

# THE TRADE-OFFS AND SYNERGIES BETWEEN FOOD PROVISIONING AND SOIL CONSERVATION SERVICES IN GUANGXI PROVINCE UNDER THE CONTEXT OF THE CONVERSION OF CROPLAND TO FOREST AND GRASSLAND

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## ***Abstract***

The farmland-to-grassland-and-forest conversion program in Guangxi Province has enhanced soil conservation while significantly impacting regional food supply, highlighting the complex trade-offs between ecological protection and agricultural production. This study analyzed the spatiotemporal patterns of land use change, food supply services, and soil conservation services in Guangxi Province from 1990 to 2020, combined with Pearson correlation analysis, to reveal the dynamic relationship between the two. The results show that the farmland-to-grassland-and-forest conversion program has significantly altered the land use pattern in Guangxi Province, with arable land first increasing and then decreasing, while forest land has continued to increase. During this process, food supply services have shown an overall upward trend but with uneven spatial distribution; soil conservation services have declined, especially in the western and northern regions. The Pearson correlation coefficients between food supply services and soil conservation services in 2000, 2010, and 2020 indicate a significant negative correlation between the two, although this trade-off has eased by 2020. While the farmland-to-grassland-and-forest conversion program has improved the ecological environment, it has also had some impact on food production. However, with the advancement of ecological protection measures, the conflict between the two is gradually being mitigated. It is necessary to optimize land use practices to balance food production and ecological protection and achieve sustainable regional development.

*Keywords:* Guangxi Province; Farmland-to-Grassland-and-Forest Conversion; Food Supply; Soil Conservation Services.

## ***Introduction***

With the rapid growth of the global population and the swift development of the economy, food security and the sustainability of ecosystems have emerged as significant challenges that urgently need to be addressed (Kumar et al. 2023). As the most populous country in the world, China faces a particularly dilemma in balancing food production and ecological protection. Guangxi Province, as an important agricultural production area and an ecologically vulnerable region in China, is confronted with the dual pressures of food production and ecological conservation (Xinran et al. in press, Chen et al. 2024). In recent years, the farmland-to-forest-and-grassland conversion program, as a vital ecological restoration measure, has been widely implemented in Guangxi Province. It aims to improve the ecological environment and reduce soil erosion through vegetation restoration and land use adjustment (Pang et al. 2024). However, while this program has enhanced ecosystem services, it has also had certain impacts on food production, thereby triggering trade-offs and coordination issues between food supply services and soil conservation services.

Food supply services are fundamental to maintaining regional food security, while soil conservation services are crucial for ensuring land ecological health and sustainable utilization (Powlson et al. 2011). The farmland-to-forest-and-grassland conversion program in Guangxi Province has significantly increased vegetation cover and reduced soil erosion but has also led to a reduction in arable land area, imposing certain limitations on food production (Chen et al. 2024). Land use change is an important factor affecting food supply and soil conservation services. By altering land cover types and vegetation structures, the farmland-to-forest-and-grassland conversion program has directly impacted the regional supply capacity of ecosystem services. Therefore, how to achieve the synergistic optimization of food supply services and soil conservation services under the context of the farmland-to-forest-and-grassland conversion program is a core issue for the sustainable development of Guangxi Province. The goal of this article is to analyze the spatiotemporal dynamics of food supply and soil conservation services in Guangxi Province from 1990 to 2020, quantify their trade-offs and synergies under the Grain for Green Program, and propose strategies to reconcile ecological restoration with agricultural sustainability.

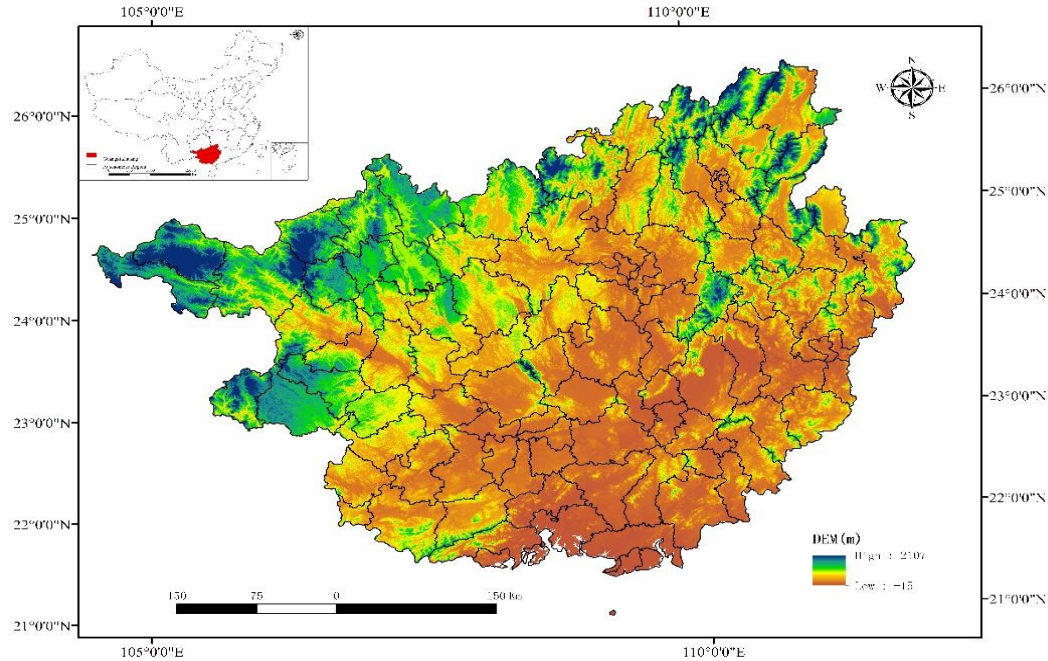
## ***Methodological approach***

### *Study Area*

Guangxi (N20°54'09"–26°23'19", E104°26'48"–112°03'24") is located in southern China. The topography of Guangxi is characterized by high elevations in the northwest and lowlands in the southeast, forming a basin landscape dominated by mountains and hills. Karst topography is widely distributed across the region, covering 40.72% of the total area, with primary distributions in central, northwestern, southwestern, and northeastern Guangxi. The climate of Guangxi is subtropical monsoonal, characterized by abundant heat and plentiful rainfall, with an average annual temperature ranging from 16°C to 23°C and an annual precipitation of 1200–2000 mm. These climatic conditions are suitable for the growth of a variety of crops. Agricultural production

in Guangxi is mainly based on rice, sugarcane, and fruits, making it an important sugarcane-producing area and subtropical fruit base in China.

**Figure 1. Geographical location and elevation distribution of Guangxi Province**



## Methods

### *Calculation of Food Supply Services and Soil Conservation Services*

Food supply service is an essential component of ecosystem services and plays a significant role in regional food security. As one of the important grain-producing areas in China, the spatiotemporal variation characteristics and driving factors of food supply service in Guangxi Province hold important research value (He et al. 2024). This study employs long-term NDVI (Normalized Difference Vegetation Index), combined with Land Use and Land Cover Change and grain yield statistics, to conduct a spatiotemporal analysis of food supply service in Guangxi Province. The formula is as follows:

$$GPI_i = \frac{NDVI_i - NDVI_{min}}{NDVI_{max} - NDVI_{min}} \times GPT$$

$NDVI_i$  indicates the Normalized Difference Vegetation Index at time  $t$ .

$NDVI_{min}$  indicates the minimum NDVI value observed during the study period.

$NDVI_{max}$  indicates the maximum NDVI value observed during the study period.

GPT: represents the Growth Productivity Threshold, which is a preset value used to convert NDVI into a productivity metric.

Soil conservation service is a vital component of ecosystem regulating services and plays a crucial role in maintaining regional ecological balance and ensuring food security. Located in the subtropical monsoon climate zone, Guangxi Province has abundant vegetation cover and faces significant soil erosion issues that have attracted widespread attention. In this study, the soil conservation module of the InVEST model is employed to assess soil conservation services by calculating the difference between potential and actual soil erosion (Jian et al. 2024).

*Trade-offs and Synergies between Soil Conservation Services and Food Supply Services*

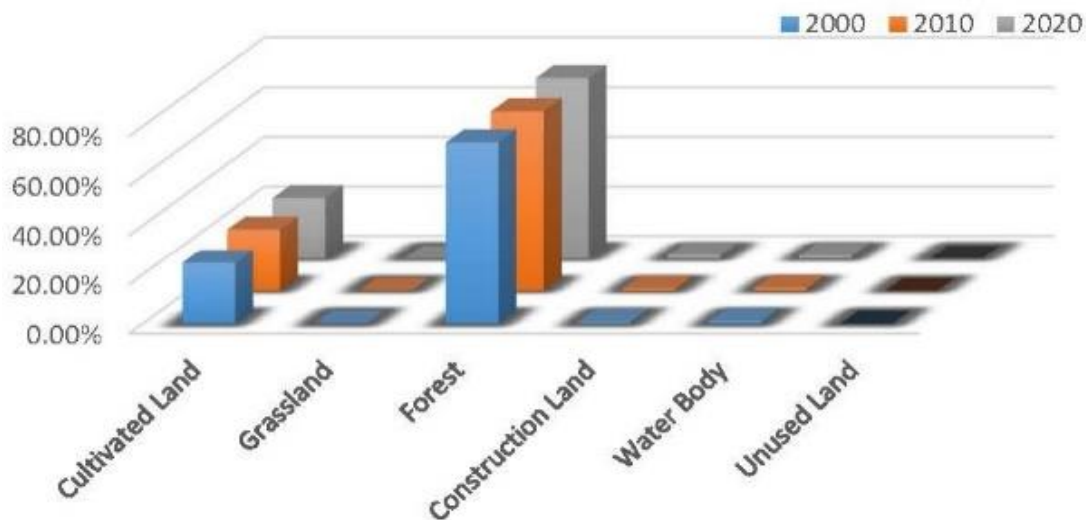
This study uses Spearman correlation analysis to examine the trade-offs and synergies between food supply services and soil conservation services in Guangxi Province from 2000 to 2020.

**Analysis results**

*Farmland-to-Forest-and-Grassland Conversion Areas in Guangxi Province from 1990 to 2020*

From 2000 to 2020, the land use types in Guangxi Province were predominantly forest land and arable land (Fig. 2). The proportion of arable land in Guangxi Province first increased and then decreased from 2000 to 2020. The share of arable land was 24.70% in 2000 and decreased to 24.57% in 2020. This trend is closely related to the implementation of the farmland-to-forest-and-grassland conversion policy. The policy aims to improve the ecological environment and enhance land productivity by reducing the area of arable land and increasing the areas of forest and grassland. Among all land use types, the proportion of urban construction land showed the most significant change, increasing from 0.66% in 2000 to 1.29% in 2020, a rise of approximately 0.63 percentage points. This change reflects the acceleration of urbanization and the demands of economic development in Guangxi Province. With the advancement of urbanization, the increasing demand for urban construction land has led to a significant rise in its proportion.

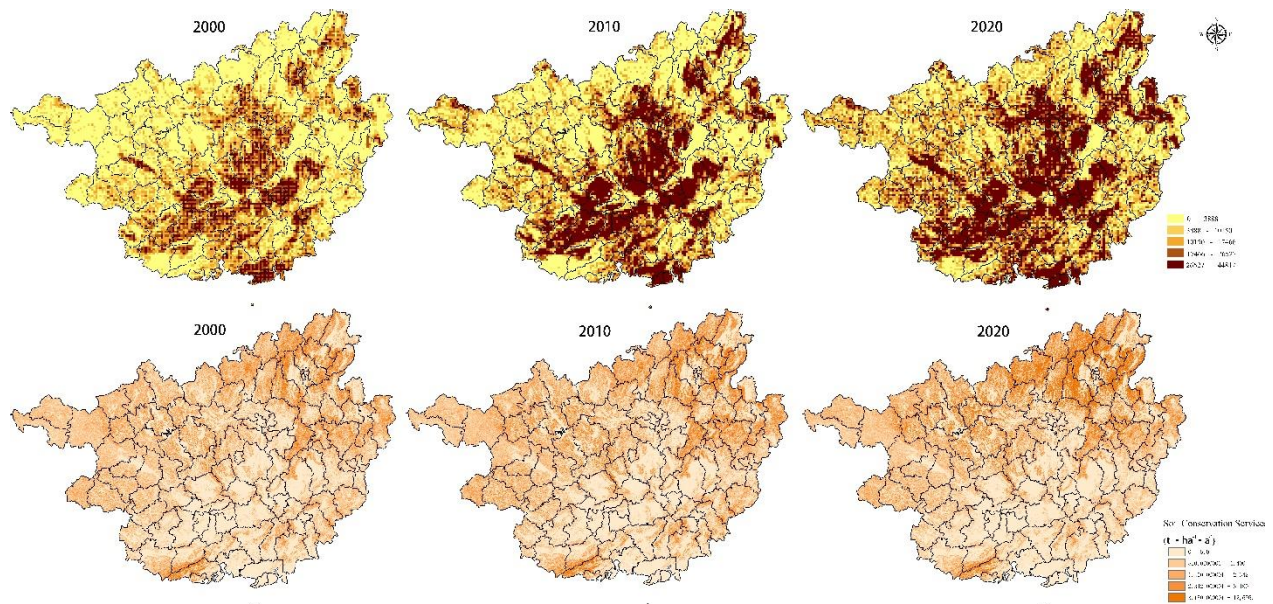
**Figure 2. Proportion of Different Land Use Types in Guangxi Province from 2000 to 2020**



### *Spatiotemporal Distribution of Food Supply Services and Soil Conservation Services from 1990 to 2020*

The food supply service in Guangxi Province showed an increasing trend from 2000 to 2020, due to the improvement of agricultural equipment that increased yields within limited areas (Figure 3). Spatially, the distribution of food supply service was uneven across different regions. The central and eastern regions had higher Food Supply Service (FSS) values, as these areas had better agricultural production conditions and higher land use efficiency, resulting in higher food supply service values. In contrast, the western and northern regions had lower FSS values, likely due to limitations imposed by natural conditions such as topography, soil fertility, and water resource distribution, which weakened agricultural production capacity and led to lower food supply service values. The FSS values in the central region remained relatively stable between 2000 and 2010 but showed a significant decline in 2020. This may be related to adjustments in agricultural policies, changes in land use patterns, and climate change in the region.

**Figure 3. Spatiotemporal Distribution of Food Supply Services and Soil Conservation Services in Guangxi Province from 2000 to 2020**



The amount of soil conservation services in Guangxi Province showed an upward trend from 2000 to 2020 during the study period, indicating that soil conservation capacity improved in the region during this period. In 2020, the value of soil conservation services was relatively high, especially in the central and eastern regions, which may be related to land use patterns, vegetation cover, and soil management practices at that time. From the perspective of spatial distribution, SCS values in central and eastern regions were lower. SCS values are lower in the western and northern regions,



which have better vegetation cover and proper soil management practices, so soil conservation service values are higher.

#### *Trade-offs and Synergies*

The Spearman correlation coefficients between food supply services and soil conservation services in 2000, 2010, and 2020 were  $-0.600^{**}$ ,  $-0.598^{**}$ , and  $-0.502^{**}$ , respectively. These values indicate a significant negative correlation between the two services, meaning that an increase in food supply services is often accompanied by a decrease in soil conservation services. The trade-off between food supply and soil conservation services remained stable and significant over the decade. However, by 2020, the correlation coefficient decreased to  $-0.502$ , suggesting that the trade-off had eased. This change is likely related to the implementation of ecological protection policies in recent years. With the continued advancement of ecological protection measures and the optimization of land use practices, the conflict between food supply and soil conservation services is expected to be mitigated, thereby achieving a win-win situation for both ecology and economy.

#### *Discussion and Conclusions*

This study analyzed the spatiotemporal characteristics of land use change, food supply services, and soil conservation services in Guangxi Province from 1990 to 2020, revealing the trade-offs between food supply and soil conservation services under the context of the farmland-to-grassland-and-forest conversion program. The results show that while the program significantly increased vegetation cover and soil conservation capacity, it also led to a reduction in arable land, thereby imposing certain limitations on food production. This trade-off was particularly significant between 2000 and 2010 but eased by 2020, indicating that the continuous implementation of ecological protection measures may have played a positive role in mitigating the conflict between the two services.

Regarding land use change, the trend of increasing and then decreasing arable land area in Guangxi Province is closely related to the farmland-to-grassland-and-forest conversion policy. Although the reduction in arable land helps to reduce soil erosion, it also has a negative impact on food supply services. However, with the advancement of agricultural technology and improved land use efficiency, food supply services have shown an overall upward trend. This suggests that optimizing agricultural management and land use practices can help alleviate the trade-off between food supply and soil conservation services to some extent.

The spatial differences in soil conservation services also reflect the impacts of regional ecological environment characteristics and land use patterns. The central and eastern regions have higher soil conservation services due to better vegetation cover and effective soil management practices. In contrast, the western and northern regions have weaker soil conservation capacity due to limitations in topography, vegetation cover, and soil types. This spatial heterogeneity indicates that regional

differences should be fully considered when developing ecological protection and agricultural development strategies, and measures should be tailored to local conditions.

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