High-Resolution Biogeochemical Modeling of Bioenergy Landscapes

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Colorado State University

Natural Resource Ecology Laboratory

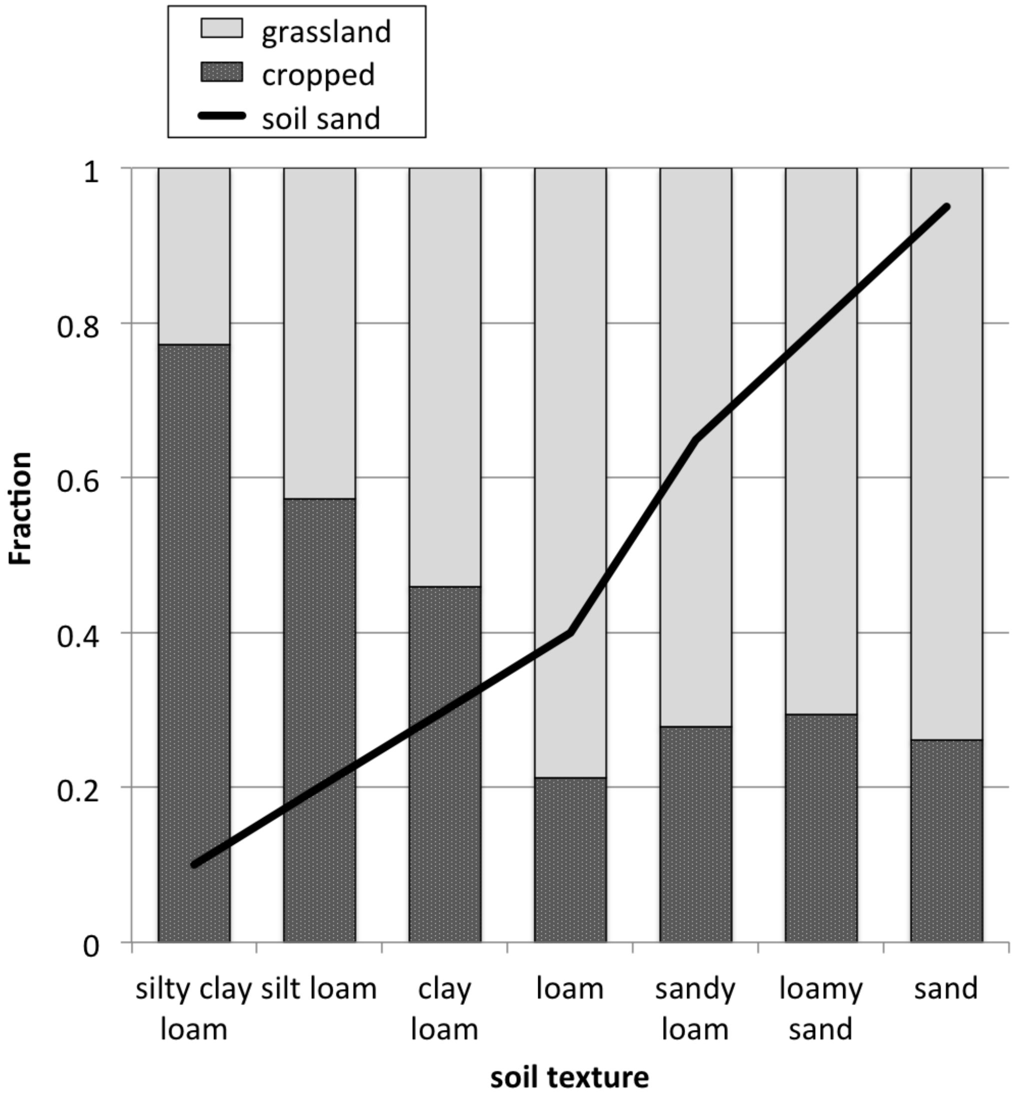
MAS BioEnergy

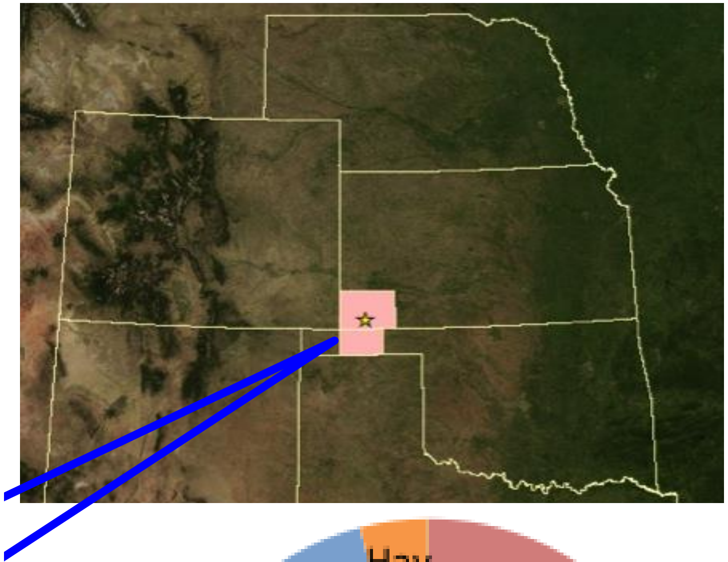
Goal: understand cellulosic crop landscape tradeoffs

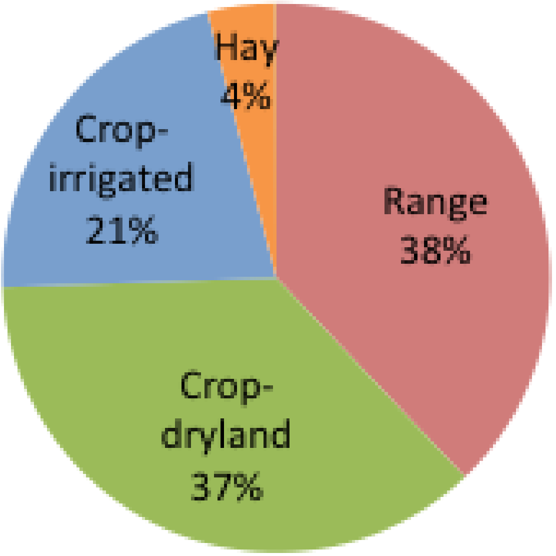
- Basic strategies for ***landscape design*** and ***management practices*** poorly understood:
  - Intensification vs. extensification?
  - Land sharing vs. land sparing?
- Implications for GHG ***intensity*** difficult to generalize
  - Intensification based on increasing N fertilizer rates:

$$\frac{(N_2O-)-(soilC-)}{yield-} = ??$$

Case study- Hugoton KS







Methods- Spatial data inputs

- Nationwide intersect of GIS coverages representing environmental, management variables

<u>Data sources, scale, years covered:</u>

- Weather- NARR
  - 32 km, 1979-2009
- Soil type- SSURGO
  - ~10 m, NA
- Land use- NLDC
  - 30 m, 2006
- Irrigation- MIrAD-US
  - 250 m, 2007

Methods- High-throughput analysis

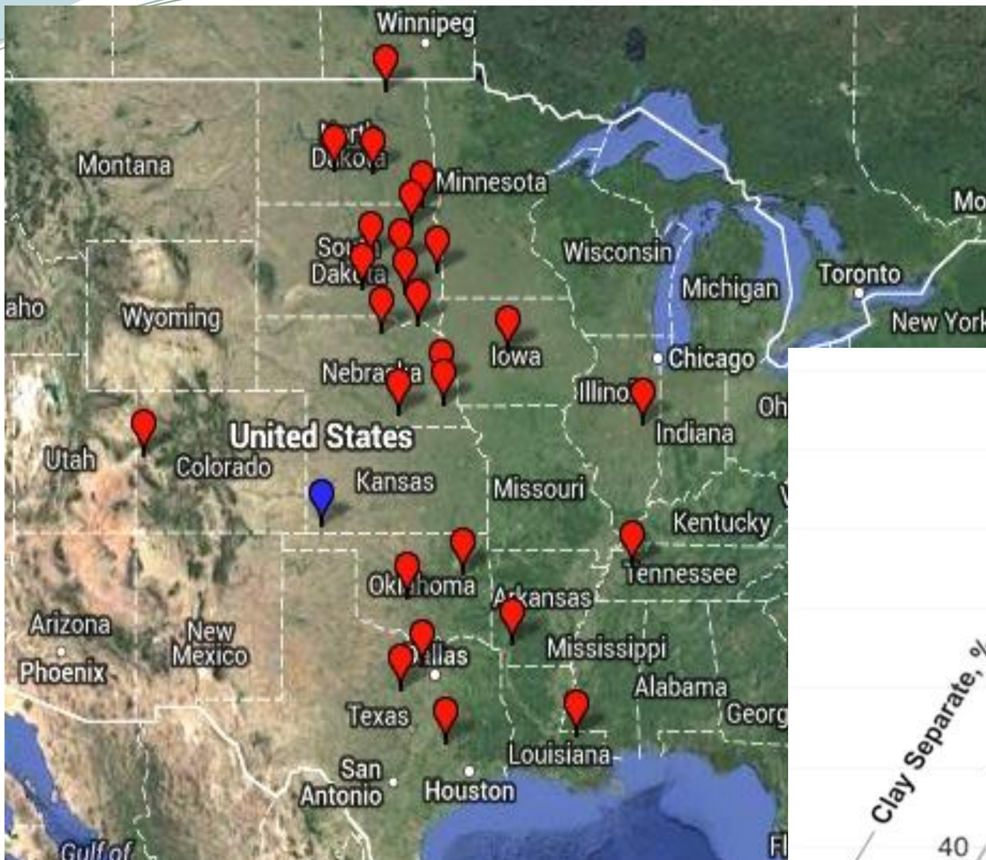
- Parameterization/validation and landscape analysis automated in **Python**
  - Model pre-initialized for all US soil/climate/landuse combos
  - Capability to run 100s of forward simulations in parallel on NREL cluster
- Data analysis also automated
  - Data processing in **SQLite**
  - Figures generated with **matplotlib**

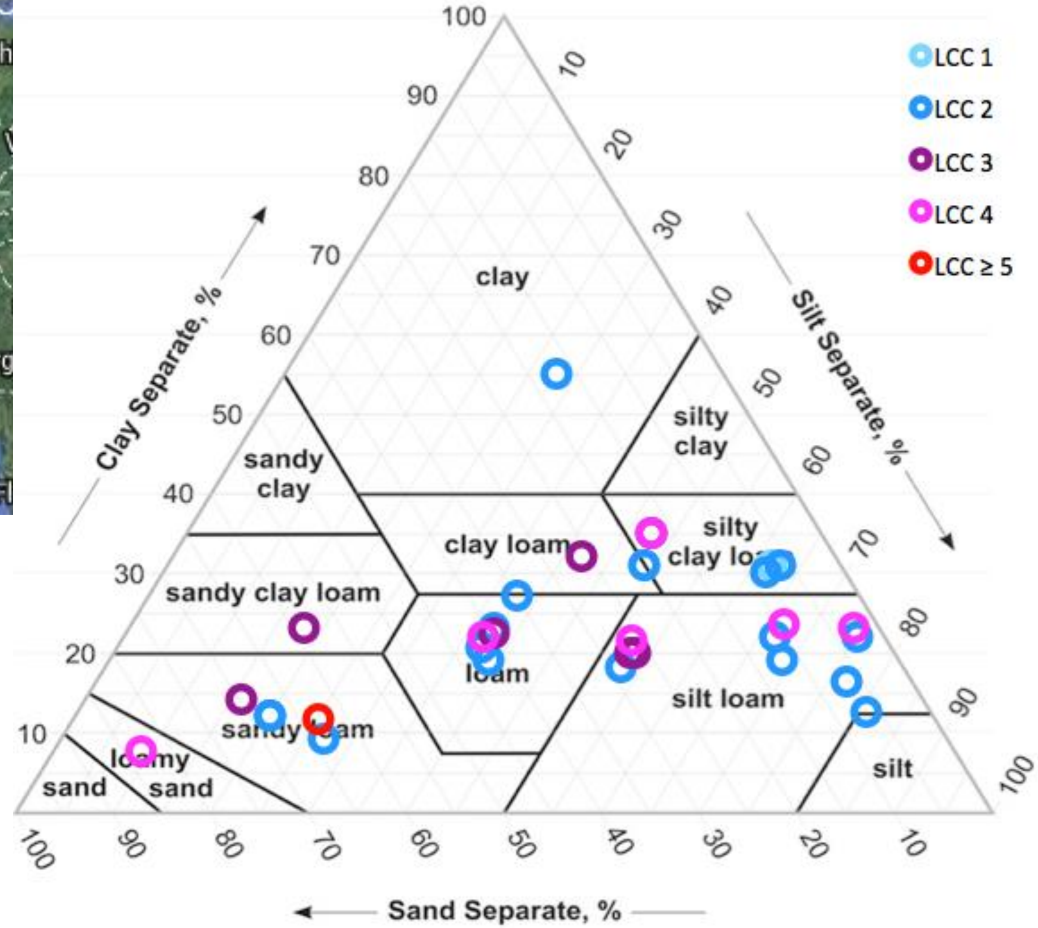
```
def n2o_fig(csv_fpath, plot_file):
    """Generate modeled-vs-measured N2O figure
    :param csv_fpath: full path to .csv file containing tr
    :param plot_file: name with which figure will be saved
    :return:
    """
    categories, measured, modeled, ns, slopes, intercepts,
        extract_csv_series(csv_fpath, 2, "N2O_N", "n2o_tot
    meas_err = extract_csv_series(csv_fpath, 2, "N2O_sterr
    ipcc_min_max = extract_csv_series(csv_fpath, 2, "IPCC_
    x_error = meas_err[1]
    ipcc_min = ipcc_min_max[1]
    ipcc_mid = meas_err[2]
    ipcc_max = ipcc_min_max[2]

    # for each extracted category, create a plot series, a
    combined_measured = []
    combined_modeled = []
    for i in range(len(categories)):
        color = next(default_colors)
        for j in range(len(ipcc_min[i])):
            # bands representing IPCC range
            range_x = [ipcc_min[i][j], ipcc_max[i][j]]
            range_y = [modeled[i][j], modeled[i][j]]
            mid_x = [ipcc_mid[i][j]]
            mid_y = [modeled[i][j]]
```

Parameterization dataset

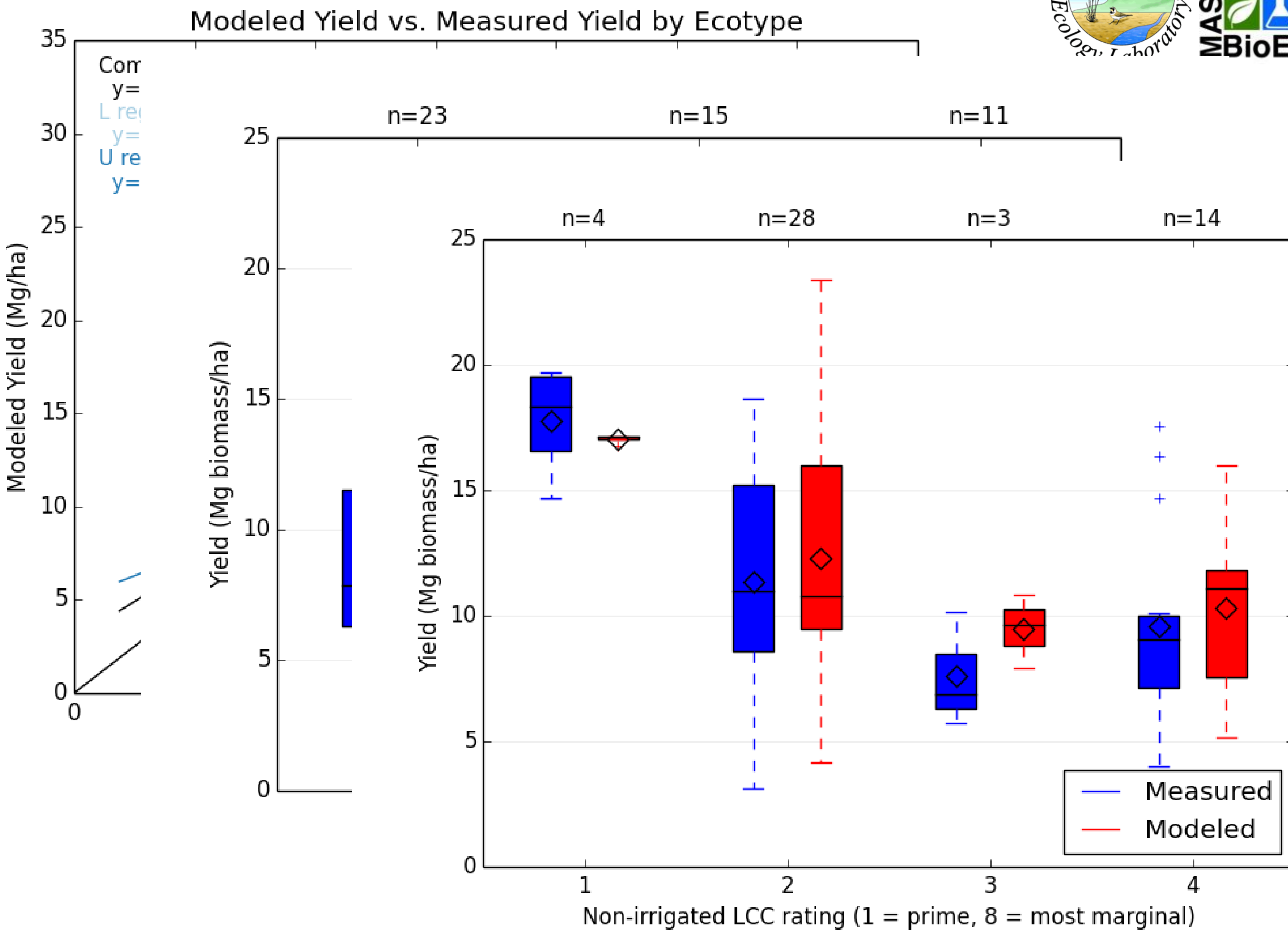
- 31 sites
- 80 treatments



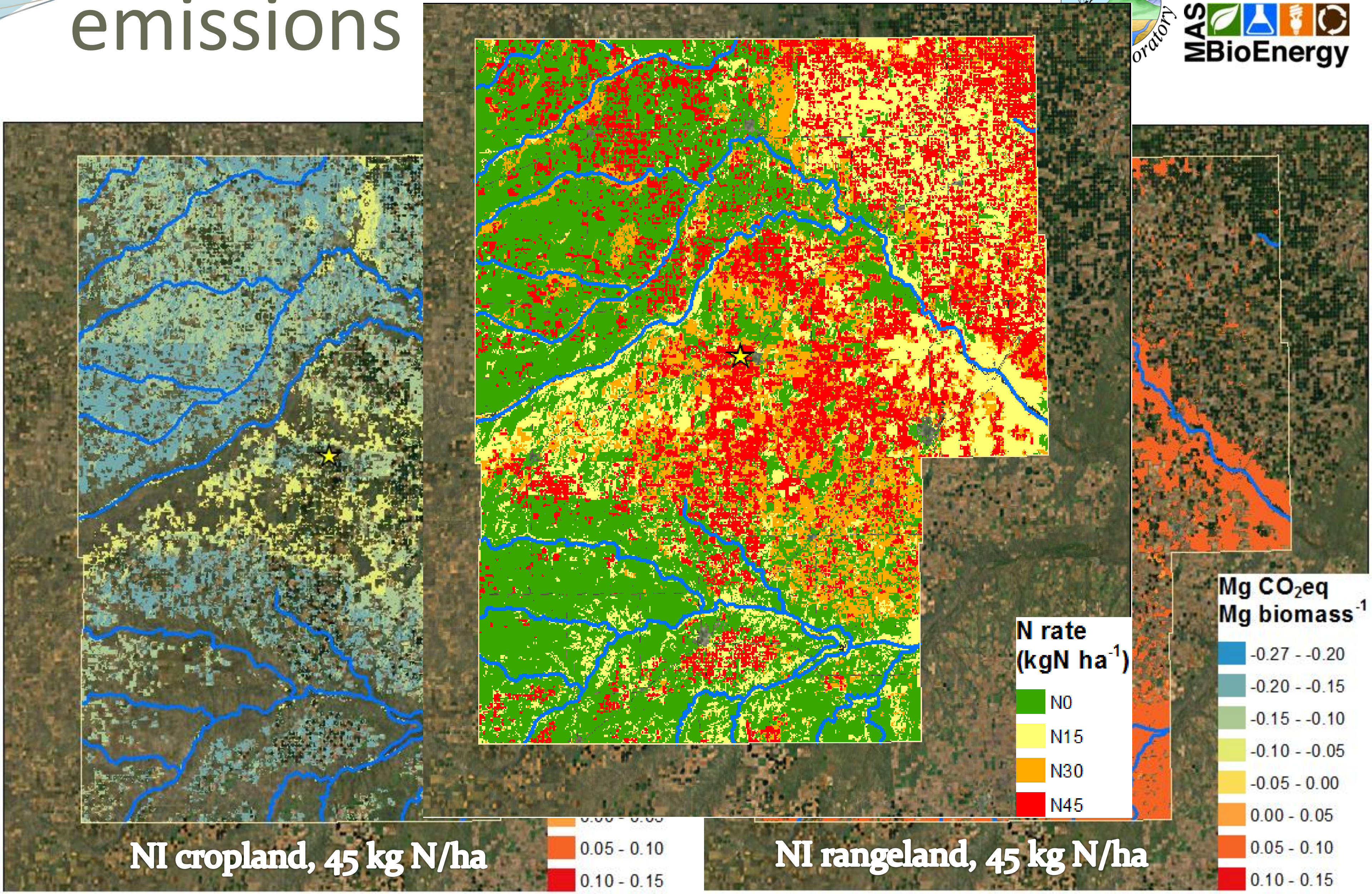


- Wide range of soils, climates, agricultural suitability ratings covered

Yield validation results



Minimizing landscape GHG emissions



Preliminary conclusions

- Landscape-scale analysis possible through model run automation **if standardized data on soils, climate, land use history are available**
- With careful parameterization, DayCent capable of **accurate yield predictions**, responsive to **environmental & management gradients**
- Extrapolating across a real-world bioenergy landscape, cultivation GHG intensities show **wide variation over small spatial scales**

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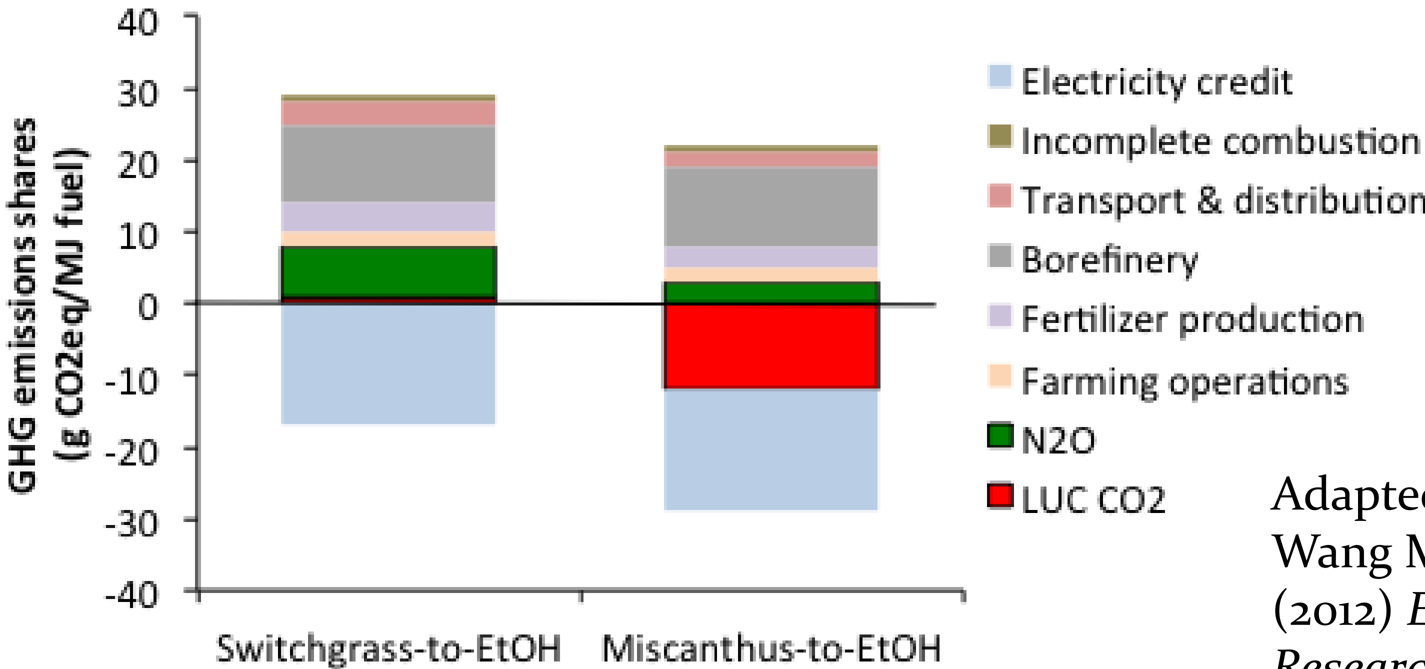
Thank you!!

Ecosystem emissions in the biofuel lifecycle

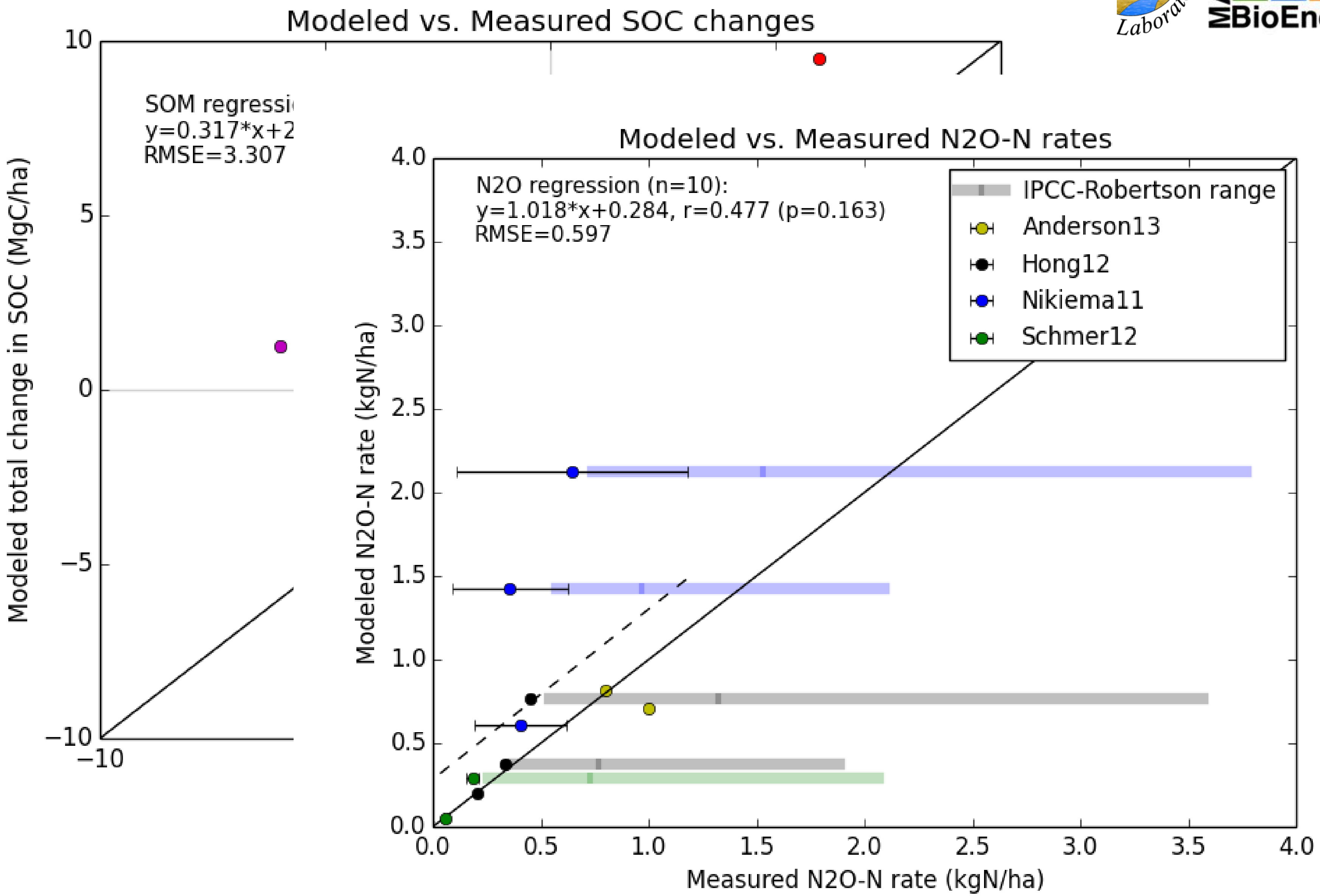
- Ecosystem emissions are significant in magnitude…



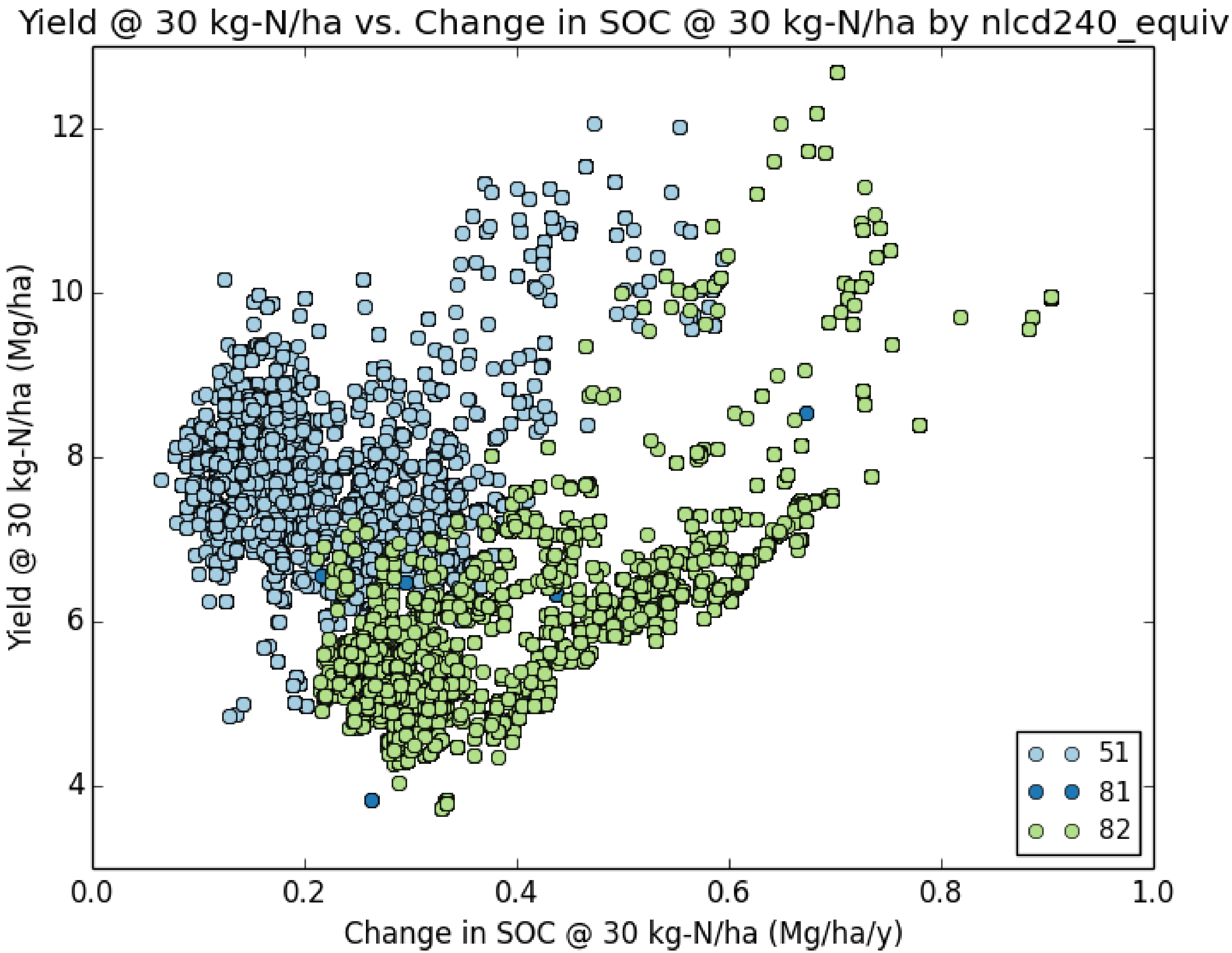
Adapted from Wang M *et al.* (2012) *Envi. Research Letters*

- … and highly variable!
  - Spatially- Zhang X *et al.* (2010) *GCB Bioenergy*
  - By 'management'- Davis SC *et al.* (2013) *GCB Bioenergy*

GHG validation results



Scaling to full landscape



Integrating other tools for policy-relevant results