LAND USE CHANGE UNDER CHINA'S 2020 BIOETHANOL TARGET: A CGE BASED ANALYSIS

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Overview

Bioethanol is widely considered a promising option to alleviate energy shortage and to address climate change. However, some adverse effects are also proposed, like problems relating to food security, carbon sequestration and biodiversity. In recent years, the sustainability of bioethanol has been a hot debate and there's no consistent answer currently. Wicke et al. (2012) suggested that many of these impacts are related to land use change (LUC) driven by feedstock planting. So based on this perspective, it is necessary to explore the LUC impact of bioethanol production.

As a big consumer of energy, China began to produce bioethanol in 2002, and now becomes the third largest bioethanol producing country in the world. But sustained development still requires a lot of efforts. According to China's 13th Five-year Planning for Renewable Energy Development, the bioethanol production target is 4 million tons per year by 2020, nearly twice of the quantity in 2015 (2.1 million tons). Besides, the major feedstocks in China are food grains (mainly corn and wheat) (Qin, et al., 2017), which can cause competition with food production for land. Thus, achieving China's 2020 bioethanol goal would inevitably bring great changes to land use, and may put further pressure on food supply. Nevertheless, previous studies about LUC mostly focused on the US, Brazil and the EU, and there is no literature that specifically quantifies the impact of China's bioethanol expansion on LUC.

In this context, our paper intends to address this gap by quantifying the land use change (including direct LUC and indirect LUC) driven by China's 2020 bioethanol target. What's more, we analyse the induced impacts on food security and GHG emissions under different land use policies, aiming to identify a suitable land use pattern which can maximize the synergies of bioethanol expansion while avoiding negative impacts. Each of these has crucial practical policy implications for bioethanol development in China, especially for feedstock choice and land use management. Besides, our work lays a foundation for further integrated impact assessment of biofuel development.

Methods

In this study, we develop a static multi-sector computable general equilibrium (CGE) model augmented with an explicit land use module. Compared with traditional market equilibrium models or allocation models (Wicke, et al., 2012), our CGE model presents more detailed representation of land conversion across alternate uses, which can simulate the changes in land demand of different sectors under policy shocks, and provide a more encompassing assessment of the bioethanol emergence on LUC and other economic activities.

The Social Accounting Matrix (SAM) is obtained from the 2012 Input-Output (IO) table. According to related data selected from National Agricultural Products Costs and Benefits Compilation, China's Annual Report of Biofuels, FAO Database, as well as the USDA Global Agriculture Information Network, we do some aggregation and separation with original sectors. Specifically, "agricultural products" sector is divided into rice, wheat, corn, non-grain feedstock (cassava and sweet sorghum) and other agricultural products. And "wine and alcohol" sector is split to generate bioethanol sector. What's more, we split the land natural resources with eight sub accounts from the "capital" account. Considering the land heterogeneity, we employ a constant elasticity of transformation (CET) function by which an aggregate endowment of land can be transformed across alternative uses, and a three-level nested structure governs the response of land supply to changes in relative price. The nested structure and transformation parameters are in line with Timilsina et al. (2012) and Fujimori et al. (2014), respectively. In the production structure of agricultural sectors, land factor is first combined with capital, then labor factor is combined with land-capital, and finally combined with other intermediate inputs to generate the final output.

All scenarios are based on 2020 bioethanol target, but we make a distinction between land conversion assumptions for feedstock planting in different scenarios. To be specific, the incremental bioethanol production is realized by S1-land conversion between existing cropland, i.e., land endowment remains the same as the base year, forest and grassland are kept constant over time; S2-land conversion between existing cropland, forest and grassland, i.e., forest and grassland can also be transformed to feedstock land, and the aggregate land endowment remains constant; S3-land conversion between existing cropland, forest and grassland, but land endowment is increased due to the reclamation of marginal land, which can be used for planting non-grain feedstock. The land data are collected from the National Land Survey Database, and the amount of marginal land follows the work of Chen et al. (2017).

Results

(1) Land use change

To achieve China's 2020 bioethanol target, changes in aggregate land allocation between different land use types are shown in Fig. 1. In S1, the land supply for bioethanol feedstock (wheat, corn and non-grain feedstock) is realized by occupying the land from rice, other grains and other crops, which decreases by 0.016%, 0.398% and 0.043%, respectively. In S2, bioethanol expansion still causes land competition with food grains, but the conversion among different cropland is alleviated to some extent since the sacrifice of some forests (-0.023%) and grasslands (-0.023%). Due to the increment of potential land supply from marginal land that can be used for non-grain feedstock cultivation, the competition among different land uses is eased in S3.

(2) GHG emissions

Then, according to FAO Database, we calculate the GHG emissions/removals from cropland, forest and grassland which may be influenced by LUC. Setting S1 as a benchmark, the results illustrate that net emissions from the total land will increase 71,000 tons/year in S2 because of deforestation, and decrease 253,000 tons/year in S3.

(3) Food security

As indicated in Table 1, expanding bioethanol production leads to an increase in food price in S1 and S2. Because some rice land converts to plant feedstock, the reduced rice supply triggers higher market price. As for wheat and corn, the demand will increase to meet the bioethanol target, which would also raise the price. In S3, food price declines slightly as the production of bioethanol depends on more non-grain feedstock which can be cultivated on marginal land. Further, food price will affect the households' final consumption (Table 2).

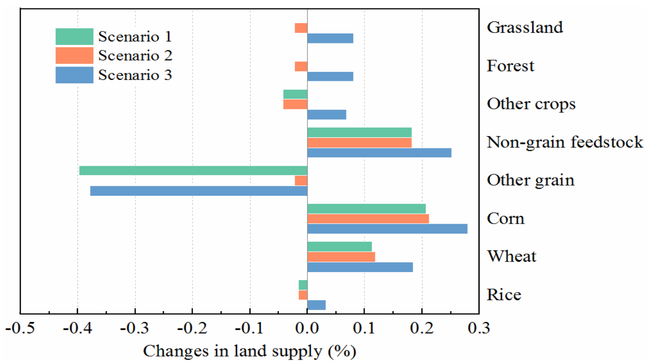

Fig. 1 Changes in land supply (%) relative to the baseline

Table 1 Changes in food price (%)

Food type	Scenario 1	Scenario 2	Scenario 3
Rice	0.0594	0.0602	-0.2954
Wheat	0.1266	0.0849	-0.3948
Corn	0.1288	0.0861	-0.4037

Table 2 Changes in food consumption (%)

Food type	Scenario 1	Scenario 2	Scenario 3
Rice	-0.0492	-0.0499	0.1106
Wheat	-0.0895	-0.0648	0.1706
Corn	-0.0908	-0.0655	0.1760

Conclusions

Based on the land explicit CGE model, this paper explores the impact of China's bioethanol production target on land use change. The results demonstrate that LUC occurs when existing lands are converted to other uses because of bioethanol expansion, and it would cause a rise in food price without potential land input. However, if forest and grassland can be used to meet the new land demands for bioethanol production, it may increase net release of GHG emissions from land use. Fortunately, when marginal land can be reclaimed for non-grain feedstock planting, negative impacts on food security and GHG emissions would be alleviated, which manifests that developing bioethanol can achieve multi-synergies in this land use pattern.

Finally, we can draw some policy implications. Non-grain energy crops grown on marginal land could significantly contribute to bioethanol feedstock resources in China, promote the sustainable development of bioethanol without compromising food security and deforestation. Therefore, government should improve the land use management and encourage more non-grain feedstocks under the bioethanol goal. But it should be noted that the cost of reclaiming marginal land would be high and large-scale reclamation may generate risks for ecological vulnerability. Overall, this paper explicitly analyses the total LUC driven by China's bioethanol target, and identifies a sustainable land use pattern to avoid possible negative impacts on food security and GHG emission.

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