Dr. Anthony Janetos
Science Division/Code YS
Office of Earth Science
NASA HQ
300 E. St., SW
Washington, DC 20546

May 4, 1998

Dear Dr. Janetos,

As you have requested, this letter summarizes our progress on our project ‘Land-cover Change in the Great Plains: Predicting Impacts of Regional Forest Expansion on Biogeochemical Processes’ funded through the NASA Land-cover and Land-use Change Program. Also enclosed is our revised budget for the upcoming one-year budget increment ($174,380).

As you may recall from our proposal, eastern Kansas (KS) has the largest expanse of tallgrass prairie remaining in the world and is second only to TX in livestock productivity. However, in the last several decades, forest cover has doubled in KS and may jeopardize future sustainability of these productive grasslands. Our study has begun to quantify land-cover change in eastern KS and its consequences for ecosystem C and N dynamics and fluxes of CO_2, energy, and H_2O. Although this study is focused in KS, the results will help predict consequences of forest expansion also occurring throughout the Great Plains.

The <u>ultimate goal of this research</u> is to develop a method that will allow repeated inventories of land-use and land-cover from space and then to evaluate the ecosystem consequences of observed and predicted land-cover changes in the Great Plains. Without an understanding of the biogeochemical consequences of such major land-cover change as in the eastern Great Plains, it will not be possible to manage resources to insure their sustainability. To achieve this goal, we are using aerial photos, remote sensing and GIS techniques coupled with *in situ* process-level biogeochemical and ecosystem flux studies. We will link the biogeochemical studies to land-cover change using the Marine Biological Laboratory-General Ecosystem Model (GEM) and GIS techniques and ultimately predict long-term changes on a regional scale.

<u>Specific objectives</u> of this proposal are to:

- 1. assess the current distribution of land-cover, document the historical change in land-cover (especially forest cover) using aerial photographs and remote sensing (using both historical and present data), linked to a GIS data base which will have important information on the potential forcing factors (socioeconomic vs climatic, ecological),
- 2. quantify the effects of forest expansion on biogeochemical processes controlling the quantity, quality, and distribution of soil organic matter and soil C, and N cycling and availability,
- 3. determine how these life-form shifts alter ecosystem C balance and fluxes of CO_2, H_2O, and energy, and
- 4. incorporate a spatially-explicit model (GEM) that will link our *in situ* biogeochemical and ecosystem studies with spatial information on land-cover change to predict ecosystem consequences of the impact of future forest expansion.

In only the last 9 months since receiving our NASA funding, we have made significant progress in meeting our stated goals and objectives. We have established three paired forest-grassland study sites in which we have begun conducting our intensive, process-level in situ biogeochemical measurements and C flux studies. These three forests range in age from 40 (Dobson, Carlson sites) to 60 years old

(Borg forest) and represent the ecological endpoint of the shift from grassland to forest. Additionally, we have begun acquiring and processing the necessary remote sensing imagery and GIS data which will allow us to scale up the ecosystem consequences of forest expansion to the regional level of eastern KS. Our progress is also documented on our web page (http: //climate.konza.ksu.edu /general nasalandcover/landuse.html established in March 1998). Below we provide specific details as to our progress.

1) Assessing current and historical landcover change using remote sensing

a) Data Acquisition and GIS construction

In our first 9 months of funding, we have begun to acquire the necessary remote sensing data to document the change in landcover in Eastern KS. One of the most promising acquisitions has been the Landsat MSS - NALC (North American Land Characterization) imagery. This set of imagery covers three decades (1974, 1986, and 1992) over a 34 county area of eastern Kansas. To complement these imageries we have obtained Thematic Mapper (TM) imagery from every year possible and, so far, have obtained images for the years 1983 through 1997 (except 1985 when no data were available). In addition, for our three intensive study sites in which much of the process-level studies are being conducted, we have acquired historical aerial photos for the years 1937, 1957, 1969, 1978, 1985, and 1996. These photos have been scanned and recently geometrically registered using as a base Digital Ortho Quadrangle (DOQ) photos of the sites. The DOQ have a spatial resolution of 1 meter and will be very valuable to the project. DOQs are available for almost all of eastern KS and will aid in ground-truthing the vegetation and landcover classifications. These will be used for correlating juniper woodland expansion to specific land use practices.

For the GIS data base, we currently have on order, the 7.5 minute Digital Elevation Models (DEM) for the three intensive study sites. Detailed digitized soil maps have been incorporated into the data base. Other GIS coverages that we have developed for this project include county boundary, state geology, hypsography (topography) at 1:100K and 1:250K scales, and the Statsgo soils GIS coverages. In addition, many of the 34 counties in eastern Kansas have GIS coverages partitioned into as many as 22 land use types and we are checking into the possibility in using them as well for some of the grouth-truthing of our classification scheme described below. We are also compiling data on socioeconomic drivers of landcover change e.g., human population by county, housing starts, cattle prices, number of head of cattle produced, acreage in rangeland.

b) Data Processing

A preliminary supervised classification of the 3 band (green, red, NIR) MSS images covering three decades was used to identify closed canopy cedar forests. This approach was very good at identifying mature juniper forest. However, this method was not as accurate as we had hoped on identifying grass-forest ecotones. We have recently combined our earlier work with Tasseled Cap imagery in hopes of improving our supervised classification. Early results suggest that the combination of both approaches will help in the discrimination of ‘confusion’ areas (forest-grassland transition areas). We will then mask out all other areas (grasslands, croplands, residential) and use an unsupervised classification to further discriminate between juniper forests and confusion areas.

The scanned aerial photos will be used to parameterize spatially explicit population models we will be developing later this year as well as precisely monitor the rate of expansion of cedar forests.

2) Biogeochemical and ecosystem consequences of forest expansion

We have made significant progress on quantifying the biogeochemical and ecosystem consequences of forest expansion. We have begun to assess the differences in production and decomposition associated with this fundamental life form shift from prairie to cedar forest. While we can draw on productivity and decomposition data from Konza Prairie LTER, we have no knowledge about these processes in cedar forest. Since last fall, we have set out litterfall traps (20 per intensive study site, litter collected each month) to quantify forest aboveground production. This summer we will also assess biomass of juniper woodland by establishing allometric growth equations for junipers and applying the allometric relationship to estimate juniper biomass.

Litter decomposition is predicted to be altered profoundly in juniper woodland, due to the poor litter quality of Juniper foliage and microclimate effects. Changes in litter decomposition dynamics between juniper woodland and prairie are being assessed using reciprocal litterbag transplants and measurements of mass loss over time. The reciprocal litterbag experiment was set up last fall when litterbags (~500) were placed in the paired juniper-grassland study sites. These litterbags will be collected at monthly intervals and dry mass and nitrogen remaining at the time of collection will be determined. To begin to assess N cycling and N availability in juniper woodlands, we will measure net N mineralization in the field using an in situ soil core incubation (30-day) method. These mineralization studies are presently being conducted and will continue on a seasonal basis. These studies will complement on-going studies at Konza Prairie.

We originally hypothesized that changing land-cover from tallgrass to juniper will alter the quality, quantity and distribution of soil organic carbon (SOC). Due to differences in discrimination against ^{13}C in C_3 and C_4 photosynthesis, SOC developed under native C_4 tallgrasses has a ^{13}C near -13.0 per mil, while that derived from C_3 junipers is about -27 per mil. A comparison of ^{13}C of bulk soils and soil particle size fractions in forest and tallgrass prairie allowed us to estimate the impact of changing landcover on soil organic carbon. Using this approach, ^{13}C of SOC in three juniper forest study sites indicates that at shallow soil depths (0-7.5 cm), as much as 38% of the SOC of the bulk soil is juniper in origin and is contained primarily in coarse size fractions. Prairie-derived C dominates at greater depth especially in the fine size fractions. Using this ^{13}C isotope approach, we have determined that fundamental vegetation shifts are altering the quality and distribution of SOC in Kansas soils in as few as 40 years (Smith and Johnson, 1997).

3) <u>Changes in ecosystem fluxes of CO_2, H_2O, and energy</u>

We expect forest expansion to have a profound impact on carbon, water, and energy exchange between the surface and the atmospheric boundary layer. Over time, these fundamental changes in life form will have regional and perhaps global implications for land-atmosphere interactions. We proposed to examine the effect of forest expansion on these processes by making simultaneous measurements of boundary-layer fluxes over a Juniper woodland and a paired grassland site. These studies will complement on-going studies in which Jay Ham (one of the co-PI's on the NASA project) is using micrometeorological towers to obtain continuous flux meausurements at Konza Prairie and in other land-use types (rangeland, row-crops). Therefore, the technology is already in place to build, operate, and manage towers. Indeed, the additional measurement towers in the paired forest-grassland site have already been fabricated and should be installed in June, 1998. The post-doctoral associate on the project (Dale Bremmer) will be hired this May.

5) <u>Spatial and temporal scaling of ecosystem processes using GEM (General Ecosystem Model)</u>

While our <u>in situ</u> studies will be extremely valuable in understanding how components of the ecosystem respond to changes in land cover, an important goal is to integrate these data so that the biogeochemical dynamics of the land surface and its interactions with the atmosphere can be extrapolated over space and time. We will use the General Ecosystem Model (MBL-GEM), a process-based model of ecosystem biogeochemistry and GIS techniques, to integrate the <u>in situ</u> data , predict long-term changes in ecosystem processes on a regional scale, and to derive a process-based understanding of long-term (decades to centuries) changes in ecosytem processes over for the land-cover mosaic in eastern KS. We will use the experimental data from our prairie-forest transects to calibrate MBL-GEM for 1) tallgrass prairie and 2) the successional replacement of prairie by forest. The calibrated model will be evaluated by comparing simulated C and N stocks and fluxes to measured data not used for the calibration; these data will include the eddy-flux measurements of the net exchange of CO_2 between the ecosystem and atmosphere at prairie and *Juniperus* sites. We will then link the calibrated MBL-GEM to a GIS (Arc/Info) so that changes in ecosystem processes within our study area can be simulated for individual pixels, as defined by vegetation and soil type. With our Landsat analysis of historical changes in land-cover, the GIS will also enable us to project the transitional probability for a change in vegetation state (i.e., prairie to forest) within each pixel. By driving the MBL-GEM/GIS system with predicted changes in land use, climate, and CO_2, we can predict biogeochemical consequences over the landscape.

We are in monthly contact with our collaborator (Bob McKane-Terrestrial Ecosystem Ecologist, U.S. EPA) responsible for modeling. We are presently involved in parameterizing the model to meet our stated goals and objectives. We envision the modeling effort to be a major component of our activities in the final year of funding as we use GEM as a tool for synthesis and integration.

In summary, we believe we are making excellent progress in meeting our stated goals and objectives of the project. Our progress is due in large part to the three motivated graduate students hired to assist on the project (Greg Hoch, remote sensing; Dixie Smith, soil C dynamics, Mark Norris; productivity and decomposition and N cycling). All three have made significant progress; two of the three have submitted abstracts for paper presentation at the 1998 ESA meeting. Additionally, a post-doctoral associate to assist with the eddy accumulation studies will be hired this May.

Please feel free to contact us if additional information is required.

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