Evaluation of Potential Land Competition Between Open-Pond Micro Algae Production and Terrestrial Dedicated Feedstock Supply Systems

Matthew Langholtz[1*], Andre Coleman[2], Laurence Eaton[1], Mark Wigmosta[2], Mark Downing[1], Aaron Myers[1], Tim Theiss[1]
Author Affiliation: [1]Oak Ridge National Laboratory Environmental Sciences Division, [2]Pacific Northwest National Lab
*Contact: langholtzmh@ornl.gov

Introduction

Biofuels produced from both terrestrial and algal biomass feedstocks are projected to contribute to energy security while providing economic and environmental benefits. We aim to develop an integrated biomass resource assessment that 1) includes both terrestrial and algal feedstocks, 2) accounts for potential land competition between the two feedstock types, and 3) identifies areas where algal and cellulosic feedstocks have opportunities for production with a minimum of competition for available resources.

Work in progress aims to evaluate competition for lands where these feedstocks may be produced by calculating a county-level pasture competition index. Next steps include reporting algal and terrestrial feedstocks in common units and making results available in the Knowledge Discovery Framework. Future research aims to incorporate terrestrial and algal feedstock production and associated land-use change within a common modeling framework.

Background

National biomass feedstock assessments (Perlack et al., 2005; DOE, 2011) have focused on cellulosic biomass resources, and have not included potential algal feedstocks. Recent research (Wigmosta et al., 2011) provides spatially-explicit information on potential algal biomass and oil yields, water use, and facility locations. Oak Ridge National Laboratory and Pacific Northwest National Lab are collaborating to integrate terrestrial and algal feedstock resource assessments. Following is a summary of both studies:

Terrestrial feedstocks: DOE (2011) is a terrestrial biomass resource assessment, with simulations derived from the Policy Analysis System (POLYSYS). POLYSYS is a linear program run at the county level, which allocates land as reported from the USDA Census of Agriculture. In this study, approximately one billion dry tons/year of terrestrial feedstocks (herbaceous and woody, residues and dedicated) are identified as potentially available, and are reported by price, year, and scenario at www.bioenergykdf.net . This study allows for conversion of some pasture east of the 100th meridian, which in some cases can compete for pasture land allocated to algae production in a study by Wigmosta et al. (2011).

Algal feedstocks: A study by Wigmosta et al. (2011) is a high-resolution spatiotemporal assessment that brings to bear fundamental questions of where production can occur, how many land and water resources are required, and how much energy is produced. This study suggests that under current technology, microalgae have the potential to generate 220 × 109 L yr^{-1} of oil, equivalent to 48% of current U.S. petroleum imports for transportation, assuming unlimited resources (17% of imports using a more realistic water constraint). This would potentially use 126 million acres of land, including 3 million acres of privately-owned pasture land across the U.S.


National microalgae biofuel production potential and resource demand

In summary pasture land east of the 100th meridian is the only land resource accessed by both of these assessments. Here we aim to quantify this potential competition between algal feedstocks, terrestrial feedstocks, and forage production.

Land Description	Area (ac)	% of National Total	% of Screened Total
Total U.S. Pastureland	134,304,137	-	-
Total Pastureland w/ Microalgae Land Screening	3,102,256	2.3%	-
Total Screened Pastureland under Federal Ownership	114,460	0.09%	3.7%
Total Screened Pastureland under Potentially Leasable Federal Lands	106,996	0.08%	3.4%
Total Screened Pastureland East of the 100th Meridian	420,930	0.31%	13.6%
Total Screened Pastureland West of the 100th Meridian	2,681,326	2.0%	86.4%

Methods

To evaluate potential competition between terrestrial dedicated biomass feedstocks and open-pond micro algae production, we calculate algae competition indices, where county-level variables include:
A=conversion of CDL/NLCD private pasture to algae (Wigmosta *et al* 2011)
B=conversion of pasture to terrestrial feedstocks (DOE 2011, base case, 2022, $60/dt)
C=Private pasture (CDL/NLCD pasture land, 2010/2006)
D=Private pasture in farms (permanent pasture and cropland pasture, USDA Census of Agriculture, 2011)

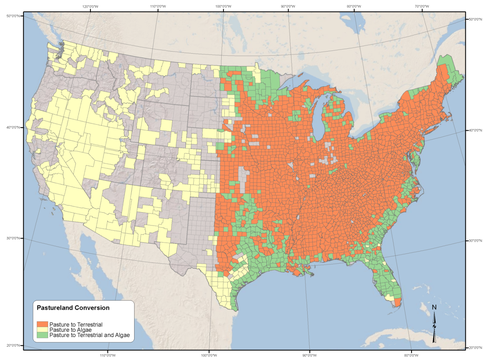

Figure 1. Private pasture allocation to terrestrial and/or algal production.

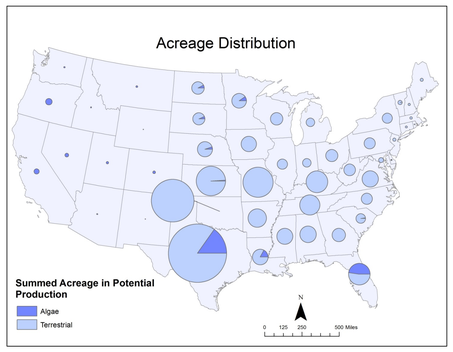

Figure 2. Private pasture allocation to terrestrial and algal production by state.

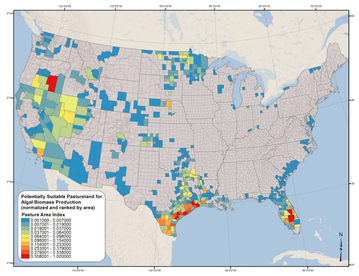

Figure 3. The Pasture Land Index (P) where p is the total land screened pasture area in acres for a given county: $P = \frac{p - p^{min}}{p^{max} - p^{min}}$

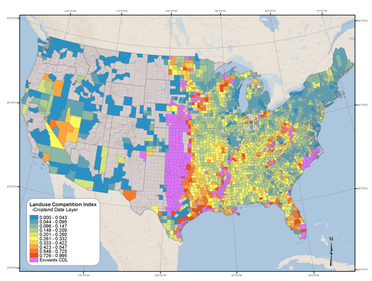

Figure 4. Landuse competition index (CDL/ NLCD).

$$LCI = \frac{(A+B)}{C}$$

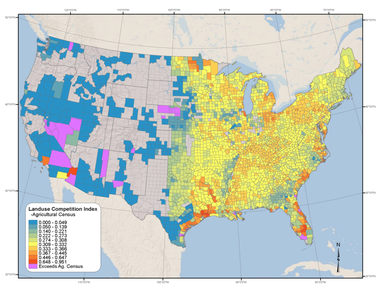

Figure 5. Landuse competition index (Census of Agriculture).

$$LCI = \frac{(A+B)}{D}$$

Conclusions and Future Research

Future energy demands may drive conversion of pastureland to production of algal and terrestrial dedicated feedstocks. Initial results suggest this combined demand for pasture could exceed available pasture in 25 counties using data from the Census of Agriculture, or 284 counties using CDL/NLCD data, equivalent to 10% and 41% of private pastureland, respectively. CDL/NLCD private pasture land used by Wigmosta et al (2011) is 1/3 that reported by the Census of Agriculture used by DOE (2011), emphasizing the need for future research in quantifying pasture land and marginal lands potentially available for biomass production. Next steps include comparing terrestrial and algal production in consistent units, comparing with RFS2 targets, and uploading results to www.bioenergykdf.net. As economics of algae production are elucidated, future research should integrate algae resource assessment in an economic modeling framework, to evaluate economic tradeoffs between the two feedstock types. Future economic analysis can further explore other resource constraints and environmental externalities.

Acknowledgments

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References

Perlack, R., Wright, L., Turhollow, A.F., Graham, R.L., Stokes, B., Erback, D., 2005. Biomass as feedstock for a bioenergy and bioproducts industry: the technical feasibility of a billion-ton annual supply. Oak Ridge National Laboratory, Oak Ridge, TN, pp. 1-78.

U.S. Department of Energy. 2011. U.S. Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry. R.D. Perlack and B.J. Stokes (Leads), ORNL/ TM-2011/224. Oak Ridge National Laboratory, Oak Ridge, TN. 227p.

Wigmosta, M. S., A. M. Coleman, R. J. Skaggs, M. H. Huesemann, and L. J. Lane (2011), National microalgae biofuel production potential and resource demand, *Water Resour. Res.*, *47*, W00H04, doi:10.1029/2010WR009966.