

Recent Advances in Dynamic Vegetation Modeling for Dry Regions

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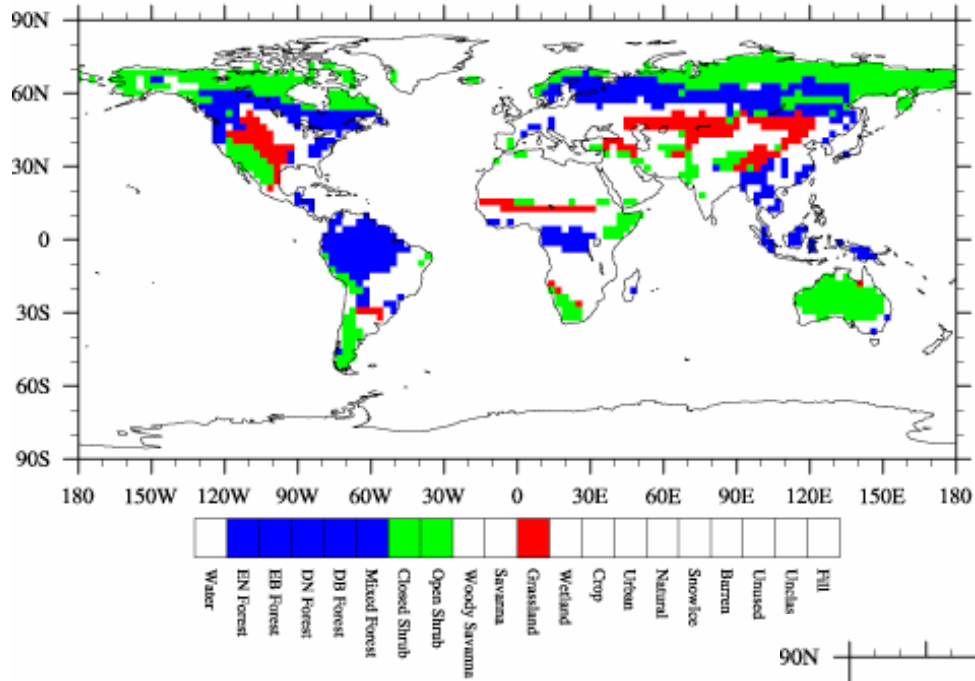
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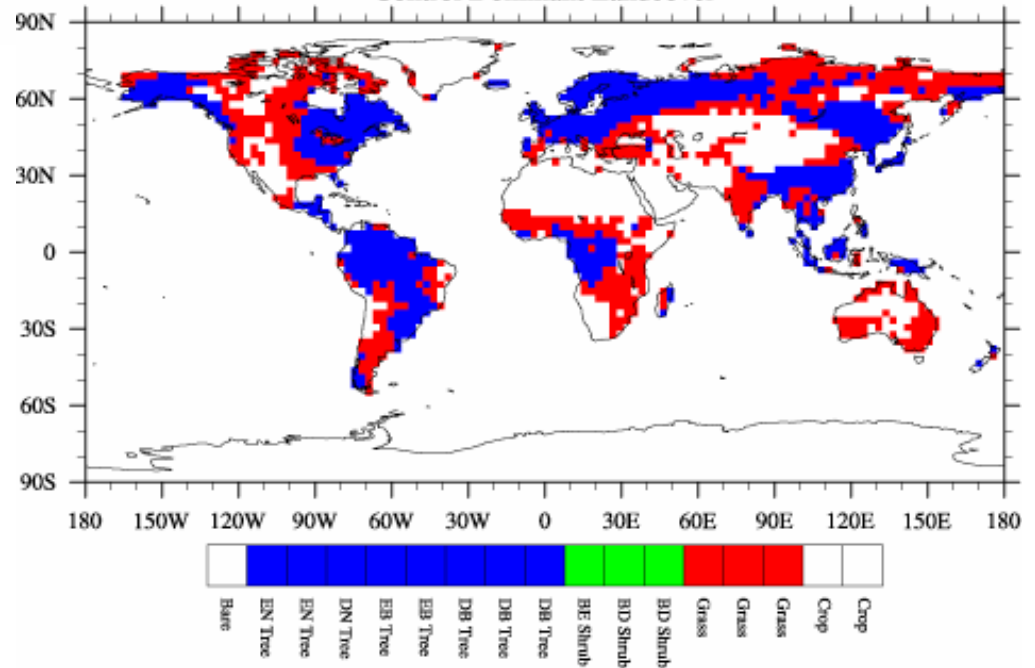
Motivation

- Dry regions represent a large fraction of the global land;
- Most of the existing Dynamic Global Vegetation Model (DGVMs) do not include shrubs or do not effectively distinguish shrubs from grasses;
- Exclusion of DGVMs and associated carbon cycle is recognized as one of the main deficiencies of IPCC AR4 model simulations;
- Equilibrium vegetation models or ecological models for individual plants (e.g., forest gap model) are not discussed, because only DGVMs are used in climate system models for the study of global transient vegetation-carbon-climate interactions

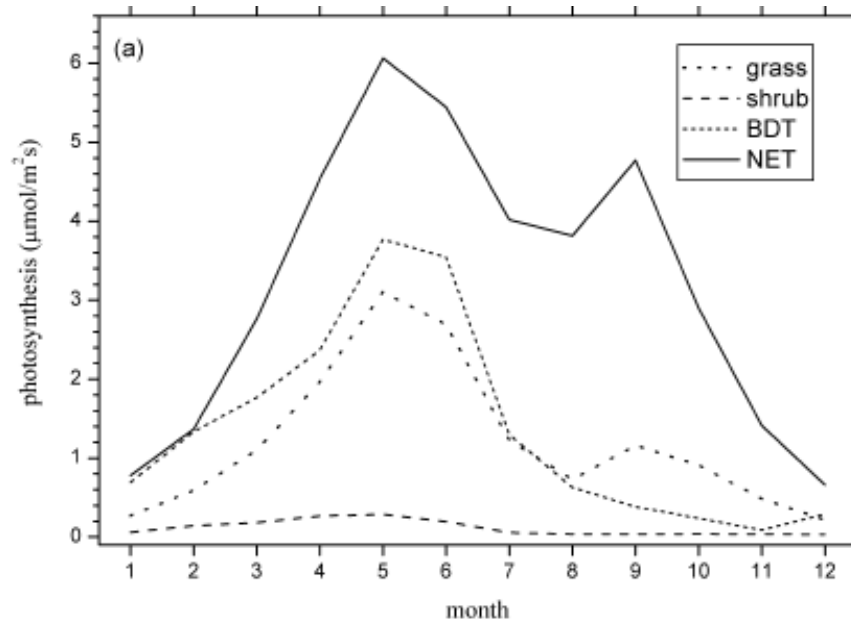
MODIS Dominant Landcover



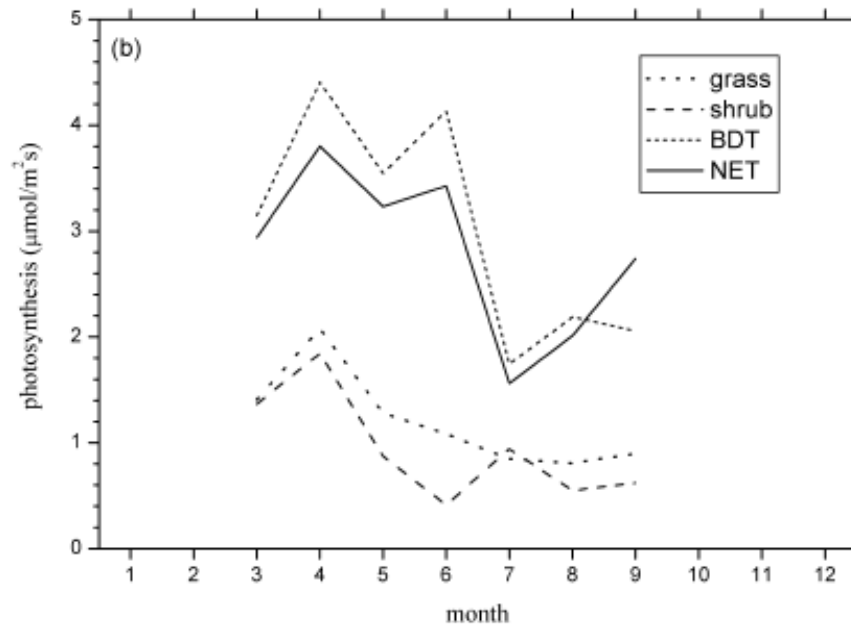
Control Dominant Landcover



Default DGVM
photosynthesis
over SW U.S.



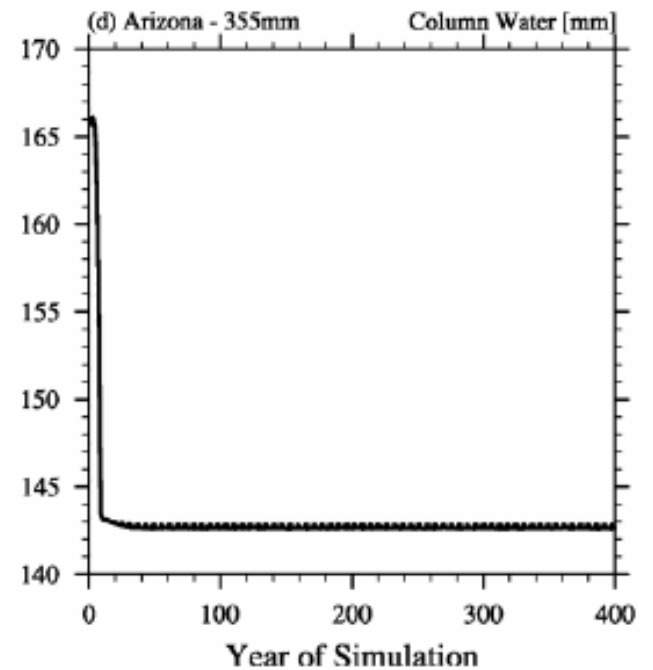
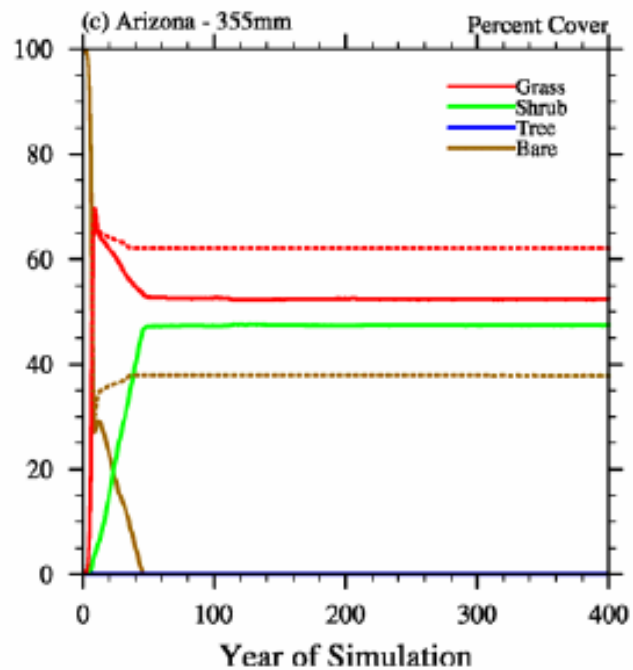
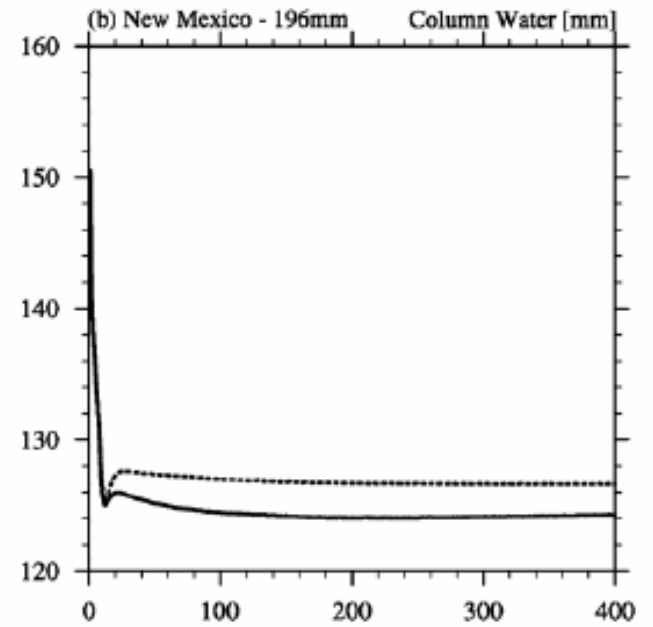
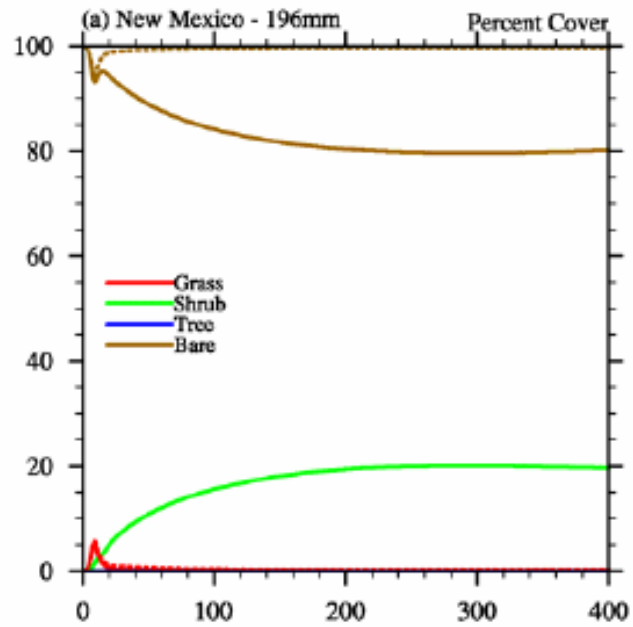
MODIS-based
photosynthesis
(from Running
et al.)

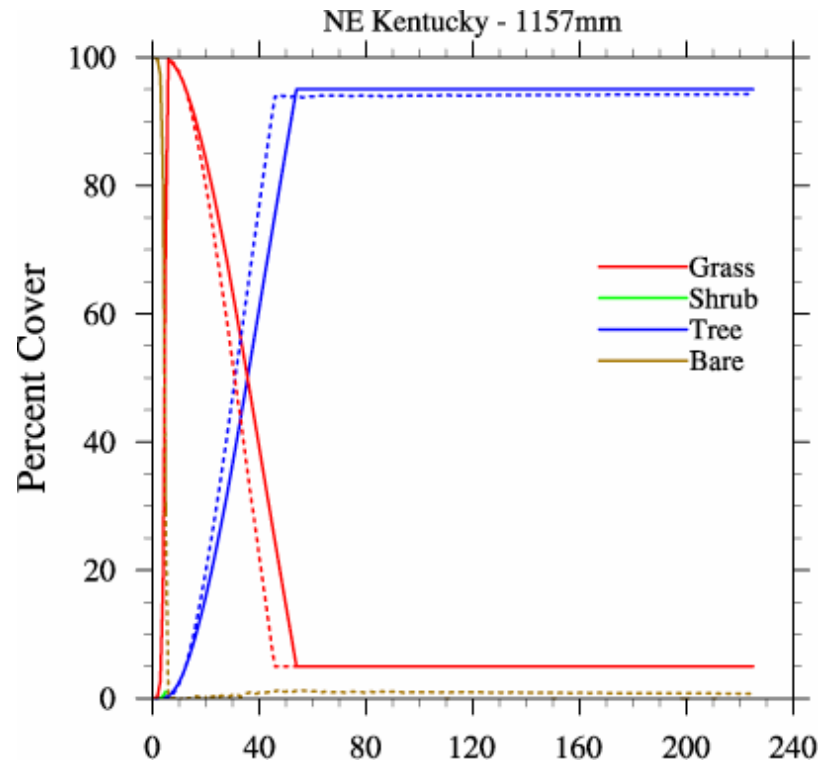
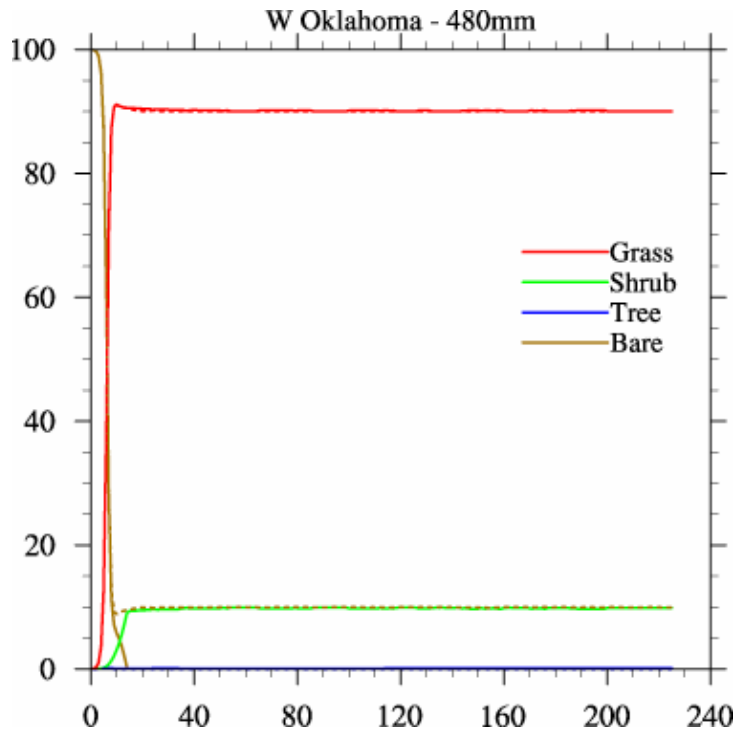


Shrub Submodel

- explicit consideration of shrubs' drought-tolerance nature in the photosynthesis computation;
- use of appropriate phenology type and morphology parameters for shrubs;
- consistent treatment of fractional vegetation coverage;
- development of tree/grass/shrub hierarchy for light competition

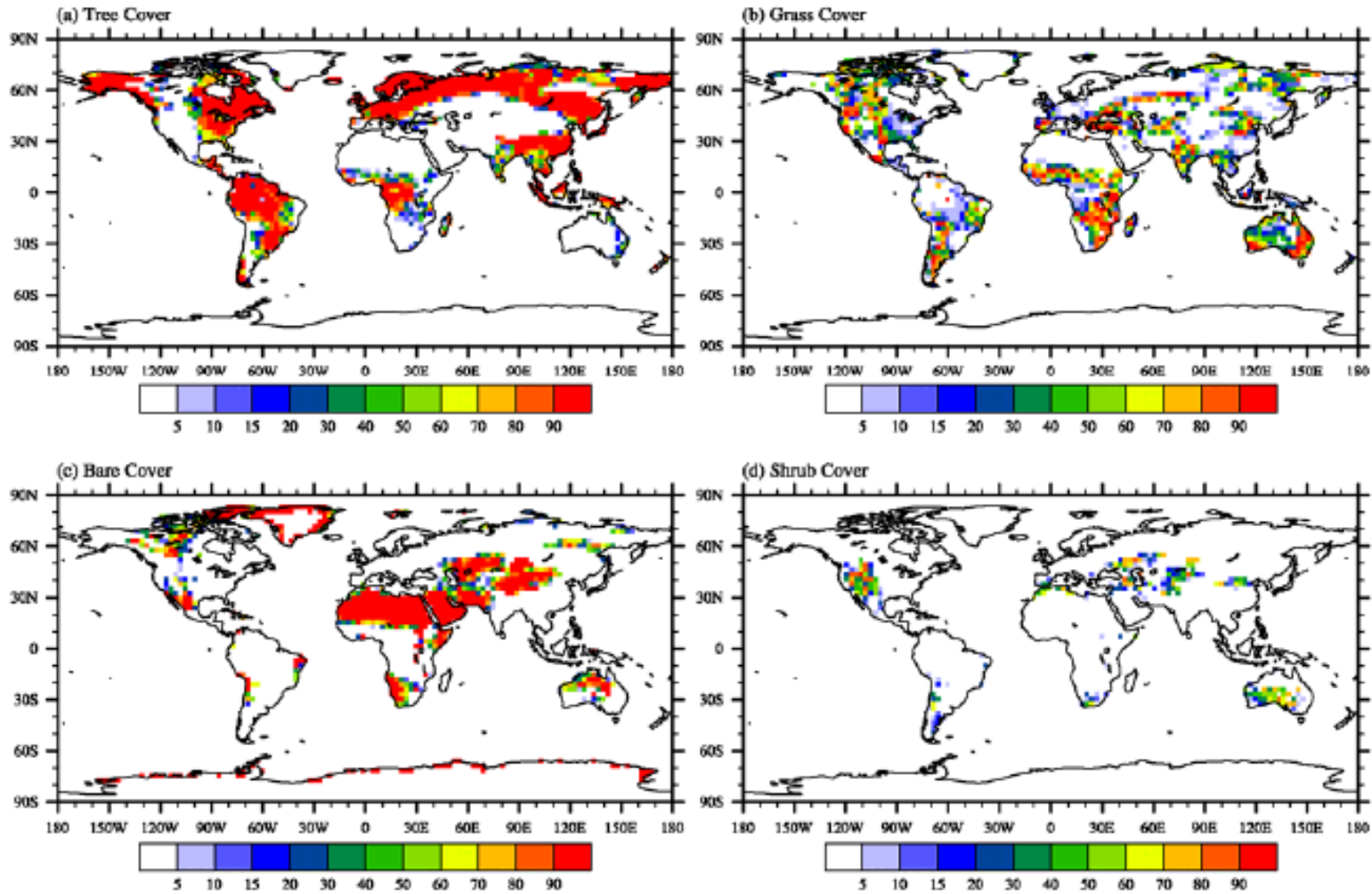
Solid line: new
Dotted: control



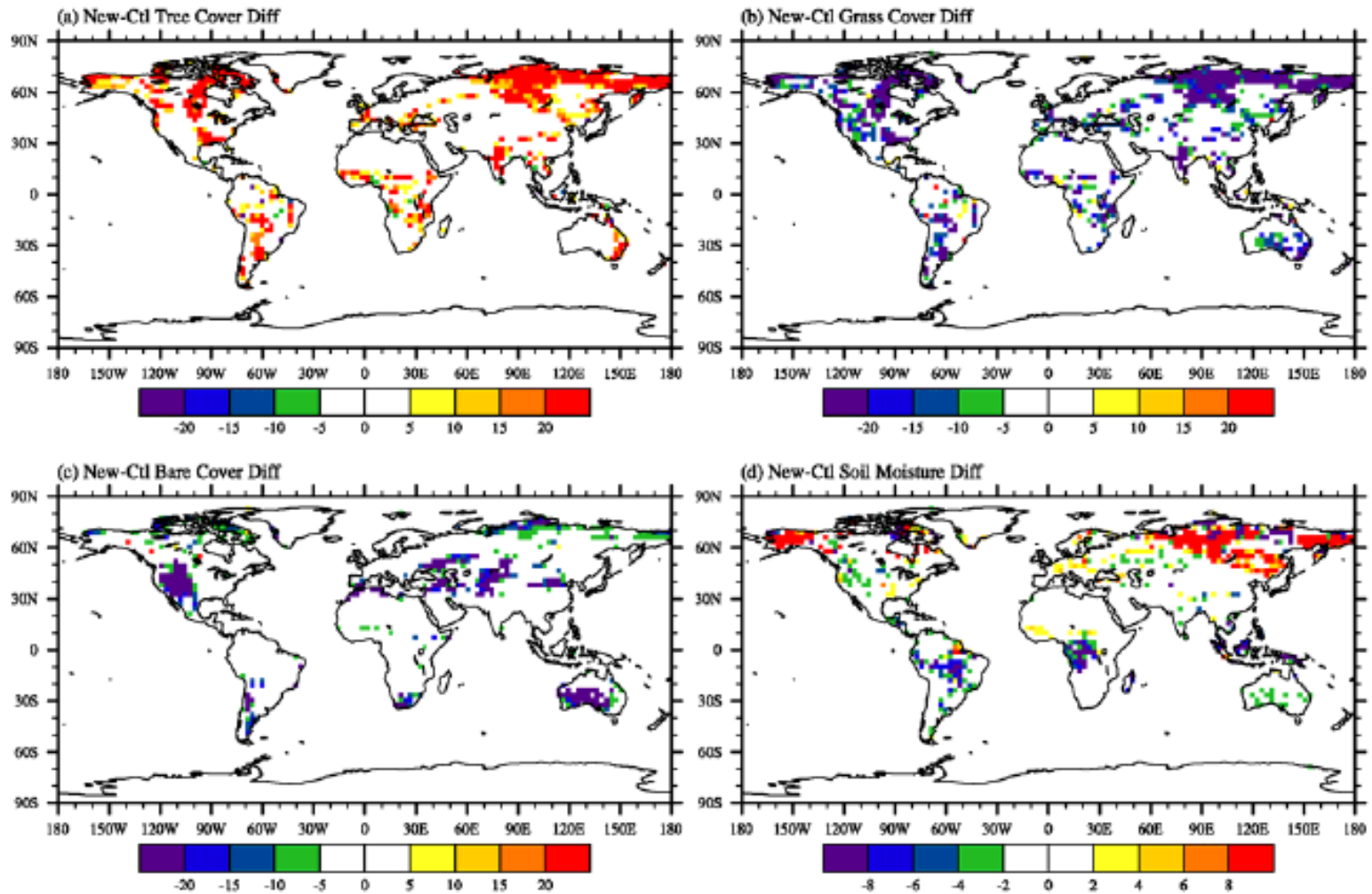


Solid line: with shrub
Dotted line: DGVM

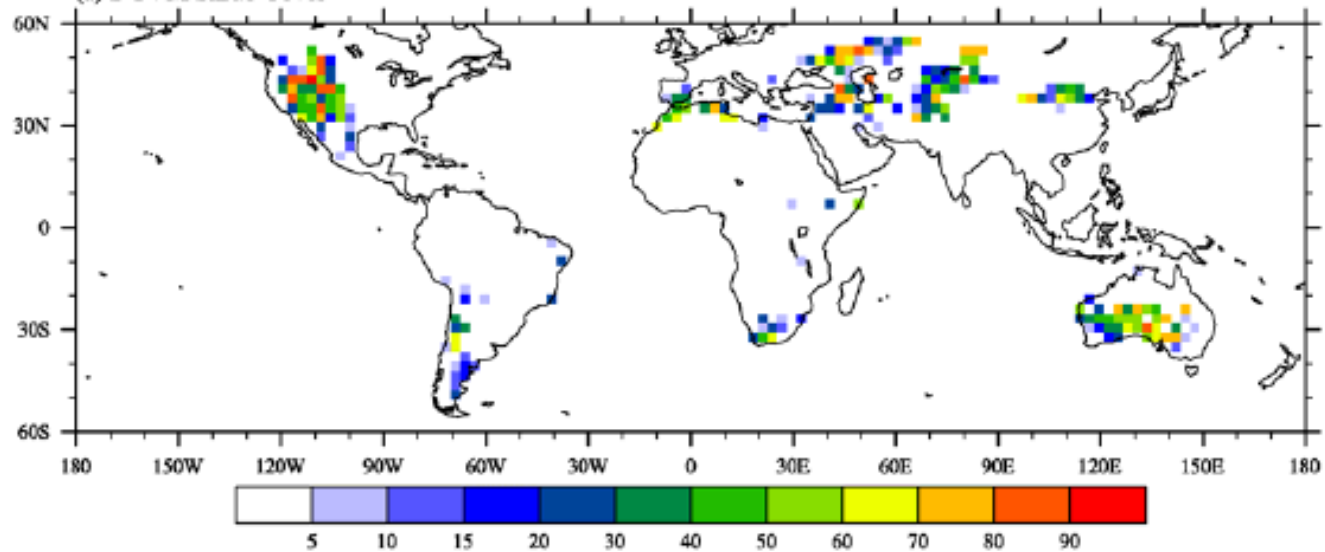
400-Yr Simulation using DGVM with shrub submodels



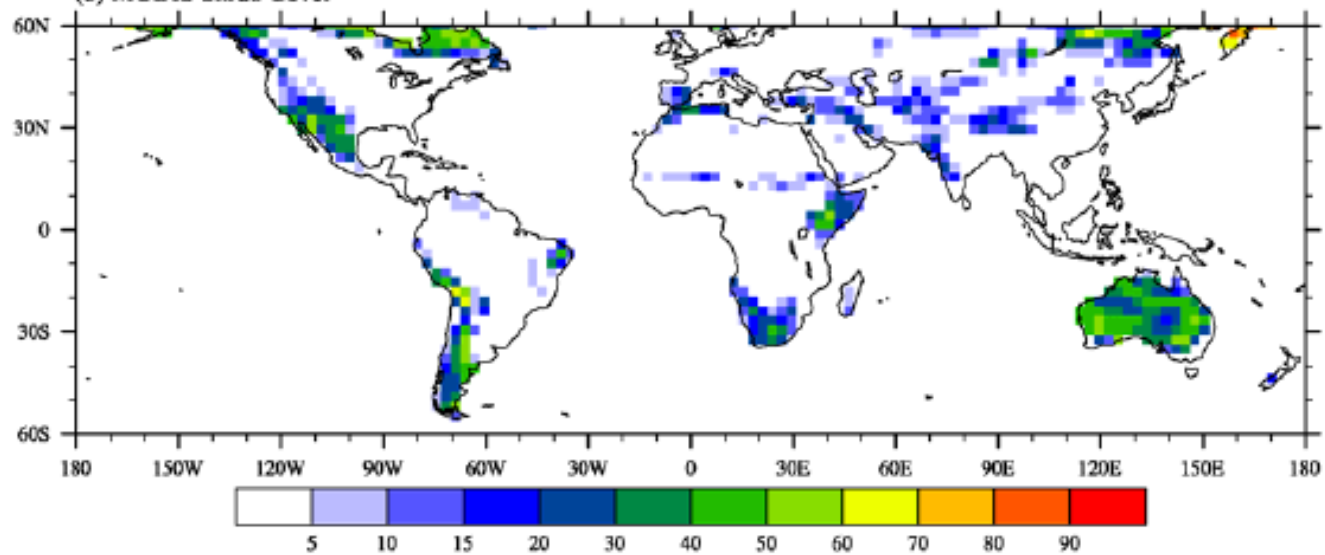
New -- Control



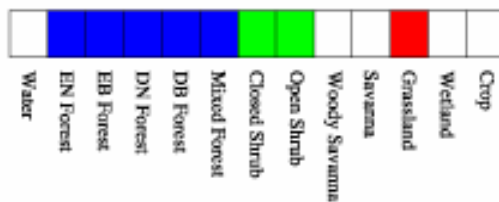
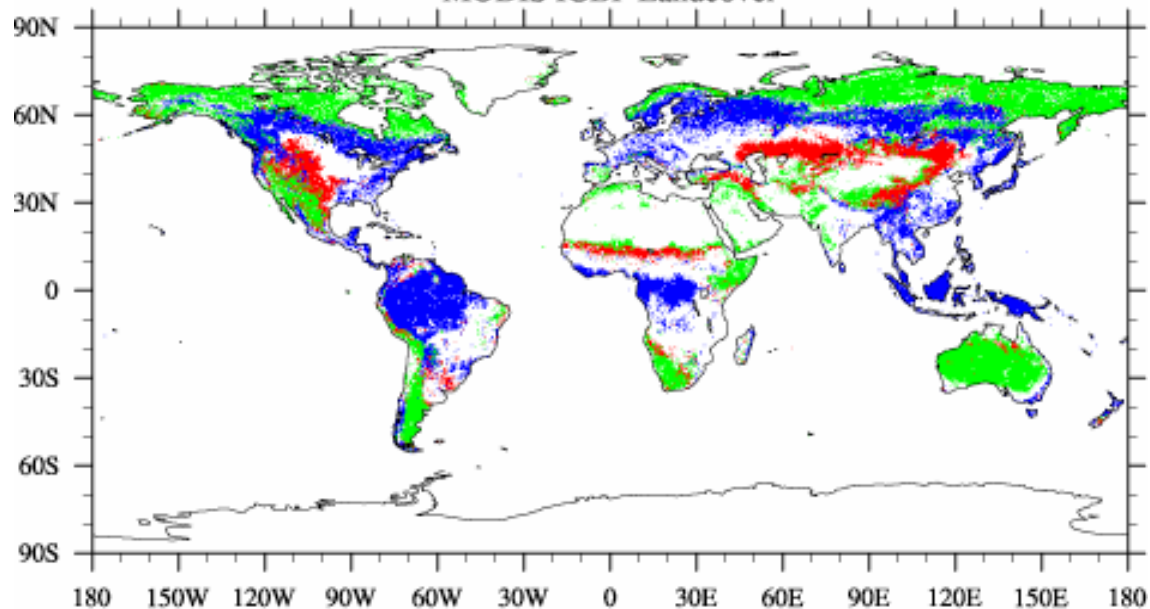
(a) DGVM Shrub Cover



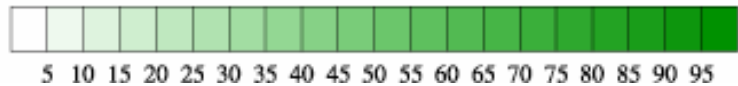
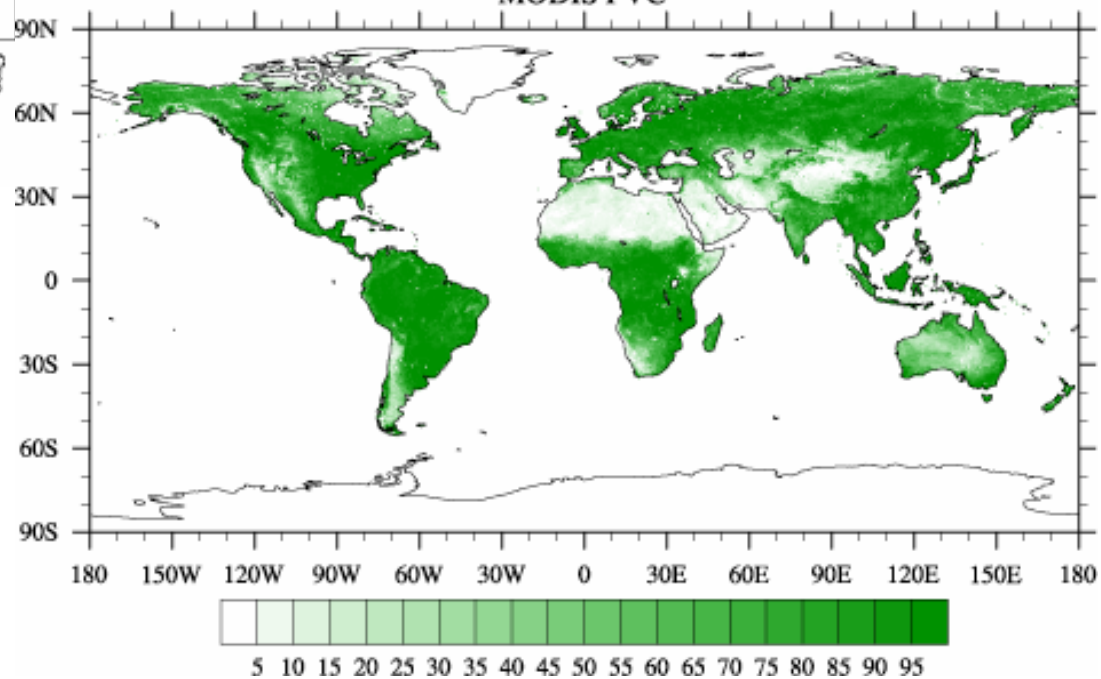
(b) MODIS Shrub Cover



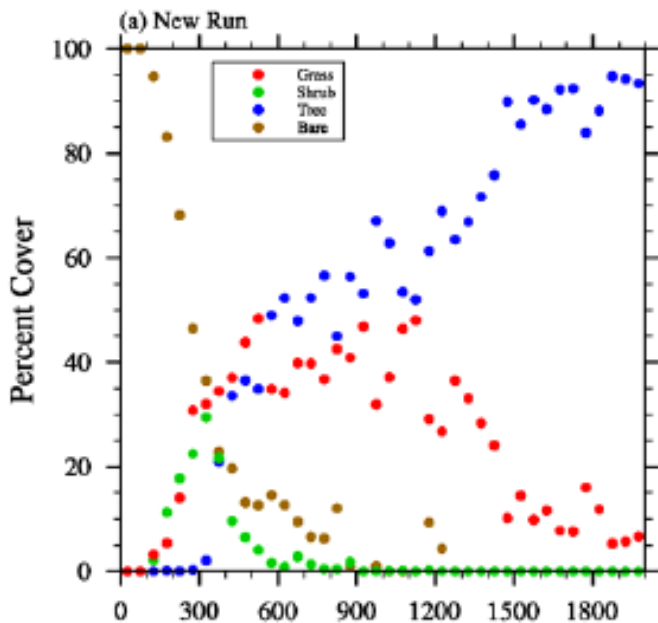
MODIS IGBP Landcover



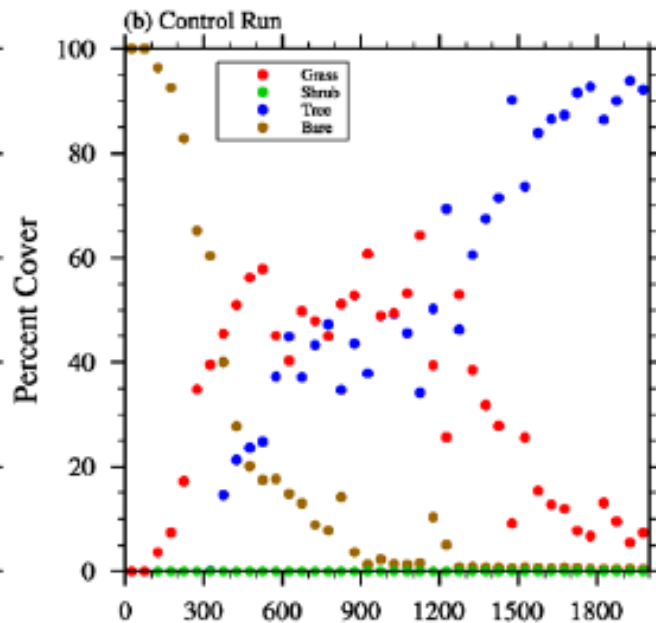
MODIS FVC



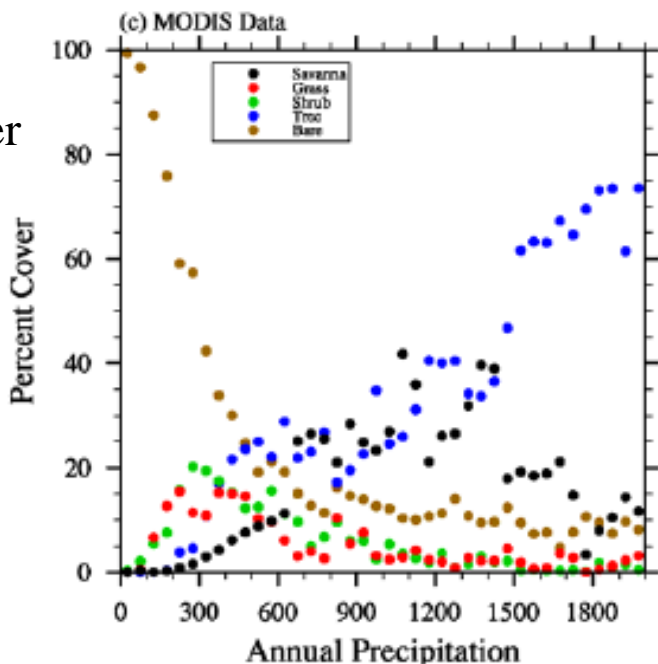
NEW



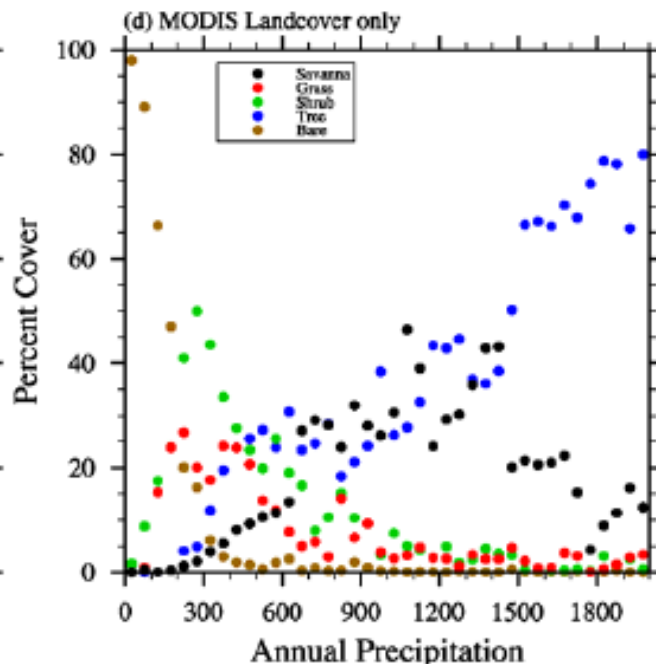
OLD



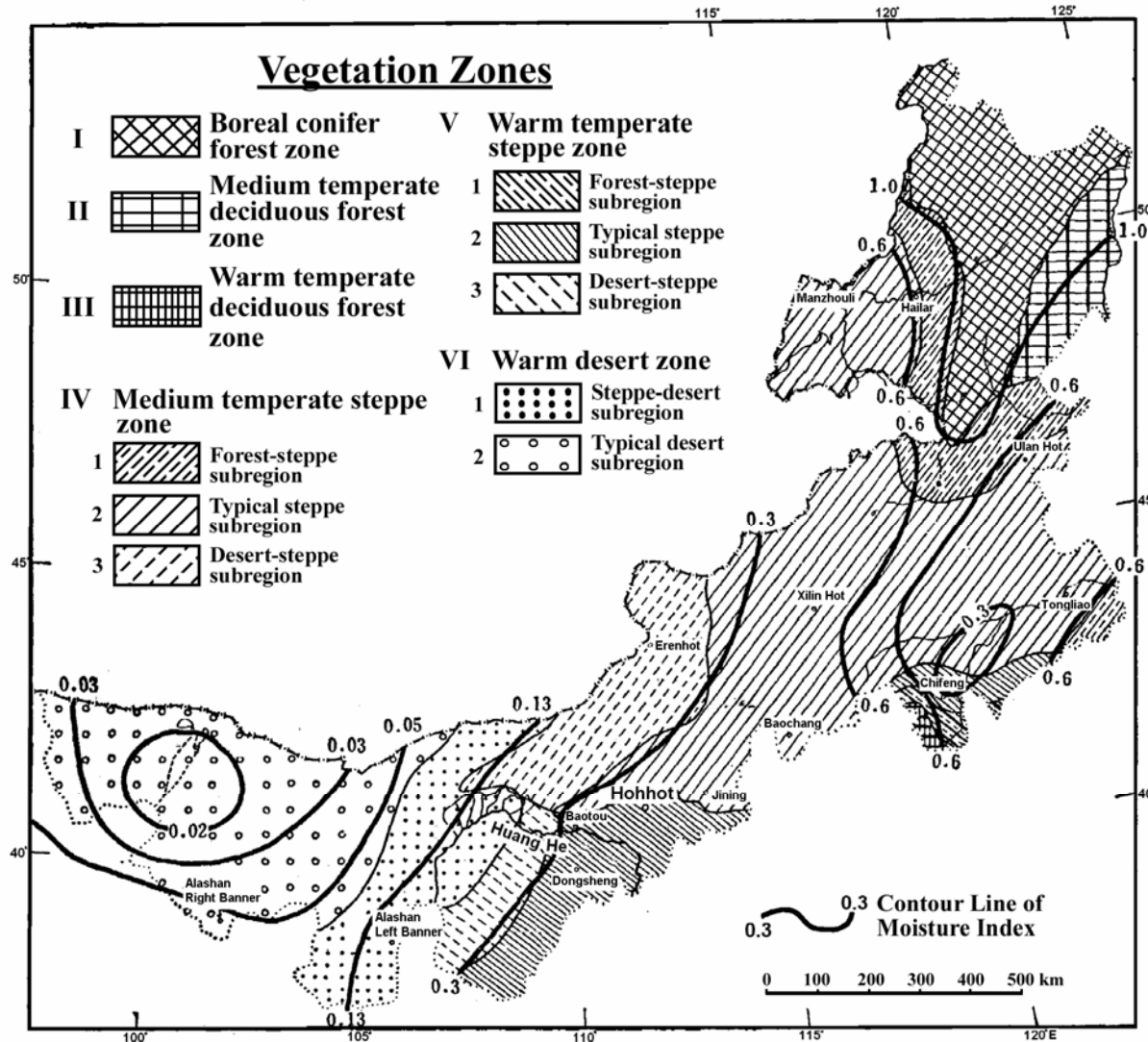
MODIS
Land cover
+ FVC



MODIS
Land cover
only



Transition and Patterns

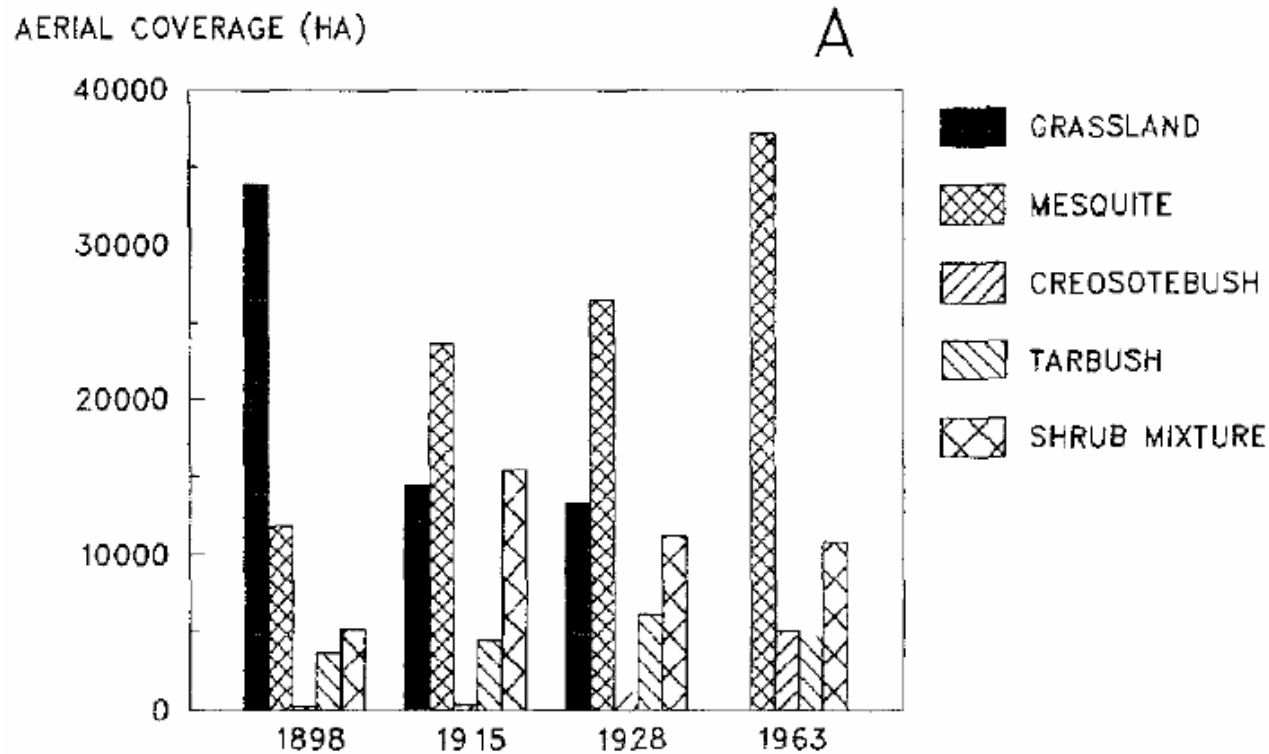


Moisture index
= P/E_p

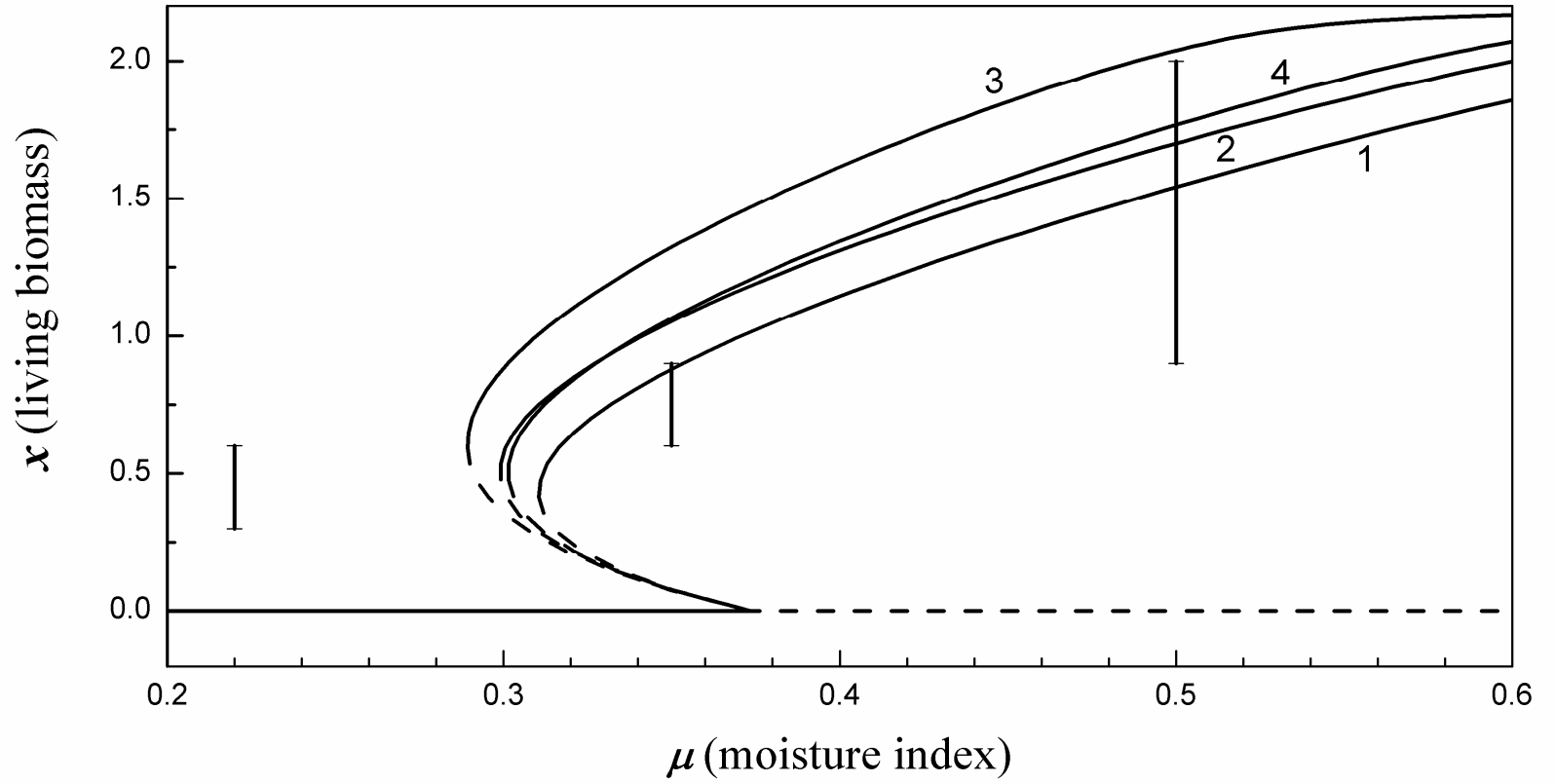
Three-variable model:

Living biomass;
Dead biomass;
Soil moisture

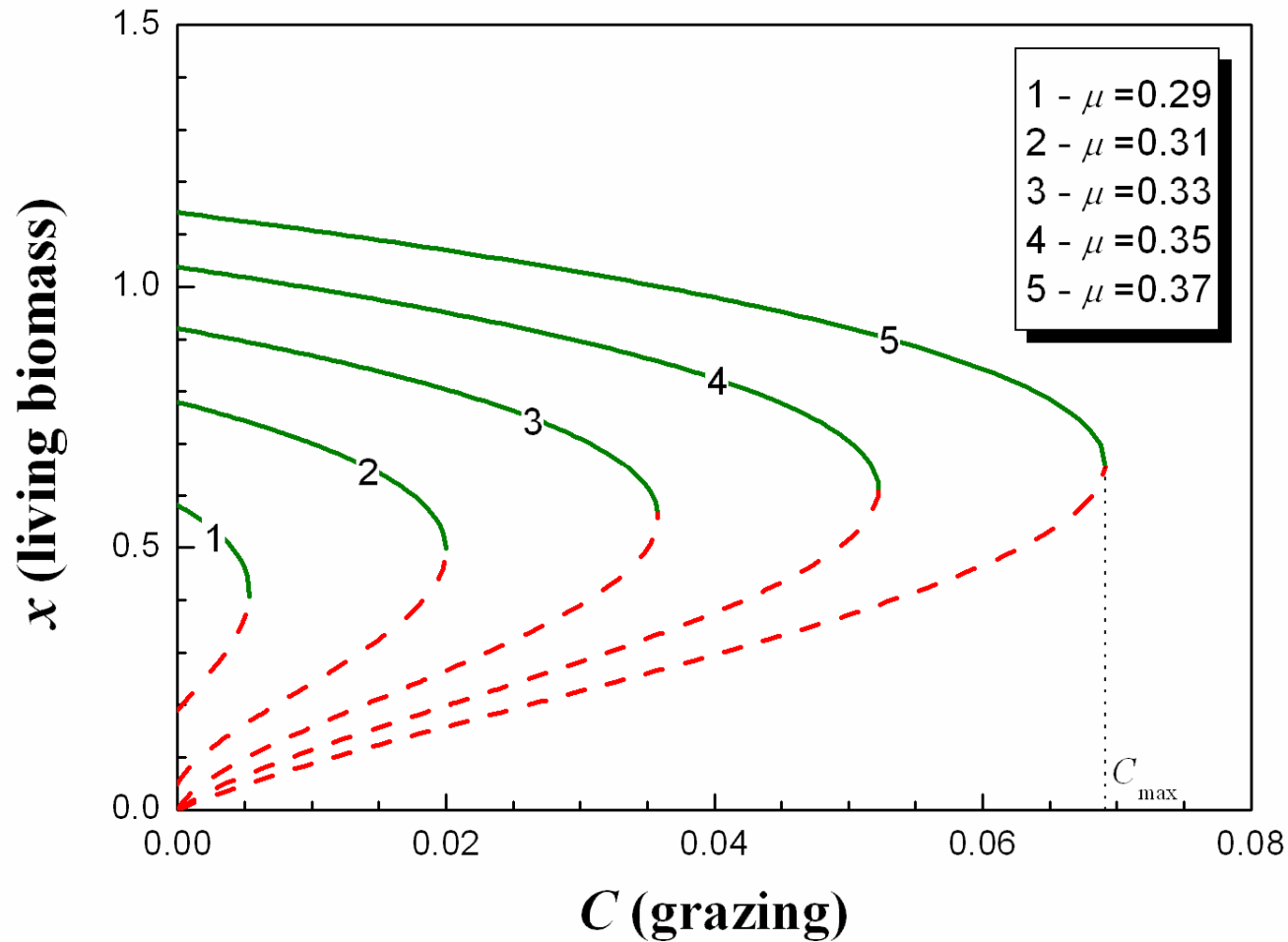
Summary of change in the areal coverage (ha) of several vegetation types on the Jornada Experimental Range, south-central New Mexico (Grover and Musick 1990; Buffington and Herbel 1965)



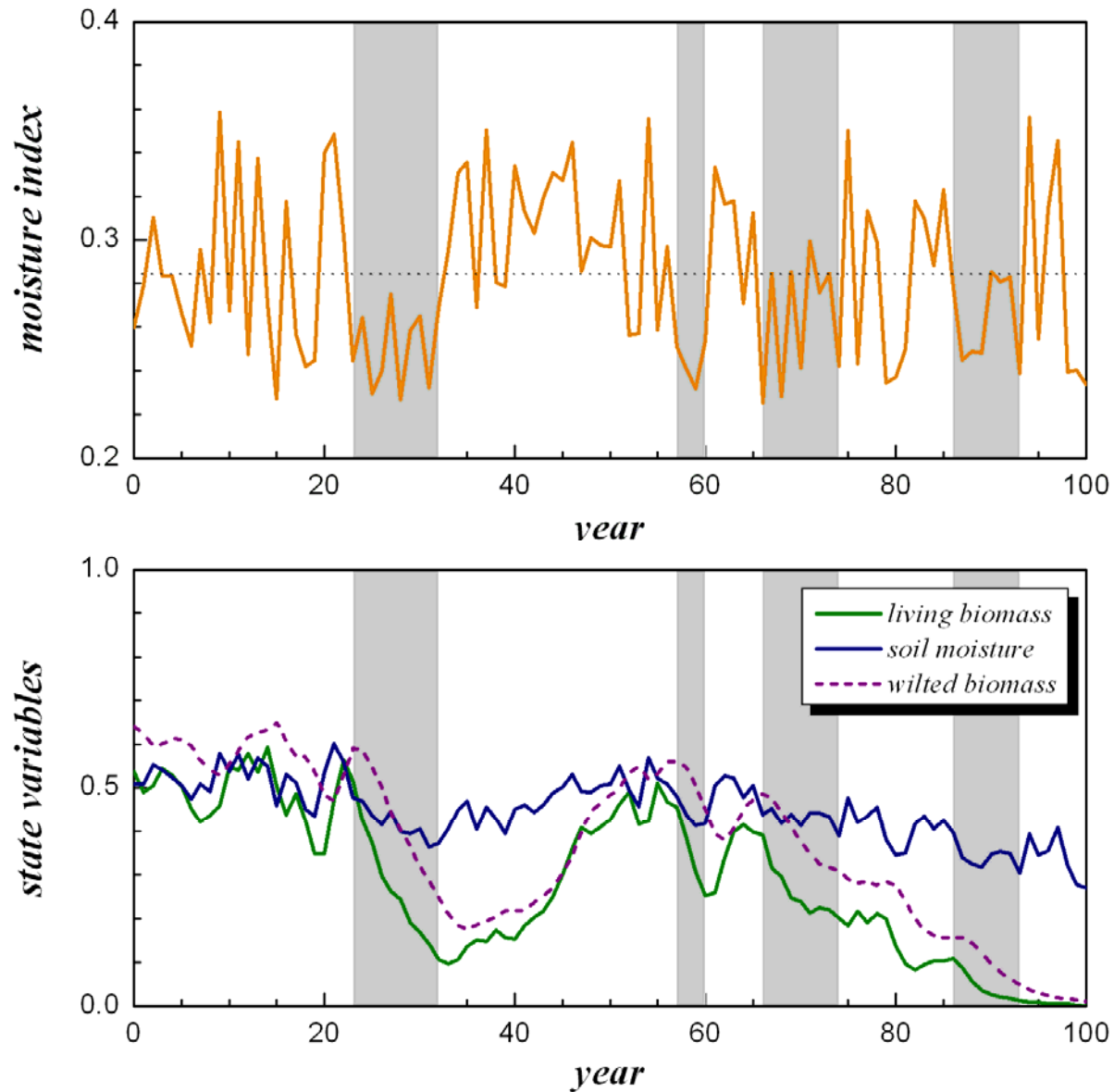
- The total area included in this study is 58,468 ha
- 43% shrub cover in 1915 has increased to 100% in 1963
- Mesquite shrub dominates over grasses and other shrubs



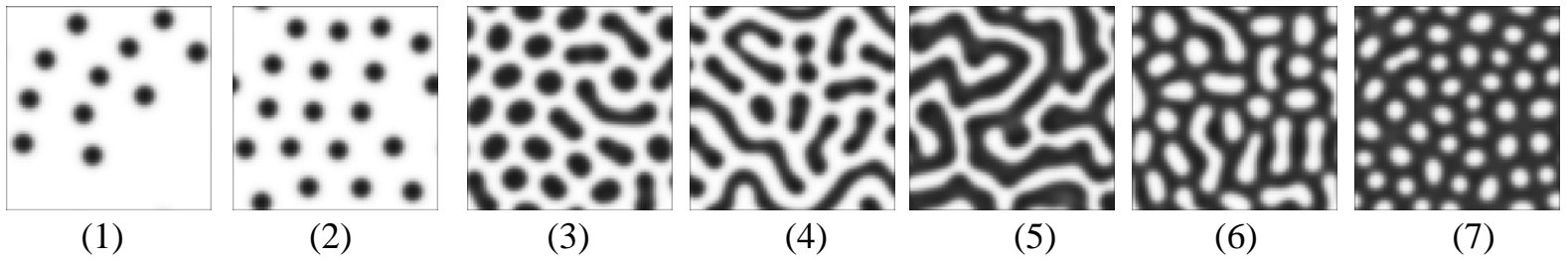
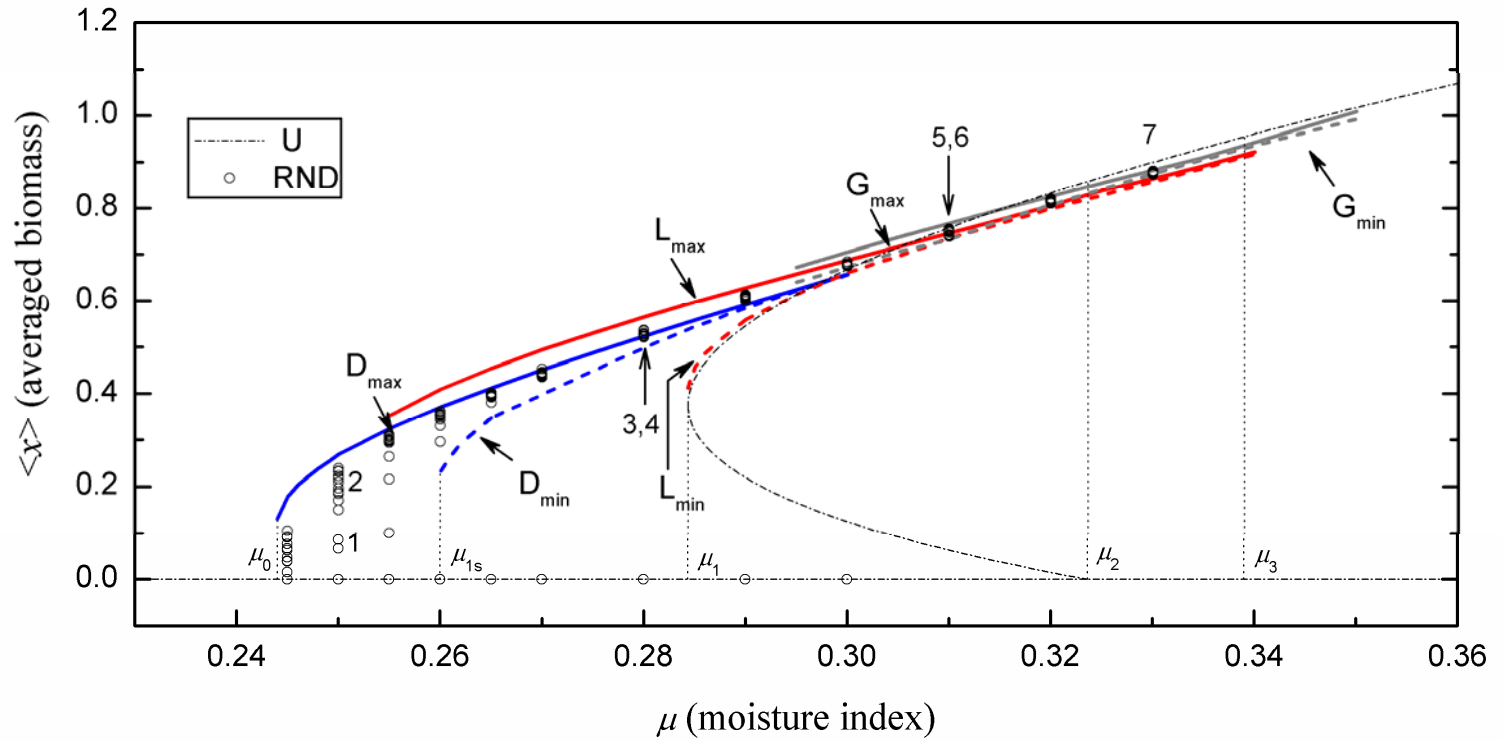
Q: What is the maximum grazing that can be taken from a grassland without leading it into desertification?



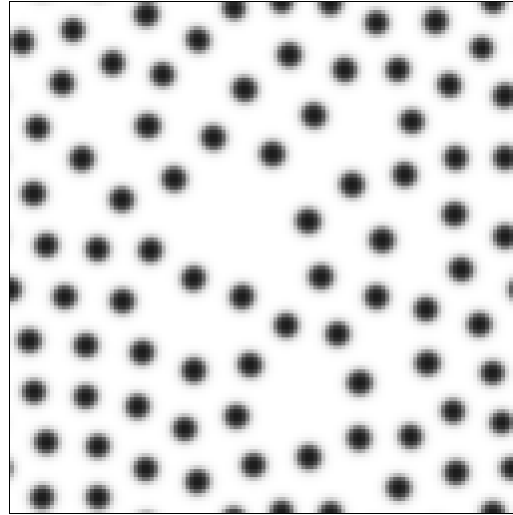
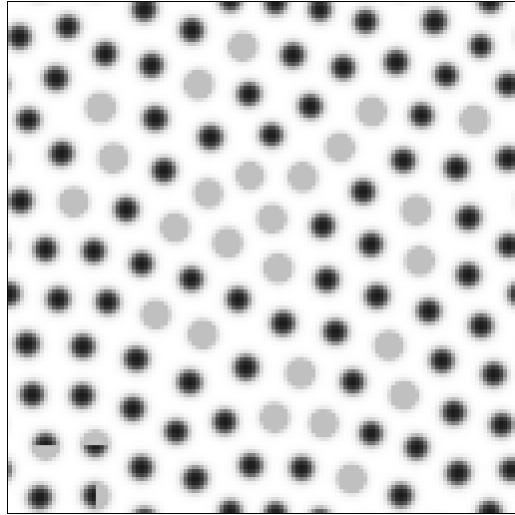
Q: How does interannual variability of drought lead to desertification?



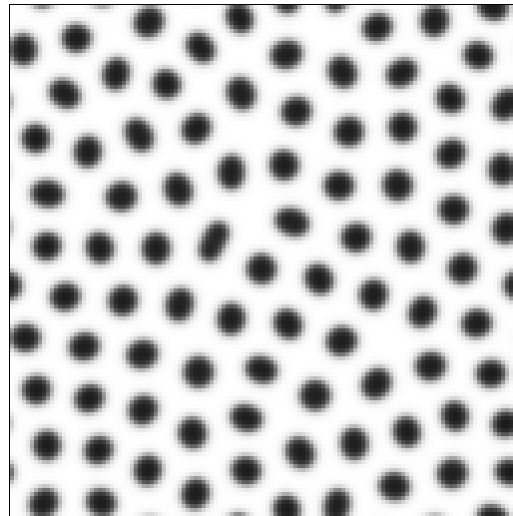
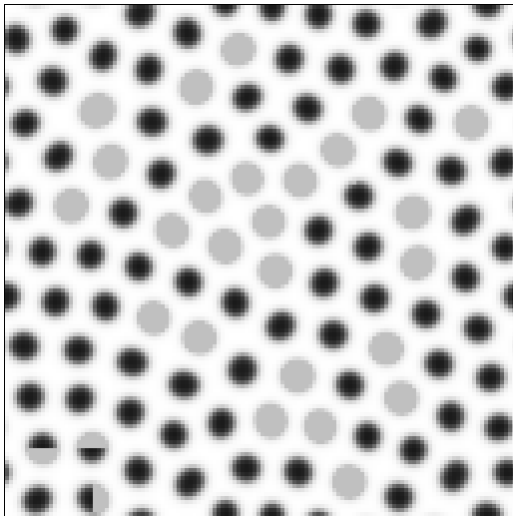
Vegetation Pattern and Diversity



Response of Ecosystem to Perturbations



Moisture index
= 0.25 (very dry)

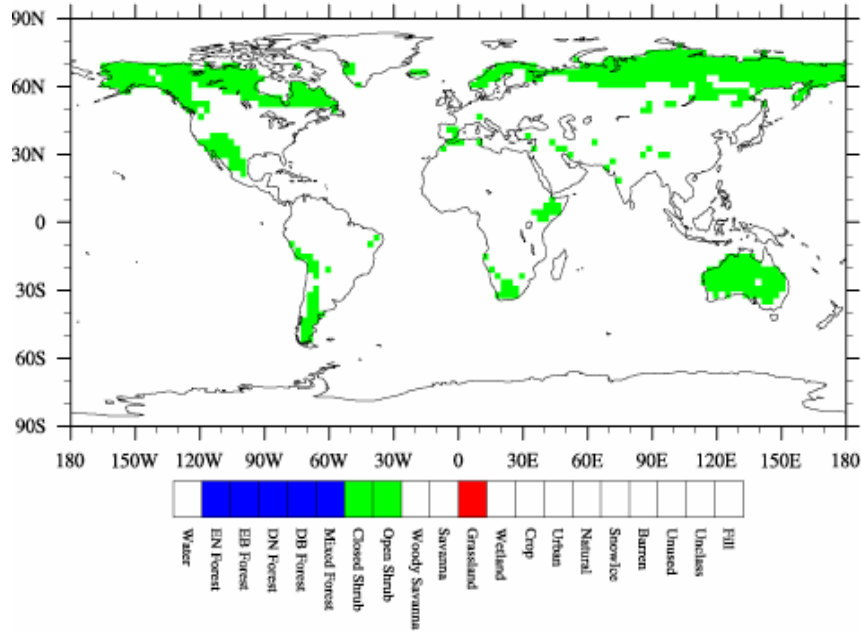


Moisture index
= 0.26 (dry)

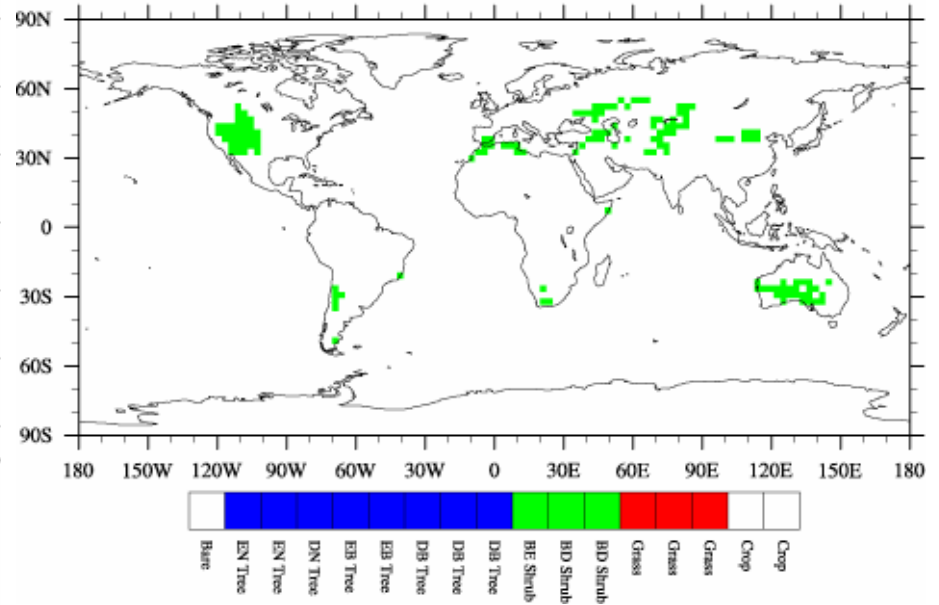
Summary

- Developed a shrub submodel for the DGVM for the global competition of trees, grass, and shrubs
- Shrubs grow primarily by reducing the bare soil coverage and to a lesser degree, by decreasing the grass coverage
- Shrub coverage reaches its peak around annual precipitation (Pann) of 300 mm, the grass coverage reaches its peak over a broad range of Pann (from 400-1100 mm), and the tree coverage reaches its peak for Pann = 1500 mm or higher
- Use of MODIS land cover data alone is not sufficient for the DGVM model evaluation (particularly for shrubs)

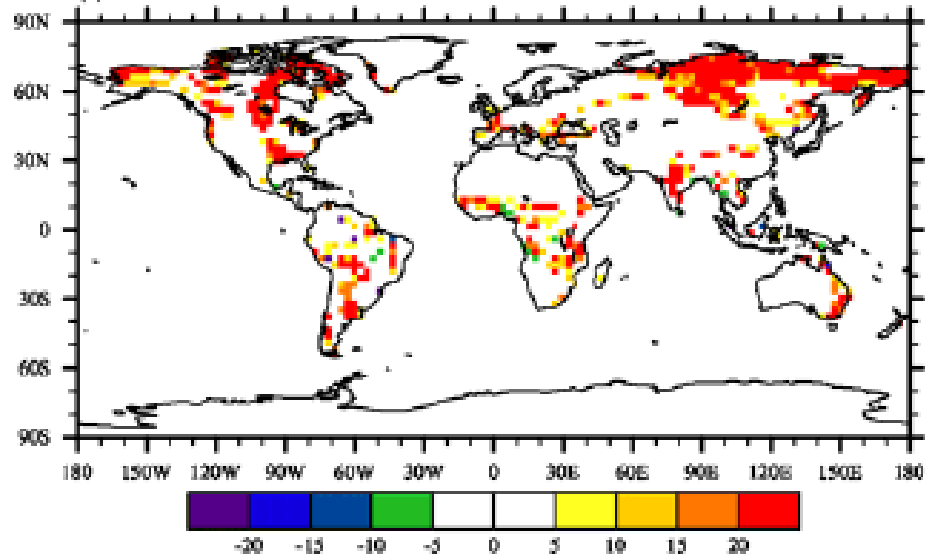
MODIS Shrubcover > 20%



DGVM-Shrub: Shrub > 20%

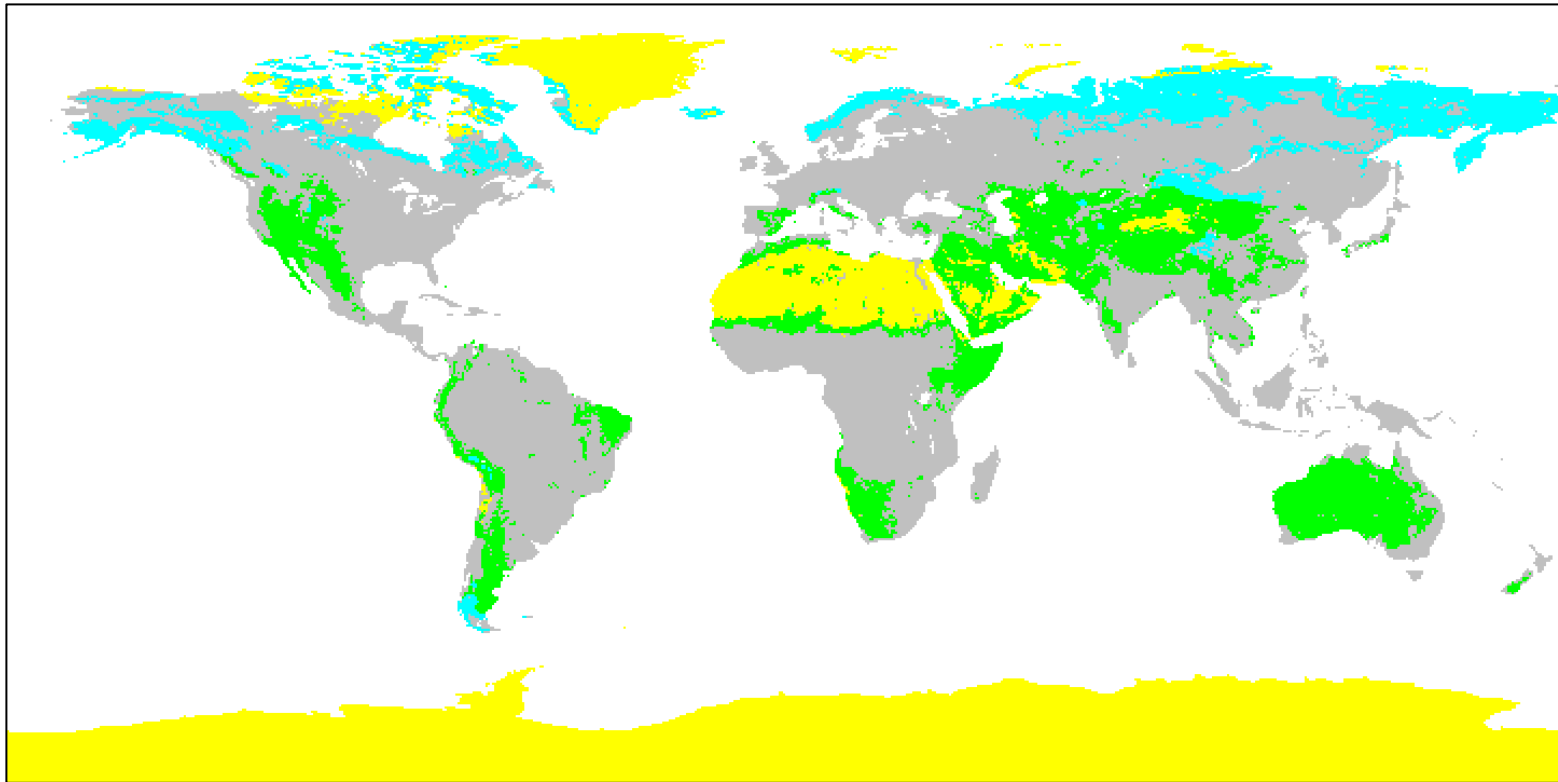


(a) New-Ctl Tree Cover Diff



- Developed a 3-variable ecosystem model for dry regions: bifurcation; grazing; climate variability
- When spatial interactions are included, vegetation can exist even under the environmental condition in which uniform vegetation cannot exist
- None of the current DGVMs or land models considers spatial interactions
- Indicator of stress and degradation: when spatial vegetation patterns appears
- Indicator of fragile and unstable vegetation: when spatial patterns and average biomass change significantly over an area
- These modeling results need to be confirmed using high-resolution satellite and insitu data

Dynamic Global Vegetation Model (DGVM)



Global distribution of shrubs

(from CLM surface data)

■ Temperate shrub >5%

■ Boreal shrub >5%

■ Bare soil >95%