FOREST ECOSYSTEM ANALYSIS USING A GIS*

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ABSTRACT

Forest ecosystem studies have expanded spatially in recent years to address large scale environmental issues. We are using a geographic information system (GIS) to understand and integrate forest processes at landscape to regional spatial scales. This paper presents three diverse research studies using a GIS. First, we used a GIS to develop a landscape scale model to predict forest soil erosion rates given alternative forest management practices and weather conditions. Second, a GIS was used to evaluate the cumulative impacts of land use practices on water quality for a 4350 ha basin. Third, we used a GIS to store and manipulate complex data bases for modeling the influence of climate change on forest hydrology and productivity across the southern U.S. We anticipate the demand for GIS techniques will greatly increase because of the need to address increasingly complex ecosystem questions.

INTRODUCTION

The research branch of the USDA Forest Service increasingly addresses complex questions related to impacts on the environment. These questions vary in spatial scale the watershed to the region, and at temporal scales ranging from months to decades. \ address these questions through ecosystem measurement and modeling. Research at l temporal and spatial scales require that innovative methodologies be employed to manipulate and analyze measured data or model inputs and outputs. A Geographic Information System (GIS) is a powerful tool that we can use for all phases and scales < ecosystem research (Everham et al. 1991). Various GIS's have existed since the early 1960's (Tomlinson et al. 1976), but only since the mid-1980's have reductions in softv and hardware costs and increased program flexibility made GIS's a tool viable for eco research (Iverson & Risser 1987, Drayton et al. 1992). For these reasons, Lanfear (1 concluded that the impact of GIS may be as important as the introduction of the FORT programming language for understanding environmental processes. This paper discus the use of a GIS in three forest ecosystem studies in the southern U.S.

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Traditional predictions of soil erosion are for whole watersheds, not for poin watershed. Our research used a GIS to predict soil erosion under a variety of mi practices (including road building, timber harvesting, burning, and creation of v plots), for a range of seasonal storm intensities. Through a GIS, model predicti erosion can be spatially distributed across the watershed and displayed as map < Maps will help the land manager to identify which sections of the watershed are susceptible to soil erosion. The model can be rerun until a management strateg strips, brush barriers, or altering the season in which management activities are are found which minimize (or reduces to an acceptable level) soil erosion. We u universal soil loss equation (USLE) to predict soil sediment loss for a 1140 ha v

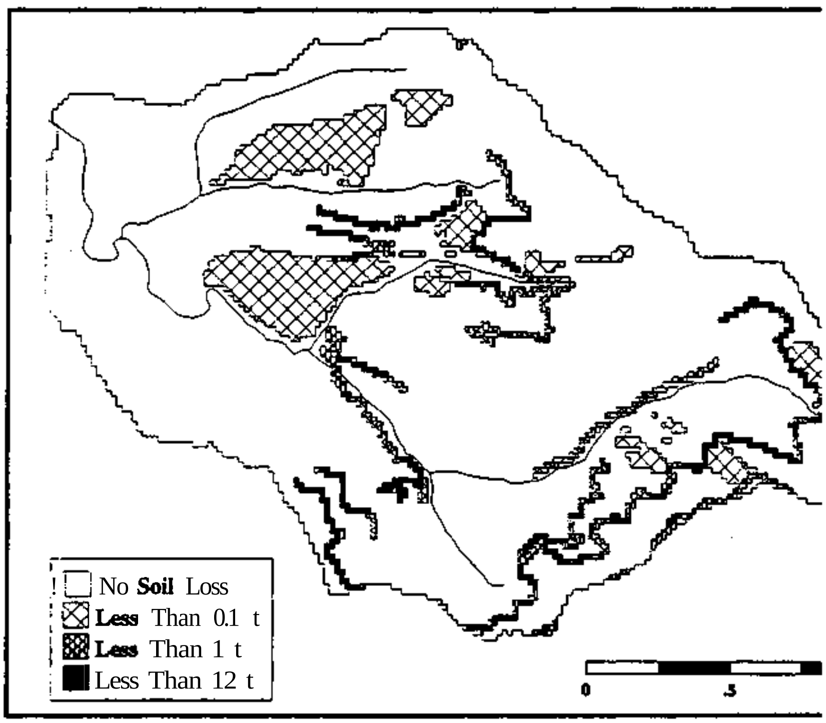

Figure 1. USLE Predicted Soil Erosion in a 1140 ha Watershed Given Poorly Roads and Average Annual Precipitation.

that contained various forest management activities (McNulty et al., 1995). The grain size was $30m^2$ and the temporal resolution was seasonal.

STUDY # 2 LANDSCAPE SCALE LAND USE

In the previous example, we used a GIS with a soil erosion model to minimize the of forest management practices on stream water quality. However, despite our best attempts, many natural and anthropogenic events can degrade streams. Therefore, environmental planning and regulatory legislation require assessment of water quality changes associated with a variety of land uses. Methods for evaluating the relative contributions of nonpoint source pollution from different activities would be particula useful to guide land use planning. Toward this goal we conducted research on the cumulative impact of land use practices on water quality of Coweeta Creek, a fifth on stream in western North Carolina (Swank and Bolstad, 1994). Managed forests occu upper watershed; subsequently, the stream flows through agricultural, recreational an residential lands.

Five water quality monitoring stations were located over the 8.7 km length of Cow Creek. Samples were collected during baseflow and storm events, and analyzed for chemical, biological, and physical parameters for 30 months. Using aerial photograp GIS technology, nine base spatial layers were developed for the watershed. Catchme characteristics (e.g., % nonforest, building density, agricultural area) were analyzed t applying a cartographic buffering operation in a GIS. Cartographic buffers were then used to characterize near-stream conditions from each of the digital data layers. GIS generated spatial data showed good correlation with water quality criteria such as turbidity (Fig. 2), bacteria populations, and NO_3 concentrations over the longitudinal stream gradient. GIS capability is essential in this type of research that entails complex spatial distributions of potential nonpoint sources of pollution.

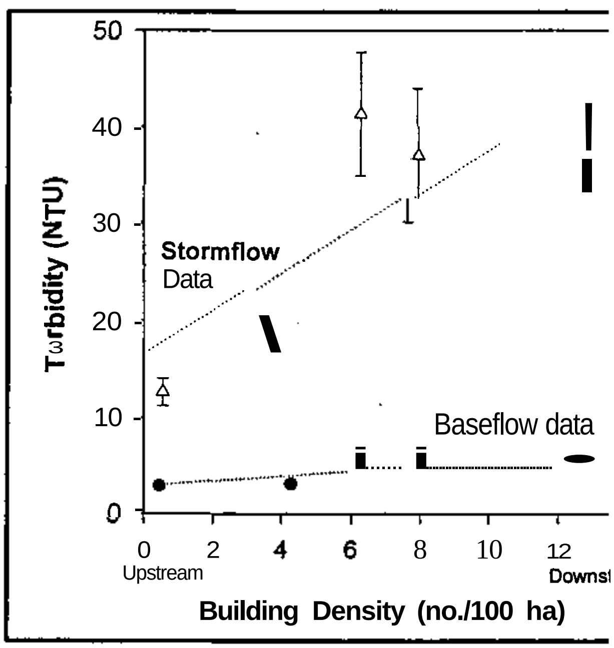

Figure 2. Relationship Between Stream Turbidity and Buil Density.

During the next century, changes in the amount and distribution of **precipitatic** increases in global surface temperature and atmospheric **CO_2** concentration may < **(Mintzer 1990).** These climatic changes could have profound impacts on forest £ and function across the southern United States. Due to the potential social and a implications of these changes, the Forest Service is developing broad scale **ecosy** process models to predict the potential impact of climate change on forest **hydrol** **productivity.** To assess the possible effects of climate change on southern pine ft used a **processed-based** ecosystem model called **PnET-IIS** that used climate, soil vegetation data as input variables to predict forest growth **(McNulty** et **al. 1994).** development of databases necessary to define and validate these models are **diffic** compile and use. The use of a **GIS** can simplify database management and **mode** interpretation.

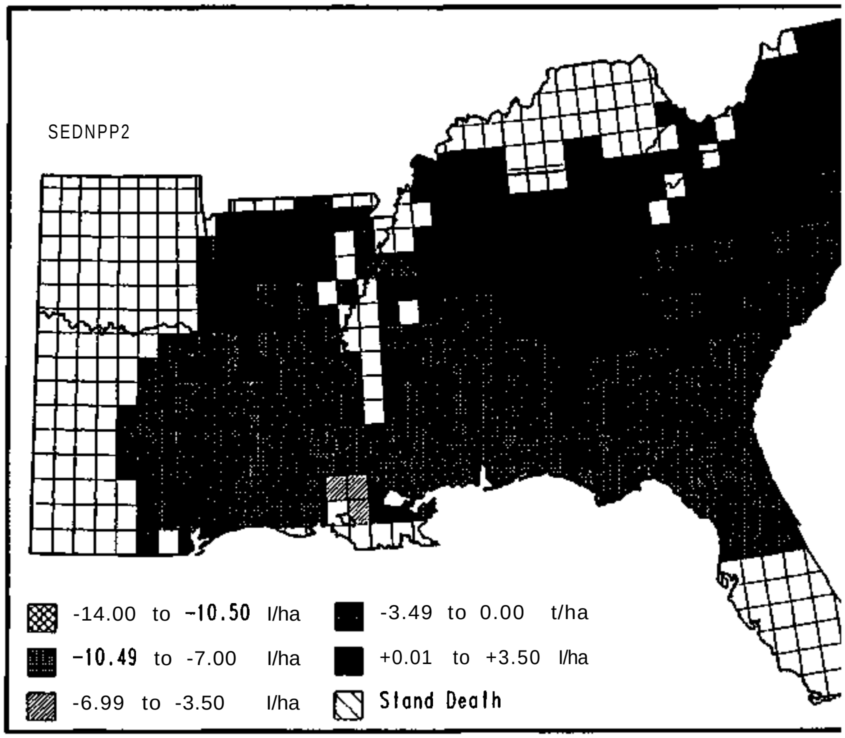

Figure 3. **PnET-IIS** Predicted Change in Southern U.S. Pine Forest Net Primary **I** Given a Doubling of Atmospheric **CO_2.**

Once we entered all model inputs (i.e., historic and predicted climate, vegetation **coefficients),** we used **PnET-IIS** and a **GIS** to predict how southern U.S. pine forest **g** measured as net primary productivity, would change given a doubling of atmospheric 2° increase in average monthly air temperature and a 20% decrease in total monthly precipitation (Figure 3).

SUMMARY

Whether for preventing, assessing or projecting ecosystem changes associated **wit** natural or anthropogenic environmental impacts, a GIS is an important total for **lands** scale research. The ability of a GIS to temporally and spatially store, manipulate and data allows ecosystem researchers the ability to address environmental questions. The questions were not possible to answer a decade ago when these tools were not availab research issues increase in scale and complexity, the need for GIS will also increase.

REFERENCES

R.S. **Drayton,** B.M. Wilde, J.H.K. Harris, "Geographical Information System **Approa** Distributed Modelling." *Journal* ***of Hydrological*** *Processes,* Vol. 6, pp. **361** -368, **J** 1992.

E.M. **Everham** ffl, **K.B. Wooster,** C.A.S. **Hall, "** Forest Regional Climate Modeling." *Proceeding of the Symposium on Systems Analysis in Forest Resources,* Charleston South Carolina, p. **743, 13-16,** October **1991.**

L.R. **Iverson, P.G. Risser,** "Analyzing **Long-Term** Changes in Vegetation With Geographic Information System and Remotely Sensed **Data,".** *Advances in Space Re* Vol. 7, No. **11,** pp. **183-194,** November 1987.

K.J. **Lanfear,** "Editorial: Geographic Information Systems and Water Resources Applications." *Water Resources Bulletin,* Vol. 25, No. 3, pp. v-vi, March **1989.**

S.G. **McNulty,** J.M. Vose, W.T. Swank, J.D. **Aber,** C.A. **Federer,** "Landscape Scale **F** Modeling: Data Base Development, Model Predictions and Validation Using a **Geog** Information System." *Climate Research,* Vol. 4, pp. **223-231,** December **1994.**

S.G. McNulty, Swift, L.W. Jr., J. Hays, A. **Clingenpeel, "** The Use Of A GIS For Assessing Management Alternatives To Reduce Over-land Sediment Production and Transport." [Microfiche] **In** *Proceedlings of the 1995 Annual International Meeting American Society of Agricultural Engineers,* Chicago, Illinois, Paper No. **95-2701.** Joseph, MI: ASAE, **11** p., **19-23** June **1995.**

I.M.Mintzer, "Energy, Greenhouse Gases, and Climate **Change."** *Annual* ***Revie***
Energy **Vol. 15,** pp. **513-550, 1990.**

W.T. Swank, **P.** V. Bolstad, "Cumulative **Effects** of Land Use Practices on Wate
Proceedings of the ***Hydrochemistry*** *1993* ***Rostov-on-don*** *Symposium: Hydro*
Chemical and Biological Processes Affecting the Transformation and ***Transp***
Contaminants in Aquatic Environments, eds, N.E. Peters, R.J. Allan, V.V. **Ts**
Oxfordshire, United Kingdom, **IAHS Publ.** Vol. 219, pp. **409-421,** May **1993.**

R.F. **Tomlinson,** H.W. Calkins, D.F. Marble, "Computer Handling of **Geographi**
UNESCO **Press.,** Paris France, 9 p., **1976.**