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Modeling spatial and temporal economic activity in forested landscapes

Wiktor Adamowicz, Scott Heckbert, Jennifer Jabs, Robin Naidoo, Marian Weber, and Yaoqi Zhang

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Modeling spatial and temporal economic activity in forested landscapes: forest management, non-timber values, habitat, wildlife, access, cumulative effects, disturbance, recreational use, subsistence use and human dynamics

A NETWORK OF CENTRES OF EXCELLENCE
UN RÉSEAU DE CENTRES D'EXCELLENCE

Modeling Spatial and Temporal Economic Activity in Forested Landscapes

Principal Investigator: W. Adamowicz (U of A)
Collaborators: Glen Armstrong (U of A), Fiona Schmiegelow (U of A), Grant Hauer (U of A), Lee Foote (U of A)

Graduate Students and PDFs: S. Heckbert (M.Sc. expected completion, October 2003), J. Jabs (M.Sc. completed, 2002), R. Naidoo (Research Associate), M. Weber (PDF), Y. Zhang (PDF)

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Modeling Spatial and Temporal Economic Activity in Forested Landscapes: Forest Management, Non-timber Values, Habitat, Wildlife, Access, Cumulative Effects, Disturbance, Recreational Use, Subsistence Use and Human Dynamics

Project Report:
Modeling Spatial and Temporal Economic Activity in Forested Landscapes

Authors:
Adamowicz, Wiktor: Professor, University of Alberta
Heckbert, Scott: Master's Student, University of Alberta
Jabs, Jennifer: Former Master's Student, University of Alberta
Naidoo, Robin: Former Ph.D. student and Research Associate, University of Alberta
Weber, Marian: Former Post-doctoral Fellow, University of Alberta
Zhang, Yaoqi: Former Post-doctoral Fellow, University of Alberta

Contact Info:
Dr. W.L. Adamowicz
Department of Rural Economy
University of Alberta
515 General Services Building
Edmonton, AB
CANADA T6G 2H1
Phone: (780) 492-4603 (Office)
Fax (780) 492-0268
Email: vic.adamowicz@ualberta.ca

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Introduction (Research Questions and Objectives)

Traditional models of integrated resource management contain relatively simple representations of human spatial economic behavior—the processes within them do not fully represent the system's complexity in terms of heterogeneity of spatial processes, individual preferences and perceptions. The ecological models often lack economic and human dimensions, while the economic models generally lack both spatial explicitness and heterogeneity of individual preferences and perceptions. In order to understand the magnitude of human impacts on the environment and how the changing environment affects humans, the interaction between ecological and economic sectors must be better represented.

In linking this project with the Boreal Ecology & Economic Synthesis Team (BEEST) project structure, there were three main objectives to better integrate the ecological and economic system: improving understanding, tool development, and policy analysis.

The key findings developed in this research include:

- A model of human behaviour (recreational fishing) was built and integrated with ecological systems (fish populations) and existing access networks for a region in northeastern Alberta. This model is flexible and can be grafted into other modeling systems.
- A policy simulation was conducted using this economic-ecological model to assess the efficacy of various regulatory approaches for maintaining fish populations in light of access and human population pressures. The most effective approach appears to be a quota system, although even this system results in reductions in angler benefits.
- A model integrating forestry, human moose hunting behaviour, access (roads, seismic lines, etc) and moose populations was developed using agent based modeling.
- The model was used to assess various strategies for access management in northeastern Alberta, resulting in the finding that a “best practices strategy”, as defined in the study, can yield significant benefits.
- Models of energy sector behaviour were developed to better understand the value of energy activities in the forested landscape. These values need to be understood in order to assess the opportunity cost of environmental policies.
- A model of energy sector spatial behaviour was also developed to better assess the dynamics of the sector. This model identified that spatial development patterns area affected by prices and existing infrastructure.
- A tradable land use rights system was proposed as a mechanism for biodiversity conservation in an area with multiple agents generating surface disturbance. In addition, this approach was tested using a modeling approach and was found to yield significant benefits relative to existing approaches for biodiversity conservation.

Contributions to Improved Understanding:
Understanding the relationships between forest management, access, resource use and spatial economic behaviour are key elements in the interaction of forestry and energy sector developments, wildlife and human use of forests. Ultimately, this understanding leads to a better comprehension of non-timber values and associated impacts and implications of access management on non-timber resources, recreationists and industry.

The first form of spatial economic behavior assessed in this project was recreational use of wildlife resources (fishing, hunting). Interactions between these activities, disturbance of forest habitat (by fire, harvesting and energy sector removals) and fish/wildlife resources were developed using existing data but employing new spatial microsimulation and individual agent modeling approaches.

Energy sector behavior was also examined. Spatial economic analyses of energy the sector were used to examine their dynamic behaviour and to develop models of the value of energy resources. These models can be used as predictions of energy sector behaviour in models of forest management, and they can provide information on the opportunity costs of regulatory actions that restrict energy sector activity.

These modeling efforts facilitate assessment of non-timber values and cumulative effects through improved understanding of spatial economic behavior for three sectors; forestry, fish/wildlife resource users, and the energy sector.

Contributions to Policy Analysis:
A key element of this project was construction of the framework for policy analysis and the development of a generalized approach permitting hypothesis testing and adaptive management, policy and economic dimensions. The project examined alternative access management policies and their effects on human welfare and ecological conditions. As well, the project examined how the energy sector responds to changes in incentives/regulations and how will these in turn affect the ecological system.

Progress, Findings, and Policy Implications

Each of the topics was successful in developing improved understanding of the relationships between forest management, access, resource use and spatial economic behaviour. These relationships are key elements in the interaction of forestry and energy sector developments, and wildlife and human use of forests.

Access Management
The implications of access management on non-timber resources and values were examined and could potentially aid in planning for road construction and distribution of other linear disturbances and regulatory change.

Recreational and subsistence-based (fishing, hunting) spatial economic behavior was assessed and interactions between these activities, disturbance of forest habitat (by fire, harvesting and energy sector removals) and fish/wildlife resources were developed using existing data but employing new spatial microsimulation and individual agent modelling approaches. The energy sector activities were then included as exogenous to the system.

Although FEEnix was proposed as a platform for such models, it was found that for recreational fishing models, an opportunity arose to link a previously constructed model of a typical Alberta walleye lake (constructed in STELLA) to the human preference model. In addition, STELLA provides a general approach compatible with the data set and subsequently, the simulations of various regulatory options. It also provides an excellent format for dynamic modeling with an intuitive and user-friendly graphical interface and can be used to develop simple student models or complex research models. This model was used to assess the implications of access (and access management) as well as other regulatory approaches on fish populations and benefits from recreational fishing.

The agent-based wildlife resource model for Northern Alberta required a program that could link the human component and the landscape in a dynamic and spatial manner for various management scenarios. The program ABLE (Agent Based Landuse Experiment) was designed to improve the understanding of relationships between natural processes and human activities. The ABLE project aims to:

- Test hypotheses regarding alternative access management scenarios
- Develop a spatially explicit model of human resource use including recreational and subsistence uses of wildlife resources, disturbance and the interaction between human disturbance and wildlife resources.
- Examine the relationships between access, resource use and spatial economic behaviour.
- Develop the human use sector so that the impact of management scenarios can be examined to help identify and examine cumulative impacts management tools.

The program Dualplan (constructed by G. Hauer) incorporates non-timber values into forest management modelling. The methods for incorporating behavior of non-timber forest users (and values) into the Dualplan optimization model were developed in this project by D. Nanang. Specifically, the integration of utility functions derived from recreation site choice/random utility models into the objective function of the optimization model was completed by linking utility functions to access considerations, forest stand characteristics and wildlife population levels.

Policy implications for the fish/hunting models

Altering regulation has substantial impact on not only the ecology of an area, but also on the anglers and hunters in an area. One of the main questions was “Is it possible to prevent loss of fish numbers/ habitat/ moose numbers while maintaining (or increasing) angler/ hunter well-being?” With this in mind, do some regulatory approaches perform better than others? How will access management approaches, or other regulatory systems, perform in terms of wildlife populations and benefits to recreationists?

In the study of northern Alberta lakes, several conclusions can be made about the affects that fishing regulations have on both fish populations and angler welfare.

- A population-dependent site closure can cause high population volatility and the “whack-a-mole” effect, as well as decreased angler utility
- A quota system was found to be a reasonable alternative. Similar to Alberta’s current hunting draw system, anglers could draw for the right to fish at a lake for a certain weekend. This would cause a more stable level of angler effort, and less volatile fish populations.

The best policies for fish sustainability were found to be single site and multiple site angler effort quotas and site fees. This resulted in less volatile fish populations and less relative angler welfare loss. However, each policy, regardless of its effects on walleye populations, causes a net decline in angler welfare. Even the lake quota, which results in an increase in the quality of fishing, does not increase angler utility enough to make up for the disutility of relocating to another lake.

In the agent based model, which focused on moose populations, forestry and hunting, it was found that industrial "best practices" can mitigate resource impacts in complex systems, but also significantly decrease hunter utility. As well, earlier reclamation of roads slows the rate of local extirpation. Reclaiming access mitigates impacts on remote wildlife populations, however hunting pressure is focused more on local areas, resulting in a greater number of local extirpations.

All of the changes in policy examined, that impose restrictions on the recreationist, resulted in negative effects on the recreationist. The future benefits of improved fish populations did not offset the impacts the restrictions had on reducing other positive factors of that site besides the fish and wildlife. The research did not incorporate passive use values, which would have perhaps showed a net positive welfare change after a stricter policy imposed to sustain wildlife population levels.

Policy implications for the energy models

The response to changes in economic factors (prices, interest rates, etc.) and regulatory change on energy sector uses of forest resources were developed as the project progressed.

The energy sector was modeled with a combination of three categories of variables: infrastructure, reserves, and temporal effects. It was found that the resulting model is statistically significant and a majority of the variables entered the model with coefficients in the expected direction. The strongest predictors were the one-year lag of price and the density of pipelines, both of which were positive influences on gas well density.

The energy sector models were also estimated using geo-statistics to attempt to simulate and hypothesize the oil and gas exploration spatially and temporally. The alternatives considered were: prices at the same year, prices with a lag, and weighted prices. The models each perform well to forecast future well drilling activities.

Thus, the energy sector will continue to be influenced largely by price and existing infrastructure. As price increases, so will energy development. As well, there is a strong correlation between existing pipelines and well density. A cumulative effects management regime would be a policy option to cap the amount of habitat fragmentation and total biodiversity disturbance.

Cumulative Effects Management

Given the concerns that arise from the impacts that many smaller disturbances can cause to an ecosystem, cumulative effects and habitat fragmentation have been increasingly important. This has led to proposing a tradable landuse rights (TLR) scheme. TLRs are an important tool for reducing cumulative effects in managed forest landscapes. Because cumulative effects are not localized, the tradeoffs of individual developments must be considered at a regional scale. Under Alberta's public land management system, the costs of habitat loss are not accounted for in the disposition phase of development and there is no incentive to coordinate land-use between sectors. This is inefficient from both an environmental and economic perspective. The results of this research project argue that tradable land-use rights that entitle owners to disturb public forest land can be used to manage cumulative effects by controlling the rate of habitat loss. By creating an opportunity cost for alternative land uses, TLRs maximize the economic value of land development while maintaining threshold levels of available habitat. TLRs also force governments to be explicit in setting land-use objectives, allowing stakeholders to debate publicly the merits of alternative land-use constraints rather than the merits of individual projects.

The TLR scheme can be viewed as a coarse filter approach to biodiversity protection. Under TLRs, economic criteria determine the distribution of development activities and protected habitat on a landscape. This allows the regulator to reduce the level of habitat loss for a given cost. Given that there is a tradeoff between habitat loss and configuration in biodiversity protection, TLRs can increase the utility of habitat set aside as reserve. It is important to note that TLRs are a partial solution to the problem of reducing cumulative effects and are not proposed as a solution for protecting sites with rare local features or social significance. Rather, TLRs can complement decision rules used to protect a wider array of landscape values. Future research effort should aim at quantifying the risk to biodiversity loss of alternative landscape designs and identifying habitat thresholds for species at risk and/or vulnerable habitat types. Specific case studies would be helpful for understanding some of the more complex implementation issues associated with ecosystem dynamics.

The main challenges with TLRs are unintended externalities (“third-party effects”), noncompliance, and the process for determining the actual initial allocation of rights. Sorting out these issues will be challenging in the BFNR. The determination of initial rights is almost always based on historical use; however, the dominance of a few large players on the landscape suggests that it might be necessary to modify the grandfathering approach. Noncompliance and issues associated with monitoring and enforcement can be addressed only through the dedication of sufficient resources to these tasks.

Technological advances, including satellite imaging, may significantly reduce monitoring costs. An important advantage of TLRs is that habitat loss is relatively easy to monitor and can be linked to biodiversity outcomes through simulation models. Finally, third-party effects, particularly those that arise from spatial networks, may be the most difficult issues to address. Given that many land-based resources are currently allocated in spatial markets, experience in other markets and jurisdictions will provide insight into approaches that may be best in the TLR context.

Initial simulations of the TLR scheme illustrate its value. A significantly lower cost of achieving a conservation (protected areas) target results from using TLRs, or significantly larger protected areas can be established at the same cost as "traditional" systems for establishing protected areas.

Follow-up Research

The methods and data used in this research provide many note-worthy results, but since many of these topics are relatively recent, there is much that can be further examined in future projects.

Spatial Ecological Models

In regards to the spatial ecological models, data availability was a major constraint. For the recreational fishing model, it would be helpful to use a combined stated preference/ revealed preference approach rather than only using revealed preference data. A better data set would also make modelling dynamic movements of anglers more effective in order to learn their perceptions and preference changes (as regulations change.) The preference changes would also need to include the angler's preference for not only the number of fish caught, but the preference for fish that are caught but released. With these data, one could calculate more realistic values for welfare measures associated with regulations.

As well, an interesting extension of this project would be to add component with a variety of different types of anglers and fish species preferences to improve the explanatory power of the model. Various other site attributes that were excluded (e.g. campgrounds, picnic sites, measures of scenery, congestion etc.) could be incorporated into the angler preference model. The model could be incorporated into a GIS program or into another program such as FEEnix.

The agent based model of economic activity in the Boreal Forest successfully incorporates human economic behaviour into spatial and temporal ecological models. However, similar to the recreational fishing model, this research would be enhanced by increasing site fidelity. This includes site attributes and human preferences, as well as the topographical and spatial details of each site. Learning agents would also be a useful addition to the model. When hunters learn of new access routes and hunting areas, the trip forecasts would not be as accurately represented by randomness. The regulatory framework could also be further included into the behavioural component, including compliance and hunter welfare loss. A periodic regulatory measure implemented s best, adjusted to encompass a larger choice set of lakes or area of land. This would better represent the true decisions and substitutions that recreationists must make.

Energy Sector

The development of predictive measures and "optimal land use plans" for the energy sector has many future research possibilities. First, it is important that future research efforts aim at quantifying the risk to biodiversity loss of alternative landscape designs and identifying habitat thresholds for species at risk and/or vulnerable habitat types. This includes increasing understanding of the ecological tradeoffs associated with fragmentation to assess full benefits of an alternative regulatory mechanism. Specific case studies would be helpful for understanding some of the more complex implementation issues associated with ecosystem dynamics.

The geostatistical drilling-forecast models can also be significantly extended. The current study is based on the township level and likely could be improved if examined at a Section level. Although the well head prices are included there are four important variables not yet included. These are: the cost of well drilling, technological development, policy variable regarding the taxation and regulation on oil exploration, and other spatial variables, such as road networks and other industrial development. If these variables are incorporated together with more updated reservoir information, forecast ability may be significantly increased. Likewise, advances in prediction functions for spatial regressions will enhance the ability to use similar models to predict the timing of oil and gas development in Alberta's Boreal Forest

Participating Partners and Affiliates

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Publications, Posters, Presentations

Adamowicz, W. A Different Approach to Cumulative Effect Management in the Boreal Forest: Presented to the Department of Biological Sciences. March 2, 2001.

Adamowicz, W. *Public Forest Land Management in Canada: Is it Sustainable?* February 22, 2002: Yale School of Forestry and Environmental Studies. Invited seminar sponsored by the Department of Foreign Affairs and International Trade Canada.

Adamowicz, W. *Public Forest Land Management in Canada: Is it Sustainable?* April 12, 2002: Regional Resource Institute, West Virginia University, Morgantown WV. Invited.

Adamowicz, W. Sustaining Canada's Forests. Public Panel Presentation at the Sustainable Forest Management Network Annual Conference. Edmonton. November 13-15, 2002.

Armstrong G.W., Adamowicz W.L., Beck J.A., Cumming S.G., Schmiegelow F.K.A. 2003. Coarse Filter Ecosystem Management in a Nonequilibrating Forest. Forest Science. 49(2): 209-223.

Heckbert, S. Agent Based Modeling of Spatial and Temporal Activity in Forested Landscapes. Conference Proceedings from "CEAS-CES 2003 Annual Conference" Canadian Agricultural Economics Society. Montreal, Quebec. July 27-30

Jabs, J. 2002. Effects of Regulatory Mechanisms on Anglers and Walleye Populations in Northern Alberta Lakes. Master's Thesis, Dept. of Rural Economy, University of Alberta.

Jabs, J.H and W.L. Adamowicz. Regulating Recreational Fishing in Northern Alberta: Effects on Anglers and Walleye Populations. Conference Proceedings from "CEAS-CES 2002 Annual Conference" Canadian Agricultural Economics Society. University of Calgary: Calgary, Alberta, Canada. May 30-June 1 2002.

Jabs, J. and W. Adamowicz. 2002. Effects of Regulatory Mechanisms on Anglers and Walleye Populations in Northern Alberta Lakes. Proceedings of the Sustainable Forest Management Network Conference, "Advances in Forest Management: From Knowledge to Practice", 13-15 November 2002, Edmonton, Alberta.

Naidoo, Robin. 2003. Spatial Econometric Analysis of Energy Sector Activities in Alberta. Draft working paper. University of Alberta.

Nanang, David. Fall 2002. Optimization Based Forest Planning Tools for Sustainable Forest Management. PhD Thesis. Dept. of Rural Economy, University of Alberta.

Weber, M. and W. Adamowicz. 2002. Tradable Land Use Rights for Cumulative Environmental Effects Management. Proceedings of the Sustainable Forest Management Network Conference, "Advances in Forest Management: From Knowledge to Practice", 13-15 November 2002, Edmonton, Alberta.

Weber, M. May 3, 2002. Poster Title: Tradable landuse rights and cumulative environmental effects management [Poster] Alberta Environment, Economic Instruments Implementation Network , Emissions Trading Workshop, Edmonton, Alberta.

Weber, M. and W. Adamowicz. 2002. Tradable Land Use Rights for Cumulative Environmental Effects Management. Canadian Public Policy. 28(4). Pg 581-595.

Weber, Marian L. Decentralized reserve design strategies: a framework for analysis, Sustainable Forest Management Network Working Paper 2001-3 (Internal)

Weber, M. and W. Adamowicz. 2001. Decentralized instruments for conservation of biological diversity: An economic approach to cumulative effects management. Sustainable Forest Management Network Working Paper 2001-2. University of Alberta.

Weber, Marian. 2002. The challenge of biodiversity conservation in Canada's boreal forests, Tomorrow's Forests, Winter 2002. (note: SFMN publication editorial - not peer reviewed journal).

Weber, M. Cost Effectiveness and Biodiversity Conservation: Exploring the Impact of Tradable Permits for Reserve Design in the Boreal Mixedwood Forest. Submitted, Environmental and Resource Economics.

Weber, M. Cost Effectiveness and Biodiversity Conservation: Exploring the Impact of Tradable Permits for Reserve Design in the Boreal Mixedwood Forest". 4th BioEcon Workshop on Biodiversity Conservation, Fondazione Eni Enrico Mattei, Venice Italy, August 28, 2003.

Weber, M. Tradeable landuse rights and cumulative environmental effects management Alberta Agriculture, Environmental Goods and Services Working Group. Edmonton, June 21, 2002.

Weber, M. Implementation issues for tradeable landuse rights in Alberta’s Northeast Boreal Forest Region. Alberta Environment. Edmonton. June 17, 2002.

Weber, M. Tradeable landuse rights and cumulative environmental effects management [Poster] Alberta Environment, Economic Instruments Implementation Network, Emissions Trading Workshop. Edmonton. May 3, 2002

Weber, M. Tradeable landuse rights for cumulative environmental effects management. Alberta Environment, Hot Topics Seminar. Edmonton. April 26, 2002.

Weber, M. The Costs and Benefits of Ecological Reserve Networks, BEEST Partners’ Meeting. Edmonton. Partners: AlPac, Weyerhaeuser, Alberta Government. December 14, 2001.

Weber, M. and Adamowicz, W. Tradeable landuse rights and cumulative environmental effects management. Radio Interview, Innovation Alberta, CKUA. Edmonton. Nov 14, 2002.

Weber, M. Comparing the welfare effects of using alternative biodiversity metrics in reserve design. [Poster] Sustainable Forest Management Network Annual Conference. Edmonton. November 13-15, 2002.

Weber, M. Decentralized mechanisms for selection of natural reserve areas. Canadian Resource and Environmental Economics Annual Meeting, October 12-14, 2001.

Zhang, Y. 2002. Co-management of Forest Resources in Canada: An Economically Optimal Institutional Arrangement. SFM Working Paper 2002-4.