*Desalination and Water Treatment*
www.deswater.com

doi: 10.5004/dwt.2021.27790

241 (2021) 324–330
November

# Spatio-temporal evolution of urban land use and ecological water demand based on remote sensing image technology

Wang Fang

*School of Architecture and Art, Hebei University of Engineering, Handan 056038, China, email: fangwanghued@yeah.net*

Received 20 August 2021; Accepted 23 September 2021

**ABSTRACT**

The purpose of this study is to study the evolution of urban land use in Tianjin, predict the future evolution trend of urban land use in Tianjin, and further understand the development of urban planning in China. Firstly, the extensive application of remote sensing image technology and its role in the study of urban scale development are expounded. Then, the paper studies the connotation of the basic ecological water demand in the river channel, discusses the hydraulics method to calculate the ecological water demand in the river channel, especially the theory of wet-cycle method. Finally, the temporal and spatial evolution of urban land use in Tianjin is qualitatively and quantitatively studied. The results show that the RS technology can be used to study the spatio-temporal evolution of urban land use in Tianjin, and the specific situation of urban land use in different periods can be accurately understood. The results show that remote sensing technology can effectively map the specific situation of urban land use. This exploration provides a new perspective and a new method for the study of urban land use change, provides a guarantee for the in-depth study of urban planning and urban and rural planning, and provides a reference for future related studies.

*Keywords:* Remote sensing imaging technology; Tianjin; Urban planning; Spatiotemporal evolution

## 1. Introduction

As the rapid development of China's economy and the continuous improvement of urbanization, the speed of urbanization has risen from 39.1% at the end of 2002 to 51.27% at the end of 2011. The continuous increase of urban land use and the continuous expansion of urban areas have an inevitable contradiction with the reduction of arable land in China. Since 2009, the Ministry of land and resources proposed "1.8 billion mu (1.20 trillion $m^2$) of the arable land red line" to further reduce the urban expansion land, so the fine research of urban land use has been put on the agenda gradually [1,2].

Urbanization is the process of urban extension and the form of urban development in "quantity". The expression of urbanization in Records of the Historian is the expansion of urban land scale, and the interaction between urban land use and urban development, and the promotion between each other. On the other hand, the increase of urban land area makes the development of urban economy and commerce further change, and further attract investment and population inflow, making the cluster effect of urbanization more obvious, which further ensures the sound and sustainable development of the city [3,4]. Tianjin, referred to as "Jin", is also known as "Jinmen", which is the provincial administrative unit of the state and also a municipality directly under the central government. By 2019, there are 17 districts as well as 245 streets and towns in Tianjin, with a total area of 11,966.45 $km^2$, including central city, ring city district, Binhai new area and suburban area. The permanent population reaches 156,000, of which the urban population is 130,000 [5], and the urbanization rate reaches 83.49%.

Remote sensing image (RS) technology is the use of aerial photography and satellite photography means to record ground objects and terrain. The RS processed by computer needs to be a digital image, and the analog image obtained by photography needs to be converted into the digital image by image scanning and conversion. Traditional aerial photography uses the optical lens and photosensitive film to record the influence of things, while new digital photography uses photosensitive elements for photoelectric signal conversion to record the image of things. Using RS technology to study the change of city can clearly understand the change and change scale of each region of the city, and improve the efficiency and effect of urban management, so as to promote the healthy development of the city [6,7].

Water demand of ecological environment is the core of dealing with the relationship between human and ecology. For a long time, people's economic development, industrialization and urbanization progress, in the allocation of water resources in the industrial and agricultural water, seriously disturbed the ecosystem, causing different degrees of damage to the ecosystem [8]. As a result, natural vegetation decline, river shrinkage, biodiversity destruction, rare animals and plants extinction, land desertification, soil erosion, surface and underground water pollution, riverbed siltation, flood and waterlogging disaster and groundwater area overexploitation are serious ecological consequences. Therefore, we should protect the ecological environment, rationally use the limited water resources, and realize the sustainable development of human existence and economic society.

## 2. RS technology applied to spatiotemporal evolution of urban land

### 2.1. RS technology

Remote sensing, as the name suggests, it is the "remote perception". It is a theory, method and application of science and technology, which means the use of different sensors mounted on various mobile/stationary platforms to detect the electromagnetic radiation and reflection characteristics of target objects, and simultaneous interpreting the properties and states of target objects according to their characteristics [9,10]. Remote sensing platform includes different satellites, airplanes, balloons and various ground moving equipment. Generally, the RS technology system consists of three parts.

- Data acquisition refers to the process of recording the electromagnetic wave characteristics of the target object by using various sensors.
- Data processing refers to the use of optical instruments and computer equipment to correct and analyze the acquired remote sensing data, master or clear the errors in the original remote sensing data, and try to restore the original features of the object to be detected, so as to meet the needs of further application.
- Remote sensing application refers to the application process of remote sensing data in various business fields according to different application objectives of different industries or professionals. The application of remote sensing has been gradually promoted from military and scientific research fields to all aspects of social and economic life, such as military, agricultural monitoring and production estimation, geological and mineral exploration, natural resources survey, map mapping, environmental monitoring and urban construction and management [11].

### 2.2. Concept of urban land and RS identification of the urban built-up area

Urban land refers to the general name of the land with certain use and function in the urban planning area, which is used to maintain the normal function of the city and the demand for construction. The construction activities of urban facilities such as factories, houses, supermarkets and hospitals in cities are all based on the bearing capacity of the land, and the organic operation of the city as a whole can be guaranteed only after all types of land have been strictly planned. The attributes of urban land are divided into four categories: natural attribute, social attribute, economic attribute and legal attribute [12]. Table 1 shows the specific classification of urban land.

The spectral characteristics of high resolution RS in the built-up area are as follows.

- Most buildings and streets in urban construction area are cement or brick tile surface, which are mostly silicate structures and have impermeable characteristics. Therefore, the spectral characteristics of the buildings are the same or similar under the detection of remote sensing electromagnetic wave.
- The urban area is characterized by the large gray level change and the change rate of the image, and the gray level of the adjacent pixels in the city is obvious because of the surface treatment of the buildings. Outside the urban area, the RS change and its rate of change are small because there are mainly fields and a small number of houses.
- The edge of urban buildings is mostly short lines, and because of the wide range of remote sensing, the image size is several pixels. In the image of urban buildings, two peaks appear in the histogram direction of short line, and the phase difference between the two peaks is about 90 degrees [13].

### 2.3. RS technology for urban land boundary extraction

#### 2.3.1. Extraction of RS in the boundary area

Fig. 1 is the main flow of extraction.

The preprocessing process of RS includes geometric correction, image registration, image mosaic, RS cutting, image fusion, image band combination, image enhancement and so on.

- Geometric correction: it includes rough correction and precise correction. Under normal circumstances, the satellite remote sensing data obtained by the ground station has passed the geometric rough correction. Therefore, the image needs to be recovered to obtain the original shape

Table 1
Specific classification of urban land

| Purpose | Code data | Concrete content |
|---|---|---|
| Residence | R | Construction of housing, public service facilities, residential roads, residential greening |
| Public facilities | C | Official office, non-official office, public welfare organization office, commercial and financial work office, cultural and recreational facilities and places, hospitals, schools, research institutes, design institutes, cultural relics and historic sites protection |
| Industry | M | It can be divided into three types: type 1, type 2 and type 3 industrial land. |
| Storage | W | General goods storage, dangerous goods storage, open storage, open or semi open storage |
| External transportation | T | Railway freight transportation, highway freight transportation, pipeline transportation, port freight transportation and airport freight transportation |
| Inner road and square | S | Urban roads, squares, social parking lots and social parking garages |
| Municipal and public facilities | U | Water supply, gas supply and heating facilities, transportation facilities, post and telecommunications facilities, environmental cleaning facilities, sanitation facilities, construction and maintenance facilities, funeral services and cemeteries, and other municipal engineering facilities |
| Green land | G | Public greening and production protection greening |
| Special | D | Military facilities, foreign affairs facilities, security facilities |
| Water and agriculture | E | Rivers and lakes, arable land needs to be irrigated, garden land, woodland, pasture land, village and town construction land |

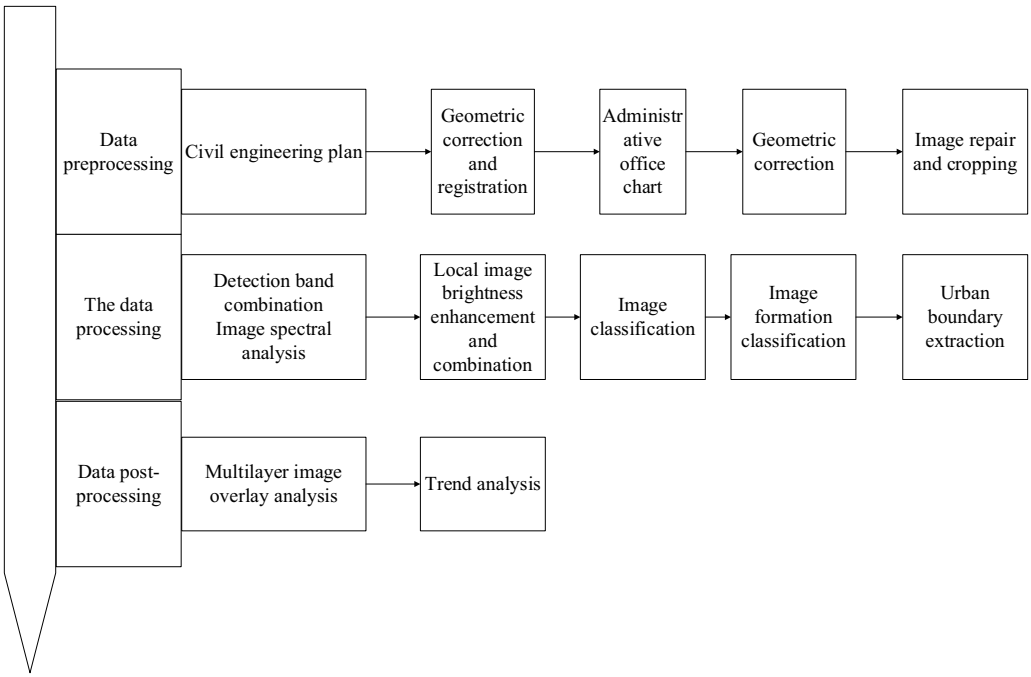


Fig. 1. Extraction of the urban area boundary.

characteristics of the image, and precise correction is needed. The ground control point is needed for geometric precise correction, so that GCP data is used to simulate the original data transmitted by satellite. The original satellite image simulated by mathematics corresponds to the ground standard map correction, and the changed pixels are mapped to the correction space to achieve precise calibration [14,15].

Fig. 2 presents a flow chart of image geometric correction.

- Image registration: image registration is to use the benchmark image to calibrate the new image, so that the same object in the two can be correctly registered; the comprehensive analysis of multiple periods and phases can be used for registration processing. To unify in the same coordinate system, the pixels of the same object in

different time periods need to overlap with each other. The dynamic multi-layer coverage can be carried out by using the software, and the registration and evaluation of the benchmark image and the correction image can be compared.

- Image mosaic: when the research area is distributed on multiple images, image mosaic is needed so that the processing, interpretation and analysis can be performed in a unified way. RS digital image mosaic processing requires multiple images of the same object or place to be merged, and the image needs to contain different projection type information, different pixels, and the same number of bands. In mosaic processing, a certain image is taken as a benchmark to determine the contrast matching degree of mosaic image and the map projection, pixel size and data type of the image after processing. Fig. 3 presents the flow chart.
- Image cutting: it is to cut on RS, select the same region and discard other regions.
- Image fusion: RS with the different spatial resolution are fused, which means to get multispectral characteristics to enhance the influence.
- Band combination: the combined multispectral image can enhance its spectral characteristics, indicating the change of the reflectivity of the ground object for the electromagnetic wave in each band, which is conducive to object recognition.
- Image enhancement: it can improve the visual saliency of related images, so that analysts can clearly identify the content of the image, and extract useful quantitative information. Multi spectral curve can be rendered to make the curve have different colors, which can improve the brightness of the image and highlight a piece of texture information.

#### 2.3.2. Classification of RS based on computer

After the RS inside the boundary is extracted, the computer should be used to classify many images. The process is as follows.

- The purpose of image classification and the problems that need to be solved in classification need to be clarified. The region image that needs to be classified is selected, and the pixel, resolution, time and image quality of the image are considered.
- All kinds of classification methods are compared and analyzed to find out the suitable method and determine the algorithm.
- Classification system and classification categories are developed, and statistical features are found according to image characteristics.
- Each pixel is classified. According to the characteristics of the pixel, it is segmented first and then classified.
- Accuracy check.

#### 2.3.3. Boundary extraction

Because there is no clear demarcation between urban land and non-urban land, it is impossible to make a clear distinction, so the subsequent fine processing is carried out after the automatic processing of the computer. Nowadays, there are two kinds of fine processing methods: A. human eyes are used for artificial recognition, and description and discrimination are performed directly in RS. This method is easy to operate and easy to implement, but the disadvantage is that there is no unified criterion, which depends on people's subjective consciousness, and will lead to judgment error due to people's consciousness. Therefore, it needs professional training before it can be carried out. b. Automatic density recognition method based on edge point. Because the streets, squares and buildings in the city have a large number of edge points, it can be judged by this method, but this method is not suitable for the city with more water and more open space.

Therefore, in order to improve the accuracy, the automatic density recognition method based on edge point is used first, and then artificial recognition is carried out [16,17].

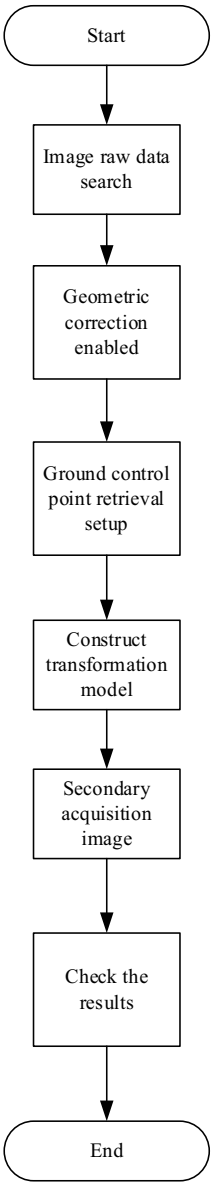


Fig. 2. Flow chart of image geometric correction.

### 2.4. Characteristics of ecological water demand

Ecological water demand is the amount of water that needs to be maintained to meet the function of a specific ecosystem in a specific time and space. It has the dual characteristics of water and biology in an ecosystem. The characteristics of river ecological water demand are time, space, domain value, consistency of water quality and quantity and goal.

#### 2.4.1. Timeliness

The timeliness of river runoff determines the timeliness of river ecological water demand. The timeliness of river runoff is expressed by runoff process. The timeliness of runoff is divided into certainty of runoff and randomness of runoff, and the timeliness of ecological water demand is expressed by the process of ecological water demand, which is divided into certainty of ecological water demand and randomness of ecological water demand. The certainty of river runoff is mainly cyclical, so is the certainty of ecological water demand.

#### 2.4.2. Spatiality

Because the runoff plays a decisive role in the river ecosystem has spatial characteristics, ecological water demand, which reflects the relationship between runoff and ecosystem in the ecosystem, must have spatial characteristics.

#### 2.4.3. Domain values sex

The water demand of ecological environment should at least be able to ensure the balance between things and energy required for the operation of basic functions of the system, which means that there is a minimum (or maximum) critical value (min value) corresponding to the water demand of any function.

#### 2.4.4. Consistency of water quality and quantity

Water quality and quantity are two aspects of river runoff, and are inseparable two attributes of runoff, both belong to the life support system. Moreover, as a part of water resources, ecological water demand should have the properties of water resources, which can not be called water resources with "quantity" or "quality" without "quantity".

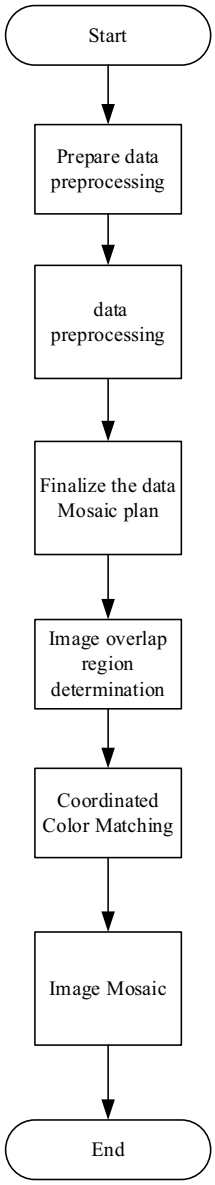


Fig. 3. Image mosaic workflow.

## 3. RS research results of urban land use in Tianjin

### 3.1. RS of Tianjin

Figs. 4 and 5 are the results of the preprocessing and RS information extraction of urban land images in Tianjin.

Table 2 shows the change of residential area in Tianjin.

The dark area in Fig. 6 is urban land in Tianjin, and the light area next to it is the non-urban area. It suggests that the urban land use in Tianjin is further expanded. Compared with 1998, the area of 2021 increases by 38.4%, occupying the surrounding arable land, woodland, water bodies and other land resources, especially the bare land

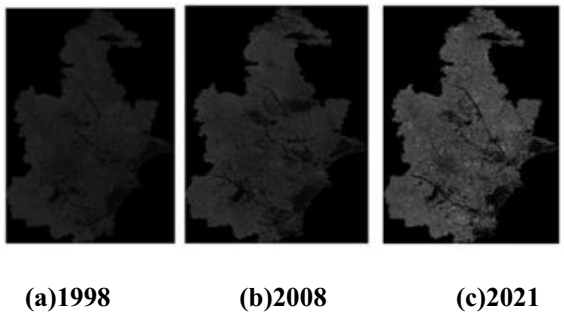


Fig. 4. RS of urban land in Tianjin (a) 1998, (b) 2008, and (c) 2021.

and arable land. The loss of various water bodies such as lakes and swamps is also increasing.

### 3.2. RS accuracy evaluation

Because of the use of object-oriented analysis and processing methods, it is necessary to evaluate and verify the results. If the results are qualified, they can be applied. Fig. 6 is an evaluation result of the accuracy of the classification result.

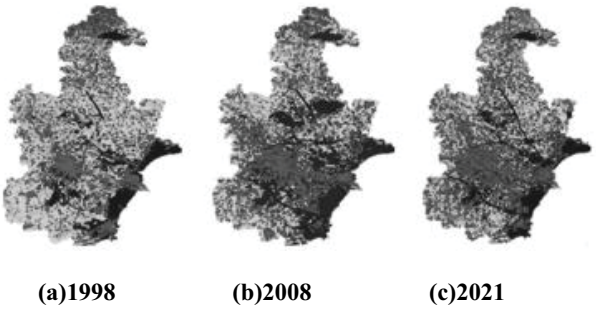


Fig. 5. Object-oriented classification results of urban land use images in Tianjin (a) 1998, (b) 2008, and (c) 2021.

The results of classification are evaluated. The overall classification accuracy of 1998, 2008 and 2021 is 93.4122%, 89.5877% and 88.2339%, respectively. It reveals that the overall classification accuracy is more than 85%, so the

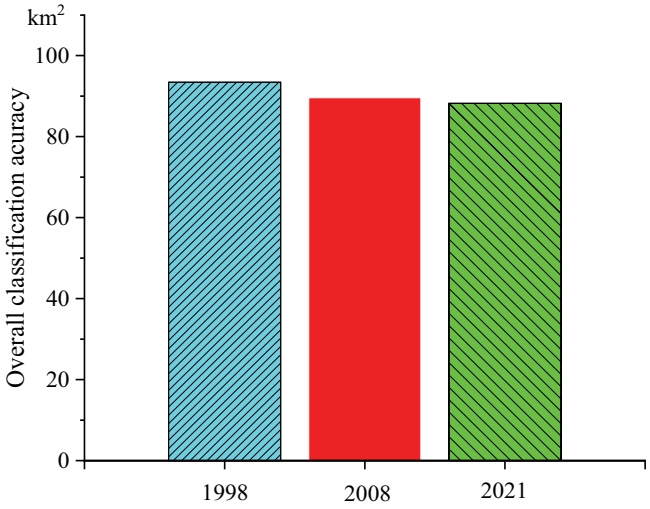


Fig. 6. Evaluation results of the accuracy of classification results.

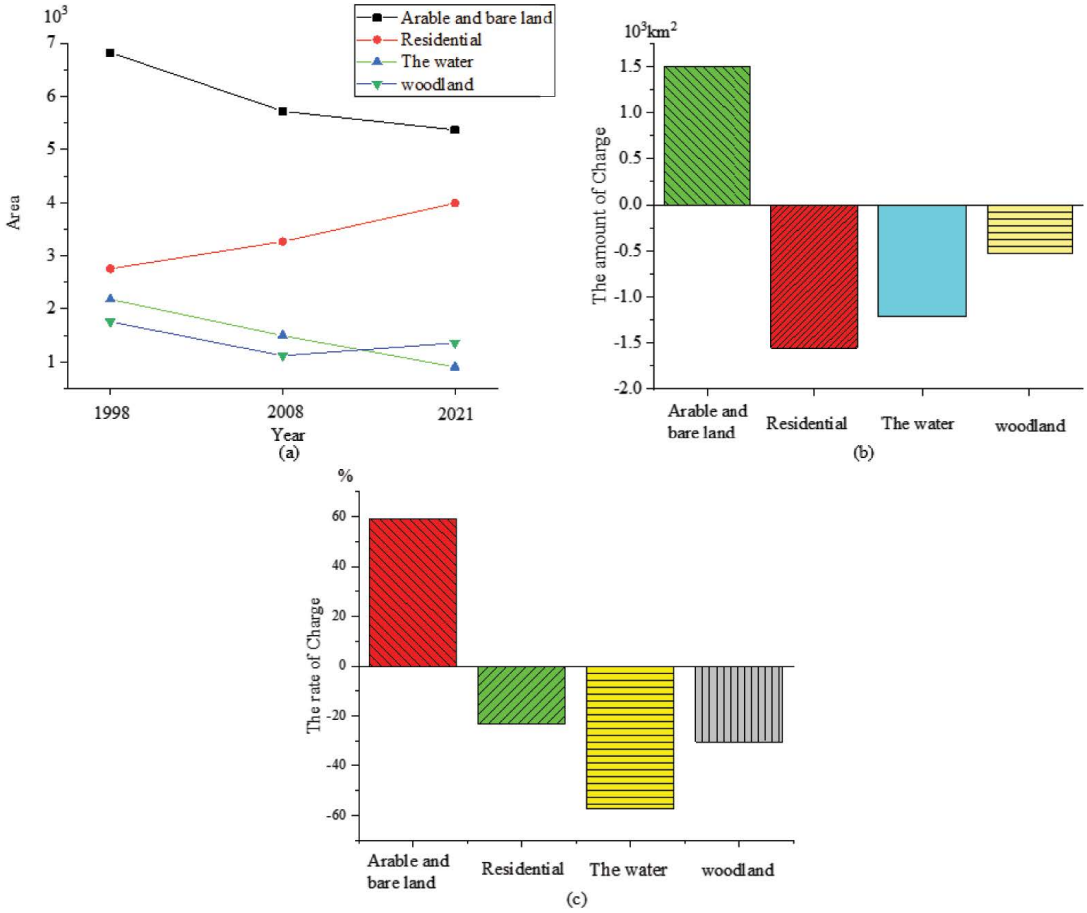


Fig. 7. The change of urban land area with time in Tianjin (a) the change trend of urban land area, (b) the change amount of urban land area, and (c) the change rate of urban land area.

Table 2
The change of residential area in Tianjin

| Time | Area ($km^2$) | Variation ($km^2$) | Change rate |
|---|---|---|---|
| 1998 | 2,460.81 | | |
| 2008 | 3,273.07 | 812.3 | +32% |
| 2021 | 3,995.31 | 722.2 | +21% |

classification accuracy of this result is high, the effect is good, and can be used for subsequent experimental analysis.

### *3.3. Analysis on spatiotemporal evolution of urban land use in Tianjin*

The above classification methods are used, and Fig. 7 presents the results.

Fig. 7 suggests that the area of residential land in Tianjin was 2,522.43 $km^2$ in 1998, increased to 3,372 $km^2$ in 2008, and reached 4,021.57 $km^2$ by the beginning of 2021. Therefore, after more than 20 y, the scale of urban residential land increases sharply by 59.2%; the area of arable land and bare land decreases with the change of time and the increase of urban scale. The arable land area in 1998 was 6,712.30 $km^2$, that was 5,698.74 $km^2$ in 2008, and that has decreased to 5,155.21 $km^2$ by the beginning of 2021, with a decrease rate of 23.2%; the water area in 1998 was 2,110.32 $km^2$, and that was 1,486.72 $km^2$ in 2008. At the beginning of 2021, the water area dropped to 898.64 $km^2$. It has decreased by 1,211.68 $km^2$, with a decrease rate of 57.4%. The area of woodland in 1998 was 1,727.14 $km^2$, and that was 1,208.24 $km^2$ in 2008. By the beginning of 2021, the area of woodland was reduced to 1,201.72 $km^2$, a decrease of 525.42 $km^2$, with a decrease rate of 30.4%.

## 4. Conclusions

This paper analyzes the spatial-temporal evolution of tianjin urban land based on remote sensing technology, and takes photos with remote sensing technology. Then, the remote sensing images of urban land use in tianjin in 1998, 2008 and 2021 were analyzed and compared, and the changes of urban land use in Tianjin in 22 y were obtained. Combined with the characteristics of China, the hydraulic method is taken as the research method of ecological water demand in river channel, and the wet-cycle method and velocity method are emphatically studied. When estimating the minimum ecological water requirement of the river, the characteristics of the river, such as water quality, biodiversity, sediment concentration, and the regional climate environment should be combined. It is not possible to generalize all the rivers, which is also determined by the complexity of the river ecosystem itself.

Although the expected research objectives have been basically achieved and some valuable research conclusions have been drawn, there are still many shortcomings in the research work due to the limited academic accomplishment. Conclusions may be limited by the following two factors: (1) the limited amount of historical data available and the inadequate definition of RS. (2) With the demand of social development, RS shooting is subject to more interference. This also points the way for future research. Future work will mainly focus on the following two aspects: (1) to further collect relevant data and cooperate with relevant research institutions at home and abroad to find historical data and images with appropriate definitions. (2) Improve the transform processing method, and filter the RS interference factors by technical means.

## References

[1] M.B. Peerzado, H. Magsi, M.J. Sheikh, Land use conflicts and urban sprawl: conversion of agriculture lands into urbanization in Hyderabad, Pakistan, J. Saudi Soc. Agric. Sci., 18 (2019) 423–428.
[2] J. Mirás Araujo, Urbanization in upheaval: Spanish cities, agents and targets of a slow transformation, Elisa Marti Lopez, 4 (2021) 218–234.
[3] B. Jean-Claude, T. Rigobert, E. Joachim, F. Tchuente Périclex, D.M. Guela Guy Basile, Geological context mapping of Batouri Gold District (East Cameroon) from remote sensing imagering, GIS processing and field works, J. Geogr. Inf. Syst., 11 (2019) 766–783.
[4] S.K. Meher, Granular space, knowledge-encoded deep learning architecture and remote sensing image classification, Eng. Appl. Artif. Intell., 2 (2020) 342–359.
[5] H.J. Munneke, K.S. Womack, Valuing the redevelopment option component of urban land values, Real Estate Econ., 12 (2020) 48–52.
[6] M. Gholami, J. Torkashvand, R.R. Kalantari, K. Godini, A. Jonidi Jafari, M. Farzadkia, Study of littered wastes in different urban land-uses: an 6 environmental status assessment, J. Environ. Health Sci. Eng., 3 (2020) 23–37.
[7] A. Faizal, S. Werorilangi, W. Samad, Spectral characteristics of Plastic Debris in the Beach: case study of Makassar Coastal Area, The Indonesian J. Geogr., 2 (2020) 52–54.
[8] D. Baral, A. Paudel, H. Acharya, M. Prasad Neupane, Evaluation of soil nutrient status in apple orchards located in different altitudes in Kalikot District, Nepal, Malaysian J. Sustainable Agric., 5 (2021) 99–103.
[9] N.S. Abdullah, M.A. Naim, N. Mohd-Nor, Z.A. Zainal Abidin, Diversity of cultivable bacteria by strategic enrichment isolated from farmed edible red seaweed, *Gracilaria* sp., J. Clean WAS, 4 (2020) 17–20.
[10] S. Ibrahim, J.I. Magaji, Z. Isa, Simulation of sediment yield and supply on water flow in different Subbasins of Terengganu Watershed From 1973–2017, Water Conserv. Manage., 4 (2020) 1–6.
[11] E. Olsen, M.I. Helander, T. Mehl, I. Burud, Spectral characteristics and spatial distribution of thermal donors in n-Type Czochralski-Silicon Wafers, Phys. Status Solidi A, 217 (2020) 23–42.
[12] M. Harris, V. Niekerk, Radiometric homogenisation of aerial images by calibrating with satellite data, Int. J. Remote Sens., 23 (2019) 322–374.
[13] A. Abdollahi, B. Pradhan, N. Shukla, Road extraction from high-resolution orthophoto images using convolutional neural network, J. Indian Soc. Remote Sens., 1 (2020) 1–15.
[14] N. Shabanov, Extending the stochastic radiative transfer theory to simulate BRF over forests with heterogeneous distribution of damaged foliage inside of tree crowns, Remote Sens. Environ., 250 (2020) 23–31.
[15] M.M. Joshi, B. Mills, M. Johnson, A capacitor-discharge mechanism to explain the timing of orogeny-related global glaciations, Geophys. Rese. Lett., 46 (2019) 437–456.
[16] F. Kourim, A. Beinlich, K.-L. Wang, K. Michibayashi, Feedback of mantle metasomatism on olivine micro–fabric and seismic properties of the deep lithosphere, Lithosphere, 12 (2019) 328–337.
[17] A. Azizian, The effects of topographic map scale and costs of land surveying on geometric model and flood inundation mapping, Water Resour. Manage., 33 (2019) 1–19.