

# Evolution of the Nanjing urban green land based on GIS analysis

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## Abstract

Nanjing is one of the important central cities in the Yangtze River Delta, which goes through dramatic urbanization development in recent 40 years. In this research, green land distribution data in 1966, 1981 and 2004 were extracted from topographic maps, aerial imagery, and so on. Time series analysis has been conducted on the GIS platform; characteristics of the evolution of urban green land from 1966 to 2004 were summarized from the perspective of the scale, function, pattern analysis. The results reveal that an environmental function plays an important role, status of recreational function began to rise, the spatial pattern of green land has a tendency of specialization and complication, the downward of its total size accelerates. Woodland which maintain the basic pattern of the recent 40 years green land system in Nanjing remains stable structure.

*Keywords:* green land, evolution, GIS, analysis, Nanjing

## 1 Introduction

The research of urban green land not only includes the qualitative and quantitative study of its distribution and functional characters, but also contains a deep understanding of the historical evolution characteristics of the green, only in this way, the crisis and mechanisms could be fully diagnosed, planning and construction methods and goals will also be further cleared. Analysis of the evolution of the characteristics of urban green land should be based on three aspects, namely scale, function and pattern, The scale reflects the total size of all kinds of green lands, the function reflects whether the role of the relationship between urban structure of green land and human dwelling is reasonable, the pattern implies the structural characteristics represented by different functions and different scales of green space. The evolution features of green land can be comprehended essentially from size, function and pattern. The purpose of this research aims at grasping the changing nature of the characteristics of various types of urban green lands development through the analysis of the evolution, and accumulating research data for scientific planning.

Former research related to the evolution of green was basically qualitative, because of limited data and methods. In recent years, Landscape ecology methods and information technology had been taken to analyse quantitatively the green pattern, but the evolution analysis of urban green land lacked. In the aspect of Quantitative research, Suzuki M, etc. use different years ancient map data to conduct a time-sequence to analyse the centre green area in Tokyo on a GIS platform, and to explore the 100 years of evolution characteristics in the Tokyo Green Area [1-9]. In this research, we focus on the

green lands in Nanjing, analyse its evolution quantitatively from scale, function and pattern, sum up the characteristic variation, and grasp the mechanism of green land variation.

## 2 Materials and methods

Nanjing is located in the lower reaches of the Yangtze River Ningzhen hills and mountains area, north latitude 31°14' to 32°37', longitude 118°22'~119°14'. Urban population reached 5.48 million in 2011, which is one of the important central cities in the Yangtze River Delta region.

Nanjing has a distribution of low hills around the city with the Yangtze River cutting through and has environmental characteristics of dense rivers and lakes. In the past half century, the velocity of urbanization in Nanjing was rapid, which exert a serious impact on the ecological environment. Therefore, it is necessary to study the changes in the urban green land system.

The scope of this research include the south of the Yangtze River, west of Rao city highway, south to first-line Andemen, North qixia avenue - East shogunate first-line of the city, involving the main city of Nanjing Gulou district, all parts of Baixia, Qinhuai district, the most parts of Xuanwu, jianye, and Xiaguan district, part of Qixia, Yuhuatai district in Nanjing, all of which are dense areas for peoples' living and dwelling. These areas are the main city now, which are the typical regions that witness the changes of urban green land for nearly 4 decades.

Analysis of the historical development of the green land must begin with the time-section that is needed for concrete explanation. Three time cross-sections were selected and analysed in 1966, 1981, 2004, due to the lack

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of the Nanjing map data before the founding. Aviation image and topographic maps of 1966, 1981 and 2004 were performed by vector processing in MapInfo software, green land distributions for these three time sections were extracted and analysed. Characters of green land evolvement of the 1966-1981 and 1981-2004 period were further compared from the difference analysis of size,

function and pattern.

Figure 1 shows the extracted green lands, which included parks, neighbourhood green spaces, squares, woodland, affiliated green land, waterfront green land, agricultural land and other patches of green land. Table 1 shows types of green lands selected in this study.

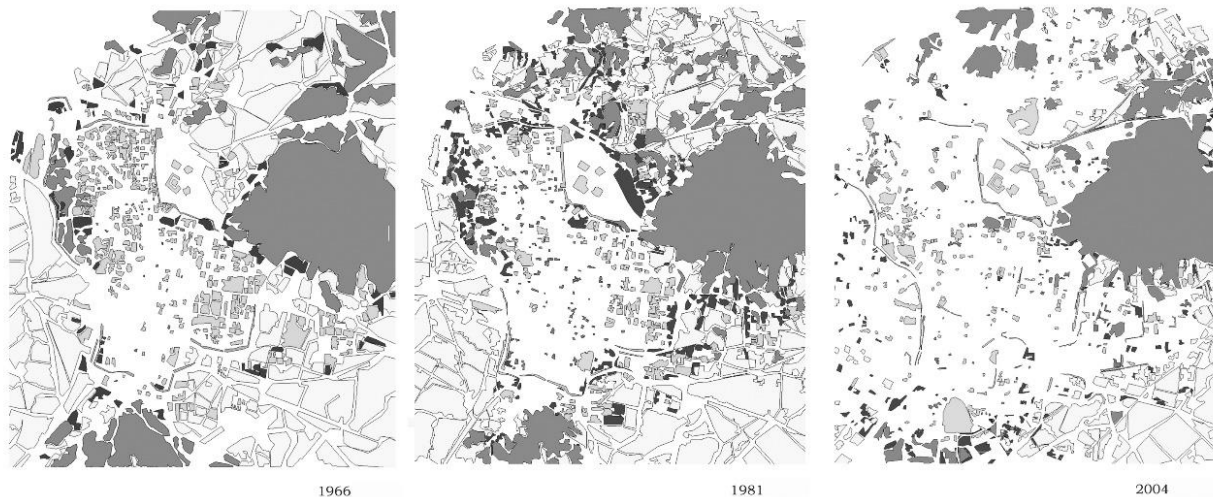


FIGURE 1 Green lands extracted using GIS

TABLE 1 Types of green lands selected in this study

green land types	scope
park	various types of parks specified by city government, exclusive of lakes in the parks
road green belt	green belt in the middle and side of the road
block green belt	concentrated green land in the residential area
square	city square, street square
waterfront green land	belt-like waterfront green land
woodland	acres of forest land containing facilities inside
affiliated green land	affiliated green land of constitution, schools, factories, and research institutes
agricultural land	Farms, farmland
other green land	other patches of greened open land

### 3 Analysis and results

Green space in the 1966 can be divided into parks, woodland, agricultural land, affiliated green land, block green belt, waterfront green land and others. Patches of complete agricultural land were distributed in north, west, south of Qinhuai River and northeast, north of Xuanwu Lake, The woodland was mainly distributed in the hilly land of the peripheral urban area. The city is littered with affiliated green land patches. Hunan Road, Xinjiekou area was a traditional residential centre with high dense living units and relatively sparse affiliated green land. There were chunks of affiliated green land in the military sites located in the south of Purple Mountain. Even in the suburbs areas, such as South of Qinhuai River, north of Xuanwu Lake, some factories and some affiliated green lands scattered there. Block green belt were very few, dotting around the city. There were intermittent waterfront green lands in the west of Xuanwu Lake and both sides of the Qinhuai River.

In terms of size, agricultural land was the largest part

of Nanjing green lands in 1966, accounting for 50% of the weak. Followed by woodland, it accounted for 34% of the total. The affiliated green land accounted for 10.4% of the total. Other types of green lands accounted for less than 6% of the total size. The affiliated green land constituted the main green land of the city.

Green spaces in 1981 included parks, woodland, agricultural land, affiliated green land, block green belt, waterfront green land and others. The more fragmented setup of green land was in consistent with that in 1966, surrounded by large tracts of agricultural land and woodland. The affiliated green land was still the subject of urban green space, accounted for 7% of the total size. There was an expanding tendency for affiliated green land compared with that in 1966. Factory in the suburbs showed an increasing tendency, while factory in the residential land decreased, so did the affiliated green land in urban areas. But peripheral affiliated green land increased and revealed decentralized and miniaturize. There was also an increase for block green belt within the city. As major

outdoor recreation places for the locals, park green land and block green belt accounted merely for relatively low ratio of 2%. Waterfront Green land was located on both sides of Xuanwu Lake and Qinhuai River. Open green land in urban fringe increased significantly, indicating that the city-building activities in 1981 became common.

Green land in 2004 included parks, road green belt, block green belt, square, waterfront green land, woodland, agricultural land, affiliated green land and unknown others. Woodland was a major component of the Nanjing urban green space, and its distribution was mainly concentrated in the hilly land of the eastern outskirts, woodland in the main urban area was basically depleted. The outskirts distributed large numbers of agricultural land, large proportions of it lied in southeast, less and fragmented in southwest and northeast, its distribution ratio gradually reduced from the countryside to urban built-up area. The affiliated green land was the most widely distributed type within the city, but with generally small patches and a high degree of fragmentation. Park, block green belt and squares played the role of urban leisure. Green parks were mainly concentrated in the areas that were famous for its natural history and culture; however, serious shortage existed within the residential areas. block green belt was generally small, sparse and distributed unevenly. Numbers of square and waterfront green lands were few.

From 1966 to 1981, the scale of agricultural land, and waterfront green land was essential flat. Woodland and affiliated green land had decreased slightly; there were also small increases in the size of the green parks and block green belt. The green open land for unknown use (other green lands) increase larger. Although the total amount of green lands did not change significantly, the ebb and flow of the various types of green scale resulted from joint effect of various urbanization factors, the result indicated that Nanjing city was on the eve of new expansion cycle.

From 1981 to 2004, due to the effect of urbanization, the green land reduced sharply in total. Recreational functions-based and government-invested green land was significantly increased in various types of green land. Increment of block green belt and waterfront green was weak; Decrement of woodland was relatively small. The expansion of the city's eroded agricultural land around the original town, due to the increment in building density, the primary affiliated green land was occupied by the large numbers of buildings; the original green open lands were substituted by others, resulting in the half reduction of affiliated green land, agricultural land and others.

Figure 2 shows scales of various green lands of Nanjing city in 1966, 1981, and 2004. From 1966 to 2004, the total green lands reduced by 21%. Affiliated green land and agricultural land reduced most in various types of green lands, decreased by 70% and 61% respectively. Size of woodland decreased by 12%. Greater growth existed in

parks and block green belt with an increment of 5.8 times and 8.5 times separately. But the waterfront green land increased by 13%. Overall, the effect of urbanization green deepened since 1981, resulting in larger variation of the green land than that in 1981.

Functional evolvement of green land could be discovered from changes in the size of the various types of green lands. From the year 1966 to 1981, agricultural land and woodland based on production function and environmental protection were the main component of green land. Recreational function was still taken on by parks and block green belt despite the increment of its size, the fact that its overall proportion was less indicated that the recreation was not the main function, but the dominant role of urban green land remained. The affiliated green land can only provide limited recreational and ecological role due to the absence of public properties.

Recreational function was valued and enhanced with the proportional increment of parks and block green belt since 1981. Affiliated green land declined accordingly. Under the effect of expanding urban, the proportion of agricultural land decreased from 50% to 32%. The productive function of green land gradually weakened. The proportion of woodland scale rose from 32% to 48.8% in spite of its slightly decrement, the environmental protection in green land strengthened accordingly.

In general, environmental protection remained the major function of Nanjing green land from 1966 to 2004, with the expansion of the city and the necessities of habitat living productive function gradually weakened and recreational functions gradually increased.

Figure 3 shows patch numbers of various green lands of Nanjing in 1966, 1981 and 2004. In this research, patch density index (PD) and landscape shape index (LSI) were adopted, the interferential and fragmented extent of each time cross-sectional area was compared, and the evolve mental characteristics of green land patterns from 1966 to 2004 were analysed [10]

Figure 4 shows PD value changes of various green lands of main urban area of Nanjing from 1966 to 2004. Figure 5 shows LSI value changes of various green lands. From 1966 to 1981, the PD value of agricultural land plummeted, LSI value rose sharply before 1981, and then both showed a downward trend since 1981, the fact indicated that the urbanization process continuously exert a effect on the size agricultural land, which had been seriously interfered, crushed and then disappearing. The spatial structure of block green belt fragmented increasingly with its growing scale, PD values and LSI values continued rising. Firstly, the affiliated green land had been disturbed, and then showed a fragmentation trend, after that, this suffix block disappear faster, manifesting as PD values firstly increased and then decreased and LSI values continued to decline. PD and LSI value of Waterfront Green land and Park was essentially

flat before 1981, and then improved. The fact indicated that there is no change in these two types of green space before 1981; structure complexity was enhanced with its increment in size and patch since 1981. The PD value of the woodland remained stable, LSI values firstly increased and then declined, this indicated that the body of spatial structure showed an ordered trend and a lowering fragmentation despite the certain interference.

Some green lands showed larger changes such as

agricultural land, affiliated green land, block green belt and others before 1981, changes of LSI value did exist in agricultural land and affiliated green land. Greater variation happened in PD and LSI value of parks and waterfront green land, which indicated that urbanization process had greater influence on agricultural land, affiliated green land, block green belt and others, however park and waterfront green land were promoted by human conscious construction activities since 1981.

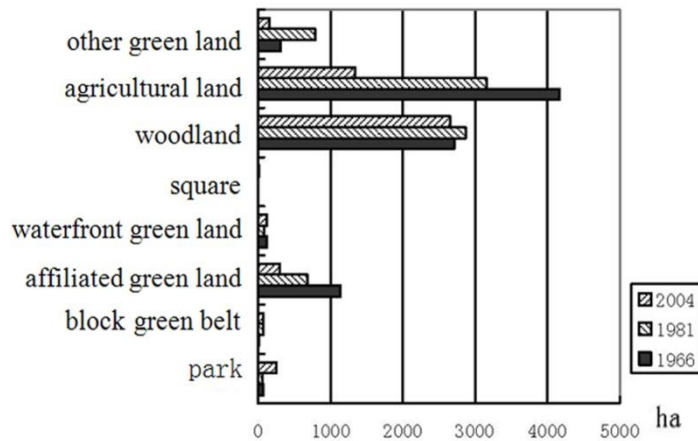


FIGURE 2 Scales of various green lands of Nanjing city in 1966, 1981, and 2004

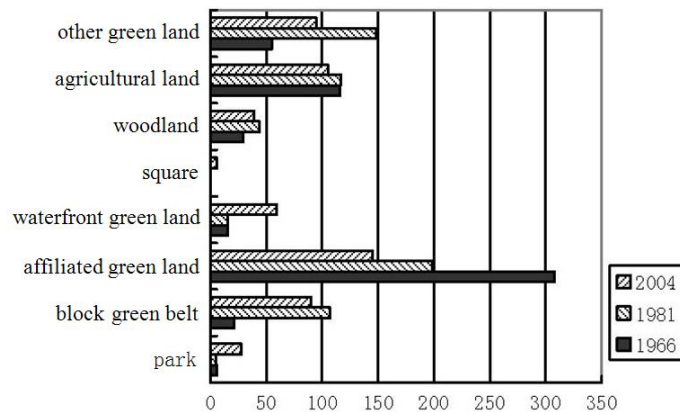


FIGURE 3 Patch numbers of various green lands of Nanjing in 1966, 1981, 2004



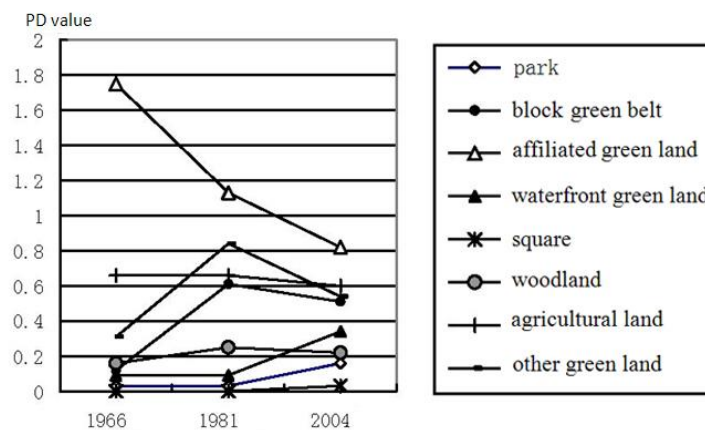


FIGURE 4 PD value changes of various green lands of main urban area of Nanjing from 1966 to 2004

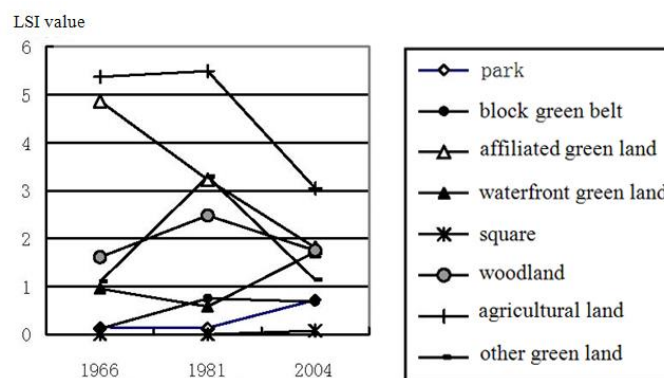


FIGURE 5 LSI value changes of various green lands of main urban area of Nanjing from 1966 to 2004

It was concluded from the variation curves of overall PD and LSI that there were greater variations in the agricultural land, affiliated green land, block green belt and others, and milder variations in waterfront green land and park. Variations in the woodland showed the smoothest character. The fact indicated that spatial structure of woodland is the most stable one, better structural stability were showed in the waterfront green land and parks. Agricultural land, affiliated green land, block green belt and others possessed the least structural stability.

**4 Conclusions**

Prior to the 1980s, the scale changes of the Nanjing urban green land are small. Proportions of all kinds of green land were stable, but the spatial structure was susceptible to be interfered, and showed a general tendency of fragmentation. In this stage, the main functions of the green land were production and environmental protection.

After the 1980s, the total size of the Nanjing urban green lands reduced sharply, influenced by the rapid urbanization process. Suburban agricultural land had been eroded greatly and then disappeared, because of urban sprawl and the impact of human activities. The size of

affiliated green land suffers from such a significant reduction that isolated island emerged. A mild size increment of park, waterfront green land and block green belt suggested that recreational function was valued gradually.

During the evolvement of urban green land in Nanjing, the most stable structure was the woodland, which was the main factor to keep the green pattern, environmental and recreational function that woodland embodied had important implications for city of Nanjing.

Overall, during the evolvement of urban green land in Nanjing, environmental function had been a major role; role of recreational function began to rise, spatial pattern of green land showed ever-growing fragmentation and complexity trend, the size of the total green lands declined accelerated.

The green land distributing information was extracted from the Nanjing Aeronautics photographs and topographic maps on the GIS platform, green land information in 1966, 1981 and 2004 was gathered and quantitatively compared for the first time, the result indicated that woodland which showed an stable structure maintained the basic 40-year-green land pattern of Nanjing, green land space pattern fragmented continuously, environmental protection was the main

function of the Nanjing Greenland, GIS data processing and analysis capabilities contributed to the accurate grasp of green land evolution in qualitative and quantitative analysis method, and also provided serialized reference for the analysis of urban green land and the construction.

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