Biofuel Development, Food Security and the Use of Marginal Land in China

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With concerns of energy shortages, China, like the United States, European Union, and other countries, is promoting the development of biofuels. However, China also faces high future demand for food and feed, and so its bioenergy program must try to strike a balance between food and fuel. The goals of this paper are to provide an overview of China's current bioethanol program, identify the potential for using marginal lands for feedstock production, and measure the likely impacts of China's bioethanol development on the nation's future food self-sufficiency. Our results indicate that the potential to use marginal land for bioethanol feedstock production is limited. Applying a modeling approach based on highly disaggregated data by region, our analysis shows that the target of 10 million t of bioethanol by 2020 seems to be a prudent target, causing no major disturbances in China's food security. But the expansion of bioethanol may increase environmental pressures due to the higher levels of fertilizer use. This study shows also that if China were able to cultivate 45% of its required bioethanol feedstock on new marginal land, it would further limit negative effects of the bioethanol program on the domestic and international economy, but at the expense of having to apply another 750 thousand t of fertilizer.

The rapid growth of China's energy demand has led to mounting concerns about its national energy security. China is now the third-largest energy-consuming country in the world, behind the United States and Japan (Fischer et al., 2009). In 2007, China's net import of oil reached 186 million t, accounting for 49.6% of its total oil demand (NBSC, 2008). The rises in oil demand and oil imports are expected to continue with the expansion of China's economy. The International Energy Agency projects that 77% of China's oil consumption will be imported by 2020. The situation will become even worse by 2030, when 84% of the nation's oil is projected to be imported (IEA, 2005).

Given these concerns, the search for alternative sources of energy has become a top policy priority of China's government (Wei et al., 2006). Biofuels are high on the government's list as a possible substitute for liquid fuels in cars, mainly in the form of bioethanol. Other goals of any policy to expand the production of biofuels include reducing carbon dioxide (CO_2) emissions—but this effect is generally thought to be modest at best. Furthermore, biofuels can serve to continue the demand for certain feedstock crops, such as cassava (*Manihot esculenta* Crantz), maize (*Zea mays* L.), oilseeds and sugarcane (*Saccharum officinarum* L.) (MOA, 2007). Because a large fraction of the production of many of these crops originates from relatively poor parts of China, higher prices and deeper markets would help in contributing to poverty alleviation.

In response to these challenges and the new potential opportunities associated with the new biofuel technologies, as in many other countries, China initially formulated an ambitious biofuel development strategy. Before 2007, the government had discussed the production of 20 to 30 million t of biofuels annually by 2020. During these initial years, some officials envisioned China as one of the largest biofuel producers in the world.

Authorities quickly began to understand, however, that if initial goals were realized, the competition of bioethanol originating from crops such as maize, cassava, and sugarcane (and of biodiesel originating from oilseeds) with human and animal nutrition could pose a serious threat to national food security. In particular, the spikes in world food prices that occurred in 2007 and

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Abbreviations: CAAE, Chinese Academy of Agricultural Engineering; DDGS, Dry Distiller's Grain with Solubles; MLR, Ministry of Land and Resources.

2008 had the effect of reminding China that world markets could not be relied upon unconditionally to fill the possible gaps between domestic food and feed supply and the demand that would appear if large shares of agricultural resources were put into biofuel feedstock production. Although international trade has become a major pillar of China's food system, with both large export (vegetables, fruits, and to a lesser extent, rice [*Oryza sativa* L.]) and large import (sugar, vegetable oil, soybean [*Glycine max* (Merr.) L.]), the government is still hesitant to rely on imports for large shares of the country's food supplies (Central Committee of Communist Party of China, 2008).

Other voices also expressed concerns about the effect that the rise of biofuels could have on the environment. In particular, if prices in China rise, farmers might be induced to apply chemical fertilizers at rates that exceed their already-high application levels (Huang and Rozelle, 1995; Peng et al., 2002). With high rates of chemical fertilizer, water pollution and soil contamination are expected to be intensified (Keyzer et al., 2008).

In fact, after reassessing its biofuel policy, the government announced a sharply modified policy—one that recognizes the importance of maintaining food self-sufficiency. In 2007, China reduced its annual bioethanol target to 10 million t by 2020 and also prohibited the expansion of any biofuels using major cereals as inputs. Instead, new policies encourage the use of sweet sorghum [*Sorghum bicolor* (L.) Moench], cassava, sweet potato [*Ipomoea batatas* (L.) Lam.], and other noncereal crops. Officials also have made pronouncements that any additional feedstocks are supposed to be produced on marginal lands.

In this study, we seek to examine China's bioethanol policies and its bioethanol targets for 2020. (We use the term *bioethanol* when reference is made to the specific policy program or to a quantitative assessment of fuel ethanol. The term *biofuel* is used in more general discussions where it applies to both bioethanol and biodiesel.) What is the consequence of China setting a target of 10 million t of production of bioethanol by 2020? What is the implication of not allowing land that is currently being cultivated to be planted with bioethanol feedstocks? While this is a broad topic, we focus here on four questions. Will China's bioethanol policy lead to major disturbances in the food system due to substitution away from food crops? What are the consequences for the balance of China's international trade? Will bioethanol production in China provide a boost to farm incomes? Will there be serious ecological damage triggered by increased fertilizer use from bioethanol expansion?

In this study, these questions are addressed at both national and regional levels using analysis from a set of scenario simulations created by the CHINAGRO model. The CHINAGRO model is a geographically detailed, general equilibrium model that comprehensively depicts China's farm sector at the county level, while connecting the county units to each other through trade and transportation flows, as well as connecting the farm sector in each county to the nation's urban and rural consumers and to international markets (Keyzer and van Veen, 2005; Fischer et al., 2007). This type of model is particularly well suited for answering the questions of our study. Because of the highly heterogeneous geographical conditions and agricultural production patterns in the different regions of China, it is necessary to model the production and consumption patterns of a commodity, such as bioethanol, with a model that can capture the regional differences and can explicitly represent the production choices and the competition among crops for available land, labor, and nutrient resources. As background to the discussion, Fig. 1 shows the provinces of China and their aggregations to the main CHINAGRO regions.

Bioethanol Developments and Policies in China

Bioethanol Production in China

China's bioethanol industry has expanded rapidly since the early 2000s. Bioethanol production reached about 1.5 million t in 2008, making China the third-largest producer of bioethanol in the world (EIA, 2009). Four large-scale, state-owned bioethanol plants were set up in Heilongjiang, Jilin, Henan, and Anhui provinces in 2001. The total annual bioethanol production capacity of these four plants, which use mainly maize as feedstock, is approximately 1.5 million t. In 2007, China set up another bioethanol plant using cassava as the main feedstock in Guangxi Province (Qiu et al., 2010). This plant started its operations in early 2008. The current annual bioethanol production capacity of this plant is 0.2 million t. On the consumption side, E10 (gasoline mixed with 10% ethanol) is being used in the transport sector in five provinces (Heilongjiang, Jilin, Liaoning, Anhui, and Henan) and in 27 cities in Jiangsu, Shandong, Hubei, and Hebei provinces.

Policies and Targets of China's Bioethanol Production

China began its policy support for bioethanol development in the early 2000s. The Special Development Plan for Denatured Fuel Ethanol and Bioethanol Gasoline for Automobiles was announced in early 2001 as part of the 10th Five-Year Plan (NDRC, 2001). The main goal of the initiative was to experiment with bioethanol production, marketing, and support measures. Interestingly, the first push into bioethanol was part of an effort to dispose of huge stocks of grain reserves that China accumulated in the late 1990s and 2000. Because the grain had been sitting in granaries for several years, large parts of the stocks were no longer suitable even as animal feed. The pilot testing program was extended in 2004. In 2004, officials set a target of annual bioethanol use in automobiles at 1.02 million t.

The initial efforts were supported by additional policies put into place in the mid-2000s. In 2005, China issued the Renewable Energy Law, making it clear that China was committed to pushing the development of renewable energy, including biofuels (NPC, 2005). In June 2007, under the guidelines stipulated by the Renewable Energy Law, China's Medium- and Long-Term Renewable Energy Development Plan was issued (NDRC, 2007). According to this plan, annual bioethanol and biodiesel production by 2020 was targeted at 10 and 2 million t, respectively. To support the expansion of the biofuel industry, officials introduced policies that encouraged and/or mandated (i) a mandatory mixing of 10% bioethanol in gasoline in five provinces and 27 cities; (ii) waiving the 5% consumption tax on bioethanol and refunding the 17% value added tax; (iii) direct subsidies of 1370 yuan (~US$200) per tonne to biofuel plants. The costs of the mandatory mixing policy are borne by the government and hence included in these subsidies.

At the same time that pro-bioethanol policies were being promoted, advocates of food security within the government began to make their voices heard and took steps to constrain growth of the sector. For example, in 2007, officials announced that, except for the case of the four existing bioethanol plants that had been built earlier in the decade, cereals would no longer be allowed to be used as bioethanol feedstock. In addition, the four existing plants were prohibited from expanding their capacities on the basis of cereals. Noncereal crops, such as sweet sorghum, cassava, and sweet potato, were to be allowed, but preferably produced on marginal lands (MOA, 2007). In a clarification document, the policy was stated in more formal terms: the future expansion of biofuel in China “must not compete with grain for land, must not compete with consumers for food, must not compete with livestock for feed, and must not inflict harm to the environment.”

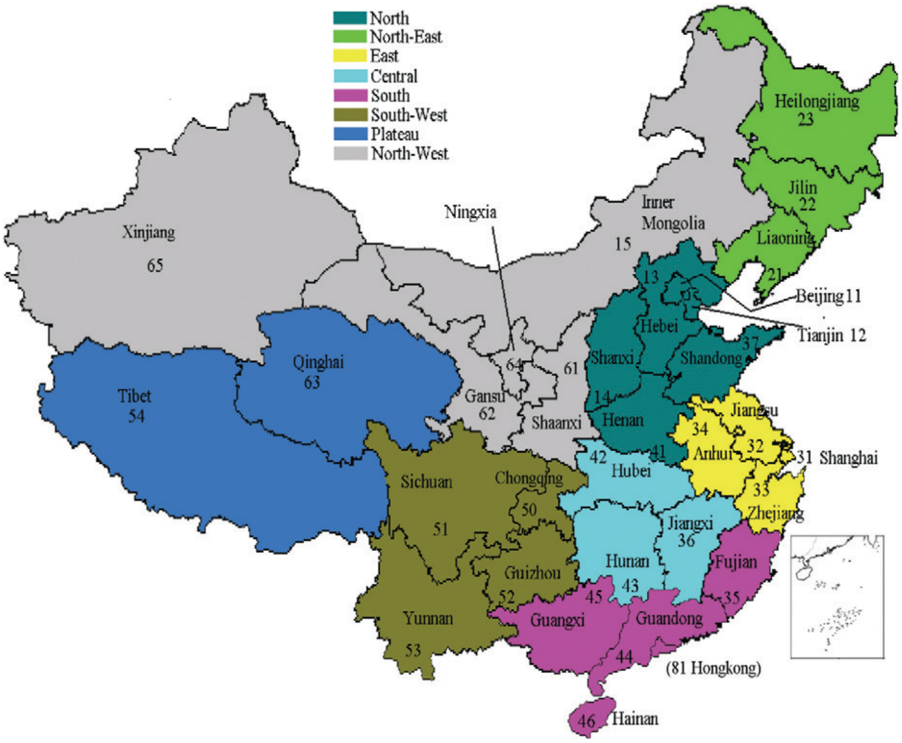

Fig. 1. Map of mainland China with provincial boundaries and designations of the eight CHINAGRO regions.

The Potential for Feedstock Production on Marginal Land

China has limited marginal arable lands with potential for biofuel feedstock production. Moreover, these potential arable lands are usually fragmented. According to a survey conducted in 2003 and 2004 by the Ministry of Land and Resources (MLR, 2004), China’s potential usable arable land was estimated at 6.7 million ha. However, there is a caveat raised in the report produced by the MLR: although these marginal lands are potentially cultivatable, this does not mean that the entire area can be used for cultivation without costs. A large share of the land would likely have adverse effects on ecosystem services if brought into cultivation.

A recent study conducted by the Chinese Academy of Agricultural Engineering (CAAE, 2007) addressed the question of how much of China’s potential marginal land could realistically be used to realize the nation’s bioethanol targets in 2020. Using the survey data collected by China’s MLR, the CAAE study identified and eliminated marginal lands that are highly fragmented and the lands with important ecological and environmental functions (including lands that are in important wetland resources, fragile grasslands, etc.). After eliminating these types of lands, the CAAE estimated that 3.22 million ha of marginal land can be used for bioethanol feedstock production in 2020.

The study by CAAE shows that the available marginal lands are highly concentrated in particular regions (Table 1), particularly Inner Mongolia and Xinjiang, which together account for more than 50% of total potential lands for bioenergy crops in China. There are also sizable areas identified in parts of the Loess Plateau (12.5%), the middle and downstream areas of the Yangtze River (9.8%), and North China (7.8%). In contrast, the study found limited marginal land resources available in other parts of North China, South China, or Southwest China. Under the assumption that the yields on those marginal lands are comparable with those of the same crops on land that is currently being cultivated, the CAAE study estimated that China could produce 8.5 million t of bioethanol with the

Table 1. Distribution of suitable arable lands for energy crops in different regions of China (1000 ha).†

Region	Energy crop	2012	2020
Northeast China	Sweet sorghum	86	214
North China	Sweet sorghum, sweet potato	101	252
Loess Plateau	Sweet sorghum, sweet potato	161	402
Inner-Mongolia and Xinjiang	Sweet sorghum	733	1832
Middle and lower Yangtze River	Cassava, sweet sorghum	126	316
South China	Sweet potato	24	60
Southwest China	Cassava	59	148
Qingzang Plateau	None	0	0
Total		1290	3220

† Data source: CAAE (2007).

feedstocks from these marginal lands in 2020. This additional biofuel production would, together with the output from the currently existing plants, approximately meet the quantity target set by government policy. It should be noted, however, that these CAAE results rely on rather optimistic assumptions about yields.

In fact, several obstacles must be overcome before ethanol production from marginal land can play a significant role in China's fuel supply. These include high costs to put marginal lands into production, difficulties associated with collecting and transporting feedstock from the highly segmented marginal lands to ethanol plants, the shortage of water resources, and the low natural fertility of these marginal lands (Qiu et al., 2010). In addition, raising the fertility of marginal land via application of fertilizer may, jointly with the reclamation of new lands for biofuel cultivation, threaten biodiversity, especially when fertilizer is given in combination with the use of pesticides and herbicides. This is a serious problem as these marginal areas tend to harbor important pools of genetic diversity.

Furthermore, there are also difficulties related to the bioethanol feedstocks themselves. According to government policy, sweet sorghum, cassava, sweet potato, and sugarcane are the major potential noncereal feedstocks (MOA, 2007). Because of the low fertility and the scarcity of irrigation water on marginal lands, the yields of bioethanol feedstock crops on those lands will almost certainly be lower than the yields on currently cultivated land. These low yields and high inputs could dissuade farmers from spending time and capital on producing feedstock crops on marginal lands. It also will be difficult for the government to monitor whether biofuel feedstocks are actually being produced on marginal lands, as compared to regular arable land.

Methods and Assumptions

CHINAGRO Model

The CHINAGRO model is particularly suited for the intended exercise because of its capacity to depict China's geographical diversity. CHINAGRO is a general equilibrium welfare model of China with a focus on its agricultural sector, and it is one of the most detailed models of China's national and regional agricultural economy (Keyzer and van Veen, 2005), with production modeled at the county level, distinguishing 2433 counties. For each county, the model includes 28 outputs (including rice, maize, wheat, sugarcane, oil crops, pork, and poultry) covering most of China's major agricultural products. Every county also considers 14 distinct farm types that are involved in cropping and livestock production. In crop production, for example, it distinguishes irrigated land from rainfed land. Having such highly disaggregated crop choices and production systems is important for an analysis that is attempting to capture the competition for land, labor, and nutrient resources between biofuel crops and the crops needed for food, animal feeds, and fibers. As noted in the previous section, the scope for expanding these biofuel crops varies greatly across regions, and only a few areas and types of farming systems qualify.

Consumption is also represented in a relatively disaggregated way, albeit with less detail than production, since it distinguishes consumption by region for six income groups in each region, including three groups of urban consumers and three groups of rural consumers. Consumption demand together with supply reactions and adjustment of foreign and interregional trade, subject to various policy interventions such as tariffs and quotas on international trade, jointly determine the regional prices from which the product patterns follow. The model operates on an annual basis, evaluating solutions under given scenario conditions for selected years.

Defining the Simulation Scenarios

To understand the likely impacts of China's bioethanol development on its agricultural economy and food security, as well as its potential impact on fertilizer use, three simulation scenarios have been designed, including one reference scenario and two alternative bioethanol scenarios.

The reference scenario, denoted S0, is constructed to reflect a baseline situation that in the specific context of China as a planned economy, represents the preferred and anticipated pattern of development in the absence of intensification of specific policies such as biofuel policies. This scenario has the following five major assumptions. First, bioethanol production in China from 2007 to 2020 will only just be expanded beyond its production level in 2007 (from 1.35 to 1.5 million t). In addition, we also assume for the reference scenario that all bioethanol will be produced from maize. Second, the scenario assumes that no new marginal land will be used for feedstock production. Third, there will be no improvement in the yield of feedstock crops. Fourth, international agricultural prices will generally follow the patterns projected by OECD–FAO (2008). And, finally, the scenario assumes that the byproducts of maize-based bioethanol production (Dry Distiller's Grain with Solubles [DDGS]) will be used as animal feed, which can partly substitute for maize, soybean meal, and other feeds.

The biofuel scenarios are variants of the baseline that describe outcomes under targeted bioethanol policies. In the biofuel scenario without marginal land, denoted S1, we assume that China will achieve its annual production target of 10 million t by 2020. The "Development Planning of China's Bioenergy Industry (2007–2016)" issued by the Ministry of Agriculture of China states that sweet sorghum, cassava, sugarcane, and sweet potato will be the major nongrain crops for China's future biofuel expansion. It also states that although maize can still be used for biofuel production in existing bioethanol plants, the future expansion of biofuel production should be fully nongrain based (MOA, 2007). Following this policy, in S1, we assume that the 10 million t of bioethanol are produced in the following diversified way: (i) the amount of maize based bioethanol will be kept at the same level as under the reference scenario, hence accounting for 15% of bioethanol in 2020; and (ii) 50% of bioethanol output will come from sweet sorghum cultivated in the north, northeast, and northwest of China; 20% from cassava in South China; 7.5% from sugarcane produced in South and Southwest China; and 7.5% from sweet potatoes from North and Southwest China. (These scenario specifications are formulated on the basis of government policy [MOA, 2007]. In quantifying the target, we take into account the feasibility of the target, using discussion with academics from China's agricultural academies, as well as information gained from interviews with officials from the Ministry of Agriculture. In other words, we use expert opinion to quantify the target at a level that we believe is close to the intentions of those that wrote the policies in the first place, and which is feasible.) The contribution of sugarcane will remain limited (despite its efficiency as bioethanol feedstock), due to the expected increase in sugar import needs.

A critical element of the specification of scenario S1 is to define the extent to which China can rely on international markets for additional supplies. Securing 10 million t of bioethanol from the domestic market would seem excessive since it would require purchasing 30 million t of feedstock if measured in terms of maize equivalents. Hence, the question is how China could procure the extra 30 million t. At one extreme, one might assume that all feedstocks can be imported smoothly from abroad at unchanged import prices. In this case, China could shift its bioethanol-associated demands to the world market. At the other extreme, one might rule out any additional imports, to reflect the idea that the rest of the world should not be made to bear the consequences of China's target-induced demand. Such an assumption could be particularly salient at a time that many countries are already expanding their biofuel demand via subsidies and mandatory use policies. However, biofuel scenario S1 opts for an intermediate route. Specifically, it assume that the world market prices of certain types of feed (especially cassava-related feeds) and minor grains will rise by 25 to 50%. The prices of other, more tradable commodities increase somewhat less. A comprehensive list of the scenario assumptions is given in Table 2.

The biofuel scenario with new marginal land, denoted S2, is designed to assess the likely impact of allowing marginal lands to be used for bioethanol feedstock production in China. It builds on the biofuel scenario (S1) and adds assumptions about the use of marginal land (Table 2). It assumes that the 3.22 million ha of marginal land identified in the CAAE study will be taken into production by 2020, planted with sweet potato, cassava, and, especially, sorghum. By setting the yields of these crops at 75% of the average yields on currently used land and keeping the biofuel production processes as in S1, the scenario has 3.5 million t of bioethanol coming from marginal land. This is approximately 45% of the total bioethanol from sorghum, sweet potato, and cassava necessary to meet China's output target in 2020. Hence, we are less optimistic about the feedstock and biofuel outputs that can be attained from newly opened marginal land than is the CAAE (2007) study. Since in S2 more domestic resources will be available for feedstock production, import demand will be lower than under S1. So, in S2, we also assume that the general world price increases are lower than in S1 due to China's lower levels of imports (Table 2).

Results

Impact of China's Biofuel Expansion without Using Marginal Land

The outcomes of the simulations show that if no marginal land is used for feedstock production, bioethanol development in China will have significant impacts on the prices of the feedstock crops but will have relatively small effects on prices and, hence, output of other agricultural commodities (the second column of Table 3 and the middle section of Table 4, respectively). Price increases will be high for the commodities in "other staple food" and carbohydrate feed-related commodities. (Note that the CHINAGRO model has a different commodity classification at the trade level than is used at the farm level, to be able to account for the processing of crops with multiple outputs. The commodity "carbohydrate feed" is a basket of commodities that covers several types of feed with high carbohydrate content, including cassava and other root crops. The commodity "other staple food" mainly consists of minor grains, such as sorghum and millet.) Compared with the reference scenario results in 2020, the prices of these commodities under S1 will rise by 21 and 47%, respectively (Table 3). Prices will rise only negligibly in the cases of the major food crops, such as wheat (*Triticum aestivum* L.) and rice. Hence, the burden of the price increases to the consumers remains limited. Because of this, the average national calorie intake will decline by about only 1% compared with the results under the reference scenario in 2020, that is, from 2796 to 2776 kcal d^{-1}.

Table 2. Key assumptions of the three simulation scenarios.

Scenarios	Bioethanol output in 2020	Component of feedstocks	Utilization of new marginal lands	International price changes	Processing technology
	million t				
Reference scenario (S0)	1.5	Maize (100%)	No new marginal land used		2.82 t of maize can produce 1 t of ethanol, with 0.89 t of DDGS.†
Biofuel scenario without marginal land (S1)	10	Sorghum (50%); cassava (20%); maize (15%); sweet potato (7.5%); sugarcane (7.5%)	No new marginal land used	Price of commodities higher than in the reference scenario: maize 2.5%; minor food grains 25%; sugar 5%; other carbohydrate feeds 50%; protein-rich feeds 5%	3 t of sorghum can produce 1 t of ethanol with 0.75 t of DDGS. 8 tonnes of fresh sweet potato can produce 1 t of ethanol with 0.45 t of DDGS.
Biofuel scenario with marginal land (S2)	10	Sorghum (50%); cassava (20%); maize (15%); sweet potato (7.5%); sugarcane (7.5%)	3.22 million ha of new marginal land used, yielding ~45% of the total of sorghum, sweet potato, and cassava feedstocks	Price of commodities higher than in the reference scenario: minor food grains 15%; sugar 5%; other carbohydrate feeds 30%; protein-rich feeds 2.5%	7.5 t of fresh cassava can produce 1 t of ethanol with 0.45 t of DDGS. 12.5 t of sugarcane can produce 1 t of ethanol with 0.25 t of DDGS.

† DDGS, Dry Distiller's Grain with Solubles.

Table 3. Average national market prices by commodity for the three scenarios, 2020, in yuan per kilogram (food) or yuan per megacalorie (feed).†

	Price level under S0	Price increase in S1 compared with S0	Price increase in S2 compared with S0
		%	%
Rice	1.78	0.3	0.2
Wheat	1.36	0.4	0.1
Maize	1.32	2.4	0.1
Other staple food	3.25	20.9	12.3
Vegetable oil	6.89	0.0	0.0
Sugar	2.70	4.6	4.6
Fruit	1.61	0.0	0.0
Vegetables	0.81	3.9	2.2
Beef and mutton	14.92	0.0	0.0
Pork	14.22	1.7	0.9
Poultry meat	15.21	0.8	0.7
Milk	3.09	0.0	0.0
Eggs	4.46	1.8	0.9
Fish	9.31	0.0	0.0
Carbohydrate feed	0.29	46.7	28.1
Protein feed	0.41	4.7	2.2

† Agricultural prices are normalized to the 1997 average manufacturing price level.

In part because of the increase in prices, the direct supply effect on the production of feedstocks will be significant, although less in the case of other crops. Table 4 quantifies these supply effects. Compared with the reference scenario in 2020, the production of other staple foods and carbohydrate feed commodities in S1 will increase by 9 and 5%, respectively. At the same time, demand by consumers will fall due to the higher prices. In total, because of the increase in production of these commodities and the fall in demand by consumers, only about 20% of the biofuel input of other staple food and 40% of the biofuel input of carbohydrate feed will need to be met by additional imports in 2020. In view of the highly variable geographical conditions among different regions of China as discussed above, the increase of feedstock production under S1 will be uneven across China's different regions. Figure 2 gives an indication of where the increases in output of carbohydrate feeds will occur. The illustration shows that the increases will be substantial in Northeast, North, and Southwest China.

Even though more than half of the additional bioethanol feedstock demands under S1 will come from China according to our simulation, the rise in import demand for some crops, particularly for carbohydrate feeds, is large (Table 4). The rising imports and the large increase in the international prices of these commodities will make China's agricultural trade deficit increase from US$8.3 billion under reference scenario, S0, to US$11.2 billion in S1 in 2020. (In the CHINAGRO model, and thus the discussion of this section, prices are normalized to the 1997 manufacturing price level.) Given that China will keep a large surplus on its balance of payments under both the S0 and S1 scenarios, such an increase in agricultural trade deficit should pose no problems.

The difference in agricultural trade deficits under scenarios S0 and S1 (US$2.9 billion) may be interpreted as the cost to obtain the extra 8.5 million t of bioethanol under S1. In terms of energy equivalents, 8.5 million t of bioethanol is equivalent to about 38 million barrels of crude oil. Assuming that the price of crude oil in 2020 will be the same as in 2007 (~US$65 per barrel), the value of oil that would be saved is close to US$2.5 billion. In other words, under S1, by promoting bioethanol, China can save US$2.5 billion of oil imports at the cost of the increase of the agricultural trade deficit of US$2.9 billion.

Table 4. Supply, demand, and net imports by commodity for the three scenarios, 2020, in million tonne (food) or million Gcal (feed).

	Reference scenario (S0)				Biofuel scenario (S1)				Biofuel scenario (S2)			
	Domestic supply	Demand excluding biofuel	Biofuel input†	Net import	Domestic supply	Demand excluding biofuel	Biofuel input†	Net import	Domestic supply	Demand excluding biofuel	Biofuel input†	Net import
Rice	131.0	130.2		–0.8	130.6	130.1		–0.5	130.8	130.1		–0.7
Wheat	82.9	82.9			82.9	82.9			82.9	82.9		
Maize	125.3	138.4	3.8	16.8	124.0	137.6	3.8	17.4	124.4	137.8	3.8	17.2
Other staple food	22.0	25.6		3.6	23.9	24.3	3.9	4.3	24.4	24.7	3.9	4.2
Vegetable oil	10.6	20.5		10.0	10.5	20.5		10.0	10.6	20.5		10.0
Sugar	9.1	11.7		2.6	9.3	11.6	0.7	2.9	9.3	11.6	0.7	2.9
Fruit	75.7	70.8		–4.9	75.2	70.8		–4.3	75.4	70.8		–4.6
Vegetables	265.0	254.3		–10.6	263.6	252.9		–10.6	264.2	253.5		–10.6
Beef and mutton	9.0	9.0			9.0	9.0			9.0	9.0		
Pork	55.4	55.4			54.9	54.9			55.1	55.1		
Poultry meat	15.1	15.1			15.0	15.0			15.0	15.0		
Milk	30.7	34.4		3.7	30.6	34.4		3.8	30.6	34.4		3.8
Eggs	29.8	29.8			29.5	29.5			29.6	29.6		
Fish	36.5	35.0		–1.5	36.5	35.0		–1.5	36.5	35.0		–1.5
Carbohydrate feed	285.2	352.9		67.7	298.6	349.6	29.1	80.1	312.4	351.1	29.1	67.9
Protein feed	210.9	330.4	–2.4	117.0	211.1	327.5	–3.8	112.6	211.6	328.9	–3.8	113.4

† A negative value indicates that a commodity becomes available as a byproduct of biofuel.

We further calculated the necessary government subsidy to fulfill the bioethanol target in 2020. Taking the price-weighted average of the five types of bioethanol inputs (maize, sugarcane, cassava, sweet potato, and sorghum), the feedstock costs per tonne of bioethanol production under S1 in 2020 is estimated at 3820 yuan, and the value of the byproducts (DDGS) is 550 yuan. According to our field survey data, other production costs of bioethanol, such as capital, labor and fuel, are about two-thirds of the feedstock costs (or about 2550 yuan t^{-1}). This means that the total cost of per tonne of bioethanol production is 5820 yuan (3820 + 2550 – 550). In addition, we assume that the price of bioethanol will be kept at the price of 2007, which is about 5000 yuan t^{-1}. From this it can be deduced that the government must give bioethanol plants a subsidy of at least 820 yuan t^{-1}. And for the 10 million t of bioethanol production in 2020, the total subsidy that China's government will need to pay reaches 8.2 billion yuan (or about US$1.2 billion at the current exchange rate).

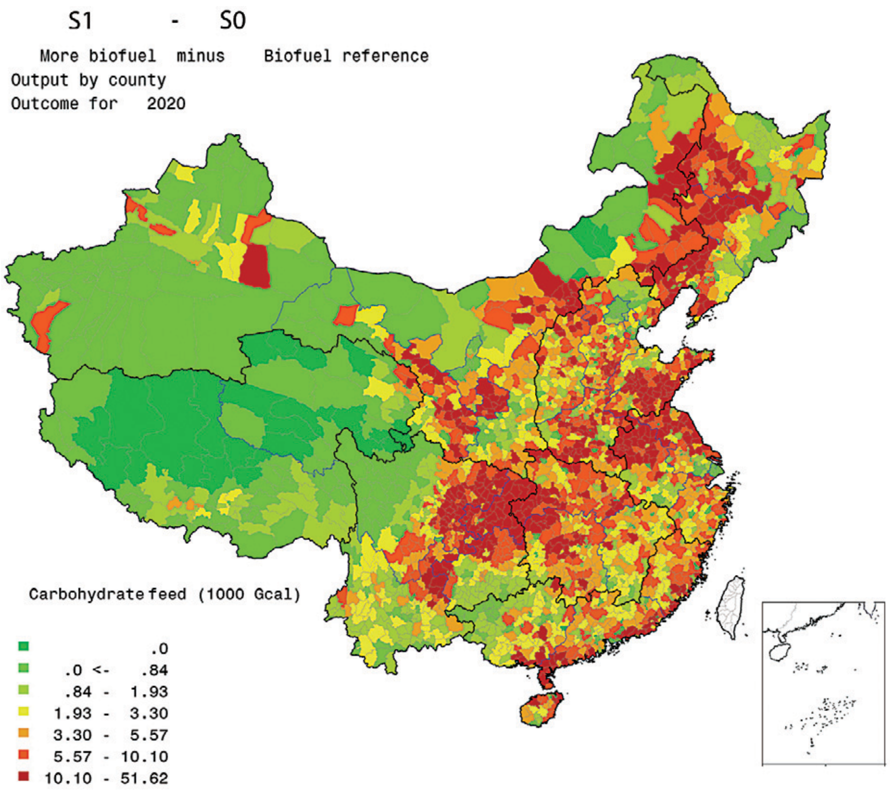

Fig. 2. Additional output of carbohydrate feed in the biofuel scenario without new marginal land (scenario S1) compared with the results under the reference scenario (S0), where we assume no expansion of China's bioethanol production until 2020.

Farmers can be seen to both gain and lose with the expansion of biofuel feedstock production. On the one hand, there will be a rise of the value added in cropping due to biofuel expansion. For the country as a whole, the relative gain in crop income will be about 5% compared with the results under the reference scenario in 2020. In contrast, higher feed prices mean that there will be a fall in the output of the livestock sector and hence a decline of income from livestock production. Our results predict that farmers' income from the livestock sector (or the income of farmers specialized in the livestock sector) will fall by about 6% compared with the reference scenario in 2020. With the value added in cropping about twice as large as the value added in livestock, the total increase in the income of farmers as a whole is estimated to be about 1.5%. It also appears that impacts of biofuel development on farmers' income are highly unequal among regions. As seen in Fig. 3, while the gain is spread among farmers across most of the counties, the loss seems to be overwhelmingly concentrated in those counties where farmers predominantly specialize on livestock. For example, farmers in Inner Mongolia and other western (relatively poor) regions of the country get hurt. Therefore, while the poor in China may gain on average, a segment of farmers will not. (Several studies, such as Huang and Rozelle [2006], show that after 30 yr of development of China's rural markets, commodity prices in rural markets are highly integrated with consumer prices across regions. Therefore, in this analysis, we assume that the agricultural price increases due to biofuel expansion are transmitted to farmers.)

The expansion of biofuel and the rise of the crop prices will also increase fertilizer use in China. Although in most areas of China, farmers were already using high-input levels of fertilizer before the advent of biofuels, the additional production of biofuel feedstocks adds to fertilizer usage rates—albeit moderately (Fig. 4). According to our findings, in addition to input rates that can reach more than 700 kg of fertilizer (organic plus chemical) per hectare per year without bioethanol expansion (S0), increases under the biofuel scenario S1 will exceed 1 kg ha^{-1} in only a limited number of counties in 2020. The simulation results show that China's total increase of fertilizer use under S1 will be about 42 thousand t. While chemical fertilizer use will increase by 114 thousand t, organic fertilizer use will decrease by 72 thousand t due to the reduction of livestock production under S1.

Major Findings When New Marginal Land is Used

Our analysis shows that if scenario S2 were to prevail, rather than scenario S1, some of the adverse effects of the emergence of biofuels would be attenuated. First, as expected, the volume of imports will be less. Therefore, in this sense, the agricultural resource of the world outside of China will be required to bear less of a burden. Second, the incomes of livestock farmers will fall less. The moderation of the negative effects of biofuels stems primarily from the fact that feed costs in scenario S2 will rise less than in scenario S1. Third, consumers will also face lower price increases (Table 3). In fact, the average calorie intake under S2 will stay closer to the results of the reference scenario. Fourth, the agricultural trade deficit in 2020 will be only US$9.7 billion, which is US$1.5 billion lower than that of S1 and US$1.4 billion higher than that of S0.

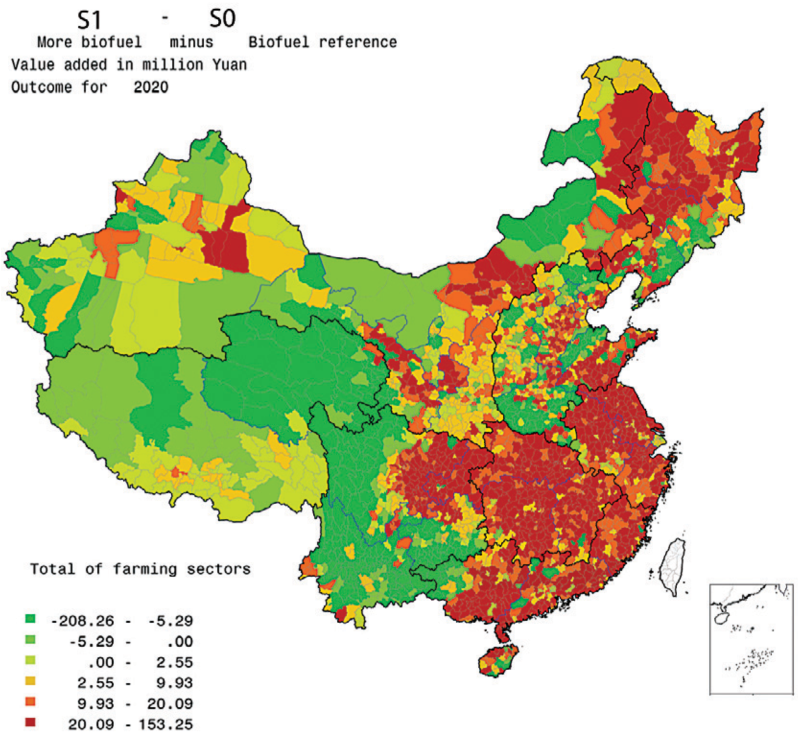

Fig. 3. Biofuel development under scenario S1 will increase the income of farmers as a whole by 1.5%, but these impacts will be very unequal among regions and farmer groups. While the gain is spread among farmers across most of the counties, the loss seems to be overwhelmingly concentrated in those counties where farmers predominantly specialize on livestock.

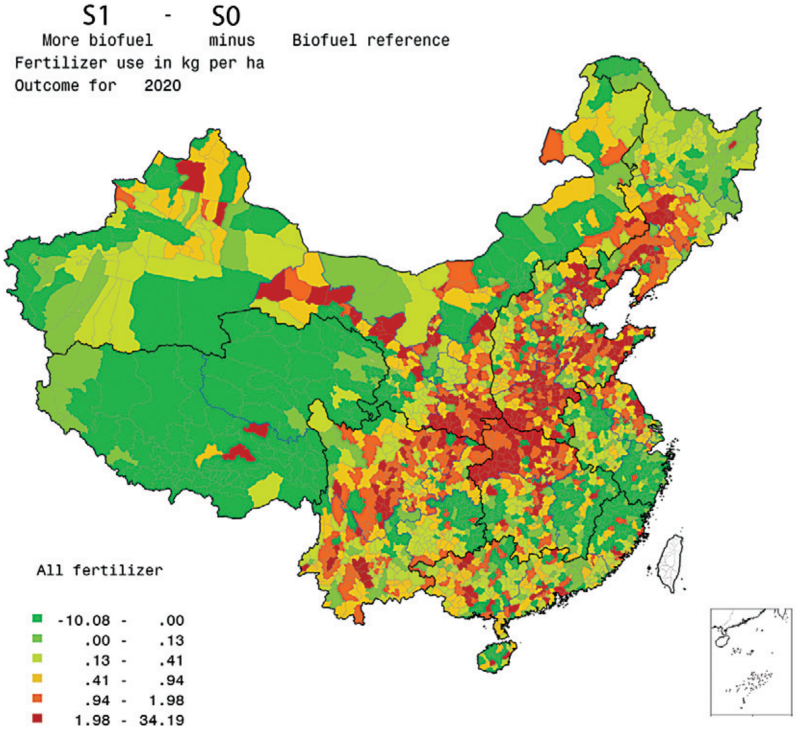

Fig. 4. Under the scenario that China will fulfill its bioethanol production target in 2020 without using new marginal land, total fertilizer use in China increases by about 42 thousand t (0.3 kg ha^{-1} on average), among which chemical fertilizer use will increase by about 114 thousand t and organic fertilizer use will decrease by 72 thousand t due to the reduction of livestock production.

The effects on national food supply and demand are summarized in Table 4. Due to the use of additional land, the output of other staple foods will be 2% higher than that of S1 in 2020. The output of carbohydrate feed will be even higher (by 5% over scenario S1). Interestingly, in S2 compared with S1, the higher production of other staple foods and carbohydrate feeds occurs despite the lower prices of these commodity groups. This is because producers are moving these crops onto marginal lands that are capable of producing these crops. Because of these relative rises in domestic production under S2, the reliance on world markets for the provision of bioethanol feedstocks will be less than in S1. In total, China will import only about 10% of the total additional feedstock to meet its 10 million t bioethanol target in 2020.

In contrast to the effects on production and trade, the effect on cropping incomes is mixed when moving from S1 to S2. On the one hand, the additional output on marginal lands will bring extra value added to farmers. On the other hand, the reduced prices of agricultural commodities will result in lower value added. Therefore, S2's addition to value added will be almost zero when compared with total farm value added in S1. The increases in farmer incomes (Fig. 5) in most of China's regions under S2 are similar to the results under S1 (Fig. 3). There are exceptions, however. Farmers in Xinjiang Province (Western China), part of North China, and parts of Inner Mongolia will gain more compared with the results under S1 because, as was shown in Table 1, those regions have more marginal land that can be used. Similar to the results under S1, farmers in regions specializing on livestock will still lose due to biofuel expansion—albeit less. Figure 5 demonstrates that farmers in most parts of the Qingzang Plateau, Southwest China, and parts of North China will be net losers due to the expansion of biofuels.

Although using marginal land for bioethanol feedstock production will mitigate some of the adverse effects of biofuel scenario S1, such as the higher consumer and feed prices and the burden on international agricultural markets, it may at the same time put more pressure on the environment. It appears that under S2 fertilizer use in China will increase by 750 thousand t compared with the results of S1. (Here we assume that fertilizer use on marginal land will be the same as the average application on rainfed land, i.e., about 250 kg ha^{-1} yr^{-1}.) This additional amount is about 1.5% of total fertilizer use of China in 2020, not much in a relative sense but nevertheless large in absolute terms, which calls for careful application, especially in environmentally fragile areas. Chinese agriculture has intensified greatly since the early 1980s, with large rises in the input of chemical fertilizers (Huang et al., 2006). In fact, this also means that overuse of chemical fertilizer has already become a serious challenge of China. In 2009, 54 million t of chemical fertilizers was used by Chinese farmers (NBSC, 2010). This implies that on average, farmers use more than 440 kg ha^{-1} of farmland, which is far above the level used in most developed countries (225 kg ha^{-1}). The overuse of fertilizer can indeed lead to significant risks of environmental pollution (e.g., the acidification of croplands, eutrophication of lakes and rivers, and the increase of greenhouse gas emission [Guo et al., 2010]). Marginal lands, like other cultivated lands, do require additional fertilizer. If the fertilizer mix is not well adjusted to the types of soils in these marginal lands, nutrient surpluses or deficits can occur. How much damage these additional fertilizers may cause needs to be the target of future research.

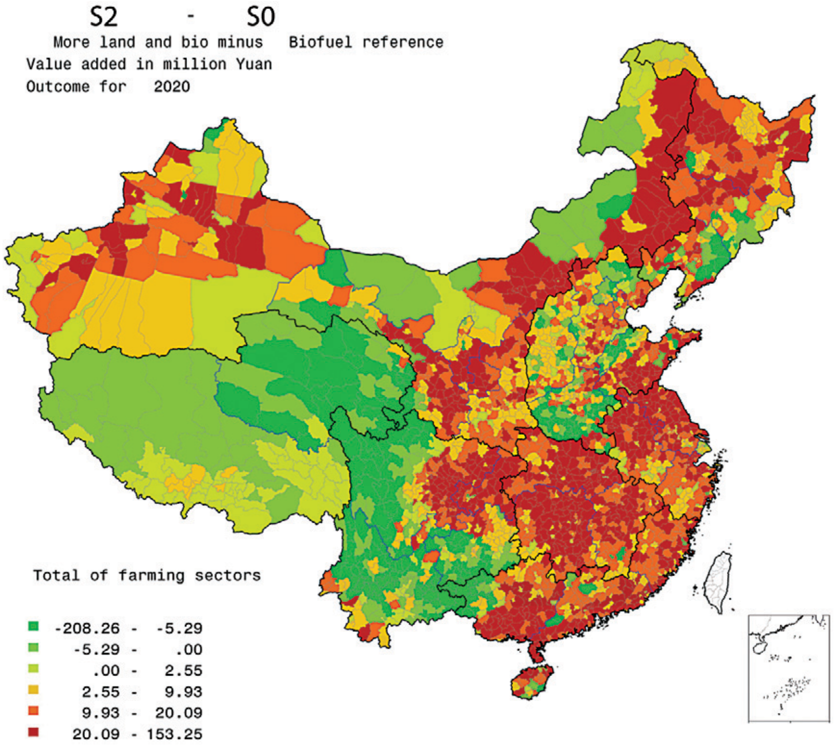

Fig. 5. Farmers' income will increase also under the scenario that China will fulfill its bioethanol target in 2020 using part of its marginal lands (S2). However, there are differences with the results of the scenario without using marginal land (S1). Farmers in Xinjiang Province (Western China), part of North China and parts of Inner Mongolia will gain more because of the marginal land that can be used in those regions. Farmers in most parts of Qingzang Plateau and Southwest China and some parts of North China still lose due to the higher feed prices, but their loss is less than in S1.

Conclusions

Using the results of a highly disaggregated model (CHINAGRO), this study examined the potential impacts of China's future biofuel expansion on its food security, fertilizer application, international trade balance, and farmer income. Our results show that the target of 10 million t of bioethanol by 2020 seems to be a prudent target that causes no major disturbances in national food security. The option of cultivating bioethanol feedstocks on new marginal land is shown to actually limit the negative pressure on international markets (albeit certainly not removing it), but it may at the same time bring additional environmental pressure on China's already vulnerable areas. About 30% of additional feedstocks demand from China's bioethanol development is shown to be shifted to the world market under S1 (scenario without marginal land), a fraction that falls somewhat under S2 (scenario with marginal land). Interestingly, the results reveal that bioethanol development will reduce China's total trade surplus. This is true because while there are oil import savings (of US\$2.5 billion), the nation needs to increase agricultural imports by US\$2.9 billion. However, most poor cropping farmers, especially those specializing in feedstock production, will gain from bioethanol expansion. The analysis also shows that using new marginal lands for bioethanol feedstock production in China must be planned carefully to prevent negative environmental impacts. If feedstocks for 3.5 million t of bioethanol will be produced on marginal lands, about 750 thousand additional tonnes of fertilizer will have to be used, especially in these environmentally fragile areas. As mentioned above, application of such amounts of fertilizer may threaten biodiversity in these areas, in addition to the direct loss of the original animal life and vegetation in the newly cultivated fields.

The results from this study have several policy implications. First, the expansion of biofuels is good for most farmers in China, particular those poor farmers who are engaged in crop production. For regions with comparative advantages in producing noncereal feedstocks, biofuel expansion can be one effective measure to increase local farmers' income and reduce poverty. Second, while the overall impact on farmers' income is positive, biofuel development will have a moderately negative impact on livestock producers' income. Some farmers in major livestock production areas such as the southwest, Plateau, and part of Inner Mongolia will lose from biofuel development. Supporting policies for livestock production in these regions should accompany the expansion of China's biofuel program. Third, if the increased demand for noncereal crops used as feedstock for biofuel can be met largely by the imports from the rest of world, China may not need to bring millions of hectares of marginal land into cultivation, although this of course shifts the burden to other countries. Last, but certainly not least, environmental consequences (e.g., nutrient pollution, soil erosion, water demand, and biodiversity) of large-scale use of marginal land should be carefully examined before marginal land is put into production.

Acknowledgments

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