Land and Net Primary Production Requirements of Biofuels

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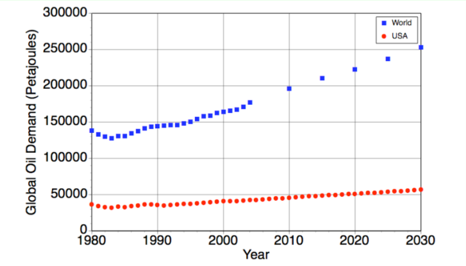
INTRODUCTION

Biofuels, or fuels made from plant matter, have been identified by many governments as an important component of our future energy supply. Supplying this bioenergy would require additional land, and presumably lead to the conversion of large natural areas into agroecosystems. Such a conversion to supply human energy needs would have consequences for many of the millions of other species that depend on the natural landscape for resources. Based on calculations of the most optimistic reported net energy values of eight potential biofuel sources: corn, oil palm, prairie grass or low-input high-density biomass (LIHD), rapeseed, soybean, sugar cane, sunflower, and switchgrass, we estimated the amount of land and net primary production (NPP) that would be required to produce enough plant matter to meet current and projected energy demands.

Figure 1: Current & Projected Global Oil Demand[D]



TO WHAT EXTENT CAN PLANTS REPLACE FOSSIL FUELS?

In terms of energy demand alone, the amount of plant matter required will depend on three variables: 1) the energy content of the plants, 2) the proportion of this energy that is lost during the process of converting plant matter to usable fuel, and 3) the amount of additional energy required to produce the feedstock and convert it to fuel. To estimate the smallest amount of plant matter necessary to accomplish this replacement, we can assume (simplistically and unrealistically) that we could directly replace the energy content in fossil fuels with energy in plants.

RESULTS

- Based on our calculations, the biofuel sources with the highest net energy per land area are switchgrass, oil palm, and sugarcane. In terms of net energy per unit biomass, they are switchgrass, LIHD, and oil palm (see Figure 2 and 3).[1]
- The efficiency of a biofuel source depends on the unit of measurement. Because a biofuel source's net energy value in terms of land area depends largely on the crop yield, plants with higher yields tend to have more GJ/ha. The net energy value in terms of unit biomass depends on the fraction of the total plant biomass that is turned into biofuel; the greater the fraction, the higher the MJ/kgC.

Figure 2: Land Requirements Based on Net Energy Values in GJ/ha

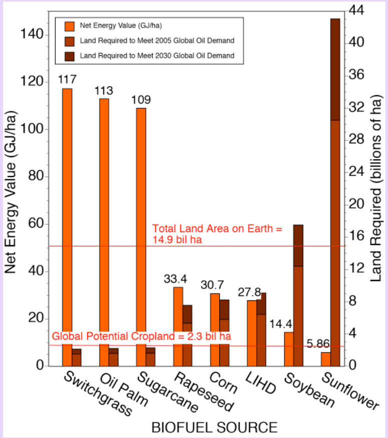
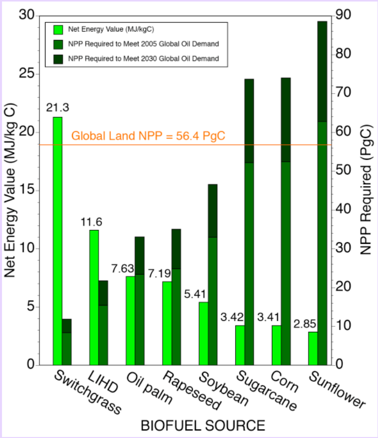


Figure 3: NPP Requirements Based on Net Energy Values in MJ/kgC



- Our conservative estimates suggest that, using the biofuel sources with the 3 highest net energy values, we would require a minimum of 15% to 42% of global terrestrial NPP or a minimum 66% to 71% of the global potential cropland to produce enough biofuels to meet global oil demands in 2005.[2] Biofuel from LIHD, a mix of native grassland species, would require about 1.1 times the global grassland area, 2.6 times the global potential cropland or 80% of combined global grassland area and cropland.[4]
- In order to meet current and projected oil demand, all eight biofuel feedstocks require over 60% of potential cropland, which would reduce the land availability of food crops. Due to specific environmental requirements, only a fraction of global potential cropland would be suitable for each biofuel source as well.
- Currently, humans use 32% of terrestrial NPP.[F] Additional appropriation of terrestrial NPP can deplete ecosystem resources and disrupt the services they provide, which could also be harmful to the economy.

WHAT ABOUT GASOLINE AND DIESEL DEMAND?

- We would require a minimum of 18% and 20% of global potential land for global gasoline and diesel demand, respectively (see Figure 4) and a minimum of 4.1% and 12% of global terrestrial NPP for gasoline and diesel, respectively (see Figure 5).

*Figure 4: % Potential Land**

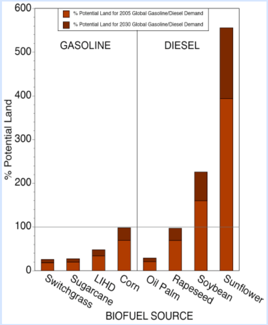
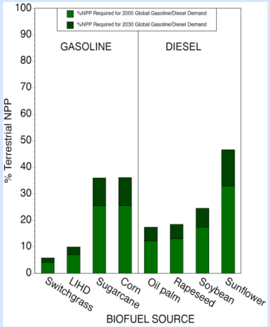


Figure 5: % Terrestrial NPP



*"Potential Land" refers to global grassland cover for LIHD and global potential cropland for all other biofuel sources.

CONCLUSION

Although methods of biofuel production will hopefully improve over time, it is important to consider the ecological consequences of current methods of converting plant matter into biofuels. If increased biofuel production will represent part of a strategy to reduce greenhouse gas emissions and meet global energy demands, we must develop production methods that minimize the negative effects of this additional demand on our planet's resources.

FOOTNOTES

1. We calculated the net energy values using the Energy and Resources Group Biofuel Analysis Meta-Model (EBAMM)[A], and then converted them to GJ/ha (energy per land area) and MJ/kgC (energy per unit biomass).
2. Global potential cropland is estimated to be 2.3 billion hectares[B], global terrestrial NPP is estimated to be 56.4 PgC/year[C] and the global oil demand in 2005 and 2030 was 179,000 PJ and 252,000 PJ, respectively.[D] (1 PJ = 10^{15} joules).
3. Out of the global petroleum demand, gasoline accounted for 25% and distillate fuel (which we used as an estimate of diesel fuel demand) accounted for 27% in 2004.[D] For our calculations, we assumed that this fraction remains relatively constant through time.
4. Global grassland area is estimated to be around 5.25 billion hectares.[E]

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