Grassland Ecosystem Simulation System for Temperate Eurasian Steppe: a multi-source terrestrial model development, evaluation and mathematical analysis

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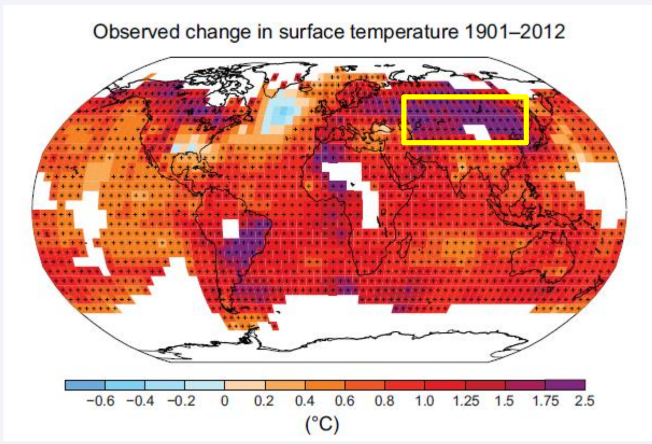
NEESPI Synthesis conference, April 9-12,2015, Prague, Czech Republic

TEMPERATE EURASIAN STEPPE(TES): convergence of climatic change and human activities

1. Faster Climatic Change, Sensitive Response

- The regional warming is among the fastest in the past century
- Grassland ecosystem is sensitive to global change, especially in arid/semi-arid areas



Spatial distribution of global warming trend (IPCC 5th report)

2. Traditional Pasture, Vulnerable Ecosystem

- World's important source of agriculture products, animal products and mineral resources.
- Grassland degradation and desertification has been identified during the recent decades

Major Disturbances in TES

PROPER MONITOR AND PREDICTION: find suitable regional model instruments for TES

Regional study gaps:

- LARGE RESEARCH DISCREPANCY EXISTS
  Most studies are mainly concentrated on Mongol Steppe, while other regions of TES were less investigated by the international research community.
- FROM FIELD MEASUREMENTS TO REGIONAL MONITOR
  Currently research of disturbance from husbandry industry generally based on field measurements, while we need a better regional understanding.
- TO FIND THE BEST WE HAVE NOW AND IMPROVE IT AGAIN
  We have many terrestrial biosphere models with similar contracture. We need to know which one works best, where is the major uncertainty and how to make further refinement

Model Simulations and Modifications ⇄ Uncertainty Evaluation and Benchmark System

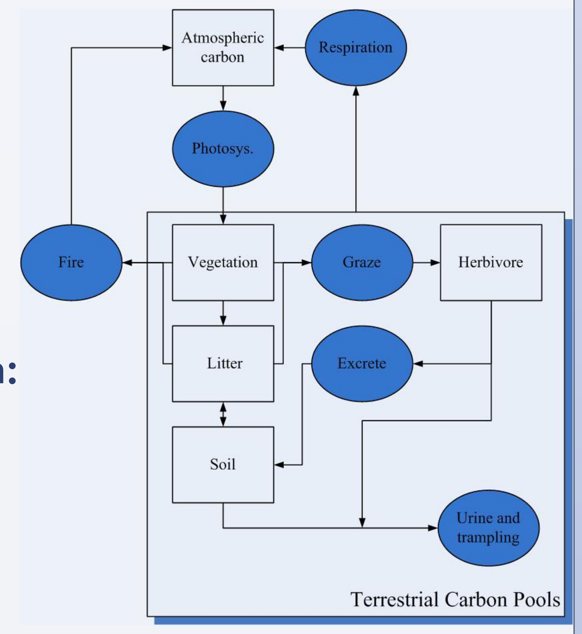
GRASSLAND ECOSYSTEM SIMULATION SYSTEM (GESS Ver. 1.0) DESIGN

1. Terrestrial Biogeochemical Model:

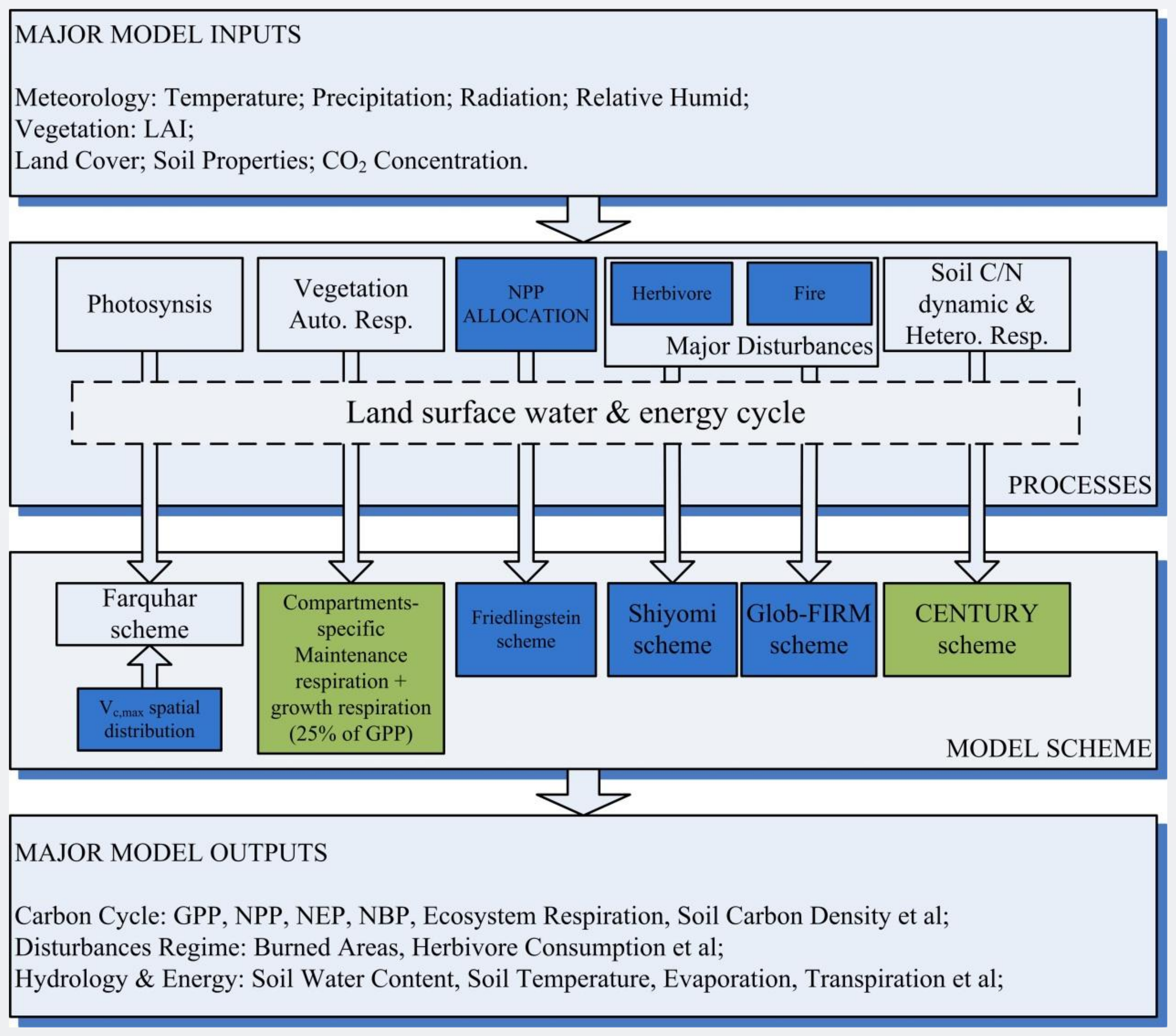
- **Prototype Model:** Boreal Ecosystem Productivity Simulator (BEPS) with photosynthesis, soil carbon and terrestrial hydrological and energy scheme;
- **Model Scheme Modifications:** NPP allocation, autotrophic respiration;
- **Parameterization on Grassland Ecosystem:** $V_{c,max}$ Spatial Distribution, Q_{10} for autotrophic respiration et al.

2. Disturbance Model:

- Graze Module: Modified Shiyomi grassland management scheme
- Fire Module: Glob-FIRM



Schematic diagram of Main Carbon Pool and Flux in GESS



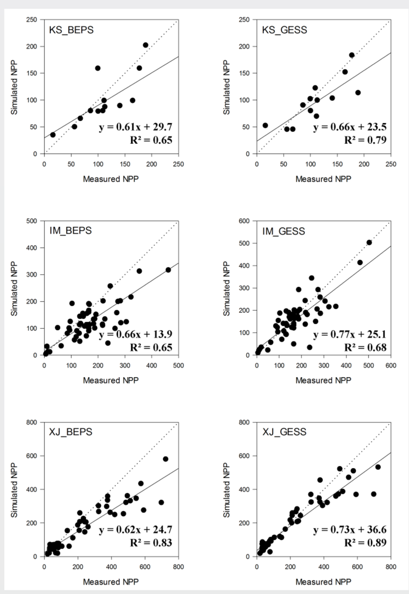
GESS model framework

MODEL PERFORMACE: Evaluation against multi-source dataset

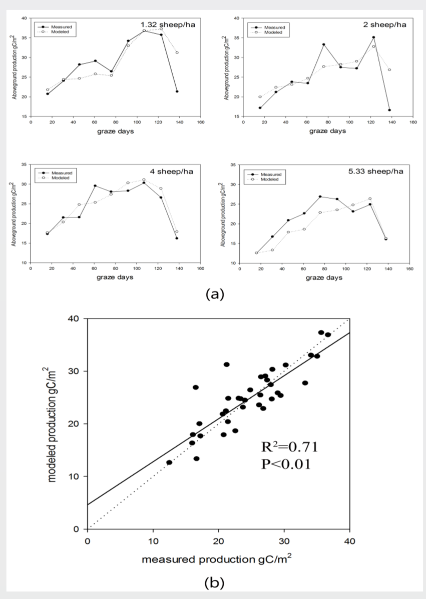
- NPP results from GESS showed good agreements with field measurements in the three sites (R^2=0.75);
- GESS model performed better than original BEPS to the three sets of field measurements. The correlation in KS shows the largest R^2 enhancement with 0.14 comparing with BEPS (0.79 versus 0.65).

- The overall correlation R^2 between model and field results is 0.71;
- the model usually under-estimated production during strong growth period (often from July to August) while over-estimated production during weak growth period (May and September), especially at the end of growth season.

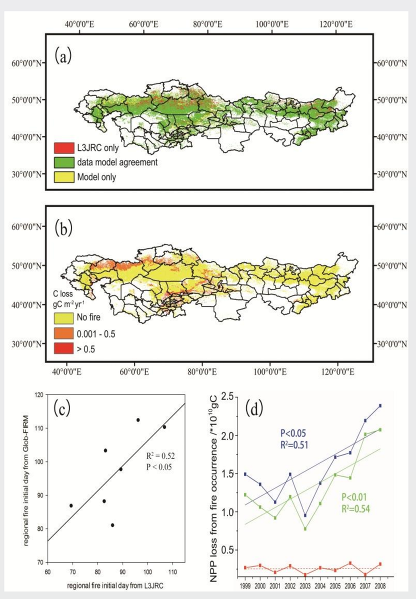
- 86% of the pixels are in agreement with the L3JRC dataset. The major disagreement is from the mountainous areas in north Kazakhstan and Kyrgyzstan.
- the model could catch the regional temporal pattern when fire starts to appear (R^2 = 0.52)



NPP validation against field measurements



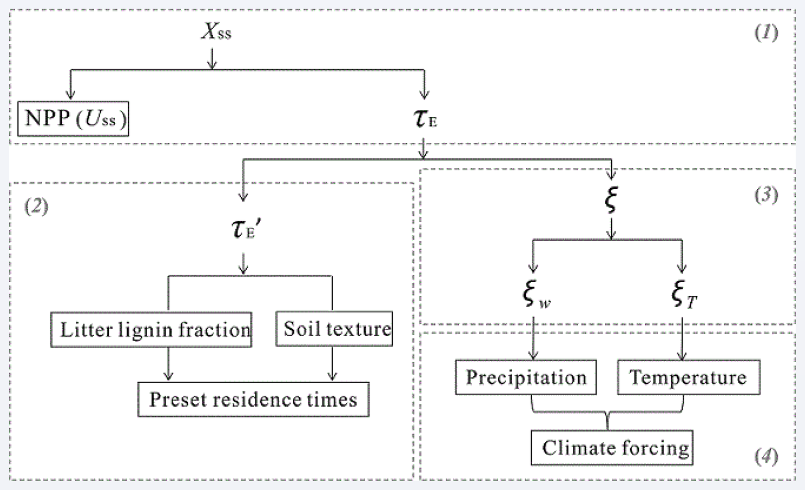
Graze module validation against field measurements



Fire module validation against remote sensing database

MATHETICAL ASSESSMENT ON DIAGNOSTIC TERRESTRIAL MODEL: model decomposition on GESS

Most of current terrestrial biosphere models could be decomposed into a few traceable components based on following matrix model (Luo et al, 2003, Xia et al, 2013):

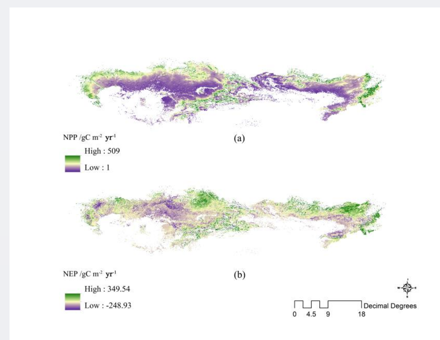


Schematic diagram of the traceable model framework (Xia et al, 2013)

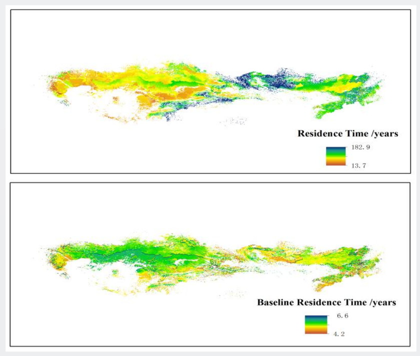
$$\frac{dX(t)}{dt} = BU(t) - A\xi CX(t)$$

- $\frac{dX(t)}{dt}$: carbon storage change
- $X(t)$: carbon storage at time *t*.
- C: potential turnover rates.
- ξ: environmental scalar on carbon decomposition
- A: carbon transfer matrix
- $U(t)$: net carbon influx
- B: carbon allocation

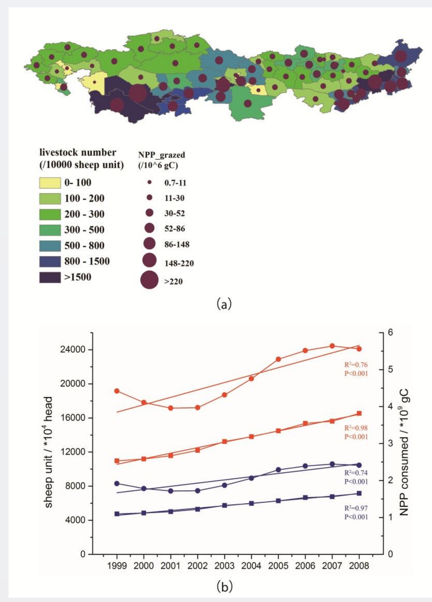
REGIONAL RESULTS PRESENTATION (PARTLY)



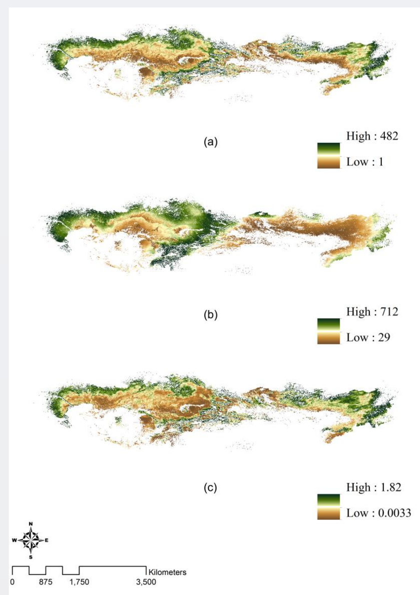
Regional results of (a) NPP, (b) NEP from 1999 to 2008



Regional carbon residence time and baseline residence time



Regional results of graze model output from 1999 to 2008



Regional results of (a) NPP, (b) Evaportranspiration, (c) Water use efficiency from 1982 to 2008

FUTURE WORK AND PERSPECTIVES

- Further model evaluation, especially for Kazakhstan Steppe;
- Pixel-based graze model development;
- Regional Model inter-comparison and benchmark.

Main references:
Xia J, Luo Y, Wang Y P, et al. Traceable components of terrestrial carbon storage capacity in biogeochemical models[J]. Global change biology, 2013, 19(7): 2104-2116.
Luo Y, White L W, Canadell J G, et al. Sustainability of terrestrial carbon sequestration: a case study in Duke Forest with inversion approach[J]. Global biogeochemical cycles, 2003, 17(1).
Thonicke K, Venevsky S, Sitch S, et al. The role of fire disturbance for global vegetation dynamics: coupling fire into a Dynamic Global Vegetation Model[J]. Global Ecology and Biogeography, 2001, 10(6): 661-677.
Ju W, Chen J M, Black T A, et al. Modelling multi-year coupled carbon and water fluxes in a boreal aspen forest[J]. Agricultural and Forest Meteorology, 2006, 140(1): 136-151.

Please feel free to contact us if you are interested or have any questions about (detail of) our study
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