The Dynamic Land Ecosystem Model (DLEM) and Its Applications to Carbon and Ecosystem Studies

Hanqin Tian[1], Mingliang Liu[1], Chi Zhang[1], Wei Ren[1], Guangsheng Chen[1], Shufen Pan[1], Hua Chen[1], Steven Running[2], Jerry Melillo[3] and Jiyuan Liu[4]

School of Forestry and Wildlife Sciences, **Auburn University**, Auburn, AL, USA; [2]Dept of Ecosystem and Conservation Sciences, **University of Montana**, Missoula, MT 59812, USA; [3]The Ecosystem Center, **Marine Biological Laboratory**, Woods Hole, MA 02543, USA; [4]Institute of Geographical Sciences and Natural Resources Research, **Chinese Academy of Sciences**, Beijing, 100101, China; ***Contact information:** email:tianhan@auburn.edu

The Dynamic Land Ecosystem Model (DLEM)

The DLEM is a highly integrated land ecosystem model which couples major biogeochemical cycles, hydrological cycle, and vegetation dynamics to make daily, spatially-explicit estimates of water, carbon (CO_2, CH_4) and nitrogen fluxes (N_2O) and pool sizes (C, N and water) in terrestrial ecosystems (Fig. 1). DLEM builds on the experience and heritage of the existing Terrestrial Ecosystem Model (Raich et al. 1991; Melillo et al. 1993; McGuire et al. 1992, 2001; Tian et al. 1998, 1999, 2000, 2003; 2005, Felzer et al. 2004, 2005) and Biome-BGC (Running and Hunt 1993; Thornton, P.E. 1998, 2002). DLEM includes five core components (Fig. a): 1) biophysics, 2) plant physiology, 3) soil biogeochemistry, 4) dynamic vegetation, and 5) land use and management. DLEM also integrates algorithms of N_2O emission from DNDC (Li and Aber 2000) and CH_4 emission from other previous studies (Huang et al. 1998,2005; Zhuang et al. 2004). The biophysical component includes the instantaneous exchanges of energy, water, and momentum with the atmosphere. Plant physiology component simulates major physiologic processes such as photosynthesis, respiration, allocation among various parts (root, stem and leave), nitrogen uptake, transpiration, phenology, etc. Soil biogeochemistry simulates mineralization, nitrification/denitrification, decomposition and fermentation. The dynamic vegetation component in DLEM simulates two kinds of processes: the biogeography redistribution when climate change, and the plant competition and succession during vegetation recovery after disturbances. The additional detail of model structure has been shown in Fig. 1b).

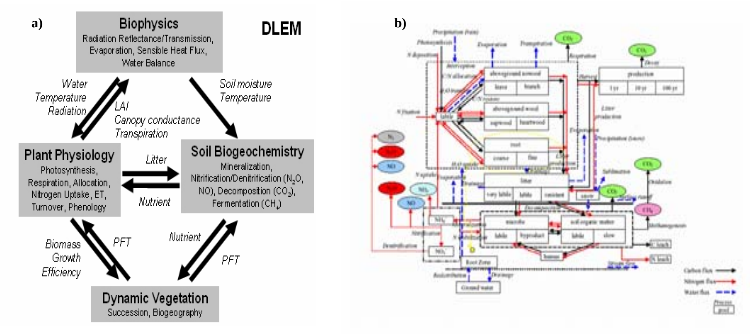


Fig. 1 The Dynamic Land Ecosystem Model: a) Model components and b) Model Structure

Plant Functional Types:

Like most DGVMs, DLEM builds on the concept of plant functional types (PFT) to describe vegetation distributions. The DLEM has also emphasized the modeling and simulation of managed ecosystems including agricultural ecosystems, plantation forests and pastures. This model has been calibrated using field data from 18 plant functional types (PFTs) across China and USA (Fig. 2.). (type 3: Boreal needleleaf evergreen forest)

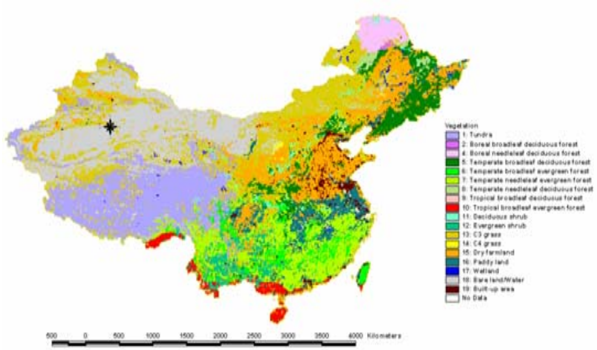


Fig. 2 DLEM Plant Functional Types

Calibration and Validation of the DLEM model:

The DLEM model has been calibrated against 18 plant functional types across China and USA. Most field data for model calibration are from CERN (Chinese Ecosystem Research Network) and LTER (Long-term Ecological Research in US). We also have worked on model validation against observations at field sites not used for model calibration/parameterization. Fig. 3 & 4 show the examples of model validation that we have done in wetland and plantation forest.

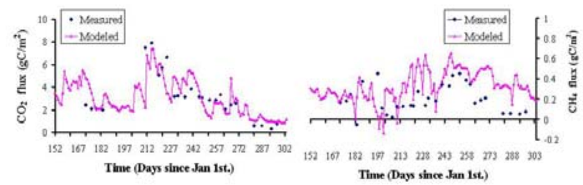
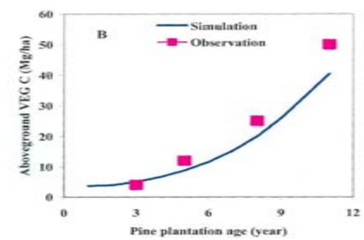


Fig. 3 Measured and simulated CO_2 and CH_4 fluxes in 2002 in a wetland in Northeast China

Fig. 4 Simulations of loblolly pine plantations in Georgia using DLEM model. aboveground vegetation carbon storage simulation versus observed data of a pine plantation receiving N fertilization.



Regional Applications:

A) CO_2 flux and its controls:

Net carbon storage in China shows substantial year-to-year variation. For the period of 1981-2000, DLEM simulation indicates that the land ecosystems were a sink of carbon to the atmosphere. Net carbon storage also shows substantial spatial variations across the China. During 1981-2000, China's land ecosystems as a whole acted as a sink of CO_2, but some parts of the China still released carbon to the atmosphere. Interannual variations in net carbon storage were primarily caused by climate variability; the effect CO_2 fertilization was primarily responsible for the increase in carbon storage in China's terrestrial ecosystems.

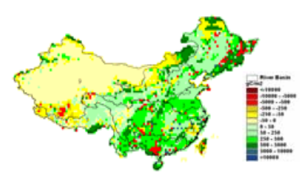


Fig. 5 Change in carbon storage during 1981-2000

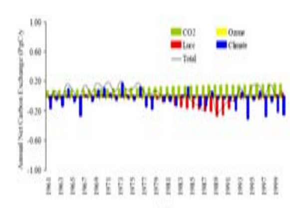


Fig. 6 Relative contribution of climate, CO_2, O_3, and land-use to annual net carbon exchange between 1961 and 2000.

B) CH_4 Emission From Paddy Land

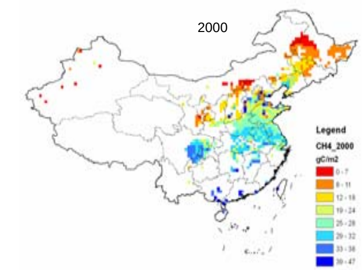


Fig. 7 CH_4 emission from paddy land as estimated by DLEM. The southern paddy land shows larger methane emission than northern paddy land.

C) Change in water yield and its controls:

Water yield has increased in Southeast China, but North and Central China show a decrease since the 1960s (Fig. 8). Climate variability is the primary factor that controls substantial inter-annual variability in water yield (Fig. 9). Climate made a slight increase trend in water yield with 5 mm per decades. Increasing atmospheric CO_2 led to a slight increase in water yield, about 1 mm per decade. Land-use change led to the water yield decrease of about 5 mm during 1961-2000.

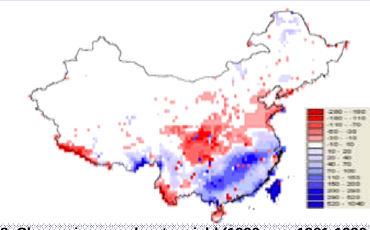


Fig. 8 Change in annual water yield (1990s vs. 1961-1990 long-term mean) estimated by DLEM (mm/year).

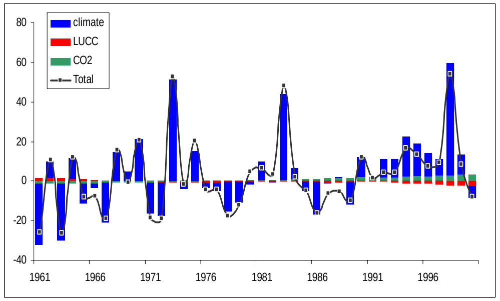


Fig. 9 Factors influencing historical change in water yield (mm/year)

Acknowledgement

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