Predicting Feedstock Production and Ecosystem Services

David LeBauer, PhD

Overview for GSB / LACAf Meeting

August 27, 2014

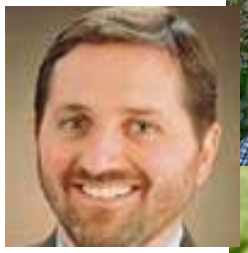
Energy Biosciences Institute

ILLINOIS

NCSA

EBI Feedstock Modeling Program.

Lead PI
Steve Long



Co-PI's
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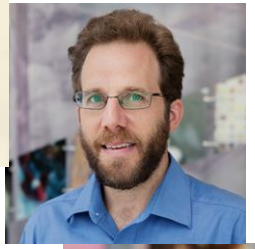
Dan Wang



Scientist
David LeBauer

Programmer
Scott Rohde

Manager
Ank Michielsen

EBI Modeling Program: Broad Objectives

Evaluate the production and sustainability of second-generation, lignocellulosic feedstocks.

Use mechanistic understanding of plants and ecosystems to provide the best estimates of potential productivity from existing and future lignocellulosic feedstocks.

Support decisions related to crop selection, management, and improvement for productivity and ecosystem services

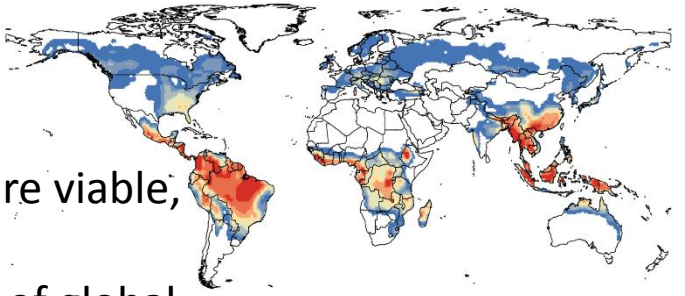
Cross-scale questions

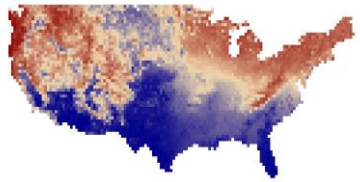
Which plant species can be sustainable bioenergy feedstocks?

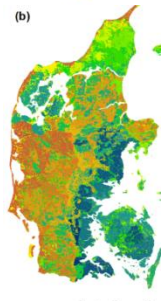
Where and *how much* feedstock can we produce?

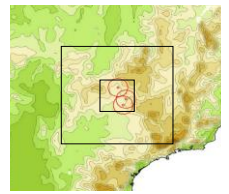
What are the costs and benefits of management options?

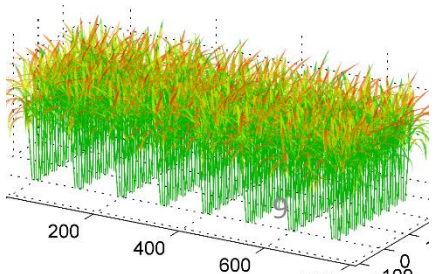
Spatial Scale	Questions
10^5 m	Which crops are viable, … and where? What fraction of global energy demand?
10^4 m	Climate driven biogeography
	County level mean yields Supply chain optimization
10^3 m	
	Local topography effects on soil, hydrology Sub-field management
10^2 m	
10^{-3} m	Crop Architecture Row Spacing Row Orientation Harvesting Equipment Shading response







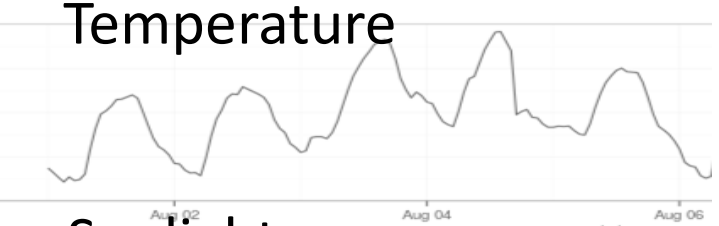




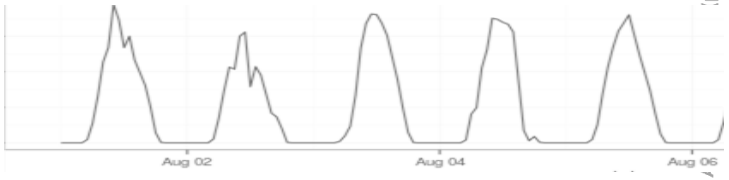
BioCro, Our Feedstock Productivity Model

Drivers

Temperature



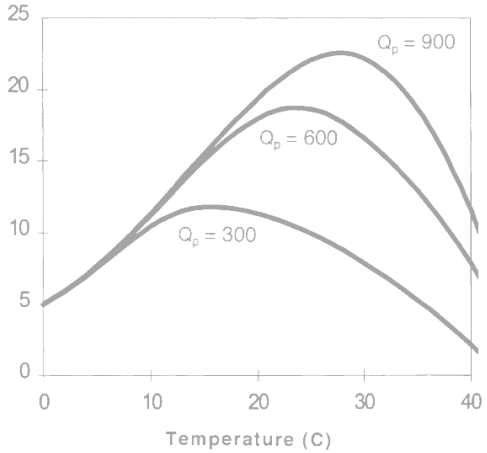
Sunlight



CO_2
H_2O (rain, vapor)
Soil
Management

Parameters

Photosynthesis



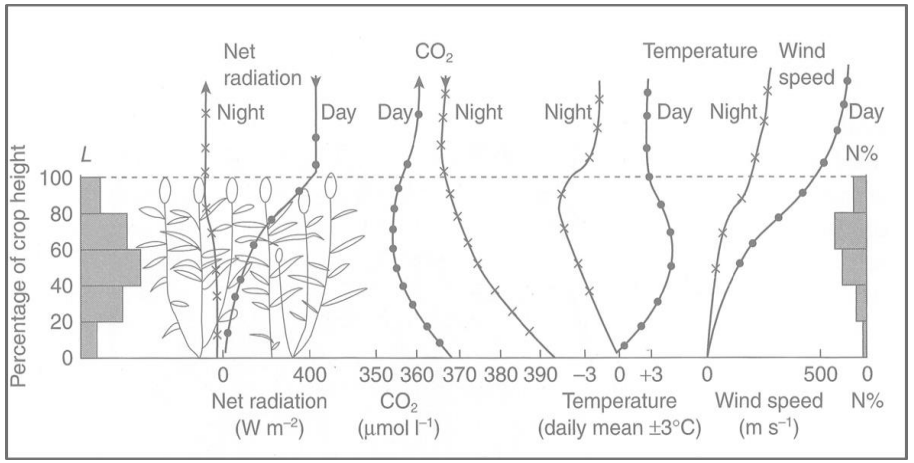
Shape, Size
Phenology
Allocation

Simulation

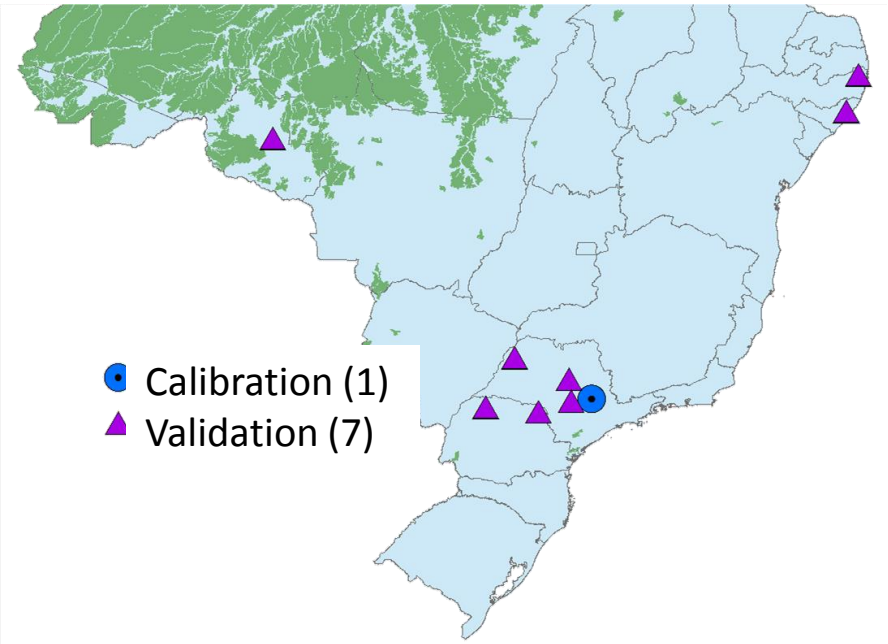
Light Interception
Energy, Mass Balance
Leaf Photosynthesis
Biomass Partitioning
Soil Hydrology
DayCent Biogeochemistry (CH_4, N_2O)

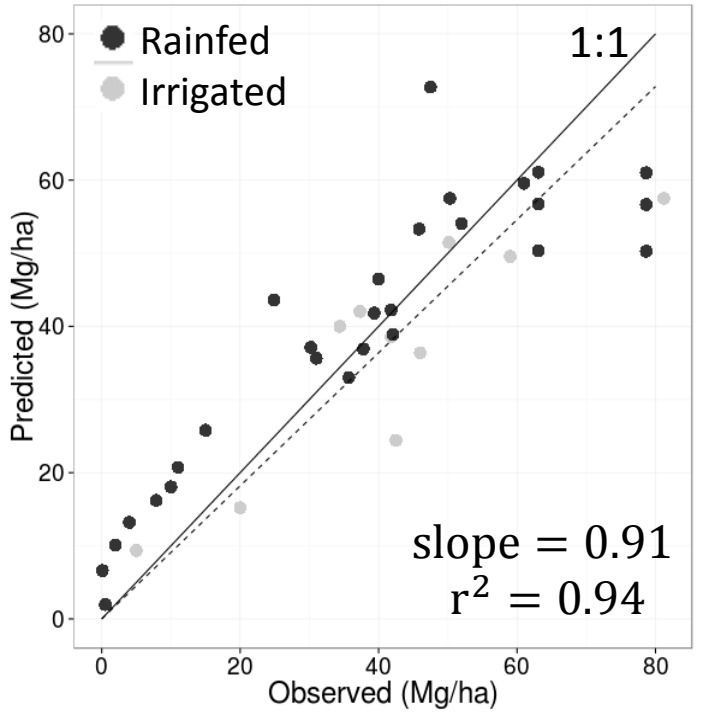
Outputs

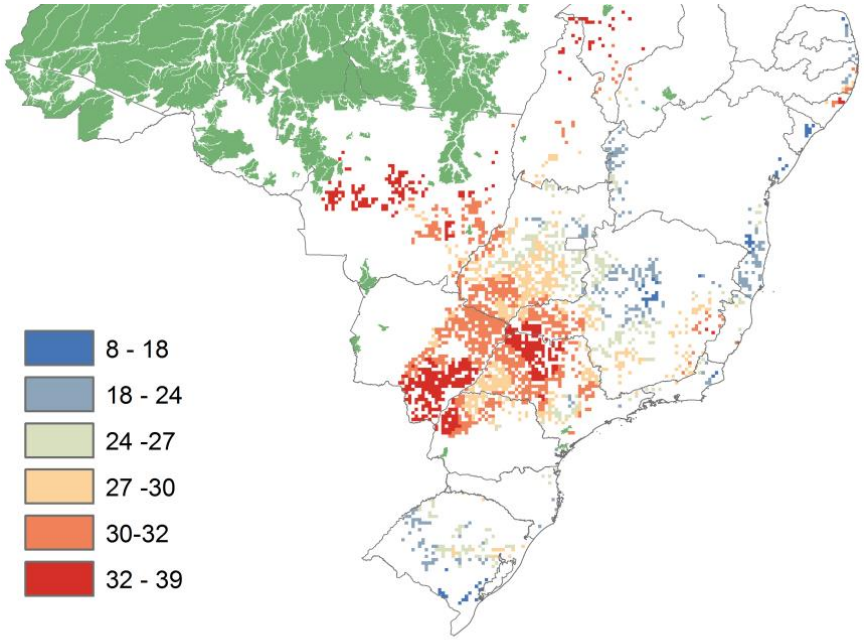
Productivity
Water Use
Ecosystem Services
Greenhouse Gases



Calibration, Validation, and Prediction: Sugarcane Yield







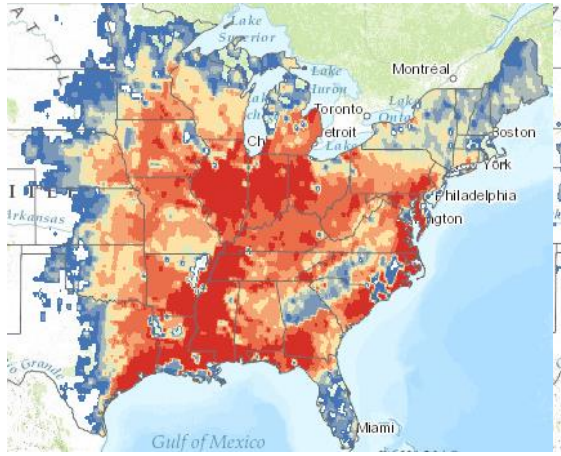
Jaiswal et al, *in prep*

US Feedstock Production Potential

Yield (Mg/ha/y)

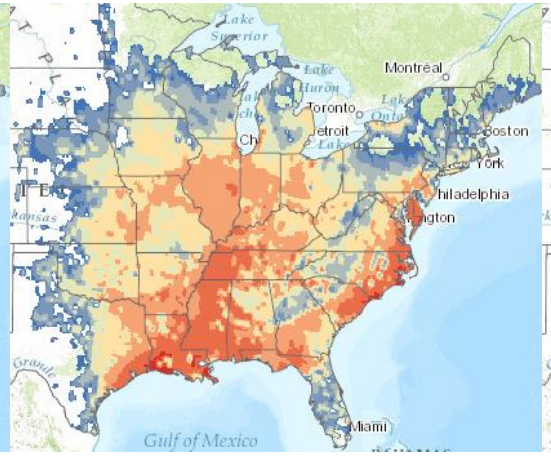
- 5 - 9
- 9 - 12
- 12 - 15
- 15 - 18
- 18 - 21
- 21 - 24
- 24 - 27
- 27 - 30

Miscanthus



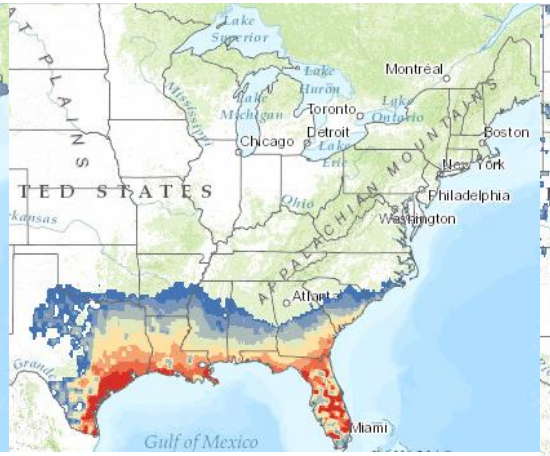
Miguez et al, 2009

Switchgrass



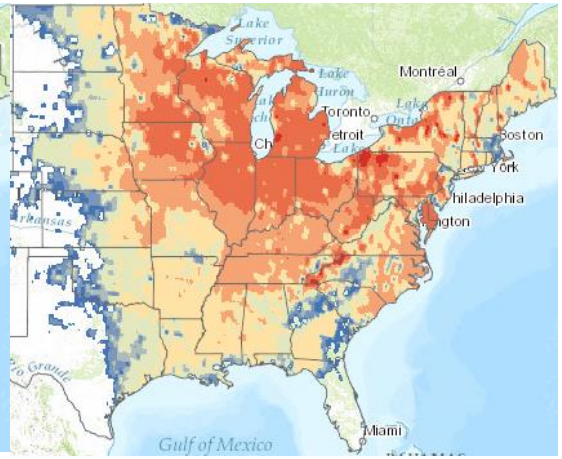
Miguez et al, 2012

Sugarcane



Jaiswal et al, *in prep*

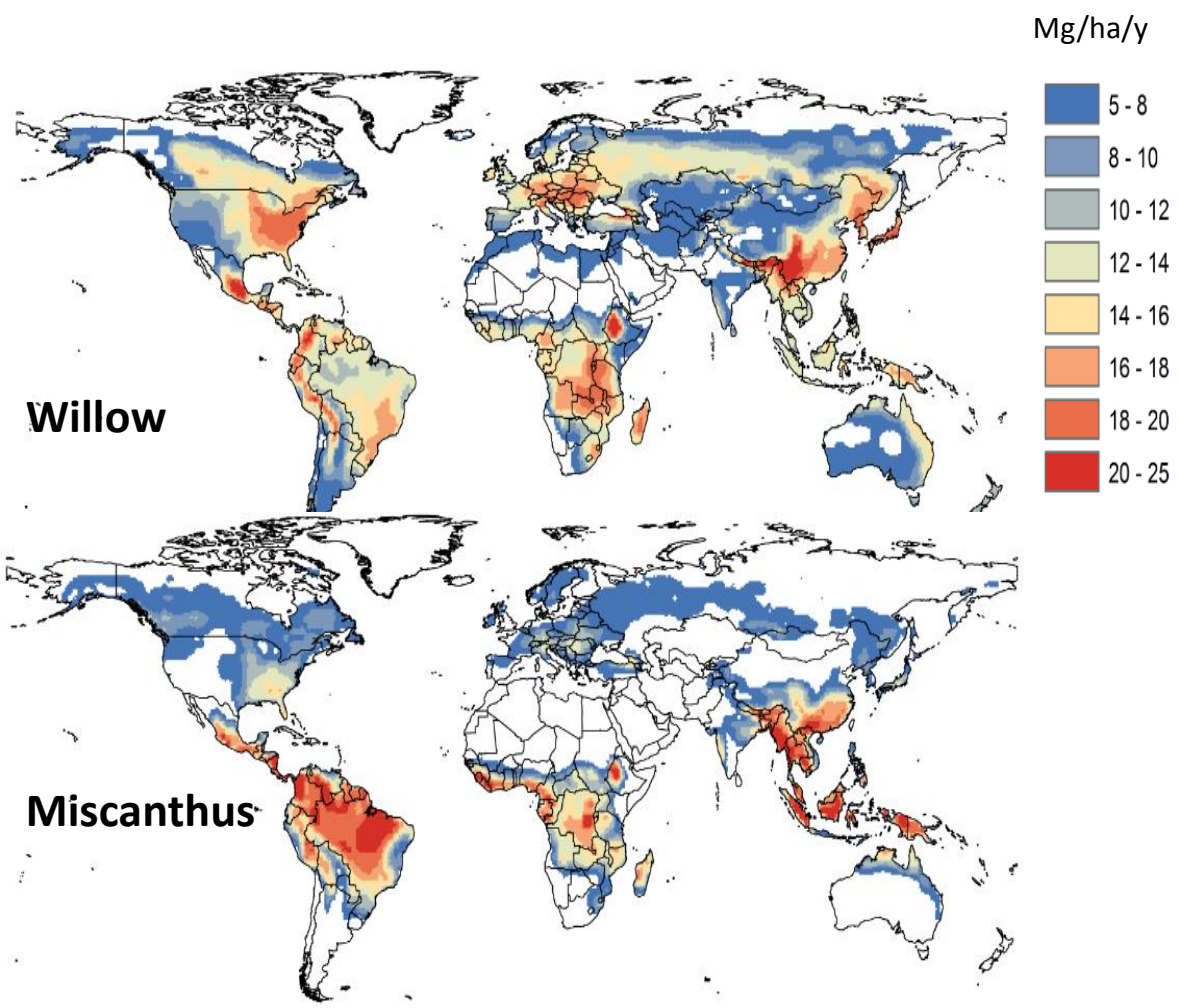
Willow



Wang et al, *in review*

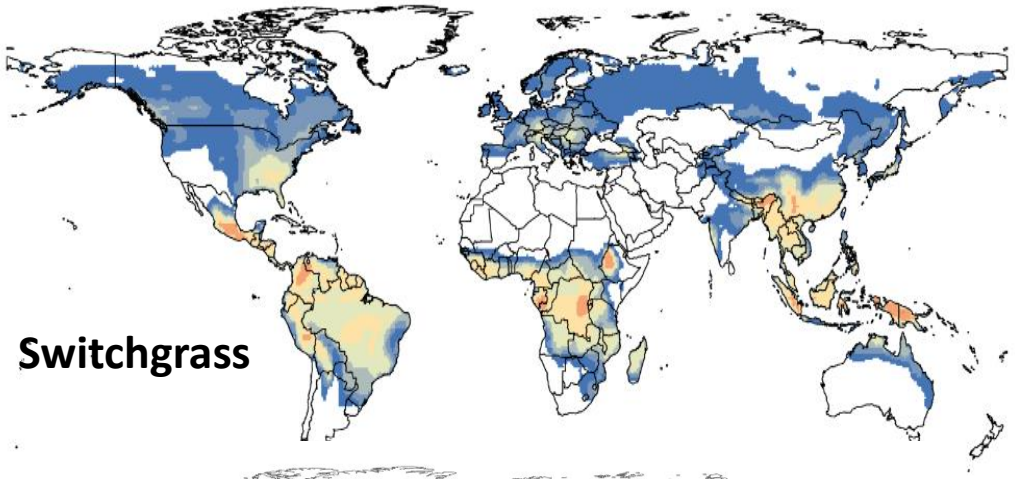
Other crops under development: Agave, Arundo, Poplar, Pine

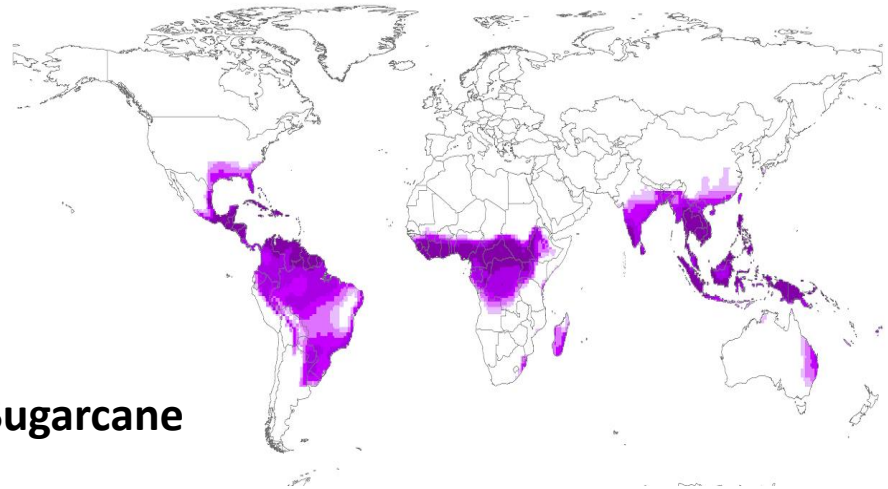
Global Feedstock Production Potential



Mg/ha/y

- 5 - 8
- 8 - 10
- 10 - 12
- 12 - 14
- 14 - 16
- 16 - 18
- 18 - 20
- 20 - 25

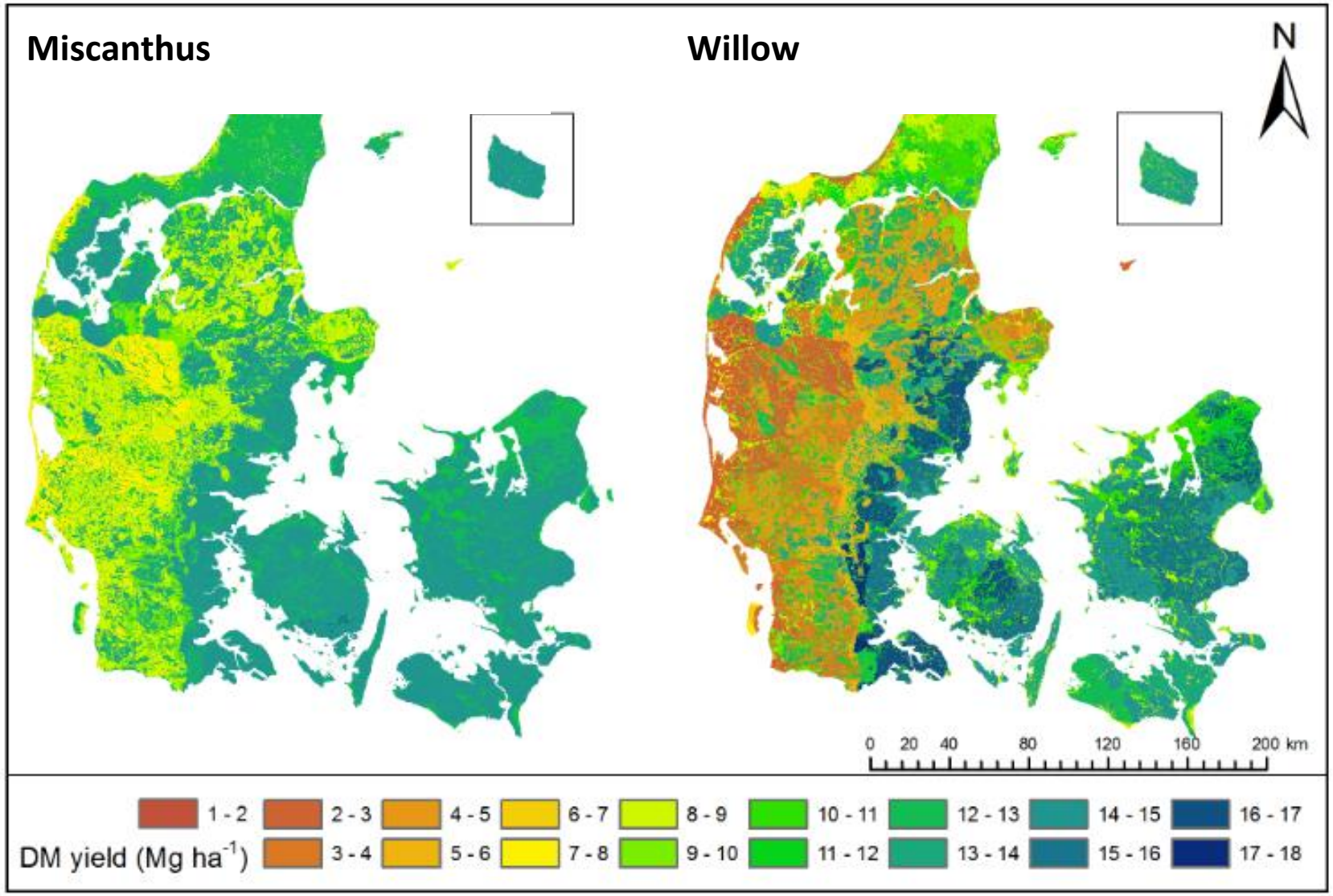




Mg/ha/y

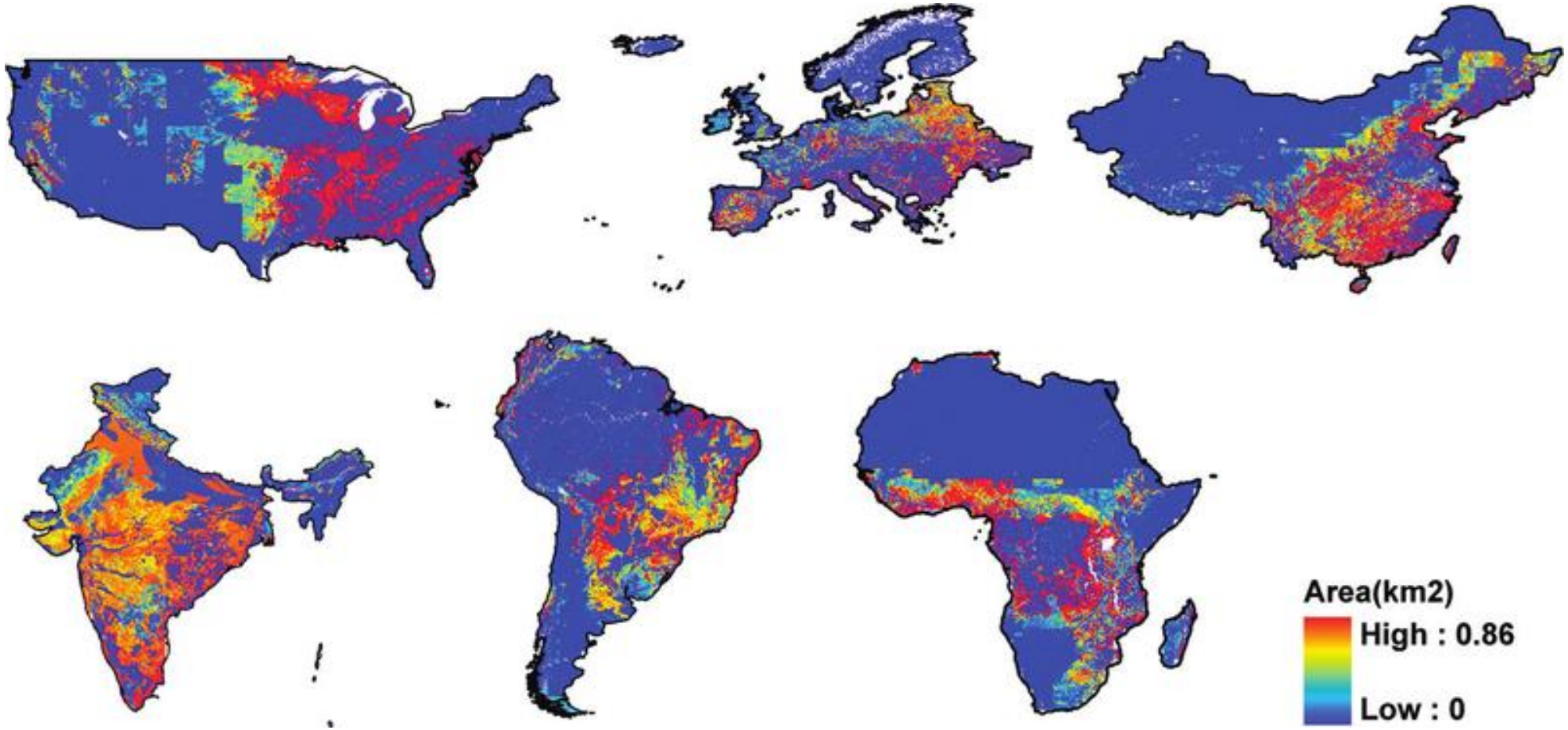
- < 25
- 26 - 30
- 31 - 35
- 36 - 40
- 41 - 45
- 46 - 50

Farm-Scale Predictions



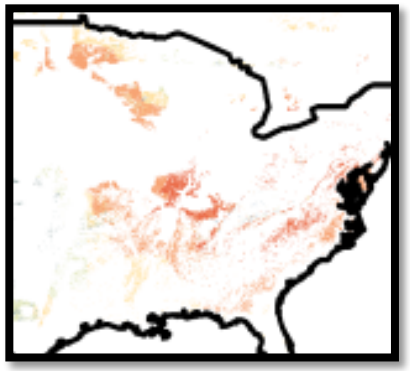
Larsen et al, *in prep*

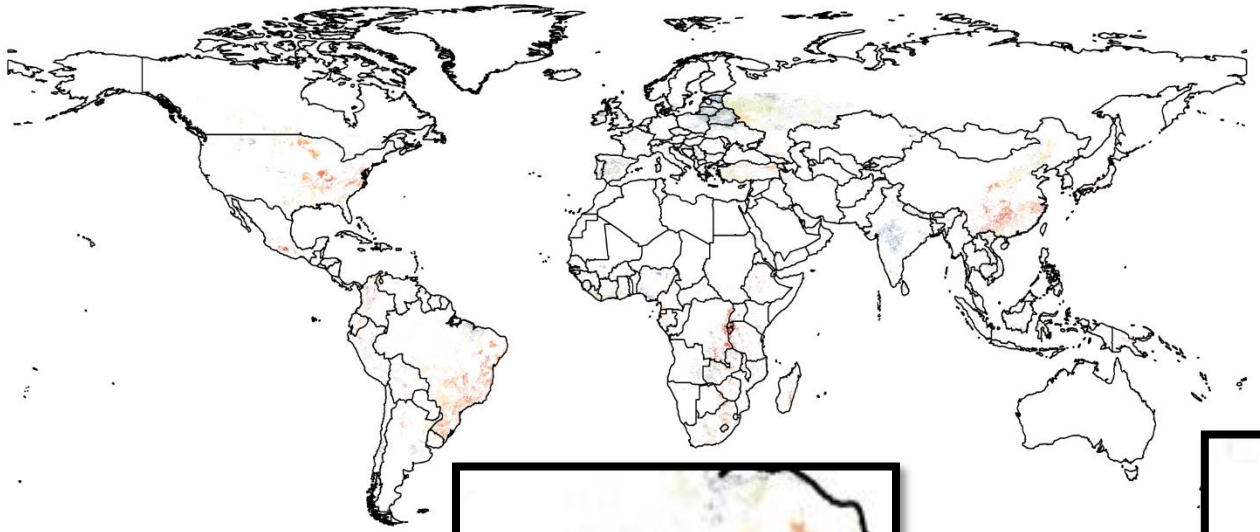
Marginal Land Available for Biofuel Production

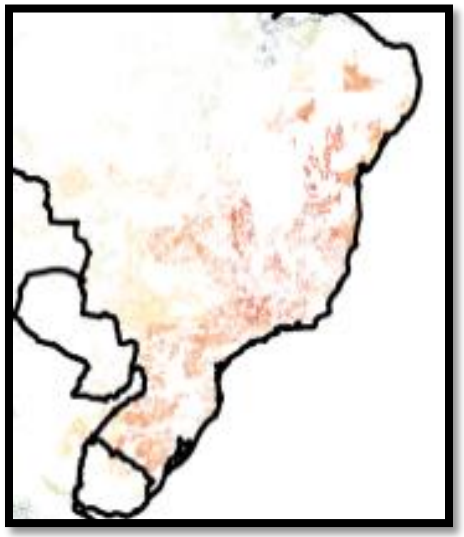


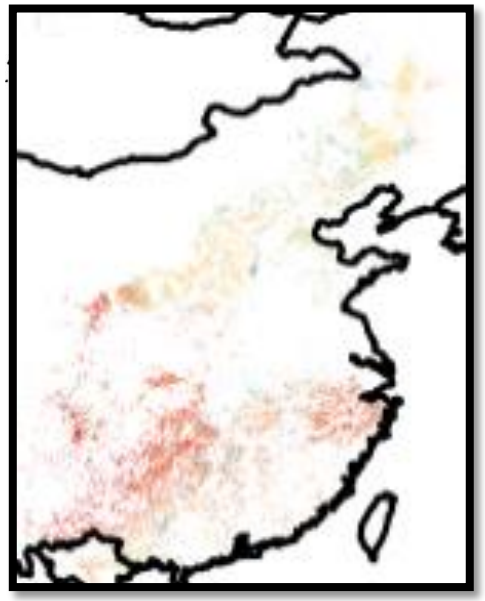
(Cai et al 2011)

Willow on Marginal Lands, Globally





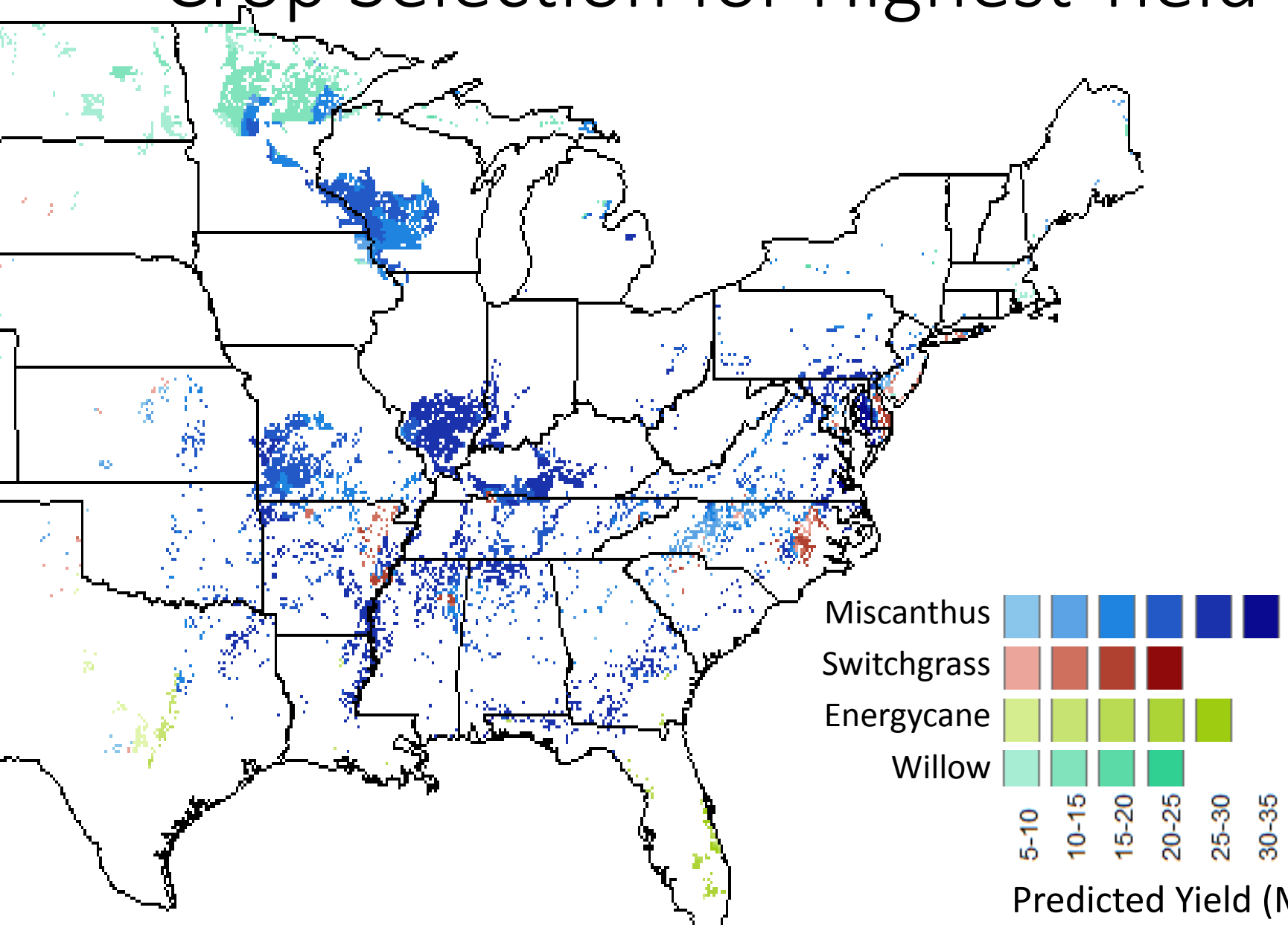




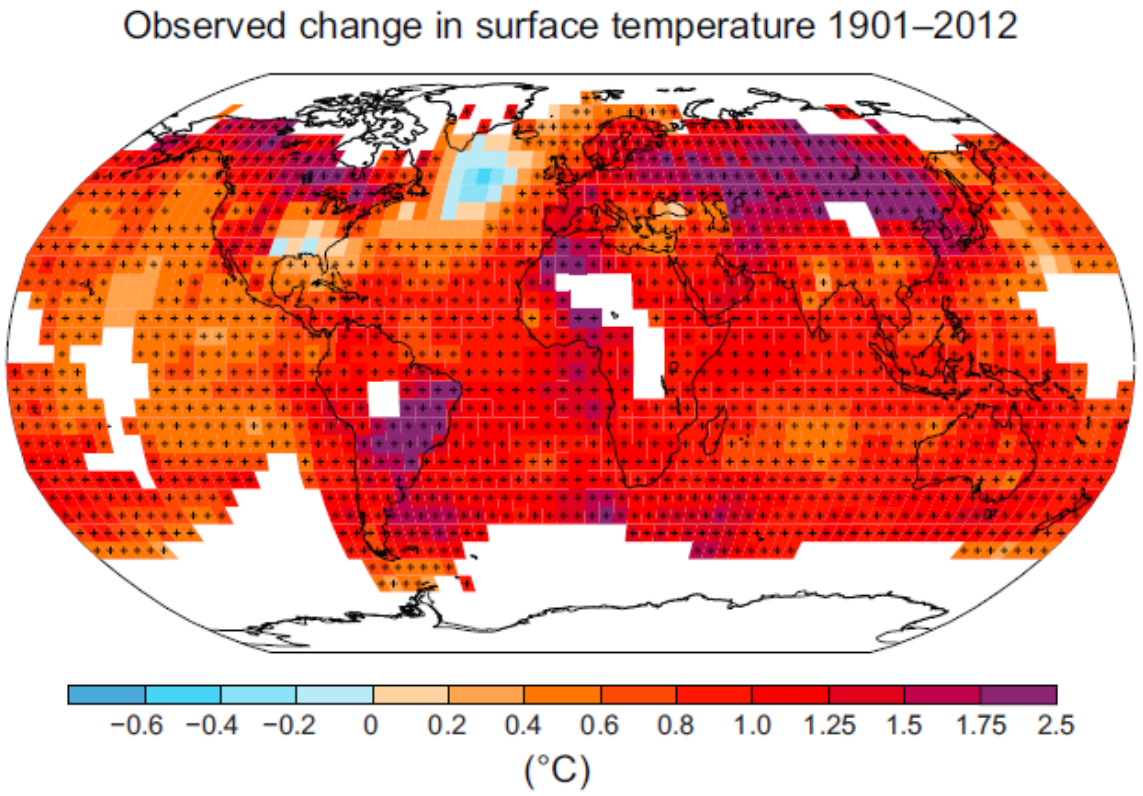
Mg/ha/yr

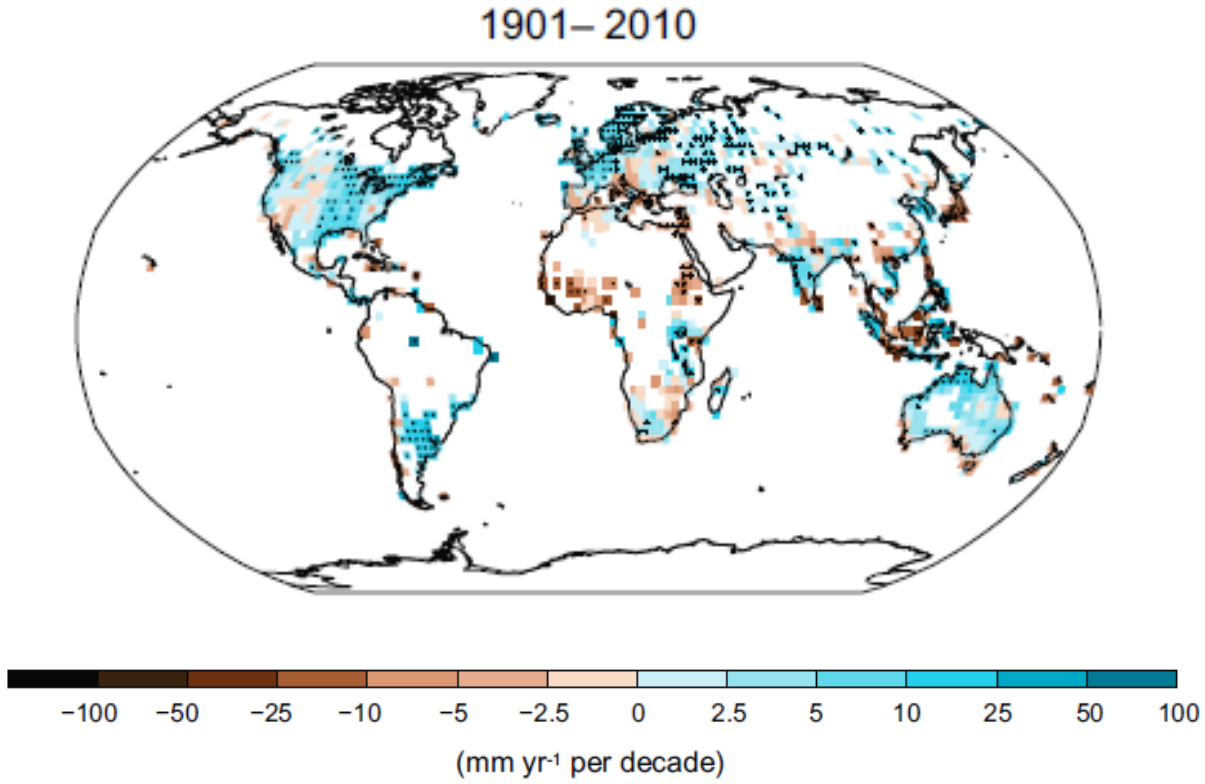
- 5 - 8
- 8 - 10
- 10 - 12
- 12 - 14
- 14 - 16
- 16 - 18
- 18 - 20
- 20 - 25

Crop Selection for Highest Yield



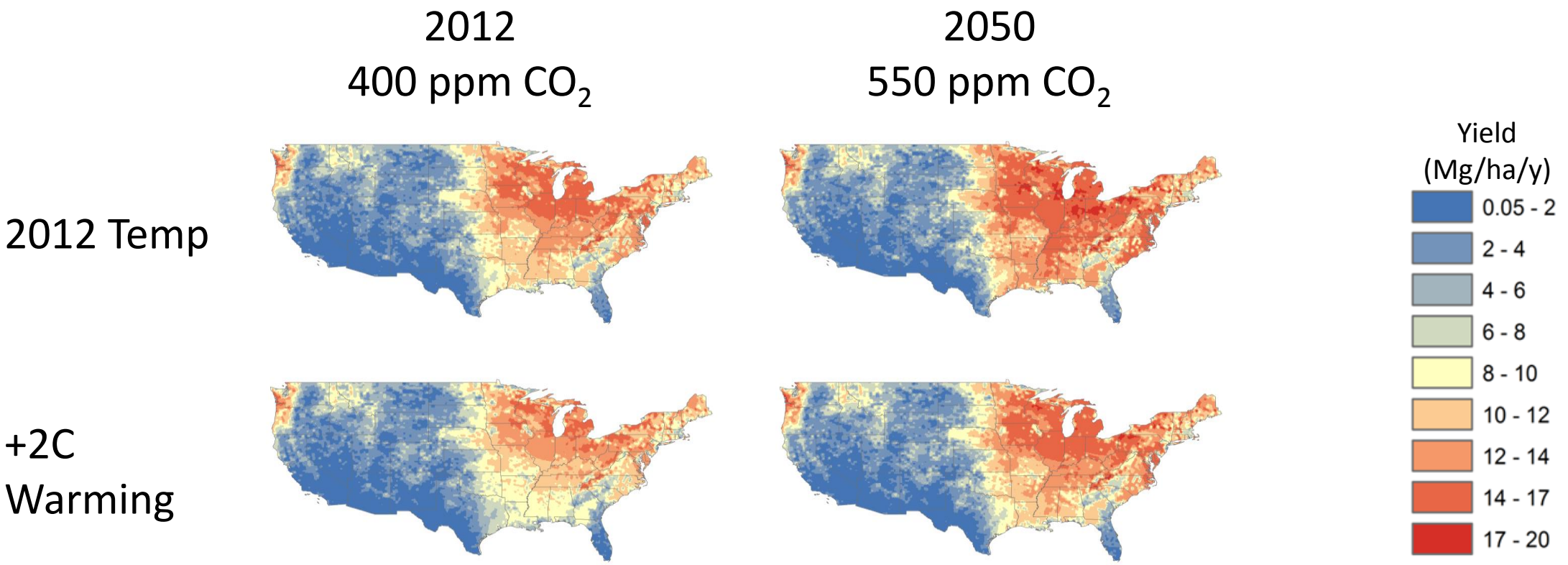
Regional and Global Climate Change Effects





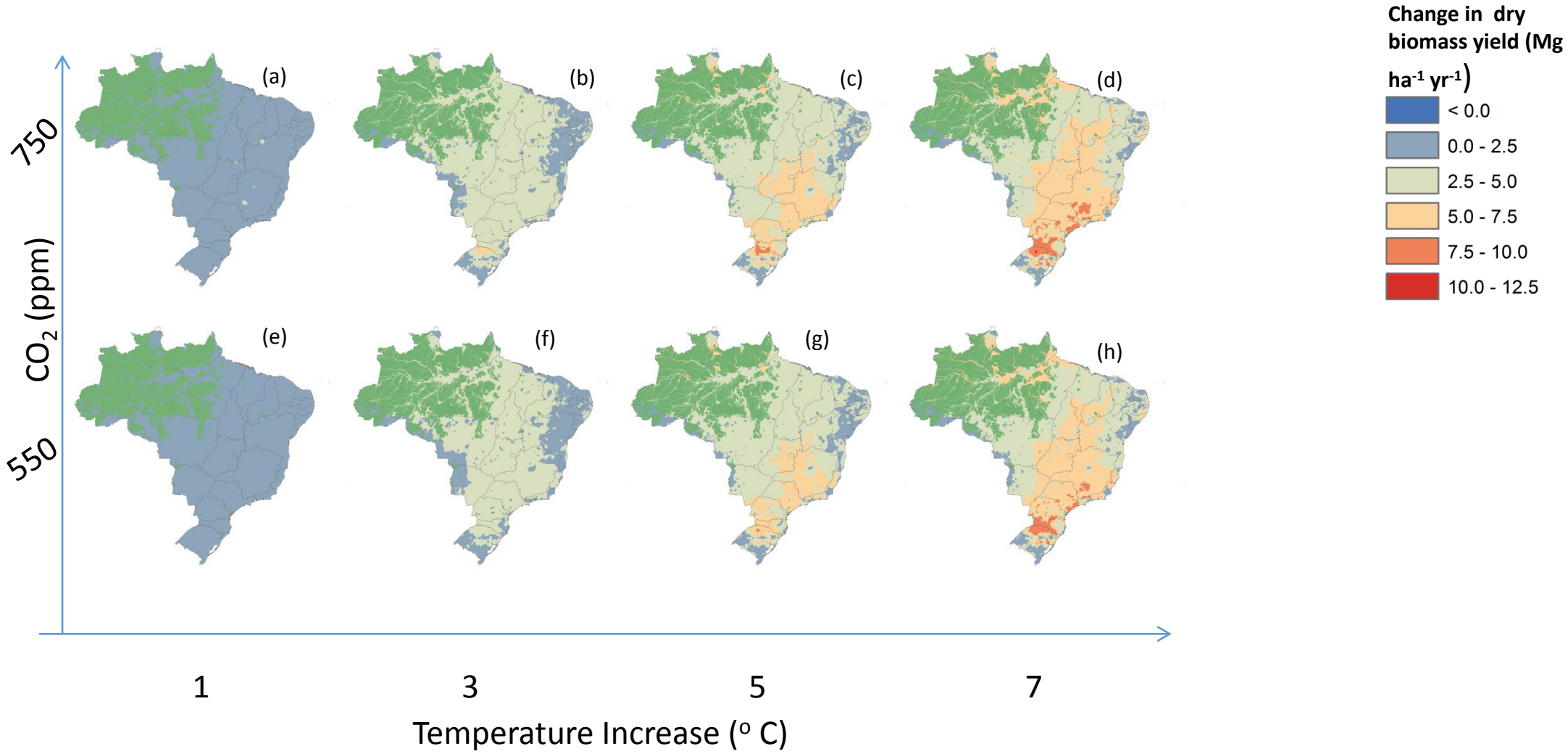
IPCC AR5, 2014

Willow: CO_2 mitigates Temperature effect



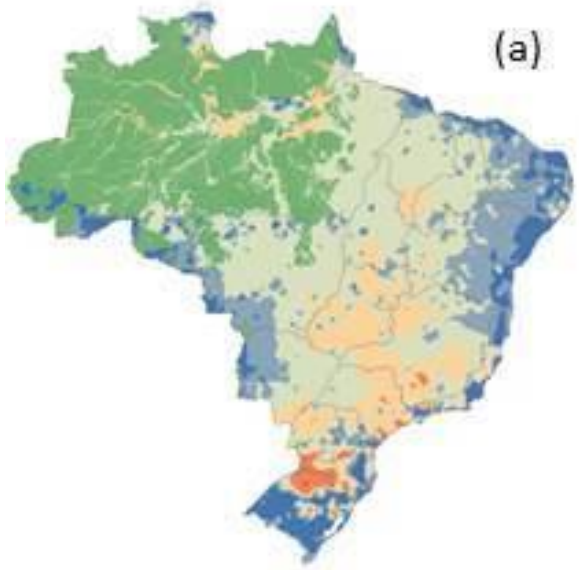
Wang et al, *in review*

Sugarcane: Temp increases yield, CO_2 doesn't



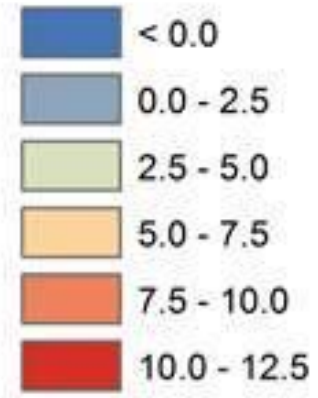
Sugarcane: Precipitation at future Temperature, and CO_2

-20% Precip



Current Precip

+ 20% Precip



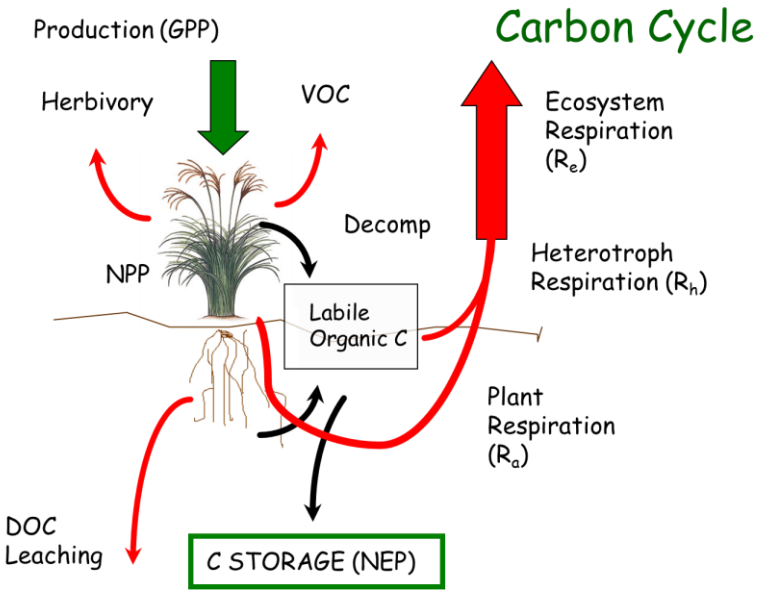
Change in dry biomass yield

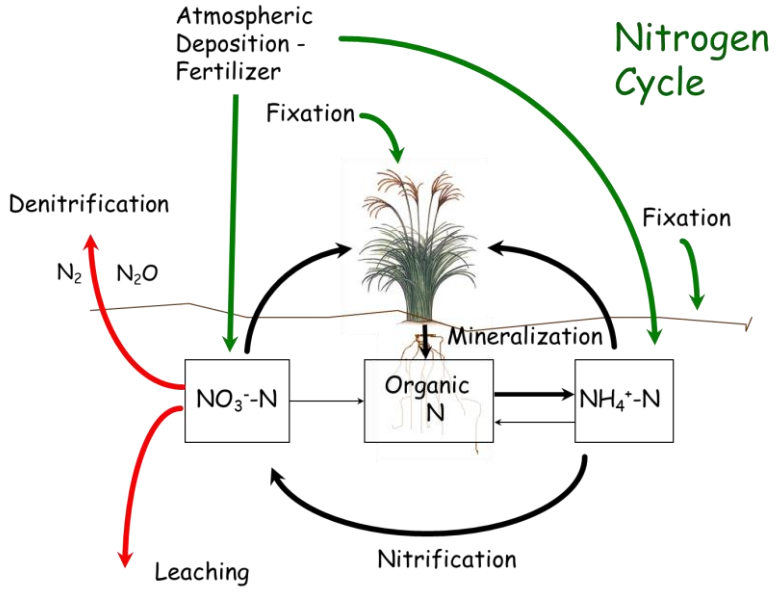
(Mg ha^{-1} yr^{-1})

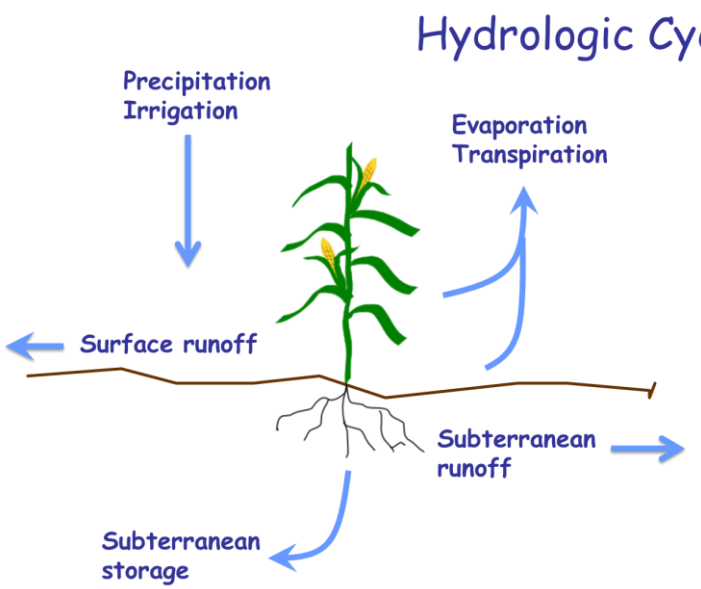
Model-Data Synthesis

- Open-access, open-source software and data to advance second-generation bioenergy feedstock production

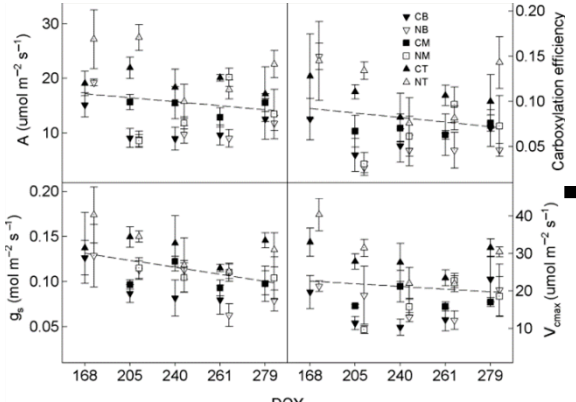
Ecosystem Models: a Data "Scaffold"



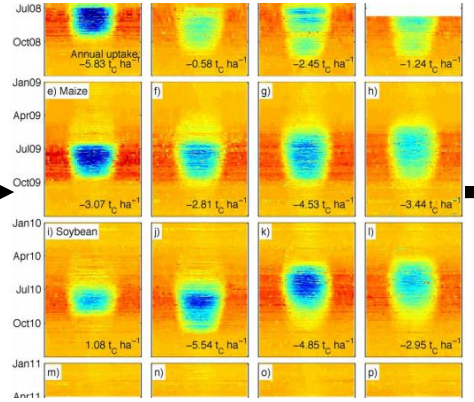




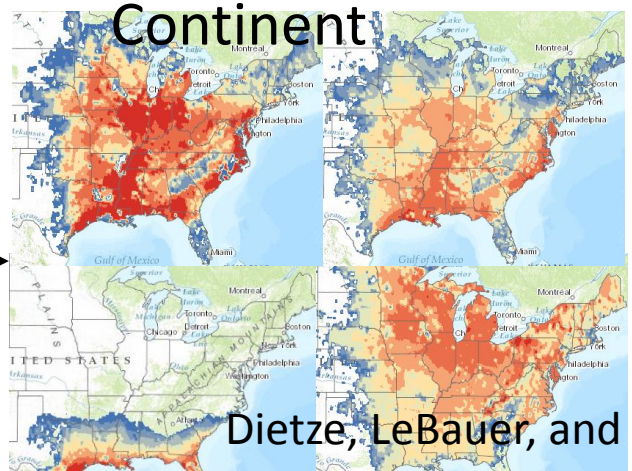
Enzyme



Ecosystem

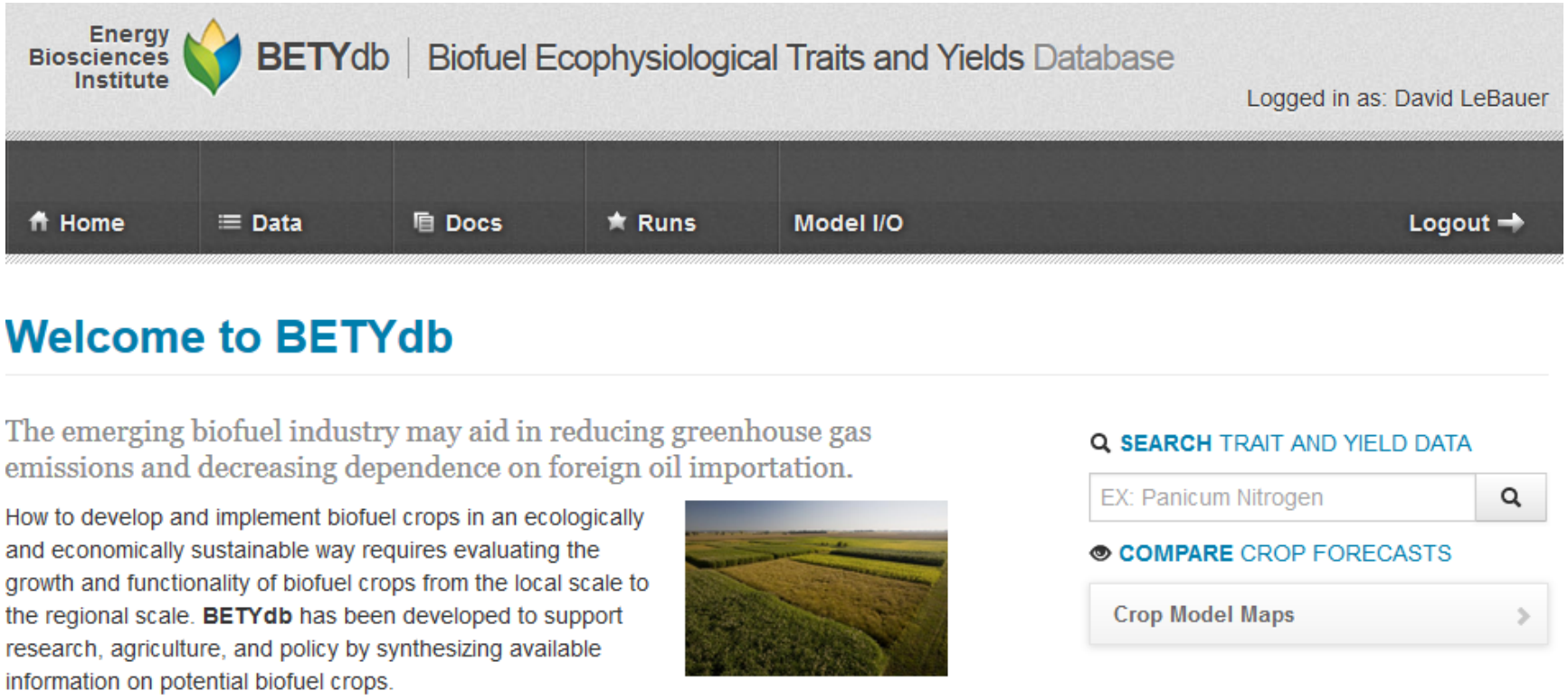


Continent



Dietze, LeBauer, and Kooper 2013 PC&E

BETYdb:
Biofuel Ecophysiological Traits and Yields Database



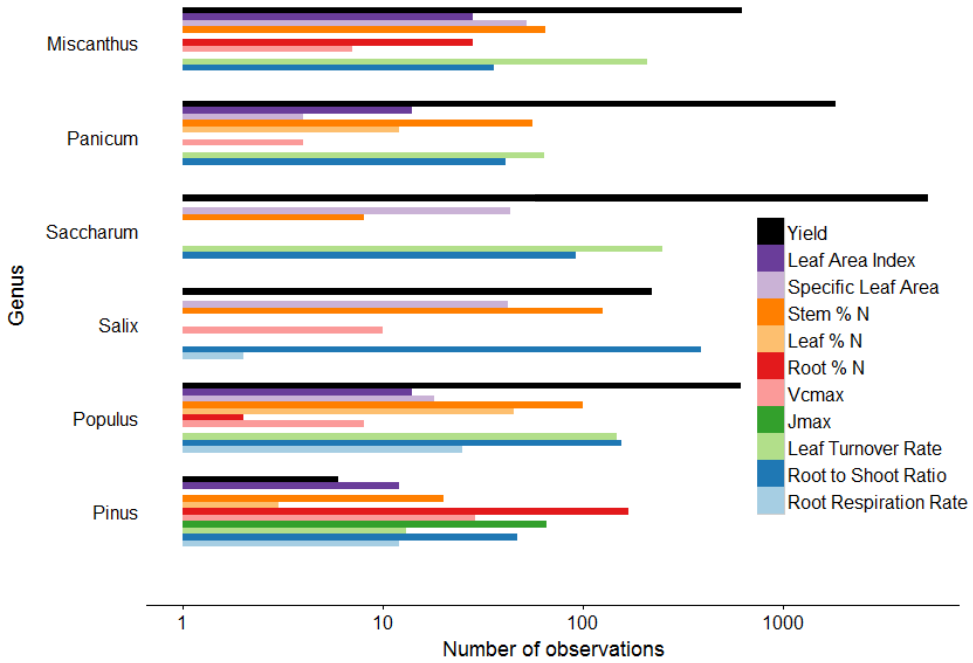
BETYdb:
Database of Biofuel Traits and Yields

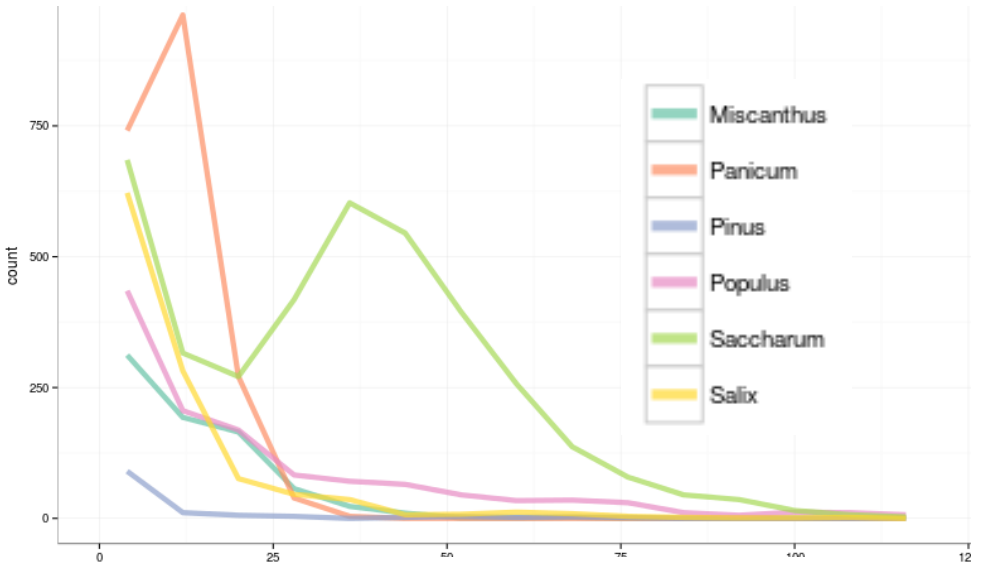
Contents

- Traits, Yields, Ecosystem Services
- Published and primary data

Applications

- Model Parameterization
- Data synthesis
- Outreach

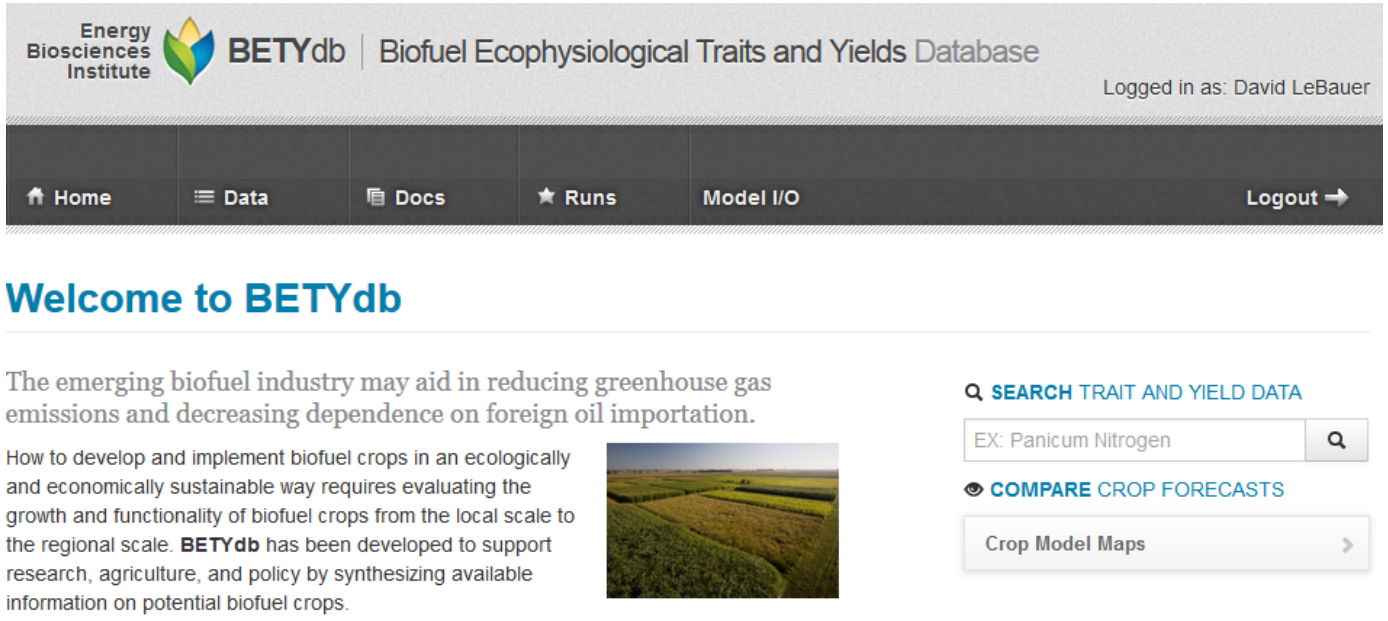


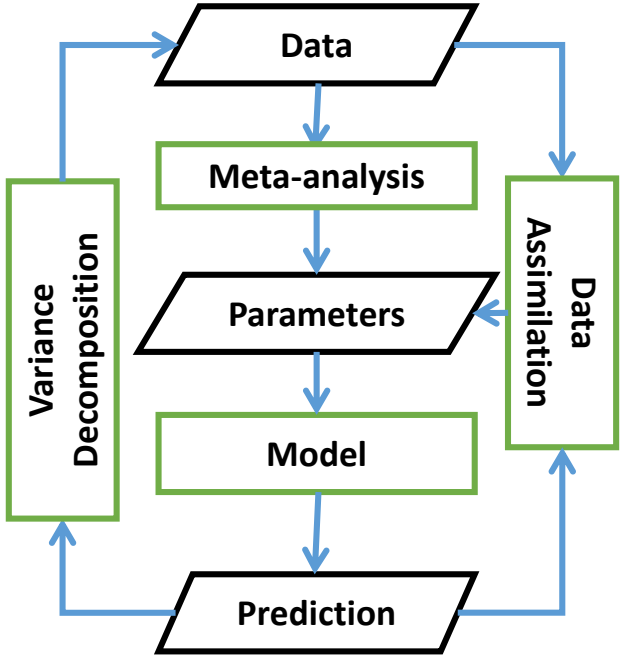


PEcAn:
The Predictive Ecosystem Analyzer

BETYdb:

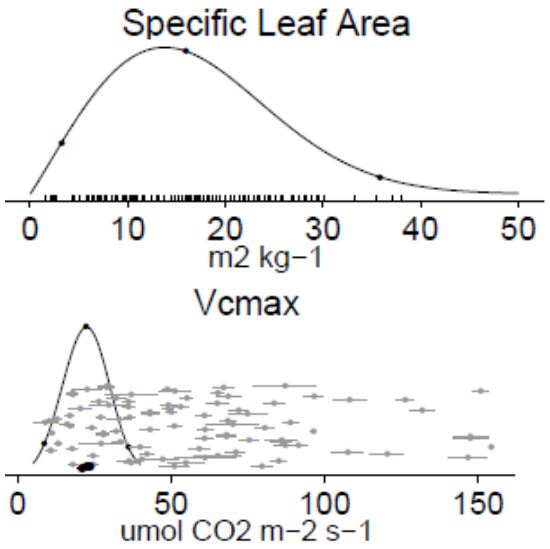
Biofuel Ecophysiological Traits and Yields Database



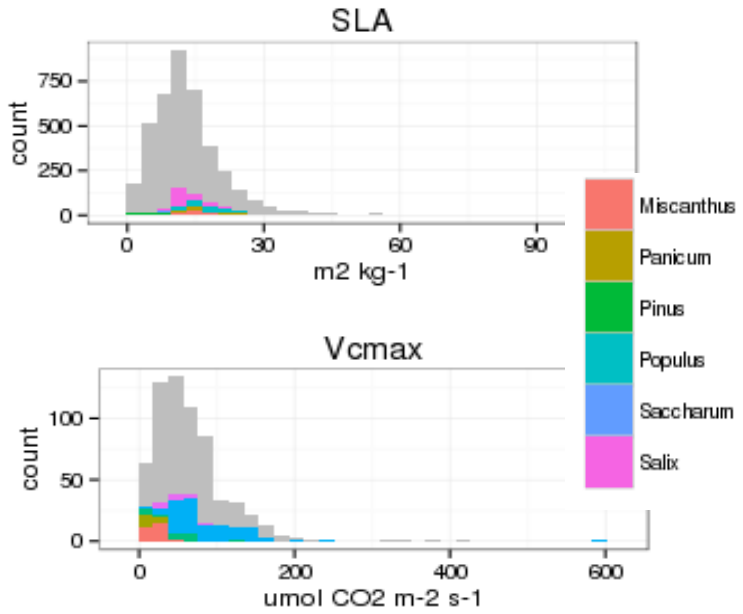


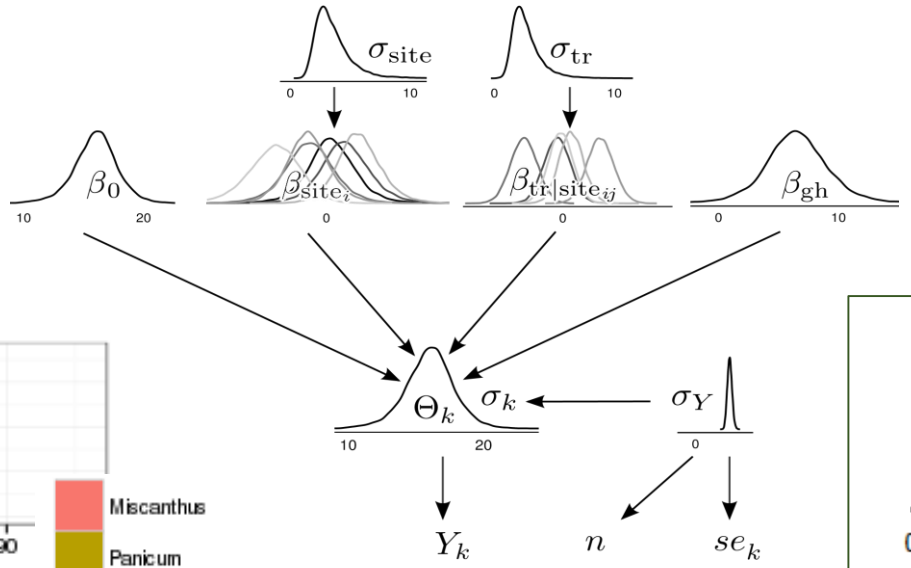
Meta Analysis

Priors

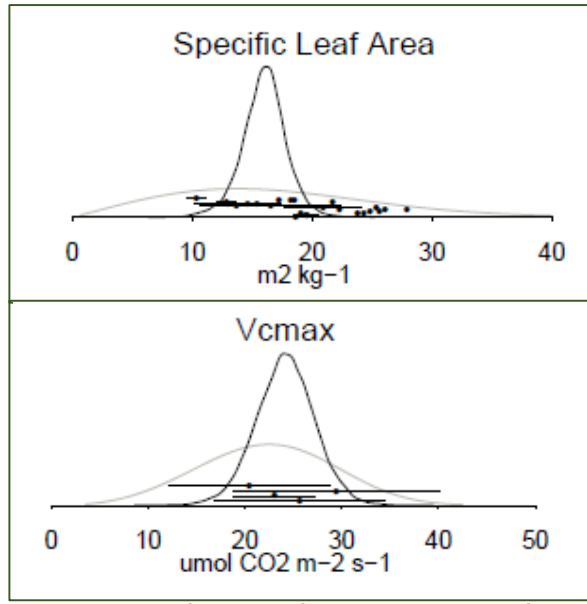


Data



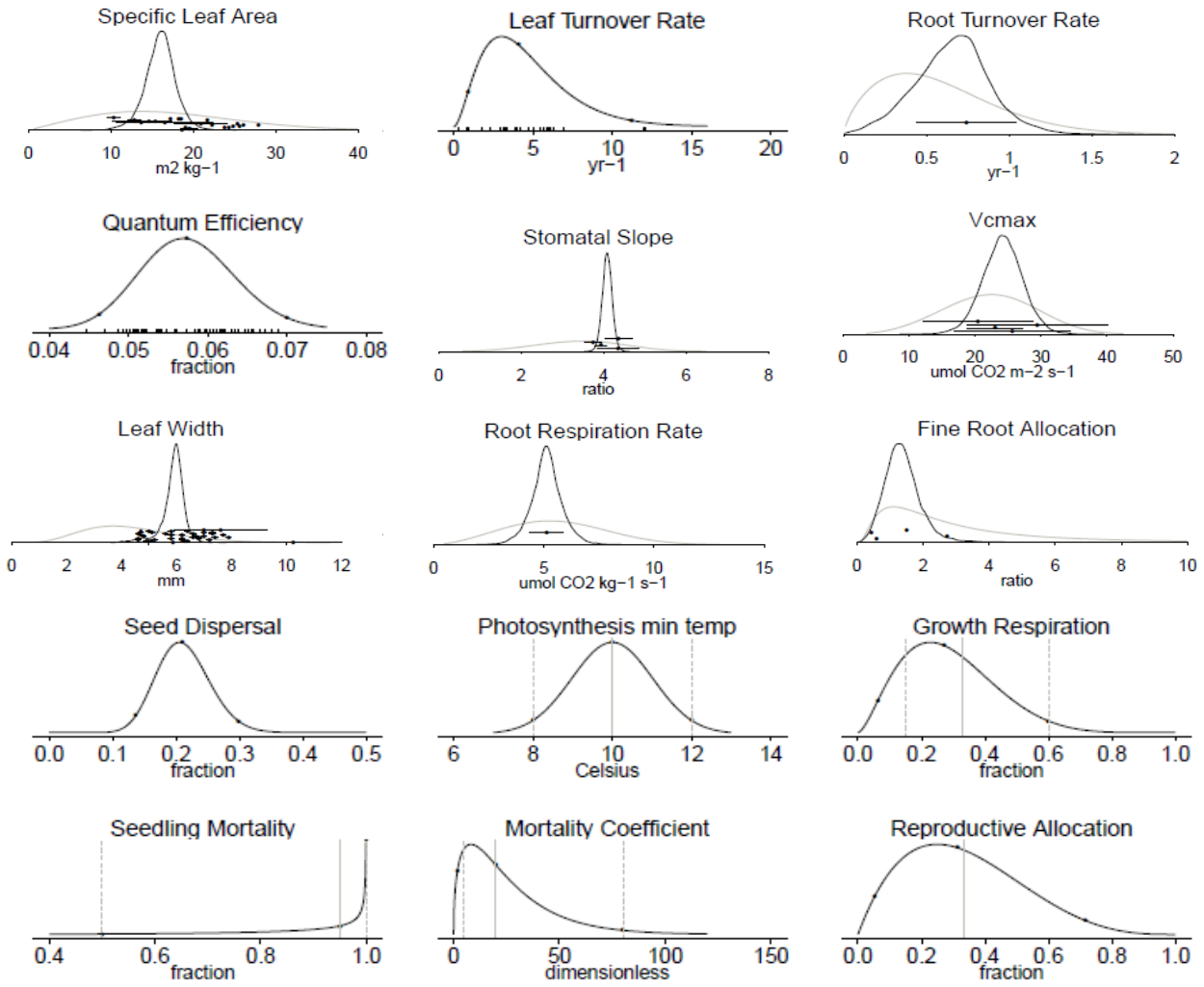


Model Parameters



LeBauer et al 2013 Ecological Monographs

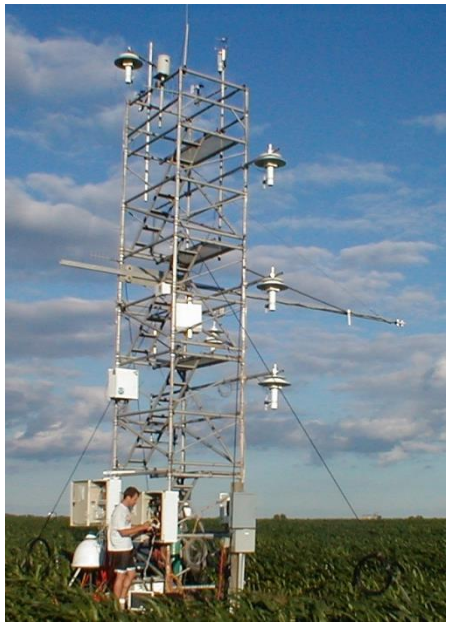
Model Parameters

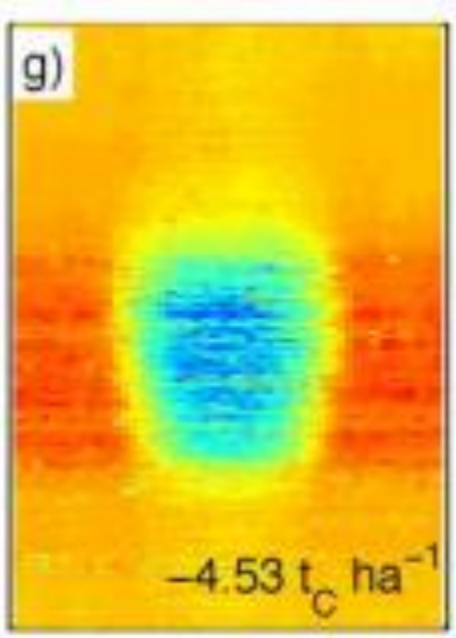


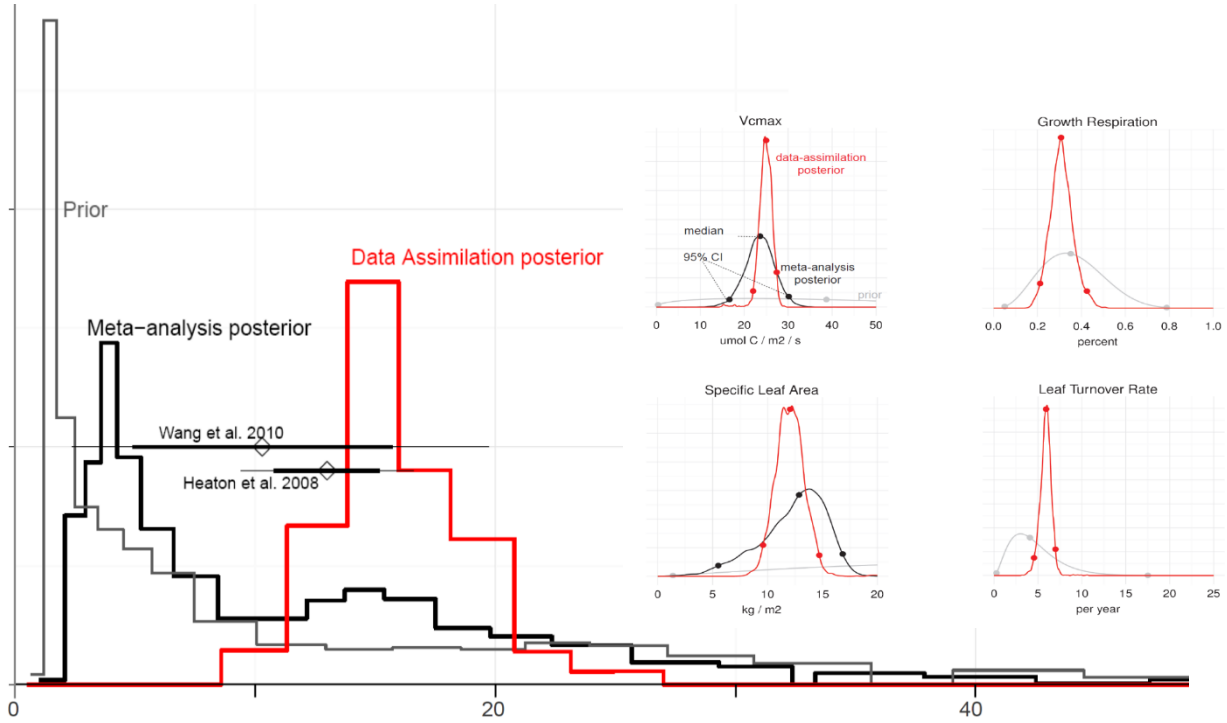
LeBauer et al 2013 Ecological Monographs

Data Assimilation

Net Ecosystem Exchange
2/h (from 10hz) x 1 year



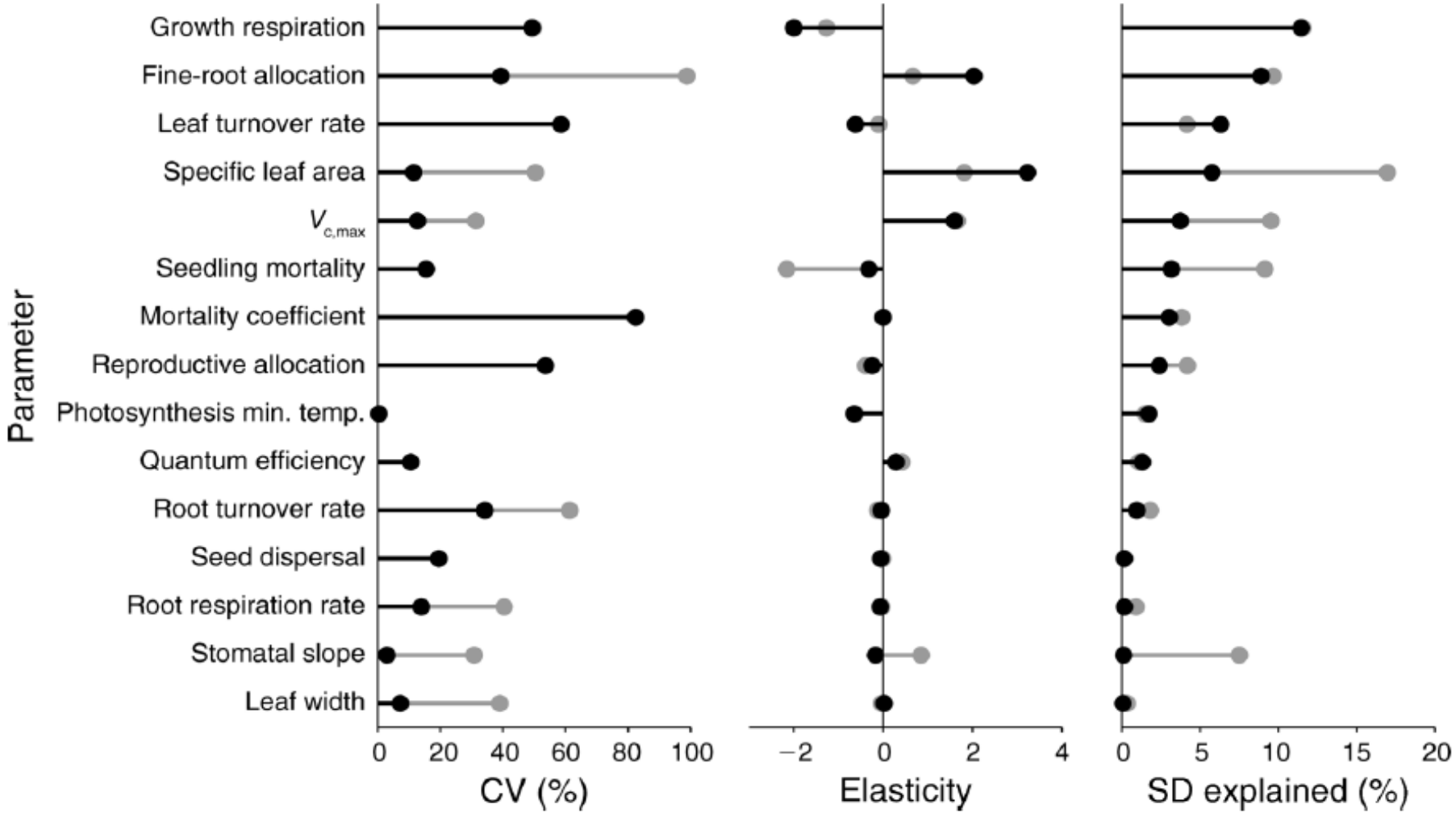




Zeri et al 2013
Global Change Biology-Bioenergy

LeBauer et al, *in prep*

Variance Decomposition: Sources of uncertainty

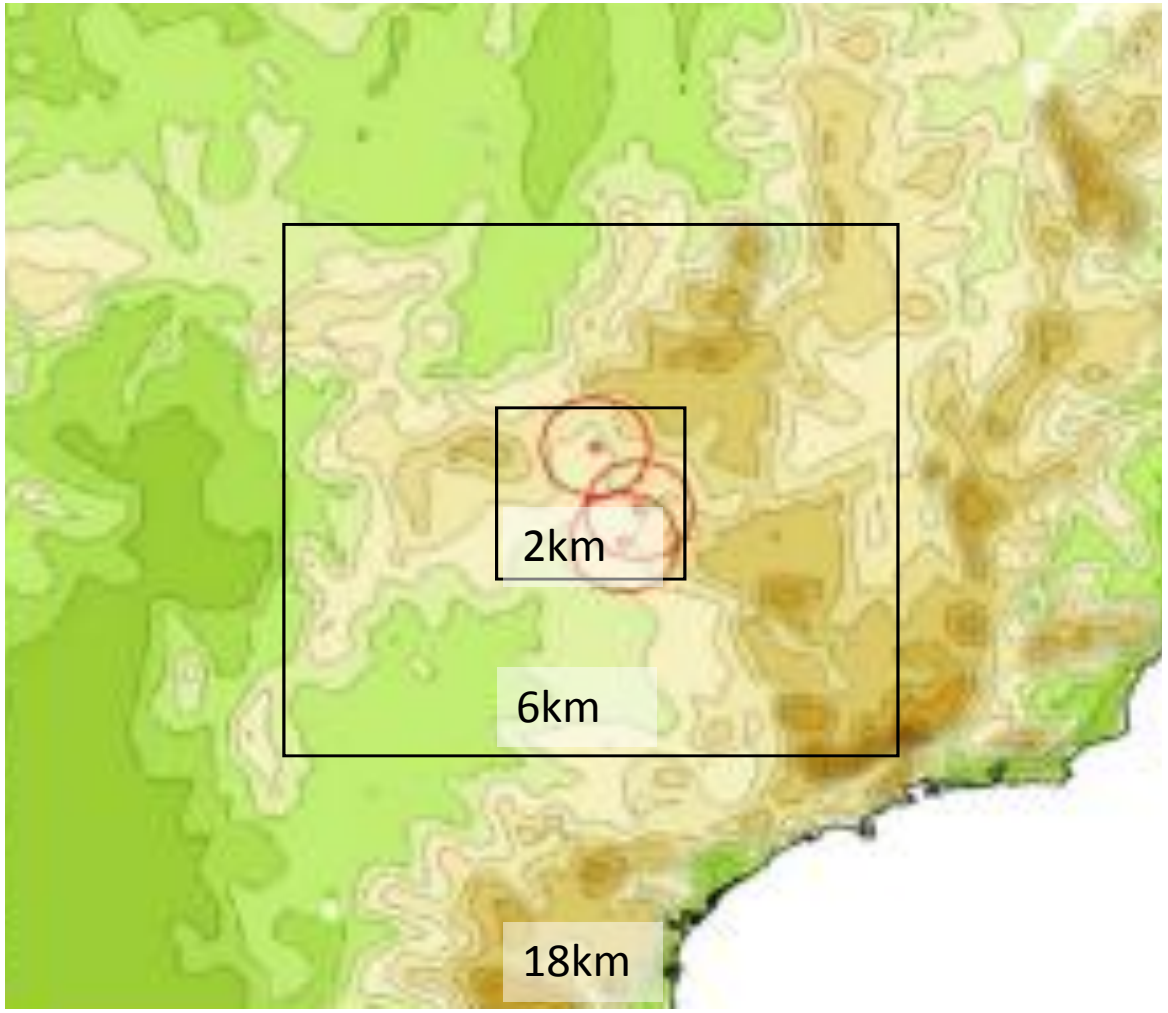


DAVID S. LEBAUER ET AL.

Ecological Monographs
Vol. 83 No. 2

A look at current and future research

Dynamical Met Downscaling



Available Data:

ERA-INT 6 hr ~50km grid

Dynamical Downscaling:

1987-2013 at 1 hr @2, 6, 12 km

Statistical Downscaling

IPCC/CMIP-5

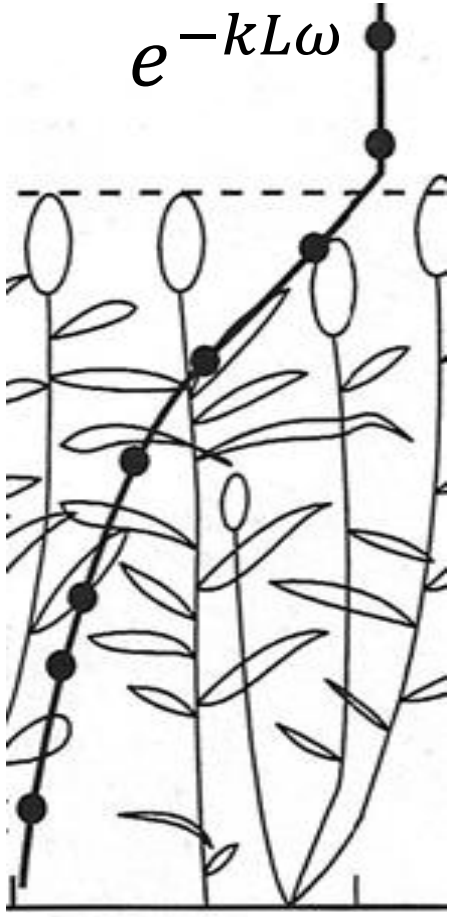
1950-2100 @ " " " "

x 4 scenarios x 5 models

With: Scott Capps, UCLA / Aliveritum; Tao Lin NCSA / CyberGIS program

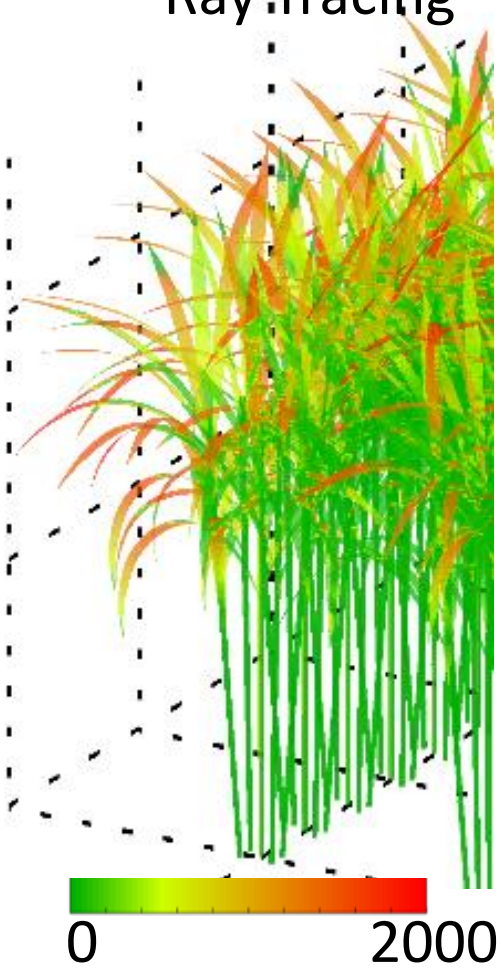
Light Interception: 1 vs 3 dimensions

$e^{-kL\omega}$



0 2000

Ray Tracing



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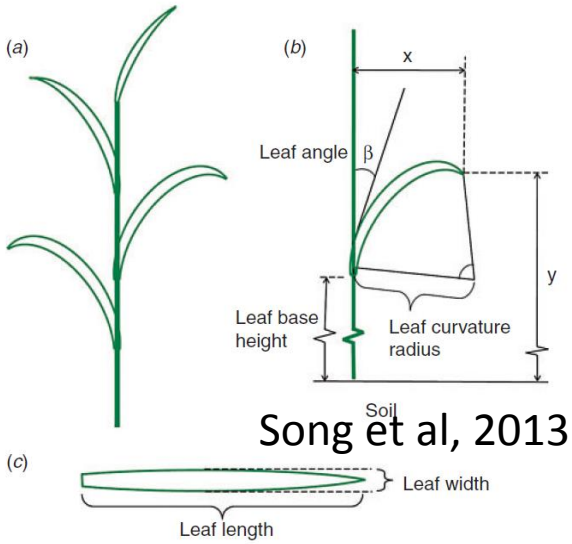
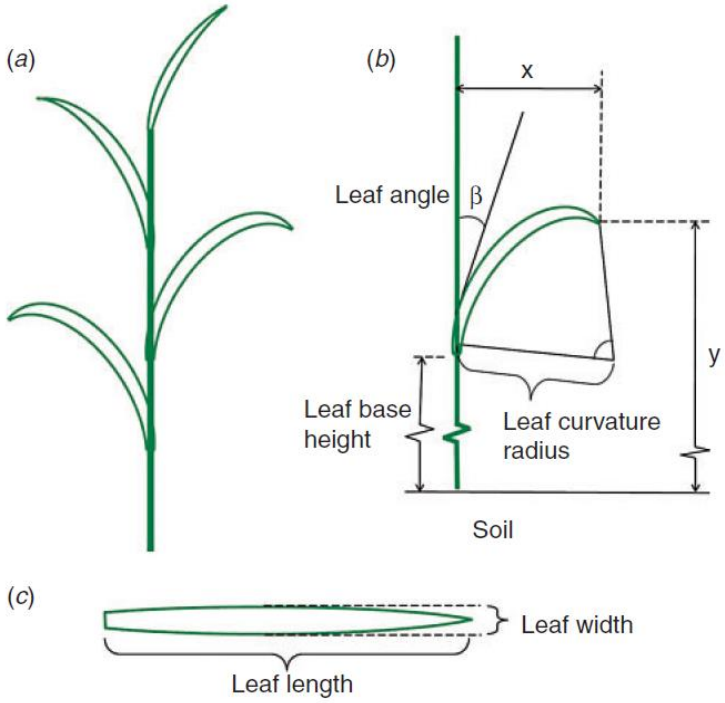


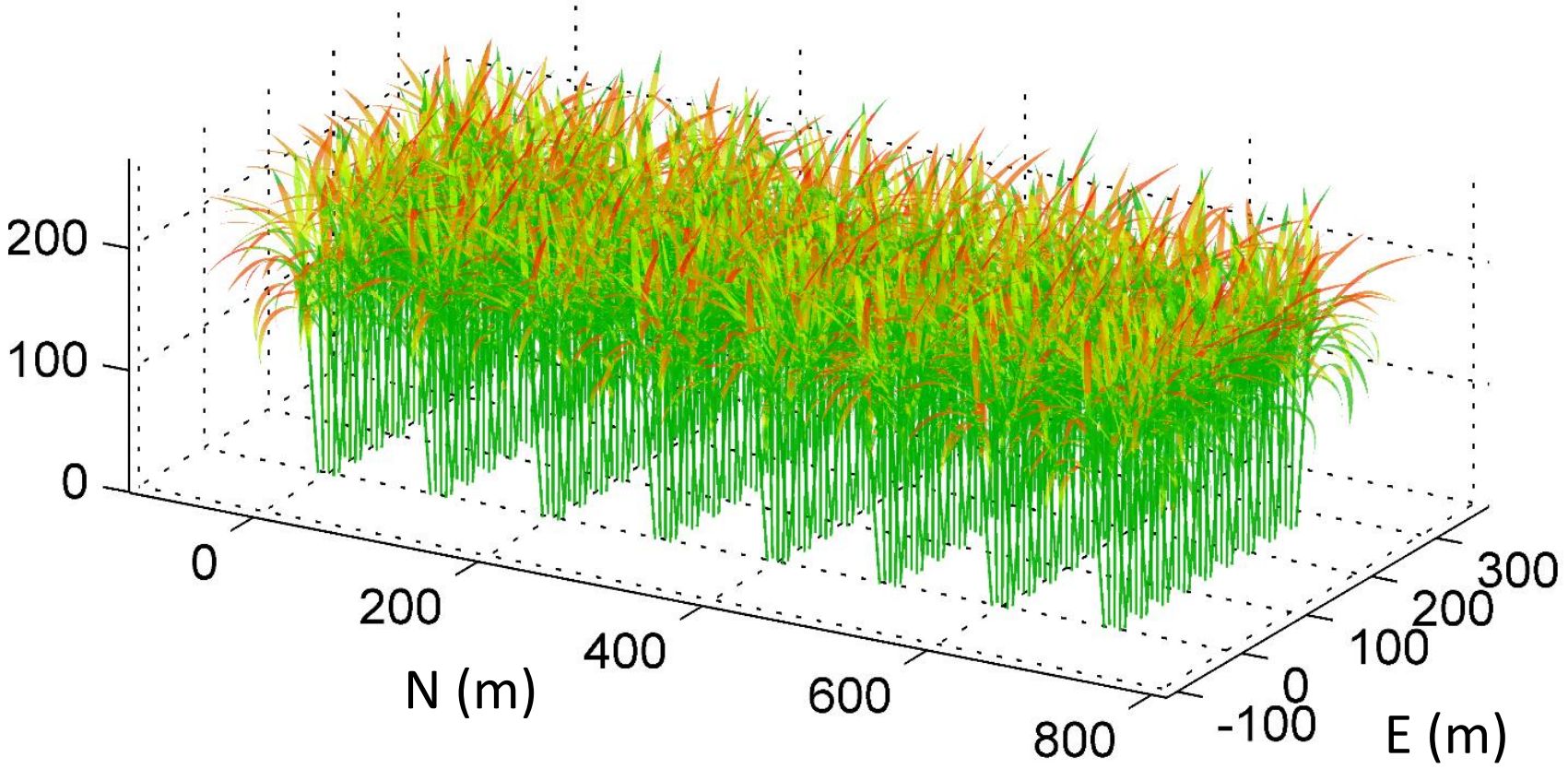
Song et al, 2013

Photosynthetically Active Radiation (W m^{-2})

With Qingfeng Song, Xin-Guang Zhu, Yu Wang Chinese Academy of Sciences

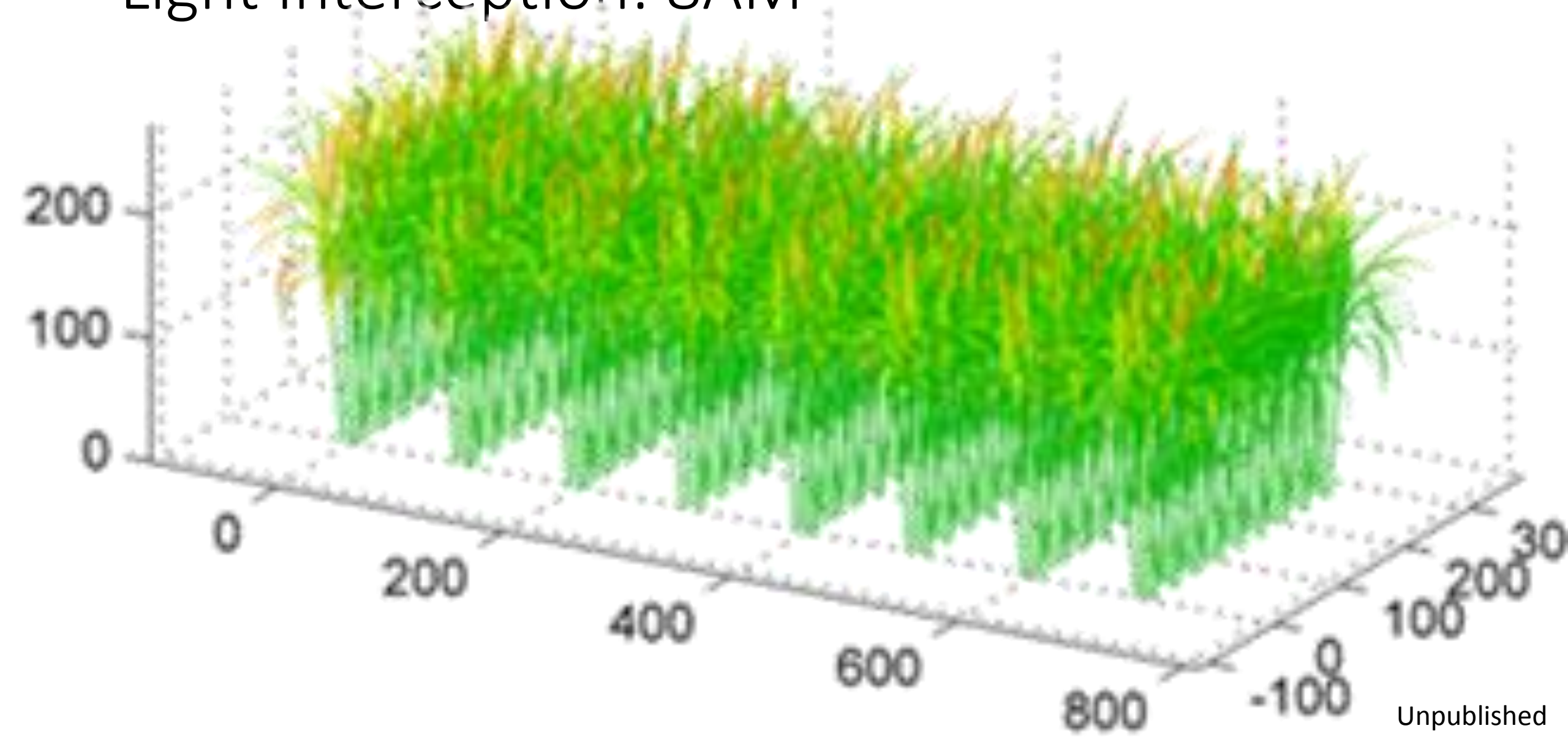
3D Canopy + Ray Tracing Model





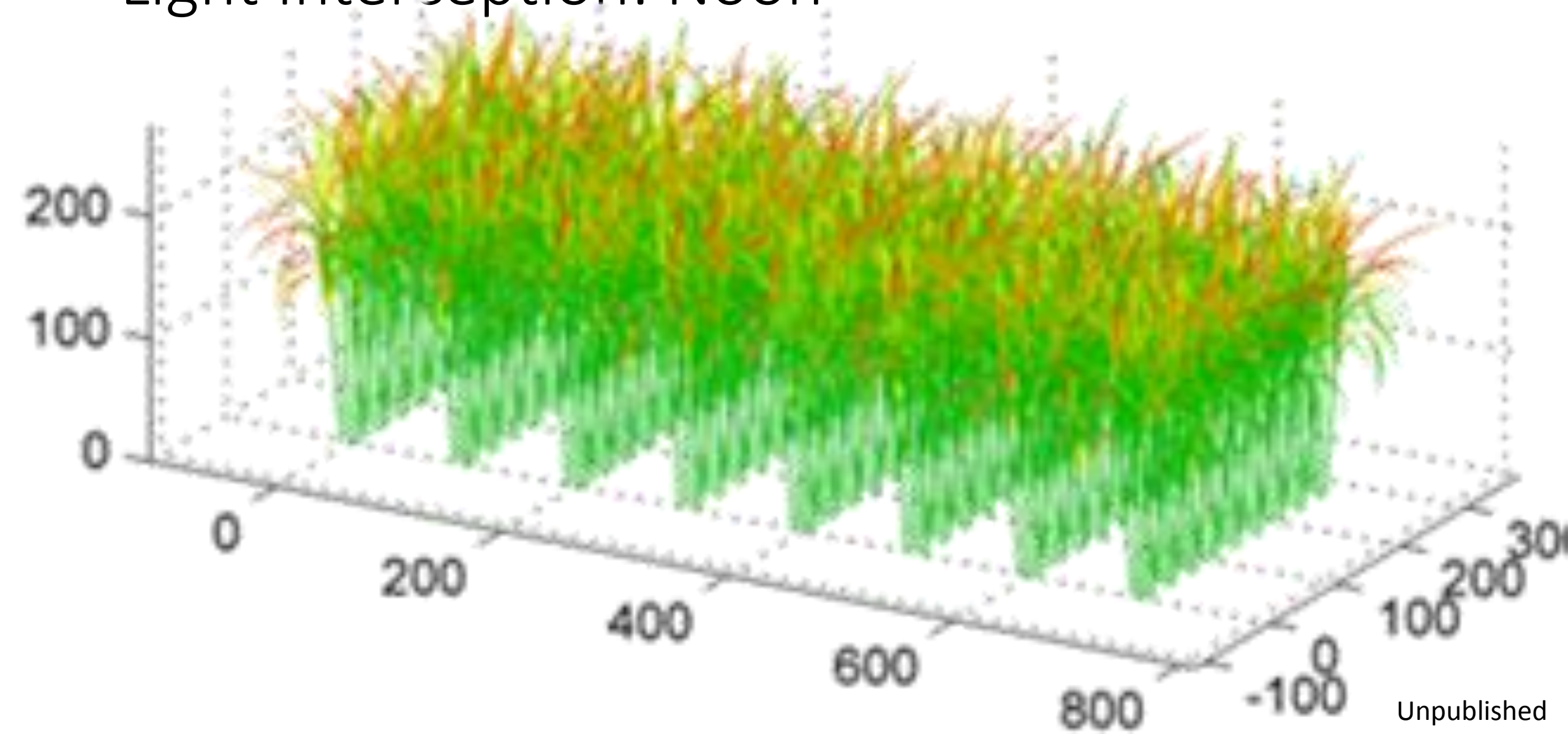
Song et al, 2013

Light Interception: 8AM



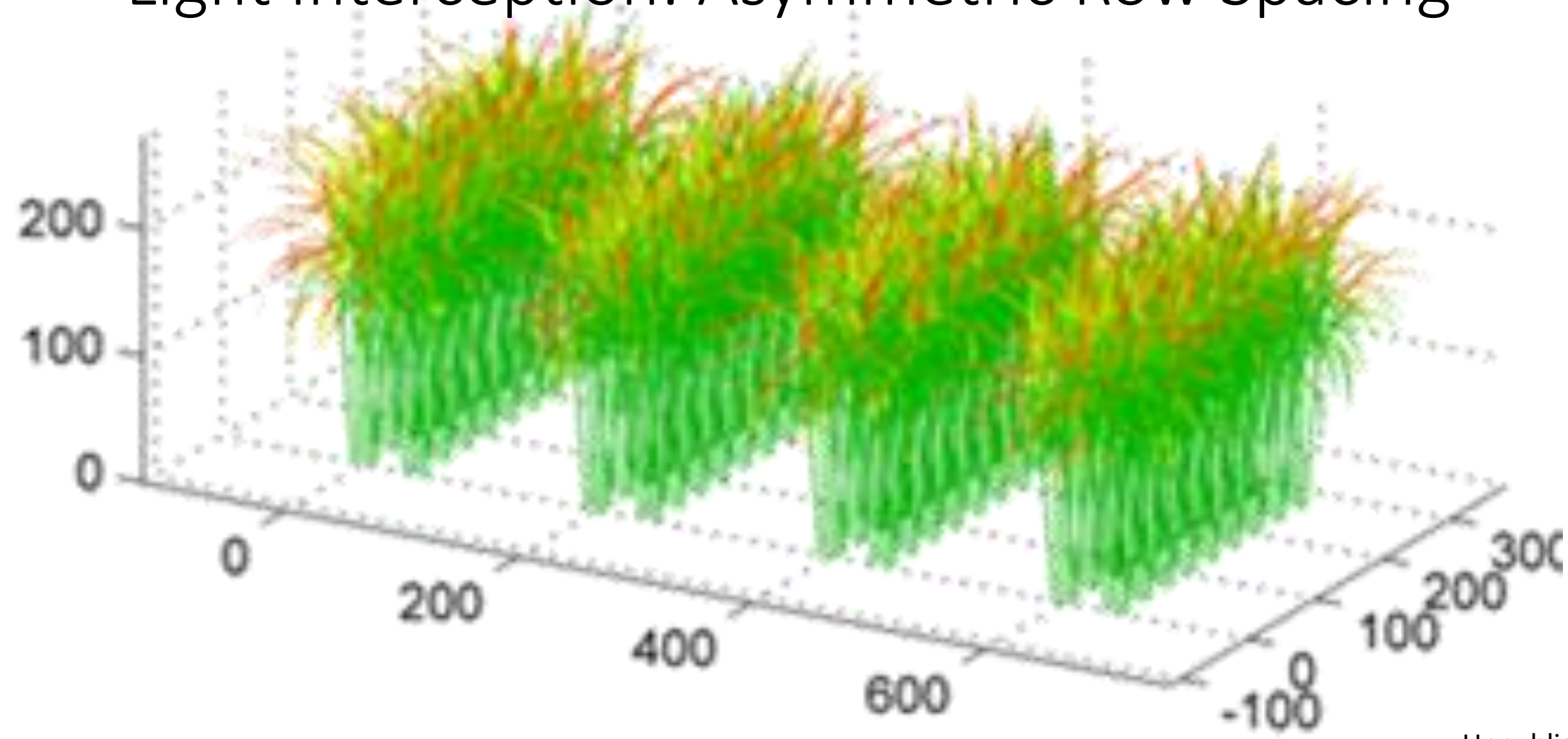
Unpublished

Light Interception: Noon



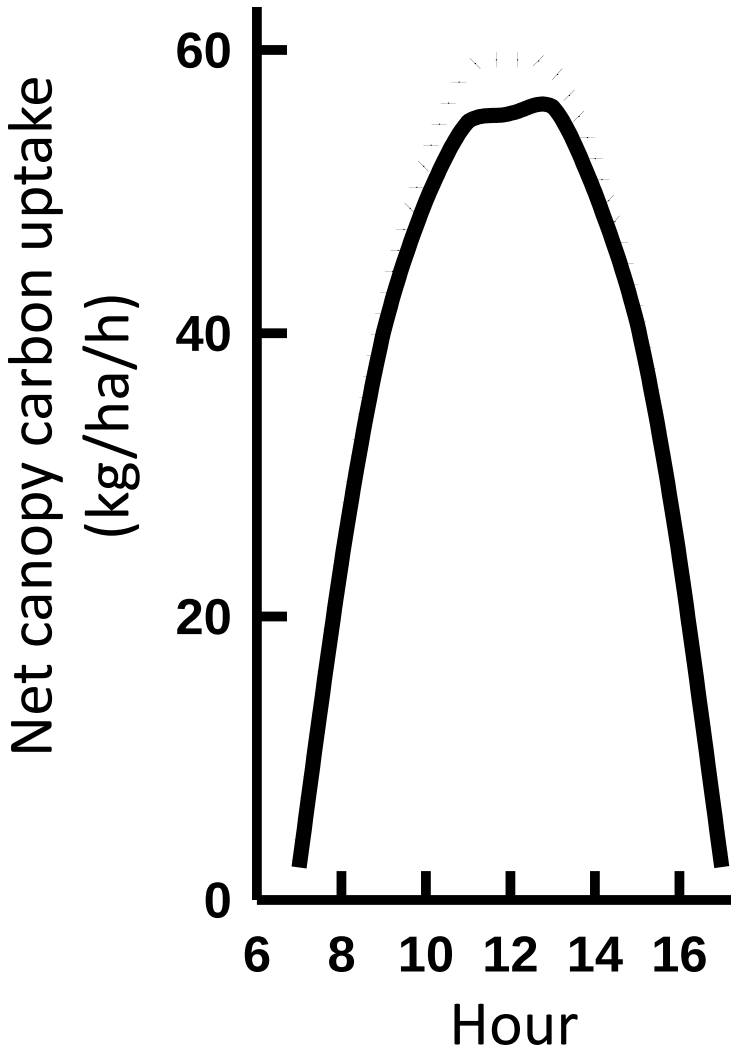
Unpublished

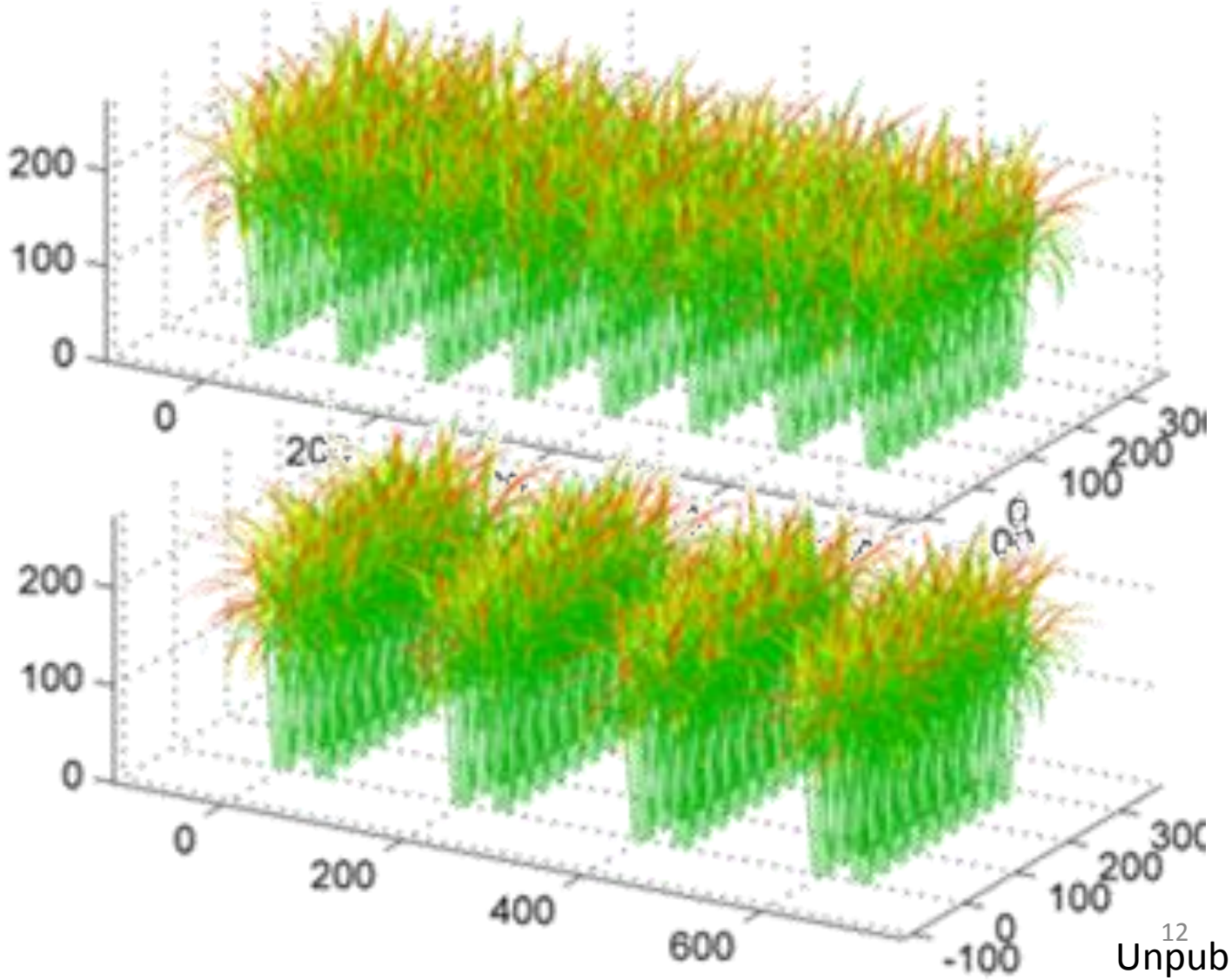
Light Interception: Asymmetric Row Spacing



Unpublished

Effect Row Spacing On Photosynthetic C gain

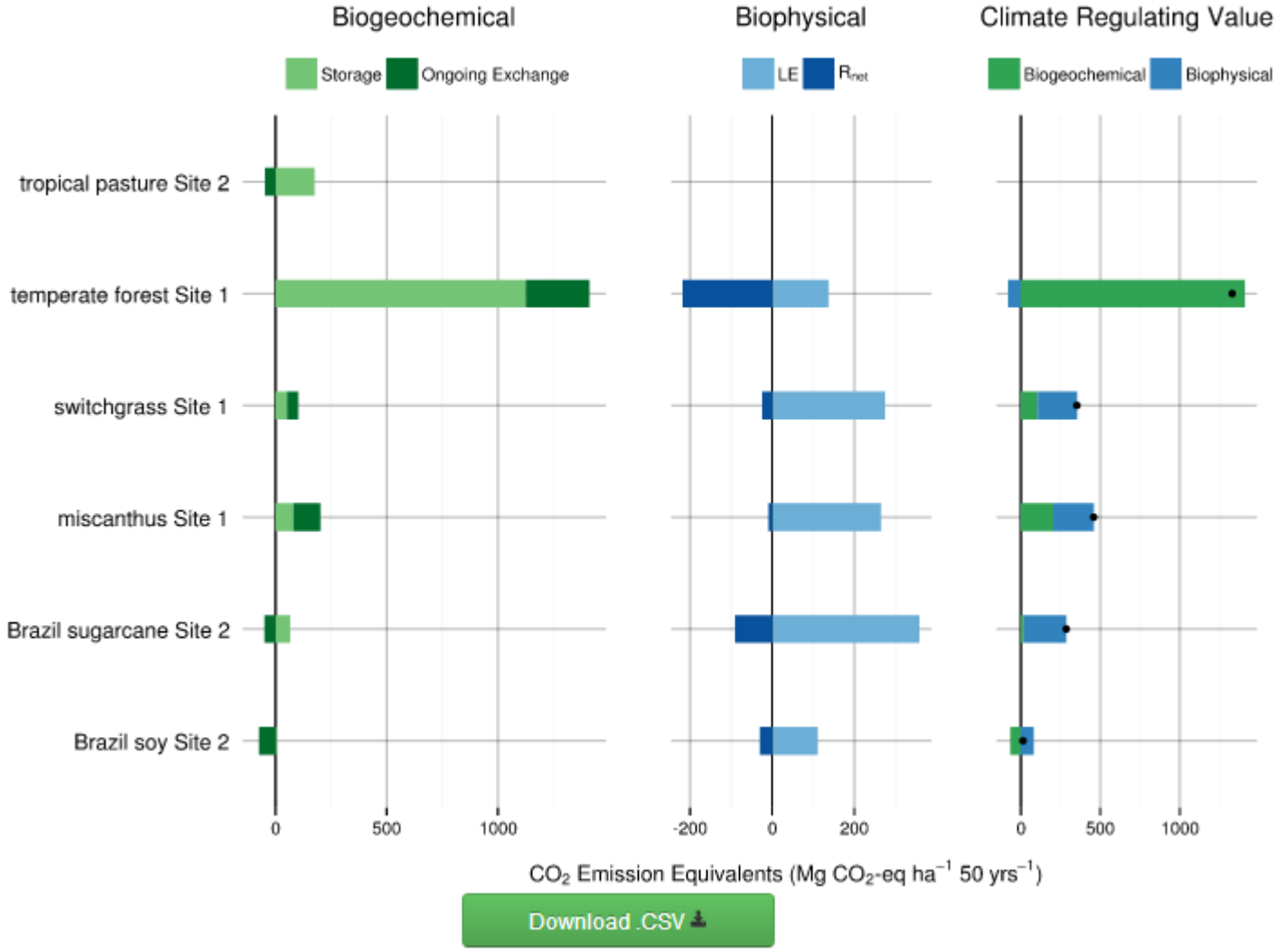




Unpublished

3D Imaging (as input to Ray Tracing Model)

Climate Regulating Value Calculator



Anderson-Teixeira & DeLucia 2011; Anderson-Teixiera et al 2012

Conclusions

Model-data synthesis informs research, management, and policy

Many species are potential biofuel feedstocks

Simulation to explore future scenarios: climate, breeding, management

Coordinated informatics and simulation efforts

Thank you

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