Impacts of multiple environmental changes on water and carbon cycles in the terrestrial ecosystems of the Southeastern United States

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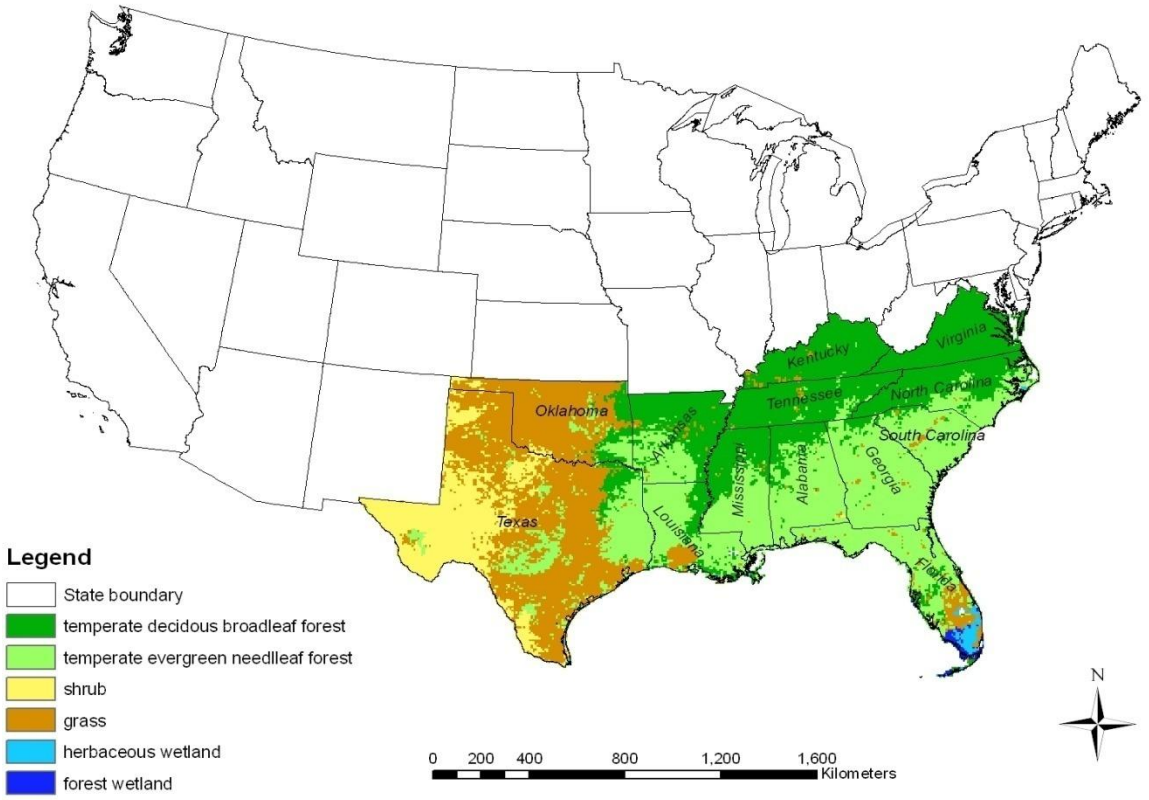
Outline

- Study region and questions
- Methodology
- Multiple environmental changes in the Southeastern United States
- Impacts on carbon fluxes
- Impacts on water fluxes
- Impacts on the interaction of carbon and water fluxes
- Uncertainties

Study region



Questions

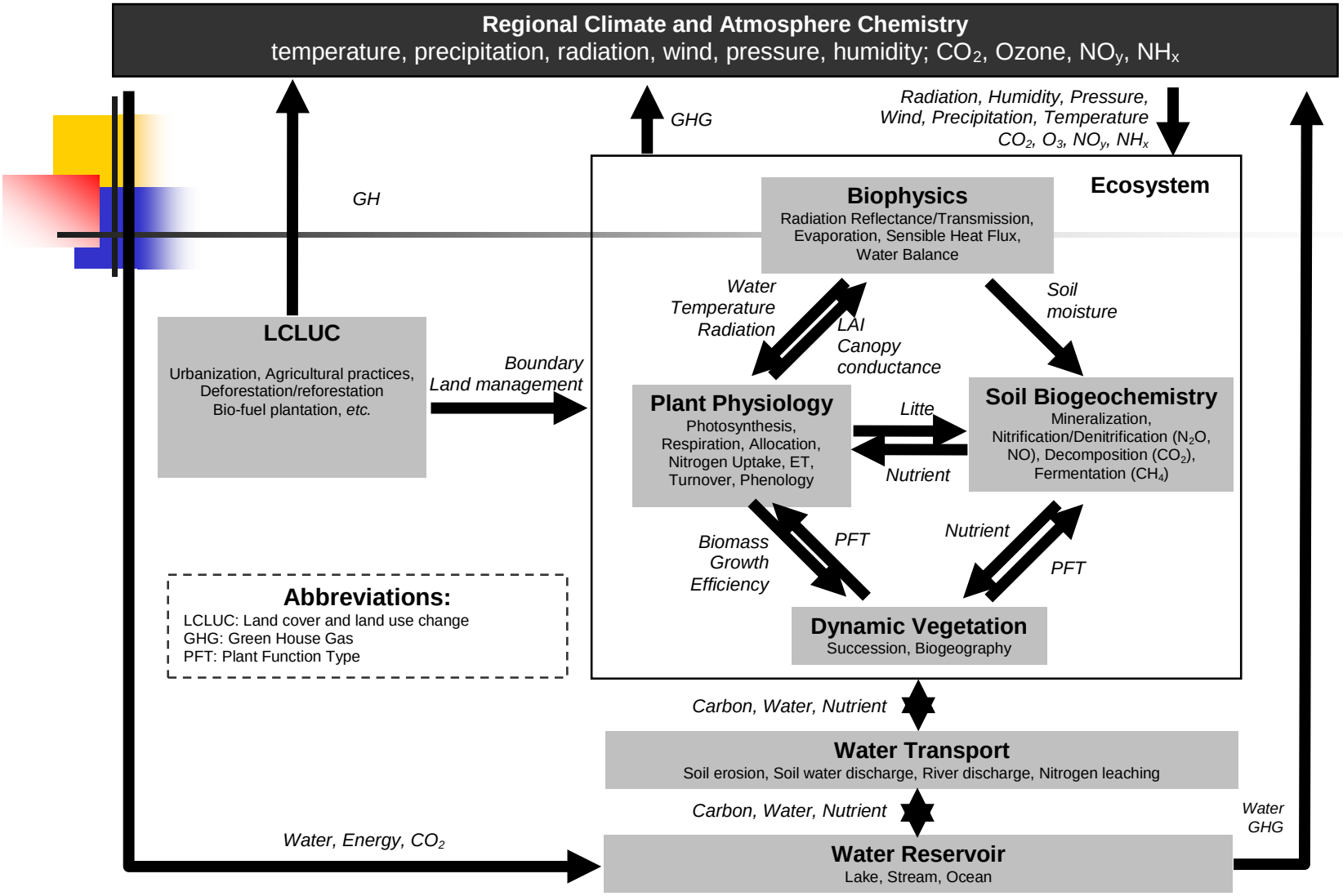
- Rapid environmental changes
  - Land-use and land-cover types
  - Climate: precipitation, air temperature, radiation
  - Air pollution: tropospheric ozone, nitrogen deposition
- Water availability
- Bio-energy production
- Water and carbon tradeoff

Methodology

- Dynamic Land Ecosystem Model (DLEM)
- Simulation scenario design

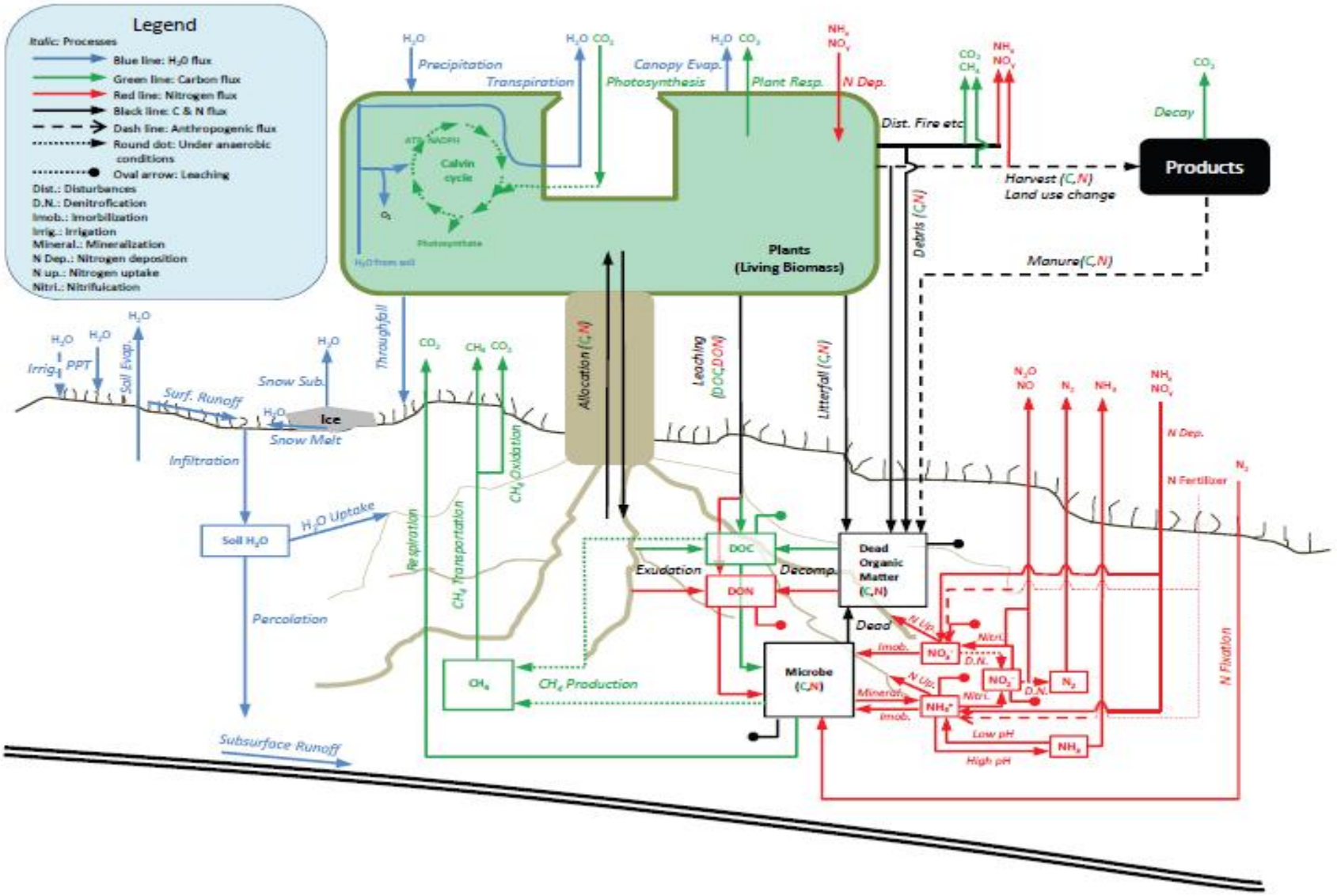
Dynamic Land Ecosystem Model (Tian et al. 2009)

- Daily time step
- Multiple GHG emissions
- Multiple factors:
  - CLM, LUCC, NDEP, Ozone, CO2, Disturbances, land management, etc.
- Coupling of carbon, water and nitrogen cycles
- Widely applied in different regions

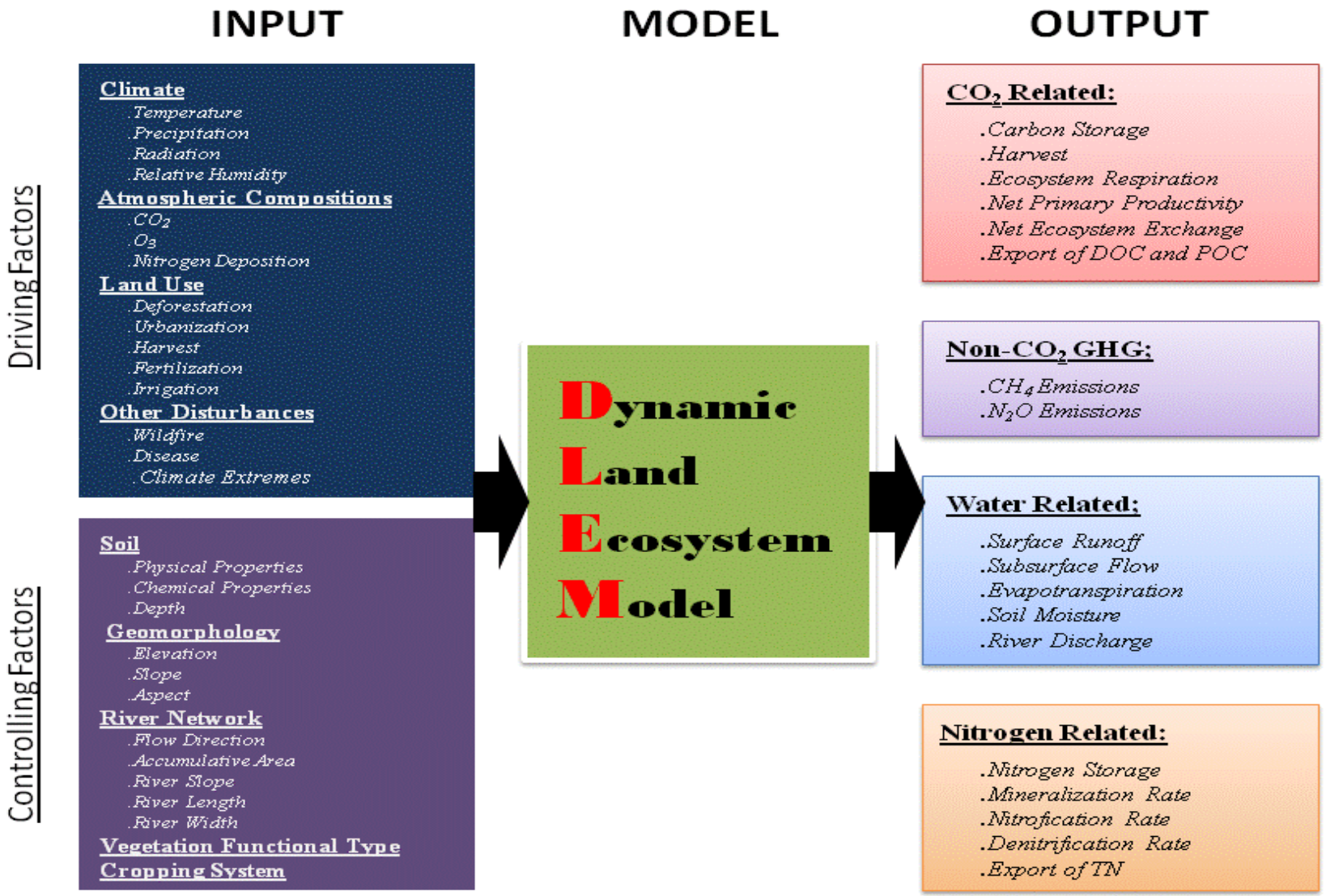


Key components of Dynamic Land Ecosystem Model (DLEM)

DLEM Framework



DLEM Framework – Input and Output



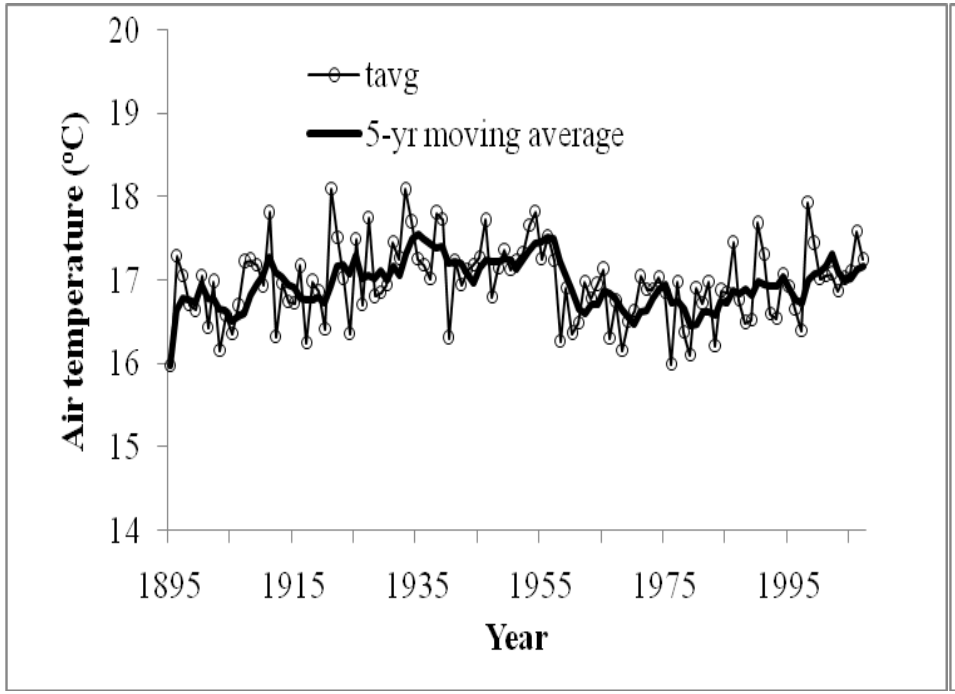
Simulation scenarios design

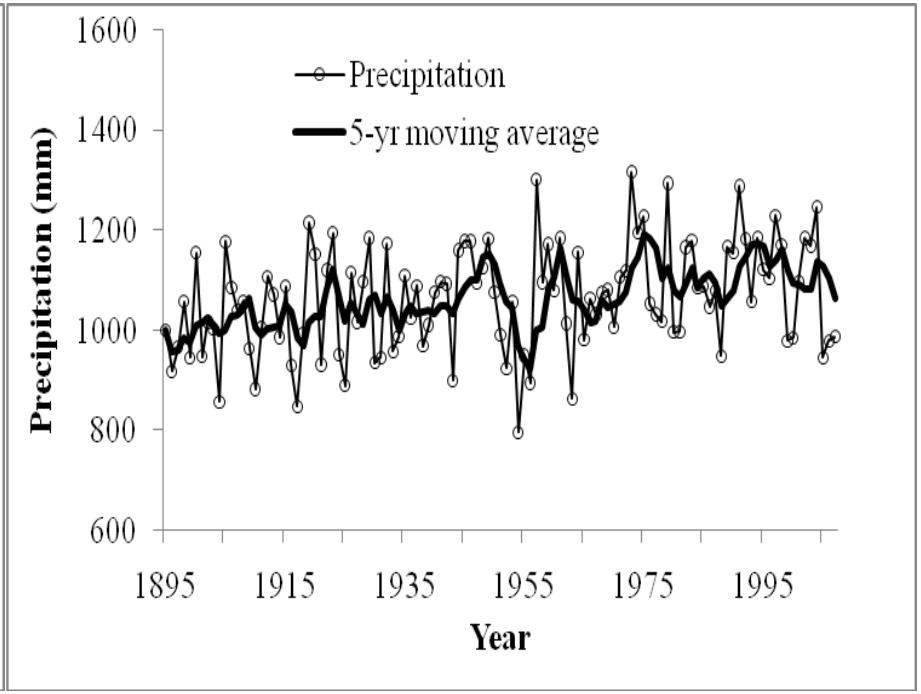
- CLM: Climate change only
- NDEP: Nitrogen deposition only
- CO2:
- LUCC: Land use/land cover change only
  - Natural and managed ecosystems
  - Land management practices
- OZONE:
- COMBINED: combination of all above factors

Change magnitude of environmental factors

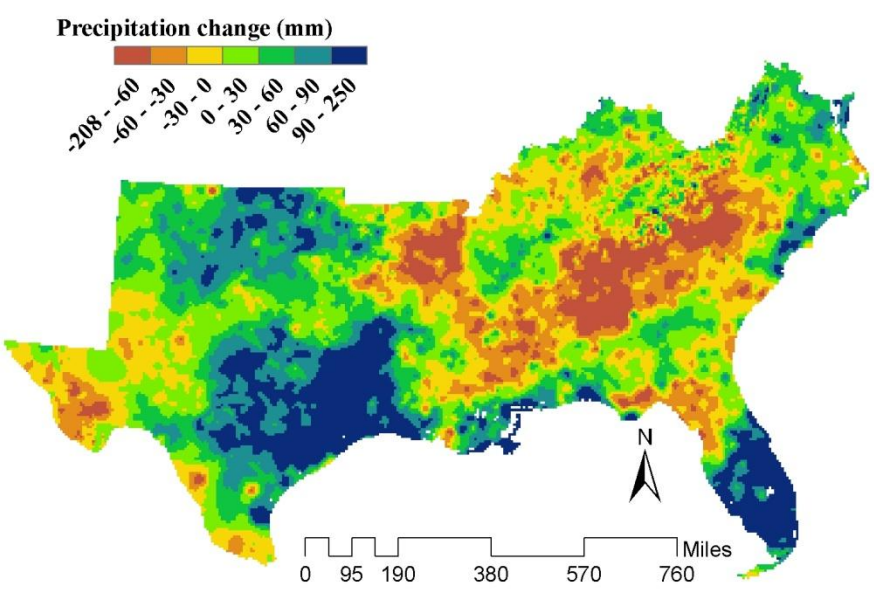
- Climate change
- Land-use and land-cover change
- Air pollution (Tropospheric ozone and atmospheric N deposition)

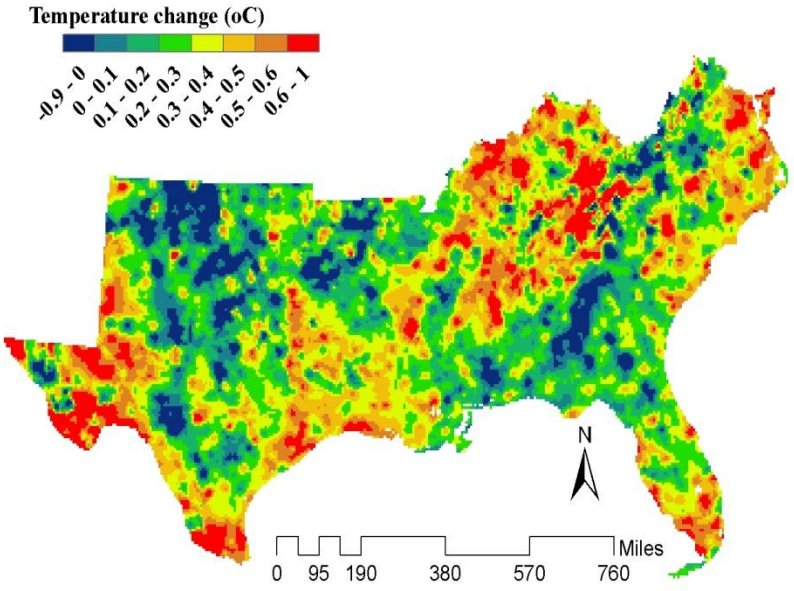
Climate change-temporal





Climate change-spatial

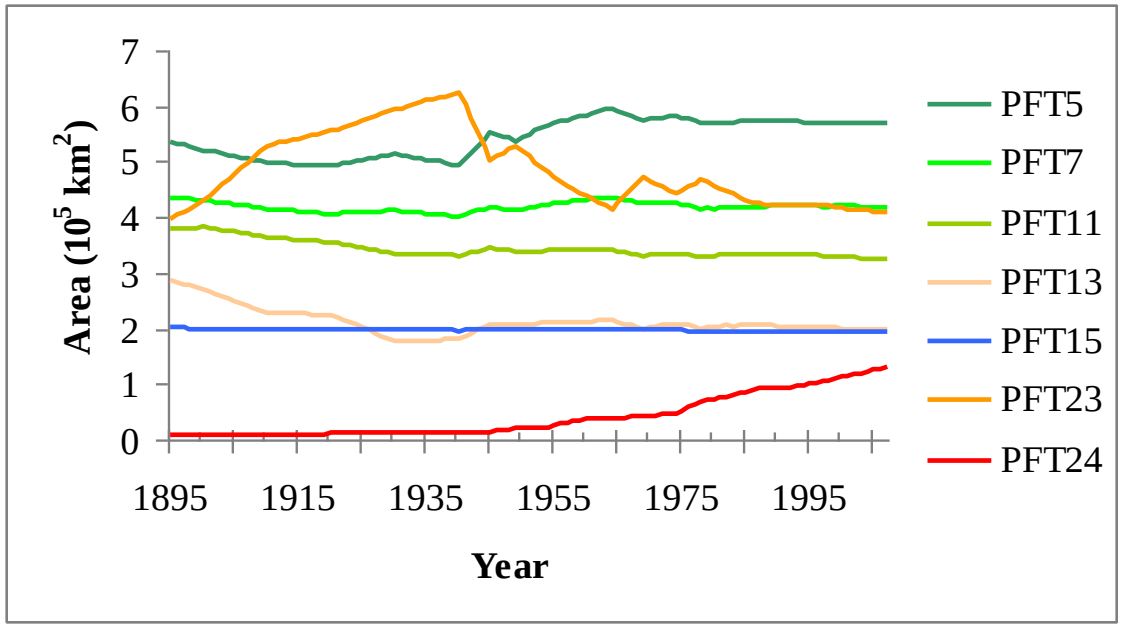




Annual mean precipitation (mm) and air temperature (°C) changes from 1961-1990 to 1991-2007

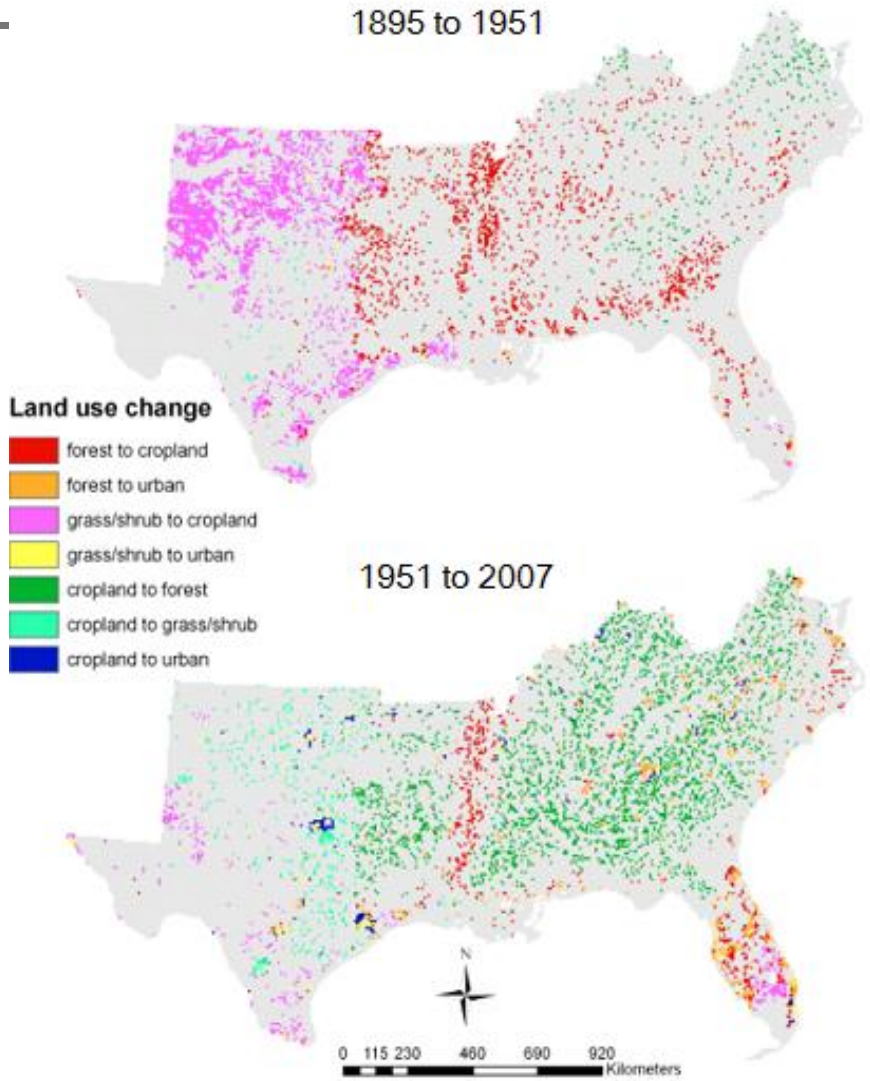
Data generated based on NARR and PRISM Group

Land-use and land-cover change in the SUS

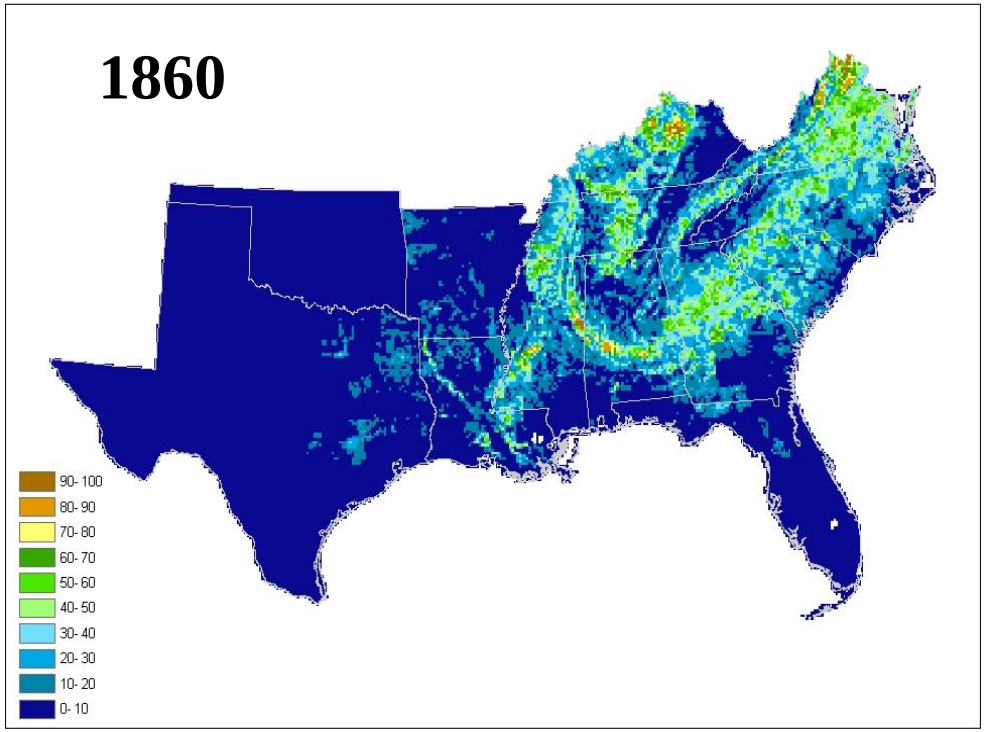


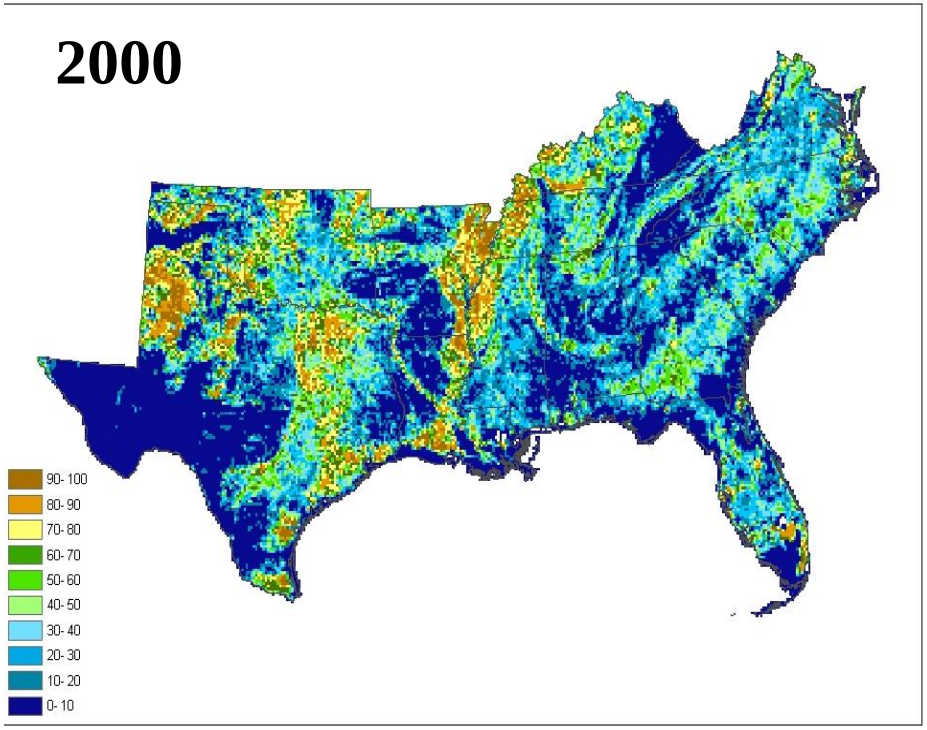
PFT5: Temperate deciduous broadleaf forest;
PFT7: Temperate evergreen needleleaf forest (including mixed forest);
PFT11: deciduous shrubland;
PFT13: C3 and C4 grassland;
PFT15: Grass and forest wetland;
PFT23: cropland;

Land-use and land-cover change



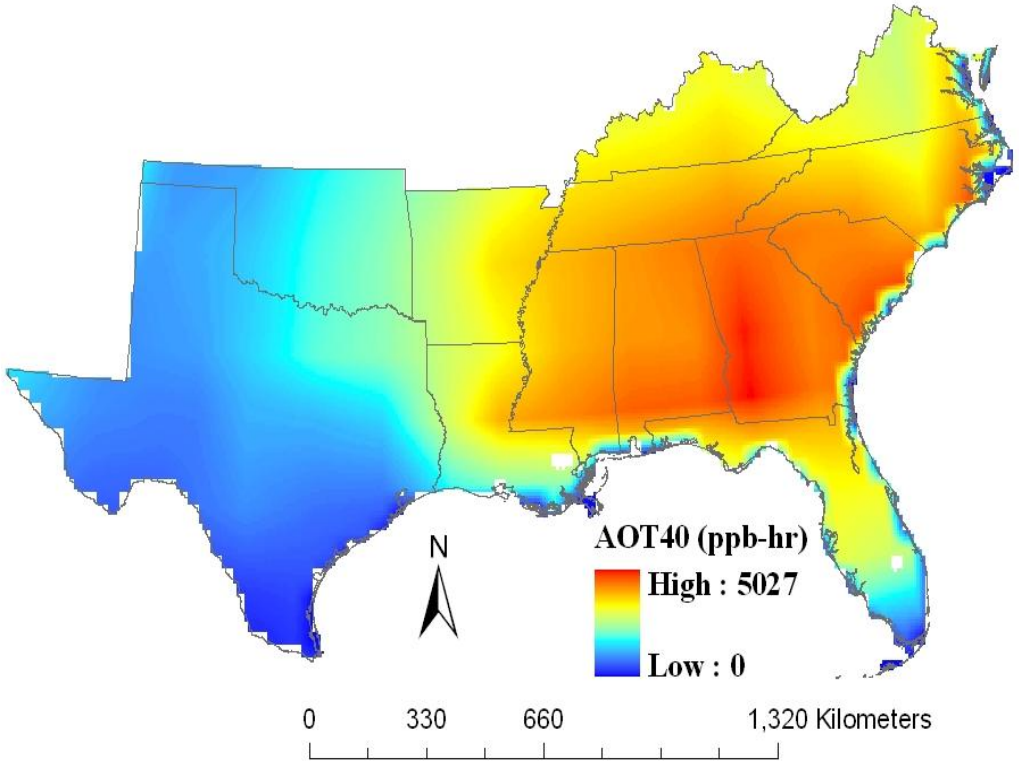
Historical change of cropland area





Cropland percentage (%) change from 1860 to 2000

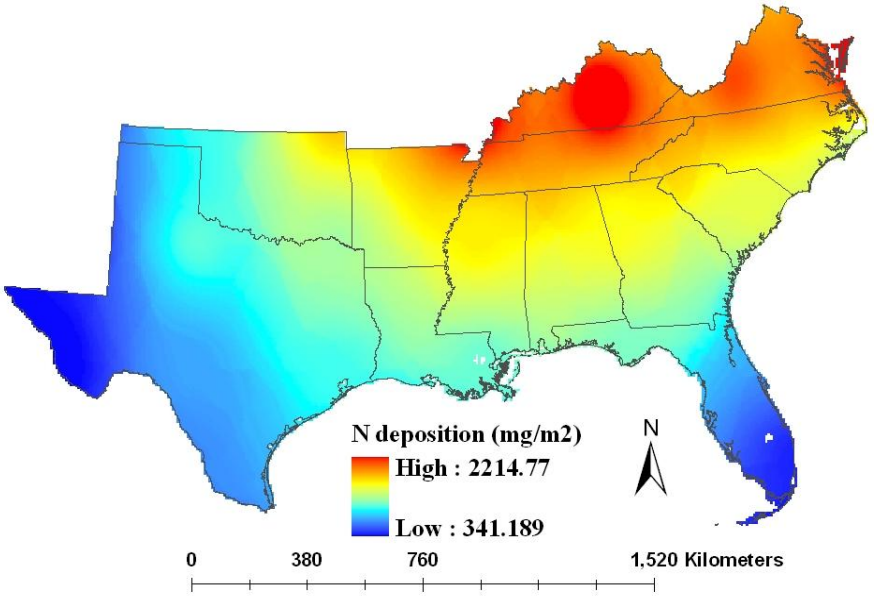
Air pollution-tropospheric ozone

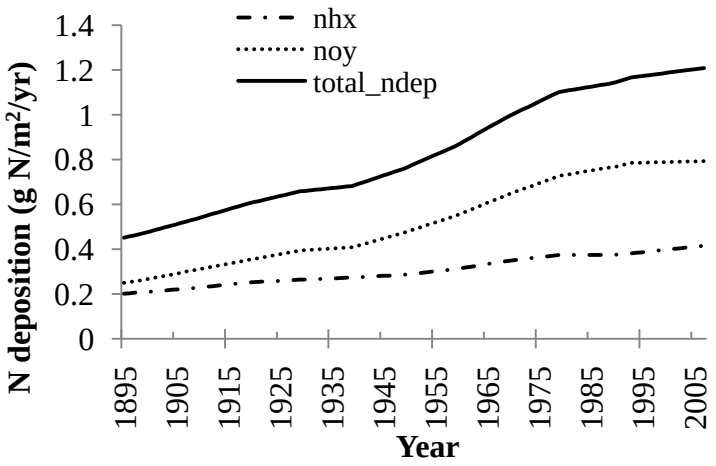


Average AOT40 in 1993 (ppb-hr)

Data from Felzer et al. (2004)

Air pollution-N deposition





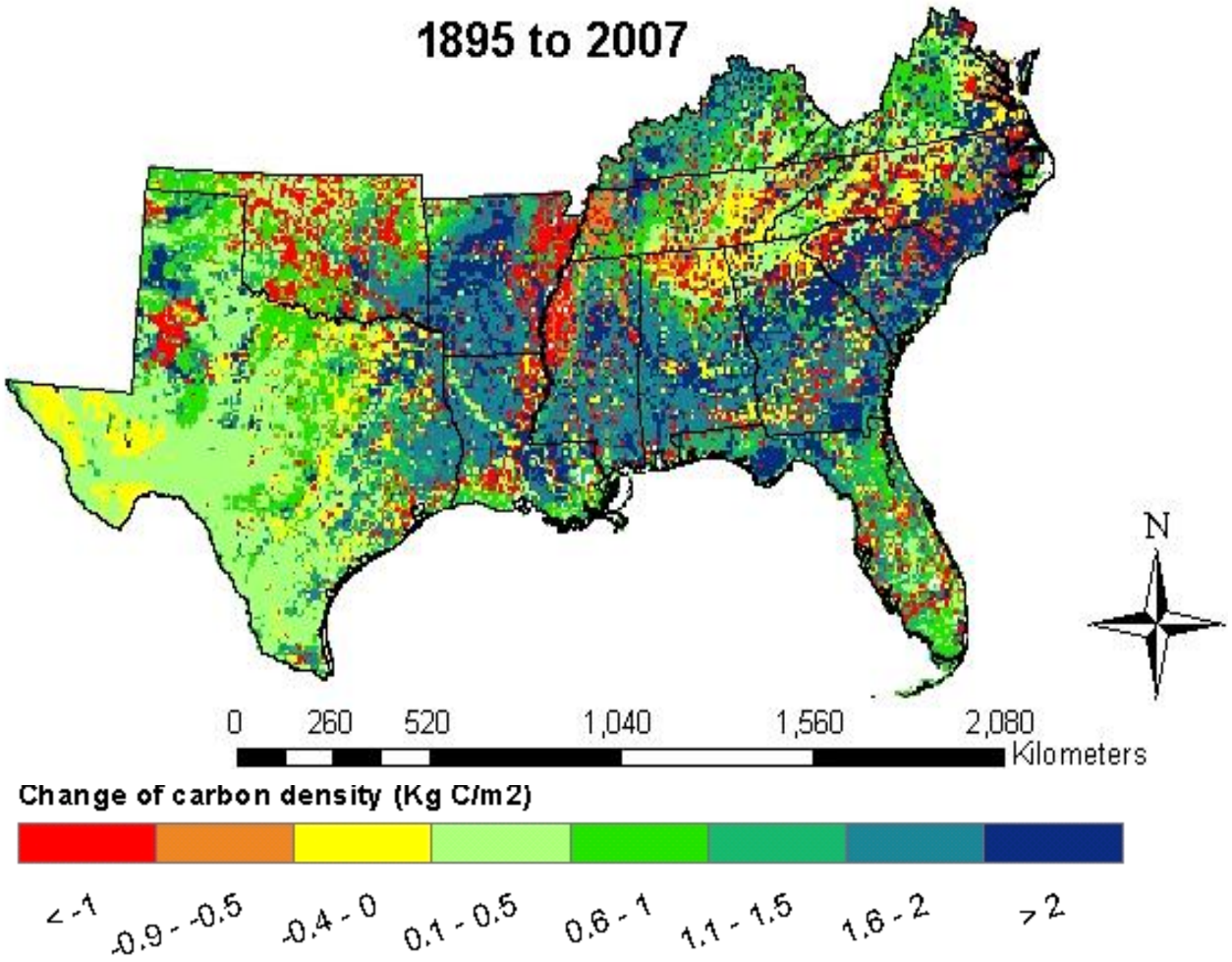
Annual N deposition in 1993 (mg N /m^2)

Data from Dentener (2006)

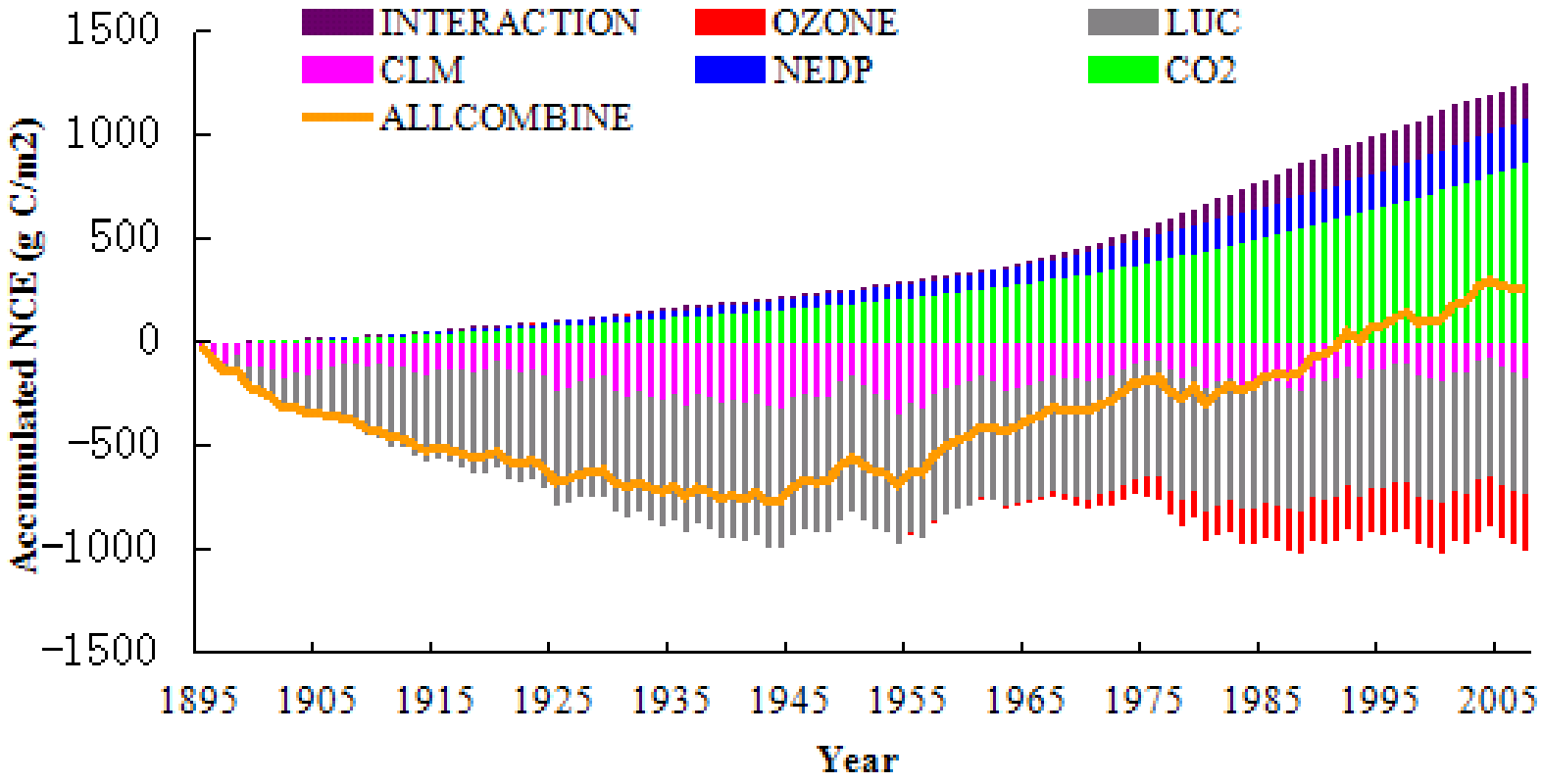
Impacts of environmental change on carbon cycle

- Spatial pattern of carbon density
- Temporal pattern of net carbon exchange rate (NCE, positive value indicates C sink)
- Impacts of individual factors to NCE
  - Contributions of individual factors
  - Land-use and land-cover change
  - Climate change

Carbon density change from 1895 to 2007

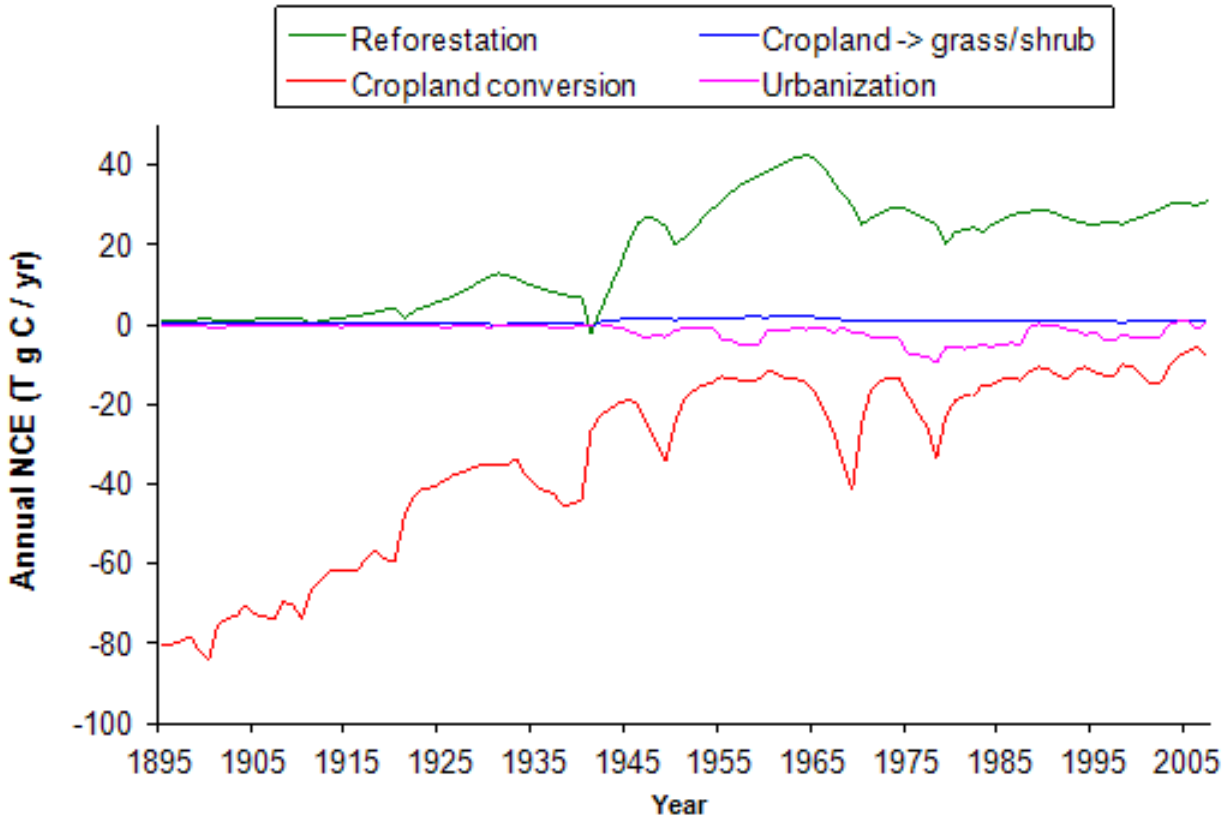


Contribution of individual environmental factors to accumulated NCE

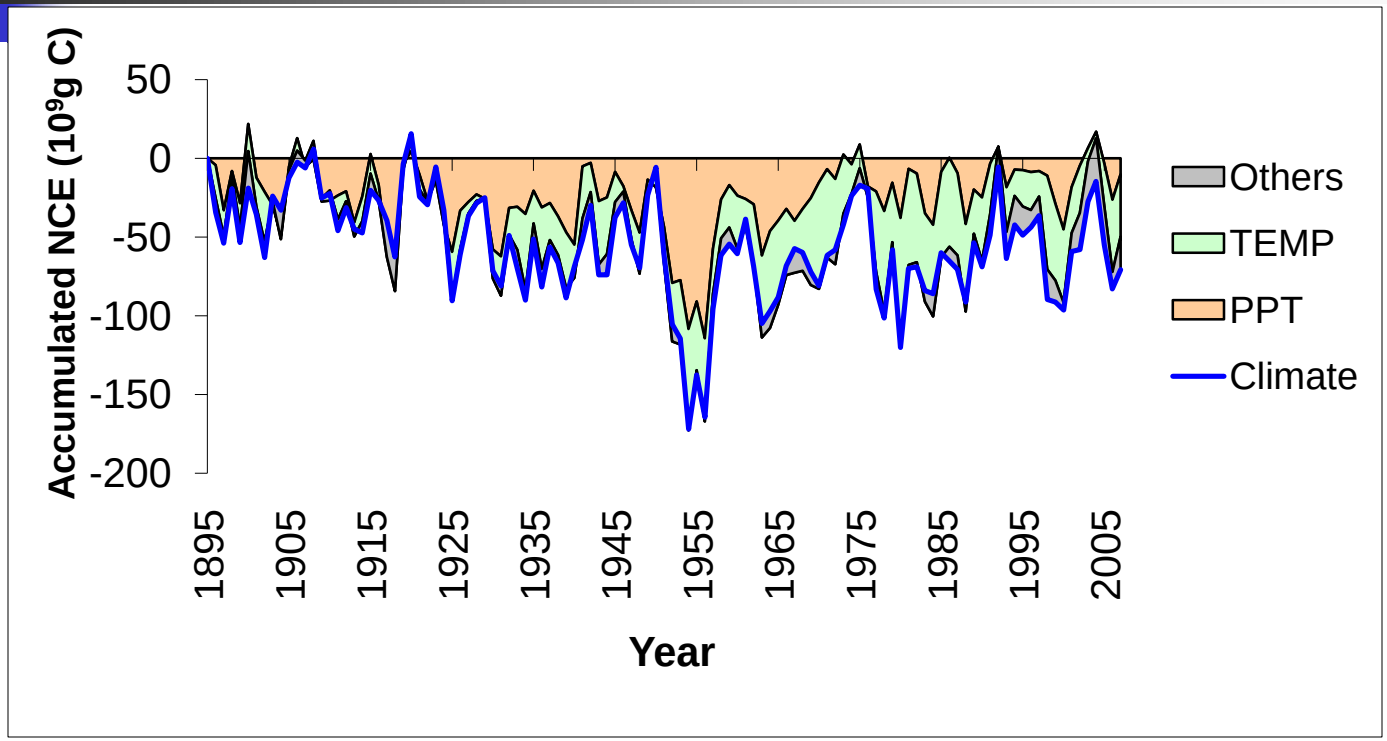


Contribution: ozone: -12%; LUC: -33%; CLM: -5%; CO2: 29%; NDEP: 11%; interactive effect: 10%

Impacts of land-use and land-cover change on accumulated NCE



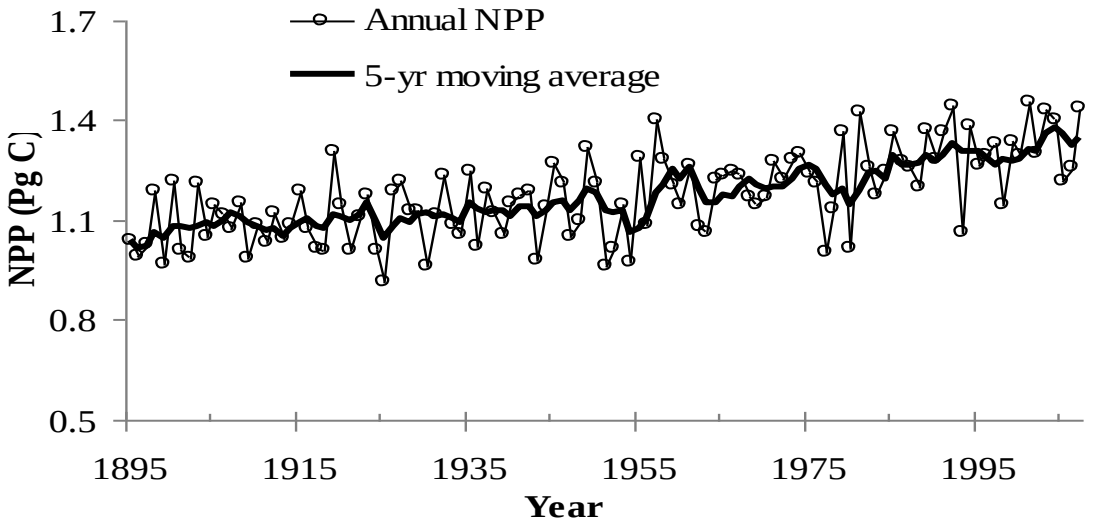
Climate change on accumulated NCE



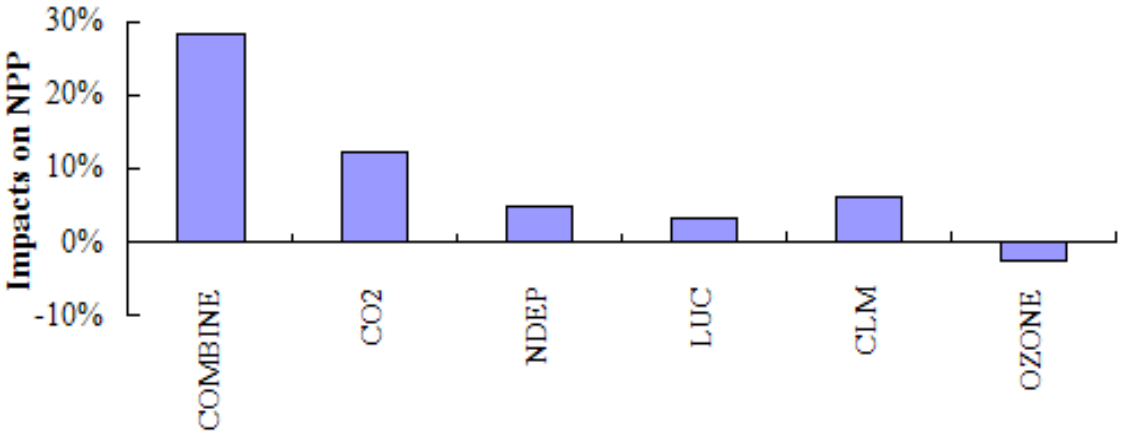
Contribution of temperature (TEMP) and precipitation (PPT) to accumulated NCE induced by climate change. PPT, TEMP and other climate factors (relative air humidity and radiation) contribute 14%, 56% and 30%, respectively

Temporal change of annual NPP and impacts of multiple factors

1 Pg = 10^{15} g



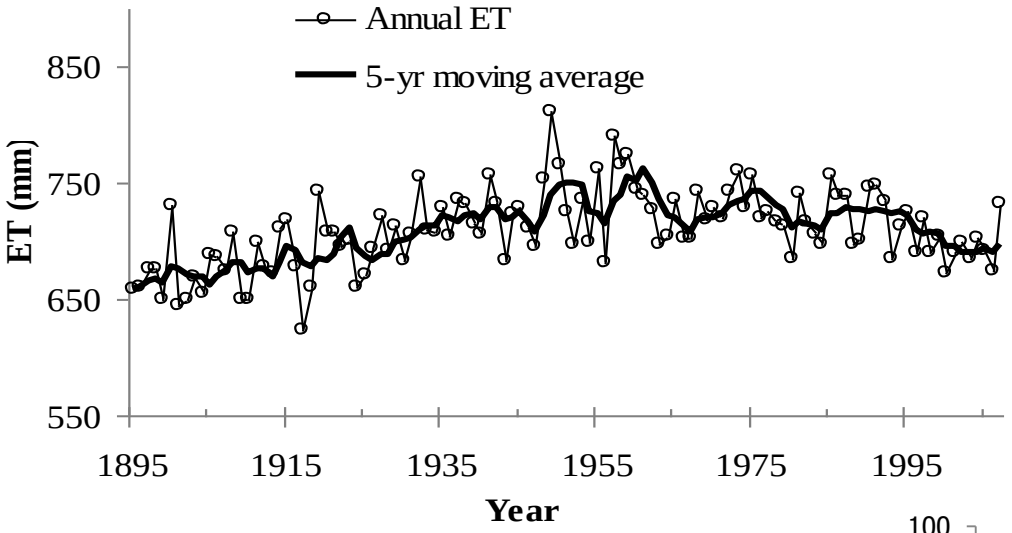
Change of NPP from 1895 to 2007 in response to different environmental changes. The impact on NPP = (NPP2000s - NPP1890s) / NPP1890s

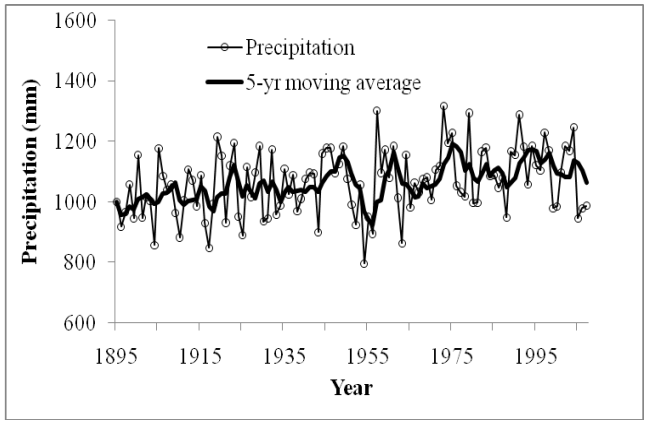


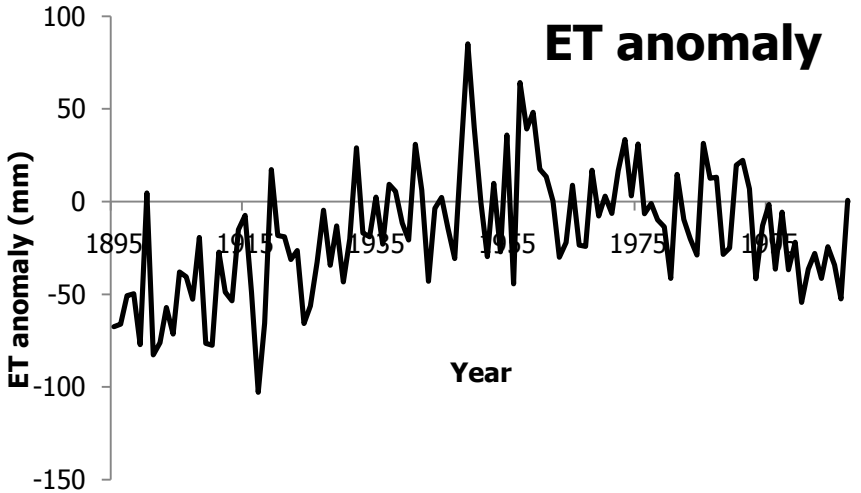
Impacts of environmental change on water cycle

- Temporal and spatial pattern of ET
- Contribution of individual factors to ET
- ET of different biomes
- Temporal pattern of water yield

Impacts of on ET

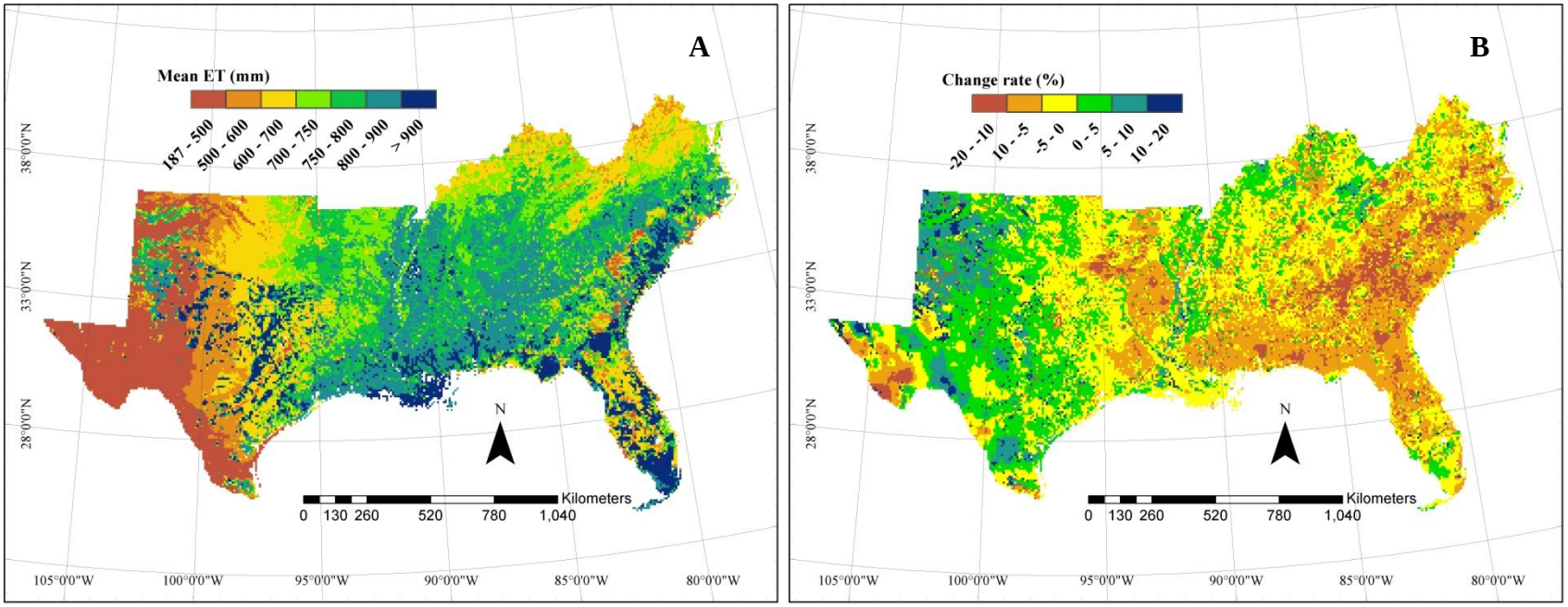






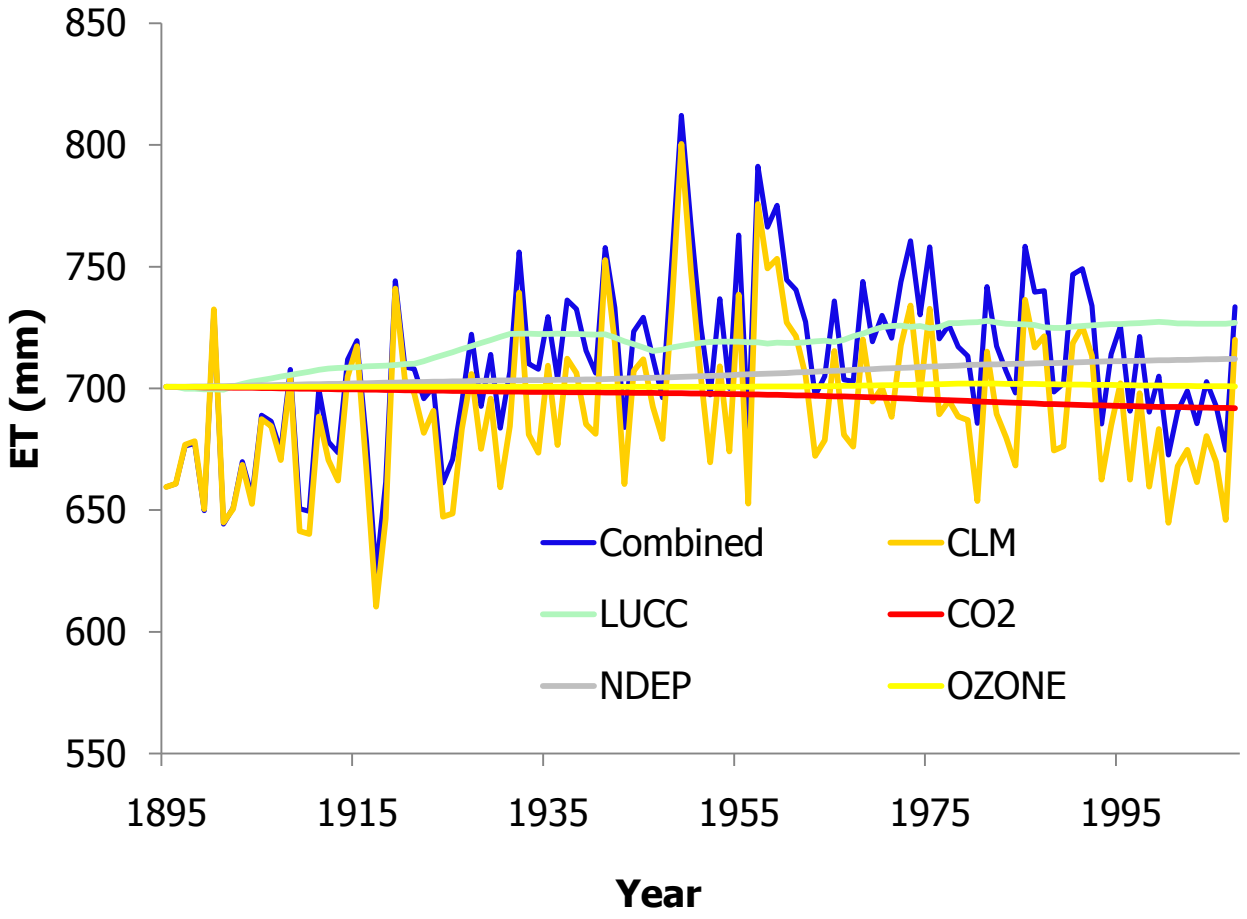
Annual mean ET and anomalies relative to 1961-1990 mean

Spatial pattern of ET



Spatial distribution of annual mean ET during 1895-2007 (A) and ET change rate (%, B) from 1961-1990 to 1991-2007

Contribution of different factors on ET



Water use of different biomes

PFT5: Temperate deciduous broadleaf forest;
PFT7: Temperate evergreen needleleaf forest (including mixed forest);
PFT11: deciduous shrubland;
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PFT15: Grass and forest wetland;
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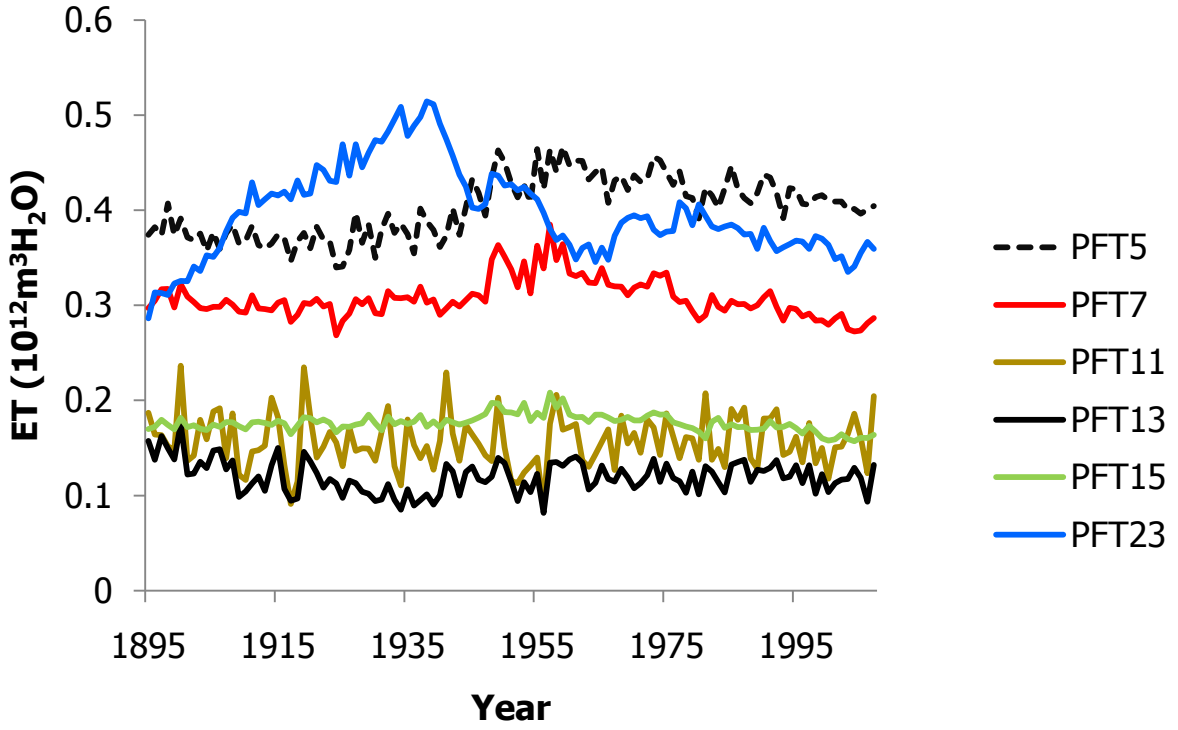
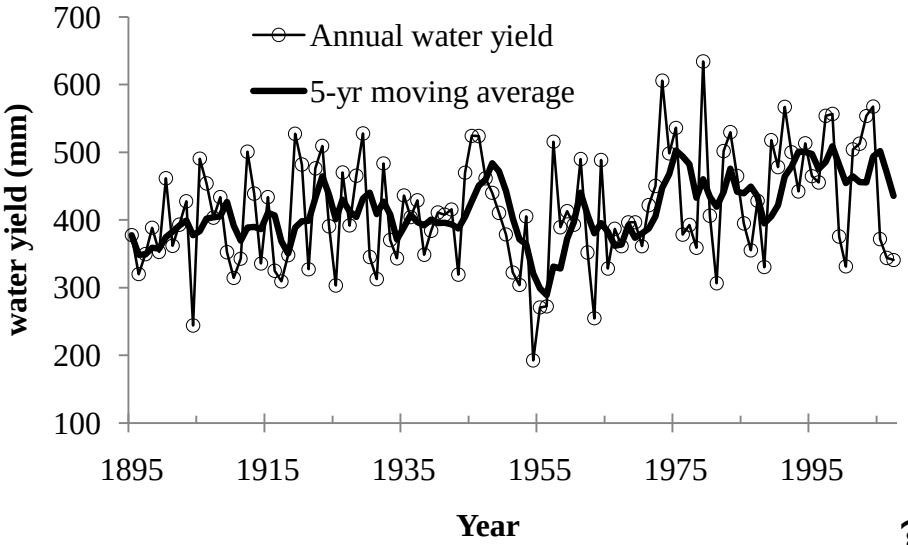
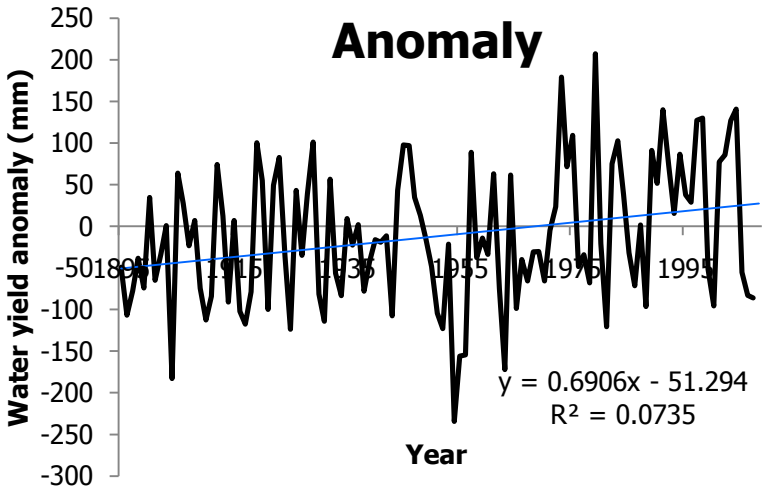


Impacts on water yield



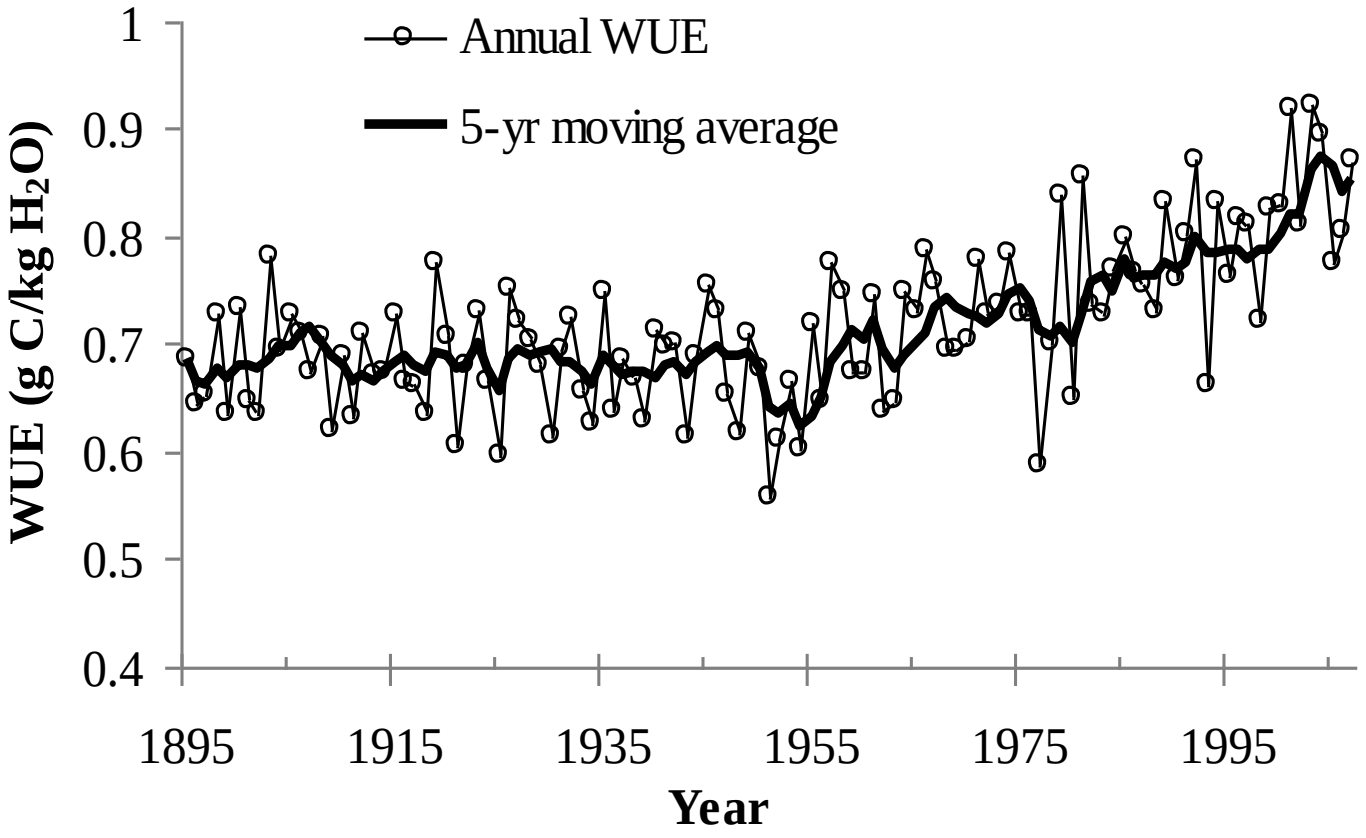


Annual mean water yield and anomalies relative to 1961-1990 mean

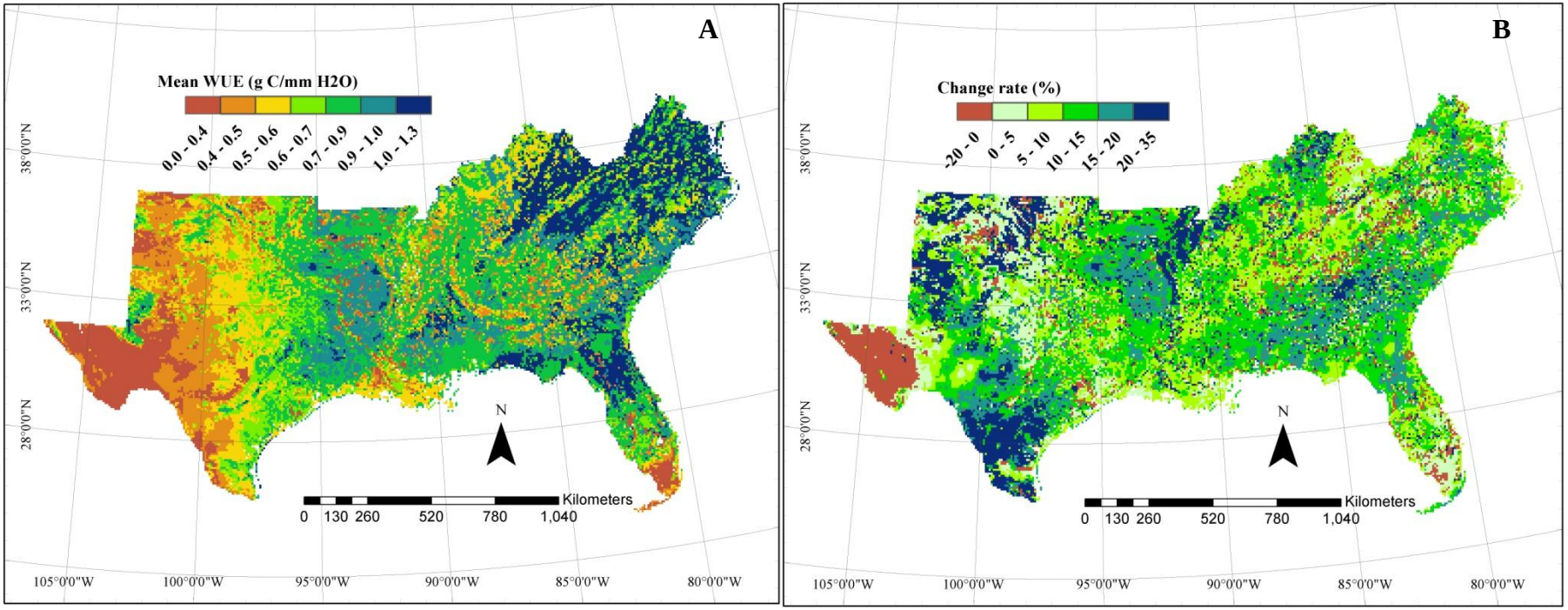
Water and carbon interactions

- Temporal and spatial pattern of water use efficiency
  - Water use efficiency: defined as NPP/ET ratio
- Contributions of different factors to water use efficiency

Impacts on water use efficiency

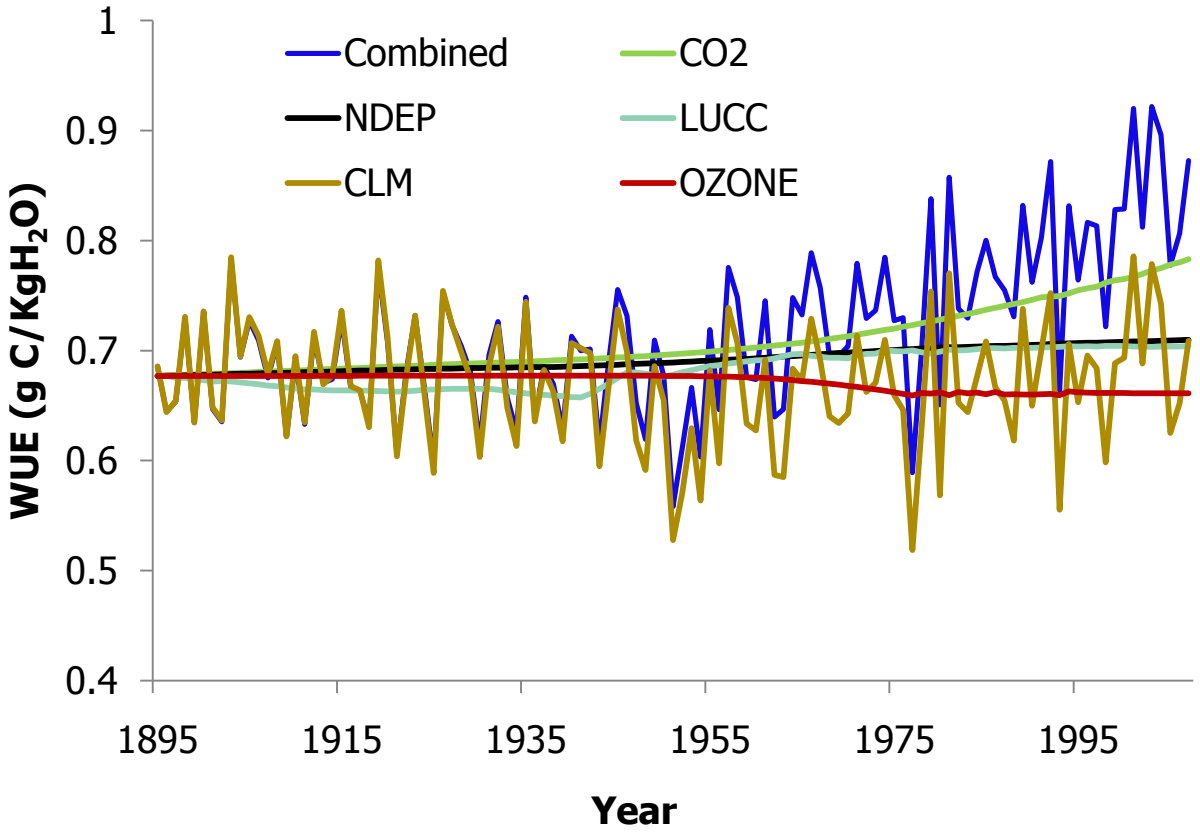


Spatial distribution of WUE



Spatial distribution of annual mean WUE during 1895-2007 (A) and WUE change rate (%, B) from 1961-1990 to 1991-2007

Contributions of environmental change to WUE



WUE changes for different biomes

PFT5: Temperate deciduous broadleaf forest;
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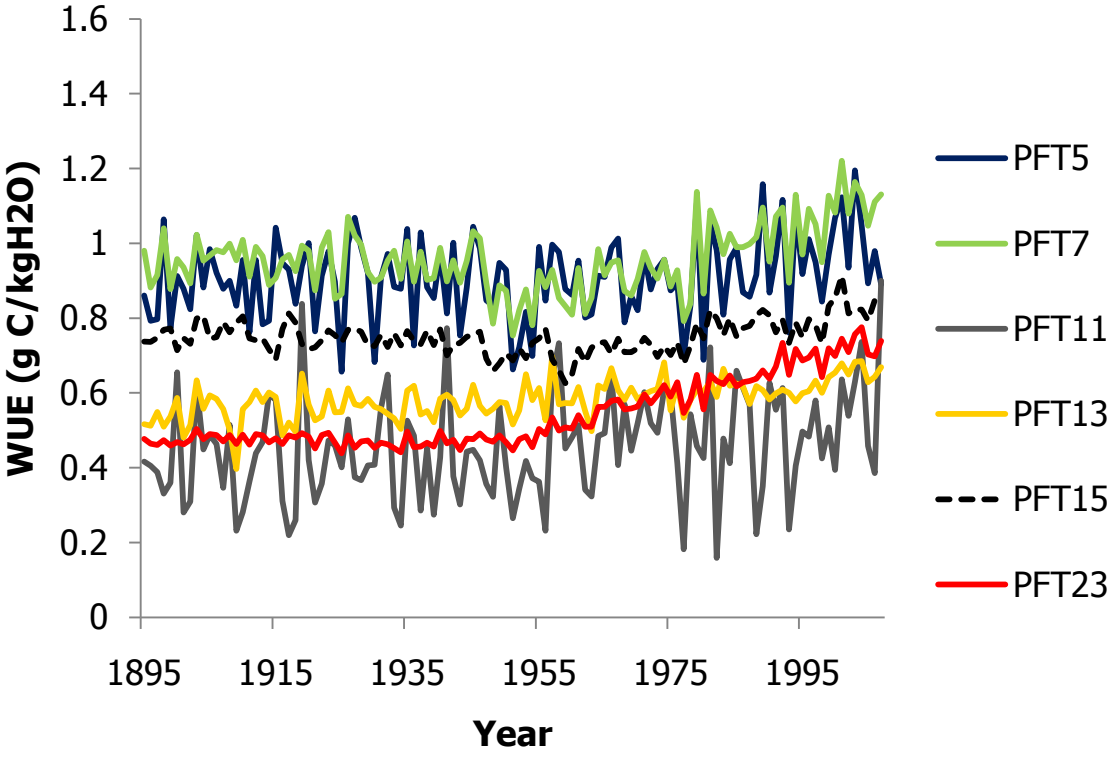
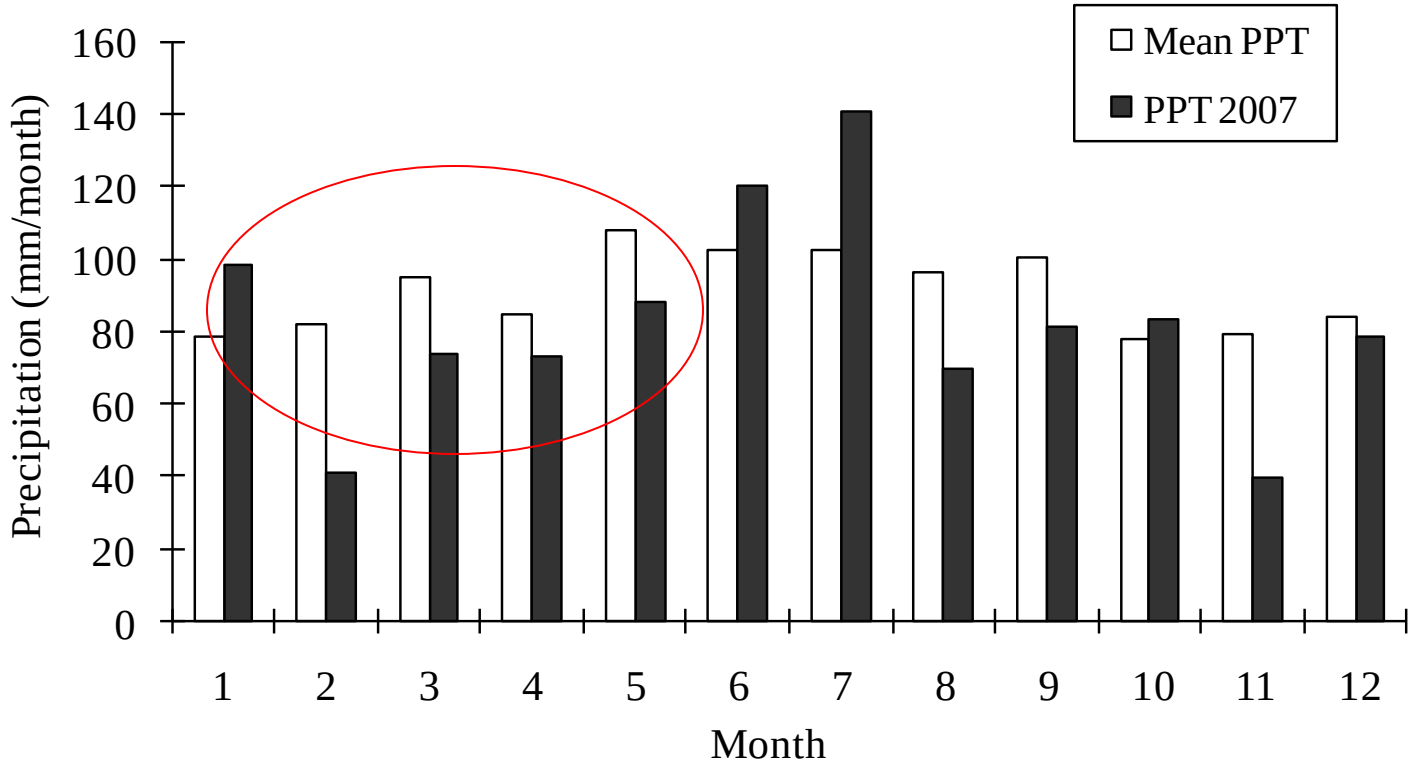
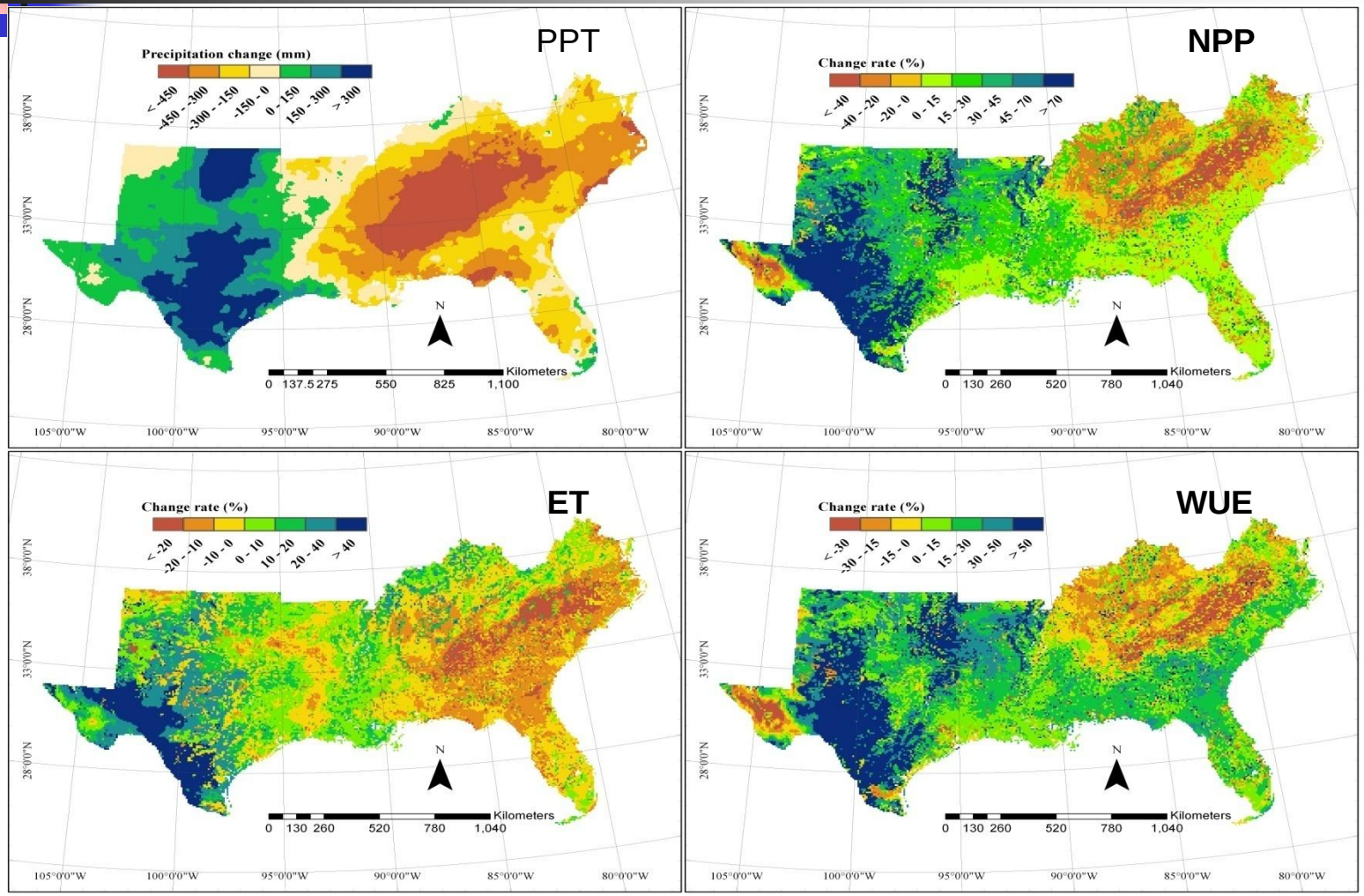


Drought in 2007



Monthly precipitation in 2007 and long-term mean monthly precipitation (1961-1990)

PPT, NPP, ET and WUE anomalies in 2007



Uncertainties

- Driving data for model
- Model parameterization and structure
- Omission of forest disturbances and management

Major conclusions

- Environmental factors have been changed greatly in the SUS showing huge spatial and temporal variability
- SUS was a carbon sink and NPP greatly increased which are primarily attributed to CO_2 effect and counteracted by LUCC effect
- ET increased slightly but showed great temporal variability

Major conclusions

- WUE increased greatly from 1895 to 2007 with the largest contributions from increasing CO2 concentration and N deposition
- Although increasing NPP and carbon storage was not at the expense of increasing water use (ET), policy makers should pay more attention to the tradeoff between carbon sequestration and water availability in the drought years and to the huge regional variations in NPP, ET and WUE.

Acknowledgements

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