Impact of climate zone migration on geographical distribution of indigenous vegetation in Northeast China

Yunyang Wu¹, Shengju Li¹, Xue Wang¹, Yuehua Zhang¹, Ye Gu¹*, Lan Li²*
¹College of Science, Jiamusi University, Jiamusi City, Heilongjiang Province, 154007, China
²College of Big Data and Software Engineering, Wuzhou University, Wuzhou City, Guangxi Province, 543000, China
*Corresponding author’s e-mail: bubian1119@sina.com; ljmsu@163.com.

Abstract. Based on the relationship between climate and vegetation, this study uses the time lag of vegetation response to climate change, simulates the dynamic response process of different vegetation types to climate change, retrieves relevant literature and collates data, and deduces the actual occurrence and geographic distribution of vegetation under the current climate potential and future climate change scenarios. This experiment infers the adaptation relationship between plant geographical distribution and climatic conditions. The results show that the plants in Northeast China are generally more adaptable to climate change. The areas with poor adaptability are mainly at the junction of forest shrubs and grasslands. The geographical distribution of plants has changed, accounting for about 5%. The grassland ecosystem in the bush-grassland transition zone in the Greater Xing'an Mountains is also less adaptable to climate, accounting for about 35%. The vegetation in these areas tends to degenerate. The geographical distribution may change. The adjustment of plants in Northeast China to the future climate change is usually reasonable. 84% of the vegetation changes are positive changes. Especially in the eastern regions, the vegetation deduction conditions will be improved in the future, and the vegetation coverage in these regions may be improved. About 79% of the potential changes in vegetation can adapt to the future climate. Nevertheless, the grassland ecosystems in the Greater Xing'an Mountains and parts of Inner Mongolia are less adaptable to future climate change and tend to degrade. It provides new ideas for assessing vegetation adaptability or ecosystem adaptability. Research on the interaction between climate change and terrestrial ecosystems of different scales needs to be strengthened in the context of global change.

1. Introduction
The adaptability of ecosystems to climate change at different scales is a key issue [1]. However, existing research mainly focuses on the molecular level of plants and the physiological mechanism of vegetation [2]. Research on plant populations, ecosystems, landscapes and regional scales little, lack of understanding of the response and adaptation mechanisms of vegetation or ecosystems to climate change on larger spatial scales and longer time scales, making it one of the main sources of uncertainty in predicting future trends in terrestrial ecosystems [3]. It also limits the application of many climate vegetation models in predicting the long-term effects of climate change. The impact of climate change on vegetation and ecosystems has attracted great attention from scholars at home and abroad. A new generation of ecosystem process models has been aware of this problem and has embarked on a series
of theoretical integration and improvement on the adaptation mechanism of ecosystems to climate change [4]. Still, the long-term adaptation mechanism of vegetation or ecosystems needs to be continuously and effectively understood. [5]. Based on the experiment, a breakthrough in this area requires long-term accumulation [6]. Climate change has brought a profound impact on the terrestrial ecosystem from pattern to function. The geographical distribution of vegetation and its response to climate change is the specific manifestations of the interaction and adaptation between ecosystems and the environment [7]. To understand the mutual adaptation relationship between vegetation and climatic conditions, a quantitative description of the sustained impact caused by the time lag of adaptation or incomplete adaptation is indispensable. A large number of studies on the relationship between climate and vegetation have been carried out at home and abroad, and have widely used in many aspects such as the impact on ecosystems [8]. Experiment recognize and analyze the adaptation relationship between the geographical distribution of vegetation and climatic conditions. Based on the climate-vegetation relationship in the northeast region, the geographical distribution pattern of natural vegetation in the area is retrieved. The time lag and response of different vegetation types to climate change [9]. The quantitative relationship between climate and vegetation simulates the dynamic impact of climate change on the geographic distribution of vegetation. It establishes a quantitative expression method of the adaptability of vegetation distribution pattern to climate change according to the direction and frequency of vegetation geographic distribution change to evaluate the adaptation relationship between vegetation and climate conditions. To understand the impact of climate change on natural vegetation in China and its relationship with climate, so as to provide reference for methodology and comparison of results.

2. Materials and research methods

2.1. Model improvement and data CEVSA (Carbon Exchange between Vegetation)

The model has been successfully applied to the assessment of ecosystem changes at global and regional scales and has achieved good research results for the simulation of the main processes and functions of ecosystems. To be able to evaluate the impact of climate change on the geographical distribution pattern of vegetation, to more fully and accurately express the ecosystem's response and adaptation to climate change, the climate-vegetation relationship in the northeast region was established according to the characteristics of climate vegetation in the eastern region, based on the CEVSA model. Increase the simulation of the dynamic response process of geographical vegetation distribution to climate change. In this study, natural vegetation divided into 12 categories, namely, evergreen coniferous forest, deciduous, coniferous forest, deciduous broad-leaved forest, mixed forest, forested land, forest grassland, canopy shrub, sparse shrub, grassland, desert and bare land. Regarding the climate-vegetation relationship of the Dolly model, select climatic factors that significantly limit plant growth and physiological activities, establish a quantitative relationship between the main climatic factors and vegetation types, and invert the geographic distribution of natural vegetation types under set climate conditions pattern. The selected climate indicators include the average temperature of the coldest month, the average temperature of the warmest month, the accumulated temperature of ≥0℃ and ≥5℃, and the humidity index (θ). The average temperature of the coldest month and the warmest month determines the heat limiting factors of the vegetation distribution. The accumulated temperature used to determine the thermal conditions for plant growth and the length of the plant growing season, and the humidity index is an indicator of the degree of climate dryness and humidity, which determines the life of the vegetation type.

The regression equation of the absolute minimum temperature and the average temperature of the coldest month means:

\[ T_{ab\min} = (T_{\text{min}} \times 1.30) - 19.54 \]  \hspace{1cm} (1)

\[ \theta = \frac{\text{AET}}{D} \] \hspace{1cm} (2)

Note: \( T_{ab\min} \) is the perfect lowest temperature; \( T_{\text{min}} \) is the average temperature of the coldest month. Without considering the influence of water conditions, \( T_{ab\min} \) is between -15℃ - -40℃, the plant life
form is deciduous; -35℃ - 42℃ is evergreen coniferous forest; <-55℃ is deciduous needle leaf
Lin >-15℃ is evergreen. D is the potential evapotranspiration, which depends on energy supply, such
as net surface radiation; AET is the actual evapotranspiration, which is related to soil moisture content
and vegetation growth.

2.2. Affected by the combined effects of monsoon climate and topographical conditions
The geographical distribution of vegetation in the Northeast region has unique regional characteristics,
and the climate characteristics of the Northeast region have been fully taken into account when
determining the climatic threshold of vegetation distribution. The potential vegetation distribution
types and approximate ranges simulated by the improved CEVSA model compared with the
simulation results of the BI-OME3 model in the northeast region. The simulation of the geographic
distribution of potential vegetation in Northeast China is reasonable and feasible. However, different
research institutes have different classification standards for vegetation types, and there are also
differences in research methods. This study simulates the potential geographic distribution of natural
vegetation, the simulation results of BIOME3 based on vegetation function, and the northeast region
based on the actual vegetation distribution. There are still some differences in vegetation distribution
maps (in Tab 1). Vegetation and environmental conditions lags are constantly. Vegetation and an
environmental condition are constantly interacting and influencing each other, including the adaptive
relationship between the two, and is a dynamic response process. The simulation of this process
mainly refers to the MOVE (Migration of Vegetation) model. That is, different vegetation types have
different lag times for climate change, among which forest lag time is extended, shrub, and grassland
lag time is short. Due to the limitation of scenario data, the simulation time is shorter than that of
forests and other vegetation types. To reflect the migration of vegetation types and their potential
changes, the lag time of the vegetation used in this study is roughly the minimum time (in Tab 2).

### Tab. 1 The primary indicators for recognizing vegetation types

| Vegetation Types  | TEMP\(_{\text{min}}\)/℃ | GND\(_5\)/℃ | δ       |
|------------------|---------------------|----------|--------|
| Forest           | 3                   | ≥550     | 0.45   |
| Evergreen leaves | ≥-12                | /        | 0.50-0.7/0.45-0.5 |
| Coniferous broadleaf | ≥-12             | /≥2200  | 0.45-07/0.45-0.7 |
| Mixed forest     | ≥-25                | 1100-4500| 0.45   |
| Woodland         | -12~ -15            | ≥2200    | 0.42-0.45 |
| Forest grass     | -25 ~ -18           | ≥1100    | 0.35-0.55 |
| Shrub            | <1.5                | ≤4500    | 0.08-0.50 |
| Meadow           | /                   | ≤3000    | 0.08-040 |
| Desert           | /                   | /        | <0.15 |
| Bare ground      | /                   | /        | /      |

Note: TEMP\(_{\text{min}}\) means the average temperature in January; GD5 is the accumulated temperature
of> 5℃; δ is the wetness index.

### Tab. 2 Comparison of the results with other researches

| Model name | BIOME3 | MAPSS | Dynamic model | CEVAS |
|------------|--------|-------|---------------|-------|
| Climate scenario Vegetation classification | Hadley GCM | Had CM22 | Hypothetical scenario | Hadley R CM A2 |
| Tropical deciduous forest, Savannah, shrubs, grass | 18 | 11 | 20 | 12 |
| Evergreen broadleaf forest, evergreen coniferous forest, deciduous forest, meadow grass family dwarf shrub | Tropical evergreen broad-leaved forest, subtropical coniferous, broad-leaved mixed forest, evergreen coniferous forest, shrub | Evergreen broadleaf forest, evergreen coniferous forest, deciduous forest, shrub |
Attenuated vegetation representative types

| Northern Deciduous Subtropical Coniferous Desert Tundra Polar/Glacier Subtropical coniferous forest, deciduous, coniferous forest, Savannah, deciduous shrub, zonal Northern forests, tundra, belts, deserts Deciduous coniferous forest, mixed forest, forest grassland, grassland; desert |

Note: The assumption doubled CO₂ scenarios, the monthly average temperature increase of 2°C, and February 20% increase in average precipitation.

2.3. Assessment method of vegetation geographical distribution on climate change

Under the long-term continuous influence of climatic factors, plant will change accordingly with the evolution of climate. Still, different vegetation types have a different response time to environment, weather, that is, the lag effect of plant on climate change. The length of the lag time varies according to the type of plant. The lag time of the forest vegetation is long, and the lag time of the shrubs and grasslands is short. In the lag period of vegetation response, although the type has not changed, it has not been adapted to the existing climatic conditions. To express the adaptation and response of the geographical distribution of vegetation to climate change, the vegetation cover types divided into four categories: forest, shrub, grassland, and desert, specifically, evergreen coniferous forest, deciduous, coniferous forest, and deciduous broad-leaved forest. Mixed forests, and forested land merged into forests, grasslands, canopy shrubs, and sparse shrubs classified as shrubs, plus grasslands and deserts, and the transition of vegetation from desert to wood defined as the positive effect of climate change on vegetation growth. The result is the positive change, and the reverse is the reverse change. The study uses the actual differences and potential changes and directions of vegetation to suggest the adaptation of the geographic distribution of vegetation to different climatic conditions. Positive changes in vegetation indicate that the climatic conditions are favorable for vegetation distribution. Although the geographic distribution of vegetation may not have changed, there is a tendency for plant to change positively, indicating that the potential impact of climate is favorable, that is, vegetation and climate. The conditions can adapt to each other well; the negative changes of vegetation are just the opposite, that is, the adverse effects of climate change on vegetation are relatively large, which may change the geographical distribution of plant and cause vegetation degradation, that is, the existing vegetation types cannot or it is challenging to adapt to such climatic conditions (in Tab 3).

Table 3. The lags of different vegetation types to climate change in improved CEVSA model

| type | Min death (year) | Migrate Sprout (year) | Ideal (year) | Total | type | Min death (year) | Migrate Sprout/ (year) | Ideal (year) | Total |
|------|-----------------|----------------------|-------------|-------|------|-----------------|------------------------|-------------|-------|
| Evergreen Coniferous forest | 30 | 10 | 25 | 65 | Forest meadow | 10 | - | - | 10 |
| evergreen Broadleaf forest | 40 | 5 | 5 | 50 | Shrub canopy | 5 | - | - | 5 |
| Defoliation Broadleaf forest | 30 | 15 | 25 | 70 | Sparse Shrub | 2 | - | - | 2 |
| Defoliation Coniferous forest | 40 | 10 | 30 | 80 | Meadow | 5-10 | - | - | 5-10 |
| Mixed forest | 40-30 | 10 | 25-30 | 75-70 | desert | - | - | - | - |
| Woodland | 20 | 5 | 20 | 45 | Bare ground | - | - | - | - |
3. Results and discussion
The change of the geographical distribution of potential natural vegetation in the eastern region mainly occurred in the forest-shrub and shrub-grassland transition zone and the junction of grassland and desert ecosystems in the Da Xing’an Mountains area. Even if the geographic distribution of vegetation has not changed, the adaptation relationship between vegetation and climate has changed. The description of the possible invisible changes in the interactions can more clearly express the adaptation between vegetation and climate. Therefore, the analysis of the potential changes in the geographic distribution of vegetation is also beneficial to most ecosystems. That is, from the perspective of the ecosystem’s self-adaptability, the plant can better adapt to the climatic conditions during this period, especially in North China and parts of Northeast China, the number of positive potential changes is higher, indicating that the relationship between vegetation and climatic conditions is better. Climatic conditions will facilitate the shift in vegetation coverage to a more top type. Also, there are some areas in Inner Mongolia and Northwest China that show potential negative changes, accounting for about 35% in total, indicating that the climate change in these areas harms the distribution of vegetation, and the plant cannot adapt well to the climate. From the perspective of vegetation types, most of the vegetation types that exhibit negative changes are grasslands, indicating that the future climatic conditions may be detrimental to grassland ecosystems, that is, grassland ecosystems may not be able to adapt well to future climate conditions and degrade.

4. Analysis
Under the current climatic conditions, the vegetation at the junction of forest-shrub and grassland-desert adapts poorly to climatic conditions, and about 5% of the plant has degraded. From the perspective of potential changes, the plant in most areas has better adaptability to the current climatic conditions. The impact of climatic conditions on vegetation shows a significant positive change, especially in the north of Yichun North, the versatility of plant to climatic conditions is relatively good, and vegetation coverage may be improved. In recent years, it has widely carried out in the field of global change, and many vegetation models driven by climate data have established. However, it limited by the current research level of vegetation adaptation mechanism, and the research on the assessment of the adaptation relationship between vegetation and climate is also very minimal. This study is based on a relatively simple and quasi-dynamic vegetation dynamic response model. The focus of this study is not to simulate the impact of climate change on the vegetation distribution pattern, but the possible changes in the geographic distribution pattern of vegetation caused by climate change. The purpose is to judge the adaptive relationship between climatic conditions.

Acknowledgments
Heilongjiang Provincial Department of Education Basic Research Project, China, (2018-KYYWF-0955). the scientific and technological innovation projects in Jiamusi University, Heilongjiang Province, College students: 201910222010.

References
[1] Cao M K, Woodward F I. (1998) Dynamic responses of terrestrial ecosystem carbon cycling to global climate change. J. Sci. Nature, 93: 249-252.
[2] Cao M K, Prince SD, Li K R, et al. (2003) Response of terrestrial carbon uptake to climate interannual variability in China. J. Sci. Global Change Biology, 94: 536-546.
[3] Hansen MC, Defries RS, et al. (2000) Global land cover classification at 1 km spatial resolution using a classification tree approach. J. Sci. International Journal of Remote Sensing, 21: 1331-1364.
[4] Woodward F I, Smith T M, Emanuel W R, et al. (1995) A global land primary productivity and
phytogeography model. J. Sci. Global Biogeochemical Cycle, 9: 471-490.
[5] Prentice I C, Cramer W, et al. (1992) A global biome model based on plant physiology and dominance, soil properties, and climate. J. Sci. Journal of Forest Biogeography, 19: 117-134.
[6] Gao Q, Yu M, Yang X S. (2000) An analysis of the sensitivity of terrestrial ecosystems in China to climatic change using spatial simulation. J. Sci. Climatic change, 47: 373-400.
[7] Andrei PK, Allen M S. (1998) Modeling dynamic vegetation response to rapid climate change using bioclimatic classification. J. Sci. Climate Change, 38: 15-49.
[8] Dominique B, James M. L, Daly C, et al. (2001) MC1: A Dynamic Vegetation Model for Estimating the Distribution of Vegetation and Associated Ecosystem Fluxes of Carbon, Nutrients and Water. J. Sci. Technical Documentation, 33: 15-21.