, K-Mean clustering. We classified Wuhan's land cover/use into the four classes, which are (1)urban, (2) water, (3)bare, and (4)vegetation.

Research question and objectives

Urbanization can have an profound impact on characteristics of landscape and land covers (Li et al., 2006). Moreover, rapid urbanization result in rapid change of land covers that can lead to serious environmental deterioration in urban areas (Sun et al., 2016). Therefore, to contribute to sustainable development goals, it is necessary for urban planners to take measures to examine the process of urbanization. In fact, not only has urban expansion arouse people's attention in the sustainable development management but also it is a hot topic in the fields of geographical information science and remote sensing techniques (Cheng & Masser, 2003). By using multi-temporal satellite images provided by digital change detection techniques, landscapes dynamics can be examined in depth (Rawat & Kumar, 2015).In terms of this paper, the research is intended to study the process and progress of urbanization in Wuhan city using remote sensing techniques, and find out the change of patterns of several land covers (vegetation, agriculture, waterbody, and urban areas) along with the process of urbanization. Therefore, the research question of this study would be: to what extent has the process of urbanization been by quantifying the changes of five land covers (vegetation, agriculture, waterbody, urban areas, and construction land) from 1990 to 2020 ?

Several objectives are aimed to achieve in this research, and will be illustrated in detail in this paragraph. First of all, the research paper will illustrate the spatio-temporal dynamics of land cover/use in Wuhan city which is related to the process of urbanization. The images of study area will be classified as mainly five parts namely urban areas, vegetation, agriculture, and water body by using supervised classification with MLC in PCI Geomatica and unsupervised classification with K-means. The changes of these land covers will be quantified over a 30-year period by performing pixels based comparison and creating change matrix. In addition, the impacts of urbanization on these land covers will be characterized in this study. It is significant to explore the potential detrimental impacts that urbanization has on vegetation, agriculture land and water body individually. Moreover, some potential useful suggestions will be provided to lower the risks of environmental degradation and prioritized the economic benefit along with this unavoidable trend of urban construction and expansion. To conclude, due to the rapid urbanization process and the unique characteristics of urban ecological environment in Wuhan, it is of great significance to study the urbanization development and ground features change in Wuhan. Therefore, the purpose of this study are: (1) to calculate the rate of urbanization in Wuhan city from 1990 to 2020 and (2) to analyze the land use/cover change and the urban sprawl in Wuhan city from 1990 to 2020 and (3) advise on the future development trend of urbanization in Wuhan.

Method

Study Area

Figure 1 Map of Wuhan

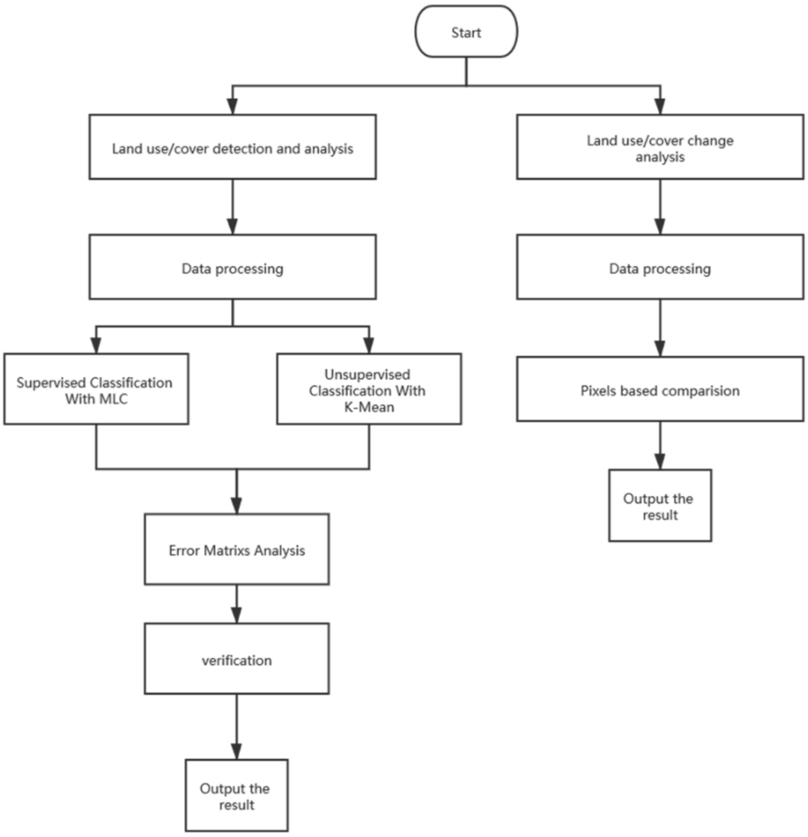
The study area of this project is Wuhan City, Hubei Province, China. Wuhan is the capital of Hubei Province, located in the hinterland of China. With an area of 8569.15 square kilometers, Wuhan is located between 113° 41'E -115° 05'E, 29° 58'N -31° 22'N, with a permanent population of 11,212,200. Wuhan is a transitional area from the southeastern hills of Hubei Province through the eastern margin of the Hanjiang Plain to the southern foothills of the Dabie Mountains. It is low and flat in the middle, surrounded by hills and ridges in the north and south, and lined with low mountains in the north. In terms of climate, Wuhan belongs to the north subtropical monsoon climate, the annual average temperature is 15.8°C to 17.5°C, and the annual precipitation is 1150 mm to 1450 mm. The rainfall is concentrated from June to August each year, accounting for about 40% of the annual rainfall. In terms of hydrology, the Yangtze River and the Han River intersect in the center of Wuhan, and 166 lakes are distributed in all parts of the city. In terms of land, there are 8 soil types and 17 subspecies in Wuhan, among which 45.5 are paddy soil. In terms of vegetation, the flora of Wuhan is a transitional zone from subtropical evergreen broad-leaved forest to northern subtropical deciduous broad-leaved forest, and the main vegetation types are mixed forests composed of evergreen broad-leaved forest and deciduous broad-leaved forest. In recent years, Wuhan has developed rapidly. With the acceleration of urbanization, a large area of farmland and vegetation covered area has been requisitioned, and the land use type has changed significantly.

Data

Based on the land use/cover monitoring analysis done by Rawat and Kumar in the Almora, Uttarakhand, India. (2015), this project uses the collection 2 Level-1 data of Landsat 4-5 TM and Landsat 8 OLI/TIRS for land use/cover classification. The data are obtained from USGS earth explorer site (http://earthexplorer.usgs.gov/). As we are aiming at detecting the land/use cover change and urbanization process between 1990 and 2020, we choose the begin, end and middle of this time period (1990, 2005 and 2020) as three time point, and classify the Landsat images of this three years.

In the process of selecting data, we find two issues. The first is that according to the WRS2 system of Landsat, Wuhan stretches over more than one images. In fact, Wuhan stretches over three images, which are WRS2 path 123 row 39, WRS2 path 123 row 38, WRS2 path 122 row 39. They are not captured by the satellites by the same time, but if the time among them is too long, the land use/cover may not keep the same. The second is that many images have clouds, which will greatly decrease the reliability of the classification result. As we tried to remove the clouds but have little effect, we decide to choose images with few clouds. So, our finally rules of selecting image are:1. there are few clouds on the images to cover Wuhan, and 2. time between three images are not two long. (This leads to the result that images in some years are captured in different season, but as the season do not have big impact on urban land cover, we do not regard it as a big issue).

Analysis



In this project, two analysis are preformed, which are Land use/cover detection and analysis, and Land use/cover change analysis. In the Land use/cover detection and analysis, we classify the collected Landsat images to into urban, vegetation, bare and waterbody and detect the distribution of these four kinds of land use/cover. In the Land use/cover change analysis, we use the classification result to study proportion change of these four land use/cover types from 1990 to 2020. Among the proportion of these types, the proportion of urban is regarded as urbanization rate, which is what we are most concerned. The change of urbanization rate reflects the urbanization process of Wuhan.

For the Land use/cover detection and analysis, the processing of the collected Landsat data should be done previously. As is illustrated previously, Wuhan usually stretches over three Landsat images. Among remote different kinds of sensing and photogrammetry software that are able to process earth observation data, PCI Geomatica is able to process images using existing and new aerial-processing technology (PCI Geomatica, n.d.), and is proved to be a reliable software in the use at past. So, we choose PCI Geomatica as the software to process the images. With the mosaic tool in PCI Geomatica, three images are merged together. And using the Clipping/Subsetting tool and Wuhan boarder shapefile boundary, the study area can be delimited. To preview the images, we create false color composite for these images by changing the RGB to near-infrared, red and Green. The false color composite can briefly tell the land use/cover types distribution in Wuhan.

In this project, we decide to use a supervised classification and an unsupervised classification. Varity classification methods are employed by researchers to classify remote sensing images around the world, and they have different advantage and disadvantage. Among them, machine learning is a kind of algorithm that fetches the information, finds out patterns and improves prediction accuracy by repeated learning from training data, and has been employed to many land cover classification-based researches such as Multiple Criteria for Evaluating Machine Learning Algorithms for Land Cover Classification from Satellite Data done by DeFries and Chan (2020). But when trying to employ machine learning into our project, we find out that machine learning has a high requirement for the computer configuration, which we cannot meet. So, we have to try other methods.

Based on K-means algorithm classification on urban landscapes done by Lemenkova in Taipei area, Taiwan (2013), and Land use classification and change detection done by IsLam etc. in Chunati wildlife sanctuary, Bangladesh (2013), we decided to employed K-means clustering as the unsupervised classification methods and Maximum likelihood algorithm as the supervised classification. As an iterative algorithm, K-means clustering tries to divide the dataset (pixels in the images) into K distinct non-overlapping subgroups. It maximum the similarity among intra-cluster data and the difference among the clusters (Dabbura, 2018). Maximum likelihood classification is one of the statistical classification methods that is the most widely used (Le, L., 1990). Maximum likelihood classification makes an assumption that the statistics for each class in bands follow normal distribution and based on that, the probability that a given pixel belongs to a certain class are calculated

(L3Harris Geospatial, n.d.). Pixels are assigned to the most possible class. And if a threshold is set, the pixels whose highest probability is lower than the threshold not be assigned to any classes. PCI Geomatica has the function to achieve K-mean clustering and MLC classification, and their requirement to computer configuration is acceptable for us, so these two methods are suitable for the project.

After the images are calculated by K-mean clustering and MLC, the preliminary pixel classification results can be obtained. In order to ensure the reliability of data and obtain better classification results, the error matrixes are established and used as a reference for classification reliability. And the land use/cover classification maps are made based on the verified data to show the classification results.

For the land use/cover change analysis, we employed pixel-based comparison to the classification results. By checking the attribute tables of the classification result, we can check the total area of the pixels that has the same pixel value. The data should be processed previously to match the pixel value with corresponding land use/cover type. Then, the proportion of these land use/cover types can be calculated. By comparing these proportion between these three years, land use/cover change in Wuhan could be analyzed.

3. Result

This research is based on three sets of Landsat remote sensing images taken in 1990, 2005, and 2020.After the correction, Mosaic and cropping of the three groups of images, three remote sensing satellite images of Wuhan in different time are obtained. Then, the K-Means classification and Maximum Likelihood classification (MLC) are used to classify the land cover types in Wuhan City, and the final results are obtained. In this experiment, the land types in Wuhan were divided into four categories, namely water, bare, vegetation and urban.

3.1 Result of 1990

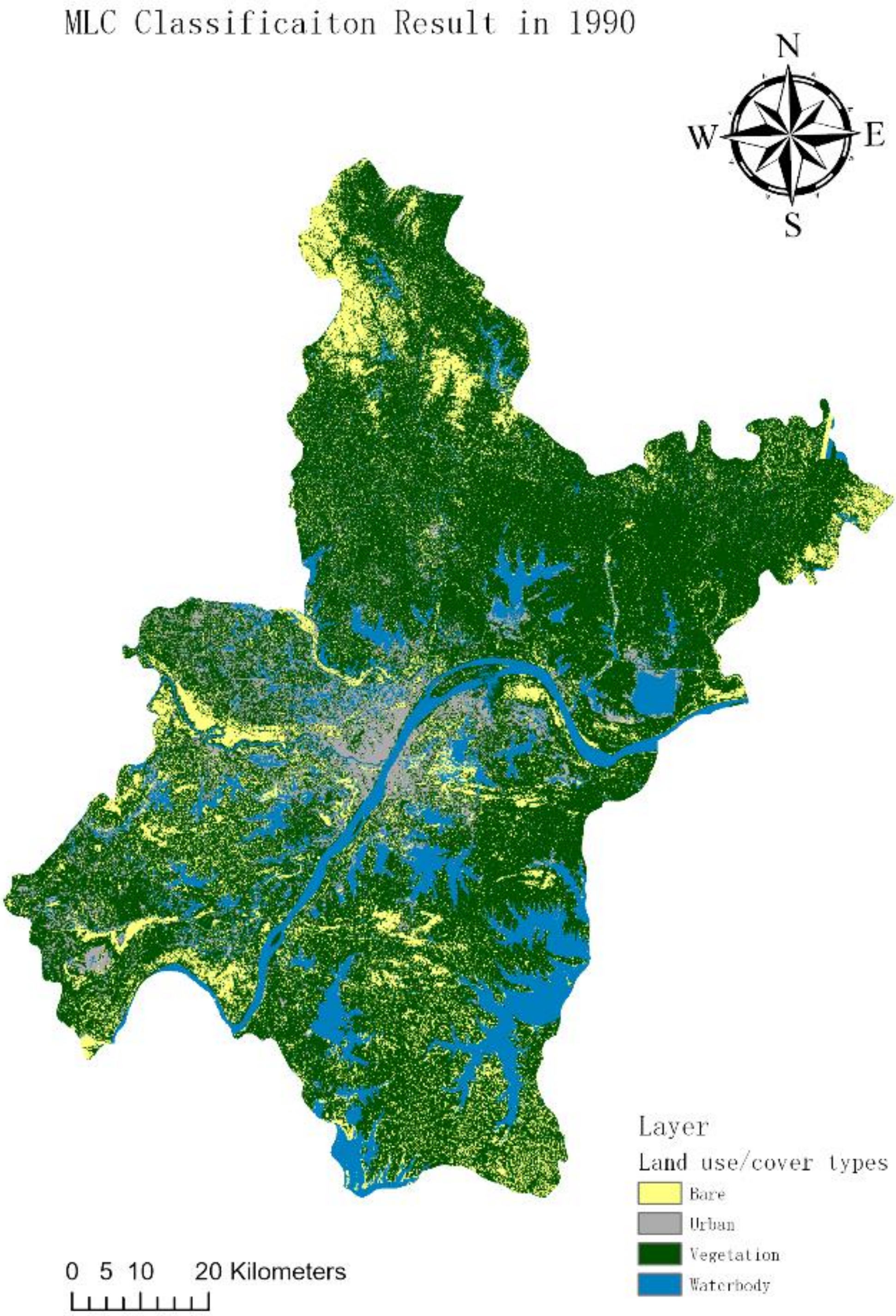


Figure 3.1.1 MLC Classification Result in 1990

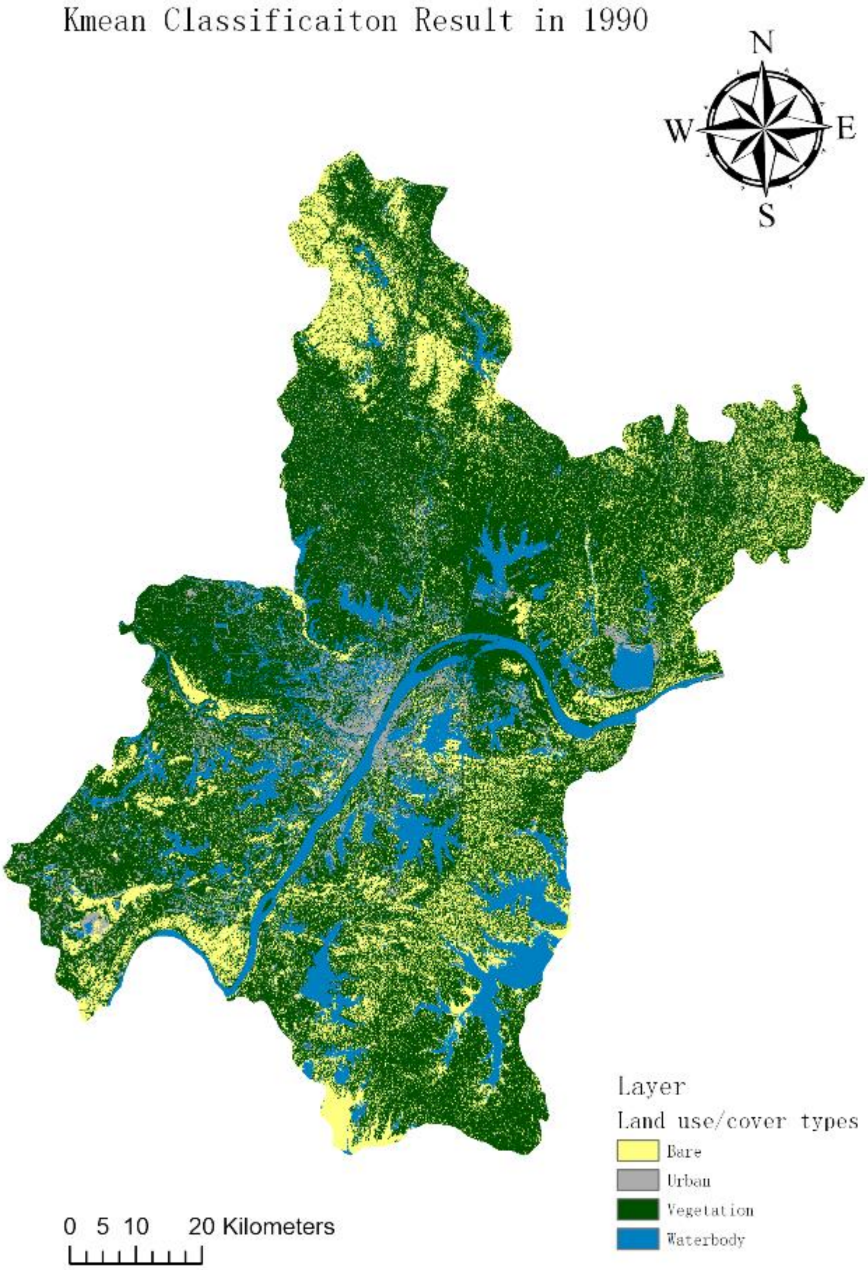


Figure 3.1.2 K-Means Classification Result in 1990

	MLC	**K-Means (%)**
Urban	9.39%	7.65%
Water	13.26%	13.61%
Bare	62.88%	58.70%
Vegetation	14.47%	20.05%

Table 3.1.1 Classification results of land cover percentage in Wuhan, 1990

The classification results of Wuhan's land cover percentage in 1990 using MLC and K-means are shown in Figure 3.1.1 and Figure 3.1.2. Based on the results of the two classification methods, the coverage percentages of the four land types can be obtained after calculation, as shown in Table 3.1.1. The photo taken in 1990 was taken in December, 1990, in the winter of Wuhan, so the vegetation coverage was relatively low, accounting for only 9.39% and 7.65% in the two classification methods. On the contrary, bare land was higher, reaching 62.88% and 58.70%. In addition, in the results of the two classification methods, the water coverage is very close, 13.26% and 13.61% respectively. At this time, the urban area of Wuhan is small, which does not exceed 21% in either of the two classification methods, accounting for only 14.47% and 20.05 respectively.

3.2 Result of 2005

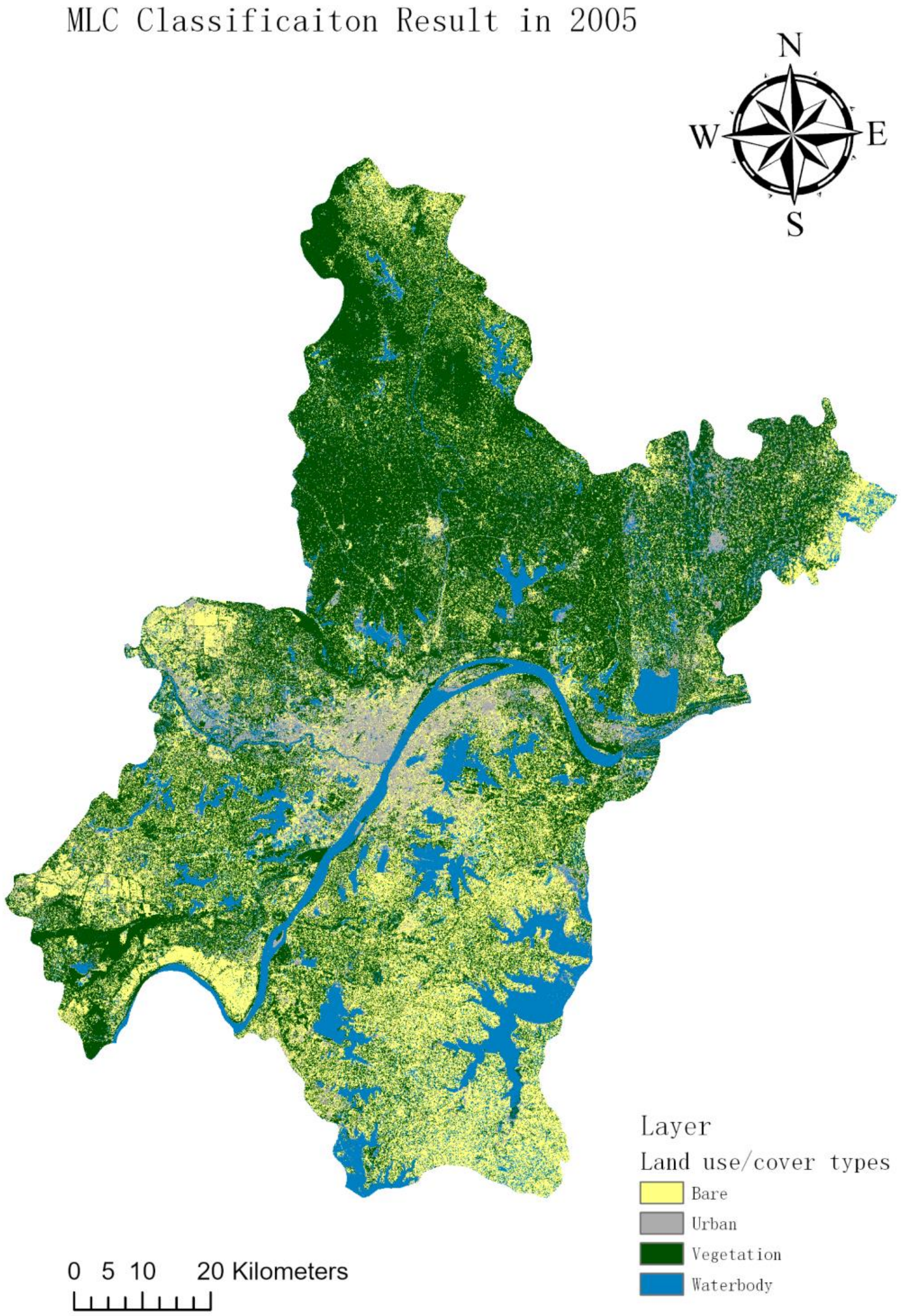


Figure 3.2.1 MLC Classification Result in 2005

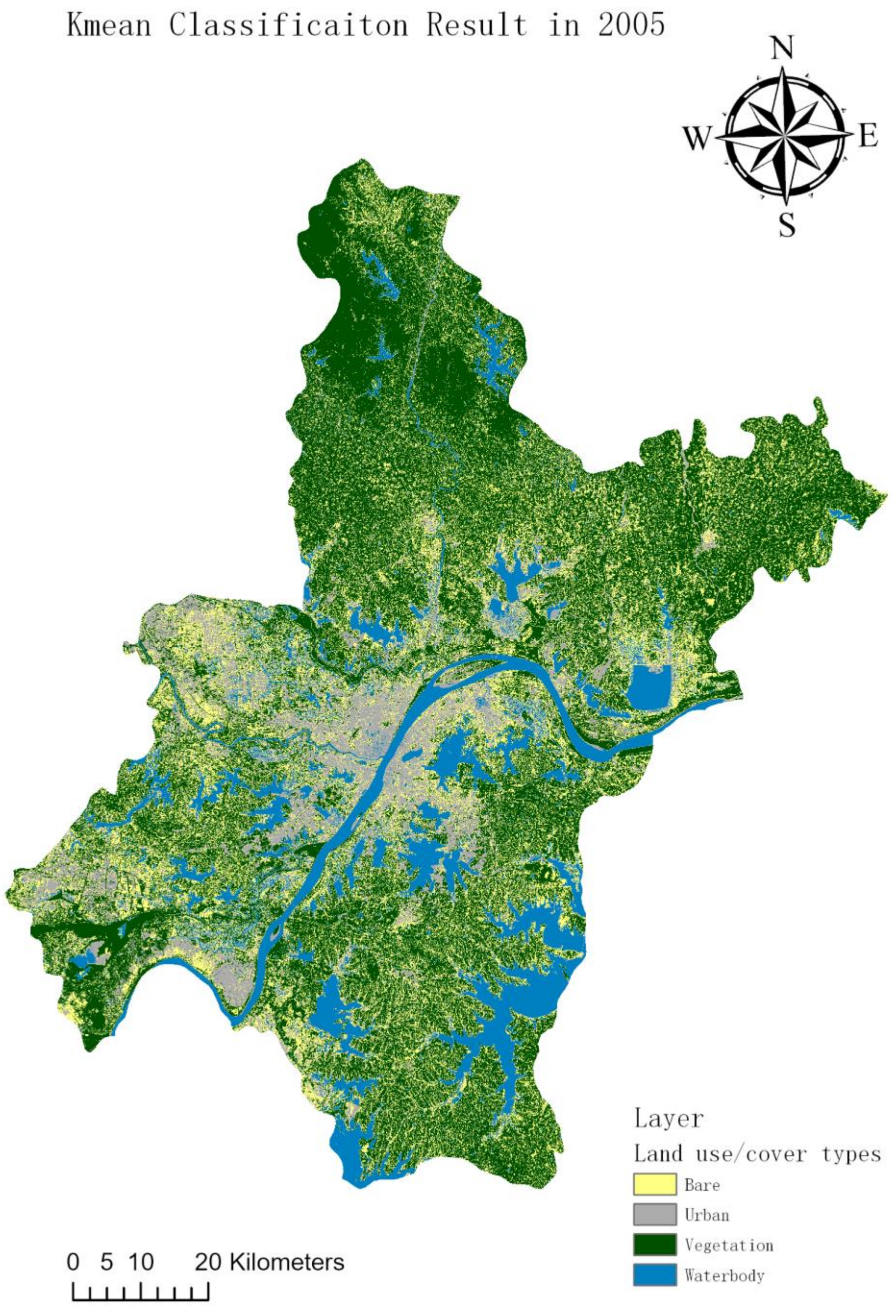


Figure 3.2.2 K-Means Classification Result in 2005

	MLC	**K-Means**
Urban	10.96%	13.40%
Water	8.29%	13.25%
Bare	31.18%	24.86%
Vegetation	49.57%	48.49%

Table 3.2.1 Classification results of land cover percentage in Wuhan, 2005

The classification results of land cover percentages in Wuhan in 2005 using MLC and K-means are shown in Figure 3.2.1 and Figure 3.2.2, and the coverage percentages of the four land types are shown in Table 3.2.1. In 2005, the area of Wuhan urban area increased to a certain extent, and the results of the two classification methods were 10.96% and 12.40% respectively, which expanded by about 1.5% and 5.8% compared with 1990, respectively. At this time, the undeveloped area of Wuhan accounted for about 86% to 89%. Since the 2005 image was taken in summer, the vegetation coverage was relatively high, accounting for 49.57% and 48.59% respectively in the two classification methods. In addition, the bare land coverage rate is 31.18% and 24.86%. There are some differences in the water coverage rates calculated by the two classification methods, 8.29 percent and 13.25 percent respectively, which may be caused by some degree of degradation of Wuhan's lakes and rivers.

3.3 Result of 2020

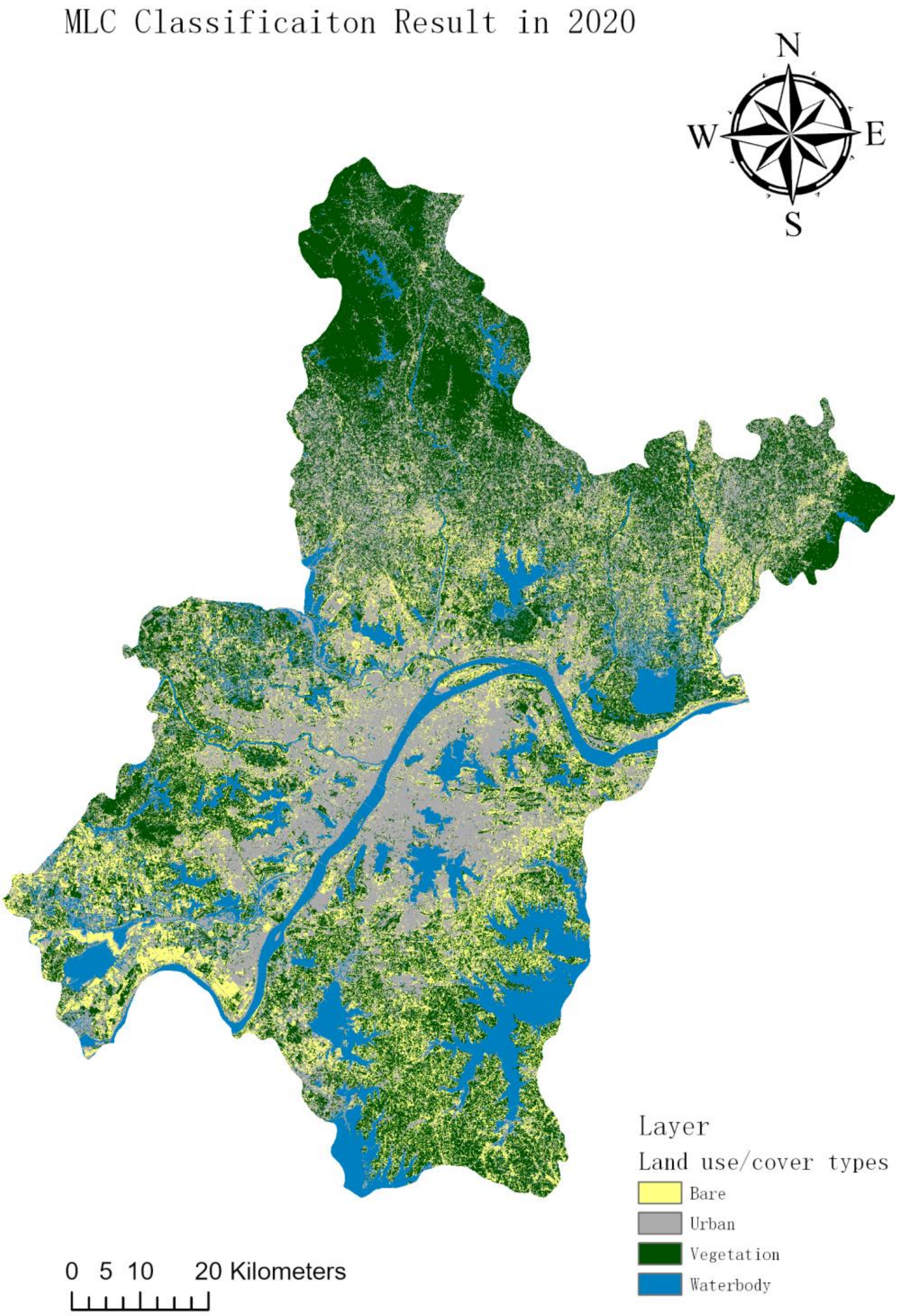


Figure 3.3.1 MLC Classification Result in 2020

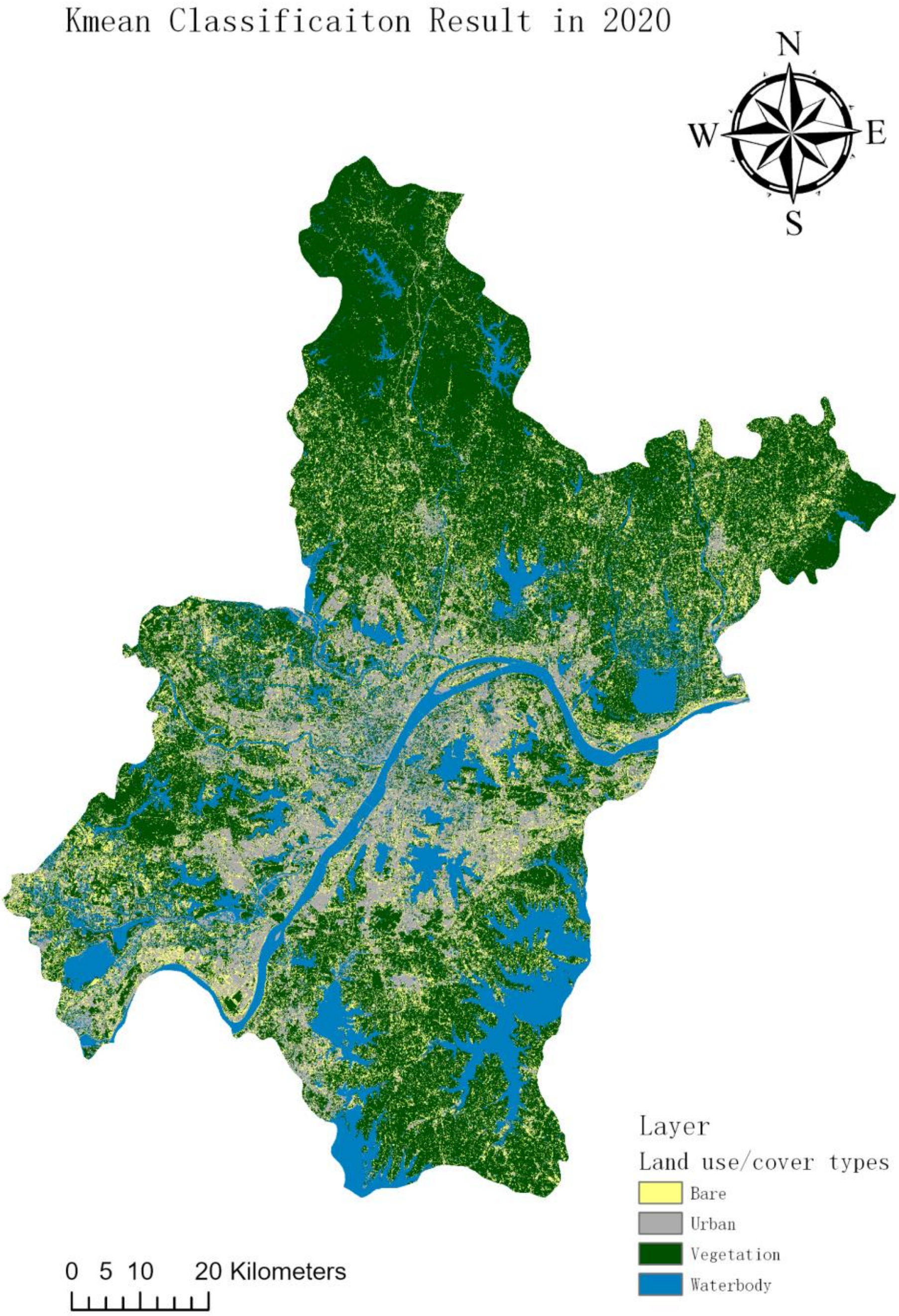


Figure 3.3.2 K-Means Classification Result in 2020

	MLC	**K-Means**
Urban	31.82%	27.44%
Water	8.11%	15.91%
Bare	21.23%	13.59%
Vegetation	38.84%	43.05%

Table 3.3.1 Classification results of land cover percentage in Wuhan, 2020

The classification results of Wuhan's land cover percentage in 2020 using MLC and K-means are shown in Figure 3.3.1 and Figure 3.3.2, and the coverage percentages of the four land types are shown in Table 3.3.1. In 2020, the area of Wuhan urban area has increased greatly, and the results of the two classification methods reached 38.84% and 43.05% respectively, which were three times and two times of the results of the two classification methods in 2005. The huge growth of urban area is matched by the reduction of vegetation and bare land. MLC classification results show that the percentage of vegetation and bare land in the total area of Wuhan has decreased by nearly 20%, and K-means classification results show that the percentage of vegetation and bare land in the total area of Wuhan has decreased by nearly 15%. However, different from the rapidly shrinking vegetation and bare land area, the area of water hardly changed in MLC classification results, and even the results of K-means showed that the water coverage rate in Wuhan increased by 2% to 15.91%.

Discussion

Interpretations

The percentages of land cover in 1990, 2005 and 2020 are integrated and drawn into a table, as shown in Table 3.4.1. Through comparison, it can be found that the results of both MLC classification and K-means classification show that the urbanization rate of Wuhan has been greatly improved in the past 30 years, and the urban area has expanded rapidly. Moreover, taking 2005 as the dividing line, Wuhan entered a period of rapid development in the following 15 years, and the expansion rate of urban area was several times higher than before. There are some differences between the two classifications for the change of water coverage. The results of MLC classification show that before 2005, Wuhan did not protect water resources enough, resulting in a certain degree of water resources shrinkage. However, after 2005, the percentage of water covered area remained stable and basically did not change. According to the results of K-means method, Wuhan's water resources hardly changed from 1990 to 2005, with only a slight shrinkage. However, after 2005, the percentage of water coverage in Wuhan did not decline, but increased. Summing up the results of the two classification methods, Wuhan may not attach much importance to the protection of water resources before 2005, but after that, it becomes more important to the protection of water resources. In contrast to the situation of water resources, the vegetation and bare land coverage area of Wuhan are shrinking rapidly, which makes the natural environment of Wuhan inevitably damaged. In the context of climate change, Wuhan needs to implement some remedial measures to make up for the damage to the ecological environment caused by the disappearance of vegetation and land.

	MLC 1990-2005-2020	**K-Means 1990-2005-2020**
Urban	9.39%-10.96%-31.82%	7.65%-13.40%-27.44%
Water	13.26%-8.29%-8.11%	13.61%-13.25%-15.91%
Bare	62.88%-31.18%-21.23%	58.70%-24.86%-13.59%
Vegetation	14.47%-49.57%-38.84%	20.05%-48.49%-43.05%

Table 3.4.1 Classification results of land cover percentage in Wuhan, over 1990 to 2020

Applications

There are broader implications based on this research. Land cover change detection, being a growing trend, could help with the following aspects, such as building a smart city and consolidating ecological systems.

As Malarvizhi explained in his article "Use of High Resolution Google Earth Satellite Imagery in Landuse Map Preparation for Urban Related Applications", it is significant for policy makers to acquire the information about current land use and the changes in the past few years. Then, the data of land use could be analyzed by GIS, distinguishing different areas of the city, and make an optimal solution of city planning (Malarvizhi, Kumar, & Porchelvan, 2016).

In addition, there is no denying the fact that the ecological system is one of the most significant fundamental to a city. Extreme weather events might occur frequently given that the ecosystems are not protected appropriately. By mapping the city's land cover, the vegetation for example could have an overall management. It would be easier to understand how the city's ecological system was influenced by the process of urbanization. Furthermore, policy makers and the government would put forward better suggestions about how ecological resources can be managed and developed (McPhearson, Kremer, & Hamstead, 2013).

Limitations

In this study, we used both unsupervised classification and supervised classification to detect land use /cover change in Wuhan area, and we also produce an urbanization rate to show the process of Wuhan' urbanization. We believe that the results we obtained are sufficiently credible in this case study. However, there still are some foreseeable limitations in this study. One is in the section of selecting Landsat images. As mentioned above, the area of Wuhan city contains more than one images according to the WRS2 system of Landsat, WRS2 path 123 row 39, WRS2 path 123 row 38, WRS2 path 122 row 39. This lead that we cannot get the full images of Wuhan city on the same time. Therefore, the result images we selected are from different seasons, that will bring some mis-classification. For instance, we include vegetation in the classification of ground objects, but different seasons have a great influence on vegetation, which is manifested in the color and dense degree of vegetation. Another constraint is the clouds on images, the clouds will obscure features and lead to ineffective classification. Although we have choose the images with less clouds, there are still no guarantees against the cloud. In addition, to research the process of urbanization, we chose 1990, 2005, 2020 three different time period, but the resolutions are differences between the three time periods. The low resolution will bring inaccurate classification. These three factors lead our final composite images of Wuhan city contain different times, the different section of the composite images may from different seasons, that will result in incorrect classification.

In our approach, for the supervised classification, the ground features in Wuhan area are identified by Maximum Likelihood Classifier (MLC). MLC is the most widely used method, it is a supervised classification method and requires training samples to define different classes (Sun, Yang, Zhang, Yun, & Qu, 2013). Preparing for the training samples will take time and effort, especially in the multiple images between different dates, since the ground cover may have changed. One of the limitations of MLC is time-consuming (Evans, 1998). Furthermore, the spectral distinctness of the different classes will also influence the accuracy (Supervised classification, n.d.). For instance, the urban area and the construction land might be similar in the spectral distinctness, that will bring mis-classification.

In this research, we use both unsupervised classification and supervised classification in the land use/cover detection and analysis part. In general, the supervised classification is more accuracy to the unsupervised classification, because the supervised classification needs training samples to define different classes, while the unsupervised classification is depended on the spectral characteristics of ground features. However, the training samples have a great influence on the results of the classification. If the training samples do not include various types of ground objects, it will lead to large errors.

The study uses pixel-based to compare the changes of land cover between 1990 to 2020. The traditional pixel-based paradigm is based on the spectral properties of individual pixels, while ignoring the shape, texture and other analyzable features of the monitored object (Hussain et al., 2016). This may bring difficulty to the change detection and influence the accuracy. In addition, for the time period, we chose 1990, 2005 and 2020 three time points to research process of Wuhan area, the time interval is too long to provide a more detailed variation. Machine learning algorithms such as decision trees and neural networks, are more accuracy than unsupervised clustering algorithms and supervised algorithms (DeFries & Chan, 2000). However, due to the high condition for the computer configuration, we have to choose other methods.

Conclusion

Urbanization has been a common phenomenon especially in the developing countries like China. It accelerate economic development, however, it also lead to many environmental issues which includes occupation of vegetation and arable land, the imbalance of ecological systems, and the potential impacts on human health. The study chose Wuhan as study area, which is the largest city in the central China. In our research, the ground features are divided into four parts namely urban, water, bare, and vegetation. Both of supervised classification and unsupervised classification are applied to detect land covers change. The result indicates that Wuhan's urban area has expanded rapidly, and the city has developed greatly in the past 30 years. Moreover,
in this study, one of the limitations is because of the data selection. The area of Wuhan city stretches over three images according to the WRS2 system of Landsat, this lead that we cannot get the images at the same time. In addition, the clouds on the images are uncertain, so in this study, to get the images with few clouds, the time of the images we finally chose may in different season. The inconsistencies of the time, season and clouds condition have caused some influence to our classification. A novel advance is that we can optimize data selection, choose a satellite with a shorter orbit period to avoid the error of not being able to obtain images at the same time and in the same season.

In addition, to monitor the urban sprawl process from 1990 to 2020, we chose 1990, 2005 and 2020 as three time point. However, the time interval is long, and the change of land use/cover might have a huge difference, narrow the time interval to get more detailed results. Furthermore, in this study, we use PCI Geomatica to do the unsupervised classification and supervised classification. That is a huge amount of data to analysis the urbanization process of Wuhan city. Another novel advance is to use the Google Earth Engine to process the data, this process can be completed on the website. Using Google Earth Engine can save the time and space needed to download and store a large amount of data, and can also be used for image processing through code, which can improve efficiency. Wuhan, as a city with rapid urbanization development, provides a good model for urbanization research. Although during 30 years of rapid urban expansion, the area of wasteland and vegetation has been reduced, but water conservation has been well controlled. Wuhan municipal government has enacted more than 20 laws and regulations related to lakes to make plans for the future development of the city. In the future, in the process of continuous urbanization and expansion of large cities, relevant departments should formulate relevant policies to pay attention to the environmental hazards caused by urbanization (Liu et al., 2021).

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