Available online at www.sciencedirect.com

ScienceDirect

http://www.elsevier.com/locate/biombioe

BIOMASS & BIOENERGY

Review

The biophysical link between climate, water, and vegetation in bioenergy agro-ecosystems

Justin E. Bagley [a], Sarah C. Davis [b], Matei Georgescu [c], Mir Zaman Hussain [a], Jesse Miller [a,d], Stephen W. Nesbitt [e], Andy VanLoocke [a,d,f], Carl J. Bernacchi [a,d,f,*]

[a] Energy Biosciences Institute (EBI), University of Illinois at Urbana-Champaign, Urbana, IL 61801, USA
[b] Voinovich School for Leadership and Public Affairs and Department of Environmental and Plant Biology, Ohio University, Athens, OH 45701, USA
[c] School of Geographical Sciences and Urban Planning, Arizona State University, Tempe, AZ 85287, USA
[d] Department of Plant Biology, University of Illinois at Urbana-Champaign, Urbana, IL 61801, USA
[e] Department of Atmospheric Sciences, University of Illinois at Urbana-Champaign, Urbana, IL 61801, USA
[f] USDA-ARS, Global Change and Photosynthesis Research Unit, Urbana, IL 61801, USA

ARTICLE INFO

Article history:
Received 27 February 2014
Received in revised form
12 September 2014
Accepted 8 October 2014
Available online 28 October 2014

Keywords:
Bioenergy production
Biophysical climate feedbacks
Ecosystem–atmosphere interactions
Land use change
Land–atmosphere interactions

ABSTRACT

Land use change for bioenergy feedstocks is likely to intensify as energy demand rises simultaneously with increased pressure to minimize greenhouse gas emissions. Initial assessments of the impact of adopting bioenergy crops as a significant energy source have largely focused on the potential for bioenergy agroecosystems to provide global-scale climate regulating ecosystem services via biogeochemical processes. Such as those processes associated with carbon uptake, conversion, and storage that have the potential to reduce global greenhouse gas emissions (GHG). However, the expansion of bioenergy crops can also lead to direct biophysical impacts on climate through water regulating services. Perturbations of processes influencing terrestrial energy fluxes can result in impacts on climate and water across a spectrum of spatial and temporal scales. Here, we review the current state of knowledge about biophysical feedbacks between vegetation, water, and climate that would be affected by bioenergy-related land use change. The physical mechanisms involved in biophysical feedbacks are detailed, and interactions at leaf, field, regional, and global spatial scales are described. Locally, impacts on climate of biophysical changes associated with land use change for bioenergy crops can meet or exceed the biogeochemical changes in climate associated with rising GHG's, but these impacts have received far less attention. Realization of the importance of ecosystems in providing services that extend beyond biogeochemical GHG regulation and harvestable yields has led to significant debate regarding the viability of various feedstocks in many locations. The lack of data, and in some cases gaps in knowledge associated with biophysical and biochemical influences on land–atmosphere interactions, can lead to premature policy decisions.

Published by Elsevier Ltd.

* *Corresponding author*. USDA-ARS, 193 E.R. Madigan Laboratory, Urbana, IL 61801, USA. Tel.: +1 217 333 8048.
E-mail address: bernacch@illinois.edu (C.J. Bernacchi).
http://dx.doi.org/10.1016/j.biombioe.2014.10.007
0961-9534/Published by Elsevier Ltd.

1. Introduction

Between 30 and 40% of total global ice-free land is devoted to pasture or cropland [1]. Much of the remaining land is considered unsuitable, inaccessible, or inappropriate for agricultural development. The agricultural development that has occurred in recent years been focused in the tropics and has led to regional deforestation with extreme ecological and climatological consequences. The spatial and ecological limits of arable land combined with the effects of growing global energy and dietary demands in a changing climate necessitate comprehensive assessment of how to optimize the services that agro-ecosystems provide. Recently, the fraction of arable land being devoted to bioenergy production has increased, largely due to the increased fraction of harvested maize (*Zea mays*) being apportioned to ethanol production in the United States and increased sugarcane (*Saccharum officinarum*) production in Brazil (Fig. 1). The change in land use associated with increased bioenergy production will lead to biogeochemical and biophysical impacts on climate and coupled

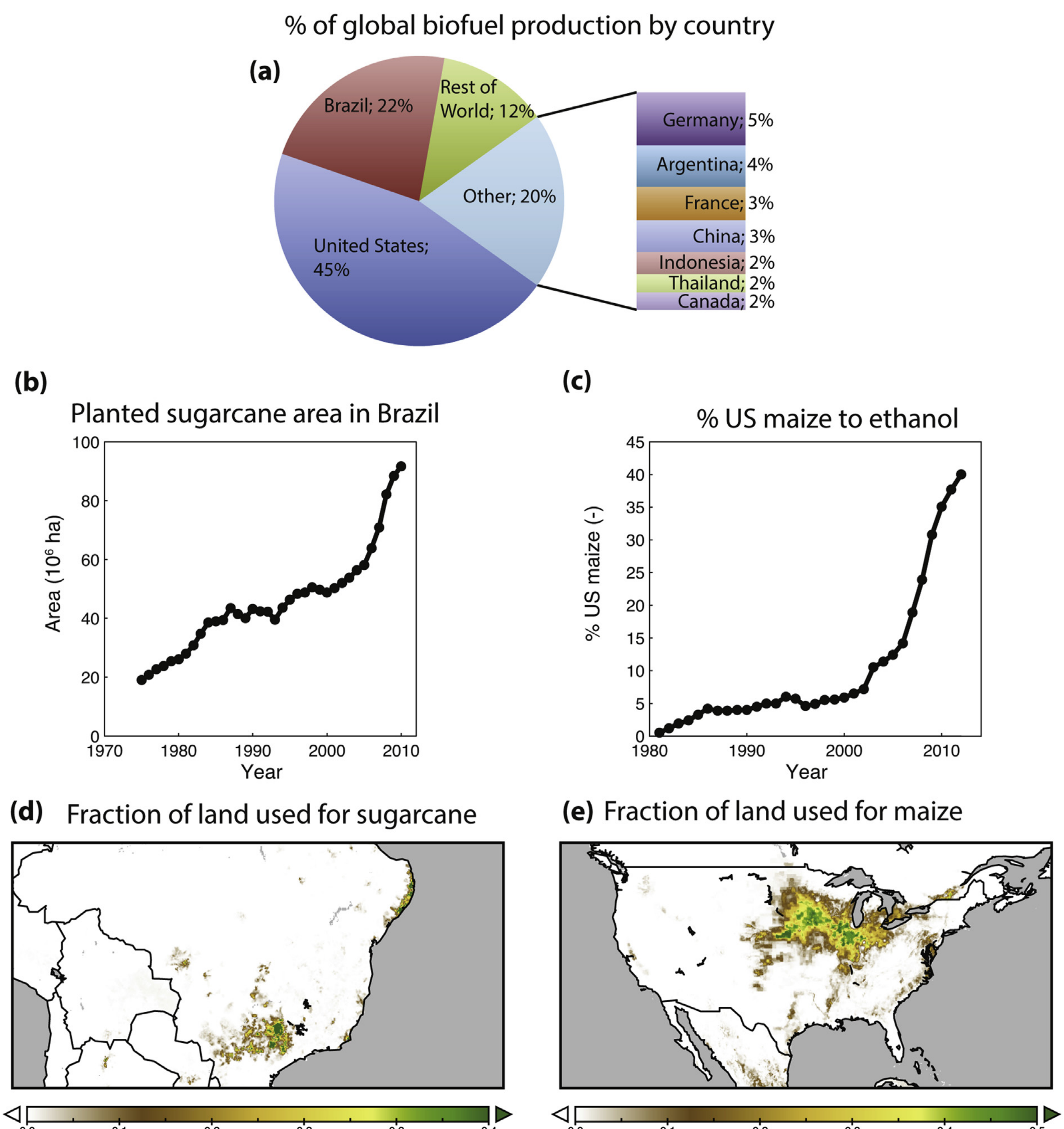

Fig. 1 – (a) 2012 global distribution of biofuel production (Source: BP statistical review of world energy [105]). (b) Total Brazilian Sugarcane Production (Source: Brazil Ministry of Agriculture [106]). (c) Percentage of US maize production utilized for ethanol (Source: USDA Statistics [107]). Map of fraction of land used for sugarcane in Brazil (d), and maize in the US (e) (Source: Monfreda et al. [108]).