Modeling Forest Dynamics Using Field Data from Zoar Valley, Western New York State

Irena Lanc (Computer Science)
Erin Pfeil (Biology)
Alina Lazar (Computer Science)
Thomas P. Diggins (Biology)
Youngstown State University

1. Introduction

Riparian (river-dominated) zones are continuously reworked by dynamic and multi-directional interactions among physical, geological, and biological processes. Unfortunately, riparian ecosystems are also among the most altered by human activities. They are therefore seldom studied in their truly natural state, especially within the heavily populated northeastern United States. On-going research by the proposers in the unlogged and unregulated Zoar Valley Canyon of Cattaraugus Creek in western New York State (Diggins and Kershner 2005, Diggins 2005, Basto-Salgado et al. 2005, Pfeil et al. 2007), however, has offered a rare opportunity to study the ecology of an undisturbed eastern riparian zone.

Although highly quantitative, work thus far has largely described existing ecological *patterns*. The initiatives proposed here will focus on reconstructing and modeling ecological *processes*. We intend to continue research within the wooded riparian zone of Zoar Valley, integrating processes such as forest succession and disturbance regimes, fluvial landform deposition and erosion, stream hydrology, and watershed land uses into a comprehensive understanding of ecosystem structure and function. We further aim to develop and validate predictive simulation models for this site, which will prove invaluable both in understanding the dynamics of intact riparian systems and in managing and/or restoring impacted systems.

Increment core-based tree age estimates in Zoar Valley (Pfeil et al. 2007) have verified a 350-year chronosequence (i.e., present-day evidence of ecological history) ranging from nascent gravel bars to raised terraces that support exemplary “climax” communities. Additionally, detailed aerial photographs and satellite imagery spanning 75 years (Erie County NY 2007, NYS Office of Technology 2002) provide unequivocal documentation of more recent geomorphological changes in Cattaraugus Creek and its immediate surroundings, including changes in vegetative cover within the riparian zone and watershed. Studies of riparian forest community structure and composition (Diggins and Kershner 2005), treefall and woody debris accumulation (Pfeil et al 2007), and understory fern diversity (Sinn et al. 2005) have been recently completed. Other dynamics must be examined further, as proposed here, in order to fully reconstruct and model ecological processes within the riparian zone of Zoar Valley. Foremost among these, although not exclusive, are quantification of stream channel migration and landform changes, and increment core-based analysis of past canopy disturbance history.

Computer simulations have already been used with success to model forest ecosystems and to estimate the effect of environment disturbances and species migrations. The data collected in the Zoar Valley will provide values for the initial state and the parameters used to run the simulation.

2. Specific questions

Questions addressed by a reconstruction/simulation model would include, but not be limited to:

1) How is vegetative succession (i.e., ecological development over time) on fluvial landforms (created by flowing water) related to river flow regimes and processes of deposition and erosion?
2) How do riparian (river-generated) ecological processes interact with predominantly terrestrial processes such as treefall and gap formation as fluvial landforms develop and mature?
3) How have land use changes within Cattaraugus Creek's watershed influenced ecological processes within the pristine refuge of Zoar Valley, and how might further changes influence such processes in the future?
4) How to use computer simulations to find answers to the previous stated questions?

3. Methods

An ecosystem is by definition a complex system with emergent properties that do not have a direct connection with every individual unit. Many complex models of forest dynamics have been implemented in the recent years as software simulations. The main motivation behind using computer simulations to model forests is that the forest as a system is usually too slow, and too large to observe. For this project students will use two well known simulation software to model the Zoar Valley forest and to potentially answer to research questions: SimForest and LANDISII.

Given the multidisciplinary nature of this project, for its first part, the participating students will have to grasp and understand concepts from the discipline in which they do not major. To facilitate this process, SimForest will be used for the first part of the project. SimForest is a forest ecology modeling software developed mainly for inquiry-based teaching. Usually, this kind of computer simulations allow students to "learn by doing" or to model realistic systems that can be observed and analyzed. Using SimForest our team will not only be able to simulate tree and forest growth over time but also how environmental variables, including river disturbances, influence vegetative succession. The software includes a set of parameters that can be varied systematically in order to observe the emergent behavior of the system. These parameters include: rainfall, temperature, soil fertility, soil texture, soil depth and 30 species of trees.

Once the students become comfortable running forest simulations, we will upgrade to LANDIS-II, a software developed at the University of Wisconsin-Madison. LANDIS-II, like SimForest, simulates forest succession and disturbances. However, LANDIS-II does not represent individual trees, but rather individual species and their characteristics. Each species' characteristics are input in the simulations by using a set of attributes, that include when and where a species establishes, how long it grows, how it responds to disturbances. The simulation takes place into a two dimensional grid composed out of sites that can be grouped in ecoregions based on climate and soil. The current version is not appropriate for modeling succession driven by hydrology, but the software can be extended to include river disturbances.

As modeling of the multivariate Zoar Valley data progresses, additional field and map/image data may be collected and analyzed as needed. In addition to the data on riparian woodland structure, species composition, stand age, and coarse woody debris that are already available, further ecological evidence of forest disturbance history may be revealed by increment coring of eastern hemlock (*Tsuga canadensis*) trees beyond that already conducted for stand age estimation. This exceptionally shade-tolerant species preserves a record of canopy openings (disturbances) in patterns of suppression (narrowly spaced) and release (widely spaced) in its annual rings. Also, comparisons of aerial images across the available 75-year record (the most recent of which are compatible with GIS) could yield estimates of rates of important fluvial parameters such as channel migration and landform deposition.

Table 1. Project Time Table

Task Name	2007					2008							
	A	S	O	N	D	J	F	M	A	M	J	J	A
Literature review research about forest ecology, modeling and computer simulations.													
Zoar Valley site visits and collection of additional ecological data as needed.													
Developing programs that automatically test new data mining algorithms against developed packages for classification and prediction													
Full scale integration of LANDIS-II simulations with the Zoar Valley's data.													
Dissemination of results through papers and communications at specific conferences.													
Evaluation of the applicability of the computer simulations to other areas.													

4. Impact on the Goal of MRO-W

The foremost goal of the MRO-W project is to encourage females and minorities to pursue research project, which are interdisciplinary by nature, but have an applied computer science component. This project will provide a realistic research experience for the two female undergraduates by active involvement in the planning, execution and interpretation of scientific research. Well-developed research projects can significantly enrich the educational experience for undergraduate students. Working on this research project, students will be able to enhance their computer and programming skills, apply those skills to investigate scientific problems, learn how to formulate questions and problems, and to participate in the discovery of new knowledge. A good research experience can foster an enthusiasm for lifelong learning and a desire to continue education beyond the baccalaureate. Successful scientific instruction should develop in students a sense of wonder and curiosity about the world. The students will be exposed to both sides of the scientific investigation: hypothesis testing and development of theoretical explanations of observations. No science education is complete without research related activities, technical writing, and oral presentations.

Irena Lanc feels that this project will certainly support the goals of MRO-W. As an undergraduate female with intentions of pursuing graduate work in computer science, this project will give her, a useful introduction to the practical applications of her studies for research. This is a project that can potentially be a foundation for her senior thesis, and the computer simulations will be a wonderful basis for a research poster.

Erin Pfeil feels that this project will be of the utmost importance to her academic career, especially as she intends to pursue a doctoral degree and a career in academia as a quantitative ecologist. Erin has previously gained experience in mathematical ecology through a research program jointly mentored by the biology and math departments. The work proposed here would represent her first exposure to computer modeling applications – and increasingly powerful approach to ecosystem ecology.

Both students intend to present this project at this year's QUEST at Youngstown State University (a program highlighting student research). Both students will likely also present findings at regional and/or national scientific meetings within their fields. Results generated by this project will be included in one or more future manuscripts, with participating students afforded full opportunity to share the responsibilities and rewards of authorship.

4. Student Activity and Responsibilities

Specific tasks for the two participant students will include: literature search and review, reading and discussing research articles, designing and implementing agent-based simulations, data mining and machine learning algorithms, data processing, data analysis and interpretation, summarizing and preparing results for presentations and publications, YSU QUEST 2008 participation and writing the final report. Students will also partake in some field data collection, which will prove especially valuable in orienting them to the field site providing the data for computer modeling.

The primary responsibility of the two students is to participate in all phases of the project: proposal, development, experiments, and dissemination. The students will be required to do weekly independent work and to schedule team meetings. It is important that they work together as a team. The faculty advisor will meet with the students every other week. Email will be used for questions, announcements and documents interchange.

5. Faculty Activity and Responsibilities

As faculty advisor for the proposed project Dr. Alina Lazar will work to actively mentor the two students and continuously supervise their progress during the one year period. She will meet with the students on regular basis to guide their activities and answer their questions related to the project. Dr. Lazar has extensive experience in agent-based simulations, data mining, machine learning and artificial intelligence and she has written several papers related to the subject of this proposal. Her knowledge will make this project an enjoyable research experience for the undergraduate students. The department will supply a small computer lab and Dr. Lazar will provide the necessary software from funds previously obtained through the university. She guided the students on how to develop and write the present proposal and she will help them with the final report and also with the preparation of a conference paper.

Dr. Thomas Diggins will mentor students in the ecological aspects of this project, providing them with insights into the relevant background of riparian ecological dynamics, and helping to interpret findings of the modeling research. He will also organize site visits to Zoar Valley, where he has extensive research experience, and direct the collection of any needed field data.

The overall guidance and mentoring will not refer only to this project but it will provided insights about how to apply and how to succeed in graduate school, about being a female scientist and what the options are after graduate school.

6. Budget

For the proposed project we are requesting $7000 for each of the two participant female students. The additional $1500 will be used to buy computer media, books, and other materials necessary for the project. While working on the project the students will be encouraged to apply for the Undergraduate Research Grant Award sponsored by the Youngstown State University and other scholarships.

8. References

Basto Salgado GP, TP Diggins, CG Johnston, and W Fairchild. 2005. Water quality and benthic community structure in Cattaraugus Creek, Zoar Valley, NY. *Hydrological Science and Technology*. 21: 1-10.

Diggins TP. 2005. From gravel bars to old growth: primary succession in the Zoar Valley Canyon, NY. Proceedings of the 6th Eastern Old-growth Forest Conference, Moultonboro, NH.

Diggins TP, and B Kershner. 2005. Canopy and understory composition of old-growth riparian forest in Zoar Valley, New York, USA. *Natural Areas Journal*. 25: 219-227.

Erie County NY. 2007. Erie County Aerial Photos 1920s. http://www.erie.gov/aerials/1920s/20s_map.html.

Murray, T. (2004) Classroom Strategies for Simulation-Based Collaborative Inquiry Learning. Proceedings of ICLS-2004, San Mateo, June, 2004.

Murray, T., Winship, L. , Stillings, N. 2003 Toward Characterizing Best-Practice Pedagogy for Inquiry in Simulation-Based Leaning Environments. Proceedings of Cognitive Science. July, 2003, Boston, MA.

NYS Office of Technology. 2002. NYS GIS Clearinghouse (1-m satellite ortho-imagery). http://www.nysgis.state.ny.us/gateway/mg/.

Pfeil EK, N Casacchia, GJ Kerns, and TP Diggins. 2007. Volume, composition, and orientation of down deadwood in old-growth riparian woodlands in Zoar Valley, New York, USA. *Forest Ecology and Management.* 239: 159-168.

Reynolds R.G., A. Lazar. 2002. Simulating the Evolution of Archaic States. *2002 Congress on Evolutionary Computation (WCII 2002),* Hilton Hawaiian Village, Honolulu, HI, May 12-17, 2002.

Scheller, R.M. and D.J. Mladenoff. 2005. A spatially dynamic simulation of the effects of climate change, harvesting, wind, and tree species migration on the forest composition, and biomass in northern Wisconsin, USA. Global Change Biology 11:307-321.

Sinn, BT, and CF Chuey. 2005. A possible refugium for pteridophytes in Zoar Valley Gorge. Northeast Ecology and Evolution Conference (poster). Pennsylvania State University, State College, PA. March, 2005.