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Article

Application of US and EU Sustainability Criteria to Analysis of Biofuels-Induced Land Use Change [†]

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Abstract: This research asks and answers a question that had been avoided by all the previous research on biofuels impacts. That is, to what extent are the US and EU biofuels sustainability criteria binding in the sense that if applied, sufficient land would be available to implement the programs? In answering the question, we simulate the global land by agro-ecological zone that would be needed to supply feedstocks for the US and EU biofuel programs using an advanced version of the GTAP-BIO model. Then we estimate the global area of land that would not be available due to sustainability criteria restrictions, again by agro-ecological zone. Finally, we determine the extent to which the US and EU sustainability criteria are binding and find that they are not binding at the biofuel levels currently targeted by the US and EU. In addition, we evaluate the same question, but this time freezing global food consumption, and get the same answer—plenty of land is available to meet the targets and supply food demands.

Keywords: biofuels sustainability criteria; biofuels mandates; biofuels and food consumption

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1. Introduction

National biofuel programs, in particular in US and EU, have two major components. The first component defines a timeline to achieve certain levels of biofuel production over time. The second component defines sustainability criteria. In recent years several studies have examined the land use and economic impacts of national and multi-national biofuel targets [1–16]. Land use change is considered to be important because when land is converted from pasture or forest to cropland to meet the biofuels demand, there is an increase in carbon dioxide emissions. Part of the increase is due to the immediate release of CO_2 to the atmosphere in the form of harvested wood, pasture, or soil carbon loss. Part of it is the foregone opportunity to continue to sequester carbon in natural forests and pasture. In this area of research only a few papers have also examined consequences of biofuel production for sustainability of food consumption, for example see [7]. However, to the best of our knowledge almost no one has examined the consequences of biofuel targets in the presence of land sustainability criteria. Previous research in this area mainly ignored sustainability criteria of biofuel programs and implicitly assumed that the land sustainability criteria do not impose binding constraints on biofuel production. This paper fills the gap in this area by taking into account the fact that biofuels policies consist of biofuel targets and land sustainability criteria. The main objective of this paper is to determine the extent to which the US and EU (two major biofuel producers with explicit sustainability criteria) land use sustainability criteria are binding. In other words, once all the lands excluded by the US and EU sustainability criteria are removed for the candidate land base, is there enough remaining land to meet the biofuel targets.

In 2012, the world's leading producers of biofuels were the US, Brazil, and EU. The US is the world's largest biofuel producer and produced 13.3 billion gallons (BGs) ethanol and 1.1 BGs biodiesel. Brazil produced 5.6 BGs ethanol and 0.7 BGs biodiesel, and the EU produced 1.3 BGs ethanol and 2.9 BGs biodiesel.

The United States' interest in biofuels dates back three decades. Ethanol production in the US has always been supported by the government in some form such as tax credit, trade barriers, and/or direct mandates [17]. The most important US renewable policy today is the Renewable Fuel Standard (RFS). The Renewable Fuel Standard (RFS) began under the Energy Policy Act (EPAct) in 2005 establishing the first mandate for renewable fuels in the US. The RFS program was later expanded in the Energy Independence and Security Act (EISA) of 2007 [18]. EISA expands the RFS program to include biodiesel, increases total renewable fuel target to 36 billion gallons (BG) ethanol equivalent by 2022, and establishes new categories of renewable fuels and introduces life-cycle greenhouse gas thresholds for renewable fuels. As explained in the next section of this paper, the US RFS bans using some types of land to produce feedstock for biofuel production.

The EU initiated its biofuel programs and policies in early 2000s, and the noteworthy document was the 2003 Biofuels directive. Current policy is driven by the Renewable Energy Directive (RED) 2009/28/EC, which is part of the EU Energy and Climate Change Package (CPP) [19]. The RED mandates the 20/20/20 targets for biofuels in the EU. The RED imposes some land sustainability criteria that are applied not only on EU lands, but also globally. These restrictions are examined in the next section of this paper.

Biofuel production in Brazil has a long history, but the significant turn happened after the oil crisis in the 1970s. The Brazilian federal government created the National Alcohol Program better known as

PROALCOOL in 1974 after suffering from the doubling of payments for oil imports. PROALCOOL implemented and regulated the use of hydrated ethanol as fuel and also anhydrous ethanol that could be blended with gasoline. Other biofuel programs such as the Production of Vegetable Oil for Energy Purposes (Pro-Oleo) and Program for Biodiesel Technological Development (ProBiodiesel) are also used to promote biofuel production in Brazil [20–22]. Brazil has defined land conservation programs and implemented land sustainability criteria. However, we were not been able to find clear links between these criteria and the Brazilian biofuel programs. Hence, while Brazil is a large biofuel producer, in this paper we do not include any Brazilian land sustainability criteria.

In recent years, many papers have used the partial and general equilibrium economic models in combination with biophysical data to analyze induced land use changes due to the expansion in first generation biofuels produced in US, Brazil, and EU [8–16]. The first generation biofuels are produced from grains (e.g., corn ethanol in US and wheat ethanol in EU), sugar crops (e.g., sugarcane ethanol in Brazil and sugar beet ethanol in EU), and oilseeds (e.g., biodiesel produced from oilseeds such as soybean, rapeseed, palm, and sunflower seeds). Only a few studies examined the induced land use changes due to the second generation biofuels. For example, Taheripour, Tyner, and Wang [14] and Taheripour and Tyner [16] have introduced the second generation biofuels in the GTAP-BIO model and examined the induced land changes due the production and consumption of the second generation biofuels produced from corn stover and two dedicated energy crops: switchgrass and miscanthus.

This paper estimates whether or not the US and EU sustainability criteria actually would impinge on achieving the respective biofuel targets. To accomplish this task we undertake two activities. First, we determine prohibited lands for biofuel production according to the US and EU biofuel sustainability criteria using GIS software and exclude them from the stock of global available land for biofuel production. Then we evaluate land use implications of expansion in the global biofuel industry using a computational general equilibrium model with two land data sets—one with all available land and one that incorporates the new land use base with sensitive lands excluded. We compare the results of these two simulations to determine in what part of the world the eligible land for feedstock production is not enough to meet the demand for land conversion due to biofuel production. The results indicate that the land use criteria defined in the US and EU biofuel programs do not impose binding constraints on biofuel induced land use changes at least up to the biofuel levels targeted by the two programs.

2. Experimental Method

2.1. Computational General Equilibrium Model and Scenarios

The US and EU biofuel mandates are large enough to affect agricultural markets worldwide. They also could affect energy markets and interact with other economic activities at the global scale. Thus, we used a global computable general equilibrium model to assess the land use impacts of the US and EU biofuel mandates. General equilibrium models capture all the economic interactions among product and factor markets. Thus, they are ideal for evaluating policy issues such as biofuel policies that have impacts throughout the economy. The model is an extended version of the GTAP-BIO model [2,5,6,13]. GTAP, which stands for Global Trade Analysis Project, is a global model that has been used for analysis of trade, energy, and environmental policy options since 1994. It is a general equilibrium model with as many as 113 regions and 57 sectors. However, most simulations, including ours, aggregate both regions and sectors to sizes appropriate for the questions being addressed. GTAP-BIO has new sectors added for ethanol from maize and sugarcane and biodiesel from soybean and rapeseed oil. GTAP-BIO also includes the byproducts associated with the biofuel activities. In addition, this version of the model has a land use component, so changes in land use driven by changes in biofuel production and policy can be quantified.

This model is frequently used to assess induced land use changes due to the US and EU biofuel mandates under alternative economic setups and assumptions. Taheripour, Tyner, and Wang [14] and Taheripour and Tyner [16] introduced second generation biofuels produced from corn stover and two dedicated energy crops (switchgrass and miscanthus) into this model and used the advance model (called GTAP-BIO-ADV) to evaluate land use impacts of the first and second generation biofuels produced in the US.

We tuned and used this model to assess the land use and economic consequences of the US and EU biofuel mandates in the following four cases:

- Scenario I: Expansion in first and second generation biofuels produced only in the US with no land constraint,
- Scenario II: Expansion in first and second generation biofuels produced only in the EU region with no land constraint,
- Scenario III: Expansion in first and second generations biofuels produced in the US and EU regions with no land constraint,
- Scenario IV: Expansion in the first and second generation biofuels produced in the US and EU regions with no land constraint but with global consumption of food not permitted to fall.

The first three scenarios are self-explanatory. We include the last scenario to study the interactions between biofuel production and food consumption. In this case, following Hertel *et al.* [13] we hold food consumption constant while we shock biofuels. This helps us to isolate the impacts of biofuel production on food consumption and evaluate its land use consequences. The way this works in GTAP or any general equilibrium model is that the price increase due to the biofuels shock results in less food consumption. Less food consumption means that less land is needed to grow food. Thus, the decrease in food consumption reduces the additional land needed for biofuels. By freezing food consumption, we prevent the model from giving biofuels a land use “credit” for reduced food consumption. As a practical matter, it would be difficult to do this, but the results do give us an indication of the relative importance of the food consumption decrease in the standard case.

For the scenarios involving the US biofuel mandate, the 2022 targets of 15 BGs of conventional biofuel (or corn ethanol), 16 BGs ethanol equivalent of cellulosic biofuel, and 1 BGs of biodiesel are implemented. The other biofuel, mostly sugarcane ethanol, does not need to meet the RFS sustainability requirement, and will not be covered in this research. Cellulosic feedstocks corn stover, miscanthus, and switchgrass are used to produce drop-in cellulosic biofuels to meet the RFS target. The energy content of the drop-in biofuel is assumed to be the same as that of conventional gasoline, while the energy content of tradition ethanol is two-thirds of conventional gasoline [14].

The EU biofuels mandates are defined based on Directive 2009/28 [19] and Al-Riffai *et al.* [10]. According to the EU Directive, the EU renewable energy consumption for road transportation is estimated at 316 Million tons of oil equivalent (Mtoe) in 2020. We adopt the 5.6% first-generation land-using biofuels share in the overall EU renewable energy target of 10 percent for road transportation of Al-Riffai *et al.* [10]. This 5.6 percent translates into 17.696 Mtoe for biofuels for road transportation. In the absence of any estimates of the likely breakdown among renewable biofuels, we have assumed 50 percent of this being biodiesel from oilseeds, 25 percent from cellulosic feedstock, and 25 percent from conventional ethanol. We used these shares based on Capros *et al.* [3] and Flach *et al.* [23]. The cellulosic component for the EU is likely to be biodiesel; therefore, cellulosic drop-in fuel from miscanthus is used to represent this. Even though this biofuel does not exist in quantities today, we used the best available estimates of conversion rates and costs to represent the technology. It is a thermochemical conversion technology that converts the cellulosic material to renewable diesel or gasoline that can be used directly in existing distribution systems, thus the name drop-in. With these assumptions, the biodiesel from oilseeds (rapeseed and palm oil) plus cellulosic drop-in fuel accounts for 75% of the total renewable fuel mix. Hence, 17.696 Mtoe for biofuels for road transportation is broken down into 8.848 Mtoe for biodiesel from oilseeds, 4.424 Mtoe from miscanthus cellulosic drop-in fuel, and 4.424 Mtoe from wheat ethanol. To implement these targets in the model, they need to be converted into billion gallons to be consistent with the GTAP units of measurement for biofuels. With the energy contents of 21 mega joule per liter (Mj/L) and 33 Mj/L respectively for (bio) ethanol from biomass and methyl-ester biodiesel from vegetable oil from Annex III of the Directive 2009/28 [19], it is translated into the targets of 1.481 BGs for the rapeseed and palm oil biodiesel, 2.328 BGs for cellulosic drop-in fuel and 2.328 BGs conventional ethanol. The EU Directive applies to all biomass regardless of country of origin.

2.2. Land Sustainability Criteria

The US RFS allows biofuel producers to convert crops and crop residues harvested from the existing agricultural land and non-forested land to biofuels. Planted trees and tree residues harvested from the existing non-federal managed forest also can be used for biofuel production as well. The US RFS does not allow using federal land to produce feedstock for biofuel production. Wetlands also cannot be used for feedstock production for biofuels. Therefore, this paper excludes US federal land and wetlands for the sustainability land criteria for biofuel production in the US. The US biofuel program does not impose land sustainability restrictions on biofuels produced outside the US. According to the EU biofuel programs, the following types of land cannot be used for biofuel production:

i Land with high biodiversity values including:
  a. Primary forest and other wooded land
  b. Areas designed for natural protection purposes
  c. Highly bio-diverse grassland (natural and managed grassland)

ii Land with high carbon stocks including wetlands, continuously forested areas, and peatlands.

Lands that are in these categories are excluded from the land use data set that is deemed to meet the EU sustainability criteria. Each of these land categories were represented in a GIS layer and were excluded from the GTAP total land use data base to meet the sustainability criteria.

We collected data and global maps from different sources as detailed in Treesilvattanakul [24] and used the ArcGIS program to remove all the prohibited land for biomass production due to the land sustainability criteria defined in the US and EU biofuel programs from the pool of global land. This process is fully explained in Treesilvattanakul [24]. To save space here we only present the final results at the global scale.

3. Results and Discussion

Table 1 presents the pool of global managed land before and after imposing land sustainability criteria. This table indicates that at the global scale about 1066.3 million hectares of forest and 2292.2 million hectares of pasture land meet the sustainability criteria to be used for biofuel production. These figures are about 63.5% and 83.5% of the available managed forest and pasture land, respectively. The pool of eligible lands which can be used to produce feedstock for biofuels production is available by region and Agro-ecological Zone (AEZ) in Treesilvattanakul [24]. The land cover category labeled crop includes all cropland. The AEZs are defined by crop growing conditions (temperature, precipitation, length of growing period, *etc.*) and do not represent any particular region. For example, much of the agricultural zones in the US and EU are AEZs 10-12.

Table 1. The pool of global managed land before and after imposing sustainability criteria defined in the US and EU biofeul programs by agro ecological zone (AEZ)—(figures are in million hecatres).

AEZ	Before imposing sustainability criteria				After imposing sustainability criteria			
	Forest	Crop	Pasture	Total	Forest	Crop	Pasture	Total
AEZ1	0.7	26.1	203.9	230.7	0.0	26.1	185.2	211.3
AEZ2	2.3	55.4	115.8	173.4	0.0	55.4	103.1	158.4
AEZ3	13.8	117.9	134.1	265.8	0.0	117.9	102.4	220.3
AEZ4	66.6	119.1	185.0	370.7	54.8	119.1	135.6	309.6
AEZ5	156.3	117.0	190.8	464.1	106.9	117.0	146.0	369.8
AEZ6	344.3	130.4	98.1	572.8	127.0	130.4	74.5	331.9
AEZ7	7.0	105.6	780.0	892.5	3.7	105.6	649.4	758.7
AEZ8	24.8	183.9	286.0	494.6	17.2	183.9	249.6	450.7
AEZ9	94.0	175.3	118.1	387.4	78.4	175.3	105.0	358.7
AEZ10	228.5	231.2	118.1	577.8	186.0	231.2	103.3	520.4
AEZ11	128.4	108.6	73.7	310.7	106.9	108.6	64.6	280.1
AEZ12	142.0	93.8	114.7	350.5	118.8	93.8	106.1	318.7
AEZ13	13.2	28.4	149.3	190.9	4.6	28.4	130.8	163.8
AEZ14	200.2	16.8	97.4	314.3	100.9	16.8	75.2	192.9
AEZ15	241.3	32.6	62.6	336.5	153.0	32.6	48.9	234.5
AEZ16	13.3	2.4	17.1	32.8	7.6	2.4	11.9	21.9
AEZ17	1.7	0.0	0.9	2.6	0.6	0.0	0.6	1.3
AEZ18	0.0	0.0	0.2	0.2	0.0	0.0	0.1	0.1
Total	1678.1	1544.5	2745.8	5968.4	1066.3	1544.5	2292.2	4903.0

Table 2 represents the simulation results obtained from scenarios I–IV by AEZ at the global scale. The first three columns of this table represent the induced land use changes due to the US biofuel mandates obtained from scenario I. To meet the US biofuel mandates, defined earlier in this paper, the global crop land will be expanded by about 3.3 million hectares. Comparing the distribution of this figure among forest and pasture land by AEZ with the pool of available sustainable land (presented in Table 1) clearly indicates that the US biofuel mandates alone do not violate the US and EU land sustainability criteria at the global scale. The simulation results by region (for details see Treesilvattanakul [24]) also confirm this conclusion.

Table 2. Induced land use changes due to the US and EU biofeul targets obtained for scenarios I, II, III, and IV by AEZ (figures are in million hectares).

AEZ	Scenario I			Scenario II			Scenario III			Scenario IV		
	Forest	Crop	Pasture	Forest	Crop	Pasture	Forest	Crop	Pasture	Forest	Crop	Pasture
AEZ1	0.0	0.1	−0.1	0.0	0.3	−0.3	0.0	0.4	−0.4	0.0	0.4	−0.5
AEZ2	0.0	0.0	0.0	0.0	0.2	−0.2	0.0	0.2	−0.3	0.0	0.3	−0.3
AEZ3	0.0	0.1	−0.1	0.1	0.3	−0.4	0.1	0.4	−0.5	0.0	0.5	−0.6
AEZ4	0.0	0.1	−0.2	0.2	0.8	−1.0	0.2	0.9	−1.1	0.0	1.2	−1.3
AEZ5	0.0	0.2	−0.2	0.5	1.0	−1.5	0.5	1.2	−1.7	0.3	1.6	−1.9
AEZ6	0.0	0.1	−0.2	0.5	0.7	−1.2	0.5	0.9	−1.3	0.3	1.1	−1.4
AEZ7	0.0	0.6	−0.6	0.1	1.5	−1.6	0.1	2.0	−2.1	0.1	2.4	−2.5
AEZ8	0.0	0.3	−0.3	0.3	1.0	−1.3	0.2	1.3	−1.5	0.2	1.6	−1.8
AEZ9	−0.1	0.3	−0.2	−0.1	1.3	−1.2	−0.2	1.5	−1.3	−0.4	1.9	−1.5
AEZ10	−0.4	0.6	−0.2	−1.3	2.6	−1.3	−1.7	3.1	−1.4	−2.2	3.6	−1.4
AEZ11	−0.2	0.3	−0.1	−0.4	1.0	−0.7	−0.6	1.3	−0.7	−0.7	1.5	−0.8
AEZ12	−0.1	0.2	−0.1	0.3	0.5	−0.8	0.2	0.7	−0.9	0.1	0.9	−1.0
AEZ13	0.0	0.1	−0.1	0.1	0.3	−0.4	0.1	0.4	−0.5	0.1	0.5	−0.6
AEZ14	0.0	0.0	−0.1	0.5	0.1	−0.5	0.5	0.1	−0.6	0.4	0.2	−0.6
AEZ15	0.0	0.1	−0.2	0.3	0.6	−0.9	0.4	0.7	−1.0	0.1	0.9	−1.0
AEZ16	0.0	0.0	0.0	0.0	0.1	−0.1	0.0	0.1	−0.1	0.0	0.1	−0.1
AEZ17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AEZ18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	−0.7	3.3	−2.6	1.0	12.3	−13.3	0.3	15.1	−15.4	−1.6	18.7	−17.2

The second three columns of this table show the induced land use changes due to the EU biofuel mandates obtained from scenario II. To meet the EU biofuel mandates, defined earlier in this paper, global cropland will be expanded by 12.3 million hectares. Comparing the distribution of this figure among forest and pasture land by AEZ with the pool of available sustainable land (presented in Table 1) clearly indicates that the EU biofuel mandates alone do not violate the US and EU land sustainability criteria at the global scale. The simulation results by region also confirm this conclusion (for details see Treesilvattanakul [24]).

The third set of three columns of this table shows the induced land use changes due to the US and EU biofuel mandates obtained from scenario III. To meet the US and EU biofuel mandates, defined earlier in this paper, global land will be expanded by 15.1 million hectares. Comparing the distribution of this figure among forest and pasture land by AEZ with the pool of available sustainable land (presented in Table 1) clearly indicates that the US and EU biofuel mandates jointly do not violate the

US and EU land sustainability criteria at the global scale. The simulation results by region (for details see Treesilvattanakul [24]) also confirm this conclusion.

Finally, the fourth set of three columns of this table shows the induced land use changes due to the US and EU biofuel mandates with fixed food consumption obtained from scenario IV. Global land will be expanded by 18.1 million hectares. Comparing the distribution of this figure among forest and pasture land by AEZ with the pool of available sustainable land (presented in Table 1) clearly indicates that the even if food consumption is fixed, the US and EU biofuel mandates jointly do not violate the US and EU land sustainability criteria at the global scale. The simulation results by region (for details see Treesilvattanakul [24]) also confirm this conclusion.

4. Conclusions

This research asks and answers a question that had been avoided by all the previous research on biofuels impacts. That is, to what extent are the US and EU biofuels sustainability criteria binding in the sense that if applied, insufficient land would be available to implement the programs? In answering the question, we simulate the global land by Agro-ecological zone that would be needed to supply feedstocks for the US and EU biofuel programs using an advanced version of the GTAP-BIO model. Then we estimate the global area of land that would not be available due to sustainability criteria restrictions, again by agro-ecological zone. Finally, we determine the extent to which the US and EU sustainability criteria are binding and find that they are not binding at the biofuel levels currently targeted by the US and EU. In addition, we evaluate the same question, but this time freezing global food consumption, and get the same answer—plenty of land is available to meet the targets and supply food demands.

Author Contributions

All of the authors contributed equally to the research and writing on this paper.

Conflicts of Interest

The authors declare no conflict of interest.

References

1. Khanna, M.; Ando, A.; Taheripour, F. Welfare effects and unintended consequences of ethanol subsidies. *Rev. Agric. Econ.* **2008**, *30*, 411–421.
2. Hertel, T.; Tyner, W.; Birur, D. *Impact of Biofuel Production on World Agricultural Markets: A Computable General Equilibrium Analysis. Working Paper No. 53, Global Trade Analysis Project (GTAP)*; Purdue University: West Lafayette, IN, USA, 2008
3. Capros, P.; Mantzos, L.; Tasios, N.; de Vita, A.; Kouvaritakis, N. *EU Energy Trends to 2030. Directorate-General for Energy*; European Commission: Brussels, Belgium, 2009.

4. Ando, A.; Khanna, M.; Taheripour, F. Market and social welfare effects of the renewable fuels standard. In *Handbook of Bioenergy Economics and Policy-Series of Natural Resource Management and Policy*, 1st ed.; Khanna, M., Scheffran, J., Zilberman, D., Eds.; Springer: New York, NY, USA, 2010; Volume 33, pp. 233–250.
5. Taheripour, F.; Hertel, T.; Tyner, W.; Beckman, J.; Birur, D. Biofuels and their by-products: Global economic and environmental implications. *Biomass Bioenergy* **2010**, *34*, 278–289.
6. Taheripour, F.; Hertel, T.; Tyner, W. Implications of biofuels mandates for the global livestock industry: A computable general equilibrium analysis. *Agric. Econ.* **2011**, *42*, 325–342.
7. Smyth, B.; O'Gallachoir, B.; Korres, N.; Murphy, J. Can we meet targerts for biofuels and renewable energy in transport given constraints imposed by policy in agriculture and energy? *J. Clean. Prod.* **2010**, *18*, 1671–1685.
8. Searchinger, T.; Heimlich, R.; Houghton, R.; Dong, F.; Elobeid, A.; Fabiosa, J.; Tokgoz, S.; Hayes, D.; Yu, T. Use of U.S. Croplands for biofuels increases greenhouse gases through emissions from land-use change. *Science* **2008**, *319*, 1238–1240.
9. Ozdemir, D.; Hardtlein, M.; Eltrop, L. Land substitution effects of biofuel side products and implications on the land area requirement for the EU 2020 biofuel targets. *Energy Policy* **2009**, *37*, 2286–2296.
10. Al-Riffai, P.; Dimaranan, B.; Laborde, D. *Indirect Land Use Change Effects of Biofuel Mandates: Insights from a CGE Approach*; International Food Policy Research Institute (IFPRI): Washington, DC, USA, 2010.
11. Fabiosa, F.; Beghin, C.; Dong, F.; Elobeid, A.; Tokgoz, S.; Yu, H. Land allocation effects of the global ethanol surge: Predictions from the International Ifpri Model. *Land Econ.* **2010**, *86*, 687–706.
12. Hellmann, F.; Verburg, H. Impact assessment of the European biofuel directive on land use and biodiversity. *J. Environ. Manag.* **2010**, *91*, 1389–1396.
13. Hertel, T.; Golub, A.; Jones, J.; O'Hare, M.; Pelvin, R.; Kammen, D. Effects of US maize ethanol on global land use and greenhouse gas emissions: Estimating market-mediated responses. *BioScience* **2010**, *60*, 223–231.
14. Taheripour, F.; Tyner, W.; Wang, M. *Global Land Use Changes due Tothe US Cellulosic Biofuel Program Simulated with the GTAP Model*; Argonne National Laboratory: Chicago, IL, USA, 2011.
15. Timilsina, G.; Beghin, J.; van der Mensbrugghe, D.; Mevel, S. The Impacts of biofuels targets on land-use chnage and food supply: A global cge assessment. *Agric. Econ.* **2012**, *43*, 315–332.
16. Taheripour, F.; Tyner, W. Induced land use emissions due to first and second generation biofuels and uncertainty in land use emissions factors. *Econ. Res. Int.* **2013**, doi:10.1155/2013/315787.
17. Tyner, W. The US ethanol and biofuels boom: Its origins, current status, and future prospects. *BioScience* **2008**, *58*, 646–653.
18. United States Environmental Protection Agency. *Energy Independence and Security Act*; United States Department of Energy, Environmental Protection Agency: Washington, DC, USA, 2007.
19. European Commission. *Directive 2009/28/Ec of the European Parliament and of the Council of 23 April 2009 on the Promotion of the Use of Energy From Renewable Sources*; European Commission: Brussels, Belgium, 2009.

20. Nass, L.; Pereira, P.; Ellis, D. Biofuels in Brazil: An overview. *Crop Sci.* **2007**, *47*, 2228–2237.
21. Pousa, G.; Santos, A.; Suarez, P. History and policy of biodiesel in Brazil. *Energy Policy* **2007**. *35*, 5393–5398.
22. Hira, A.; Oliveira, L. No substitute for oil? How Brazil developed its ethanol industry. *Energy Policy* **2009**, *37*, 2450–2456.
23. Flach, B.; Bendz, K.; Lieberz, S. *EU-27 Biofuels Annuals: EU Biofuels Annuals 2012, Gain Report # NL2020*; United States Department of Agriculture, Foreign Agricultural Service: Washington, DC, USA, 2012.
24. Treesilvattanakul, K. Economic and Land Use Consequences of Biofuel Production and Policy with Application of US and EU Sustainability Criteria. Ph.D. Thesis, Purdue University, West Lafayette, IN, USA, December 2013.