A COMPARISON OF LAND USE PATTERNS, WATER BALANCE, AND NUTRIENT DYNAMICS IN THE CEDAR CREEK AND KELLOGG BIOLOGICAL STATION LTERS

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INTRODUCTION

The following proposal addresses the development of an edaphic, geologic, and hydrologic database linking the Kellogg Biological Station (KBS) and Cedar Creek (CC) LTERs, and the subsequent use of this database to test hypotheses regarding spatial variation in landscape patterns, water budgets, and nutrient dynamics between these LTERs.

This proposal can be considered to provide the background for a more extensive proposal, now being discussed, that will compare landscape patterns and dynamics among a number of LTERs. The two sites for this proposal, KBS and CC, were chosen because of their similarity, yet their differences. The similarities among these sites will make the initial establishment of uniform sampling and experimental protocols more straightforward while their differences will lead to framing of testable hypotheses.

Great strides have been made in ecosystem science by using the watershed approach, wherein the terrestrial ecosystem is defined as the physical watershed of a lake or stream. The properties of that lake or stream are considered to be the integrators of the processes that are occurring in the terrestrial system. This type of study has evolved from an early black-box approach to more systematic studies of terrestrial processes. These studies have been concentrated on well-defined watersheds with tight bedrock, most often in mountainous terrain in the eastern or western U.S..

There are many ecosystems or watersheds that do not conform to the ideal model. Most watersheds in the glaciated midcontinent, for example, do not drain into well-defined surface water bodies but instead drain vertically toward the groundwater. In some cases, however, lateral flow may bring this water to the surface. Previous research has avoided these diffuse watersheds because of their complexity. The contribution of each landscape element to the volume and chemistry of groundwater has always been an important question. Current interest in such topics as groundwater contamination is shifting the pendulum toward these more difficult systems; CC and KBS are good examples.

It is imperative that we understand the quality and volume of fluxes to and from each landscape element because they compose the mosaic that constitutes the earth's surface. Moreover, identifying and understanding intraecosystem processes that alter inputs and mediate losses within the landscape is necessary for wise land management. With that information, the consequence of changes in land use driven by natural factors (e.g., succession), direct activity of man (e.g., forest harvesting), or indirect activity (e.g., climatic warming due to an increase in CO_2) can be synthesized into integrated impacts on ecosystems measured at increasingly-larger scales.

Both KBS and CC are well-suited to an investigation of the processing of matter and energy on a landscape basis. Each contains a variety of ecosystems which contrast in physiognomy, age, and processes. They both occur on glaciated terrain under a continental climatic regime; KBS is located on loamy ice-contact glacial drift and CC is situated on coarse-textured outwash. Considerable data exist on the soils, hydrology, nutrient cycling and land use patterns for both LTERs, but there is no common database through which hypotheses about differences in ecosystem structure or function can be tested. Incorporation of existing spatial data from the LTERs into a geographic information system (GIS) would proved an efficient means to organize and manipulate those data on diverse landscape attributes: physiography, soil type, vegetation type, watershed boundaries, and nutrient dynamics are some examples. Moreover, with GIS we have the capacity to conduct analyses at a variety of spatial scales: for example, with soil map units as the minimum polygon size, data can be aggregated to the the catena, landform or watershed level.

Both KBS and CC have available for use the ERDAS GIS system. A recent intensive soil survey for KBS has been incorporated into ERDAS, along with high-resolution topographic data. Soil and topographic data have not yet been incorporated into the ERDAS system at CC. The advantage of a common system will be the ability to transfer and merge data between the LTERs. Once the database is compiled, it will be possible to study differences in landscape patterns, water budgets, and nutrient cycling dynamics between these two systems. Success in this endeavor will provide impetus to incorporate other LTERs into the system.

I. Land Use Patterns

The patterns and degree of landscape heterogeneity at various spatial scales have long been recognized as important factors regulating biotic diversity, nutrient dynamics, and hydrologic processes. The study of spatial heterogeneity has recently been facilitated by the introduction of fractal geometry to describe landscape complexity. The degree of spatial complexity of a given map unit (e.g. soil type, woodlot, or old field) can be characterized by calculating the fractal dimension D, which describes the relationship between the length of the perimeter of a map unit and its area (Lovejoy 1982). Fractal dimensions range between 1 and 2, with a fractal dimension of 1.5 or greater representing a landscape regulated primarily by geomorphic or hydrologic processes (Krummel et al. 1987). Increased land use or disturbance lowers the fractal dimension, indicating decreased landscape complexity. KBS has been subjected to intensive land management, while much of the land at CC has been abandoned for several decades. As a result, we hypothesize that spatial heterogeneity as defined by land use patterns is significantly higher at CC than KBS. This type of analysis may also be conducted on patterns of soils or vegetation, providing basic descriptive information on landscape patterns that transcend the existing data.

II. Water budget models.

Water budget models are driven by an understanding of how hydrologic inputs are influenced by the various spatial components of the landscape: transpiration and storage within forested lands, runoff from agricultural lands, variation in hydraulic conductivity by soil type, and storage within riparian systems. While we have a good understanding of how each type of landscape unit may function as an individual, it is necessary to understand the relative contributions of different landscape units within a watershed to accurately model water flux. We propose to acquire a number of pre-existing hydrologic models, such as PROSPER (Goldstein, Mankin, and Luxmoore 1974) for forested systems and CREAMS (Knisel 1980) for agronomic systems, install them on our computer systems, and determine their usefulness for our LTERs. So many models exist that it would be redundant for us to develop our own; many of those models may not be suited for our purposes and data base. Simply collecting, installing, and testing a number of such models will not be a trivial task. Although at a general level the climate and soils of the two LTERs are similar, we hypothesize significant differences in hydrologic budgets exist due to the periodicity of climatic events, land-use (management) differences, and soil/topography differences.

III. Nitrogen dynamics

A strong point of both KBS and CC is the research done on the processes of nitrogen mineralization and nitrification in various ecosystem types. These studies provide the framework to compare rates of nitrogen mineralization and nitrification among ecosystems that occur in similar landscape positions but are widely separated geographically. Work at KBS using geostatistical techniques has allowed the development maps of the mineralization process in a geographic coordinate systems (Robertson 1987). Similar studies at CC will allow us to compare the patterns of variation in N mineralization between these sites. Since climate and soil moisture exert a significant influence on microbially-mediated processes, we may be able to quantify some of this variation based on large scale geographic and climatic differences, as compared to local differences related to organic matter quality or land use. We hypothesize that intra-site differences in N dynamics will be greater than those between sites.

LITERATURE CITED

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BUDGET

The budget emphasizes money for travel for inter-site coordination and salary for a computer-type to collect, install, and aid in the test of the models. A post-doc will coordinate the effort and supervise the computer-type.

Travel - ca. $800/trip	$ 4000
Digitizer	$ 3000
ERDAS Digitization Module	$ 3600
Computer technician (6 mo.)	$ 12000
Post-doc (2 mo.)	$ 4000
Overhead ???	
Total	$ 26600