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The Effect of Biodiesel Production in the Unites States on the CO_2 Emissions and Oilseeds Harvest

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Abstract

This study investigated the impacts of biodiesel produced from oilseeds on global CO_2 emissions as well as oilseeds harvested area and yields. Three scenarios were defined: first scenario evaluated the effect of percent changes in the U.S. biodiesel production by 2011 based on 2001. The second one addressed the same impacts when both the U.S. and the EU produce biodiesel and the third one reported historical changes in U.S. biodiesel production. GATP-BIO model was utilized to develop the scenarios and analyze the results. The model divided each country's land endowment into 18 Argo Ecological Zones (AEZs), and the whole world into 18 trading regions and 21 industries. Results showed that as a result of the U.S. biodiesel production, both U.S. and the world's total CO2 emissions were reduced mainly due to reduction in *household consumption of diesel*. The U.S. tax credit policy was found to be efficient in biodiesel productions. It was also found that consider AEZs is critical for the economic land coverage analysis.

Keywords : Biodiesel production; Global trade analysis project; Harvested area; CO_2 emissions; Scenario evaluation

1. Introduction

Demand for fossil fuels specially petroleum and natural gas has risen over the last two decades, primary due to rapid development and urbanization that occur throughout the world [1]. Climate is changing as a result of carbon dioxide (CO_2) emissions from fossil fuel consumption [2–4]. Reducing CO_2 emissions together with limited fossil fuels reserves make renewable biofuels a viable alternative fuels [5]. Biofuels are made from the biomass, which refers to living and recently living biological materials that can be the substitute for fossil fuels. Bioethanol and biodiesel are the two main biofuels [6]. Biodiesel is an alternative diesel fuel, which can be produced from a variety of biomasses such as vegetable oils from soybean, peanut, sunflower, rape, coconut, cotton, mustard and also animal fats.

The transportation sector is the second major energy consumer in the United States [7–9]. Benefits from using biodiesel, as alternative choices in transportation sector are two fold: reduce the dependency on petroleum and decrease its environmental impacts such as CO_2 emissions [10–12]. Biodiesel can be an optimum alternative fuel for compressed ignition engine since there is no major engine modification required to use biodiesel [13]. In addition to CO_2 emissions, biodiesel mandates are blamed to have impacts on markets for land covers and agricultural commodities. Since biodiesel feedstock competes for land with other food uses, the impacts of biodiesel production on global land use could also be significant.

EU is the major biofuel producer in the word (44%) and the U.S. has the highest growth rate in biodiesel production (180%) in 2011, based on the most recent data available [14]. Generally in this study, we focus on the impacts of biodiesel produced from oilseeds on global CO_2 emissions and oilseeds harvested area and yields. Three scenarios are defined: first scenario evaluates the effect of percent changes in U.S. biodiesel production by 2011 based on 2001. The second one addresses the same impacts when both U.S. and EU produce biodiesel and the third one reports the historical changes in U.S. biodiesel production and its impacts.

2. Model

Toward this goal we employed Global Trade and Analysis Project (GTAP) model and database. The standard GTAP model is a multi-region, multi-sector, computable general equilibrium (CGE) model, with perfect competition and constant returns to scale. This model gives users a wide range of features, including unemployment, tax revenue replacement and fixed trade balance closures [15]. GTAP-E model is a modified version of the standard GTAP model that incorporates energy substitution into the standard database [16].

Most recent GTAP model extension would handle biofuel by products and accurately represent global land use. This modified version, called GTAP-BIO [17], further modifies the GTAP-E model to incorporate the potential for biofuels to substitute for petroleum products [18]. We utilized the GATP-BIO model to develop our analysis.

3. Data

The version of GTAP that we used divides each country's land endowment into 18 Argo-Ecological Zones (AEZs) as well as 18 trading regions and 21 industries. The AEZ methodology determines agricultural production potentials and carrying capacity of the world's land area based on soil and climate characteristics such as rainfall and temperature [19–21]. The base data contains complete information based on 2001 records.

4. Analysis and results

In this section we perform three scenarios. We make the production of the biodiesel exogenous in the model to be able to shock it. The following subsections explain the different scenarios and their results. The biodiesel production input data are presented in Table 1.

Table 1 Biodiesel production by year (Thousand Barrels Annual)

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
U.S.	204.2	249.6	338.3	664.4	2161.6	5962.8	11662.5	16101.3	12281.0	8177.0	23035.0
Europ	6843.	8869.	11909.	15001.	22651.	35229.	44672.	55001.	63462.	66846.	64856.

e	8	5	9	5	9	8	4	9	5	8	8

4.1. Scenario 1: U.S. biodiesel production by 2011

The first scenario evaluates the effect of percent changes in U.S. biodiesel production by 2011 based on 2001. In this part we explore the changes on CO_2 emissions, U.S. imports, Oilseeds harvested areas and oilseeds yield.

4.1.1 Total CO_2 emissions

The total world's CO_2 emission change is negative (-0.019%) which means that this policy is beneficial for the whole world but not for any other countries since CO_2 emissions increased for all the countries except U.S. and India. Under this scenario main CO_2 reduction belongs to U.S. (-0.199%) followed by India (-0.004%). The major share for increase in CO_2 emissions belongs to Brazil (0.035%) and Canada (0.024%) (See Figure 1a in the Appendix).

The contributors to the total CO_2 emission are related to CO_2 emissions from firms' usage of imports, private consumption of domestic products, and private consumption of imports. For U.S. the main contributor to the changes in emissions is private consumption of domestic products (90%), which is mostly affected by petroleum, coal products (69%) and gas (21%). It could be concluded that since household consumption of the diesel is reduced (blending with biodiesel) in U.S. its total CO_2 emissions is reduced.

For India the most important contributor is emissions from firms' usage of imports of biodiesel industry. When you look at the private consumption expenditure on domestic oilseeds in all the regions, India has the highest oilseeds' price in the whole world. So it makes sense for firms to use imported oilseeds in biodiesel industry. Since the U.S. is the main importer to India (see Figure 2a in the Appendix), and in this scenario U.S. would be interested in increasing imports and decreasing its export (specially to India by -11.3%), therefore Indian CO_2 emissions reduced due to the less firms usage.

4.1.2 U.S. imports

We are also interested in investigating the U.S. imports of oilseeds, as the primary good in biodiesel industry and gas, as a substitute for diesel (there is no diesel industry in the base model). If you look at the oilseeds and gas imported to U.S. (Figure 3a and 4a in the Appendix), Total U.S. gas imports decreased by 8.58% and the total oilseeds imports increased by 381% with the highest share from India and Middle East.

Aggregated imports is the main factor that positively contributes to the U.S. oilseeds imports (20.5% from the total of 9.5%) while domestic price and market price cause decrease in imports of oilseeds (-11% of the total of 9.5%). In the changes in aggregated imports almost the total share is related to private household demand for imported oilseeds, which is positively, affected by private consumption price and negatively by price of imports by private households.

4.1.3 Oilseeds' harvested area

The harvested areas of the oilseed crops are affected by this shock. For U.S. changes in harvested area is the highest compare to the other countries. All the other regions have the increase in percent changes in harvested area of oilseeds (see Figure 5a in the Appendix). This could be because of high us demand for imports of oilseeds. So all the other regions are producing more oilseeds to import to U.S. The total change of oilseeds harvested area is 20.3 for the whole world that shows the effect of U.S. biodiesel production on the world.

The harvested area in each region is highly correlated to the percent changes in market price of sluggish endowment in that region. Due to the higher market prices, farmers would change their croplands to the oilseeds. As the result, the harvested areas for all the other agricultural products decreased. (A total percentage of -1.81% cereal grains, -6.44% sugarcane, -2.85% other grains, and -1.81% other agricultural products)

4.1.4 Oilseeds' yield

While the harvested areas in the regions are changing, the change in oilseeds' yield is not followed by the changes in oilseed's harvested area. The global change in oilseeds yield is 4.7% while the global changes in harvested area is 20.3 %. This might be due to the impact of the AEZ zones. As shown by Figure 1, one of the largest regions with oilseeds harvesting is Canada, which is located in the boreal zone. On the other hand the Latin America and the rest of the Africa that are located in tropical regions. So, the large portions of the harvested are not productive lands, so the increase in yields is not consistent with the increase in the harvested area. The greatest changes of oilseeds yield is resulted from the U.S. (1.48%), and Oceania (0.78%) (See Figure 6a in the Appendix).

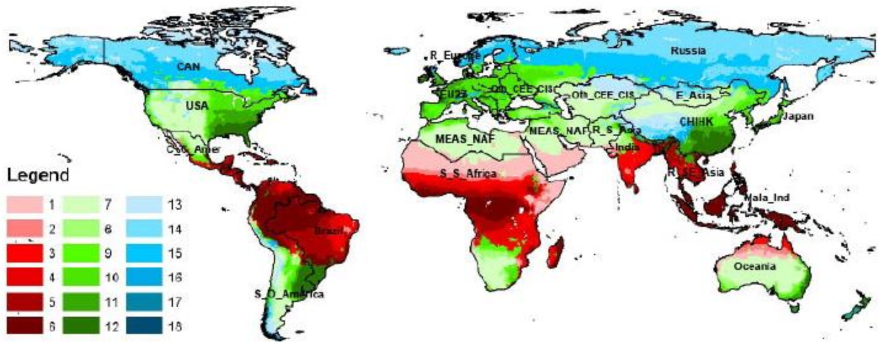

Figure 1 Distribution of AEZs and regions used in the GTAP [22].

4.2. Scenario 2: U.S. and EU biodiesel production in 2011

The second scenario addresses the same above impacts when both U.S. and EU biodiesel production increased based on the numbers provided in table 1. In this section we just relay on the differences with the first scenario in each subject.

4.2.1 Total CO_2 emissions

In this case still U.S. has the highest reduction in CO_2 emissions (-.188%), this time followed by EU (-0.109%). In this scenario the emission reduction in U.S. is less than the last scenario. Because this time U.S. oilseeds export to EU increased by 21.7%, mainly due to satisfy the demand of oilseeds for EU biodiesel production.

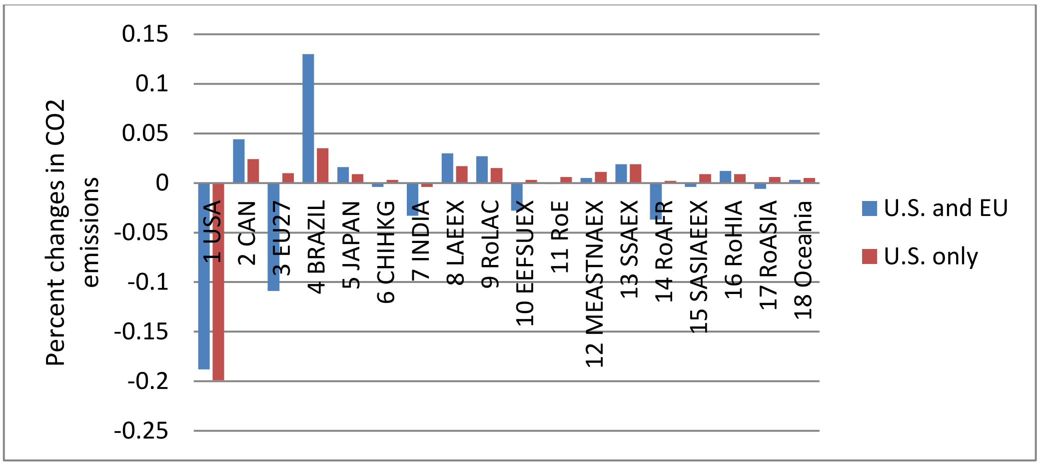

Figure 2 Comparison in Percent changes in CO_2 emissions by region.

The major share for increase in CO2 emissions again belongs to Brazil (0.13%) and Canada (0.044%). These countries both have greater increased in CO2 emission compare to the last scenario. The increase in CO2 emissions in these two countries is due to the increase in private consumption of domestic biodiesel products.

The total world's CO2 emission change is negative (-0.123% compare to the -0.019% in the first scenario). It means that this scenario is more beneficial for the whole world compare to the last scenario.

4.2.2 U.S. imports

In this scenario, total U.S. gas imports does not have change and the total oilseeds imports increased by 387% with the highest share from India and Middle East and Japan. This scenario shows that oilseeds imports increased from all the countries except EU, because EU needs to justify its demand for biodiesel industry. The total changes in U.S. oilseeds imports do not change; therefore U.S. offset its demand by importing more oilseeds from the other countries. Figure 3 denotes this fact.

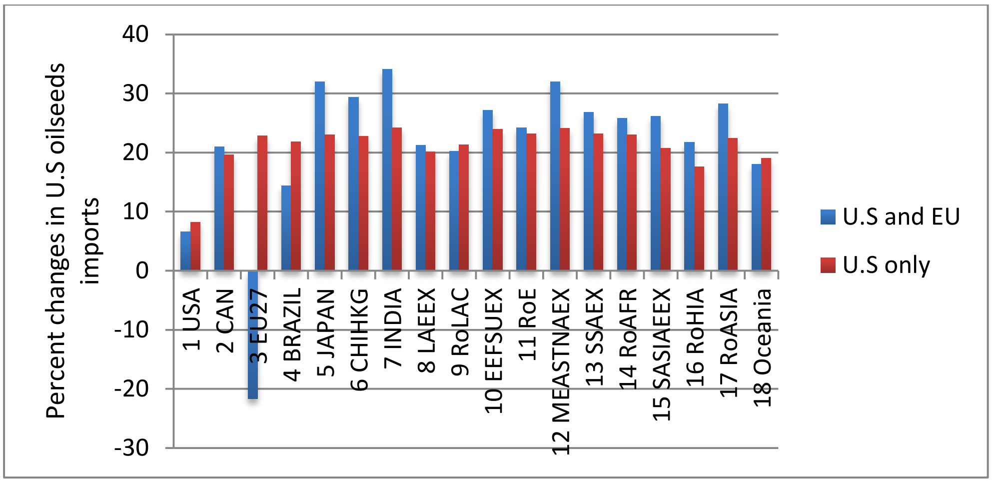

Figure 3 Comparison in Percent changes in U.S. oilseeds imports.

4.2.3 Oilseeds' harvested area

Both U.S. and EU affect the global harvested areas of the oilseed crops. In this case the changes in the EU harvested area is the highest (30.1%) followed by the U.S. (5.9%). All the other regions meet an increase in oilseeds harvested area and this change is greater than the change due to the last scenario. This could be because of the higher demand for oilseeds in the world. EU has the greatest growth in harvested area compare to the last scenario (3% to 30.1%). The total change of oilseeds harvested area is 85% for the whole world that means the great effect of EU biodiesel production on the world.

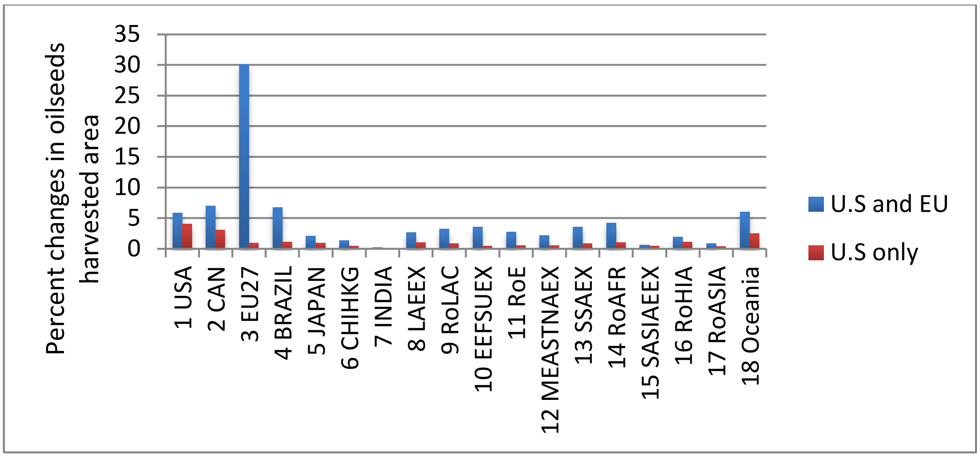

Figure 4 Comparison in Percent changes in U.S. oilseeds harvested area.

4.2.4 Oilseeds' yield

In this scenario U.S. has more increase in the oilseeds' yield compare to the first scenario (2.31% compare to 1.48%) and the U.S. exports' to EU increased by 21%. In this case the changes in the U.S. yield is the highest (2.31%) followed by Oceania (2%) and EU (1.315%). all the other regions meet an increase in oilseeds harvested area and this change is nearly greater than the change resulted from the last scenario. Figure 5 shows these changes. Although EU has the greatest expansion in harvested area (30.1%), the highest growth in oilseeds' yield belongs to U.S. The AEZ classification cause the difference since U.S. is mostly located in AEZ 7 and 8 while EU is mostly located in AEZ 10 and 11, based on Figure 1. These zones are the best for oilseeds harvesting. The global change in oilseeds yield is 13.2%. As indicated before, the increase in harvested areas does not necessarily guarantee more oilseeds' yield, due to the effect of the AEZ zones.

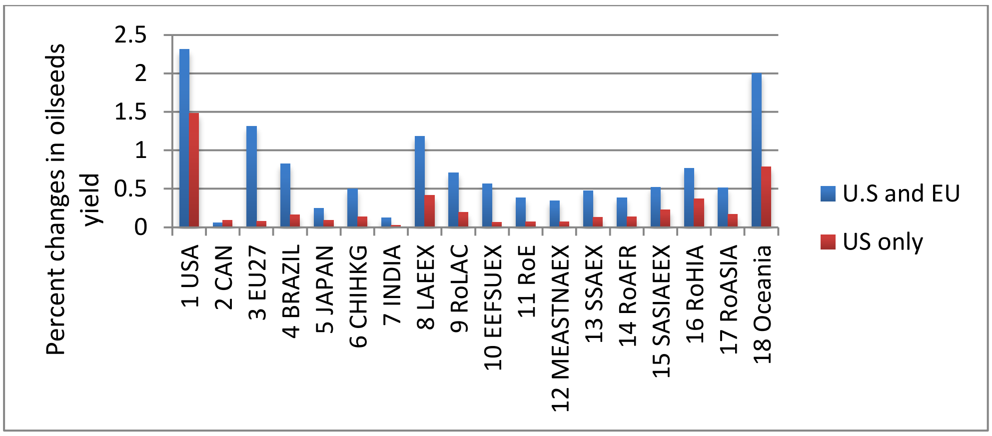

Figure 5 Comparison in Percent changes in U.S. oilseeds yields.

4.3. Scenario 3: Historical changes on the U.S. biodiesel production

The third scenario reports the historical changes in U.S. biodiesel production and its impacts. In this section we run six scenarios for target years 2010-2005 based on 2001 database. The objective of this scenario is to investigate the historical changes in the U.S. biodiesel production and its impacts.

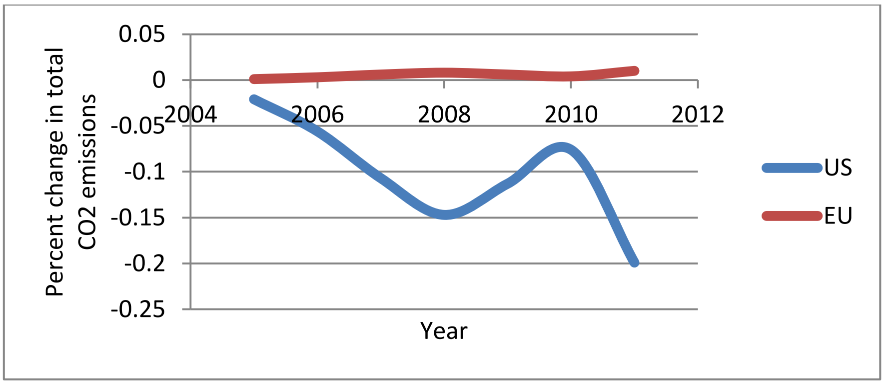

Figure 6 Percent change in total CO2 emissions by year.

As shown in figure 6, total CO_2 emissions in the U.S. decreased from 2005 to 2008 and then start to increase to 2010 and again dropped afterwards. From 2001 to 2005 no noticeable changes is found so we just use the scenarios from 2005 to 2011. The reason behind these changes is the changes in biodiesel production. Why U.S. biodiesel production changed in this way? We found the answer for this question in the tax credits applied by the U.S. government.

The U.S. federal government has several tax credits available for the production and blending of biofuels. A tax credit is an amount that can be deducted from a person's total tax liability. The American Jobs Creation Act of 2004 established the biodiesel tax credit in 2005. It was extended by the Energy Policy Act of 2005, amended by the Energy Improvement and Extension act of 2008. After showing steady annual increases, both production and consumption fell from 2008 to 2010. Because the biodiesel tax credit per blended gallon incentive expired at the end of the 2009. However production recovered in 2011 after the biodiesel tax credit was reinstated at the end of the 2011. Figure 7 shows the related production and consumption for U.S. biodiesel.

Additionally demand for biodiesel is increasing, as blenders need to reach new mandates under the Renewable Fuel Standard. The renewable fuel standard (RFS) is a requirement that renewable fuels displace a certain percentage of petroleum transportation fuels. RFS2 is a renewable fuel standard for biofuels only that requires obligated parties to sell a certain amount of biofuels per year through 2022 [23].

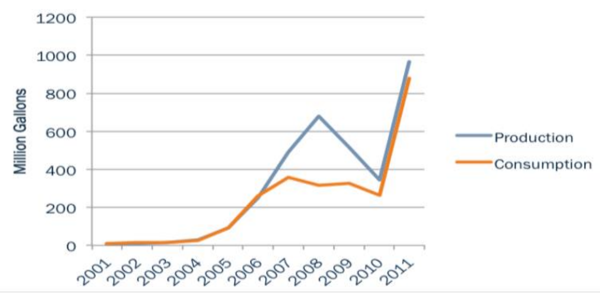

Figure 7 U.S. Biodiesel production and consumption by year

Source: Energy Information Agency (2012) [14]

Figure 6 also indicates that total CO_2 emissions in EU do not have great change due to the U.S. biodiesel production. These changes in U.S. biodiesel production will affect oilseeds' harvested areas and yield in U.S. as well as the entire world. Figure 8 and Figure 9 demonstrate these changes over years. We can see that the increasing and decreasing trend in U.S. biodiesel production is reflected in these figures and Harvested area and yield followed the trend not only in the U.S. but also in the other countries.

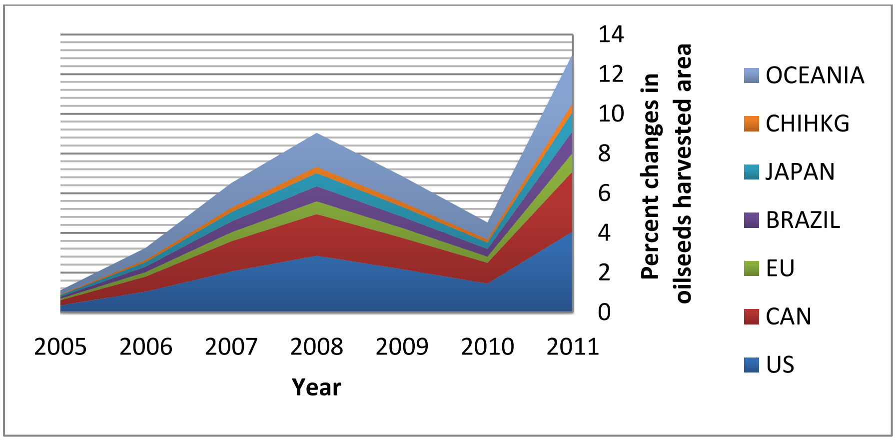

Figure 8 Percent change in oilseeds harvested area by region.

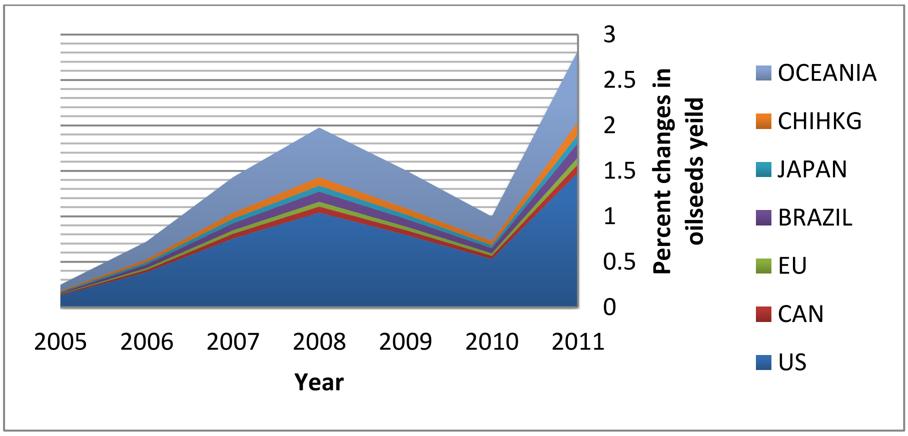

Figure 9 Percent change in oilseeds yield by region.

5. Conclusion

In this study we assessed the impacts of oilseeds biodiesel on global CO_2 emissions, oilseeds harvested area and yields. Three scenarios are described: first scenario evaluates the effect of percent changes in U.S. biodiesel production by 2011 based on 2001. While the second one addresses these impacts for both U.S. and EU biodiesel production at the same time, and the third one reports the historical changes in U.S. biodiesel production and its effects. We employed the GATP-BIO model, an improved version of the GTAP-E, to develop our analysis. The model defines 18 trading regions for the entire world and 21 industries. The model is able to consider the differences in land endowment by describing 18 AEZs.

Results show that as a result of the U.S. biodiesel production, both U.S. and the world's total CO_2 emissions are reduced mainly due to reduction in household consumption of diesel. Since the diesel is blended with biodiesel. Second scenario yields in a larger reduction in CO_2 emissions. Based on the historical analysis U.S. tax credit policy would be efficient in biodiesel productions as well as CO_2 mitigation. It is also found that an increase in the harvested areas does not necessarily guarantee the same increase in oilseeds' yield, because of the effect of AEZ zones. So, considering AEZs in this version of the GTAP is valuable for a comprehensive land coverage analysis.

Appendix

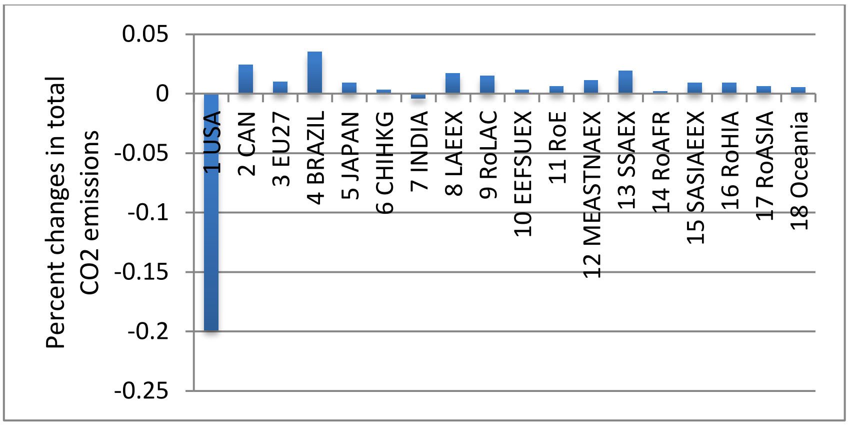

Figure 1a Percent changes in total CO2 emissions by region

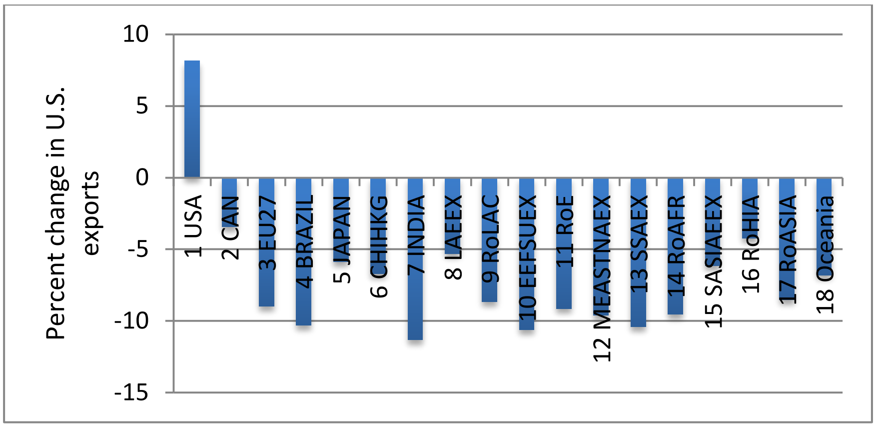

Figure 2a Percent changes in U.S. exports of oilseeds to the other regions

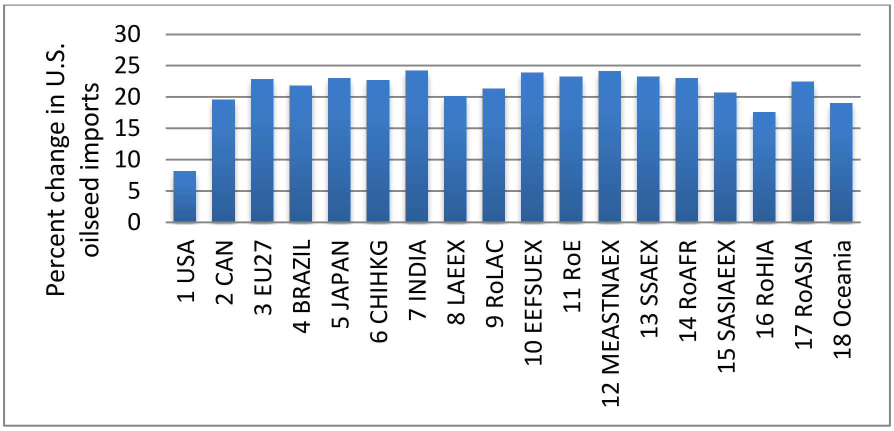

Figure 3a Percent change in U.S. oilseed imports by region

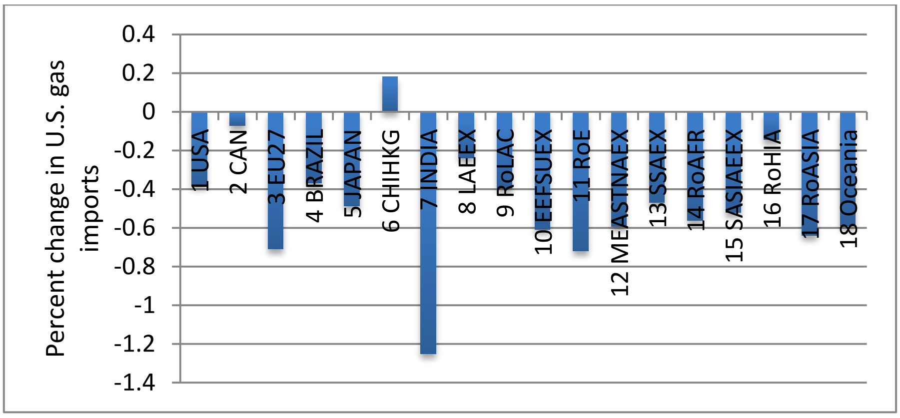

Figure 4a Percent change in U.S. gas imports by region

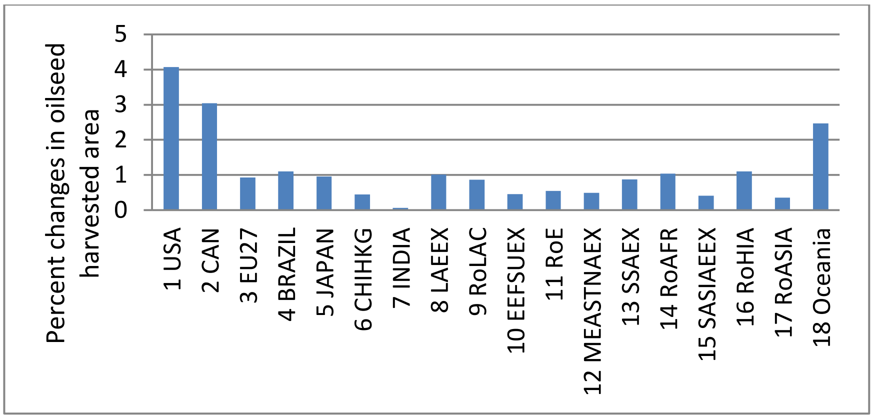

Figure 5a Percent changes in oilseeds harvested area by region

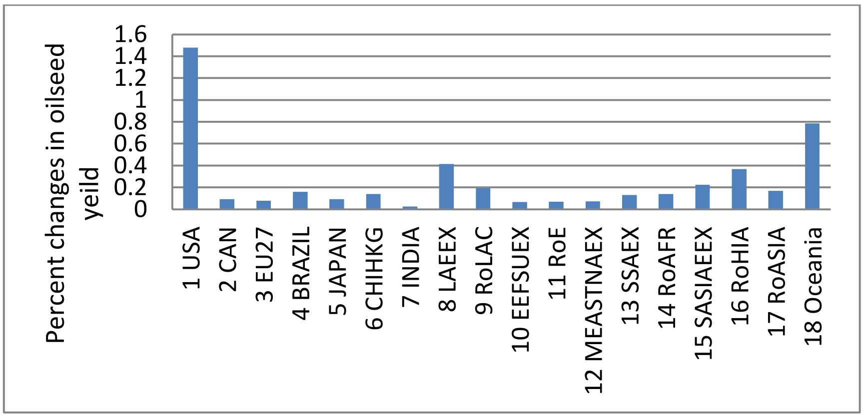

Figure 6a Percent changes in oilseeds yield by region

References

[1] Tan KT, Lee KT. A review on supercritical fluids (SCF) technology in sustainable biodiesel production: Potential and challenges. Renew Sustain Energy Rev 2011;15:2452–6.

[2] IPCC, Intergovernmental Panel on Climate Change 5th Assessment Report. Climate Change 2013: The Physical Science Basis. 2013.

[3] Javid RJ, Nejat A. A Comprehensive Model of Regional Electric Vehicle Adoption and Penetration. Transp Policy 2017:forthcoming.

[4] Javid RJ, Nejat A, Hayhoe K. Quantifying the Environmental Impacts of Carpooling on HOV Lanes in the United States. Transp Res Part D Transp Environ 2017:forthcoming.

[5] Murugesan a., Umarani C, Subramanian R, Nedunchezhian N. Bio-diesel as an alternative fuel for diesel engines—A review. Renew Sustain Energy Rev 2009;13:653–62.

[6] Rajaeifar MA, Ghobadian B, Safa M, Heidari MD. Energy life-cycle assessment and CO2 emissions analysis of soybean-based biodiesel: a case study. J Clean Prod 2014;66:233–41.

[7] Javid RJ, Nejat A, Hayhoe K. Selection of CO2 mitigation strategies for road transportation in the United States using a multi-criteria approach. Renew Sustain Energy Rev 2014;38:960–72.

[8] Javid RJ. Greenhouse Gas and Air Pollution Emission Reduction from Incentivized Carpooling. J Transp Heal 2016;3:S17.

[9] Javid RJ. Online Estimation of Travel Time Variability Using the Integrated Traffic Incident and Weather Data. Transp. Res. Board 96th Annu. Meet. Washingt. DC, 2017: forthcoming.

[10] Javid RJ, Nejat A, Salari M. The Environmental Impacts of Carpooling in the United States 2016.

[11] Salari M, Javid RJ. Residential energy demand in the United States: Analysis using static and dynamic approaches. Energy Policy 2016;98:637–49.

[12] Salari M, Javid RJ. Modeling household energy expenditure in the United States. Renew Sustain Energy Rev 2017:forthcoming.

[13] Safieddin Ardebili M, Ghobadian B, Najafi G, Chegeni a. Biodiesel production potential from edible oil seeds in Iran. Renew Sustain Energy Rev 2011;15:3041–4.

[14] U.S. Energy Information Administration n.d.

[15] Hertel TW. Global Trade Analysis: Modeling and Applications. by Cambridge University Press; 1997.

[16] Burniaux J-M, Truong T. GTAP-E: An Energy-Environmental Version of the GTAP Model. GTAP Tech Pap No 16 2002.

[17] Birur D, T. H, W. T. Impact of Biofuel production on World agriculture Markets: A Computable General Equilibrium Analysis. GTAP Work Pap 53 Cent Glob Trade Anal Prdue Univ 2008.

[18] GTAP Research: Energy n.d.

[19] The Food and Agriculture Organization of the United Nations (FAO) n.d.

[20] Salari M, Javid RJ. The effect of changing ethanol production on the area harvested and CO2 emissions. J Fundam Renew Energy Appl 2015.

[21] Javid RJ, Salari M. The effect of biodiesel production on the CO2 emissions and area harvested for oilseeds. J Fundam Renew Energy Appl 2015.

[22] Plevin RJ, Gibbs HK, Duffy J, Yui S, Yeh S. change for use with AEZ-based economic

models GTAP Technical Paper No . 34 2014.
[23] Center for Climate and Energy Solutions n.d.