AGENT-BASED MODELING: LINKING PUBLIC HEALTH AND WELL-BEING TO ECOLOGICAL GOODS AND SERVICES

IN THE CREDIT VALLEY WATERSHED

MARTIN BUNCH, YORK UNIVERSITY

Research conducted 2016-2018, Report published May 2020

WEPGN
Water Economics, Policy and Governance Network

Canadian Water Network

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WHY DID WE DO THIS PROJECT?

Watershed-level interventions effectively protect and promote human health and well-being in a wide variety of ways, including flood protection and mitigation, cleaning the air, providing green space for public recreation and enhanced mental and physical health, and reducing skin cancer by providing a robust urban canopy. Substantial health benefits are realized from the actions of Ontario's Conservation Authorities, but the dollar value of these benefits is rarely computed or expressed. The linkages between environmental interventions and public health benefits are not well-articulated, which means the potential co-benefits of environmental and public health interventions are underrealized.

This project integrated the academic literature on connections between ecological goods and services and public health and well-being in a way that was locally-relevant, easily understood and accessible. Using this literature, the project created a computer model to simulate and explore some of the critical relationships that exist between ecosystem health and public health and well-being in the Credit Valley watershed. Credit Valley Conservation Authority (CVC) will benefit from the ability to model these relationships and generate a holistic cost-benefit analysis. Ultimately, this model could inspire new conversations between CVC, public health agencies and the general public about how healthy, functional ecosystems support the health and well-being of residents living within the watershed.

Canada needs more real-world parameters related to the cost and number of conservation actions, the value of these measures in promoting human well-being, and better data on the interactions between key variables in a social-ecological system. This project builds on prior work by Bunch (2016), which examined the links between health outcomes, pathways and ecological services on a watershed basis (summary report available at cwn-rce.ca/report/WEPGN-Bunch-2016).

WHAT IS AGENT-BASED MODELING AND GEOSIMULATION?

Agent-based models are a way to explore and understand the overall effects that result from actions taken by numerous actors at different times and places in a system. Models like these are often used in ecology, social science or public health to simulate and predict the occurrence of phenomena such as flooding, disease outbreak or human behaviour. Geosimulation draws on geographic data and geographic information systems to show potential changes to specific spaces such as a watershed or sub-watershed.

A key premise of agent-based modeling is that the agents' behaviour is autonomous. Agents act independently of one another, based on a set of rules that govern how they respond to other agents' actions and to changes in their environment. As these actions unfold, individual agents are thereby influenced by the behaviour of the social, economic and ecological systems that surround them. Agents can have diverse characteristics and represent individuals or organizations. Cells represent the broader environmental or landscape features that are also governed by certain rules and can change over time. The sum total of these agents, cells and rules is the agent-based geosimulation model, which allows us to see patterns evolving out of the individual actions and interactions of the agents, demonstrating that the whole is greater than the sum of its parts.

The project's model also incorporated elements from the Millennium Ecosystem Assessment, Watershed Governance Prism and the Ecological Cascade frameworks (Bunch, 2020a).

WHAT DID WE DO?

One of the goals of the project was to identify indicators of relationships that are relevant to the Credit River Watershed so that stakeholders could understand and explore them. For example, tree planting was linked with monetary, health and ecological indicators (Figure 1). The model worked with a key relationship from the literature that links human mortality with exposure to urban green space, using data from a study of 1.3 million adults in 30 Canadian cities that examined the relationship between mortality and measures of greenness within 250 metres of people's homes (Crouse et al., 2017). The model also used:

- Geographic information system data related to ecological and land use classification (including satellite imagery data) to model vegetation patterns in the watershed
- Census data to reflect local population demographics
- Government of Canada estimates of the value of a statistical life (Treasury Board of Canada Secretariat, 2007)

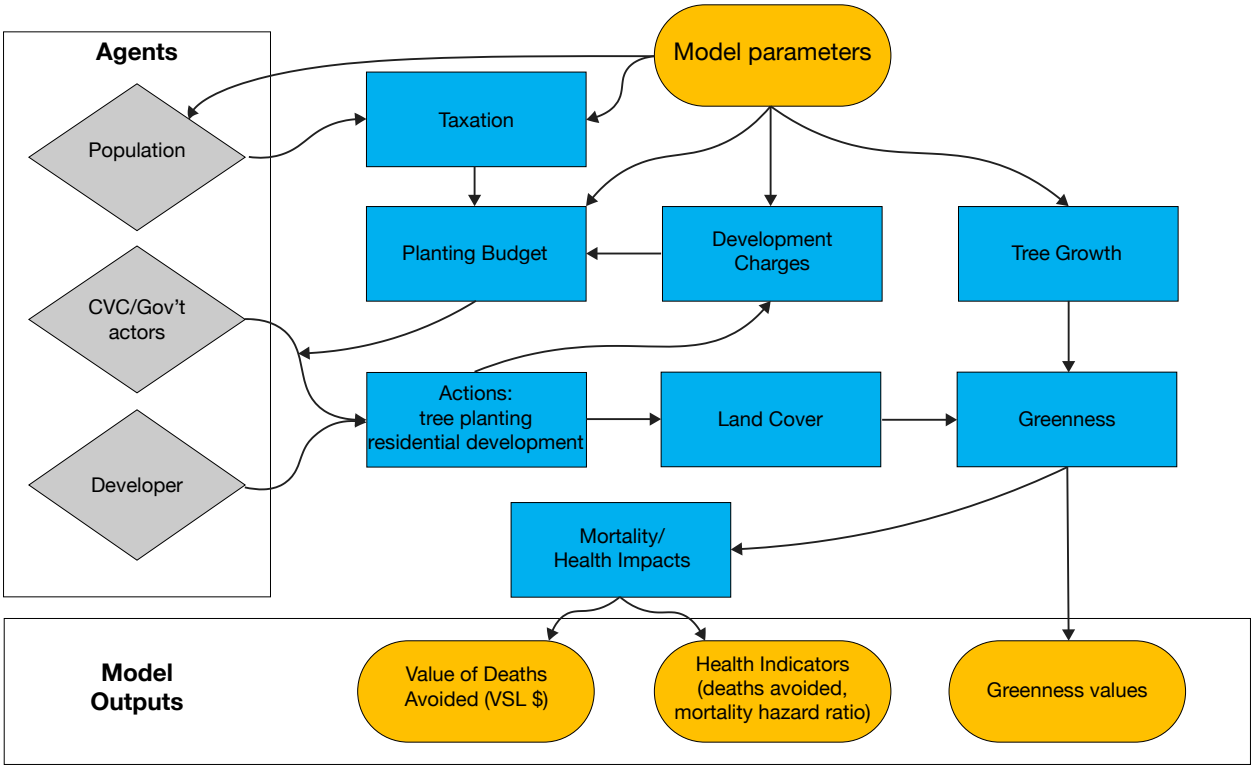

Figure 1. Conceptual framework linking tree planting with monetary, health and ecological indicators in an agent-based geosimulation model

In the model, greenness is the average normalized difference vegetation index within 250 meters of each 50-metre cell. Based on this estimate, a mortality hazard ratio is calculated using Crouse et al.'s (2017) estimates. Within the model, planting by the CVC is dictated by the following rules:

- There is a user-defined budget and cost per tree.
- Trees are only planted in suitable conditions.
- Planting is prioritized in areas with low greenness values, based on existing land cover.
- Planting continues in a given time period until they the budget limit is reached.
- Once an area has been planted, greenness improves over time based on user-selected growth rates, which decreases the mortality-hazard ratio.

Simultaneously within the model, a developer can convert undeveloped land to new residential areas. This causes a drop in greenness and increases the mortality-hazard ratio within adjacent cells. The model tracks changes in the mortality-hazard ratio over time and estimates the economic value of that change, based on the value of a statistical life. The user can set this value, but the model uses a default of $6.5M.

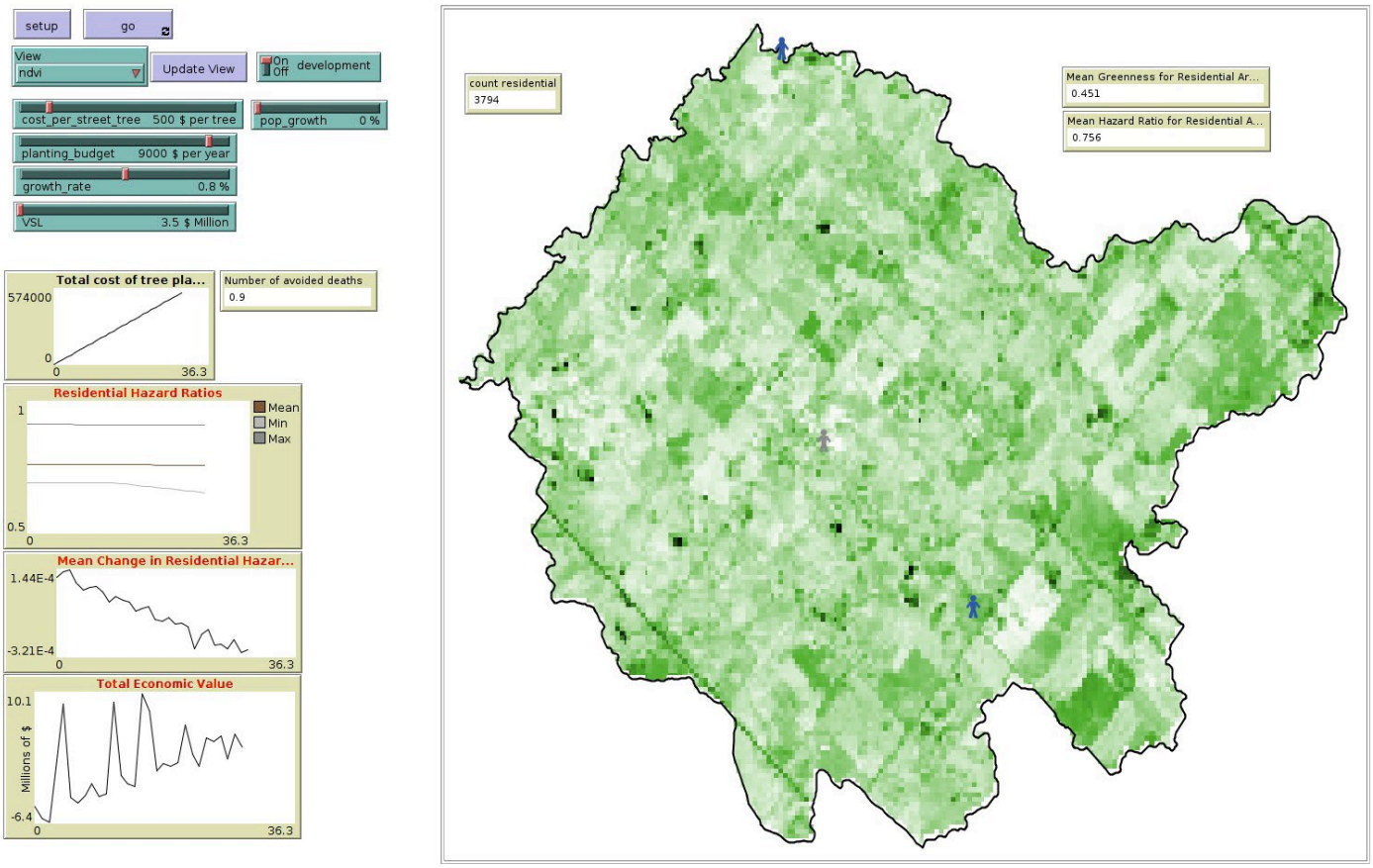

Figure 2. Screenshot of tree planting within the model

The model identifies significant health and economic benefits that can be realized through local and regional actions by the conservation community. These include benefits to ecosystem functioning and integrity, as well as benefits to the health and well-being of people living within the watershed.

NEXT STEPS

Our plan is to develop an online public interface that will enable individuals to create their own scenarios. Using separate dashboards for urban and rural communities, future iterations of the model could include scenarios with conservation or development actions that highlight:

- → Reduced exposure to air pollution, heat and noise
- → Impacts on health conditions such as cardiovascular disease and obesity
- → Increased aesthetics and recreational opportunities
- → Improved physical fitness or recovery from stress
- → Changes in mortality
- → Increased pollination and agricultural outputs
- → Better flood protection

WHAT DOES THIS MEAN FOR DECISION-MAKERS?

- Agent-based modeling differs from conventional economic models in many ways, including its ability to allow for differences among biophysical and human agents. Patterns emerge from the network of relationships encompassed by the model.
- Agent-based models that simulate real-world situations can identify new questions and enrich conversations about policy and program structures, as well as potential alternatives.
- The process of building the model is as important as the tool itself, requiring a range of stakeholders with different expertise and perspectives to come together to create a meaningful network of social and ecological relationships that can be modeled and tested.
- Eventually, such models can be made into interactive 'games' that empower users to create and evaluate their own scenarios by manipulating the parameters of the model.
- Once a range of conservation actions is included, this tool can be used by CVC staff to support high-level planning based on scenarios that target health and well-being benefits for residents living in the watershed.
- The model provides managers and decision-makers with innovative ways of valuing ecosystem services at the watershed-level to complement monetary valuation (see also Bunch, 2016). This project approaches such non-monetary dimensions through the development of scenarios that help to answer questions about the potential health and well-being outcomes of different conservation actions at different places and times in the Credit Valley watershed.

The Water Economics, Policy and Governance Network's (WEPGN) overarching goal is to build knowledge and facilitate exchange between social science researchers and partners, thereby increasing the application of research to decision-making and enhancing water's sustainable contribution to Canada's economy and society while protecting ecosystems. WEPGN was established with a SSHRC Partnership Grant. The Network's objectives are to:

- Create a vibrant and multidisciplinary network of **Partnerships** amongst researchers, government agencies and community groups;
- Provide **Insight** by mobilizing knowledge from social science perspectives to improve our understanding of water's role in Canadian society and economy;
- Strengthen **Connections** by facilitating a multidirectional flow of knowledge amongst researchers and partners to promote more efficient and sustainable water management;
- Provide high quality **Training** experiences for students and practitioners with interests in water policy decision-making and management.

This project by Bunch contributes to each of the above objectives, and is a notable example of a project that strengthens connections between researchers and partners to create and share knowledge that promotes efficient and sustainable water management.

WEPGN Water Economics, Policy and Governance Network

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REFERENCES

BUNCH, M., MORRISON, K., PUDDISTER, M., KOVESHNIKOVA, T., & PAUDEL, E. (2016). Human well-being, ecosystem services and watershed management in the Credit River Valley. Water Economics, Policy and Governance Network.

BUNCH, M., DUPONT, D., & MORRISON, K. (2020A). A review of conceptual frameworks linking public health and well-being to ecological goods and services in the Credit Valley Watershed. Water Economics, Policy and Governance Network.

CROUSE, D. L., PINAULT, L., BALRAM, A., HYSTAD, P., PETERS, P. A., CHEN, H., VAN DONKELAAR, A., Et al. (2017). Urban greenness and mortality in Canada's largest cities: A national cohort study. The Lancet Planetary Health, 1 (7), e289-e297.

TREASURY BOARD OF CANADA SECRETARIAT. (2007). Canadian cost-benefit analysis guide: Regulatory proposals. Ottawa: Queen's Printer's Press Canada. Retrieved from:www.tbs-sct.gc.ca/rtrap-parfa/analys/analys-eng.pdf