Development Sprawl Impacts on the Terrestrial Carbon Dynamics of the United States

Annual Report - Submitted April 17, 2001

Principal Investigator:

Christopher D. Elvidge
Office of the Director
NOAA National Geophysical Data Center
325 Broadway
Boulder, Colorado 80303 USA
Telephone: 303-497-6121 Fax: 303-497-6513 E-mail: cde@ngdc.noaa.gov

Co-Investigators:

Ramakrishna Nemani, School of Forestry, University of Montana,
Missoula, MT 59812 Tel. 406-243-6311 Fax: 406-243-4510
e-mail: nemani@ntsg.umt.edu

James E. Vogelmann, Raytheon ITSS Corporation, USGS EROS Data Center
Sioux Falls, SD 57103 Tel. 605-594-6062 Email: vogel@edcmail.cr.usgs.gov

ABSTRACT

Surfaces covered by constructed materials (roads, buildings, etc.) are withdrawn from photosynthesis and respiration. This loss is counterbalanced to some extent by managed vegetation (lawns, trees, etc.), which may be irrigated and fertilized. We are analyzing the impacts of development on the terrestrial carbon dynamics of the 48 states. The impact will analyzed by comparing ecosystem model runs made using land cover data with and without the current level of development.

We are making use of multiple sources of data to define the current pattern of development. This includes: 1) radiance calibrated nighttime lights from the U.S. Air Force DMSP, 2) road density form the U.S. Census Bureau, and Landsat derived land cover from the EPA-USGS National Land Cover Dataset. These data sets have been aggregated to the same 1 km grid covering the 48 states (conus).

For calibration, development levels are being measured using gridded point counts made on high resolution aerial photography selected to form transects across major urban centers and out to sparsely developed areas. This analysis will be extended to Landsat 7 data in year two. The level of development present in the 1 km grid cells will be estimated based on a multivariate analysis of the relations between the observations from the aerial photography, Landsat 7 data and the set of national data coverages.

Our results will improve understanding of the carbon budget of the US. With modification our methods should be extendible to the global monitoring of development and its impact on carbon dynamics, meeting monitoring objectives of UN Framework Convention on Climate Change.

QUESTIONS:

1.Our project addresses NASA ESE scientific questions on: a) what are the changes in land cover and/or land use (monitoring/mapping activities), b) what are the consequences of LCLUC.
2.The proportion of Social Science used in your study is estimated to be 75%.
3.Identify the proportion of the themes that are covered in your project: 25% Carbon.

YEAR ONE GOALS:

A. Nighttime Lights (NGDC): A one km grid of the nighttime lights of the USA is being assembled using cloud-free portions of DMSP OLS data acquired during 1999 and 2000. This product includes an atmospheric correction. Originally we proposed to do this using fine resolution (0.5 km GSD) nighttime OLS data, which can only be collected via special request to the U.S. Air Force. We were unable to acquire sufficient fine resolution data to make the product. As a result we used the standard resolution data (2.7 km GSD). Status: Near completion.

B. Aerial Photography (NGDC): We have extracted calibration data on the extent of development from high resolution aerial photography utilizing three broad land cover classes: 1) constructed materials(development), 2) lawns, and 3) trees/shrubs associated with development. We had originally proposed to use NOAA-NOS aerial photography and to georeference the data at NGDC. To accommodate the lower project funding level, we used commercial aerial photography and a smaller number of analyses were completed in Year One than originally proposed. Status: Technique developed, calibration data developed for Atlanta, Georgia using eleven photos.

C. One km MRLC Land Cover Grid (EDC): A 1 km Albers Equal Area land cover grid of conus will be generated by aggregating the 30 meter MRLC land cover data. Status: Complete.

D. One km Road Density Grid (NGDC): A 1 km Albers Equal Area grid of road density has been assembled for conus using 1998 TIGER data from the U.S. Census Bureau.

E. Modeling of Carbon Dynamics (UMt): We tested the model (BIOME-BGC) sensitivity to changes in land cover. As expected, changes in land cover from a deciduous broadleaf forest to a lawn (C3 grass irrigated and non-irrigated) had significant impact on the carbon sequestration. In addition, we made runs of our Regional Eco-hydrological Simulation System (RHESSys) over the conterminous U.S at 1km resolution with gridded climate, soil, LAI, and 1 km grid MRLC land cover from EDC, generating spatial depictions of variations in carbon, water and nutrient budgets. For more details see Appendix 1, submitted by Ramakrishna Nemani.

NARRATIVE:

Year One: During year one we assembled the core set of coregistered 1 km grids that will be used as inputs into the project activities. We developed a method for estimating the percent cover of constructed materials, lawn and trees using gridded point counts on color aerial photography. The 1 km land cover grids were successfully used as input into test
runs of the RHESSys model, providing depiction of carbon uptake over conus. A sensitivity analysis was performed, confirming that development does have a major impact on terrestrial carbon dynamics.

Year Two Activities: 1) Completion of the nighttime lights of the USA (NGDC). 2) Expansion of the calibration data from aerial photography to cover other representative cities of the USA (NGDC). 3) Development of models to estimate the percent cover of constructed materials, lawns, and trees at 1 km resolution for the USA (NGDC). 4) Extension of the calibration area coverage using Landsat 7 data (USGS). 5) RHESSys model runs to estimate the annual carbon uptake based on 1 km landcover with explicit estimates of the percent cover of development, lawns and trees.

New findings:

* BIOME-BGC model runs revealed lawns have lower annual carbon uptake
than deciduous broadleaf forests. This combined with the lack of carbon uptake for man made surfaces suggest that development substantially reduces carbon uptake in cities and towns of the eastern USA. See Appendix 1.

* We discovered that the brightness of lights by themselves are not a
good predictor of the percent cover of constructed material. Adding in road density improves the estimate. By adding in the percent cover for high and low density residential areas and lawns (along with lights and road density) we were able to get a very good prediction of the percent cover of constructed materials. See Figures 1, 2, 3, 4 in Appendix 2.

New Products: Coregistered 1 km grids. See Appendix 2.

Radiance calibrated nighttime lights of the USA (near completion).
Road density of the USA.
  Streets and roads.
  Major roads.
  Interstates.
  Total.
MRLC land cover from Landsat TM.

CONCLUSIONS:

All major tasks for year one were completed except for the 1999-2000 radiance calibrated nighttime lights of the USA. This will be completed in April, 2001. The project is poised to have a very productive Year Two.

Peer Review Publications:

Elvidge, C.D., Imhoff, M.L.,Baugh, K.E., Hobson, V.R., Nelson, I., Dietz, J.B., 2000, Nighttime Lights of the World: 1994-95. Submitted Global and Planetary Change.

Elvidge, C.D., Hobson, V.R., Baugh, K.E., Dietz, J., Shimabukuro, Y.E., Krug, T., Novo, E.M.L.M., Echavarria, F.R., 2000, DMSP-OLS estimation of rainforest area impacted by ground fires in Roraima, Brazil: 1995 versus 1998. Accepted by the International Journal of Remote Sensing.

Doll, C.N.H., Muller, J.P., Elvidge, C.D., 2000, Night-time imagery as a tool for global mapping of socioeconomic parameters and greenhouse gas emissions. Ambio, v. 29, no. 3, p. 157-162.

Rodhouse, P.G., Elvidge, C.D., Trathan, P.N., 2000, Remote Sensing of the Global Light-Fishing Fleet: An Analysis of Interactions with Oceanography, other Fisheries and Predators. Advances in Marine Biology, v. 39, p. 261-303.

Cinzano, P., Falchi, F., Elvidge, C.D., Baugh, K. E., 2000, The artificial night sky brightness mapped from DMSP satellite Operational Linescan System measurements. Monthly Notices of the Royal Astronomical Society, v. 318, Issue 3, p. 641-657.

Vogelmann, J.E., D. Helder, R. Morfitt, M. J. Choate, J. W. Merchant, and H. Bulley. 2001. Effects of Landsat 5 TM and Landsat 7 ETM+ Radiometric and Geometric Calibrations and Corrections for Landscape Characterization, submitted to Remote Sensing of Environment.

Vogelmann, J.E., S.M. Howard, L. Yang, C.R. Larson, B.K. Wylie, and N. Van Driel, 2001, Completion of the 1990's National Land Cover data set for the conterminous United States from Landat Thematic Mapper data and ancillary data sources, to be published as a "Highlight Article" in Photogrammetric Engineering and Remote Sensing.

White, M.A., G.P. Asner, R.R. Nemani, J.L. Privette, S.W. Running. 2000. Monitoring fractional cover and leaf area index in arid ecosystems: digital camera, radiation transmittance, and laser altimetry results. Remote Sensing of Environment, 74: 45-57.

Keyser, A.R., J.S. Kimball, R.R. Nemani, and S.W. Running. (2000) Simulating the effects of climate change on the carbon balance of North American high latitude forests. Global Change Biology, 6:1-11.

White, M.A., P.E. Thornton, S.W. Running, R.R. Nemani (2000) Parameterization and sensitivity analysis of the BIOME-BGC terrestirial ecosystem model: net primary production controls. Earth Interactions, 4, Paper No. 3. 1-85pg.

Running, S.W., P.E. Thornton, R.R. Nemani, J.M. Glassy. (2000) Global Terrestrial Gross and Net Primary Productivity from the Earth Observing System. In: Methods in Ecosystem Science, O.Sala, R. Jackson, and H.Mooney Eds. Springer-Verlag New York.

Nemani, R.R., M.A. White, D.R. Cayan, G.V. Jones, S.W. Running and J.C. Coughlan. 2001. Asymmetric climatic warming in coastal California and its impact on the premium wine industry. Climate Research (in press)

MacKay, S.D., R.R. Nemani and L.E. Band. 2001. Corroborating thermal remote sensing data and distributed hydrologic modeling in a mountainous watershed. Journal of Hydrology (in press)