

# Spatial and Temporal Evolution of Carbon Sink in the Three North Forest Region Based on Remote Sensing Data

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**Keywords:** Remote Sensing, Casa Model, Carbon Sink, Net Primary Productivity Conversion, The Three North Region.

**Abstract:** The investigation is to estimate the region carbon sink in the three North areas in different time periods by integrating forest data maps, and to further evaluate the outstanding contribution of the Three North Shelterbelt project to forest carbon sink in recent years. The casa model is the foundation of research, using primary quality productivity (NPP), which has a clear quantified index of forest carbon sink, to evaluate the relationship between modern terrestrial sink for carbon and forest vegetation cover in research region. Multiple sources of historical and existing land use, including publicly available high-resolution satellite images and remote sensing products, statistical data from various organizations we concordance and use. Based on the 16dMODIS data, we obtained the spatio-temporal date set and distribution of carbon sink in the three northern shelterbelts in 2006, the NPP of the three north region range from 0 to 877.184 gC/ (m<sup>2</sup> • a), and the vegetation coverage rate range from 0 to 80%.

## 1 INTRODUCTION

As the one of the most important country on earth and the developing country with the largest carbon emission, China has announced the climate target of reaching the peak carbon emissions by 2030 and achieving carbon neutrality before 2060 (Zeng et al., 2022). The "dual carbon" action is undoubtedly a powerful and significant measure to curb global warming. We must act from the two directions of carbon source and carbon sink at the same time, to accelerate the pace of carbon neutrality. The seemingly simple step of photosynthesis, in which carbon is fixed and stored, plays a significant role in ecosystems. The amount of carbon fixed by vegetation varies widely depending on climate, location and other reasons. Vegetation in different regions has different characteristics, for example, Forest is an ecosystem with a huge amount of biomass. As a high-quality carbon sink, it can not only fix a large amount of greenhouse gas co<sub>2</sub>, but also resist wind sand and reduce soil erosion. An accurate assessment of such a typical terrestrial ecosystem - forest helps us to study the process of carbon flow and fixation throughout the Earth system. Absorbing about 45% of co<sub>2</sub> emissions, the world's second

largest carbon reservoir, terrestrial ecosystems are not only a single vegetation, but also a large number of other types of land, such as wetlands, cultivated land and so on. The Three-North Shelterbelt project, which began to be built in the last century, has nearly half of Chinese land area, and has made an indelible help and contribution to the implementation of China's carbon neutral plan. Due to its large area and long depth, it is extremely difficult to assess and early warning through field investigation and vegetation monitoring.

In 2010, China's terrestrial carbon sink was estimated to be  $198 \pm 54 \text{TgC}^{-1}$ . From 2019 to 2021, China's terrestrial ecosystem carbon sink is about  $-0.44 \text{Pg C/ year}$ . Various of ways serve as actual tool to quantify carbon sink. Due to its fast and convenient characteristics, Remote sensing technology has long been widely and profoundly applied in the assessment, monitoring and early warning of afforestation management; Estimation of vegetation biomass at the global scale; exploration and research of the driving mechanism of carbon sinks and the spatio-temporal differences in regional ecosystems. (Zheng et al 2017 ; Jiarui Dong et al 2003 ; Bowen Pang 2024) The casa model is based on the integration of satellite images and remote sensing data and vegetation productivity is often used in the research of various regions, such as the spatial

and temporal dynamic changes of the NPP in grassland, Gannan; the NPP distribution of vegetation in northern Hebei Province, and so on. casa model can help us to carry out simple research on it

What's more, the research has provided positive economic and policy with influence. this including, but not limited to assessing and evaluating forest carbon sink and their value, and organizing the construction and maintenance of man-made forests, so as to achieve the co-development of man and nature.

## 2 METHODOLOGY

### 2.1 Study Area

The Three North Shelterbelt Forest Program construction area is located in 725 counties for 13 provinces , beginning with Bin County in Heilongjiang Province in the east, and extending to northwest China, North China, Northeast China, and the Xinjiang Production and Construction Corps, west to Uzber Pass in Xinjiang, north to the national boundary, south along Tianjin, Fenhe River, Wei River, Taohe River downstream, Burhanbuda Mountain, Karakoram Mountain, 38° 43'-53° 33'N, 118° 02'-135° 53'E.(www.forestdata.cn)

Its length is 4480 kilometers from east to west, and its width is 560 - 1460 kilometers in both directions. Covering a land area totaling 4.358 million square kilometers, which represents 45.2% of the overall land area. The construction area of the project from south to north across the zones of warm temperate, temperate, and cold temperate, belongs to the humid and semi-humid continental monsoon climate, for the vegetation type, the construction of farmland shelter forest as the basic framework, multiple forest species, multiple tree species, mesh belt, the combination of trees, agriculture, forestry and animal husbandry inlay with each other, county and county adjacent, mutual integration of regional shelter forest system.

The image can help us determine the scope of the research.

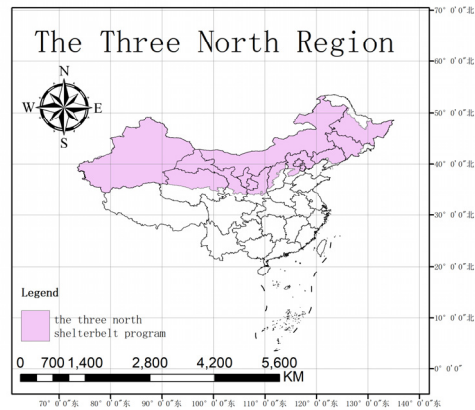


Figure1: the location of the three north region (Picture credit: Original; Date from: Shao, Q. (2022). Three-North Shelterbelt construction project [Data set]. National Data Center for Ecological Sciences).

### 2.2 Dates

#### 2.2.1 Data Sources

One of the primary instruments aboard the Terra spacecraft and Aqua spacecraft is MODIS, which stands for Moderate Resolution Imaging Spectroradiometer. MODIS vegetation indices are generated at various spatial resolutions at 16-day intervals, the date on 2006s July was used in calculatiton.

The process of data preprocessing includes geometric correction like geolocation, image registration, mosaic and cropping, orthographic correction, picture fusion, cloud removal and shadow processing, and atmospheric correction.

#### 2.2.2 Landuse

These date comes from China's first annual land cover product (CLCD) obtained from Landsat data. this date is divided into several types including farmland, woodland, shrubbery, grassland, water, ice, barren, impermeable, wetland. It selected the required date and processed it.

These data provide an abundance of research-useful information, allowing a thorough knowledge of the effects of land-use change on ecosystems and the environment. By revealing the mechanisms by which natural and human causes influence changes in land cover, data analysis can provide a scientific basis for the formulation of sustainable land management policies. Meteorological data can be used to investigate the effects of climatic change on land use simultaneously, and socio-economic data can be used

to study the effects of urbanization and economic development on land cover. These multi-perspective analyses help us understand the complexity of land use change more thoroughly.

### 2.2.3 Vegetation Carbon Sink

Aimed to estimate carbon sink, we used the date from governmental agencies, dividing the three north shelter forest region.

NPP refers to the remaining part of the vegetation after photosynthesis and respiration cancel each other. This part is very important in the ecosystem. It indicates that the vegetation converts light energy into chemical energy through its own reaction, and it relate to the health and quality of the vegetation. By quantifying NPP, we can get a better understanding of vegetation productivity and the entire ecosystem. According to the formula:

$$NPP=GPP-Ra \quad (1)$$

$$NEP=NPP-Rh=GPP-Ra-Rh \quad (2)$$

The terms "Ra" and "Rh" stand for autotrophic and heterotrophic respiration, respectively. "GPP" which means the amount of photosynthates or total organic carbon fixed by organisms. "NEP" is net ecosystem productivity.

There are significant differences in NEP, which are influenced by different land cover types. From the perspective of types of vegetation, the annual average NEP of forest, grassland and agricultural land is higher than that of the latter.

### 2.2.4 Vegetation Data Indicators

The NDVI was caculated using the equation,and The EVI, an improvement of NDVI, accounts for atmospheric scattering and land surface reflection, resulting in increased precision in regions with substantial vegetation coverage.where "Red" denotes reflectance in the red portion of the spectrum and "NIR" denotes spectral in the near-infrared wavelength range, 'Blue' on behalf of the reflectivity of the blue band in the spectrum.In view of different environment factor, the other elements are coefficients introduced to reflect different environmental conditions. The computation of EVI is outlined as follows:

$$aNDVI = (NIR-Red) / (NIR+Red) \quad (3)$$

$$EVI=G* (NIR-Red) / (NIR+K1*Red-K2*Blue+L) \quad (4)$$

With the help of this formula, EVI can more successfully reduce the effects of surface reflection and atmospheric scattering, producing data on vegetation cover that is more accurate. This development is essential for researching the dynamics of vegetation, evaluating the health of ecosystems, and monitoring the environment. Beyond the monitoring of a particular vegetation cover, EVI is widely applied and is essential to research on global climate change. Long-term EVI data series analysis provides a scientific basis for managing ecosystems and developing environmental protection policies by highlighting regional and global trends and patterns in changes in plant cover.

Furthermore, EVI has a great deal of application value in forestry, land resource management, and agriculture. It helps managers and farmers better comprehend crop growth status, forest health, and changes in land use, which improves resource use efficiency and management decisions. Additionally, as an enhanced vegetation index, EVI proves to be very accurate and dependable across a range of environmental circumstances, making it a crucial instrument in the study of ecosystems and vegetation monitoring. Its easy-to-use computation technique and wide range of applications provide essential data support and a scientific basis for comprehending and safeguarding the Earth's ecology.

### 2.2.5 Driving Factor Analysis

Formerly known as Carnegie - Ames - Stanford Approach model, the CASA model, is used for analyzing the driving factors behind the spatio-temporal evolution of carbon sinks in the three north forest regions. This model is widely recognized for its robust framework in estimating net primary productivity (NPP) by incorporating and utilizing remote sensing data and ecological principles. Our study builds upon the CASA-NPP transformation method.

In many previous studies, we have shown that the reflection features of vegetation to infrared and near-infrared light can effectively help us estimate photosynthetically active radiation, and as a driving mechanism of plant photosynthesis, it is affected by many factors, such as the amount of biomass in the area, the total amount of solar radiation in the field.

Moreover, the photosynthetically active radiation also showed a good linear relationship with the normalized vegetation difference index in a certain range, which also proved the feasibility of the method

This is a relatively classical NPP estimation method in the CASA model proposed by Zhu.

Through the measurement and calculation of NPP data, we can effectively obtain the increment of NPP in a large spatiotemporal range, so as to effectively analyze the status of forest carbon sink and evaluate the quality of the construction project of the Three-North protective fence.

$$NPP(p,m)=APAR(p,m)\times\varepsilon(p,m) \quad (5)$$

$$APAR(p,m)=SOL(p,m)\times FPAR(p,m)\times k \quad (6)$$

$$FPAR(p,m)=\frac{NDVI(p,m)-NDVI_{i,min}}{NDVI_{i,max}-NDVI_{i,min}}\times(FPAR_{max}-FPAR_{min})+FPAR_{min} \quad (7)$$

APAR is photosynthetically active radiation,  $\varepsilon$  is solar energy utilization efficiency, FPAR is photosynthesis radiation absorption ratio. “i” is the sequence of vegetation species, “p” represents the pixels, and “m” represents the months in the time series.

### 3 RESULT

Initially , We find the sequence occupied by vegetation in the land use type, confirm some basic attributes of them, deploy their static parameter files, and import pre-treated vegetation types, ndvi time series, climate factors, environmental factors, etc. into the casa calculation module to obtain the original data and import it into gis for analysing.

Then, comprehensive reclassification is carried out on the npp results and the vegetation coverage images at the same time, and the results are divided into several categories according to equal proportions, which are represented by different legends in the images. In the vegetation coverage rate, the dark green color indicates the high vegetation content in the region. Similarly, in the npp results, the color can quantitatively represent the exact npp value of the pixel. They have a trend from fewer to more. And the region showed an increasing from east to west.

The vegetation remote sensing image of NDVI can reflect the change of vegetation to a certain extent, but the image obtained by the model in this study can more truly and effectively reflect the npp distribution in the three northern regions combined with multi-breadth and multi-depth influence factors

Through the comparison of forest cover and primary quality productivity in the same year, we can conclude that forest cover and carbon sink capacity are highly positive correlation. That is, areas with high forest cover usually have higher primary productivity, which absorbs more carbon dioxide and

forms a stronger carbon sink capacity. This is a positive and benign cycle, in which forests fix atmospheric carbon dioxide into organic carbon through photosynthesis. The higher the forest coverage rate, the more obvious this carbon fixation effect is, thus improving the regional carbon sink capacity and making the effect of carbon neutrality more obvious.

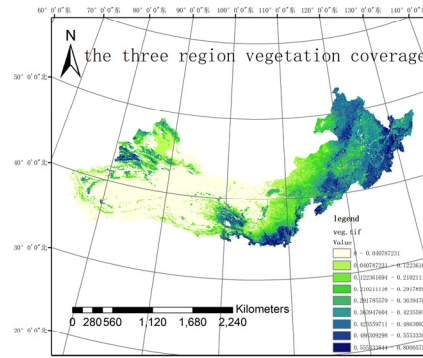


Figure 2: The three region vegetation coverage in 2006 (Picture credit: Original).

There are a little yellow areas or on the map, which means there is little or no vegetation in this region .it explains why the initial values of vegetation coverage and NPP start at 0.

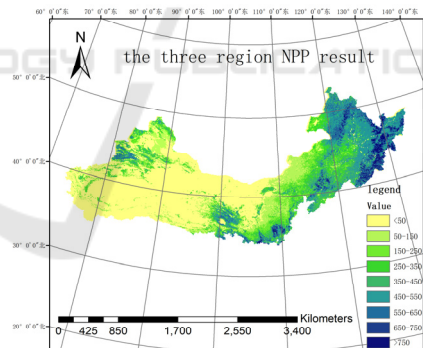


Figure 3: The Net primary productivity conversion result (Picture credit: Original).

At the same time, we obtained the temperature as the most suitable growth temperature for vegetation to fix carbon according to different time series in a year. Finally, we lock the result between month and July, and finally we can know the raster result.

The NPP of the three north region range from 0 to 877.184 gC/ (m<sup>2</sup>·a), and the vegetation coverage rate range from 0 to 80%.

## 4 CONCLUSION

Because of the importance of the Three Northern regions to Chinese "dual carbon" action, it is suggested to strengthen the continuous monitoring and evaluation of the Three Northern shelterbelts, and use the combination of remote sensing technology and ground observation to obtain more detailed and long time series data, which can also make up for the shortcomings of the small spatiotemporal range and fracture of the experiment, and the incomplete accuracy of the experimental results. To study the temporal and spatial changes of carbon sink capacity, and actively estimate the potential of forest carbon sink. At the same time, in forest management, the impact of climate change should be considered, and management action need be taken adjusting to local natural conditions, such as disaster prevention and mitigation, selecting drought-tolerant and water-tolerant tree species, and avoiding planting a large number of single tree species, so as to improve the forest resistance and carbon sink capacity, so as to achieve the goal of carbon neutrality as soon as possible.

Certainly, human intervention and protective strategies for forestry are of paramount importance. The scenario of curbing global warming is escalating in severity and urgency, yet behavior of remnants of deforestation and the subsequent situation of reduction of forest carbon sinks persist. Initiatives such as reverting cropland to forested land and implementing stringent control measures can people pay attention to, coupled with penalties for unchecked deforestation, comprise various tactics aimed at safeguarding the ecological resources within this expansive carbon reserve. In conclusion, extensive research underscores the indispensable and substantial role that the Three North regions will play in China's, and indeed the world's, future. This role is intrinsically linked to the sustainability of human society, economic progression, and ultimate prosperity.

In the whole research process, the primary productivity and vegetation coverage of the three northern regions were analyzed from a large spatiotemporal range by remote sensing. Compared with the field survey, the whole result was faster and more intuitive. However, due to the difference in data quality and other reasons, the limitations of the research results were also shown. The spatiotemporal span of the results failed to clearly show the whole change process. Secondly, only several land cover types were used in the study, which will have an impact on the results. Therefore, future studies can explore the carbon sink in the three North regions in a finer spatio-temporal range.

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