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Interdisciplinary research at the Urban–Rural interface: The WestGa project

B.G. LOCKABY*
D. ZHANG
J. McDANIEL
H. TIAN
S. PAN
School of Forestry and Wildlife Sciences, Auburn University, 108 M.W. Smith Hall, Auburn, AL 36849-5418

Abstract. As human populations increase, ecological and social issues become inextricably linked to a greater degree. Solutions to complex social–ecological problems can only be derived through the use of integrated research that can account for the interplay of many factors across traditional discipline lines. We are using such an integrated research to clarify relationships among socioeconomic drivers, ecological effects, and social and policy feedbacks associated with urban development of forested landscapes. Our approach is goal oriented and interdisciplinary in nature and involves a team composed of ecologists, anthropologists, and economists who exchange ideas and information across disciplinary lines. The team and approach has evolved through many of the barriers to interdisciplinary research that have been identified by other authors. Our goal is to develop a predictive capability in order to anticipate ecological and social implications of urban development on natural resources in the southeastern United States. Our integrated model and subsequent papers in this special issue are presented.

Keywords: urban development, interdisciplinary, ecological, socioeconomic

Introduction

Increasingly, the scientific community is stressing the need to link human and environmental perspectives in order to provide relevant answers to some of the more serious issues facing society (Pickett *et al.*, 2001; National Research Council, 2000). The pitfalls associated with studying highly complex issues such as urban sprawl from either a purely ecological or socioeconomic standpoint have been emphasized by Alberti *et al.* (2003). Basically, the problem is one of inadequacy of the research approach, i.e. attempting to study a phenomenon driven by interplay of diverse causal agents through examination of single factors. There are obvious limitations regarding the extent to which results from a singular approach can adequately explain the observed phenomenon. This concept is well described by Pickett *et al.* (2001) and Grimm *et al.* (2000) as the study of ecology in cities vs. the ecology of cities. Consequently, society will continue to grapple with the issue because no real insight into its causes, effects, and feedback mechanisms has been offered.

However, if some degree of insight can be achieved, novel solutions to complex societal problems may be presented. As an example, within the context of the Baltimore Ecosystem

*Author to whom all correspondence should be addressed.

Study, ecological restoration of degraded riparian areas is being used to reverse social declines in downtown neighborhoods (Groffman *et al.*, 2003). The approach is based on the premise that ecological rejuvenation of degraded riparian zones promotes economic and social rejuvenation as well.

Our objective is also to better understand relationships between urban development and natural resources and, to that end, we are using an integrative, research tool to link socioeconomic and ecological data at the landscape scale. We hypothesize that spatial and temporal patterns of urban development can be predicted and that environmental effects of development can be assessed and linked to policy and social changes through the use of the three models described here. In this article, we will discuss the development and components of that modeling tool while the successive articles within this dedicated issue will discuss preliminary outputs from some of the individual facets of the research. The specific objectives of this paper are (1) to describe the development of an integrated model associated with the WestGA project and the lessons learned from our efforts, (2) to present a summary of individual components of the integrated model, and (3) to lay out the objectives of the special issue and introduce the subsequent papers. The following sections are organized sequentially along these objectives.

The WestGA project and its development

The conceptual model for our integrated, urban sprawl research is presented in figure 1. Basically, a series of models are used to (A) describe the relationships between economic

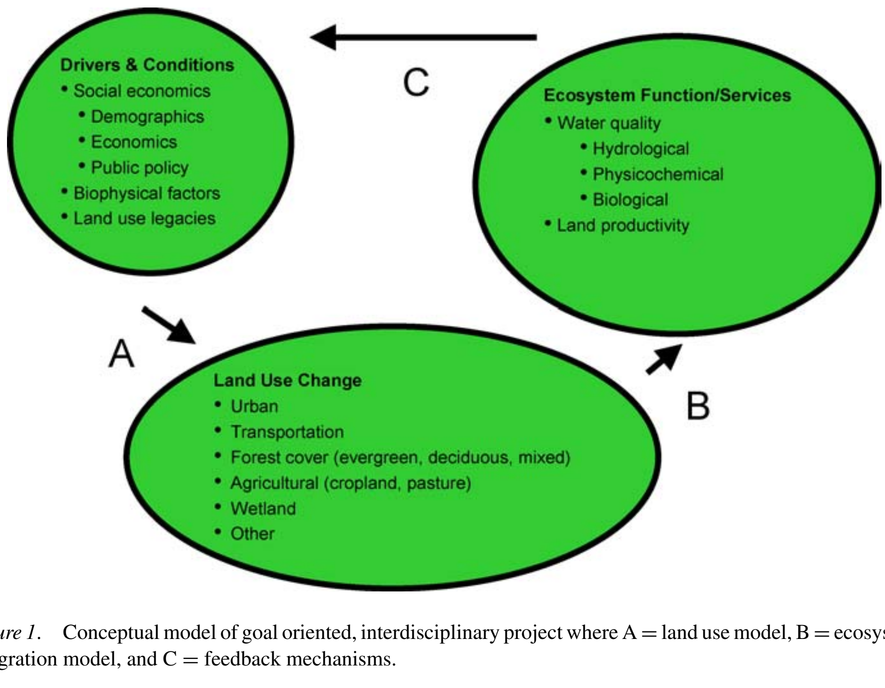

Figure 1. Conceptual model of goal oriented, interdisciplinary project where A = land use model, B = ecosystem integration model, and C = feedback mechanisms.

and demographic drivers and land use, (B) relate land use to shifts in ecological services and functions, and (C) link changes in ecological services to social and economic responses and provide feedback to (A). Although our study site is smaller in terms of population size and growth rate, our conceptual approach is somewhat similar to that proposed by Alberti *et al.* (2003) in that economics drives land use change which, in turn, causes shifts in ecological services thereby eliciting social reactions. Our approach to modeling linkages in (A) is described below as the econometric modeling effort. Current land use patterns are linked with services such as water quality and biodiversity through an ecosystem integration model (B). Predictions of future land use patterns from (A) are then used in conjunction with (B) to forecast future changes in ecosystem services. Finally, feedback influences are qualitatively and quantitatively modeled through assessment of changes in social attitudes, willingness to pay, human health, and policy implications (C).

In terms of the levels of coordination and integration suggested by Jakobsen *et al.* (2004) that range from disciplinary to transdisciplinary, our approach would be termed goal-oriented, interdisciplinary. The term implies 'coordinated interaction across multiple disciplines guided by an issue' (Jakobsen *et al.*, 2004, p. 3). Our breadth of disciplines spans the general categories of ecological (e.g. water quality, biodiversity), sociocultural sciences (anthropology, sociology), economics, and human health.

The WestGa Project (named after the location of the study in Meriwether, Harris, and Muscogee Counties in Georgia, USA) was initiated in 2000 and the group of associated scientists have encountered and worked through a number of the barriers noted by Jakobsen *et al.* (2004). In the early stages, we emphasize the need to identify scientists who show genuine interest in interdisciplinary work rather than multidisciplinary teams where no real interaction would be necessary. That interest is very crucial and will be associated, in our experience, with a much smaller number of potential participants than might be expected. Participants must have respect for the contributions of other disciplines as well as interest in the ideas and approaches used by their cross-disciplinary colleagues. Some of the respect and interest can be developed with time but personality traits such as open-mindedness are crucial at the onset.

Given the clear advantages of interdisciplinary linkages across socioeconomic and ecological boundaries, expectations should be that the concept would be embraced rapidly and result in applications to an increasingly broad range of issues. However, while the general concept is simple, its application can be fraught with barriers. Jakobsen *et al.* (2004) discuss the barriers and facilitating factors associated with two transdisciplinary research efforts, the 'Interior Columbia River Basin Ecosystem Management Project' of the US Pacific Northwest and the 'Boundaries in the Landscape' project in Denmark. Among the many factors noted as potential barriers to or facilitators of transdisciplinary work at the individual scientist level were personal characteristics of the scientists involved, lack of incentives, insecurity regarding career implications, and stress. At the group level (i.e. teams of scientists with similar backgrounds linking with teams from other disciplines), cross-disciplinary literacy (or lack thereof), use of different methods, frequent meetings, and stereotyping of other disciplines were noted. It is important to note that the same factors could be either a facilitator or barrier depending on the nature of the factor, e.g. the tendency of some personalities to show interest or apathy toward the work of other disciplines.

The authors offer recommendations regarding facilitation of inter- and transdisciplinary research, i.e. coordinated interaction across multiple disciplines guided (Jakobsen *et al.*, 2004). These include careful selection of scientists based on research and interpersonal skills, inclusion of individuals with experience in inter- or transdisciplinary work as opposed to only multidisciplinary, developing approaches to reduce anxiety concerning career ramifications, and selection of leaders who respect the range of disciplines and appreciate integration as a powerful research tool.

Concern regarding rewards (i.e. career ramifications) may reflect the insecurity of working within a large team and uncertainty about whether personal credit can accrue to individuals in a team approach as well as the long time period often required to produce results from the efforts of a large group. Such a concern is very reasonable, particularly for new researchers such as non-tenured faculty. It is also closely linked with the motivational need of all scientists to have some degree of ownership over approaches to and conduct of their research.

We approach this issue through a hierarchical organization of our research activities. There is a base level (Tier 1) which consists of a series of individual studies on carefully selected topics that are linked conceptually and through spatial analyses. As an example, a watershed approach serves as the basis for all field data collection so that those topics (e.g. water quality, social surveys, etc) are examined at the same scale across the same range of land use and cover attributes. Apart from these caveats, an investigator designs his/her approach and has the potential to produce stand alone outputs for individual facets. Investigators discuss the results with their counterparts in order to identify potential linkages that are not specified in the models. Consequently, the Tier 1 activities instill a feeling of ownership that is very important psychologically for individual scientists.

The integration and interdisciplinary creativity reside in Tier 2 which serves as the modeling template and relies on data emanating from Tier 1. Care is taken to provide credit to investigators and students who supply data to any particular output of the modeling. Consequently, investigators gain credits (e.g. refereed publication authorships) for their work to a greater extent than possible if they worked exclusively on individual or multidisciplinary efforts. Figure 2 presents the organization scheme or inputs and output flow of the integrated model. The papers presented in this special issue fall primarily in Tier II.

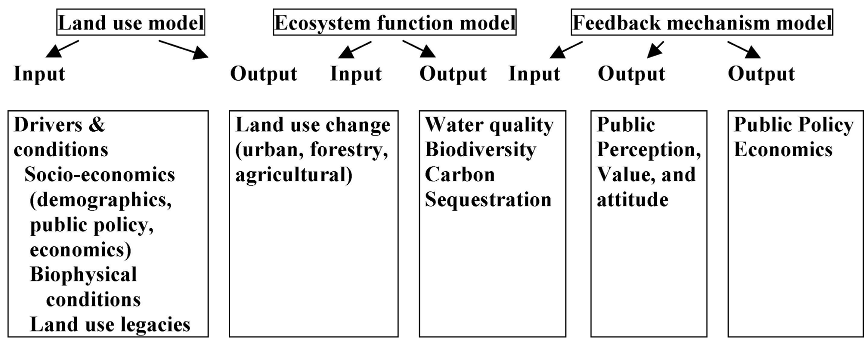

Figure 2. The organizational scheme (input and output linkage) of the integrated model.

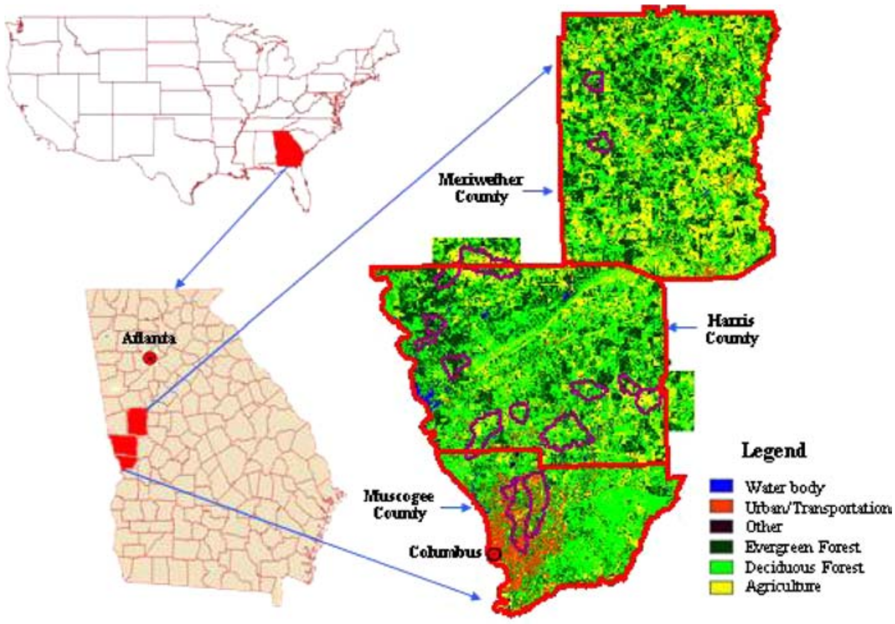

Figure 3. Location of study area and land cover map for 3 counties.

Study area and individual models

Study area

We have applied our integrated model to the Georgia Piedmont, including three contiguous counties: Muscogee, Harris, and Meriwether (figure 3). Recent analyses have indicated that trends in population expansion and related land development in the United States vary significantly by region (US Census Bureau, Census, 2000; Infoplease: U.S. Population by Region, 1990–2002). The Georgia Piedmont, in particular, displays very rapid annual development and ranks among the highest regions in terms of percentage increase in developed land area during the 1990s. Land uses impacted to the greatest degree by conversion are forest land (74% decline) followed by cropland (12% decline), and pasture (11% decline) (USDA-NRCS, 2001).

In the first stage of this assessment, we have investigated landscape alteration associated with urbanization to the northeast of Columbus, GA, the third largest city in that state. The influence of Columbus on the surrounding landscape can be appreciated by examining population statistics over the past decade in the three counties, which lie along a northeasterly axis beginning in that city. Muscogee County, which encompasses Columbus, shows high population density and moderate growth, while Meriwether County, furthest from the city, shows low density and low growth. Harris County, lying between Muscogee and Meriwether counties, shows low density but extremely high population growth, far above the national

Table 1. Population statistics for Muscogee, Harris, & Meriwether counties, GA. (U.S. Census Bureau, 2000)

County	# People (2000)	% Change (1990–2000)	# People/mile2 (2000)
Meriwether	22,534	+0.5	45
Harris	23,695	+33	51
Muscogee	186,291	+4	862
U.S. average	–	+13	79

average (Table 1). Sixteen watersheds were selected for study based on ranges in proportions of developed, forested, and agricultural land uses at a 30 m scale. At the time of the selection, the delineation of impervious surface at a 1 m scale was unavailable.

In addition, particular attention has been paid to economics and policy variables such as costs and prices, income, and taxation. The first stage of this assessment has been focused on both county- and watershed-levels. Sixteen watersheds across the three counties (figure 4) have been chosen, based on their population and distance to an urban center

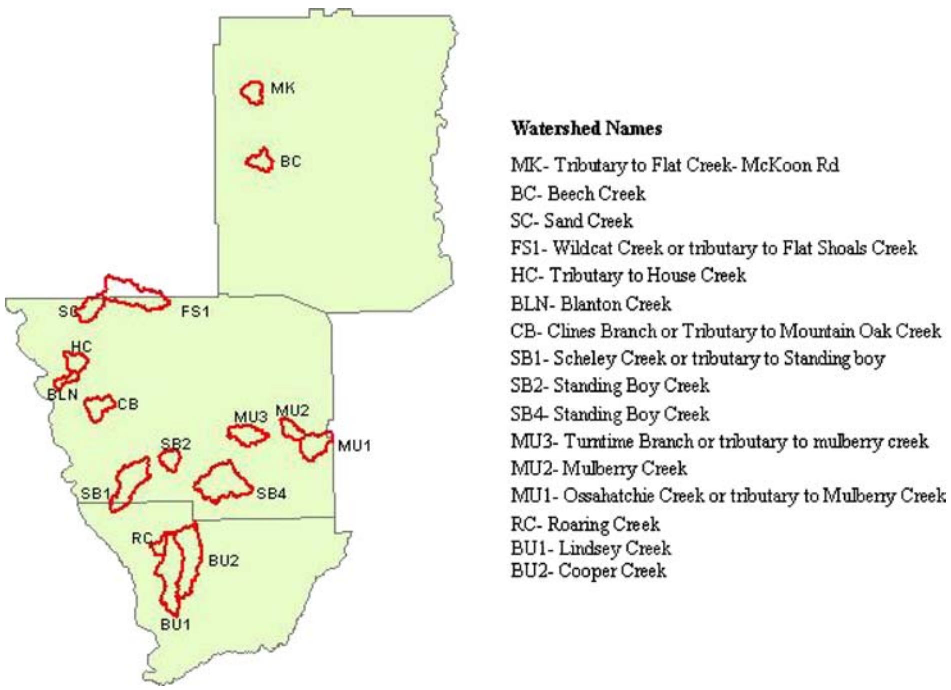

Figure 4. Distribution of 16 watersheds.

(Columbus), for addressing the effects of urbanization on water quality, biodiversity and ecosystem processes. Although one of the undeveloped, forested watersheds is state owned, the remaining watersheds are privately owned apart from some very small inclusions of city parks in Columbus.

GIIS—the GIS-based integrated information system

As previous studies have suggested (Goodchild, 2003), spatial analyses are essential for both environmental research and policy-oriented environmental management. To address spatial heterogeneity across the landscapes in the Georgia Piedmont, we used geographical information system (GIS), digital image processing and remote sensing technologies to analyze land use changes and other landscape changes as well. A core infrastructure for our interdisciplinary research is the GIS-based Integrated Information System (GIIS), which serves as a spatial modeling and analysis framework for broad applications. The GIIS provides a spatial environment for linking models of ecosystem, hydrological and economic/policy processes, and for storing data from field measurements in both aquatic and terrestrial environments as well as remotely sensed data. In essence, GIIS serves as a data gathering and clearing house for the project.

The development of GIIS spans the following stages: the first stage is the assessment and incorporation of all spatial databases included within components of the conceptual model. These databases will coalesce under a single coherent GIS with the establishment of an appropriate infrastructure. The third stage involves putting the spatial modeling framework into a decision-support system. Finally, all geo-spatial data sets and data from field measurements are organized into the GIIS for supporting the interdisciplinary research.

Land cover classification and image processing

We used a Land Cover Classification Scheme with three levels as shown in Table 2. The classes of level 1 and level 2 are mostly based on the Anderson Classification Scheme. For level 3, class 22, 23, and 24 are based on forest harvest and canopy closure. Class 25 is natural or re-established streamside forests made up of trees and shrubs. Class 20 includes areas dominated by grasses and forbs. Class 21 includes areas for recreation or aesthetic purposes, like golf courses, parks, and so on. We generated the landcover map of Muscogee, Harris, and Meriwether counties in Georgia (see figure 3) and the land use/cover dataset for sixteen watersheds (Table 3) were based on a Landsat-7 TM scene from March, 2002. However, images captured by sensors like AVHRR, Landsat TM or SPOT provide information of very limited use at the scale of watershed and sub-watershed approaches. To meet the requirements of various studies at a watershed level, we have developed the 1-meter high resolution land cover data based on aerial photo imagery. Our first effort in the 1-meter image analyses was to generate an impervious surface percentage for each watershed. Impervious surface is widely accepted as a reliable indicator of urbanization and its impacts on natural resources, particularly water resources (Schueler, 1994; Arnold and Gibbons, 1996). The first dataset of impervious surface (Table 4) from 1-meter resolution aerial images for 16 watersheds by manual digitizing has been used for investigating urbanization impacts

Table 2. Land cover classification scheme

Level 1		Level 2		Level 3	
Code	Name	Code	Name	Code	Name
1	Urban	8	High Intensity Urban	19	Impervious surface
		9	Low Intensity Urban	20	Grass/Herbaceous
				21	Recreational fields
2	Transportation	10	Paved roads		
		11	Unpaved roads		
3	Forest	12	Evergreen	22	Clear-cut or regeneration
				23	Thinned (pre-canopy close)
		13	Deciduous	24	Mature (canopy close)
		14	Mixed	25	Riparian forest
4	Agriculture	15	Pasture (grazing, hay)		
		16	Cultivation	26	Wildlife food plot
5	Wetland			27	Cropland
6	Water Body	17	Ponds/Lakes		
		18	Stream		
7	Others				

Table 3. Percent area of land use/cover classes in a watershed for the 16 watersheds as extracted from Landsat-7 TM images (March, 2002)

Watershed ID	Urban	Water	Evergreen	Deciduous	Agriculture	Total
MK	1.33	0.56	35.56	44.25	18.31	100
BC	1.01	0.56	29.65	48.35	20.43	100
FS1	1.31	1.05	15.27	35.32	47.05	100
SC	0.31	0.67	46.03	30.66	22.33	100
HC	0.07	1.15	69.98	24.92	3.87	100
BLN(BLC)	0.17	0	49.34	44.79	5.69	100
CB(MO)	0.60	0.33	52.76	34.13	12.18	100
MU3	1.41	0.76	23.54	55.11	19.18	100
MU2	2.27	0.95	34.01	26.57	36.19	100
MU1	4.95	2.82	10.90	30.25	51.08	100
SB1	1.88	0.73	16.95	51.35	29.08	100
SB2	4.20	0.94	15.73	53.21	25.93	100
SB4	3.95	1.87	20.89	49.02	24.26	100
RC	47.85	1.84	8.92	22.36	19.02	100
BU1	47.95	0.69	11.52	27.63	12.20	100
BU2	37.77	1.53	12.81	30.19	17.70	100

Table 4. Area and percentage of impervious surface (IS) for the 16 watersheds as derived from 1-meter resolution aerial imagery (March, 2003)

Watershed ID	Area (ha)	Impervious area (ha)	Impervious %
MK	662.96	15.11	2.28
BC	647.06	14.79	2.29
FS1	2419.98	59.67	2.47
SC	896.41	11.08	1.24
HC	655.32	8.69	1.33
BLN(BLC)	363.88	4.48	1.23
CB(MO)	897.03	13.73	1.53
MU3	1044.05	19.61	1.88
MU2	606.07	15.86	2.62
MU1	1194.56	44.63	3.74
SB1	2009.19	37.59	1.87
SB2	633.97	21.52	3.39
SB4	2658.89	88.58	3.33
RC	366.92	110.97	30.24
BU1	2546.70	945.14	37.11
BU2	2469.24	684.10	27.71

on water quality (see Helms *et al.* and Schoonover *et al.*, in this issue) and biodiversity (see Stratford and Robinson, Loewenstein N. *et al.* and Burton *et al.*, in this issue). A comparison between two data sets derived from Landsat TM and aerial imagery suggests that Landsat based impervious surface can be underestimated or overestimated (Tables 3 and 4). Therefore, the 1-meter resolution data set is more suitable for our study at watershed level.

To develop the whole sets of land cover data as described in Table 2, image classification of remote sensing (Baraldi and Parmiggiani, 1990; Carmel and Kadmon, 1998; Myeong *et al.*, 2001) was employed. We used the "hybrid" or "guided clustering" method (Bauer *et al.*, 1994) to classify the 1-meter resolution aerial image based on the original three band imagery. This "hybrid" method combines both unsupervised and supervised classification approaches in an attempt to gain the strengths of each (Myeong *et al.*, 2001). To reduce the confusion between water and other dark material, we masked out water areas using water coverage maps obtained from manual digitizing. Pre-classification image transformation and feature-extraction techniques (Sadler *et al.*, 1991) were adopted in this study. Aerial photo interpretation and ground truthing are essential in providing reference data for each class. We used on-screen digitizing, multiple zooming, AOL (area of interest) functionality, and other relevant GIS tools such as overlaying and recoding to improve accuracy. In addition, post-classification spatial processing such as simple majority filters and spatial (or contextual) reclassification procedures (Barnsley and Barr, 1996; Yang and Lo, 2002) have been used to reduce speckled appearance and improve object integrity and usually classification accuracy (Myeong *et al.*, 2001). In this project, we used a 10 by 10 window majority filter approach to the classified imagery.

Land use model (A of figure 1—Tier 2)

The first research facet in the conceptual model focuses on the economic and demographic factors and biophysical conditions driving land use change. The econometric model will be used to predict land use change based on projected demographic changes, economic development, and public policy. Since land use patterns are the independent variables in the ecosystem service model (B), we can forecast future changes in ecosystem services associated with land use changes. The quality of land, or the determinant of its economic potential, can be viewed as a bundle of characteristics, which have varying importance for different uses (Pearse, 1992).

The central conclusion reached in theoretical analysis is that land use patterns are influenced by relative rents and land characteristics (Alig, 1986; Parks and Murray, 1994; Miller and Plantinga, 1999; Hardie *et al.*, 2000). In these studies, researchers typically work with aggregate land use data at the county level, and the most common approach is to specify land use shares as a function of explanatory variables that include proxies for land rent under alternative uses (e.g., input and output prices), land quality measures, and other exogenous variables such as population and per-capita income. However, in order to integrate with the ecosystem service model, we need to build a watershed model.

Our model incorporates several variables that represent important agricultural, forestry, and urban economic processes, and real estate market mechanisms in determining patterns of landscape change. Our explanatory variables include population density change, per-capita income, housing price, agricultural land value, timberland value, location (watershed's proximity to urban center and to markets), zoning regulation, land productivity, slope, and elevation.

The underlying hypothesis is that as population increases and demand for land increases, forestland and agricultural land will be converted to residential and commercial uses. The conversion of agricultural and forestry lands depends on the magnitude of urbanization pressure, the market for timber and agricultural commodities, and public policies such as taxes, subsidies, and zoning regulations.

Most independent variables were collected at the watershed level. Population, household income, and (median) housing price changes were collected from the U.S. Census based on individual census tracts. The land quality variable used in this analysis is the Land Capacity Classes (LCC) from the National Resource Inventory (NRI) surveys. We overlay the LCC map at county level and the watershed map to see the distribution of LCC within each watershed. The variables representing distance to a Metropolitan Statistical Area (MSA), elevation, and average slope will be at the watershed level as well. Other dependent variables were collected at the county or regional level.

We started our model using county level data (Nagubadi and Zhang, forthcoming) and than transformed it to a watershed land use model. Our preliminary results (Bhattarai *et al.*, 2004) based on data from 1992 to 1998 on 50 watersheds are promising. We are encouraged that, even though some variables (such as land quality and median housing price) have not been included in the model, the model fits well and all variables have the expected signs.

The inclusion of land use variables within the ecosystem service model (**B**) will allow for forecasts of the effects of land use change on various indicators of ecosystem service. The results of research on land use change will be closely integrated with work on ecosystem functions and services which is described below.

Ecosystem function model (B of figure 1—Tier 2)

A central objective of our research is to understand how urbanization and land-use change affect ecosystem functions/services, which include water quality, biodiversity and ecosystem productivity. This requires an integration of physical and biotic processes, such as hydrological and biogeochemical cycles, in a range of spatial scales from site to landscape to watershed (Picket *et al.*, 2001; Loreau *et al.*, 2002). An integrated ecosystem model can provide a tool to synthesize a huge quantity of data, to analyze and predict ecosystem processes, and to provide a dynamic constraint on uncertainties in a variety of issues related to complex biotic processes, as well as heuristic clues for empirical studies (Oreskes *et al.*, 1994; Rastetter, 1996; Tian *et al.*, 1998a). The development of such a model, therefore, is essential to advance our understanding of the structure and functioning of ecosystems in response to human impacts such as urbanization.

In the first phase of ecosystem integration, we have examined how urbanization and land-use change affect the carbon cycle, an important ecosystem process. In our study, we have used an integrated ecosystem model, called the Terrestrial Ecosystem Model (TEM) (Melillo *et al.*, 1993; Tian *et al.*, 1998a, 1998b, 1999, 2003), to integrate multi-scale data sets from both remote sensing and field observations in the forested landscapes. Our analyses show changes in carbon storage in ecosystems during in the past decades. Our study in the three counties (Muscogee, Harris and Meriwether) of West Georgia has served as a pilot project for the extrapolation of our analysis into southeastern United States. We also identified gaps and limitations in existing information that need to be investigated in the future to improve our understanding of ecosystem dynamics and our ability to understand the effects of land use change on ecosystem function.

Feedback mechanism model (C of figure 1—Tier 2)

An important component of the model is a feedback mechanism from the ecosystem services and functions studies to socio-economic drivers, linking specifically with economic and public policy drivers. Feedback begins with an assessment of public knowledge and awareness of environmental change associated with land use change. The model assumes that once the public becomes aware of the environmental impact of land use change there is a measurable probability of their response through political and economic actions.

The policy focus will analyze the rise of citizen action groups who are interested in and act for the protection of the environment or quality of life. These groups may demand change in public policy such as zoning, planning, taxation, and environmental regulation. Policy makers then respond at some level to citizen activism and pressure with policy decisions that directly influence land use. The third phase in measuring feedback will assess citizens' willingness to pay for interventions aimed at producing specific ecosystem functions in terms of the integrated ecosystem model or other cultural concerns.

The feedback mechanism is based in the human ecosystem approach described by Grove and Burch (1997), as well as Machlis *et al.* (1997) that was developed as the conceptual framework of the Baltimore Long Term Ecological Research Project. The human ecosystem model is a means of integrating human and biophysical dimensions of ecosystem management through examination of critical resources (natural, socioeconomic, and cultural) and "allocation mechanisms" (ecological processes, political authority, knowledge, and information). The project looks specifically at the role of knowledge, policy action, and economic choice within this context. We are examining how socioeconomic variables are distributed according to geographic and demographic criteria, and then relating the distribution to land management practices. We view this research project as a first step in a larger investigation of social differentiation in the study area. Social differentiation is a central concept for studies of human ecosystems since it establishes the distribution of essential social resources such as political power, wealth, status, and knowledge (Grove and Burch, 1997). The spatial configuration of these types of resources is a influential factor in the distribution and dynamics of natural or biophysical resources. The fundamental goal of human ecosystems research is to enhance understanding of social and natural resilience, persistence, and variability in the ecosystem as a whole (Pimm, 1991).

Introductions to papers in this issue

This special issue is a collection of studies associated with the WestGA project. While studies related to the land use model (Bhattarai, 2004, Nagarubadi forthcoming) are presented elsewhere, the six papers assembled in this special issue concentrate on the ecosystem function and feedback mechanism models. Tier 1 studies of urbanization impacts on bird populations, abiotic and biotic water quality, vegetation (biodiversity and invasive species), and wildlife comprise the ecosystem aspect while the feedback model (Tier 2) is represented by an investigation of public perceptions and attitudes toward development.

Biotic and abiotic changes in water quality due to urbanization were examined by Helms *et al.* and Schoonover *et al.* Helms *et al.* examined relationships between stream fish assemblages (biotic diversity) and land use alterations associated with urbanization along the urbanization gradient north of Columbus, Georgia. Schoonover *et al.* examined changes in physiochemical and microbial indices such as sediment, nutrients, and fecal coliform within the same watersheds.

Burton *et al.* looked into relationships between plant biodiversity (riparian woody plant) and land use change. In particular, they examined forest structure and woody vegetation diversity indices of riparian communities with measures of urbanization and land cover. Similarly, Loewenstein and Loewenstein investigated the occurrence of invasive plant species along the urban—rural gradient.

Relationships between land development vs. bird populations were studied by Stratford and Robinson and Ditchkoff *et al.* respectively. Breeding bird survey routes were used to estimate species richness of migrant birds.

The paper by McDaniel and Ally presents the results of the first phase of the feedback mechanism model, that is, public knowledge and perception of environmental issues (quality of life indicators) associated with urban sprawl. Their paper focuses specifically on the role of local environmental knowledge as an important resource in human ecosystems, and looks at the implications of environmental knowledge loss associated with urbanization and its related demographic changes.

Summary

The WestGa project is an example of goal-oriented, interdisciplinary research designed to help understand causes, effects, and feedbacks regarding urban development—natural resource relationships. Research of this nature is difficult to conduct due to the barriers and challenges associated with many scientists working in groups that collaborate more closely than traditional multidisciplinary teams. However, with careful selection of participants and attention to provision of credits, these obstacles may be overcome.

The WestGa conceptual model, as well as that of Alberti *et al.* (2003), is an effective, first iteration tool for analyses of the causes, effects, and feedbacks associated with relationships between urban development and natural resources. As insight is gained into the complexities of these issues, new hypotheses and model renovations will develop and lead to more refined inter- and transdisciplinary research tools.

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