Annual Report (2004-2005)
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Project Title: Carbon Flux and Storage in Mixed Oak Forests of MOFEP
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Objectives: The primary objective of this study is to quantify differences in carbon flux and storage in mixed oak forests of the Southeastern Missouri Ozarks resulting from alternative management practices, landform, and climate change. The experimental units of MOFEP provide the basis for our goal of predicting Net Carbon Exchange (NCE, i.e., equivalent to net ecosystem production) at multiple temporal scales (monthly to century). We are developing a spatial context for predicting NCE and C storage using processed Landsat imagery, ecological land type phases (ELTP) and digital elevation model (DEM) databases.

Data: We completed our field data collection of soil respiration, photosynthesis of dominant tree species, litter decomposition and associated lab analysis (e.g., chemistry, carbon and nitrogen content), litter-fall, root biomass, soil chemistry, soil temperature, and the installation of two microclimate stations. All these data in addition to photo-image, analysis products are available via Internet, at the MOFEP web site: http://mofep.conservation.state.amo.us/. Hemispherical photos taken at the MOFEP units were archived in five CDs and mailed to the MOFEP data manager (Julie Fleming). An independent project funded through the JFSP purchased six Landsat TM of the region for years 2003, 1996, 1992, 1984, and 1976. We used these images to predict biomass distribution in 2003 across the MOFEP landscape (see Zheng et al. submitted).

Products: To date, we have produced four peer-reviewed publications, submitted five additional manuscripts, and completed one M.S. Thesis, which utilize results of this project. This study also supported five scientific presentations to date (e.g., ESA Annual Meetings, See appendix A). We are modifying both the PnET and GENDEC models for the MOFEP study; an interactive version, http://research.eeescience.utoledo.edu/lees/research/jfsp/model/pnet/pnet_step1.asp, allows users to run the PnET model via the Internet.

Project Highlights: Photosynthesis (PS) is the major carbon sink in forest ecosystems. We examined PS for three different age classes of trees, young (<10 years), intermediate (15-25 years), and mature (>80 years), at three canopy levels (upper, middle, and lower), for the most important species (white oak, black oak, scarlet oak, hickory and short leaf pine) on MOFEP. The average photosynthetic rate among all the species at standard conditions (i.e., 1500 μmol photons m^{-2} s^{-2} PAR, and 360 μmol/mol ambient CO_2 concentration) was 7.97 and 8.23 μmol C m^{-2} s^{-2} for the ACI and light response curves, respectively. The average maximum PS rate among all the species was 19.7 and 8.46 μmol C m^{-2} s^{-2} for CO_2 and light response, respectively. The upper canopy positions typically experienced greater capability than lower positions ($p<0.0001$ to 0.0125). Specific leaf weight was the best predictor of PS rate among the factors (i.e., SPAD chlorophyll concentration, vapor pressure deficit, temperature, and fraction of PAR intercepted).

Soil respiration rate (SRR) – amount of carbon releases from soils -- averaged 4.14 μmol m^{-2} s^{-2} at MOFEP, is the major carbon source in forest ecosystems, and was significantly different by site and by management within site (Fig. 1; $p = 0.0012$ and $p = 0.0026$, respectively).

Soil respiration rate was not significantly different between the controls and even-aged harvest (clearcut), but was significantly higher with the uneven-aged harvest (single tree selection). Soil respiration rate also was significantly different among ELTP (ecological land type phase): SRR with uneven aged harvest were higher than controls in protected ultic back-slopes, protected alfic back-slopes, and alfic bench or shoulder-ridges and lower than controls on both exposed ultic back-slopes and exposed alfic back-slopes.

Sequestration of dead organic matter in forest soils is a major sink for atmospheric CO_2. We monitored decomposition of mixed leaf litter (*Quercus spp, Juglans spp, and Pinus echinata*) decomposition 8 years after experimental manipulation. Treatments were clear-cut (EAM), intermediate cut (UAM), and control (NHM). We examined mass losses and changes in carbon chemistry (water soluble, acid soluble, and acid insoluble) of litter for 19 months, and checked for differences due to: (1) management treatments, (2) stand composition, i.e., oak (O), oak-hickory (OH) and oak-pine (OP) sites, and (3) initial litter carbon chemistry. The coefficients of decay (k) were 0.58 (±0.03, EAM), 0.45 (±0.02, UAM), and 0.44 (±0.01, NHM, Fig 3), with significant differences between treatments ($p = 0.001$), and stand composition ($p = 0.007$). Mass loss of litter was largest over 19 months for EAM (59%), then for UAM (50%), and smallest on NHM (49%) stands. The oak-hickory sites mass lost more mass (52%) than oak–pine sites (49%), but there was no significant difference between oak (51%) and other two sites. The initial leaf litter, carbon chemistry had no significant effect on decomposition. This indicated that the detailed single species leaf litter needed to discover the decomposition process behavior at MOFEP study site.

We calculated total carbon storage at MOFEP to be 182, 170, and 130 Mg C ha^{-1} for the non-harvest (NHM), singletree uneven-age cut (UAM), and clear-cut even-age (EAM) stands, respectively. The allocation of major carbon pools are 29% in living tree biomass carbon, 35% in mineral soil, 22% in woody detritus, 10% in roots, and 4% in forest floor (Fig 1). Forest harvesting did not affect tree species composition, or forest floor and root pools, but significantly ($p \leq 0.05$) changed stand tree density, mineral soil carbon, living tree biomass, and CWD. Harvesting reduced carbon storage in living trees by 31% in UAM and 93% in EAM, and increased CDW carbon pools by 50% in UAM, and 176% in EAM. Uneven aged management significantly increased the mineral carbon pool by 13%, while EAM only slightly increased (by 1%) soil carbon.

Analysis of Landsat images suggested a total aboveground biomass of 8.7 Mg (dry weight) for the region (69,555 ha), averaging 126 Mg/ha and ranging from 1 to 460 Mg/ha. Of this the total biomass, 42% was distributed at elevations 250-300 m, 52% in areas with slopes<10 degree, and 30% in southeast facing slopes. The highest mean biomass (143 Mg/ha) with the lowest standard deviation (std 16 Mg/ha) existed for the NHM while smaller means with higher variation characterized EAM and UAM sites. No statistical difference existed among biomass of the three major ELT types (11, 17, and 18; Fig 2.)

Future Plans: We have field data for three full growing seasons (2003, 2004, and 2005), as well as from a litter decomposition study spanning more than 3 years. These studies have revealed some gaps in our understanding of carbon flux in MOFEP. Our research plans for the coming season include continuing field data collection, installing new litterbags for single species, litter decay studies (e.g., oak, hickory and pine), maintaining two weather stations, expanding the data archive for MOFEP, and performing data analysis for additional publications. This includes several detailed field, and related activities:

- Nine soil pits for vertical soil respiration measurements
- New litterbags for NHM, UAM (single tree, group opening), EAM (Intermediate, clear-cut)
- Monthly soil respiration measurements at 62 selected plots
- Monthly litter fall collection from 104 litter traps
- Monthly maintenance and downloading information from 36 HOBO data loggers
- Bi-weekly maintenance of the two microclimate stations and data downloading
- Taking hemispheric photos at 36 vegetation plots and along the 100 meter transects
- Taking hemispheric photos at 104 hard mast traps.
- Organizing the database of over-story, litter fall, CWD, soil total carbon, and ground litter for quantifying carbon pools
- Conducting soil and litter chemistry analysis
- Measuring foliar nitrogen and carbon using the CHN Analyzer at the LEES lab

Additional laboratory-related activities will focus on two main goals:

- Parameterizing PnET and GENDEC models for different experiments
- Processing the other 4 Landsat TM images for manuscripts

Finally, data analysis and manuscript development will be our primary focus for 2004/2005, including the following prioritized publications:

1. The effects of forest management on carbon pools across Missouri Ozark forest landscape (*For. Ecol. Manage.*)
2. Spatial pattern of aboveground biomass in Southeastern Missouri Ozarks forest ecosystem: linking remote sensing with field observations (*Int. J. Remote Sensing*)
3. The effects of canopy removals on soil C efflux in mixed oak forests (*For. Ecol. Manage.*).
4. Contributions of decomposition to ecosystem carbon flux and storage in mixed oak forests of the Missouri Ozarks (*Ecol. Modelling*).
5. Spatial variations of soil carbon fluxes affected by experimental treatments (*Plant and Soils*)
6. Current and future carbon fluxes of Ozark Landscapes: a modeling approach (PnET)

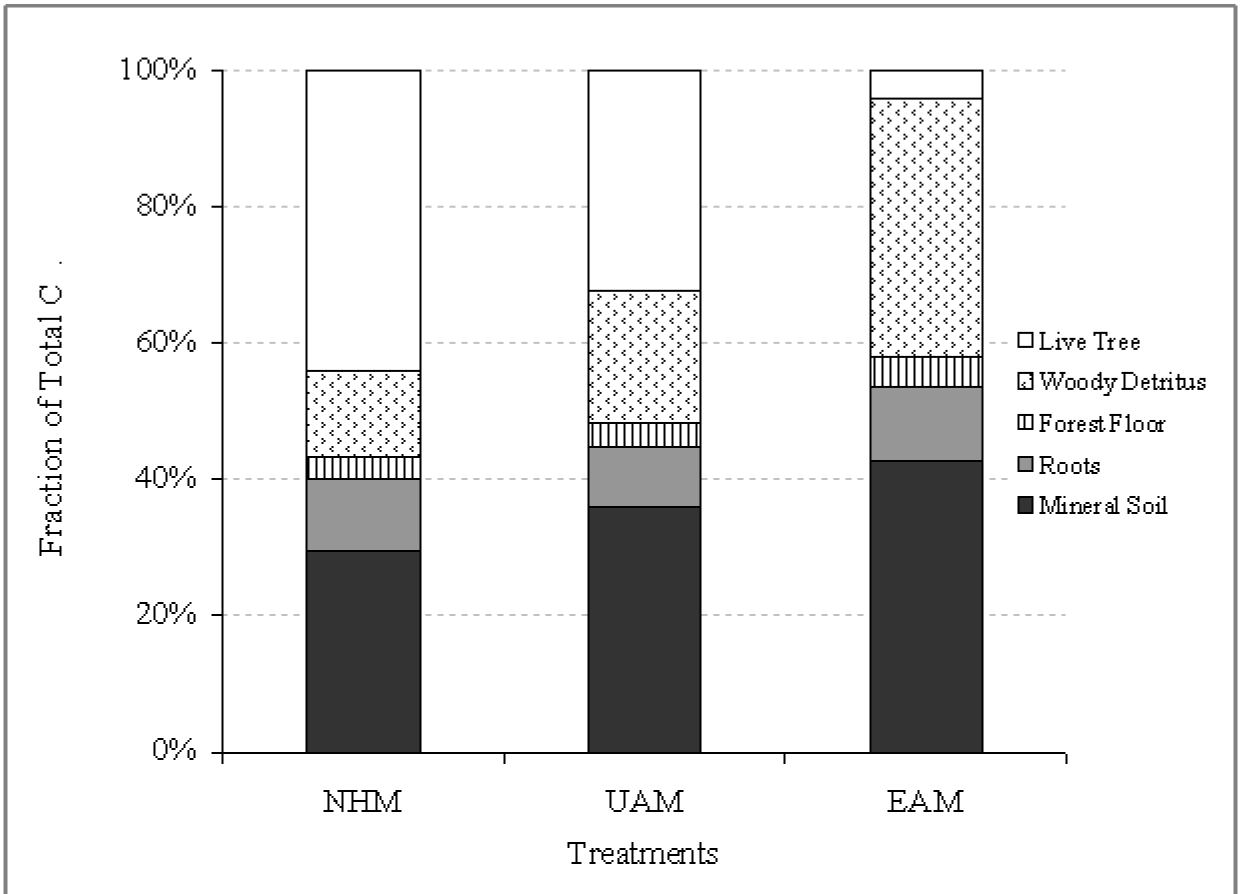

Fig. 1. Allocation of carbon and pools at MOFEP post-treatment compartment in 2004.

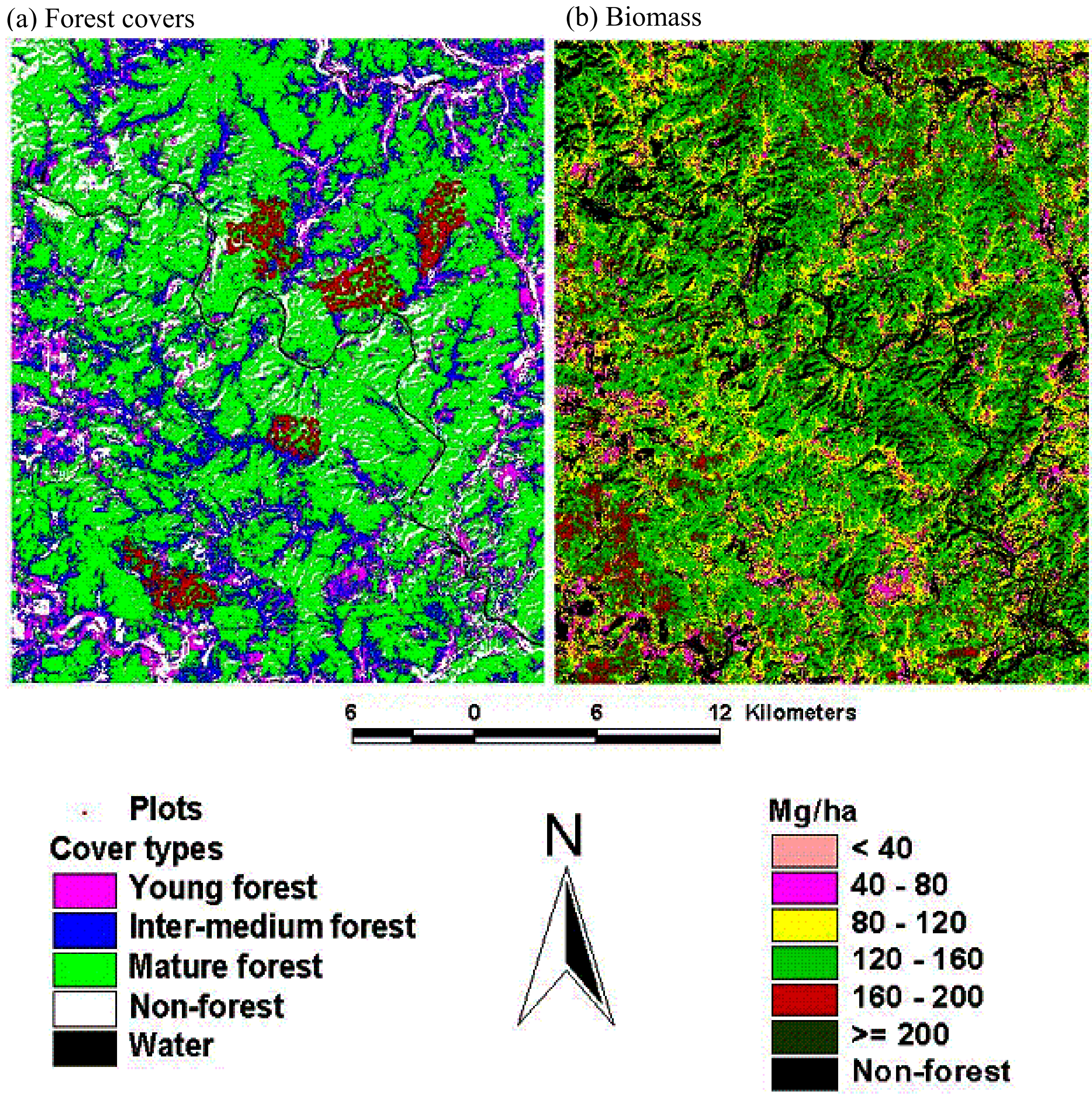

Fig. 2. General land cover types in 2003 (non-forest vs. forest) developed from a detailed land-cover map derived from Landsat ETM+ image with locations of the 648 Missouri Ozark Forest Ecosystem Project (MOFEP) plots (a); and forest aboveground biomass map 2003 (b).

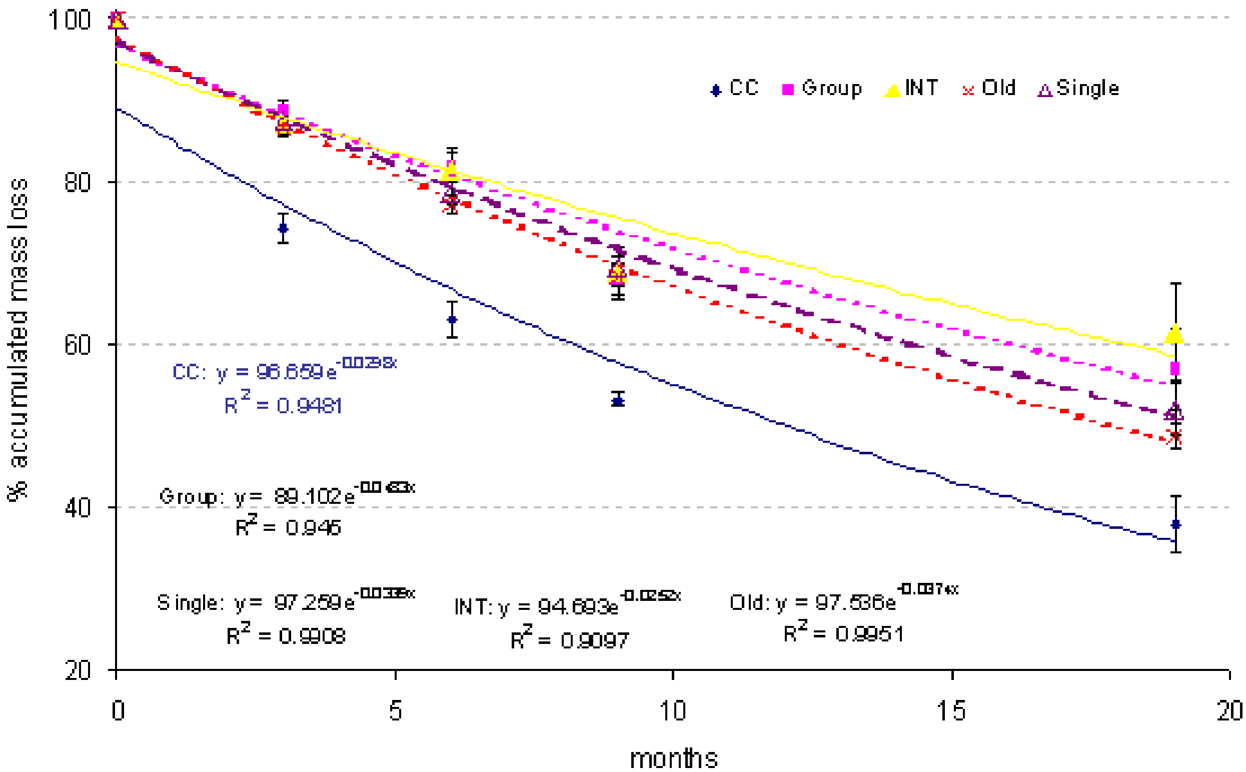

Fig. 3. Litter mass loss using a single fit for different forest management treatments at MOFEP compartments.

Appendix: Publications and Presentations

Publications:

1. Chen, J, K.D. Brosofske, A. Noormets, T.R. Crow, M.K. Bresee, J.M. Le Moine, E.S. Euskirchen, S.V. Mather, and D. Zheng. 2004. A working framework for quantifying carbon sequestration in disturbed land mosaics. *Environmental Management* 34 (3): S210-221.

2. Xu, M., Y. Qi, J. Chen, and B. Song. 2004. Scale-dependent relationships between landscape structure and microclimate. *Plant Ecology* 173(1): 39-57.

3. Ryu, S., J. Chen, T.R. Crow, and S.C. Saunders. 2004. Available fuel dynamics in nine contrasting forest ecosystems in North America. *Environmental Management 34(3): S87-107*.

4. Concilio, A. S. Ma, Q. Li, J. LeMoine, J. Chen, M. North, D. Moorhead, and R. Jenson. 2005. Soil respiration response to experimental disturbance in mixed conifer and hardwood forests. *Canadian Journal of Forest Resource* (in press).

5. Bresee, M.K. 2004. Photosynthetic characteristics of dominant tree species in two climatically different landscapes. M.S. Thesis, University of Toledo.

6. Zheng, D., Q. Li, R. Jensen, and J. Chen. Spatial pattern of aboveground biomass in Southeastern Missouri Ozark forest ecosystem: linking remote sensing with field observations. *International Journal of Remote Sensing* (submitted).

7. Euskirchen, E. S., K. A. Harper, and Q. Li. Linking the ecology of forest edges to landscapes. Book chapter (in revision).

8. Li, Q., J. Chen, J. L. DeForest, R. Jensen, D. L. Moorhead, and M. Johnason. The effects of forest management on carbon pools across Missouri Ozark forest landscape. *Forest Ecology and Management* (submitted).

9. Bresee, M, J. Chen, Q. Li, A. Noormets, J. Rademacher, and S.Ryu. Photosynthetic variation influenced by microclimate, leaf characteristics, tree age, and crown position in two deciduous landscapes. *Tree Physiology* (to be submitted).

10. Li, Q., J. Chen, J.A. Rademacher, and M.K. Bresee. Areas of Multiple Edge Influences in Fragmented Landscapes: A New Approach for Differentiating Areas of Multiple Edge Influences (AEI_i). *Landscape & Urban Planning* (submitted).

Presentations:

1. Chen, J., D. L. Moorhead, and Q. Li. 2004. ?? Jefferson city, MO, Nov. 29-30, 2004
2. Chen, J., Q. Li, L. DeForest, R. Jensen, D. L. Moorhead, and M. Johnason. 2005. The effects of forest management on carbon pools across Missouri Ozark forest landscape. ESA, Montréal Canada, Aug. 5-12, 2005

3. Zheng, D., Q. Li, R. Jensen, and J. Chen. 2005. Spatial pattern of aboveground biomass in Southeastern Missouri Ozark forest ecosystem: linking remote sensing with field observations. ESA, Montréal Canada, Aug. 5-12, 2005
4. Li, Q., D. L. Moorhead, J. Chen, J. L. DeForest, R. Henderson. 2005. Effects of forest management on mixed leaf litter decomposition in MOFEP. ESA, Montréal Canada, Aug. 5-12, 2005