The Potential of Biofuels on Marginal Agriculture Land

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Abstract

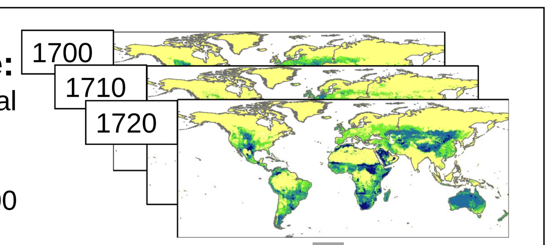
Interest and investment in biofuels is surging. However, this biofuels development lacks the biogeophysical scientific basis that is needed for optimizing climate change mitigation. From the GCEP perspective, a critical priority for research on biofuels should be identifying the sites and technologies where biomass energy can and cannot lead to a net negative forcing of climate change. Past studies indicate that biofuels agriculture expansion onto marginal agriculture land would provide a net benefit for climate mitigation (Tilman et al., 2006) while not deteriorating food security (Naylor et al., 2007). One estimate of this area at a global scale is land previously used for agriculture or pasture but now abandoned and not converted to forest or urban areas. We estimated the magnitude and geographical distribution of biofuels potential on these lands by applying land use history databases, satellite land cover maps, and ecological models (Field et al., In Review). We found areas of available marginal agriculture land that ranged from 279 to 329 Mha, globally. The biological productivity of these land areas, determined from spatially explicit ecological models, ranged from 0.9 to 1.2 Pg C yr^{-1}. The above-ground fraction of this plant production has a heat content of 17 to 24 EJ yr^{-1} or approximately 5% of current global energy demand. The biofuels potential relative to energy demand looks better in parts of Africa and South America.

Objectives

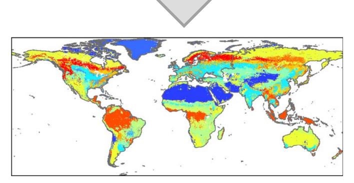
- Estimate area of land that was formerly agriculture and is not currently classified as forest or urban.
- Determine range of potential plant productivity on these lands.

Methods

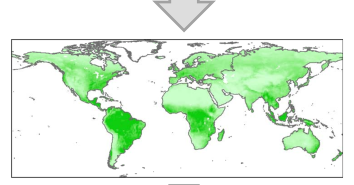
Abandoned Agriculture: Time series analysis of historical agriculture databases. Gridded crop and pasture land cover every decade from 1700 to 2000 (HYDE).



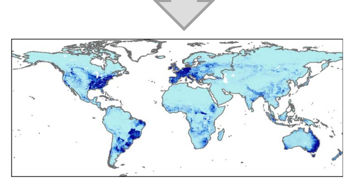
Available Abandoned Area: Overlay abandoned lands with current global land cover to account for land currently in forests and urban. Land cover classification at a 0.05 degree resolution (MODIS).



Plant Productivity: Net Primary Productivity densities (kg C m^{-2}) of natural and current ecosystem types (CASA and MODIS).



Geographical Biofuels Potential: Product of available area and plant productivity for each grid cell. Reported as the energy heat content (~40 kJ/gC) of above-ground portion of NPP (~50%) available for harvest.

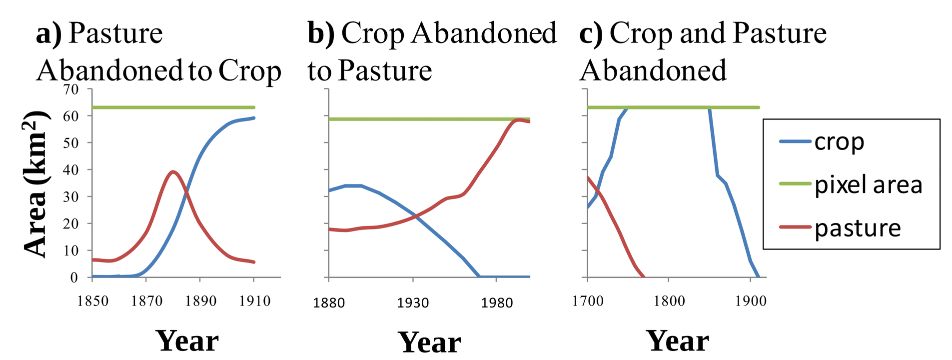


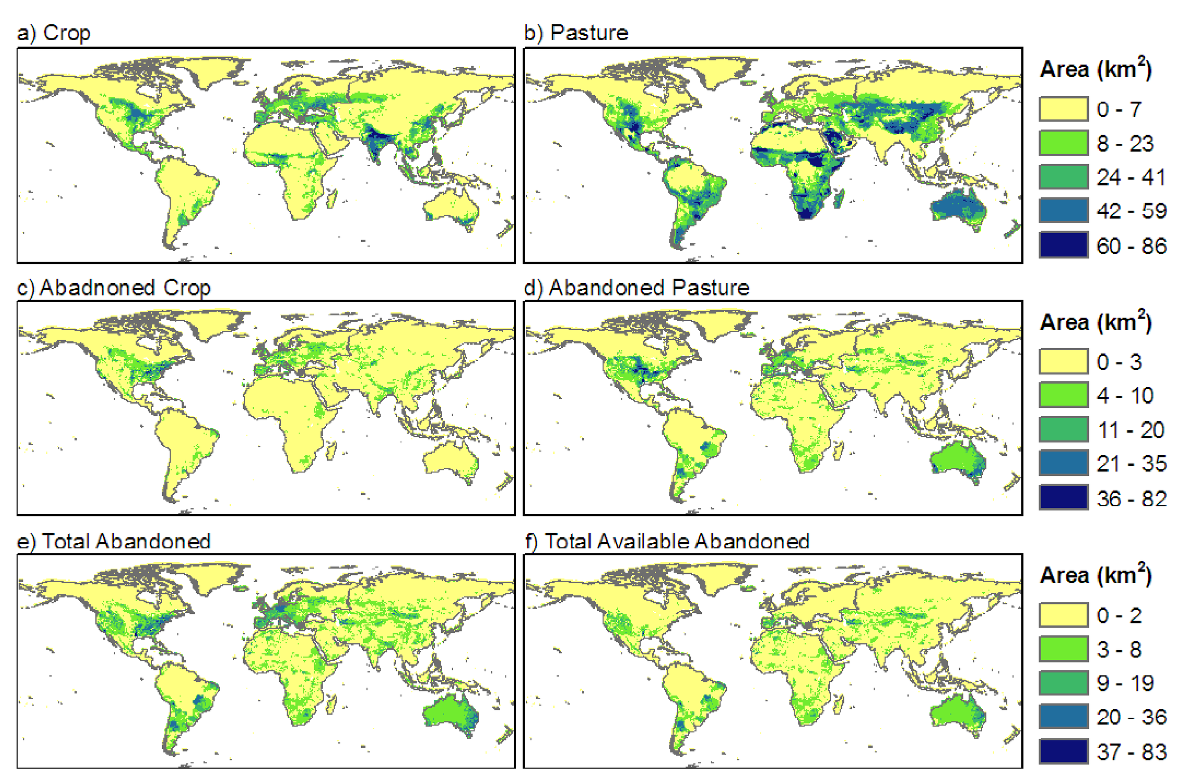
Abandoned Available Area

The historical land cover provided a geographical time series of crop and pasture data. We calculated abandoned crop area for each grid cell as the difference between the historical maximum crop area (from 1700 to 1990) and the current crop area. The same approach was also used to estimate abandoned pasture area. We used two independent approached to provide an upper and lower estimate of the abandoned area:

High Assumption: Pixel Area ≥ (Abandoned Ag + Current Ag)

Low Assumption: For each decade and pixel, a simultaneous increase of crop and decrease of pasture is a conversion of crop to pasture (and vice-versa).





Assumptions	Land Category	Area (Mha)
HYDE High	Total	579
	Available	328
	In Crop	142
	In Urban	18
	In Forest	89
HYDE Low	Total	474
	Available	278
	In Crop	106
	In Urban	17
`	In Forest	71

Abandoned Agriculture: A large fraction of the land that was formerly agriculture is now in urban, crop (pasture-to-crop conversion), and forest land covers. We assume that the remaining abandoned agriculture area could be available for biofuels agriculture. This availability may change in the future as the demand for food increases, agriculture practices transition, and climate change influences arable land areas.

Abandoned Available Agriculture: The global available area of 278 to 328 Mha are 55% to 75% of area estimates used in past studies (Tilman et al., 2006). Past estimates may be larger due to the large uncertainty of these areas and because past methodologies also considered areas where harvesting led to deforestation.

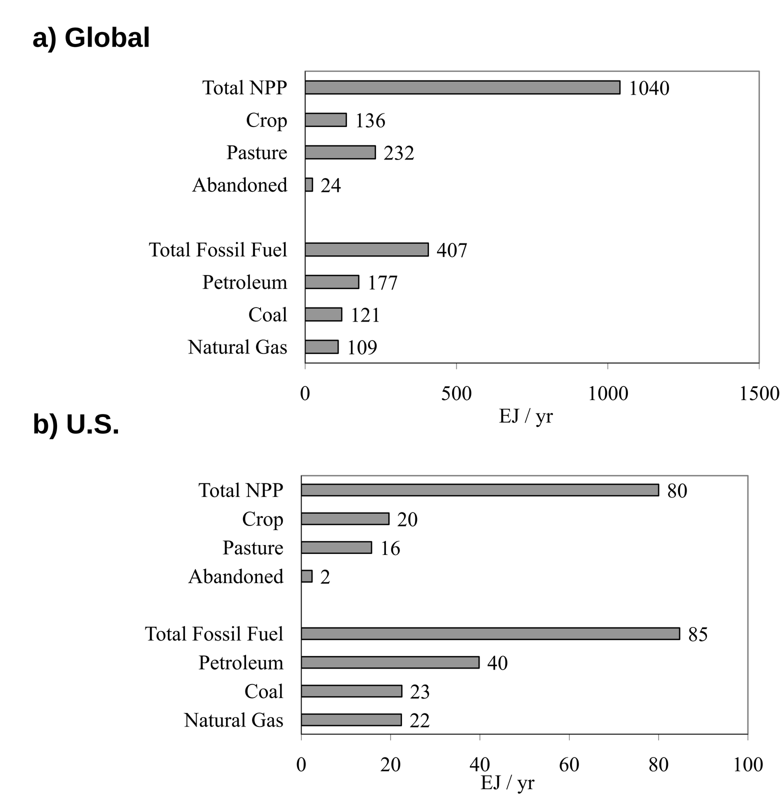
Continent	Abandoned Available Area (Mha)	
	Low	High
Asia	67	83
North America	34	39
Europe	15	17
Africa	51	66
South America	49	56
Oceania	0	1
Australia	61	65
Global	**278**	**328**

Plant Productivity

Continent	Area Weighted Average NPP (ton C ha^{-1} yr^{-1})					
	High/CASA	High/MODIS	Low/CASA	Low/MODIS	Mean	SD
Asia	1.3	1.7	1.2	1.5	1.4	0.2
North America	3.6	3.7	3.5	3.5	3.6	0.1
Europe	3.6	5.0	3.5	4.9	4.3	0.8
Africa	3.6	4.6	3.1	3.9	3.8	0.6
South America	5.6	4.8	5.3	4.5	5.0	0.5
Oceania	7.2	9.5	7.0	9.0	8.2	1.3
Australia	3.1	4.3	3.0	4.2	3.6	0.7

Geographic Potential

The geographic potential is the heat energy content of the above-ground biomass. This provides a point of comparison with fossil fuel energy demand, although conversion to liquid fuels and agriculture energy inputs may result in less biofuel potential. The global geographic potential is 6% of global fossil fuel energy demand. The U.S. geographic potential is 5% of U.S. fossil fuel energy demand.



Continent	Geographical Biofuels Potential (EJ yr^{-1})				
	High/CASA	High/MODIS	Low/CASA	Low/MODIS	Mean
Asia	2.2	2.8	1.6	2.0	2.1
North America	2.8	2.9	2.4	2.4	2.6
Europe	1.2	1.7	1.0	1.5	1.4
Africa	4.7	6.0	3.1	4.0	4.5
South America	6.3	5.4	5.2	4.4	5.3
Oceania	0.1	0.1	0.1	0.1	0.1
Australia	4.0	5.6	3.7	5.2	4.6
Global	**21**	**24**	**17**	**20**	**21**

Country Potential

Country	Abandoned Area (Mha)	Geographic Potential (TJ / yr)	Potential:Fossil Fuel Demand
Australia	64.8	4.0	1.12
United States	33.2	2.4	0.04
Brazil	25.5	4.4	1.22
Argentina	21.1	1.2	0.78
China	19.0	0.6	0.01
Mongolia	12.8	0.1	1.56
Russia	12.6	0.6	0.03
Kazakhstan	10.1	0.2	0.09
South Africa	9.4	0.7	0.14
Turkmenistan	7.9	0.0	0.06
Algeria	6.9	0.0	0.02
Spain	6.1	0.5	0.13
India	5.1	0.3	0.02
Mauritania	4.3	0.0	0.43
Ethiopia	4.1	0.4	4.87
Mexico	3.9	0.3	0.06
Angola	3.5	0.4	5.22
Sudan	3.4	0.0	0.43
Iran	3.3	0.0	0.01
Chile	3.0	0.1	0.18
Namibia	2.9	0.1	4.66
Bolivia	2.9	0.1	1.87

Conclusions

- Biofuels potential on available abandoned agriculture land could only offset a small amount of global fossil fuels demand.
- At a regional scale, biofuels potential on abandoned agriculture lands could offset all fossil fuel demand. Australia and parts of South America and Africa look especially promising due to relatively large available areas and small fossil fuel demand.
- Increasing the potential of biofuels would require increasing the land area or the productivity of the land. It is unclear whether lands could be managed for increased plant productivity. It may be difficult to increase land area for biofuels agriculture without creating net climate and food security impacts.

Literature cited

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Acknowledgments

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