Estimating the Bioenergy Potential of the United States Using Satellite Observations of Vegetation Productivity

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1. Introduction

The United States (U.S.) currently supplies roughly half the world's biofuel, with the Energy Independence and Security Act of 2007 (EISA) specifying an additional three-fold increase in annual production by 2022 (Figure 1).[1-3]

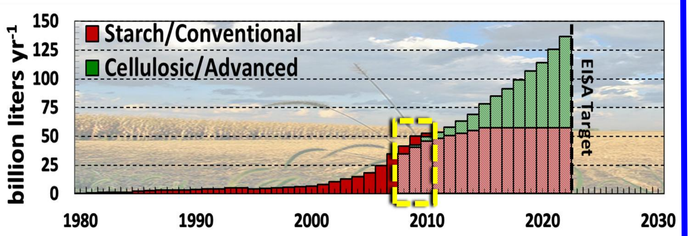

Figure 1. A comparison of actual and mandated biofuel production in the United States.[2,3] Biofuel production in the U.S. has been increasing due solely to growth in corn ethanol production. *Continuation of this trend could have significant detrimental impacts for global food prices.*

2. Objectives

- Estimate the primary bioenergy potential (PBP) of the conterminous U.S. using satellite-derived net primary productivity (NPP) data as the most geographically-explicit measure of current vegetation growth capacity.[3]
- Compare our capacity approximations to EISA energy mandates in an effort to evaluate the feasibility of current U.S. energy policy.[3]

3. Methods

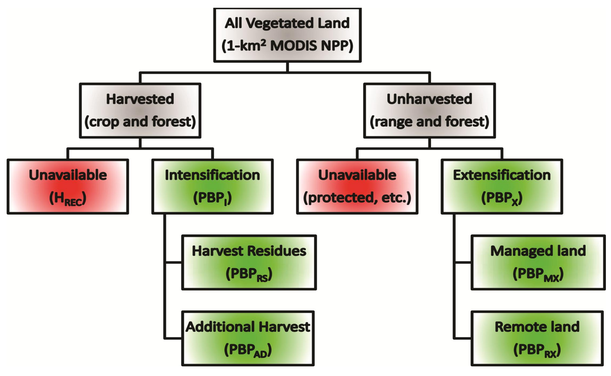

Figure 2. Flow diagram for the quantification of landcover and primary bioenergy potential (PBP) pools.[3] Green indicates PBP pools while red indicates unavailable pools. Unavailable resources were defined to include current agricultural and forestry harvest (H_{RC}) as well as protected areas, wetlands, pastures, and low productivity regions.

4. Bioenergy Potential of the United States

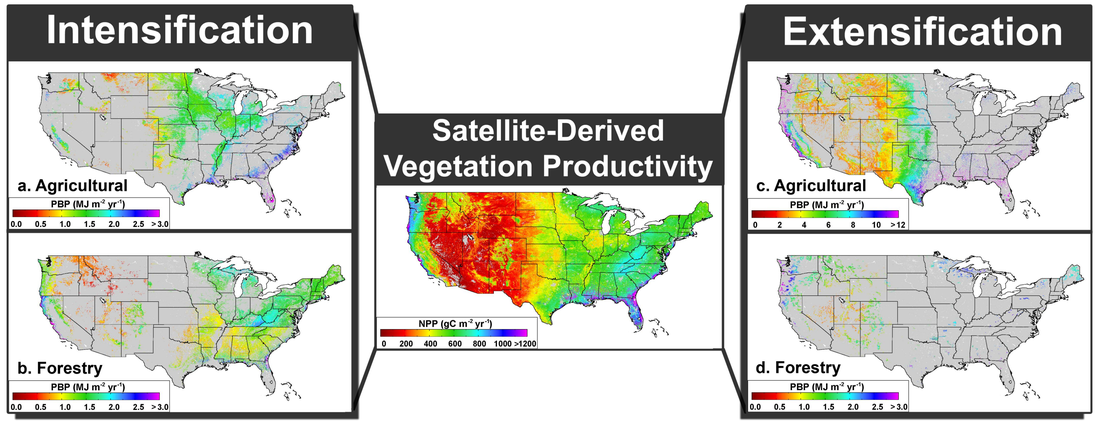

Figure 3. Spatially explicit primary bioenergy potential (PBP) of the conterminous United States.[3] (a) Agricultural intensification (PBP_I) defined to include residual harvest (PBP_{RS}) only. (b) Forestry intensification (PBP_I), including both additional harvest (PBP_{AD}) and residual harvest (PBP_{RS}). (c) Agricultural extensification (PBP_X), including both managed (PBP_{MX}) and remote (PBP_{RX}) extensification. (d) Forestry extensification (PBP_X) defined to include remote extensification (PBP_{RX}) only.

Primary Bioenergy Potential	Area (Mkm^2)	Mean Yield[a] ($MJ\ m^{-2}\ yr^{-1}$)	Total PBP ($EJ\ yr^{-1}$)
Agricultural Extensification (PBP_X)	**1.94**	**3.4-10.6**	**13.5 (1.8)**
Managed Range (PBP_{MX})	1.21	3.5-11.9	9.2 (1.2)
Remote Range (PBP_{RX})	0.73	3.3-8.3	4.3 (0.6)
Forestry Extensification (PBP_X)	**0.34**	**2.3-4.3**	**1.1 (0.3)**
Managed Forest (PBP_{MX})	--	--	--
Remote Forest (PBP_{RX})	0.34	2.3-4.3	1.1 (0.3)
Agricultural Intensification (PBP_I)	**1.39**	**2.1-3.8**	**4.1 (1.0)**
Additional (PBP_{AD})	--	--	--
Residual (PBP_{RS})	1.39	2.1-3.8	4.1 (1.0)
Forestry Intensification (PBP_I)	**1.73**	**1.4-2.8**	**3.5 (1.3)**
Additional (PBP_{AD})	1.73	0.7-1.6	1.7 (0.8)
Residual (PBP_{RS})	1.73	0.6-1.3	1.8 (0.4)
Total/Average	**5.40**	**2.3-5.4**	**22.2 (4.4)**

[a]Mean Yield represents a range of one standard deviation. Values in parentheses represent parameter uncertainty.

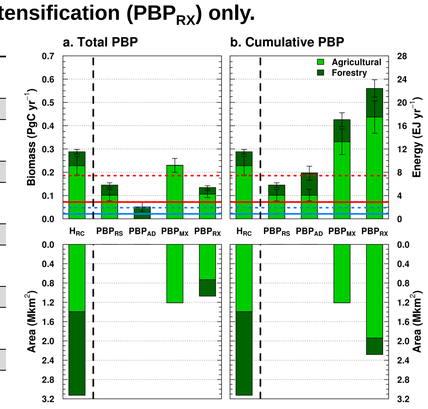

Figure 4. Primary bioenergy potential (PBP) of the conterminous United States.[3] The solid blue line represents U.S. net ethanol production in 2009 (40 billion L). The dotted blue line represents U.S. primary bioenergy production in 2009 (1.91 EJ). The solid red line represents the net energy required by the EISA (136 billion L). *The dotted red line represents the primary energy required by the EISA by 2022 (7.42 EJ).* (a) Total PBP. (b) Cumulative PBP.

5. Comparison With Current Literature Estimates

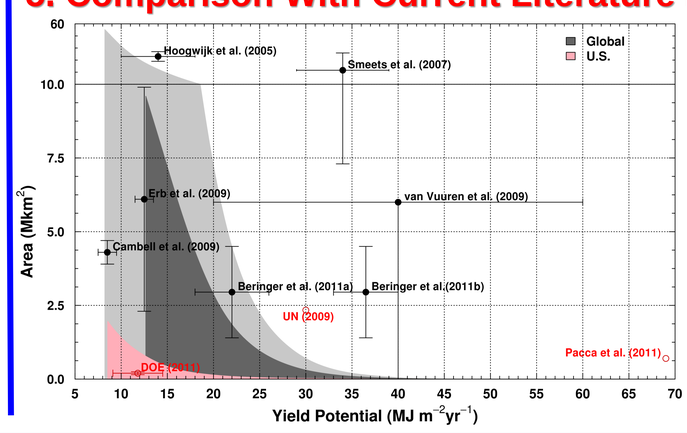

Figure 5. Cumulative maximum yield potential as a function of area.[3] ***We show that a number of recent studies used yield potential values higher than maximum natural yield potentials, which we attribute to over-optimistic assumptions regarding management or to an incomplete consideration of biophysical constraints.***[4-7]

6. Key Results

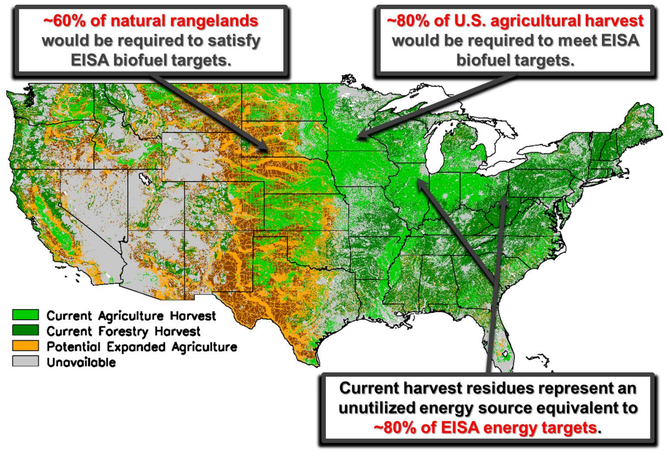

Figure 6. A spatial view of potential biofuel production regions in the United States.[3]

7. Conclusions

- Meeting EISA mandates under current technology will require large-scale changes in the U.S. agricultural landscape (Figure 6).[3]
- Future increases in U.S. agricultural yields are unlikely since rates of irrigation may already be unsustainable in many regions.[8,9] Further, 70% of U.S. counties are likely to experience climate change-driven reductions in freshwater availability by 2050 (Figure 7).[10]

Figure 7. In July 2012, nearly 80% of U.S. corn was experiencing some degree of drought, prompting the World Agricultural Outlook Board to announce a 12% cut in 2012 U.S. corn production targets. Photo Credit: Reuters.

Literature Cited

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Acknowledgments

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