Biofuel development, food security and the use of marginal land in China[1]

Jikun Huang, [1] Huanguang Qiu,[1,2, *] Jun Yang,[1] Michiel Keyzer,[3] Wim van Veen, [3] Scott Rozelle,[4] Guenther Fisher,[5] and Tatiana Ermolieva[5]

[1] Center for Chinese Agricultural Policy, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences. Jia 11, Datun Road, Anwai, Beijing, 100101

[2] Department of Financial & Management Studies, SOAS, University of London, London WC1H 0GX, the United Kingdom

[3] Centre for World Food Studies, Free University, the Netherlands. De Boelelaan 1105, 1081 HV Amsterdam.

[4] Food Security and the Environment Program, Stanford University, Stanford, California 95305, USA.

[5] International Institute for Applied Systems Analysis, Schlossplatz 1, A-2361 Laxenburg, Austria.

* Corresponding author: Huanguang Qiu, Center for Chinese Agricultural Policy, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences. Jia 11, Datun Road, Anwai, Beijing, 100101. Tel.: +86 10 64889835; fax: +86 10 64856533. E-mail address: hgqiu.ccap@igsnrr.ac.cn.

Acknowledgments

The authors would like to thank the financial support of the European Union's 6th Framework Programme (No. 044255), Newton International Fellowship of UK, Bill & Melinda Gates Foundation, and Ministry of Science & Technology of China (2008BADA8B01 and 2008BADA8B02). The authors would also thank Yu Elaine for her valuable comments.

Abstract: With concerns of energy shortages, China, like the US, EU 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 that could be used for feedstock production and measure the likely impacts of China's biofuel development on the nation's future food self-sufficiency. The analysis shows that although China's leaders have set up a requirement that any new biofuel feedstock production should be produced on marginal land, the potential to use marginal land is, in fact, limited. Perhaps as a result of this, the leadership has set what seems to be a relatively moderate annual target of 10 million tons of bioethanol of production by 2020. Using a modeling approach with a highly disaggregated data by region and by crop, our study shows that this target, in fact, is a prudent one, causing no major disturbances in the nation's food security. We also show that, in contrast to the fears of some, there is no great increase in pollution due to higher levels of fertilizer use, even if marginal lands are not used for feedstock production. However, if China were able to execute the option of cultivating biofuel feedstock on new marginal land, the analysis shows that it would even further limit any negative effects of biofuel program on the domestic economy, as well as reduce pressure on the world markets.

Keywords: Bioethanol Development; Food Security; Marginal Lands; China

[1] Earlier versions of this paper were presented at the 17th Annual Conference of the European Association of Environmental and Resource Economists in Amsterdam, June 2009, and at the International ASA-CSSA-SSSA meetings in Pittsburgh, November 2-5, 2009.

1. Introduction

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 tons, 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 percent 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 is high on the government's list as a possible substitute for liquid fuels in cars, mainly in the form of bioethanol (Chew, 2006). Other goals of any policy to expand the production of biofuel include reducing CO_2 emissions—but, this effect is generally thought to be modest at best. There are also other reasons for China to develop biofuels. Above all, biofuels can serve to support the demand for certain feedstock crops, such as cassava, maize, oilseeds and sugarcane (MOA, 2007). Since a large fraction of the production of many of these crops originates from relatively poor parts of China, higher prices and deeper markets would be welcome and contribute to poverty alleviation.

In response to these challenges and the new opportunities that are possibly 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 tons of biofuels annually by 2020. During these initial years some officials envisioned China as one of the largest biofuel producers in the world.

However, authorities quickly began to understand that if initial goals were realized then 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 2008 had the effect of reminding China that world markets could not be relied upon unconditionally to fill possible gaps between domestic food and feed supply and 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) and large import (sugar, vegetable oil, soybeans), the government is still hesitant to rely on imports for large shares of the country's food supplies (CPC, 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 their 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 biofuel target to 10 million tons by

2020 and also prohibited the expansion of any biofuels using major cereals as inputs. Instead, new policies encourage the use of sweet sorghum, cassava, sweet potato and other non-cereal crops. Officials also have made pronouncements that large parts of the new feedstocks need to be produced on marginal lands.

In this study we seek to examine the China's bioethanol policies and its bioethanol targets for 2020. What is the consequence of China setting a target of 10 million tons of production of bioethanol by 2020? What is the implication of not allowing land that is currently being cultivated to be planted with biofuel feedstocks? While this is a broad topic, in this paper we focus on four questions. Will China's biofuel 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 biofuel production in China provide a boost to farm incomes? Will there be a serious pollution problem that is triggered by increased fertilizer use due to biofuel expansion?

These questions are addressed both at national and regional levels using analysis from a set of scenario simulations that are 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 as well as to international markets (Keyzer and van Veen, 2005; Fischer et al, 2007). This type of model is necessary in order to be able to answer the questions of our study. Because of the highly heterogenous 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.

To answer the questions of interest, the rest of the paper proceeds as follows. Section 2 discusses China's current biofuel production options and policies. Section 3 briefly describes the Chinagro model, the formulation of the simulation scenarios and the key assumptions that underlie the simulations. Two biofuel scenarios were set up to look at the effects of expanding biofuels to target production levels with and without relying on the use of marginal lands. More specifically, section 4 addresses the questions above using a biofuel scenario when there are no marginal lands used. Section 5 then examines the same questions when we allow for the expansion of biofuel feedstock production onto marginal lands. Section 6 concludes.

2. Bioethanol developments and policies in China

2.1 Bioethanol production in China

China's bioethanol industry has expanded rapidly since the early 2000s. Bioethanol production reached about 1.5 million tons 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 mainly use maize as feedstock, is approximately 1.5 million tons. 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 tons. On the consumption side, E10 (gasoline mixed with 10 percent 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.

2.2 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, much of the stocks were not even suitable 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 tons.

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 tons, respectively. To support the expansion of the biofuel industry, officials introduced policies that encouraged/mandated: a) mandatory mixing of 10% bioethanol in gasoline in five provinces and 27 cities; b) waiving the 5% consumption tax on bioethanol and refunding the 17% value added tax; c) direct subsidies of 1370 Yuan (about US $200) per ton 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. Non-cereal 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."

2.3 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 (Table 1). 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) has 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 data that were discussed above and shown in Table 1), the study identifies and eliminates 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 estimates that 3.22 million hectares of marginal land can be used for bioethanol feedstock production in 2020.

One of the most important findings of the study is their result showing that the available marginal lands are highly regionalized. For example, large areas of marginal land resources in Inner Mongolia and Xinjiang can be used for feedstock production. In fact, land in these two provinces account for more than 50% of total potential lands for bioenergy crops in China. There are also sizeable areas identified in parts of the Loess Plateau (12.5%), the middle and downstream areas of the Yangtze River (9.8%) and in North China (7.8%). In contrast, the study found limited marginal land resources are available in other parts of North China, South China or Southwest China

So how much of China's bioethanol production can be produced on these lands? With a set of assumptions that the yields of those marginal lands are comparable with the yields of the same crops on land that is currently being cultivated, the study estimated that China could produce 12 million tons of bioethanol with the feedstocks produced on these marginal lands in 2020 (CAAE, 2007). This quantity of biofuel production, of course, is slightly higher than the quantity target that has been set by government policy. It should be noted, however, that these results rely on the rather optimistic assumptions about yields.

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 reclaim marginal lands, 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).

Furthermore, there are also other difficulties ensuring that biofuel feedstocks will be produced on marginal lands. According to government policy, sweet sorghum, cassava, sweet potato, and sugarcane are the major potential non-cereal feedstocks (MOA, 2007). Although compared with other major crops, like wheat, bioenergy feedstock crops are more adaptive to low quality of land, their yields on marginal land will almost certainly be lower due to the low fertility of land and the scarcity of irrigation water. These low yields and high inputs could dissuade farmers from spending time and capital on producing feedstock crops on the marginal lands. It also will be difficult for the government to monitor whether biofuel feedstocks are actually being produced on marginal lands, as opposed to regular arable land. This might be attractive to farmers due to high biofuel subsidies (which are paid to the biofuel processing plants, however could allow the procurement of feedstock crops at relatively higher prices).

3. Reference scenario for the Chinagro model

3.1 Introduction on Chinagro model

Due to the need to be able to model differences among China's regions (as well as the flow among regions), in this study we decided to use the Chinagro model. Developed by researchers in the Center for World Food Studies and Center for Chinese Agricultural Policy in collaboration with researchers of other institutes, Chinagro is a general equilibrium welfare model of China with a focus on its agricultural sector. Chinagro is one of the most detailed models of China's national and regional agricultural economy (Keyzer and van Veen, 2005). In this section we describe the model and review the reference scenario. The alternative scenarios are described in the following sections.

One of the most distinguishing characteristics of Chinagro is that it is built with a set of highly disaggregated production data. Specifically, production is modeled at the county level. In total, the model uses information from 2433 county-level production units. 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. The model also includes a range of 14 distinct farm types that are involved in cropping and livestock production. For example, for crop production, the model is divided into crop production on irrigated land and on rainfed land. Having such highly disaggregated crop choices and production systems is important for an analysis that is attempting to capture the dynamics of the set of commodities that can be used for biofuel feedstocks. As seen in the discussion from the previous section, the potential for expanding these crops is highly regional and is focused on specific types of farming systems/regions.

Consumption is also included in a number of highly disaggregated ways. Specifically, consumption is depicted at the regional level. The model distinguishes six income groups in each region including three groups of urban consumers and three groups of rural consumers. The consumption demands of each county unit is important in determining production patterns since the supply of agricultural commodities of each county responds to the market prices faced by various farm types in each county—which is in no small part determined by demand. Behaviorally, the consumers of agricultural products (which are represented for every income group in each region) are modeled as exercising demand dependent on prevailing consumer prices and income available to them.

As is the usual practice in general equilibrium analysis, supply and demand are balanced for all commodities simultaneously through intra-regional, inter-regional and international trade, jointly with price adjustment subject to various policy interventions such as tariffs and quotas on international trade. The model operates on an annual basis, evaluating solutions under given scenario conditions for selected years.

3.2 Defining the Reference Scenario (S0)

The reference scenario, denoted as S0, has the following driving forces: a.) the continuation of high non-agricultural growth, though China's growth rate is not expected to maintain the double digit growth that it has been experiencing for the past 30 years (Huang et al., 2003); b.) China's urban and industrial expansion leads to increased pressure on agricultural land and water availability in densely populated counties, with moderate losses to crop land (Lu et al., 2004); c.) at the same time, the higher incomes from the non-agricultural sector leads to shifts in consumption patterns towards more meat and dairy (Fisher et al., 2007); d.) China's government continues its policy of the liberalization of agricultural foreign trade, and its policy of reducing producer taxes and stimulating technical progress through sustained spending on research and development (Huang and Rozelle, 2006); and e.) international agricultural prices generally follow patterns that are estimated by projections by OECD-FAO (2007). Nevertheless, we assume that the declines in international prices for grains, feed and meat are less than those predicted by the OECD-FAO projections since we believe that the emergence of worldwide biofuel productions will continue to create at least some upward pressure on prices in international markets.

With respect to the production of biofuels inside China, the reference run assumes that bioethanol production will not be expanded much beyond its production level of 2007. This means that in the reference scenario we assume that in 2020 China will only produce about 1.5 million tons bioethanol (that is, equal to the amount being produced now). In addition, we also assume for the reference scenario that all bioethanol will be produced from maize. We do not allow any marginal lands to be used for the production for biofuel feedstock (or any other commodity). Finally, following Taheripour et al. (2008), we assume that the byproducts of all bioethanol production (DDGS, Dry Distiller's Grain with Solubles) will be used as animal feed.

3.3 Highlights of the results under reference scenario

The outcomes of the reference scenario demonstrate that China's agriculture supply will roughly satisfy the country's food demand in 2020. Importantly, this new self sufficiency is true even with significantly higher per capita meat demand by China's consumers, albeit there will be rising imports of feed grains. Imports of maize and carbohydrate feed (such as cassava) are considerably larger than predicted in other reports (e.g. FAO-OECD, 2008, and USDA, 2008), viz. between 15 and 20 million tons each by the year 2020. For protein-rich commodities (like oilseeds and their meal or cake) feed imports may even be as high as 40 million tons (which, by the way, is similar to the projections in other studies). The reference run also confirms the finding of others that there is sizeable export potential for fruits and vegetables for China's producers, although the absorption capacity of specific submarkets needs further investigation.

The Chinagro reference scenario also produces a number of specific predications about the impact of international and domestic drivers on farm households. The model predicts a steady and significant growth in per capita on-farm incomes. Despite robust growth of farm income, however, the earnings of farmers remain below those earning incomes from non-agricultural sectors. As a consequence, these outcomes seem to confirm present concerns about persistent urban-rural income disparity. There is general agreement that agriculture, and crop farming, in particular, cannot resolve China's inequality problem by itself, even given that we are assuming continued aggressive investment by the government in technological improvements and price supports.

With respect to environmental impacts, the simulations show that the application of fertilizer, currently already quite high, continues to increase steadily. The model predicts that fertilizer use will be especially high in densely populated areas. Together with the observed manure surpluses, these findings signal that there may be serious environmental challenges for local/regional officials to contend with in the future.

4. Biofuel scenario without marginal land (S1)

4.1 Assumptions under biofuel scenario S1

In line with China's plan for the expansion of bioethanol, in scenario S1 we assume that China will achieve its annual production target of 10 million tons by 2020. Following current practices, in this scenario we also assume that bioethanol firms will be located in the main production regions of the feedstock crops (Table 2). The model permits, however, inter-regional trade in feedstock crops as well as other agricultural commodities. Based on current prospects, we assume that in 2020 the four existing maize-based bioethanol plants will produce 1.5 million tons of bioethanol which is the same as in the reference scenario (and which is the same as what is actually occurring now). In biofuel scenario S1, we assume that the 10 million tons of biofuels are produced in the following diversified ways (Table 3):

- the amount of maize based bioethanol is kept at the same level as under the reference scenario, hence, accounting for 15% of bioethanol in 2020;
- 50% of the bioethanol output comes from sorghum cultivated in 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;
- all additional output (in S1) is produced on existing cultivated land; by assumption, no new marginal lands are allowed to come into production;
- DDGS is produced by the biofuel plants and used as animal feed.

A critical element of the specification of this scenario is to define the extent to which China can rely on international markets and existing land for additional supplies. Ten million tons of bioethanol may be quite large for China's agriculture because it would require 30 million tons of feedstock if measured in terms of maize-equivalents. The question is: how does China produce this extra 30 million tons? At one extreme, one may assume that the world delivers the extra imports smoothly from world markets into China at unchanged prices. In this case, China would be able to 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 would not be made to bear the consequences of China's target-induced demand. This assumption may be particularly salient at a time that many countries are already expanding their biofuel demand via subsidies and mandatory use policies.

The biofuel scenario S1 opts for an intermediate set of assumptions when considering international trade. Specifically, in the S1 scenario, we shift part of the burden to produce the additional supplies to meet China's bioethanol target to the world market. The remainder of the demand is met by China's domestic agricultural sector. Given the amounts of additional biofuel demand, and the already large feed imports of China in the reference scenario, we assume that world market prices of certain types of feed (especially cassava-related feeds) and minor grains may go up 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 3.

4.2 Impact of China's biofuel expansion without using marginal land

Our discussion of outcomes proceeds along the four questions posed in the introduction.

Will the additional biofuel demand lead to major disturbances in the food system due to substitution away from food crops?

The outcomes of simulations, in fact, show that if no marginal land is used for feedstock production, biofuel development in China will have significant impacts on the prices of the feedstock crops, but will have relatively small effects on the prices of other agricultural commodities (the second column of Table 4). Price increases will be high for the commodities in "other staple food" and carbohydrate feed-related commodities. Compared to the reference scenario in 2020, the prices of these commodities under S1 will rise by 21% and 47% (Table 4), respectively.[2] Prices will rise only negligibly in the cases of the major food crops, wheat 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, viz. from 2796 to 2776 kcal/day.

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 5 quantifies these supply effects. Compared to the reference scenario in 2020, the production of "other staple foods" and carbohydrate feed commodities will increase by 9% and 5%, respectively. At the same time, demand by consumers will fall due to the higher prices (which is driven by biofuel expansion). In total, because of the increase in production of these commodities and the fall in demand by consumers, it turns out that 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.

Due to 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 1 gives an indication of where the increases in output increases of carbohydrate feeds will occur. The figure aggregates underlying crops according to their carbohydrate content. The illustration shows that the increases will be substantial in Northeast, North, and Southwest China, which is understandable given the fact that Northeast and North regions of China are the major areas that are suitable for the production of sweet sorghum. The results are also due to the fact that the Southwest is the major production area of cassava and sugarcane.

What are the consequences of the additional biofuel demand for the balance of China's international trade and government fiscal budgets?

Despite the fact that more than half of the additional biofuel feedstock demands under S1 come from China, the rise in import demand for some crops, particularly for carbohydrate feeds, is large (Table 5). The rising imports and the large increase in the international prices of these commodities will make China's agricultural trade deficit increases from 8.3 billion USD under reference scenario, S0, to 11.2 billion USD in S1 in 2020[3]. Given that China will have a large surplus balance of payments under both the S0 and S1 scenarios, such an increase in agricultural trade deficit should pose

[2] The Chinagro model has a different commodity classification at the trade level than is used at the farm level, in order 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.

[3] In the Chinagro model, and hence the discussion of this section, the constant price of 1997 is used.

no problems.

We may interpret the 2.9 billion (11.2 billion-8.3 billion) agricultural trade deficits under S1 as the cost to obtain the extra 8.5 million tons of bioethanol under S1. In terms of energy equivalents, 8.5 million tons 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 (about 65 USD per barrel), the value of oil that would be saved is close to 2.5 billion USD. Hence, in this case the effects of the energy substitution on the balance of payments would be negative. In other words, under S1, by promoting bioethanol, China can save 2.5 billion USD of oil imports at the cost of the increase of the agricultural trade deficit of 2.9 billion USD.

We further calculated the necessary government subsidy to fulfill the bioethanol target in 2020. Taking the price weighted average of the five types of biofuel inputs (maize, sugarcane, cassava, sweet potato and sorghum), the feedstock costs for per ton of bioethanol production under S1in 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/ton). This means the total cost of per ton of biofuel 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 per ton. From this it can be deduced that the government must give biofuel plants a subsidy of at least 820 yuan/ton. And for the 10 million tons of bioethanol production in 2020, the total subsidy that China's government will need to pay reaches 8.2 billion yuan (or about 1.2 billion US dollars at current exchange rates).

Will the additional biofuel demand provide a boost to farmers' incomes?

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 reference scenario in 2020. In contrast, higher feed prices mean that there will be a fall in the output of livestock sector, and hence the decline of income from livestock production. Our results predict that farmers' income from livestock sector (or the income of farmers specialized in livestock sector) will lose 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 is estimated to be about 1.5%.

Is this a large gain? On one hand, it seems as if the total gain to farming from the 10 million bioethanol target is relatively modest. However, it should be kept in mind that most poor people in China are crop farmers. With the price increase of crop commodities, the poor are the ones that would benefit. The results of our model analysis suggest that biofuels will not be hurting the poor farmers in China. In fact, the poor seem to gain a bit. Hence, even though internationally there is often a message that the emergence of bioethanol is not pro-poor (von Braun and Pachauri, 2006; Runge and Senauer, 2007), it does not appear to be so in China. The key reason for the gain from the emergence of biofuels by China's poor farmers is that most poor farmers in China have their own cultivated land for crop production. Most of China's poor also are net sellers of crop commodities. Therefore, with the rise of crop prices, their net income will increase.

On the other hand, there are those that do get hurt and, as such, a biofuel initiative will inevitably create some disequilibrium in some parts of the economy. For example, almost certainly, the emergence of biofuels that is assumed in S1 will create tensions among livestock farmers. Moreover, as seen in Figure 2, while the gain is spread among farmers across most of the counties, the loss to livestock producers 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, there will be a segment of the poor that will not.

Will average fertilizer use per hectare increase significantly due to biofuel expansion?

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 only moderately (Figure 3). According to our findings, on top of input rates that can reach more than 700 kg of fertilizer (organic plus chemical) per hectare per year without biofuels (S0), increases under the biofuel scenario S1 will exceed 1 kg/hectare 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 42.2 thousand tons, among which the chemical fertilizer use will increase about 113.7 thousand tons. The use of organic fertilizer will actually decrease by 71.5 thousand tons due to the reduction of livestock production under S1. In sum, although some people have voiced concerns about the rise in fertilizer use that will be induced by the emergence of biofuels, this study shows that biofuels will only marginally raise fertilizer use in China.

5. Biofuel scenario with new marginal land (S2)

5.1 Assumptions under S2

The second alternative scenario (S2) is designed to assess the likely impact of allowing marginal lands to be used for bioethanol feedstocks. It builds upon the biofuel scenario (S1) and adds one more assumption. In scenario S2, we assume that 40% of the non-cereal feedstocks necessary to meet China's bioethanol target in 2020 (of 10 million tons) come from production on new marginal lands (Table 3). By assuming that only 40% of the production of biofuel feedstock crops comes from marginal lands, in our S2 scenario, we are less optimistic about the feedstock yields that can be attained on newly opened land than those assumed in the CAAE study (2007). Scenario S2 assumes that only 50% of the 3.22 million hectare of marginal land identified in the CAAE study will be taken into production. The scenario also assumes that the yields of the non-cereal feedstocks on marginal lands are only 60% of the yields used in that study (which is equal to average national yields on non-marginal lands). In scenario S2, only farmers that produce sweet sorghum, cassava, sweet potato, and sugarcane can use marginal land. Since in S2 more domestic resources will be available for feedstock production, import demand will be lower than that under S1. So, in S2, we also assume that general world price increases are lower than the case of S1 due to China's lower levels of imports (Table 3).

5.2 Major findings under Scenario S2

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 would be less. Therefore, in this sense, the agricultural resource of the world outside of China would be required to bear less of a burden. Second, the incomes of livestock farmers fall less. This moderation of the negative effects of biofuels is due primarily to the fact that in scenario S2 feed costs rise less than in scenario S1. Third, consumers also face lower price increases (Table 4). In fact, the average calorie intake under S2 stays closer to the results of the reference scenario. Finally, the agricultural trade deficit in 2020 will be only 9.7 billion USD, which will be 1.5 billion USD lower than that of S1.

The effects on national food supply and demand are summarized in Table 5. 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 (up by 5% over scenario S1). Interestingly, in S2 versus S1, the higher production of other staple foods and carbohydrate feeds occurs despite the lower prices of these commodity groups. Of course, what is happening is that producers are moving these crops onto marginal lands which are only capable of producing these crops. Because of these relative rises in domestic production under S2, the reliance on world markets for the provision of biofuel feedstocks will be less than in scenario S1. In total, China will import only about 10% of the total additional feedstock to meet its 10 million ton bioethanol target in 2020.

In contrast to the effects on production and trade, the effect on cropping incomes is mixed when we move from scenario S1 to scenario 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, scenario S2's addition to value added will be almost zero when compared to total farm value added in scenario S1. The increases in farmer incomes (Figure 4) in most of China's regions under S2 are similar with the results under S1 (Figure 2). There are exceptions, however. Farmers in Xinjiang Province (Western China), part of North China and parts of Inner Magnolia will gain more compared with the results under S1, because as was shown in Table 1, there is more marginal land that can be used in those regions. Similar to the results under S1, famers in those regions specializing in livestock sector will still lose due to biofuel expansion—although they will lose marginally less. Figure 4 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.

6. Conclusions and policy implications

China has taken steps to participate in the biofuel revolution since the early 2000s. The initial impetus for investment in the biofuel sector was the nation's concerns over energy security. It was also seen as a way to support farmer income. After early discussion and debate about the ultimate production target, an annual production target of 10 million tons of bioethanol in 2020 has been set. Although less than some advocates in China originally wanted, if China achieves its target it will likely be one of the largest producer of bioethanol in the world, after Brazil and the US.

However, China also faces the challenges of fulfilling its high future food and feed demands. The spike of food prices in 2007 and 2008 led China's government to seriously consider the tradeoff between food and fuel. While biofuel advocates were not ignored, China clearly decided in favor of food security. In addition to setting a target of only 10 million tons, it set other policy limits in 2007. According to current regulations, all future biofuel expansion in China must be non-cereal based. Policy documents explicitly state that additional feedstocks should be produced on marginal lands. This part of the policy itself has triggered a series of debates on whether or not China's marginal lands will be able to be reclaimed (or whether they even should be reclaimed). Both the costs and environmental impacts are part of the marginal land discussions.

Using the results of a highly disaggregated model (called Chinagro), this study then 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 tons of bioethanol by 2020 seems to be a prudent target, causing no major disturbances in national food security and does not greatly aggravate the pollution that is being created by the production of feedstock crops. The direct impact of opening up marginal lands aside, the option of cultivating biofuel feedstocks on new marginal land is shown to actually limit the negative pressure on international markets (albeit the reduction is modest when comparing the results of S1 and S2). About 30 percent of additional feedstocks demand from China's biofuel development is shown be shifted to the world market under S1, a fraction that falls somewhat under S2. Interestingly the results find that China's trade deficit actually rises. This is true because while there are oil import savings (of 2.5 billion USD), the nation needs to increase agricultural imports by 2.9 billion USD. The results show, however, that most poor cropping farmers, especially those specializing in feedstock and crop production, will gain from biofuel expansion.

The results from this study also 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 non-cereal 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 be accompanied with the expansion of China's biofuel program. Third, if the increased demand for non-cereal crops used as feedstock for biofuel can be largely met by the imports from the rest of world, China might not need to bring millions of hectares of marginal land into cultivation. Last but not least, environmental consequences (e.g., soil erosion, water demand, biodiversity, etc) of using large scale of marginal land should be carefully examined before marginal land is reclaimed.

Figure 1 Additional output of carbohydrate feed in biofuel scenario (S1) compared to the reference run (S0), (unit: 1000 Giga calorie)

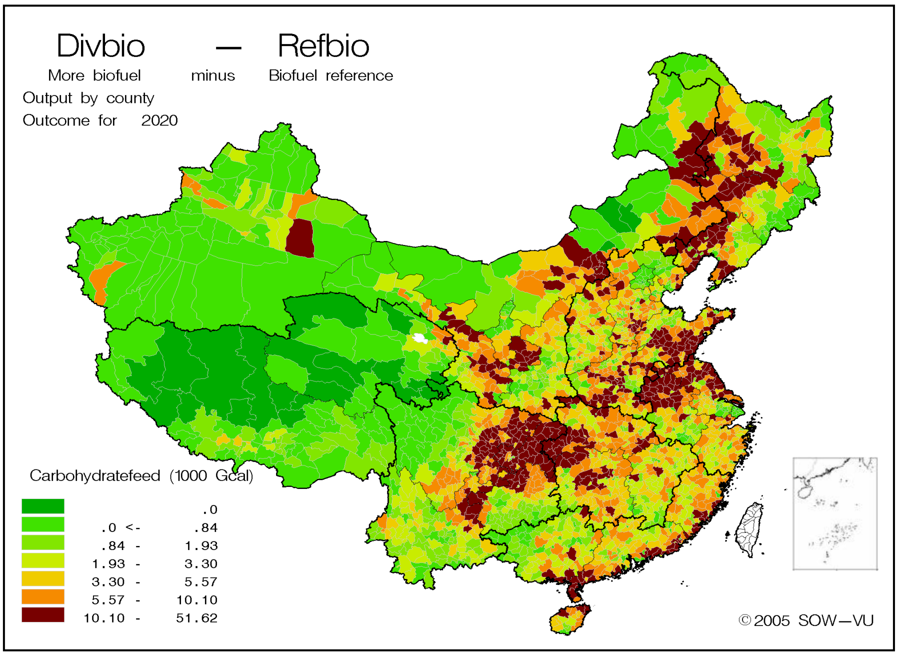

Figure 2 Net increase in farmers' income in biofuel scenario (S1) compared to the reference run (S0), (unit: million yuan)

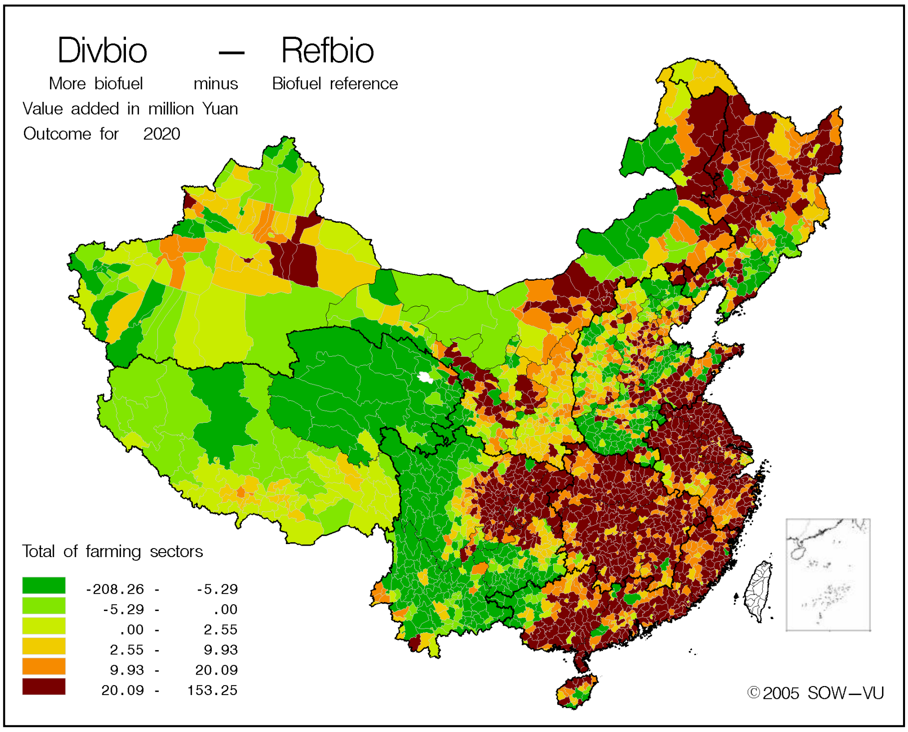

Figure 3. Net increase of fertilizer use in biofuel scenario (S1) compared to the reference run (S0), (unit: kg/ha)

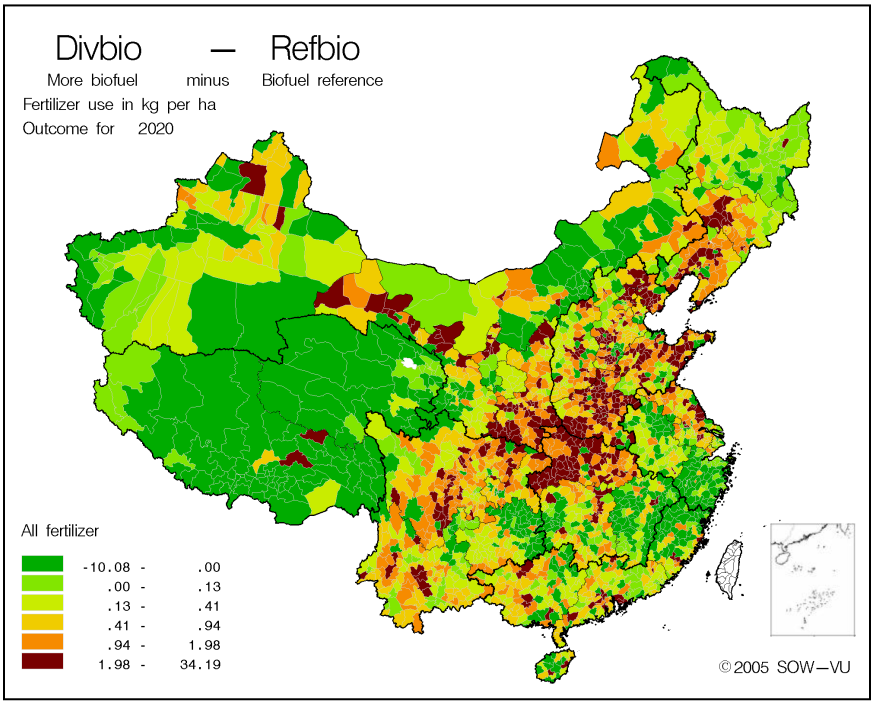

Figure 4 Net increase in farmers' income in the biofuel run with marginal land (S2) compared to the reference run (S0), (unit: million yuan)

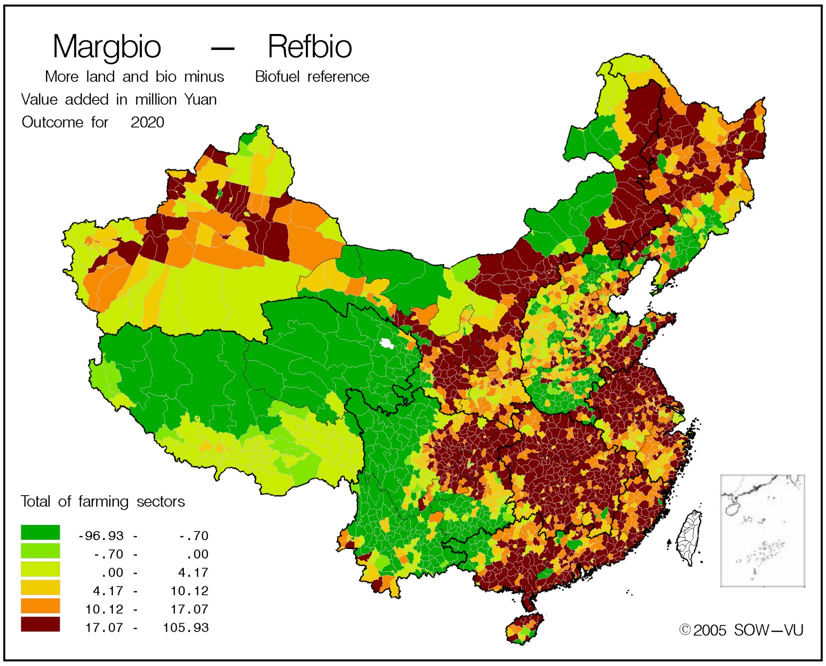

Table 1: Distribution of Potential Reclaimable Arable Land (1,000 ha)

Region	Reclaimable Grassland	Reclaimable Saline Areas	Reclaimable Mudflat	Other Reclaimable	Total
Northeast China	214.6	142.0	62.5	9.7	428.8
North China	190.2	141.2	124.5	47.5	503.4
Loess Plateau	47.91	12.03	2.86	17.63	80.43
Northwest	1,933.7	341.1	28.1	1,360.8	3,663.7
Middle and East China	336.4	5.4	227.6	62.2	631.6
South China	62.1	0.4	51.1	6.4	120.0
Southwest China	237.1	0.2	22.5	35.2	295.0
Qingzang Plateau	162.6	49.9	2.3	12.5	227.3
Total	3,615.8	800.5	547.2	1,710.6	6,674.3

Source: Ministry of Land and Resources of China, 2004.

Table 2: Assumptions on the distributions of bioethanol plants in different regions in 2020 (%)

Regions	Maize based	Sorghum based	Cassava based	Sweet potato based	Sugarcane based
North	30	50	0	50	0
Northeast	40	40	0	0	0
East	30	0	0	0	0
Central	0	0	0	0	0
South	0	0	100	0	80
Southwest	0	0	0	50	20
Plateau	0	0	0	0	0
Northwest	0	10	0	0	0
China	100	100	100	100	100

Table 3: Key assumptions of the three simulation scenarios

Scenarios	Bioethanol output in 2020 (mill. ton)	Component of feedstocks	Utilization of new marginal lands	International Price changes	Processing Technology
Reference Scenario (S0)	1.5	Maize (100%)	No new marginal land is used		2.82 tons of maize can produce 1 ton of ethanol, with 0.89 ton 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 is 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 tons of sorghum can produce 1 ton of ethanol with 0.75 ton of DDGS; 8 tons of fresh sweet potato can produce 1 ton of ethanol with 0.45 ton of DDGS;
Biofuel Scenario with marginal land (S2)	10	Sorghum (50%); Cassava (20%); Maize (15%); Sweet potato (7.5%); Sugarcane (7.5%)	40% of total of sorghum, sweet potato, cassava and sugarcane feedstocks is produced on new marginal land	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 tons of fresh cassava can produce 1 ton of ethanol with 0.45 ton of DDGS 12.5 tons of sugarcane can produce 1 ton of ethanol with 0.25 ton of DDGS

Table 4: Average national market prices by commodity for the three scenarios, 2020, in Yuan per kg (food) or Yuan per mega calorie (feed)*

	Price level under S0	Price increase in S1 compared to S0 (%)	Price increase in S2 compared to 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

Table 5: Supply, demand and net imports by commodity for the three scenarios, 2020, in million ton (food) or million Gcal (feed)

	Reference scenario (S0)				Biofuel scenario (S1)				Biofuel scenario (S2)			
	Production	Demand exclude biofuel	Biofuel input*	Net import	Production	Demand excl. biofuel	Biofuel input*	Net import	Production	Demand excl. 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
Carbohydr. 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.

References:

CAAE [Chinese Academy of Agricultural Engineering], (2007), Bioenergy Development in China. Internal report, Beijing.

Chew, C. (2006). Current status of new and renewable energies in China: Introduction of Fuel Ethanol, Report to the Institute of Energy Economics, Japan.

CPC [Central committee of Communist Party of China], (2008), Policy Guidelines for Promoting China's Agricultural Development and Farmers' Income, Beijing.

EIA [Energy Information Administration], (2009), International Energy Statistics, 2009. Available at: www.eia.doe.gov/emeu/international/contents.html.

Fischer, G., E. Hizsnyik, S. Prieler, M. Shah and H. van Velthuizen (2009), Biofuels and Food Security, Study commissioned by the OPEC Fund for International Development, International Institute for Applied Systems Analysis, Laxenburg.

Fischer, G., J. Huang, M. Keyzer, H. Qiu, L. Sun and W. van Veen (2007), China's agricultural prospects and challenges: report on scenario simulations with the Chinagro welfare model covering national, regional and county level, Centre for World Food Studies, Amsterdam.

Huang, J. and S. Rozelle, (1995), Environmental Stress and Grain Yields in China, American Journal of Agricultural Economics, 77: 853-864.

Huang, J. and Rozelle, S., (2006), The emergence of agricultural commodity markets in China. China Economic Review, Vol.17, 266-280.

Huang, J., L. Zhang, Q. Li and H. Qiu (2003), National and regional economic development scenarios for China's food economy: projections in the early 21st century, Working paper of International Institute for Applied Systems Analysis, Laxenburg, Austria.

IEA [International Energy Agency], (2005), World Energy Outlook 2005, International Energy Agency, Paris, 2005

Keyzer, M.A. and W.C.M. van Veen (2005), Towards a spatially and socially explicit agricultural policy analysis for China: specification of the Chinagro models, Working Paper 05-02, Centre for World Food Studies, Amsterdam.

Keyzer, M.A., M.D. Merbis and R.L. Voortman (2008), The biofuel controversy, De Economist, volume 156.

Lu, C., X. Li and M. Tan (2004), "China's land use changes and future availability of land resources" . Working paper of Institute of Geographical Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing, China.

MLR [Ministry of Land and Resources of China], (2004). Report on China's Reserved Land Resources, Beijing.

MOA [Ministry of Agriculture of China], (2007), Development Planning of China's Bioenergy Industry (2007-2016), China's Ministry of Agriculture, Beijing.

NBSC [National Bureau of Statistics of China], (2008), Statistical Yearbook 2008, National Bureau of Statistics of China, Beijing.

NDRC [National Development and Reform Commission of China], (2001), The Special Development Plans for Denatured Fuel Ethanol and Bioethanol Gasoline for Automobiles, Beijing, 2001.

NDRC [National Development and Reform Commission of China], (2007), China's Medium and Long Term Development Plan for China's Renewable Energy, Beijing.

NPC [National People's Congress of China], (2005), Renewable Energy Law of China, Beijing.

OECD-FAO, (2008), Agricultural Outlook 2008-2017, OrganisationOrganization for Economic Co-operation and Development and Food and Agriculture Organization of the United Nations, Paris/Rome, May 2008.

Peng, S., J. Huang, X. Zhong, J. Yang, G. Wang, Y. Zou, F. Zhang, Q. Zhu, R. Buresh, and C. Witt (2002). Challenge and opportunity in improving fertilizer-nitrogen use efficiency of irrigated rice in China. Chinese Journal of Agricultural ScienceScienc, Vol. 1, No. 7: 776-785..

Qiu, H., J. Huang, J.Yang, S. Rozelle, Yuhua. Zhang, Yahui. Zhang, and Yanli Zhang (2010), Bioethanol Development in China and the Potential Impacts on its Agricultural Economy, Applied Energy, Vol. 87, Issue 1, pp: 76-83.

Runge, C. F. and B. Senauer, (2007), How biofuels could starve the poor, Foreign Affairs, Vol. 86, No. 3: 41-53.

Taheripour, F., T. W. Hertel, W. E. Tyner, J.F. Beckman, and D. K. Birur, (2008), Biofuels and their By-Products: Global Economic and Environmental Implications, working paper of Department of Agricultural Economics, Purdue University. Available at: https://www.gtap.agecon.purdue.edu

USDA [United State Department of Agriculture], (2008), Agricultural projections to 2017, Interagency Agricultural Projections Committee, United States Department of Agriculture, Washington.

von Braun, Joachim von Braun and R. K. Pachauri, (2006), The Promises and Challenges of Biofuels for the Poor in Developing Countries, 2005-2006 Annual Report Essay of International Food Policy Research Institute, Washinton DC.

Wei Yiming, Fan Ying, Han Zhiyong, and Wu Gan, (2006), China Energy Report 2006. China Science Press, Beijing.