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The Economics of Ecosystem and Biodiversity (TEEB)

Promoting a Sustainable Agriculture and Food Sector

Implementation in China

Scoping and scenario setting report for the "Soybean Expansion" policy in Heilongjiang

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This report pertains to the second case study of the Economics of Ecosystems and Biodiversity: Promoting a Sustainable Agriculture and Food Sector (China) project (TEEBAgriFood project). The year 2019 saw the launch of TEEBAgriFood project in China, with the first pilot evaluation in Tengchong, Yunnan Province, a national "Lucid waters and lush mountains are invaluable assets" (Green is Gold) practice innovation base. In 2023, a second pilot evaluation will be carried out in Heilongjiang Province, focusing on the national "soybean expansion" policy (hereafter referred to as the "Heilongjiang case").

This report presents the TEEBAgriFood "Heilongjiang Case" scoping and scenario setting. On 28 October 2022, the project team, UNEP-IEMP, held an online stakeholder meeting with the Agricultural Development Department of the Beidahuang Group, Heilongjiang Academy of Agricultural Reclamation, and Beidahuang Research Institute to discuss the national "soybean expansion" policy and its implementation in Heilongjiang Province. This report builds on that meeting and relevant literature research. The report presents a regional overview of the agricultural system in Heilongjiang Province, policy directions and the need for transformation, and the study's scenario design.

1. Regional overview

Heilongjiang Province is located in Northeast China, with Russia across the river to the north and east, Inner Mongolia to the west and Jilin Province to the south, and is the northernmost and easternmost provincial administrative region in China, between 121°11′-135°05′ E and 43°26′-53°33′ N. It has a total area of 473,000 square kilometres, ranking 6th in China. The terrain is generally high in the northwest, north and southeast, and low in the northeast and southwest, consisting of mountains, terraces, plains and water; it straddles four water systems: the Heilongjiang River, the Ussuri River, the Songhua River and the Suifen River. Its landscape is characterised by "five mountains, one water, one grass and three fields", meaning 50% mountain, 10% waterbody, 10% grassland, and 30% plain. The climate is mainly cold-temperate and temperate continental monsoon.

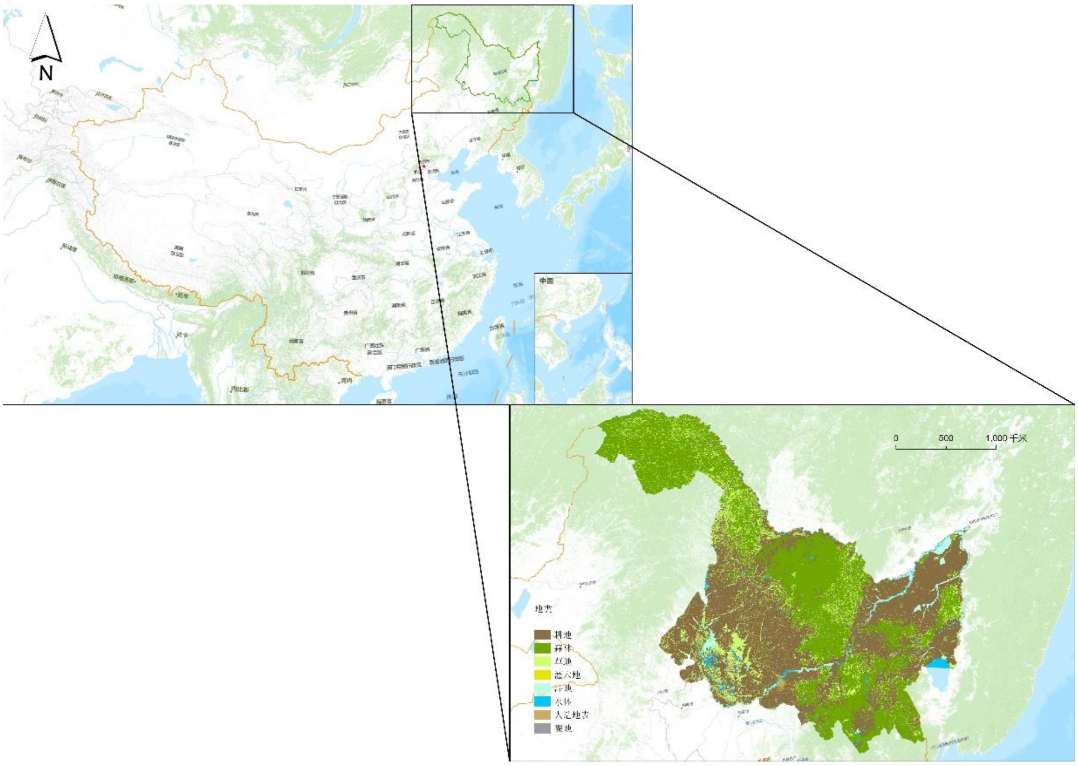


Figure 1 Location of Heilongjiang Province

In 2020, Heilongjiang Province achieved a regional gross domestic product (GDP) of RMB 1,369.85 billion, an increase of 1.0% over the previous year at comparable prices. From the perspective of the three industries, the value added of the primary industry was RMB 343.83 billion, up 2.9%; the value added of the secondary industry was RMB 348.35 billion, up 2.6%; and the value added of the tertiary industry was RMB 677.67 billion, down 1.0%. The structure of the three industries was 25.1:25.4:49.5, with the proportion of the primary industry in the economy much higher than the national average (Table 1). However, the per capita GDP and disposable income were lower than the national averages.

Table 1 Comparison of the economy of Heilongjiang Province with the national average in 2020

	GDP (100 million Yuan)	Primary industry percentage	Secondary industry percentage	Tertiary industry percentage	Per capita GDP (Yuan)	Per capita disposable income (Yuan)
Heilongjiang	13698.5	25.1%	25.4%	49.5%	42635	24902
China	1015986.2	7.7%	37.8%	54.5%	72000	32189

Data sourced from China Statistical Yearbook 2021

Arable land in Heilongjiang Province covers 15,940,850.84 hectares, accounting for 33.87% of the province's total land area (Table 2). The province's per capita area of arable land is 0.416 hectares (6.24 mu/person), which is higher than the national average of 0.09 hectares (1.36 mu/person).

Table 2 Land use conditions in Heilongjiang Province

	Area (ha)	Percentage
Forest	23245157.92	49.39%
Arable land	15940850.84	33.87%
Grassland	2034742.68	4.32%
Garden land	44930.08	0.09%
Land for water area and water conservancy facilities	2182354.05	4.63%
Land for urban village, mining and manufacturing sites	1219694.67	2.59%
Land for transport facilities	592760.97	1.26%
Other land	1808771.03	3.85%

Heilongjiang is the core area of a black soil region in China and an important part of the world's black soil resources. Black soils are characterized by their deep soil color and their richness in key basic nutrients such as organic carbon, nitrogen, phosphorus, and potassium. They are one of the most productive and fertile soils in the world. Globally, black soils cover approximately 725 million hectares, with nearly half located in Russia (covering 19% of the country's land area). Other countries with large areas of black soil include Argentina, China, Colombia, Hungary, Indonesia, Kazakhstan, Poland, Ukraine, and the United States[1].

2. Heilongjiang's plantation system

2.1 Basic overview

According to the grain production data released by the National Bureau of Statistics, Heilongjiang Province had 220.248 million mu of grain crops planted by 2022, accounting for 12.4% of the country, and total grain production of 77.63 billion kg, accounting for 11.3% of the country, ranking first in the country for thirteen consecutive years. The volume of commodities and exports ranked first in China for many years, and the production of the three major grain crops, maize, rice, and soybeans, ranked first in China[2].

As shown in Figure 2, the total planted area of food crops in Heilongjiang Province has slightly increased since 2010, with maize, rice, and soybeans being the main types of crops, accounting for over 95% of the planted area of grain crops in Heilongjiang Province. In 2020, the soybean planting area in Heilongjiang Province accounted for

[1] https://www.fao.org/global-soil-partnership/gbsmap/en/
[2] http://www.gov.cn/xinwen/2021-12/06/content_5657932.htm

about one-third of the total planting area in the province, far exceeding the national average and other provinces. As shown in Figure 3, the planting area and production of soybeans in Heilongjiang Province have accounted for over 40% of the national total for the past decade, reaching 50% in some years, making it an important soybean production base in China.

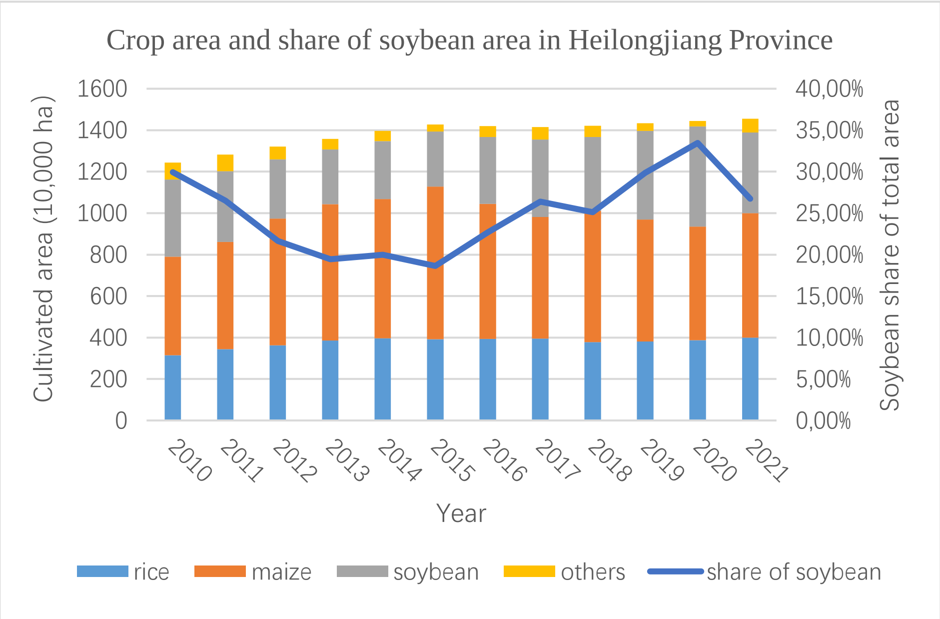


Figure 2 Cultivation structure in Heilongjiang Province (data sourced from 2010-2020 Heilongjiang Statistical Yearbook and 2021 provincial government website)

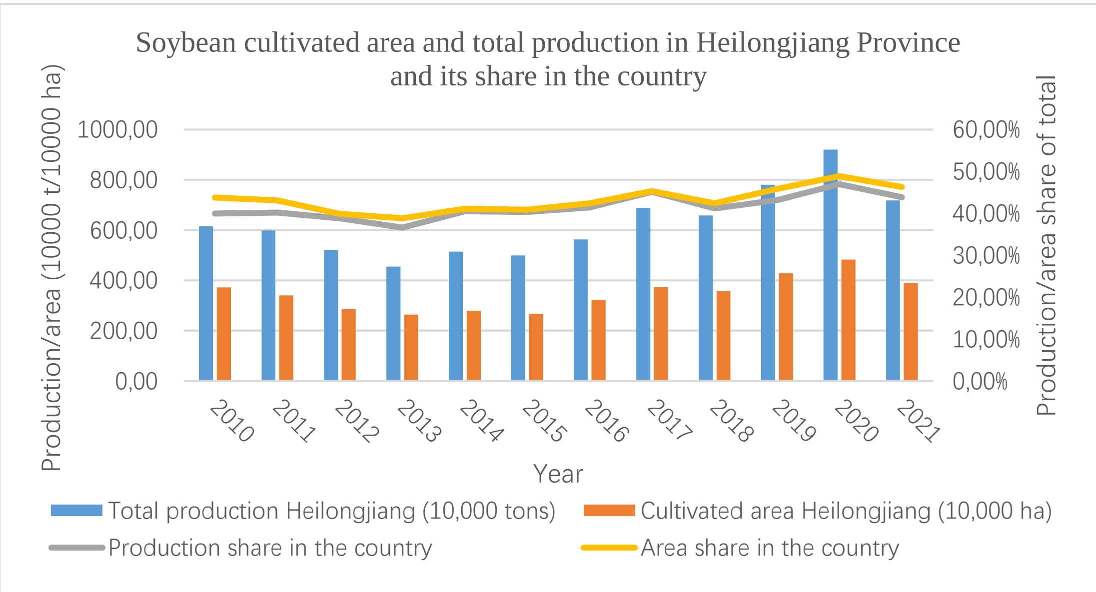


Figure 3 Soybean cultivated area and production in Heilongjiang Province and its share in the country (data sourced from 2010-2020 Heilongjiang Statistical Yearbook, China Rural Statistical Yearbook and 2021 provincial government website)

2.2 Challenges ahead

The increasing demand for agricultural water has led to a decline in groundwater levels. Water resources in the Northeast China black soil region are relatively scarce, with an average per capita water resource and irrigation amount of only 7572.04 cubic meters/hectare and 1405.44 cubic meters/hectare, respectively, which is only 30.63% and 26.32% of the national average level. In the past 20 years, the total water consumption in the Northeast region has shown a significant upward trend, with the largest increase in agricultural irrigation water use. With the expansion of cultivated land and the increase in irrigation water use, some areas have experienced a decline in groundwater levels[3], which poses a huge challenge to the sustainable development of agricultural water use and long-term agriculture in Northeast China.

Soil degradation is also a major constraint to the sustainable development of agriculture in the black soil region. Influenced by various factors such as climate change, increased agricultural development intensity, and lagging construction of farmland infrastructure, the black soil in Northeast China is showing a trend of degradation, and some areas are experiencing varying degrees of soil thinning, hardening, and thinning[4]. Soil organic matter, nutrients, bulk density, and erosion have all undergone certain changes. Although crop yields have not decreased under the current high-fertilizer planting mode, the sustained decline in soil nutrients has seriously affected the sustainable development of agriculture in the Northeast China black soil region[5].

The agricultural carbon footprint continues to increase, and the pressure to reduce carbon emissions in agriculture is increasing. Under the trend of "reducing quantity and increasing efficiency", the input of nitrogen fertilizers and pesticides in the agricultural system in Heilongjiang Province tends to be stable or even decreasing, along with the corresponding carbon footprint. However, the carbon footprint in the aspects of compound fertilizer, irrigation, and mechanical tillage continues to increase, and the total carbon footprint per unit of cultivated land continues to increase. Therefore, reducing the agricultural carbon footprint is an important aspect of the sustainable development of agriculture in Heilongjiang Province.

3. Policy direction and transition needs

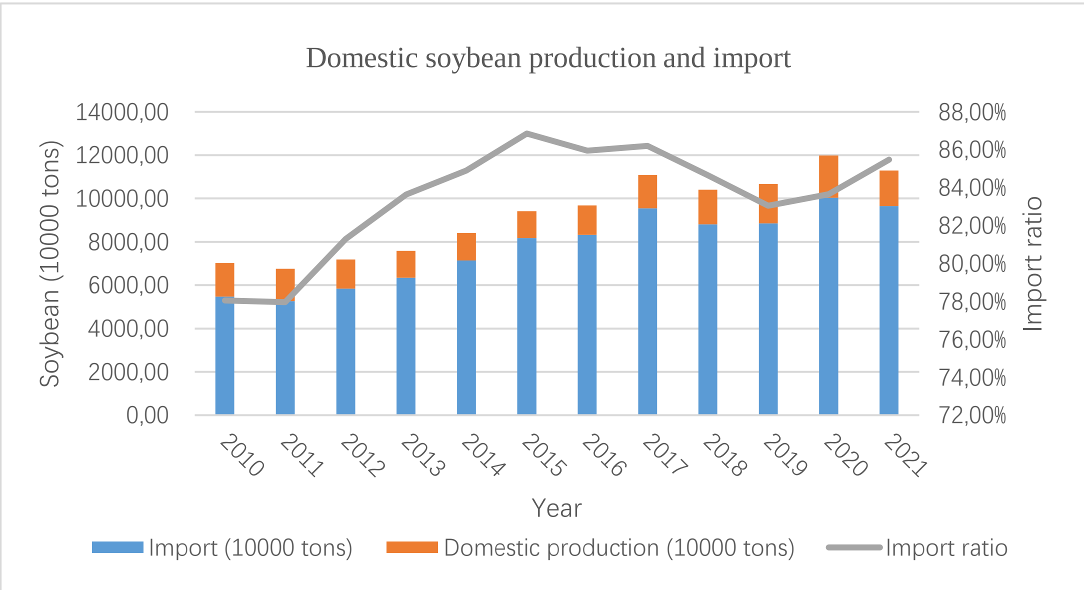
3.1 China’s soybean imports

[3] Report on the Conservation and Utilization of the Northeast Black Soil (2021)
[4] Report on the Conservation and Utilization of the Northeast Black Soil (2021)
[5] Han Z., Li N. 2018. Research Progress of Black Soil in Northeast China. Scientia Geographica Sinica, 38(7): 1032-1041.

As the economy develops and people's living standards improve, the consumption of protein and oil-rich foods increases. Soybeans are an important source of plant protein and oil, and soybean meal is also an important feedstock. China's demand for soybeans continues to increase. From 2010 to 2020, soybean demand in China increased from 70.1963 million tons to 119.9153 million tons (an increase of 70.83%, with per capita consumption in 2020 of about 86 kg). The majority of the growth was supplemented by foreign imports.

China's soybean import dependency (i.e., import ratio) has been maintained at over 80% in recent years (Figure 4, with soybean imports accounting for over 60% of world trade volume[6]). In terms of import sources, in 2020, China's soybean imports mainly came from the Americas and Central and Eastern Europe. As shown in Figure 5, the top two importers were Brazil (with an import volume of 64.2772 million tons, accounting for 64.70% of China's total soybean imports) and the United States (25.8751 million tons, 26%), followed by Argentina (6.5762 million tons), Uruguay (1.6566 million tons), Russia (0.6932 million tons), Canada (0.246 million tons), and Ukraine (0.0651 million tons) in descending order of import volume.

In recent years, due to factors such as climate change and geopolitics, the uncertainty of international soybean supply has increased. In order to cope with the continuous increase in domestic soybean demand and enhance the resilience of the food system, the Chinese government is seeking endogenous solutions, such as increasing the soybean planting area and moderately expanding soybean planting in suitable regions.



[6] http://www.cnfood.cn/article?id=1557544382999265281

Figure 4 Domestic soybean production and import (data sourced from China Rural Statistical Yearbook and Wind)

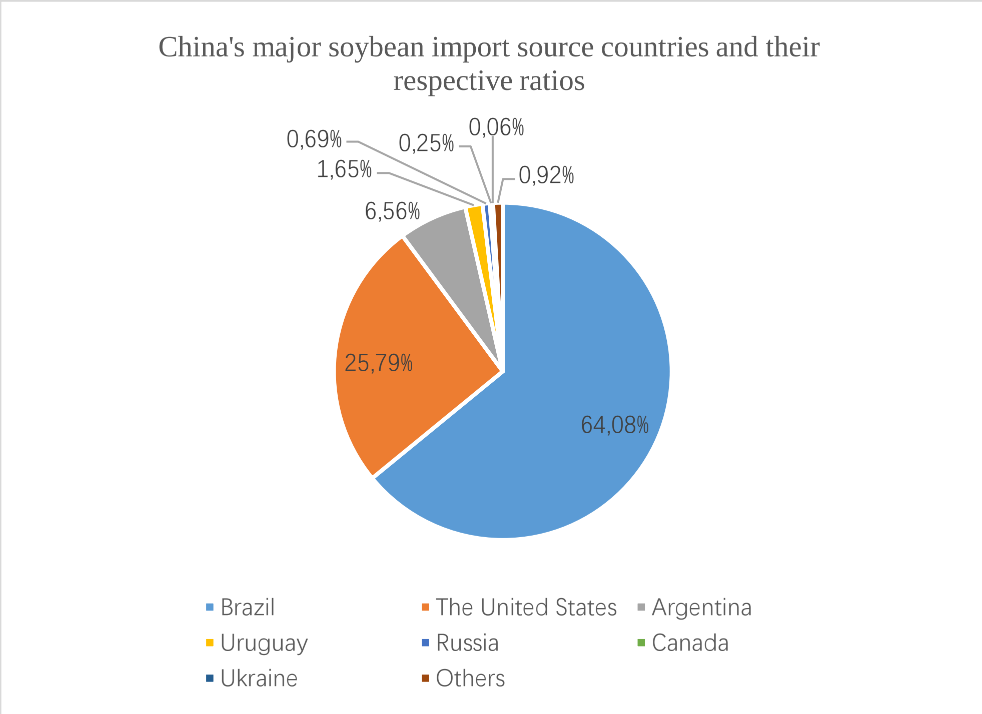


Figure 5 China's major soybean import source countries and their ratios in 2020 (data sourced from Wind)

3.2 Policy goal – expanding soybean cultivation

In 2023, the "No. 1 document" issued by the Central Committee[7] proposed expanding soybean and oilseed cultivation to increase production capacity. This will be achieved through various measures, such as the composite planting of soybeans and maize, crop rotation of grain and beans, and the development of saline-alkali land for soybean cultivation. Additionally, the government will improve subsidies for producers of maize and soybeans and initiate pilot programs for soybean planting insurance.

To implement the 2023 "No. 1 document", the Ministry of Agriculture and Rural Affairs aims to increase soybean planting areas by promoting crop rotation of grain and beans in Northeast China and expanding the planting of soybeans on saline-alkali land and abandoned land[8]. They will also accelerate the breeding of soybean-maize

[7] "Opinions of the Central Committee of the Communist Party of China and the State Council on Doing Key Tasks Well in Promoting Rural Revitalization in 2023"; http://www.lswz.gov.cn/html/xinwen/2023-02/13/content_273655.shtml

[8] "Implementation Opinions on Implementing the Key Tasks of Comprehensive Rural Revitalization in 2023 by the CPC Central Committee and the State Council"; http://www.gov.cn/zhengce/zhengceku/2023-02/22/content_5742671.htm

composite planting varieties and promote the reform of supporting farm machinery.

The soybean expansion policy is the focus of this research. The study scenario design will revolve around this policy, with differences in soybean expansion being set among the scenarios. By comparing the different scenarios, this research aims to provide information and reference for the implementation of the soybean expansion policy.

3.3 Other policy drivers – maintaining green agriculture production

Pesticide and fertilizer reduction and efficiency improvement will continue. Advancing the reduction and efficiency improvement of fertilizers and pesticides is a crucial measure for ensuring food security, guaranteeing food safety, and promoting green agricultural transformation. The "one reduction and three improvements" requirement for reducing the total amount of agricultural fertilizers, increasing the amount of organic fertilizers, promoting soil testing and formula fertilization, and improving the utilization rate of fertilizers (with a target of 43% for major grain crops by 2025) was proposed in the Action Plan for Reducing Fertilizer Use by 2025. The Action Plan for Reducing Pesticide Use by 2025 calls for a continuous reduction in the total amount of chemical pesticides used and a reduction in pesticide intensity (a 5% reduction for major grain crops compared to the 13th Five-Year Plan period and a 10% reduction for fruits, vegetables, and tea during the 13th Five-Year Plan period), as well as strengthening green pest and disease control and unified prevention and control measures.

Conservation tillage is used to maintain soil fertility. According to documents such as the Action Plan for Conservation Tillage in Northeast China's Black Soil Regions (2020-2025) (Nong Ji Fa [2020] No. 2) and the Implementation Guide for the Action Plan for Conservation Tillage in Northeast China's Black Soil Regions (Nong Ban Ji [2020] No. 3), conservation tillage will be gradually promoted in suitable areas of Northeast China, with a focus on two types of conservation tillage techniques: straw mulching and no-till, and straw mulching and reduced tillage. Efforts will be made to ensure that the area of conservation tillage in Northeast China reaches 140 million mu by 2025, accounting for 70% of the total arable land area in the suitable regions of Northeast China.

Pesticide and fertilizer reduction and efficiency improvement, as well as conservation tillage, are important components of green agricultural development in China and important drivers of future agricultural system development. This study will consider the changes brought about by these two policies in future scenarios, but no differences will be set between the scenarios. Therefore, they are not the target policies that this study aims to support.

4. Scenario setting for the study

4.1 Time scale

In this study, the short-term time point for scenario analysis is 2025, the completion year of the 14th Five-Year Plan, which is also the first five years to achieve quality and efficiency in agriculture for a moderately prosperous society; the medium-term time point is 2035, which is the target year for the basic realization of modernization and an important time point for the basic realization of modern green production and sustainable consumption; and the long-term time point is 2050, which is the target year for building a strong and modern country.

4.2 Driving forces

The driving forces affecting the agricultural system can be divided into two categories: natural environmental and socioeconomic factors. In this study, natural environmental factors mainly consider changes in natural environmental elements caused by climate change and use regional temperature and precipitation under two representative concentration pathways (RCP4.5 and RCP8.5) in the IPCC Fifth Assessment Report as indicators of future climate change scenarios. Socioeconomic factors mainly include population changes, urbanization, and the impact of agricultural policies. The analysis mainly targets the "Expansion of Soybean Planting", a land-use policy, but also incorporates the future trends driven by soybean breeding improvement, specialized cultivation, precision cultivation, reducing pesticide and fertilizer use, and promoting conservation tillage.

4.3 Specific scenarios

Based on the national "soybean expansion" policy and Heilongjiang's agricultural conditions, this study sets up three future soybean cultivation scenarios: the business-as-usual (BAU) scenario, the soybean priority (SP) scenario and the grain priority (GP) scenario, which, combined with two climate change scenarios (changes in soybean yields due to differences in hydrological and thermal conditions under the RCP4.5 and RCP8.5 climate scenarios will also be included in the analysis), form six study scenarios (Table 3). Of which:

BAU represents a situation that is very likely to happen under the current policy orientation and planning, that is, moderately expanding soybean cultivation on the existing planting mode and basis;

SP scenario is a mode of expanding soybean planting area further on the BAU;

GP scenario means not expanding soybean cultivation and maintaining the existing planting structure to ensure the planting mode of staple grains.

Table 3 Scenario setting

Scenario 1	Scenario 2	Scenario 3
RCP4.5 + BAU	RCP4.5 + Soybean priority	RCP4.5 + Grain priority
Scenario 4	Scenario 5	Scenario 6
RCP8.5 + BAU	RCP8.5 + Soybean priority	RCP8.5 + Grain priority

In terms of land use, the current "soybean expansion" practice in Heilongjiang Province will be conducted through the following two modes:

1. "Paddy-to-soy" programme: Promote pilot projects of converting rice cultivation to soybean cultivation in areas with excessive groundwater exploitation and cold areas where irrigation relies on well water;
2. "Maize-to-soy" programme: Convert maize-maize cultivation to maize-soybean annual rotation on existing farmland.

4.4 Business as usual (BAU) scenario

The BAU is based on relevant national and Heilongjiang province's development plans, and involves moderately expanding soybean planting through measures such as rice-to-soybean conversion and maize-to-soybean conversion. At the same time, soybean yield will be increased through technological innovation and precision management, and fertilizer use efficiency will be improved through slow-release fertilizers, foliar fertilizers, and rhizobium inoculants. Pesticide use efficiency will be improved through green pest control and unified prevention and control, and the proportion of no-tillage farming will be increased.

According to expert interviews, the expected increase in soybean production in China is approximately 10 million tons, with Heilongjiang Province expected to contribute 50%, i.e. an increase of 5 million tons.

The setting of yields: soybean yields in 2025 will increase by about 30% compared to 2022 levels (1.93 t/ha) to 2.51 t/ha; in 2035 by about 40% compared to 2022 to 2.70 t/ha; and in 2050 by about 50% compared to 2022 to 2.90 t/ha.

The setting of area and output: 2035 soybean production in Heilongjiang increases by 5 million tons from 2022, with acreage derived from yields and soybean yield levels for that year; 2025 soybean acreage is derived from a linear relationship between 2022-2035 acreage, with output based on 2025 yield levels and acreage; 2050 soybean acreage is the same as in 2035, and output is based on 2050 yield levels and acreage.

The BAU parameters are as follows (Table 4):

Table 4 Soybean production data under the BAU scenario

Year	Cultivated area (10000 ha)	Yield (t/ha)	Fertilizer efficiency (%)	Pesticide efficiency (%)	No-till rate (%)	Production (10000 t)
2022	493.17	1.93	40.2	40.6	0	951.82
2025	504.31	2.51	45	45	20	1265.81
2035	537.71	2.70	50	50	50	1451.82
2050	537.71	2.90	50	50	70	1559.36

2022 data sourced from https://www.hlj.gov.cn/hlj/c107856/202212/c00_31502977.shtml

4.5 Soybean priority (SP) scenario

Under the SP scenario, the expansion of soybean planting area is further increased compared to the BAU, and the trends in soybean yield, fertilizer and pesticide utilization rates, and no-till adoption are consistent with the BAU.

As shown in Table 5, the parameters for the SP scenario are as follows: by 2035, all paddy rice in the groundwater overexploited areas of Heilongjiang will be converted to soybeans (conversion area X), and all maize will also be converted to maize-soybean rotation (2022 maize cultivated area was 6 million hectares), with a total area of $1093.17 + X$ 10,000 hectares. The soybean planting area in 2025 is derived by reversing the soybean area growth trend from 2021 to 2035 (area Y). The soybean planting area in 2050 is the same as in 2035.

Table 5 Soybean production data under the Soybean priority scenario

Year	Cultivated area (10,000 ha)	Yield (t/ha)	Fertilizer efficiency (%)	Pesticide efficiency (%)	No-till rate (%)	Production (10,000 t)
2022	493.17	1.93	40.2	40.6	0	951.82
2025	Y	2.51	45	45	20	TBM
2035	1093.17+X	2.70	50	50	50	TBM
2050	1093.17+X	2.90	50	50	70	TBM

X represents the converted area of water-intensive rice cultivation to soybean cultivation in groundwater overexploited areas (to be determined in later research), while Y represents the soybean planting area in 2025 calculated based on the soybean planting area growth trend from 2021 to 2035. Total production in 2025, 2035, and 2050 are to be modelled (TBM).

4.6 Grain priority (GP) scenario

Under the "Grain priority" scenario, assuming that the "expansion of soybean cultivation" policy is not implemented, the current soybean planting area will be maintained. Soybean yield, fertilizer utilization rate, pesticide utilization rate, and no-tillage adoption rate will all be maintained at the current levels. Therefore, the soybean planting area in 2025, 2035, and 2050 will be maintained at the 2022 level of 4.93 million hectares, with a yield of 1.93 t/ha and a production of 9.52 million tons. The utilization rate of fertilizers and pesticides will be 40.2% and 40.6%, respectively, and the no-tillage adoption rate will be 0.

5. Contents of analysis

Planting soybeans, maize, and paddy rice require different labour and agricultural inputs, which result in varying crop output and economic benefits. The environmental impacts of the planting process are also different. Therefore, the impact of the differences in land use brought about by different soybean expansion policies is multidimensional, including natural, economic, and social aspects.

This study will simulate and compare the natural, economic, and social costs and benefits of the agriculture system in Heilongjiang Province under different soybean expansion policies and other driving factors (i.e., the BAU, soybean priority, and grain priority development paths) by 2025, 2035, and 2050. The results will be classified into four categories of natural capital, produced capital, human capital, and social capital, which are shown in Table 6.

The study focuses on variables such as planting area, fertilizer utilization rate, pesticide utilization rate, and no-tillage adoption rate. Among them, the planting area is the target variable, which will affect the accounting results of all four types of capital. The pesticide and fertilizer utilization rates will affect aspects such as ecological services, pollutant emissions, and public health, while the no-tillage adoption rate will affect greenhouse gas emissions and storage.

Through the above design, this study aims to compare the natural, economic, and social effects of different soybean expansion policies in the short, medium, and long term, especially by considering both visible and invisible costs and benefits. It will provide comprehensive information and reference for the implementation of soybean expansion policies in Heilongjiang Province and even across the country, and support the formulation and improvement of sustainable agriculture policies.

Table 6 Contents of analysis

Capital	**Benefit**	**Cost**
Natural	Ecosystem services: recreation enabling, water provisioning, water purification, soil retention, pollination, carbon sequestration	Pollutant emissions: air pollutants (ammonia nitrogen, nitrogen oxide, nitric oxide, nitrogen dioxide, methane, pesticides), water pollutants (chemical oxygen demand, nitrate, phosphate, pesticides), solid waste (unused straw, animal excrement), and greenhouse gases over the entire life cycle9
Produced	Crop and livestock production	Input of agricultural materials (energy, fuel, fertilizers, pesticides, etc.)
Human	Quantity of labour, skills training	Health impacts: occupational exposure, exposure to air pollution, exposure to downstream water bodies, and exposure to consumption of agricultural products.
Social	Female empowerment, social mechanisms (agricultural cooperatives)	/

[9] This report includes all greenhouse gases mentioned in the fifth report of the Intergovernmental Panel on Climate Change (IPCC), including carbon dioxide, methane, and nitrous oxide.