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Full Length Research Paper

An assessment of available lands for biofuels production in the United States using United States Department of Agriculture (USDA) cropland data layers

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Recent biofuels regulations and supporting land use models assess the use of sensitive and high carbon lands for biofuels production. However, the precautionary land use limits set by these efforts ignore the large available lands in the United States. Using 2010 United States Department of Agriculture Cropland Data Layers, this study assessed current and available lands in the continental United States at different regional scales and compared the findings to regulatory limits and selected modeling scenarios. The Cropland Data Layer analysis identifies 100 million hectares in crops and 90 million hectares of available lands. That total is 28 million hectares higher than the baseline set by the United States Environmental Protection Agency regulations (of 162 million hectares) for agricultural land that qualifies for biofuels production. Secondly, the present study shows that land requirements predicted for common biofuels production scenarios by the Global Trade and Analysis Project (GTAP) are a small fraction of the 90 million hectares of available lands across all agro-ecological zones (AEZ) in the United States. In fact, modeled land use changed from 11.5 billion gallons of corn ethanol production required just over 2% of available lands while an additional 7 billion gallons of switch grass ethanol required close to 10% of available lands. Expansion of agriculture for biofuels production should be directed towards conversion of vastly available lands. The use of cropland data layers could be an accurate tool to track and verify available lands conversions.

Key words: Ethanol, biofuels, land use, cropland data layer.

INTRODUCTION

Land use regulations and land use models for biofuels production are concerned with the conversion of sensitive and high carbon content lands (such as forests) into fuel feedstocks. The Energy Independence and Security Act requires that biofuels must come from agricultural land cultivated at any time prior to the enactment of the law in December 2007 and which is either actively managed or fallow, and non-forested (United States Environmental Protection Agency, 2010). During the implementation of this law, the United States Environmental Protection Agency established a baseline of agricultural land of 162 million hectares (base year 2007) that qualifies for the production of crop and crop residue for biofuels. Also, the California Low Carbon Fuel Standard imposes a land use penalty for biofuels that is proportional to the land area and carbon content of lands converted for biofuels feedstock production (California Environmental Protection Agency, 2009).

Land use models such as the Global Trade and Analysis Project (GTAP) model developed by Purdue University inform regulations (such as the California Low Carbon Fuel Standard) and assess land types that are converted in response to certain biofuels production scenarios. For current biofuels production volumes, for example, GTAP would predict rather large forest conversions in the US. Other studies, however, have shown that these predicted conversions have not taken place and

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that the current models need to be updated (Kim and Dale, 2011). The common problem in the current biofuels debate is the lack of an appropriate census of land that is still available for biofuels production across the United States without encroaching on sensitive lands such as forests.

The unique approach of the present study is that it utilizes United States Department of Agriculture Cropland Data Layers (CDL) to delineate available lands at various aggregation levels starting with state-by-state levels, then at the agro-ecological zone level, and finally at the national level. This allows a direct comparison with modeled results as well as national limits.

MATERIALS AND METHODS

Initially, the study accessed the CDLs from the USDA's GeoSpatial Data Gateway for the 48 continental United States for the study year 2010 (United States Department of Agriculture, 2011). The CDL is a crop-specific land cover classification that is produced annually by the United States Department of Agriculture (USDA) as an attempt to map cultivated fields in the US (Koudelka, 2011). The CDL program, begun in 1997, supplements USDA National Agricultural Statistics Service (NASS) tabular data products such as the Census of Agriculture by attempting to map the geographic location of different crop types, as well as non-agricultural land cover types. Though, the program began in 1997 for the majority of its history, CDL preparation was focused on only six corn- and cotton-producing states in the Midwest and along the Gulf Coast. However, after receiving additional funding from the EPA in 2006, the CDL program has since been expanded and starting in 2009, the CDL was made available for all 48 coterminous states.

The CDL data product was created with imagery from medium resolution satellites, primarily 56 m resolution imagery from the Resourcesat-1 Advanced Wide Field Sensor (AWiFS) and 30 m resolution imagery from Landsat-5 Thematic Mapper (TM). For areas where AWiFS and TM imagery are not available, the CDL is supplemented with 250 m resolution imagery from the Moderate-resolution Imaging Spectroradiometer (MODIS) sensor. For non-agricultural land cover assessment, the imagery from these sensors are ground-truthed using products derived from the 2001 USGS National Land Cover Dataset (NLCD), including the National Elevation, Percent Forest Canopy, and Percent Imperviousness layers (Johnson and Mueller, 2010).

The Farm Service Agency's Common Land Unit (CLU) dataset and the NASS June Agriculture Survey (JAS) are additional inputs to the CDL that are used to improve the mapping of agricultural lands. A Common Land Unit is polygons digitized from National Digital Orthophoto Imagery (NDOP), each of which represents an individual contiguous farming parcel with a single land cover type, a single owner, and a single USDA producer association. The CLU dataset is also linked with NASS tabular data and as a result is the most highly accurate and comprehensive national dataset of commodity crops available. As a means of ground truthing the CDL, Common Land Units are statistically sampled and used to both train the CDL land use classifier and test the its accuracy.

The results of the June Agricultural Survey (JAS) are similarly used in ground truthing (confirming the information via site visits) the CDL. Each June farmers are randomly selected and surveyed by the USDA about their planted and expected harvest areas. The locations of the sampled farmers' fields are then plotted, and an unbiased, probability-based spatial regression of their responses is created. Due to the sensitive nature of the results produced by the CLU and JAS datasets, both are considered confidential, and neither is made available to the public.

An important consideration in using the CDL for land use assessment is the accuracy of the product. If the product is not able to correctly estimate land use areas, it will not be useful for our analysis. One way to assess the accuracy is a comparison between the CDL calculated land area for a given land use category and other tabular census or survey data. The study compared the CDL total land areas with USDA NASS crop survey and US Forest Service Forest Service (USFS) Inventory tabular datasets to determine how well the two datasets correspond. The assumption being that the tabular datasets is compiled by the USDA would be accurate but would not offer the spatial benefits of the CDL.

The results indicated that a strong correlation exists between values for corn areas by state and forest areas by state estimated by the USDA survey and USFS inventory for 2010 and the CDL (Figure 1). It can be concluded that the CDL is capable of measuring land use commensurate to the accuracy of USDA tabular datasets with added spatial functionality.

With the accuracy of the method established, the study processed the data to identify 2010 land areas that were available nationally for conversion to cropland, given certain conversion criteria. Based on the derived amount of land readily available for conversion in each state, the study could then compare and inform land use change models such as the Purdue Global Trade Analysis Project (GTAP) model, which predicts land conversions from corn and cellulosic biofuels scenarios (Taheripour et al., 2011). Furthermore, the study could then compare the available lands to current land limits set by the EPA for biofuels production.

The 2010 CDL consists of 145 different unique land use categories in total. In order to make the dataset more manageable, these categories were aggregated into only those land cover types that concerned the availability of lands for agricultural production. Lands currently in hay, pasture, grassland, and idle cropland were deemed to meet the criterion for available lands since their current land use is most closely related to crop production. Grassland-herbaceous lands did not meet the selection criterion as an available land type since this classification typically describes land in Western states whose soils lack sufficient fertility and receive insufficient moisture to support row crop production. Forested lands were not included in the available land category but assessed separately to gain an understanding if, absent of cost considerations, available lands would be sufficient to meet common biofuels production scenarios.

The final land use classifications of each state, recoded and aggregated into ten new classes, were; corn and other cropland (including fallow/idle cropland), urban land, available lands, shrubland, grassland herbaceous, forested land, barren, water, and wetlands. The area of each of the recoded land use classes was calculated for each state using the image processing and analysis software ERDAS IMAGINE, Version 9.3.

Then, the areas for available lands, crop, and forest classes were derived on a state-by-state basis and then also aggregated to 18 agro ecological zone (AEZ) by weighing them by their respective land area fraction within each AEZ using GIS. AEZs are generally defined as land areas which have similar combinations of climate and soil characteristics, and similar physical potentials for agricultural production. For illustration purposes, while AEZs do not follow state boundaries, most Mid-western corn states are located in AEZ 10 and AEZ 11 while the states of the Western plains largely make up AEZ 7 and AEZ 8.

RESULTS

In Figure 2, an outline of AEZ 10 (grey shaded area) is overlaid over the map of state-by-state available lands. Available lands are geographically disbursed across the

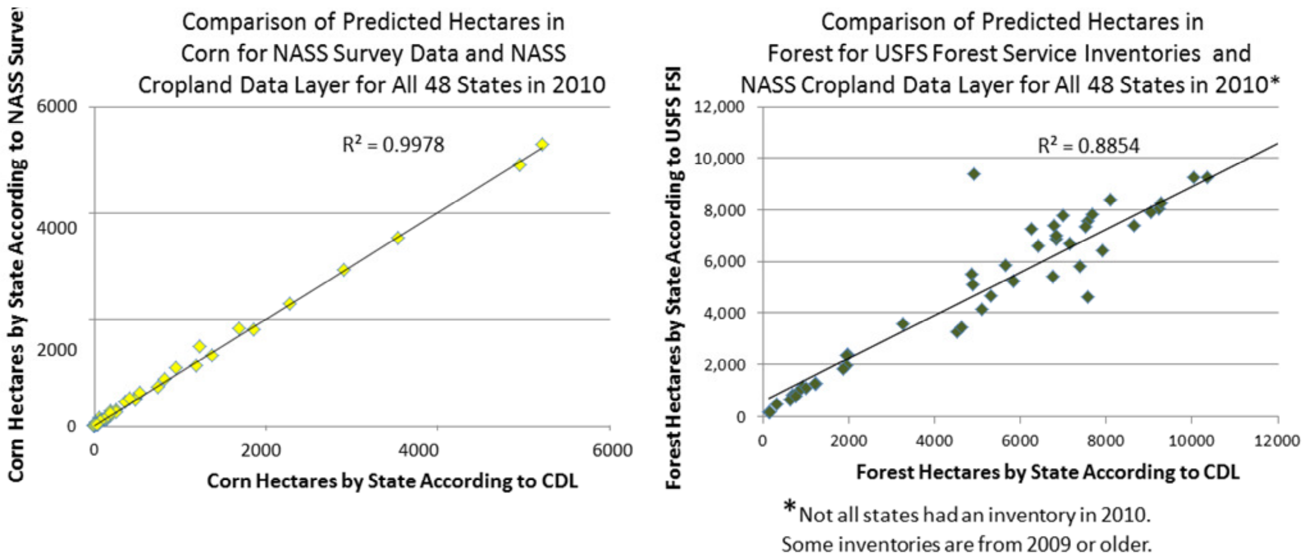


Figure 1. Correlation between cropland data layer and USDA survey data.

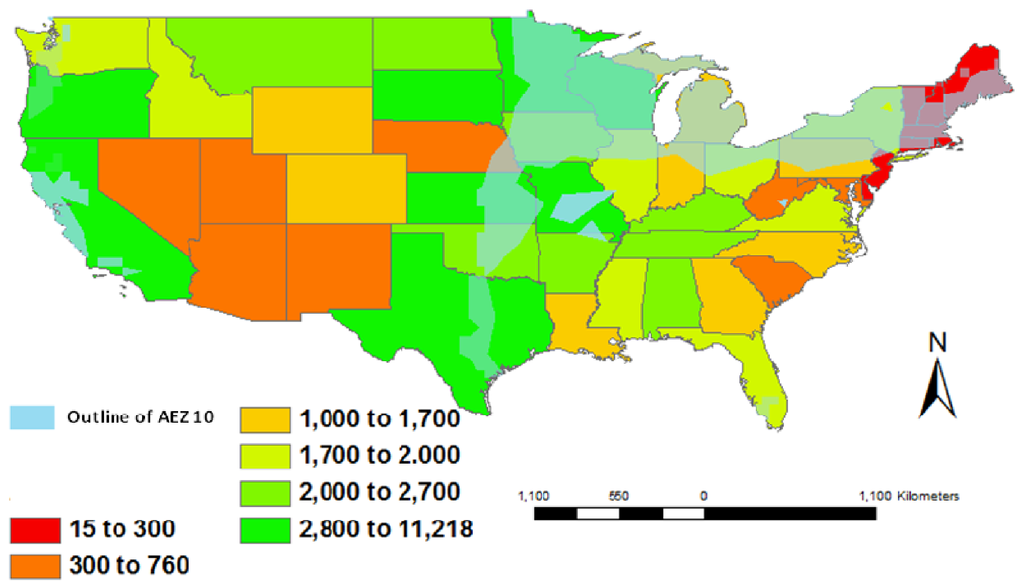


Figure 2. AEZ 10 Overlaid on 2010 available lands (pasture, grass and hay (in thousands of hectares).

Table 1. Top five states with available lands.

Rank	State	Hectare
1	Kansas	11,218,237
2	Texas	7,372,368
3	Missouri	5,908,399
4	California	4,935,444
5	Oregon	3,477,405

continental United States with 31 states having more than 1 million hectares of potential agricultural lands. The five states with the highest available lands are shown in Table 1 and the aggregation by AEZs is summarized in Table 2. Nationally, the amount of land in hay, pasture, grassland, and idle cropland which make up the available lands

Table 2. Selected land use in the US.

Parameter	Crop	Available lands
AEZ 7	15,008,438	18,131,698
AEZ 8	14,984,213	10,194,856
AEZ 9	6,340,080	4,514,335
AEZ 10	33,198,323	23,737,633
AEZ 11	21,524,137	19,834,095
AEZ 12	8,344,437	11,946,038
AEZ 13	617,468	922,147
AEZ 14	393,854	833,851
AEZ 15	143,077	235,060
AEZ 16	32,449	47,396
Total	100,586,476	90,397,108

Table 3. Predicted land use change from corn ethanol production (11.5 billion gallon).

Parameter	Forest to feedstock land	Forest to grassland	Grassland to feedstock land	Feedstock land to grassland	Cropland-pasture to feedstock land	Feedstock land to cropland-pasture	Total
	Conversions	Conversions	Conversions	Reversions	Conversions	Reversions	
AEZ 7	-3,479	0	-340,320	0	-224,128	0	-567,927
AEZ 8	-16,931	0	-133,912	0	-102,281	0	-253,124
AEZ 9	-2,022	0	-10,238	0	-64,792	0	-77,052
AEZ 10	-179,636	0	-82,626	0	-403,376	0	-665,638
AEZ 11	-93,360	0	-42,881	0	-298,278	0	-434,519
AEZ 12	-30,064	0	-14,111	0	-74,470	0	-118,645
AEZ 13	-736	0	-11,662	0	-1,340	0	-13,738
AEZ 14	-5,032	0	-3,518	0	-278	0	-8,828
AEZ 15	-200	0	-214	0	0	0	-414
AEZ 16	-5	0	-3	0	0	0	-8
Total	-331,465	0	-639,485	0	-1,168,943	0	-2,139,893

Feedstock land to forest transitions and grassland to forest transitions are excluded from this table since there are no predicted changes for these categories.

category is similar to the amount of already cropped lands across all AEZs; the amount of already cropped land totals 100 million hectares while there are a total of 90 million hectares of land available for cropland expansion. In order to illustrate the magnitude of available lands, the study looked at a recent biofuels report by Purdue University, where the GTAP model is used to assess land use change prompted by different corn and cellulosic biofuels production pathways (Taheripour et al., 2011). The scenarios in the GTAP report for corn ethanol (11.5 billion gallon scenario) and switch grass ethanol (7 billion gallon scenario) include four major land uses; forest, cropland, grassland, and cropland-pasture land. From the GTAP numbers, both land conversions and reversions can be deducted (Tables 3 and 4). The result indicates that 11.5 billion gallon corn ethanol scenario in GTAP would result in total land changes of 2.1 million hectares and an additional 7. Billion of switch grass ethanol would result in 9.2 million hectares of land changes. As illustrated in Figure 3, land use changed from corn ethanol production being small across all AEZ's and required just over 2% of available lands and 10% in the case of switch grass ethanol.

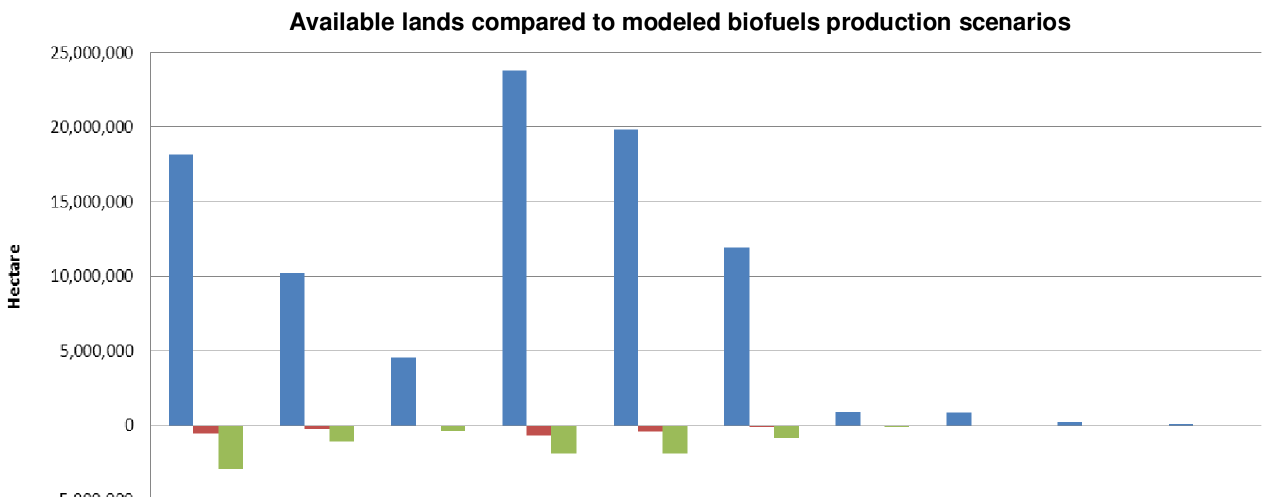
DISCUSSION

From a spatial point of view, there is ample room for cropland expansion without encroaching on forest lands or other sensitive lands. Therefore, this study would predict a low transition probability from forest land to crop for future agricultural expansion scenarios such as those modeled for biofuels production. The GTAP predicted forest conversions do take profit and land conversion considerations into account. However, this assessment suggests that there are large available lands other than forest lands. Babcock has previously demonstrated that modifications need to be made to how land use is

Table 4. Predicted land use change from switch grass ethanol production (7 billion gallon).

Parameter	Forest to feedstock land	Forest to grassland	Grassland to feedstock land	Feedstock land to grassland	Cropland-pasture to feedstock land	Feedstock land to cropland-pasture	Total
	Conversions	Conversions	Conversions	Reversions	Conversions	Reversions	
AEZ 7	-49,688	0	-16,432	0	-2,818,337	0	-2,884,456
AEZ 8	0	-79,870	0	-1,374	-1,001,533	0	-1,082,776
AEZ 9	-807	-32,094	0	0	-340,944	0	-373,845
AEZ 10	-95,568	-138,451	0	0	-1,675,529	0	-1,909,548
AEZ 11	-84,452	-100,664	0	0	-1,737,505	0	-1,922,621
AEZ 12	-41,107	-74,825	0	0	-754,337	0	-870,269
AEZ 13	-7,406	-44,787	0	0	0	-39,839	-92,032
AEZ 14	-6,525	-24,825	0	0	0	-10,468	-41,819
AEZ 15	-227	-1,833	0	0	0	0	-2,060
AEZ 16	-7	-30	0	0	0	0	-37
Total	-285,787	-497,377	-16,432	-1,374	-8,328,185	-50,307	-9,179,462

Feedstock land to forest transitions and grassland to forest transitions are excluded from this table since there are no predicted changes for these categories.



	AEZ 7	AEZ 8	AEZ 9	AEZ 10	AEZ 11	AEZ 12	AEZ 13	AEZ 14	AEZ 15	AEZ 16
Available Lands	18,131,698	10,194,856	4,514,335	23,737,633	19,834,095	11,946,038	922,147	833,851	235,060	47,396
Ethanol	-567,927	-253,124	-77,052	-665,638	-434,519	-118,645	-13,738	-8,828	-414	-8
Switchgrass	-2,884,456	-1,082,776	-373,845	-1,909,548	-1,922,621	-870,269	-92,032	-41,819	-2,060	-37

Figure 3. Comparison of available lands and land required for biofuels production.

calculated within GTAP and these results support that conclusion (Babcock, 2010). Moreover, as recently as 2002, total crops plus grass, pasture and hay land reported in the USDA Agricultural Census was over 178 million hectares when combined with total Conservation Reserve Program (CRP) hectares of close to 13 million hectares (which will also be primarily delineated as pasture, grass or hay by the CDL) the total is just over 190 million matching our total CDL calculated hectares. In contrast, the EPA established a baseline of agricultural land of 162 million hectares that qualifies for the production of crop and crop residue for biofuels. The Energy Independence and Security Act requires biofuels from corn grain and which must come from agricultural land cultivated at any time prior to the enactment of the law (December, 2007) and which is either actively managed or fallow, and non-forested. EPA's land categories include harvested cropland, cropland for pasture and grazing, and "other" cropland which most likely includes non-field crops such as fruit trees and vegetables. According to the EPA, these are derived from a USDA Farm Services Agency Historical Crop Report, the CDLs and the 2007 USDA Agricultural Census. The EPA baseline value of 162 million hectares is 28 million hectares less than 190 million hectares derived in our CDL analysis and a significant portion of this difference has been in agriculture as recent as 2002.

Conclusion

The study concludes that expansion of agriculture for biofuels production should be directed towards conversion of the vastly available lands identified by this study (rather than forest lands), which will dramatically reduce the emissions profile of biofuels production. The use of cropland data layers could be an accurate tool to track and verify available lands conversions.

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