Biofuel use and agricultural intensification in China

Jikun Huang, Huanguang Qiu, Jun Yang, CCAP, Chinese Academy of Sciences
Michiel Keyzer and Wim van Veen, SOW-VU
Scott Rozelle, Stanford University
Guenther Fischer and Tatiana Ermolieva, IIASA

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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. In 2007, China's net import of oil reached 186 million tons, accounting for 49.6% of its total oil demand (NBSC, 2008). The rise in oil demand and oil import is 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, and the situation will become even worse by 2030 when 84 percent of oil has to be imported (IEA, 2005).

Given these concerns, the search for alternative sources of energy has become a top policy priority of the Chinese government. Biofuel from crops is a case in point. It is at the center of government attention as a possible substitute for liquid fuels in cars, mainly in the form of bioethanol (Chew, 2006). Other aims of biofuel include reducing CO2 emissions but this effect is generally thought to be modest at best, and most likely negative once the direct and indirect inputs of fertilizer, fuel and agrochemicals are being accounted for. Moreover, the changes in land use generate emissions of nitrous oxides, which are far more harmful as greenhouse gases. More on these environmental effects of biofuels can be found in Crutzen et al (2007) and Fargione et al (2008), whereas Keyzer et al (2008) and Fischer et al (2009) provide analyses of the international controversies around biofuel.

Biofuel can also serve to support demand for its feedstocks such as cassava, maize, oilseeds and sugarcane, a large fraction of which originates from relatively poor parts of China where higher prices would be welcome. Biofuel purchases, at subsidized prices, can be activated as a substitute for procurement for public stockholding, in particular in years that stockpiles reach their limits.

Furthermore, biofuel provides a means to dispose of public stocks that have become unsuited for human consumption and for use as animal feeds. This is very convenient to policy makers in view of the public upheaval in China and elsewhere to press releases about food rotting away in public stock.

Finally, China finds it important to participate in the fast innovations taking place world wide under the transition from petrochemicals to bio-based feed stocks for the chemical industry. Agro-based biofuels play a technologically modest but in quantity terms significant part in this process.

As many other countries, China initially formulated an ambitious biofuel development strategy. However, its authorities gradually came to appreciate that the competition of bioethanol (originating from starchy crops such as maize, cassava and sugarcane) and biodiesel (originating from oilseeds) with human and animal nutrition could pose a serious threat to national food self reliance, commonly referred to as “national food security”, a cornerstone of the reforms over the past three decades. In particular, the spikes in world food prices that occurred in 2007 and 2008 had the effect of a wake up call, reminding China that world markets could not be relied upon unconditionally to fill possible gaps between food, feed and fuel demands (the so-called F3 issue). Although international trade has become a major pillar of China’s food system, with both large export (vegetables, fruits, fish and, to a lesser extent, rice) and large import flows (sugar, vegetable oil, soybeans, cassava), government wants to keep the country by and large self-sufficient in major cereals.

Currently, China is producing about 1.4 million tons of bioethanol, largely from low-quality maize. The target for the year 2020 has been set at 10 million ton, which would satisfy some 1.5 % of the country’s current oil demand (measured in energy terms). This may seem a prudent strategy and yet, as is the case in OECD countries as well, this small step on the energy market would have no insignificant impacts on food markets. For example, if maize was the only input, the shift would require 30 million tons of maize.

In fact, recognizing the need to maintain food self reliance, China prohibited in 2007 expansion of any biofuels using major cereals as inputs. It has now started encouraging the use of sweet sorghum, cassava, sweet potato and other non-cereal crops instead, indicating that a large part will have to be produced on marginal lands. This will not be possible without intensified application of inputs, particularly fertilizers.

Currently, China uses already about 30% of world fertilizer although it has only 10% of the world’s arable land (FAO, 2001) whereas several studies show that the fertilizer use efficiency is very low (Peng, et al, 2002; Huang and Rozelle, 1995). This low efficiency easily leads to high nutrient losses with serious environmental consequences such as groundwater pollution and eutrophication of surface waters in lakes and rivers.

In this study we will take a closer look at the 2020 bioethanol target of 10 million ton. Abstracting from aspects of technical feasibility, we focus on four questions: (i) will it lead to major disturbances in the food system due to substitution away from food crops? (ii) which are the consequences for balance of payments and government budget? (iii) will it provide a boost to farm incomes?, and (iv) will average fertilizer use per hectare increase significantly or will it remain close to current levels?

These questions are addressed for China as a whole and for regions within the country on the basis of scenario simulations with the Chinagro welfare model. The Chinagro model is a geographically detailed general equilibrium model that comprehensively depicts China’s farm sector in 2433 of its counties, while connecting these through trade and transportation flows to each other, to urban and rural consumers and to abroad (Fischer et al, 2007).

The paper proceeds as follows. Section 2 discusses China’s current biofuel production options and policies. Section 3 briefly describes the Chinagro model and key assumptions in the scenario simulations. Section 4 addresses the questions above on the basis of a central biofuel scenario. Section 5 provides additional information by analyzing variants of the central scenario. Section 6 concludes.

2. Bioethanol developments in China

2.1 Bioethanol production in China

China's bioethanol industry has expanded rapidly in recent years. Bioethanol production reached 1.4 million tons in 2008. 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, and 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) was used in the transport sector in the five provinces of Heilongjiang, Jilin, Liaoning, Anhui, Henan, and twenty-seven cities in Jiangsu, Shandong, Hubei and Hebei provinces.

2.2 Policies and targets of China's bioethanol production

China started to support bioethanol development in the early 2000s. The Special Development Plans for Denatured Fuel Ethanol and Bioethanol Gasoline for Automobiles were announced in early 2001, as part of the 10th Five-Year Plan. The main goal of these plans was to experiment with bioethanol production, marketing, and support measures. What contributed to this initiative was that after consecutive years of good harvest, China had piled up a huge stock of grain reserves, largely not even suitable anymore as animal feed. The pilot testing program was extended in 2004. Annual bioethanol use in automobiles was targeted at 1.02 million tons in 2004.

In 2005, China issued the Renewable Energy Law, making it clear that China will forcefully push the development of renewable energy including biofuels. In June 2007, under the guidelines stipulated by the Renewable Energy Law, the National Development and Reform Commission (NDRC) formulated the Middle and Long Term Development Plan of Renewable Energy**.** According to this plan, annual bioethanol and biodiesel production by 2020 is targeted at 10 and 2 million tons, respectively. To encourage the expansion of the biofuel industry, the following policies were introduced: a) mandatory mixing of 10 percent bioethanol in gasoline in the five provinces and 27 cities mentioned above; 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 in 2007. The costs of the mandatory mixing policy are borne by government and hence included in these subsidies.

However, in response to the increasing concerns about food security, government announced in 2007 that, except for the four existing bioethanol plants, cereals will no longer be allowed as bioethanol feedstock. Furthermore, the four existing plants are prohibited from expanding their capacity on the basis of cereals. Non-cereal crops, such as sweet sorghum, cassava and sweet potato were suggested instead, preferably produced on marginal lands (MOA, 2007). In more formal terms, it was stated that 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."

In the second half of 2008, due to the impact of the worldwide economic recession and relatively good harvests, China's food prices came under pressure. To secure farmers' incomes, government has largely increased its grain storage between September 2008 and June 2009. No doubt, using these maize stocks for bioethanol expansion will again become an option for discussion, in spite of the earlier ban.

2.3 Production potentials for feedstocks on marginal land

A recent study conducted by the Chinese Academy of Agricultural Engineering (2007) has addressed the question whether China would have enough potential marginal lands to realize its bioethanol target in 2020 largely on marginal land. It estimates that 3.22 million hectares of marginal land can be used for bioethanol feedstock production in 2020. With these feed stocks, China could produce 12 million tons of bioethanol in 2020, which is marginally larger than the quantity targeted by the government policy. It should be noted, however, that these results rely on rather optimistic assumptions. Several obstacles must be overcome before non-cereal-based and marginal land based ethanol production can play a significant role in China's fuel supply, such as high costs to reclaim these marginal lands, difficulties associated with collecting and transporting feedstock from the field to ethanol plants and the low natural fertility of these marginal lands. Furthermore, it will be difficult for the government to monitor whether biofuel feedstocks are actually being produced on marginal lands, as opposed to regular arable land, which would be attractive to farmers in view of the high biofuel subsidies.

3. Reference scenario for the Chinagro model

The present section describes the reference scenario of the Chinagro model, a 17-commodity, 8-region general equilibrium welfare model. Although the model has not been constructed specifically for biofuel studies, its detailed specification of agricultural activities allows representation of a variety of national and regional policies.

The model distinguishes six income groups per region, with production represented at the county level, 2432 in number. For each county, the model includes 28 outputs (including rice, maize, wheat, sugarcane, oil crops, pork, and poultry) covering most of China's agricultural products, and a range of 14 farm types involved in cropping and livestock production (including rainfed and irrigated cropping, and traditional as well as intensified livestock production, separately for ruminants and non-ruminants).

Consumption is depicted at the regional level, separately for urban and rural populations, and domestic trade is interregional. Agricultural supply of each county responds to the market prices faced by various farm types in each county. Other farm resources, such as agricultural labor, agricultural machinery, and land, are imposed as fixed constraints in the model. The total area for cultivation and the maximum yield potential on each farm type are based on existing agro-ecological zone assessments. Parameters of labor, fertilizer and animal feed requirements per unit of output are estimated econometrically using agronomic data. Crop residuals, animal manure and other local commodities are also taken into account in these input relations. Consumers of agricultural products are represented for every income group in each region, separately for rural and urban consumers, as exercising demand dependent on prevailing consumer prices and income available to them. Additional details of the model specification are described in Keyzer and van Veen (2005).

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. With respect to validation, the welfare model fully replicates for every county and region of China for the 2003 base-year conditions.

With the model, alternative scenarios can be analyzed. An extensive description of earlier analyses can be found in Fischer et al (2007). Every scenario is formulated as a coherent set of assumptions about exogenous driving forces (farm land, population, non-agricultural growth, world prices etc.), as derived from the literature and own assessments. Under these assumptions, simulations with the Chinagro model analyze the price-based interaction between the supply behavior of farmers, the demand behavior of consumers via price at regional level formation and trade flows among regions and with the foreign markets.

The reference scenario, indicated as S0 in Table 1, has as main driving forces: (1) continuation of high non-agricultural growth, albeit not anymore at double-digit rates, supported by large investments in the manufacturing and service sectors and a considerable outflow of labor from the rural areas; (2) this urban and industrial expansion leads to increased pressure on agricultural land and water availability in densely populated counties, with moderate crop land losses and continued intensification of the livestock sector as consequences; (3) at the same time, the higher incomes from non-agriculture lead to shifts in consumption patterns towards more meat and dairy; (4) population grows moderately with urbanization rising to 60%; (5) government continues its policy of liberalization of agricultural foreign trade, reduces producer taxes and stimulates technical progress by sustained spending on research and development; finally, (6) the international agricultural price projections are modest in terms of the assumed rise in meat and biofuel demand worldwide. In fact, these price trends are based on the OECD-FAO projections in the Agricultural Outlook 2008-2017, released in May 2008, with some upward adjustment of grains, feed and meat.

With respect to biofuel production, the reference run assumes that the bioethanol production will not be expanded beyond its 2008 production level of 1.35 million ton, that all bioethanol will be produced from low-quality surplus maize and that no marginal land is taken into production for biofuel feedstock. Production takes place in the Northeast, Northwest and East. Furthermore, we assume that part of the residuals (DDGS, Dry Distiller's Grain with Solubles) becomes available as animal feed byproduct.

The outcomes of the reference scenario show that China's agriculture will manage to assure the country's food supply even with significantly higher per capita meat demand, albeit at the expense of large feed imports. Imports of maize and carbohydrate feed (such as cassava) may be 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 2030. For protein-rich commodities (like oilseeds and their meal or cake) feed imports may even be as high as 40 million tons, but this prediction is similar to the other studies. Yet, the simulations confirm China's sizable export potential for fruits and vegetables, albeit that the absorption capacity of specific submarkets would need further investigation.

As regards their effects on farmers, the reference outcomes show a steady and significant growth in on-farm incomes per manyear, which remains lower than in non-agricultural incomes, nonetheless. Hence, these outcomes would seem to confirm present concerns about urban-rural income disparity. There is general agreement that agriculture, crop farming in particular, cannot resolve this problem in itself, whatever the assumed technological improvements and price support. Rural-based industrialization will be an indispensible ingredient of any solution strategy.

With respect to environmental impacts, the simulations show that the application of fertilizer, currently already quite high, keeps on increasing, especially in densely populated areas. Together with the observed manure surpluses, these findings signal serious health threats for the population.

The next section considers a scenario that meets the 10 million bioethanol target in 2020.

4. Central biofuel scenario (S1)

In line with China's plan for expansion of bioethanol in the Eleventh Five-Year Plan and the Medium and Long Term Plan (resulting in a target of 4 million ton by 2010), we assume that an annual production of 10 million tons of bioethanol will be reached by 2020. Following the current practice, bioethanol firms will be located in the main production regions of the feedstock crops used for bioethanol, but the model permits inter-regional trade in these crops and in bioethanol to accommodate for changes in specialization patterns induced by the scenarios. Based on current prospects, we assume that the additional 8.65 million ton of biofuel is produced in the following, diversified way in the central biofuel scenario (S1):

- the amount of feedstock of maize is kept the same as under the reference scenario (hence, accounting for 13.5% of bioethanol in 2020)
- half of the output comes from sorghum (Northeast and Northwest), 30% from cassava (South and Southwest) and 6.5% from sweet potatoes (Southwest)
- all additional output is produced on existing crop land, hence no new marginal land is taken into production
- again, animal feed is obtained as byproduct from the biofuel plants, albeit at a reduced rate compared to maize and with a lower protein content.

A critical element of the specification of this scenario is to define how much China can rely on international markets for additional supplies. As mentioned already in the introduction, 10 million ton of bio-ethanol is quite large for Chinese agriculture, albeit very modest for its energy market. It easily requires 30 million ton feedstock when measured in terms of maize-equivalents. At one extreme, one may assume that the world delivers the extra imports smoothly at unchanged prices. In this case, China can shift its demand problems 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 highly subsidized input use, particularly at a time that most OECD countries are already expanding their demand, via lavish subsidies and mandatory use. In this case, China has to solve its problems completely itself.

The central scenario opts for the intermediate approach. The zero additional imports option is discussed in the next section. Given the amounts of additional biofuel demand, we assume that world market prices of most animal feeds go up by 5%. A comprehensive list of the scenario assumptions is given in Tables 1 and 2.

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 simulation outcomes show that the world price increases are largely transmitted to the domestic markets, as could be expected for commodities that are in a stable import regime. The effects on cropping patterns are quite modest, because of the crops affected. Cassava, sweet potato and sorghum mainly grow on rainfed areas of low quality, with limited options for substitution to other crops. Hence, the additional biofuel demand does not pose a threat to the output of the major food crops rice and wheat. The effect on average food intake is minor as well: the average national calorie intake declines only slightly from 2796 to 2791 kcal/day.

Figure 1 gives an indication of the geographical distribution of the output increases of the crops mentioned. The picture aggregates underlying crops according to the carbohydrate content.[1] One may observe that the increases are indeed relative small (the unit 1000 Gcal may be translated into 300 ton feedgrain-equivalent) and that they occur in broad areas of the eastern half of the country.

What are the consequences of the additional biofuel demand for balance of payments and government budget?

In line with the limited provision from domestic supply, the additional biofuel demand is met largely from imports. Especially, the rise in demand for carbohydrate feed is very large and more than justifies the assumption of 5% increase in its international price. The agricultural trade deficit increases from 8.3 billion USD (1997 prices) to 10.6 billion USD. For the balance of payments this increase poses no problems given the huge non-agricultural trade surplus.

We may interpret the outcome (i.e. the increase of the agricultural trade deficit with 2.3 billion USD) also as the value of the additional imports that are necessary to obtain the extra 8.65 million ton of bioethanol. In terms of energy equivalent this volume is equivalent to about 5.5 million ton of crude oil, or 39 million barrels. Assuming for 2020 the same real crude oil price to apply as in 2006, viz. about 60 USD per barrel,[2] the value of the oil saved would also be close to 2.3 billion USD. Hence, in this case the effects of the energy substitution on the balance of payments would be approximately neutral.

About 88% of additional raw material demand has to be imported, to be processed in domestic biofuel plants. Since the raw material is far too expensive to compete directly with fossil fuel, these plants need subsidy from Chinese government. The question is how much..The Chinagro model itself cannot answer this question fully, since it only shows the feedstock input costs to the biofuel industry and the value of the byproducts (animal feed). Taking the weighted average of the four types of biofuel inputs (maize, cassava, sweet potato and sorghum), the feedstock costs can be estimated at 3000 Yuan per ton, whereas the value of the byproducts is 465 Yuan.[3] Supposing in addition that the value of the main output, the bio-ethanol, is 4.10 Yuan per liter[4] or 4820 Yuan per ton (taking 0.85 kg/liter bio-ethanol), while the production costs other than feedstock (depreciations, labor, fuel, other) are about the same as

[1] The Chinagro model has a different commodity classification at trade level as compared to the farm level, so as to account for 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 root crops and their products.

[2] The Chinagro model measures international prices in US dollars of 1997. In 2006, the average nominal price of crude oil was 64 dollar per barrel, whereas the international price level was around 5% higher than in 1997 (according to World Bank's Manufacturing Unit Value Index).

[3] All domestic prices in Chinagro are normalized to the 1997 average manufacturing price level.

[4] This price is based on a gasoline price of 4.5 Yuan per liter, as prevailing in 2006, but takes into account that the energy content of bio-ethanol is somewhat lower (factor 0.911).

feedstock costs, net operating surplus of the plants would be equal to −715 Yuan per ton (4820+465−3000−3000), which would require a somewhat smaller subsidy than the current amount of 1370 Yuan per ton mentioned in section 2. However, we should emphasize that this calculation is rather tentative, especially regarding the non-feedstock input costs. Regarding farm incomes, to which we turn now, the model outcomes are more explicit.

Will the additional biofuel demand provide a boost to farm incomes?
Since animal feeds become more expensive, the scenario leads to a rise of value added in cropping but to a fall in livestock farming. For the country as a whole the relative gain in crop income is about 1.1%, and the relative loss of livestock farmers also 1.1%. With value added in cropping about twice as large as livestock value added, farm value added is seen to increase. However, this seems like a very modest gain for such an ambitious operation. Figure 2 shows that the gain is evenly spread among most of the counties, with the exception of counties whose farmers predominantly specialize on livestock, such as Inner Mongolia and the western part of the country.

Will average fertilizer use per hectare increase significantly or will it remain close to current levels?
The answer to this question already follows from the limited output responses reported above. High fertilizer dosages are a problem in large parts of China, but obviously, as long as most of the biofuel feedstocks are being imported, even 10 million biofuels will not add much to this problem, as shown in Figures 3 and 4. At any rate the amounts applied are already very high in the reference run, often reaching more than 700 kg per hectare, and increases under the biofuel scenario are in almost all counties below 1 kg per hectare, and in some counties even turn out slightly negative, due to minor production shifts from irrigated to rainfed land.

In summary, the target of 10 million tons of biofuel seems prudent essentially because most of the feedstock is being imported. It causes no major disturbances in the food system, and fertilizer problems do not increase. At the same time, the gains are not large in terms of farm incomes, whereas the effects on the balance of payment may be positive or negative, depending on the assumption about the 2020 level of the oil prices that determines the amount of oil costs saved. We already mentioned that the gains in terms of emission are minor or even negative. The next section looks into the scope for improving farm incomes by cultivating biofuel crops on new marginal lands.

Figure 1 Additional output of carbohydrate feed in central biofuel run (S1) compared to the reference run (S0)

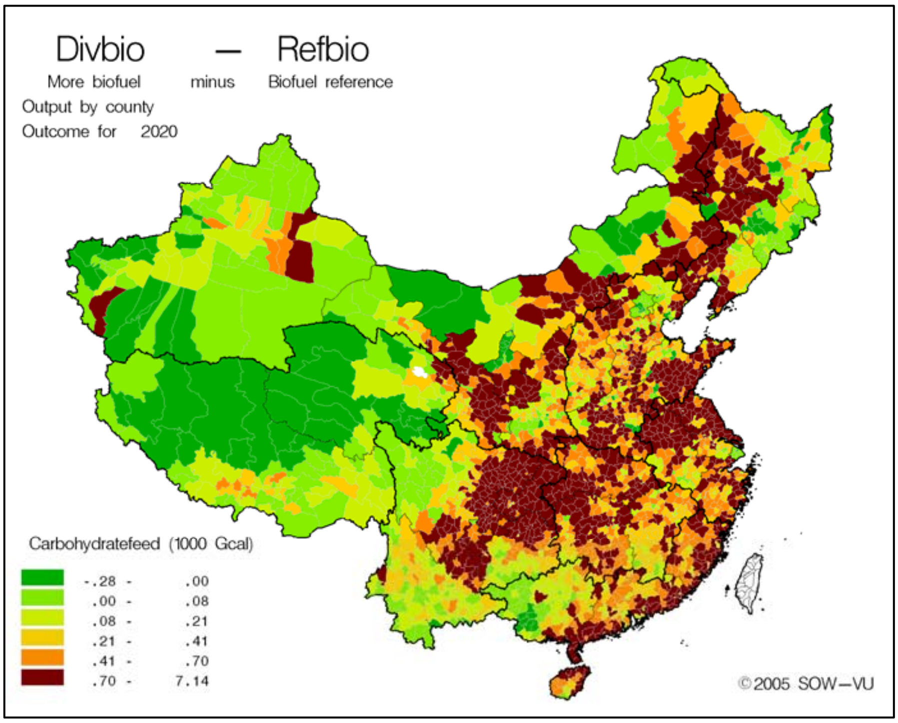


Figure 2 Net increase in farm income in central biofuel run (S1) compared to the reference run (S0)

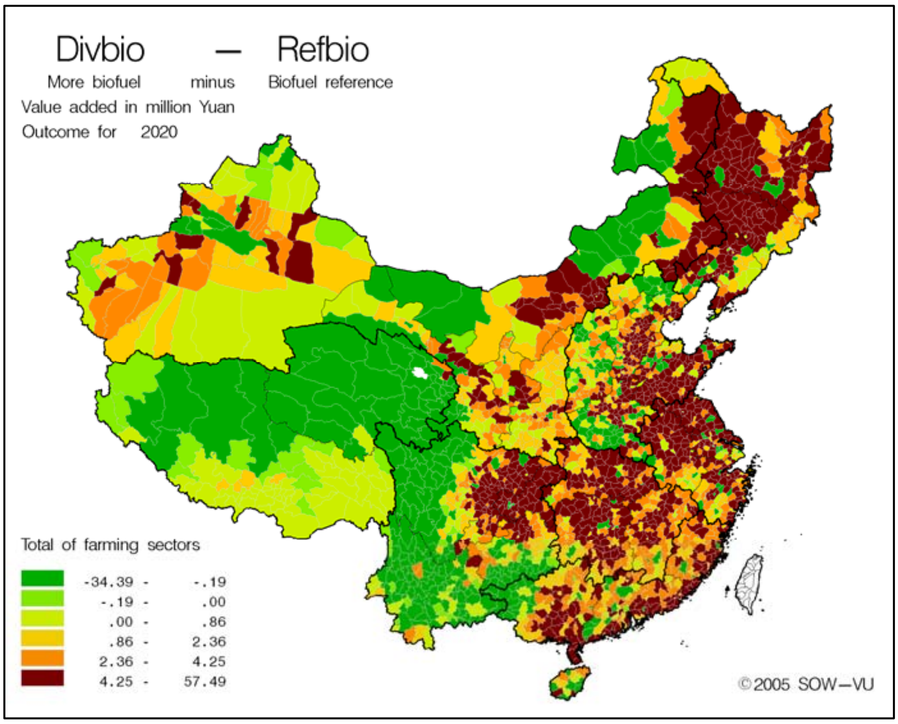


Figure 3. Fertilizer use (organic plus chemical) in kg per ha in biofuel reference run (S0)

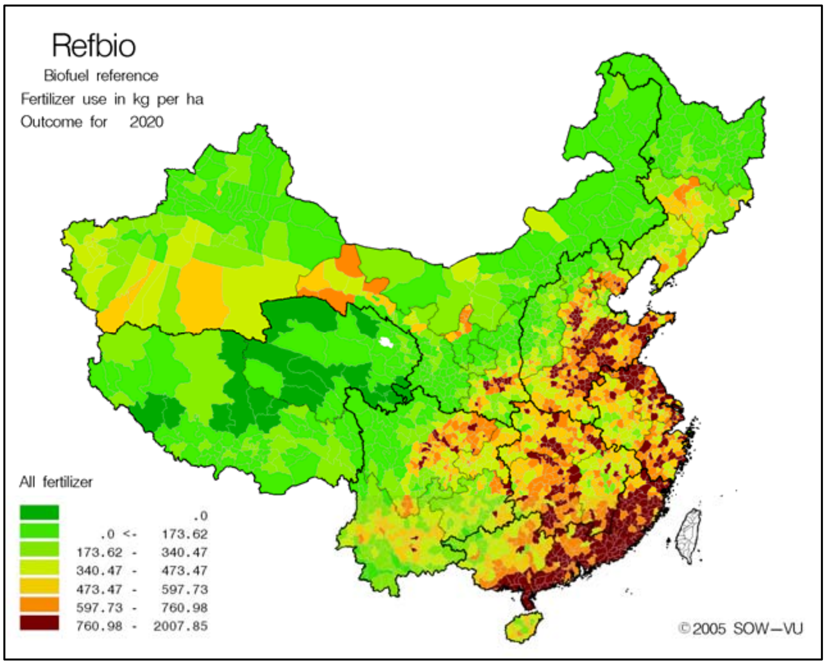
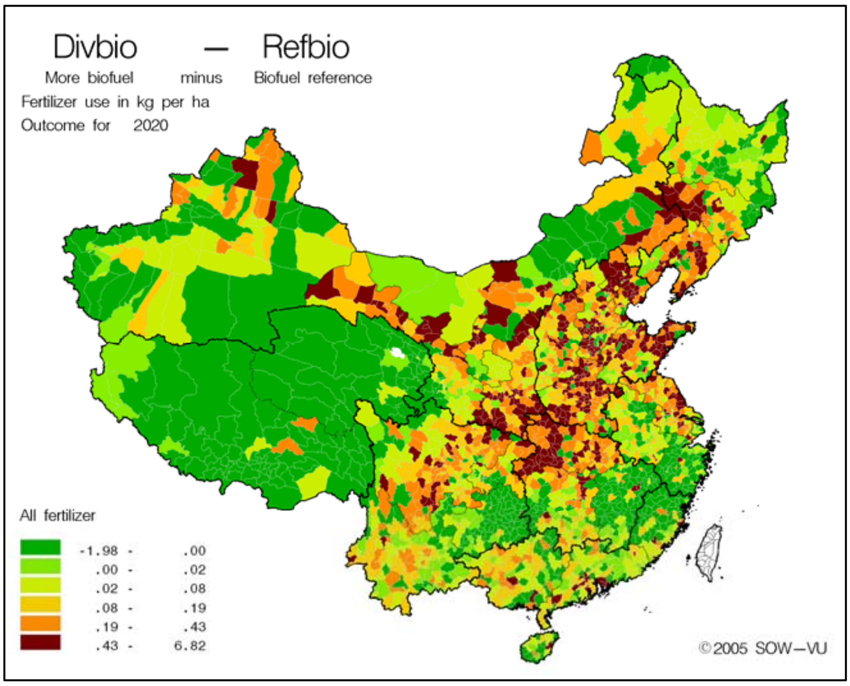


Figure 4. Net increase of fertilizer use in kg per ha in central biofuel run (S1) compared to the reference run (S0)



5. Variants

Before discussing the variant with more marginal land, we briefly return to the assumption of the increase in world prices in the central variant S1. As mentioned above in the discussion of the outcomes, the limited reaction of domestic output more than justifies the 5% increase in world animal feed prices assumed in the scenario. One could even argue that a higher price increase would be appropriate, in which case the effects on the domestic economy would become more pronounced. In this respect, we refer to an earlier biofuel study with the Chinagro model in which additional imports were not allowed at all (Qiu et al, 2009). Hence, in this study China had to solve its biofuel feedstock demand problems itself. At the same time, a larger share of the biofuel feedstock was assumed to consist of maize (and also sugarcane was used). The outcomes of this study were much more drastic in terms of domestic price increases and led to clear negative impacts on rice and wheat production. Hence, against this background, both size and composition of the current biofuel program can be considered as a prudent policy choice indeed.

The second alternative scenario (S2) is designed to assess the likely impact of increasing marginal land for bioethanol development. It builds upon the central biofuel scenario (S1) of the previous section by assuming that half of China's bioethanol target in 2020, hence 5 million ton, will be reached by output from new marginal land[5]. The output of the newly reclaimed marginal land is assumed to consist of sorghum, cassava and sweet potato. The use of maize is kept the same as in the previous scenarios. Since import demand will be lower in this scenario, also the assumption on world price increases is mitigated. Tables 1 and 2 provide the details of the specification.

We only briefly sketch the highlights of the scenario outcomes, which are largely as expected. Import flows of the feedstock commodities are in the middle between the biofuel reference scenario (S0) and the central biofuel scenario (S1), and so are the agricultural trade deficit and the overall food intake. The effect on cropping incomes is mixed. On one hand the additional output on marginal land brings extra value added, on the other hand the reduced international prices lead to lower value added. The county map with the differences in crop value added between S1 and S2 clearly shows the delineation of these two effects. Value added in livestock farming is somewhat higher across the board, due to reduced feed costs. Nevertheless, this run increases farm value added on average only with 0.3%. Hence, the positive income effects are again modest.

[5] In principle, China could produce its targeted level of bioethanol in 2020 fully on marginal lands. However, as mentioned early, it will be too optimistic to assume that all potentially suitable lands can be brought into production for feedstocks. Therefore, we make the assumption that 50% of bioethanol production will originate from marginal land.

6. Conclusion

The target of 10 million tons of bioethanol by 2020 seems a prudent target, causing no major disturbances in the food system, and no aggravation of pollution via fertilizer, essentially since around 88% of the additional biofuel feedstocks are being imported. But, in fact, the gains in farm incomes are not large either. We should emphasize that the specification of our central biofuel scenario assumes that the international price reactions to China's additional feedstock demand remain relatively small. Hence, we allow China to shift its demand problems largely to the world market.

Also the option of cultivating biofuels on new marginal land does not really change the picture of agricultural supply and incomes, at least not in terms of national averages. But it may definitely result in positive income effects that are significant for specific poor segments of the rural population in remote areas. However, the availability of such marginal lands is limited.

It must be noted that the international price reactions in the central biofuel scenario could be underestimated, considering the large increase of China's imports of carbohydrate feed. Therefore, the scenario may be too lenient for China with respect to its capacity to import biofuel feedstocks. Earlier analyses with the Chinagro model showed the turmoil that arises when international markets are not as willing to accommodate as we assume here. Against this background, it seems indeed wise for government to keep the bio-ethanol targets modest.

Table 1: Key Assumptions of the Three Simulation Scenarios.

Scenarios	Bioethanol output in 2020 (million ton)	Utilization of new marginal lands	Component of feedstocks	International Price changes	Processing Technology
Reference Scenario (S0)	1.35	No new marginal land is used	Maize (100%)		2.82 ton of maize can produce 1 ton of ethanol, with 0.89 ton of DDGS; 3 ton of sorghum can produce 1 ton of ethanol with 0.75 ton of DDGS; 8 ton of fresh sweet potato can produce 1 ton of ethanol with 0.45 ton of DDGS; 7.5 ton of cassava can produce 1 ton of ethanol with 0.45 ton of DDGS
Central Bioethanol Scenario (S1)	10	No new marginal land is used	Sorghum (50%); Cassava (30%); Sweet potato (6.5%); Maize (13.5%)	Price of feed commodities higher than in the reference scenario: maize 2.5%, other carbohydrate feeds 5% protein-rich feeds 2.5%	
Bioethanol Scenario with marginal land (S2)	10	Half of the non-cereal feedstocks produced on new marginal land	Sorghum (50%); Cassava (30%); Sweet potato (6.5%); Maize (13.5%)	Price of feed commodities other than maize higher than in the reference scenario: other carbohydrate feeds 2.5% protein-rich feeds 1%	

Table 2: The assumptions on the distributions of bioethanol plants and potential lands in different regions in 2020 (%)

Regions	**Maize based**	**Sorghum based**	**Cassava based**	**Sweet potato based**
North	30	0	0	0
Northeast	40	40	0	0
East	30	0	0	0
Central	0	0	0	0
South	0	0	40	0
Southwest	0	0	60	100
Plateau	0	0	0	0
Northwest	0	60	0	0
China	**100**	**100**	**100**	**100**

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