Human well-being, ecosystem services and watershed management in the Credit River Valley: Web-distributed mechanisms and indicators for communication and awareness

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Foreword

This major project has provided applied examples of how to create connections between natural ecosystems, urban environments and human health. In this sense, it speaks directly to the Area of Concentration of the attached Plan of Study: "Planning Green Space for Human Health". The second component of the area of concentration sought to "examine the connection between exposure to nature and human health" (Kemal Kapetanovic, Plan of Study, p. 11). The toolkits that were prepared as part of this major project aimed to directly identify the links between specific green space interventions and their effects upon human health. Learning objective 2.2 sought to better understand theories that relate human exposure to natural environments and the effects upon human health. The major project presented the idea of ecosystem services, as well as the work of the Millennium Ecosystem Assessment, which is one of the defining publications and conceptual frameworks used to relate nature and human health. The third component of the plan of study related to the professional urban planning approach when dealing with nature in cities. Throughout this project, our team worked directly with the Credit Valley Conservation Authority, and had meetings with various experts in agricultural, LID, and forestation interventions. It was through this direct research that object 3.1 was achieved, as it contrasted the theoretical ideas about ecosystem services with the applied decisions that need to be made by conservation authorities and restorationists when deciding how to manage natural ecosystems in urban environments. Ultimately, this major paper connected directly with the spirit of the plan of study on many different levels.

Abstract

This project is one section of a larger project undertaken between researchers at York University and the Credit Valley Conservation Authority (CVC). The ultimate goal of the project is to identify links between human health and natural ecosystems, and incorporate these connections into a web-based decision making tool that can be used by planners, ecologists and policy makers at CVC. The following paper provides background information about the project as well as the concept of ecosystem approaches to health or 'ecohealth'. The larger project uses the framework and vocabulary of ecosystem services as defined by the Millennium Ecosystem Assessment in order to define and describe the connections that exist between natural ecosystems and human health. This framework is described and critiqued in the paper. Finally, three toolkits are presented that specifically describe the relationship between a proposed intervention upon the landscape and the consequences it would have for human health in the surrounding area. Each toolkit contains a completed matrix based upon the cascade model of ecosystem services that shows the progression from intervention to human health benefit.

Human well-being, ecosystem services and watershed management in the Credit River Valley: Watershed Intervention Toolkits

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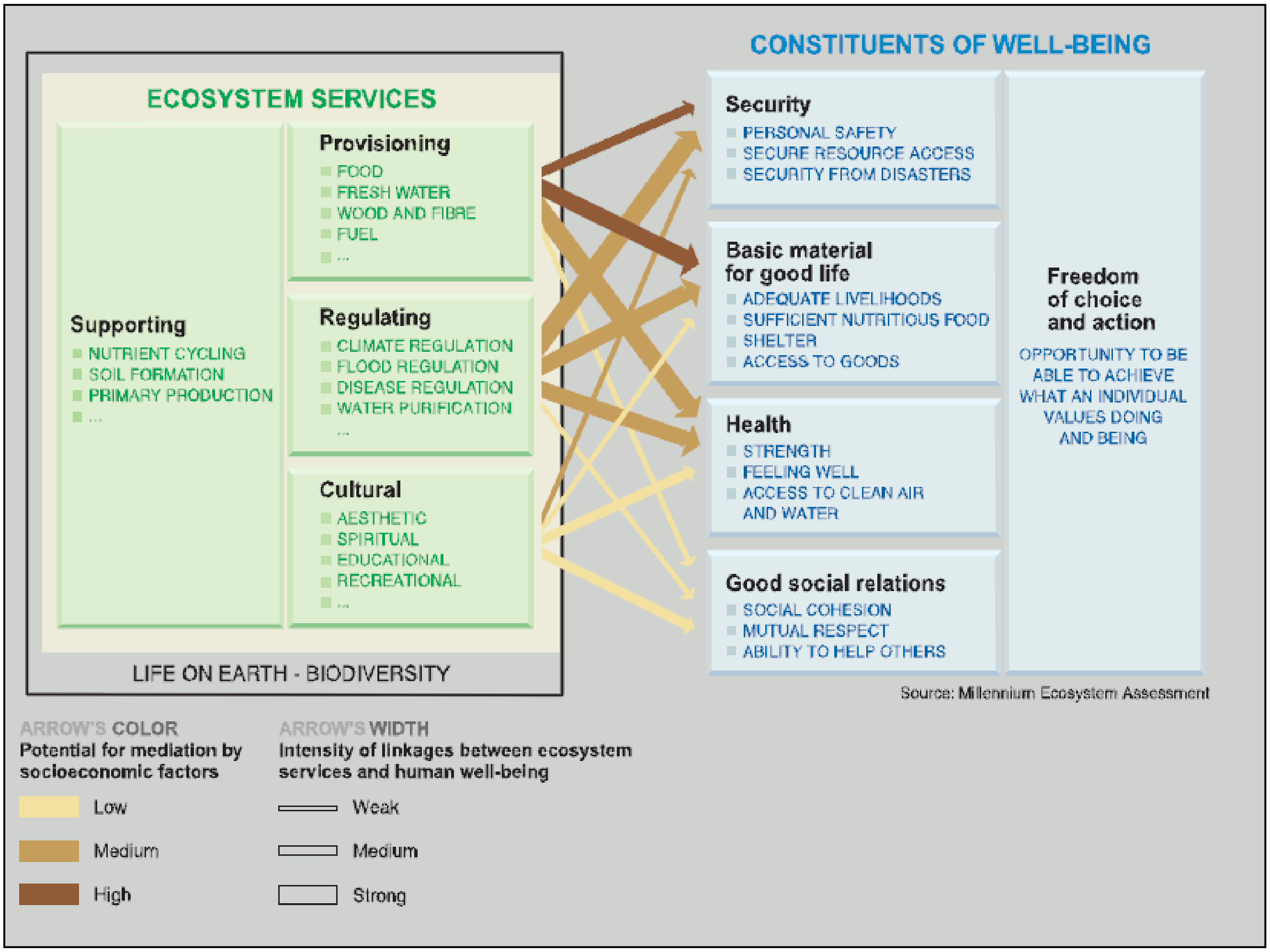
Human well-being, ecosystem services and watershed management in the Credit River Valley: Watershed Intervention Toolkits

This paper will provide a context for the three attached toolkits (I1-I3). In order to do so, it will broadly review the discussion surrounding human health and nature, it will introduce the concept of ecohealth and explain the core ideas driving the larger project. There will be a significant focus on the health & nature discussion as it relates to urban planning. This will include a discussion of the timeliness of ecohealth approaches for urban planning given the pressures of climate change. Finally, it will place the three toolkits within the context of a larger multi-year research project and then explain the specific models and frameworks that are being used to guide this project.

Introduction to the Project

This Major Project involves the research and creation of three intervention 'toolkits' that connect a direct conservation action (intervention) with the impacts that it will have upon human health and well-being. The connection is made through a targeted literature search that uses existing academic literature in order to 'connect-the-dots' between a planned intervention, a change in ecosystem function, and the effect it will have on human health. One of the key concepts used to connect ecosystem function to human well-being is that of 'ecosystem services'. The work of the Millennium Ecosystem Assessment (MEA) brought the concept to a large audience through a range of publications between 2001 and 2005. The simple and widely accepted definition of ecosystem services provided by MEA states that "ecosystem services are the benefits people obtain from ecosystems" (Millennium Ecosystem Assessment, 2005, p. v). The concept of ecosystem services has become a widely accepted tool used to describe functions occurring in a healthy natural ecosystem that provide a benefit for humans or human society. A commonly cited example of ecosystem services is the presence of natural bee populations that act as pollinators which help to sustain productive crop yields for human purposes (Kremen et al. 2007). There is a considerable wealth of research being produced on the concept of ecosystem services itself, and there are several different approaches to working with the concept. For this project, the framework and vocabulary used comes from the Millennium Ecosystem Assessment and their valuation of ecosystem services around the world. The prepared toolkits (see attached toolkits I1-I3) connecting interventions and human health impacts exclusively use the categories of ecosystem services defined by the MEA in order to provide consistent valuations that can be used for comparative purposes. The MEA report titled "Ecosystems and Human Well-Being: Health Synthesis" (Corvalan et al. 2005) has been the central reference used in the development of the framework for this project. The four categories of ecosystem services defined by MEA are (1) Supporting, (2) Provisioning, (3) Regulating, (4) Cultural. These four categories are then related to five constituents of human well-being which are defined as (1) Security, (2) Basic Material for Good Life, (3) Health, (4) Good Social Relations, (5) Freedom of Choice and Action (Corvalan et al. 2005, p. 15). The links between the ecosystem services and constituents of well being are shown in figure 1 on the following page.

Figure 1: Links Between Ecosystem Services and Human Well-Being



Source: Corvalan et al. 2005, p. 15

The toolkits are one segment of a larger project undertaken by researchers at York University and the Credit Valley Conservation Authority. The project is attempting to identify and communicate the connections between watershed ecosystems and human health, and then integrate them into decision making processes within the Conservation Authority.

The ultimate purpose of the project is to identify and communicate relationships between watershed health and human health and well-being to a number of different publics. In describing and analyzing the relationship between natural ecosystems and and human health, one quickly becomes aware of the vastness and profoundness of the impact of the natural world upon our daily lives. However, such relationships can easily go unperceived despite their overwhelming influence on every aspect of our daily lives. The project arose as part of a growing focus on the concept of 'ecohealth' both broadly in academia, environmental organizations and planning circles, as well as specifically within the Credit Valley Conservation Authority.

Human Health and Natural Ecosystems: Origins of the Discussion

Before beginning the specific research focused on human health and well-being in the Credit River Watershed, it was important to review the broad base of literature dealing with the relationships between ecosystems and human health. This section will review origins of the debate as well as several key pieces of research on the subject of human health and the natural environment. It will also point out newer research that deals specifically with this topic in the context of Southern Ontario and the GTA.

The idea that humans benefit from exposure to nature has a long history, part of which can be closely related to both the industrial revolution and the rapid expansion of cities that accompanied it. The development of steam power and industrialized methods of production meant that air quality and the health of the natural environment in cities deteriorated rapidly from the beginning of the 19^{th} century. The growing concentration of humans in cities led to dangerous levels of air pollution from coal fired heating while simultaneously putting tremendous strain upon cities' rudimentary sanitation infrastructure. The very idea of urban planning grew out of a need to mitigate public health concerns, a connection which is once again growing in importance:

> The squalid living conditions of industrialized cities in the middle of the 19th century that gave rise to both the urban planning and public health professions are again fully manifest at the beginning of the 21st century.
>
> Northridge et al., 2003, pp. 556-557

It was also a result of the poor conditions in 19th century industrial cities that urban settings came to be viewed as 'unhealthy' and 'unnatural' spaces, and the image of the city quickly became associated with darkened smoggy skies in popular western consciousness. This is starkly evident in the landscape paintings of romantic painters of 18th and 19th century England where scenes of the idyllic, pastoral English countryside are juxtaposed with dramatic, darkened scenes of industrial cities.

Dudley, Worcestershire by J.M.W. Turner[1]

[1] From: http://www.tate.org.uk/art/artworks/turner-dudley-worcestershire-tw0792

Bolton Abbey by J.M.W. Turner[2]

As can be seen from the two paintings by J.M.W. Turner above, the romanticization of the pastoral, ‘natural’ countryside and the vilification of the unhealthy urban environment began early with the growth of modern cities. Landscape paintings can be heavily imbued with the artists own political ideas and perceptions. In England, these landscape paintings were closely tied with political discussions about the changing image of the countryside, and the corresponding social and cultural changes that were being brought about by industrialization (Daniels, 1992). The vilification of the ‘unnatural’ urban environment is therefore rooted in an image of the 19th century industrial city. It is a simple and powerful caricature that has endured and become an engrained part of our thinking about cities; an unjust categorization that is often subconsciously internalized by our public discourse and rarely deconstructed or adequately critiqued.

[2] From: http://www.tate.org.uk/art/artworks/turner-bolton-abbey-yorkshire-tw0356

By cementing the association between the city and all of the public health issues caused by overcrowding and industrial pollution in the 19th century, the natural world came to be viewed as a remedy and an unquestionable source of human health and vitality. This thinking is what led many generations of urban planners to feel that they needed to 'solve the problem of cities'. The rapid, uncontrolled growth of cities in this time period created unhealthy urban environments, an association that would profoundly affect how urban planners view the triumvirate relationship between urban space, green space and human health and well-being.

One of the first important urban designers of the 19th century who was demonstrably influenced by the poor state of green space in urban environments was Frederic Law Olmsted. His designs for urban parks reflected a personal ontology that fundamentally understood the importance of green space for human wellness, but did not believe that green space needed to be divorced from the city. Olmsted's designs for urban parks reflected his belief that natural areas are of utmost importance in the life of a city, and that such green spaces can "assist citizens in cultivating a civic identity rooted in mutual reciprocity." (Kosnoski, 2011, p. 52) In this sense, Olmsted was beginning to identify the concept of 'co-benefits' between humans and nature that is so central to understanding ecosystem services. Olmsted's approach also stands in contrast to the romanticized belief that natural environments which provide human health benefits are only found outside the city. These broad ideas were expanded over many decades by influential urban theorists such as Patrick Geddes and Lewis Mumford who further defined the relationship between human health and the built environment (Munshi, 2000). However, it was not until the early 1980s that academics would publish studies demonstrating the quantifiable impacts of the natural environment on human health.

One of the first papers that really developed the discussion surrounding human health and the environment was published in 1984 by Roger Ulrich. Ulrich's study dealt with patients recovering from surgery. The research was able to demonstrate that patients in the same hospital, recovering from the same surgery, recovered at different rates depending on the view from their hospital room: patients in a room with a window that looked upon a natural setting recovered quicker than patients in a nearly identical room with a window that looked upon a brick building (Ulrich, 1984, p. 420). This was attributed to the notion that

> most natural views apparently elicit positive feelings, reduce fear in stressed subjects, hold interest, and may block or reduce stressful thoughts, they might also foster restoration from anxiety or stress
>
> Ulrich, 1984, p. 420

At the same time that Ulrich's study was able to quantitatively demonstrate the human health benefits of viewing nature, the discussion surrounding the relationship between human health and nature was being advanced by biologist Edward O. Wilson through his concept of biophilia. This is the notion that humans have an innate affection for other living things (Grinde and Patil, 2009, p. 2332). When combined with the stark lack of biodiversity in an urban environment, one begins to question how degraded ecosystems in highly urbanized settings can influence human health on an everyday level. Wilson's writings on the concept of biophilia were first published in 1984, and the association between environments with greater biodiversity and greater resilience/better health outcomes for humans has been generally accepted. In terms of urban design, Wilson's ideas and Ulrich's research have been unified by authors such as Timothy Beatley who speaks of 'biophilic design' (2011) as well as authors such as Rachel and Stephen Kaplan (1998) who published design guidelines to guide urban design with nature. There has clearly been a steady progression in the thinking about natural ecosystems in cities to the point where academic publications are able to provide applied guidelines as to how to integrate natural ecosystems and design them into urban settings.

Gaps in the Literature

Despite the substantial evolution in the debate around nature and health, there remains a distinct lack of empirical research associating biodiverse ecosystems with improvements in human health and well-being. Instead, research on human health and the natural environment has tended to focus on easily quantifiable environmental variables (e.g. air quality, urban heat) and use them as a proxy to indicate the consequences of ecosystem degradation on human health. A common thread within the current literature on human health and natural environments is the emphasis on problems caused by environmental degradation. It is simpler to look for the health impacts of environmental degradation as opposed to searching for positive associations between healthy ecosystems and humans. For example, it is far more straightforward to seek correlations between poor air quality and respiratory illness than it is to measure improved family cohesion as a result of living near parks.

In Toronto, the most significant current research dealing with health & environment has come in the form of two systematic literature reviews published by the David Suzuki Foundation and Toronto Public Health, one looking at urban heat and air quality and the other dealing with the parks. The former review was able to aggregate research in order to demonstrate the physical processes by which vegetation in cities reduces levels of air pollutants and decreases the ambient air temperature. It then brought up literature demonstrating how both air pollution and high temperatures contribute to poor human health outcomes. Nonetheless, the literature review noted that “few studies directly associate observed pollution or heat mitigation from green space with direct health impacts" (David Suziki Foundation, 2015, p. 45). Once again, it is a *direct* cause-effect link from green space to positive health outcomes that is difficult to demonstrate.

The second literature review prepared by the Toronto Public Health department deals with parks and is also quite significant in the context of urban planning in the Greater Toronto Area. It is most notable because its findings were acknowledge by the Toronto Board of Health as well as Toronto City Council. The report is also commendable for trying to uncover a link between several variables that have traditionally been difficult to define and work with such as "levels of social interaction and cohesion" as well as "cognitive restoration" (Toronto Public Health, 2015, p. 9). The review of existing studies found that the majority of research on the topic finds a positive correlation between the presence of green space and the health variables that the review defined. It seems that to date it has been possible to uncover virtually limitless positive correlations without have a clear understanding as to the underlying mechanisms that drive these correlations. A unique piece of research that did attempt explicitly to discover the mechanism by which nature improves health was described in a recent article by Ming Kuo (2015). Kuo suggests several 'potential pathways' through which exposure to diverse natural ecosystems could positively impact human physiology but cannot offer a definitive theory.

Finally, a very popular approach has been found in research that has tried to quantify the health benefits of green space in monetary terms. Not surprisingly, this angle has received a lot of attention from large publications and a great deal of discussion has been generated outside of academic circles. For example, a report from TD Bank came up with the statistic that Toronto's urban forest provides "over $80 million … worth of environmental benefits and cost savings each year" (TD Bank, 2014). The temptation to quantify the benefits of green space in monetary terms is significant, as it allows decision makers the ability to easily compare different actions using a universal metric that is very familiar to them. Nonetheless, quantifying the health benefits of green space in monetary terms risks oversimplifying the relationship between humans and natural ecosystems; economic metrics cannot accurately portray the variety of experiences and relationships nor can they take into account the preferences of one community over another. In order to drive significant policy changes and investments from the public and private sectors, the academic community needs to advance beyond the idea that this relationship is “reasonably well substantiated” (Grinde and Patil, 2009, p. 2338) and be able to definitively demonstrate the direct and immediate positive impacts of green space upon human health and well-being. This is a challenge that was noted acutely throughout the CVC Watershed Well-Being Project.

Ecohealth and Urban Planning in the Context of Climate Change

The practice of urban planning is a highly political pursuit where proposals for interventions are often judged upon their capacity to create an immediate, demonstrable impact. This project seeks to temper the political character of urban planning by applying ideas of ecohealth research. The idea of ecohealth can also be referred to as ‘ecosystem approaches to health’, and it is interested in understanding human health by looking at the ecosystems with which humans interact. Within the field of ecohealth research, there is a growing body of work that succeeds in demonstrating direct links between ecosystem health and human health in terms of relatively straightforward cause-effect relationships. For example, it has been shown that. changes in forestry and housing practices in certain villages in Guatemala have lead to decreased disease vectors (Monroy et al., 2012, p. 154). However, many issues that could benefit from an ecohealth perspective do not lend themselves to being described or analyzed as a straightforward case of cause = effect. Using an ecohealth lens to explore the relationship between cities and climate change would be unlikely to uncover many immediate and direct associations that would be sufficiently convincing to advance specific planning interventions in the face of short-term thinking decision-makers. Adopting an ecohealth lens is difficult in the context of climate change even though the effects of extreme weather (e.g. increased flooding in cities, severe droughts in farming regions) can potentially be linked to large scale changes in the global climate. The causes of climate change, and therefore the causes of these extreme weather events, are so broad and so diffuse as to make it challenging to draw a direct line that links ecosystem degradation to human health problems brought about by climate change.

Climate change will undoubtedly have significant and far-reaching consequences for human health and well-being, and there is a need to adapt current models of ecohealth research and inquiry in order to uncover and better describe these relationships. In this sense, the health-ecosystem relationship being described (healthy future populations, resilient cities, decreased rates of atmospheric warming) is linked using several loosely connected layers. Nonetheless, there is broad consensus that climate change will affect human health and well-being, and that practical interventions are urgently needed in order to develop cities that are more resilient to climate change.

When this knowledge is applied to the field of urban planning, it means that many interventions will need to be planned and undertaken not because of their immediate or direct consequences upon human health and well-being, but rather because of their capacity (present or future) to mitigate the negative impacts of climate change in urban areas. On one end of the scale, urban planning interventions such as building complete streets that encourage active transportation and reduce motor vehicle use can seek to address the root causes of climate change. This approach could create an urban environment where fewer people rely on gasoline fuelled transportation. If successful, such an intervention would reduce greenhouse gas emissions, thus reducing the greenhouse effect and improving human health and well-being by reducing the chances of climate change-related disasters and the associated health problems. However, the intervention itself is removed from the potential beneficial consequences by several steps that need to be understood conceptually. This makes it difficult to explain in a political setting that insists on direct, immediate and quantifiable impacts.

Alternately, future climate change-ecohealth research could focus on interventions that assume the arrival of climate-change driven natural disasters and seek to minimize the negative health impacts when such a disaster does occur. The creation of wetlands is one example of an intervention that can greatly reduce the risk of flooding during heavy rain events and mitigate the damage caused by floods. Wetlands are notable because they also increase an ecosystem's capacity to store carbon and therefore function mitigate the greenhouse effect as well. Once again, the challenge that was continually encountered over the course of the Credit River Watershed project was the difficulty in demonstrating an immediate or concrete connection between an intervention (e.g. the development of a wetland) and the positive benefits that would be potentially accrued down the road in a different place and time (e.g. climate change mitigation). Thinking about ecohealth on a very broad spatial and temporal scale allows one to conceptualize these interventions within the context of climate change, and allows one to understand the health benefits that are derived from mitigating the effects of climate change through a range of different policy options. All three of these examples are part of the same system that links human health with urban settings and the global climate. An ecohealth approach enables one to simultaneously explore individual components of the system (in both space and time), while not losing sight of the system as a whole. Individually, policy makers and conservation authorities are required to evaluate very different components of the system that range in time from the present to a distant and hypothetical future.

The Watershed Well-Being Project in Practice: The Role of the Credit Valley Conservation Authority

The Credit Valley Conservation Authority (CVC) is a large and far-reaching organization with a very broad mandate to protect and maintain the health of the Credit River Watershed. This includes working to preserve all of the natural heritage within the Credit River Watershed but it also includes working with urban planners in the region to ensure that development proceeds in a way that does not compromise natural ecologies. From the perspective of the Credit Valley Conservation Authority, the over-arching goal of this project is to develop a culture that recognizes connections between human health and ecosystem health within the organization. One of the primary ways to achieve this goal was the creation of a decision-making tool that weighs human-health implications of various interventions upon the landscape. This decision making tool will use non-monetary valuations to allow decision makers to compare the potential health benefits that will accrue from their various actions. One of the end goals is for the teams of ecologists, biologists and planners at CVC to become very cognizant of the human health implications of their work.

CVC, like most conservation authorities in the province, devotes a vast amount of resources towards collecting biophysical data to describe the ecosystems in which they are working. For example, CVC manages an extensive network of real-time water quality monitoring stations throughout the Credit River watershed. The data gathered is focused exclusively on biophysical parameters such as water pH, turbidity, temperature and conductivity (Credit Valley Conservation, 2016). Having such an extensive network of real-time monitoring equipment means that staff at CVC are able to accurately evaluate the impacts of human activities upon the Credit River. However, the reverse is not possible: the conservation authority is not able to detect and evaluate how changes in the Credit River affect the human population who live within the watershed.

This project is essentially proposing to broaden the entire scope of CVC's work. Noting that the Credit River watershed is highly urbanized and home to nearly 800,000 human inhabitants (Credit Valley Conservation, 2012), and recognizing that the health of humans within the watershed is affected by the natural ecosystems within the watershed, it is important to measure and consider how changes made to the natural environment will affect not only natural ecosystems but also human health and well-being. These changes to the natural ecosystem can be as widely varied as the work of the conservation authority itself. They can include large scale land use changes, zoning amendments, new developments or local restoration projects, wetland rehabilitation initiatives, wildlife protection schemes, etc. They can be undertaken by the conservation authority itself, private landowners, provincial and municipal governments and corporations. They can be as simple as a change in practice. Nonetheless, any actions and interventions within this broad range can have an impact upon the ecological systems within the watershed, and therefore can have an impact upon all of the human inhabitants living in the area. Ultimately, the relationship between natural ecosystems and humans runs in two directions, and projects undertaken by the conservation authority should be designed and selected with a full recognition of this two-way relationship.

It is the goal of this project to ultimately enumerate all of the possible green space interventions that could be undertaken by the CVC, and to link them with health benefits using the framework and language of the Millennium Ecosystem Services Health Synthesis (Corvalan et al. 2005). Once this research piece has been completed, it will be possible to develop tools for comparison in order to help decision makers at CVC to select interventions based on both human health outcomes and ecosystem improvements.

Challenge of Selecting Time Scale and Geographic Scale For Research

As mentioned above, a major challenge has been finding *direct* relationships between certain aspects of the natural world and human health. While many papers have dealt broadly with this subject, there is a dearth of research that has been able to succinctly demonstrate the causal pathway through which this link is created. Without the presence of a clear and direct connection present in one point in space and time, the research team was often challenged to determine the geographic scale at which each of the interventions would take place, as well as the time scale of the intervention and the proposed impact upon human health. This meant that any theoretical intervention could have an overwhelming number of health impacts if the scale was broad enough, or very little impact if the intervention was to be undertaken in a different area, and results were to be expected immediately. Ultimately, the goal of 'creating the link between green space and human health' is several orders of magnitude too broad to be useful for research purposes. The interaction between natural ecosystems (however one chooses to define the term) and human health is so multi-layered and multi-faceted that specific cases must be identified before effects can be usefully examined.

Future Challenges

The difficulty that our research team had in demonstrating the direct health impacts of various ecosystem changes will no doubt be felt in the remainder of the project. Many of the impacts upon human health had to be assumed and explained using general understandings of ecosystem function. For example, when researching the impacts of changing agricultural practices regarding fertilizer application (Toolkit I1: Nutrient Management Plans), the impacts upon the ecosystem were immediately understood. This primarily involved less nitrogen being leached into the groundwater and washed off into surface water. Moreover, impacts such as these can quickly and easily be measured using CVC's existing network of water monitoring stations. Once implemented, it will be very straightforward to view the impacts that the intervention has had upon the landscape.

However, the impacts on human health take place several steps down the chain and in a much more dispersed and diffuse manner. It is challenging to directly show how increased levels of nitrogen in water have a direct impact upon human health, especially in the context of a highly developed area where drinking water is thoroughly filtered, monitored and controlled before coming out of the taps of local residents. One option would be to adopt a tertiary approach, explaining that less nitrogen in the water supply places less strain upon municipal water treatment systems. It could then be argued that this reduces water treatment costs for the municipality and that the benefit is derived from cost savings. However, the vocabulary of the Millennium Ecosystem Services Assessment Health Synthesis does not provide a convenient category to describe the benefits derived from cost savings as a result of ecosystem services. One could argue that money saved by a municipality can then be put towards other social goods that produce a healthier society, but this argument is based on so many assumptions as to render it unusable. The challenge of translating cost-savings into a human health benefit came up very frequently in the research on interventions.

Shortcomings of Millennium Ecosystem Services Framework

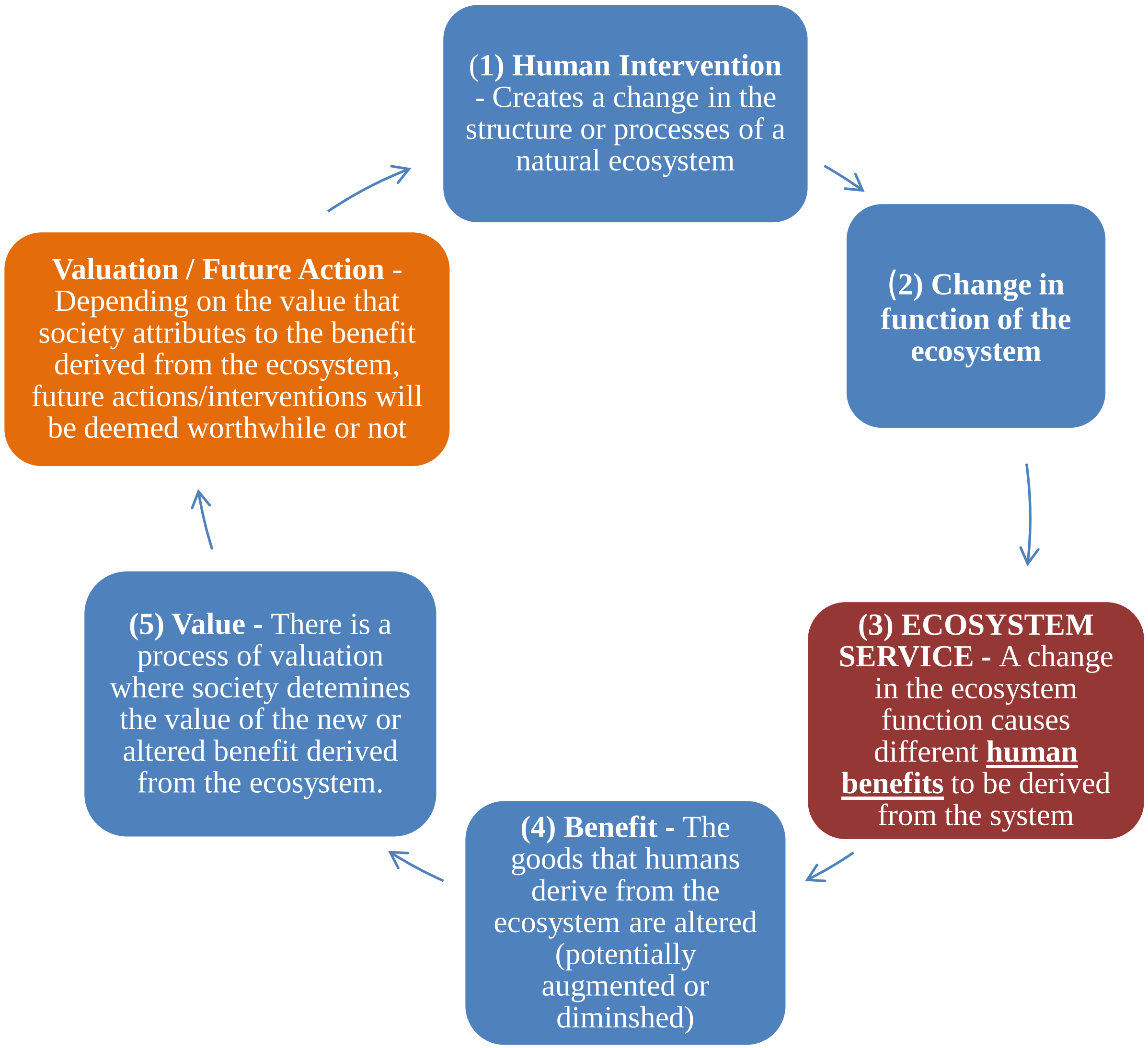
One of the greatest challenges of the project was working within the limitations imposed by the vocabulary and structure of the Millennium Ecosystem Services framework. This framework was chosen because it was a very well-known document that had been successfully used to communicate the value of green space to human life. The very idea of ecosystem services has proven to be a valuable and operational tool when trying to demonstrate the invisible goods provided by natural ecosystems, the inextricable linkages with human life, and the staggering extent to which human society and human health depend on the presence of healthy natural ecosystems to provide these goods and services. However, throughout the course of the research, it became evident that the language and categories of ecosystem services were too broad to work effectively with the site-specific interventions proposed by Credit Valley Conservation. The MEA framework is a global document and the categorization of interventions was intended to simultaneously be simple and broad enough to work across different geographical regions and socioeconomic realities. Within the MEA framework, there was an attempt to categorize five constituents of human well-being that could be linked to different categories of ecosystem services. The well-being constituent labelled as "freedom of choice and action" (Corvalan et al., 2005, p. 50) was deemed to be so broad as to render in unwieldy when applied to the work of CVC. Moreover, much of the work of CVC is so focused as to only touch on very specific ecosystems and ecosystem functions. It is challenging, but not impossible, to relate the work of CVC in terms of broad categories of the constituents of well-being such as the provisioning of shelter and secure resource access. Similarly, categories such as "access to clean air and water" (Corvalan et al., 2005, p. 50) are difficult to relate to the work of CVC because, on a practical level, there is an entire system of infrastructure being operated to ensure clean water that is independent from the work of CVC. It is very important to ensure the presence of a healthy ecosystem because it does provide services related to filtering groundwater and ensuring clean surface water, but in an urban area such as Mississauga, the human-built infrastructure is so developed as to almost supersede the ecosystem services. At best, our team was able to say that services such as water filtration provided by wetlands are able to reduce the strain upon man-made water filtration infrastructure. This is a weak connection that does not adequately communicate the importance of these ecosystem services for our society. It will be necessary to build an argument based on the imperative to keep access to clean water for recreation such as fishing and swimming. Access to clean water for recreation plays a large role in public perceptions of the environment. The challenge will be to develop such an argument for recreational benefits that can be incorporated into the CVC decision making tool in a way that will weigh it significantly against the more direct biophysical parameters. It is the disconnect between the very broad scale, global, theoretical thinking of the MEA framework, and the very site specific, applied approaches of CVC where the restrictions of using the MEA framework language were most evident.

Benefits of Cascade Model of Ecosystem Services

One of the most useful and straightforward tools used in this research project was the Cascade Model of Ecosystem Services (Haines-Young & Potschin, 2010). While the concept of ecosystem series is quite simple, it can be difficult to explain in a way that makes it a useful communication tool. The lynchpin to understanding ecosystem services is the idea that it is an anthropocentric concept and that ecosystem function and ecosystem service are not the same concept. The cascade model clearly allows one to visualize the flow of changes from an intervention that creates a (1) <u>change in structure or process</u>, that leads to a (2) <u>change in the function of the ecosystem</u>, that ultimately affects the (3) <u>the provision of the ecosystem service</u>. In this model, the provision of the ecosystem service (a service for human populations and not for the ecosystem itself) is affected by the change in ecosystem function that results from an intervention. Once again, the ecosystem service connects the functions of the natural world and the needs of humans. In the second half of the cascade model, one can visualize the flows from the ecosystem service to (4) the benefit derived by society and ultimately (5) the value placed upon that benefit by the society that receives it. This model is visualized on the next page. It is even possible to close the loop proposed by the cascade model of ecosystem services by connecting stage 5 and stage 1. In this sense, human society undertakes a valuation of the benefits derived from the change in ecosystem services (5), then decides whether or not a future intervention or change in structure and process will take place (1). In essence, the decision making tool being created by the teams at York University and CVC is attempting to close this loop and use a valuation exercise to determine the need for future interventions that change ecosystem function. The cascade model was a key tool that was used in the preparation of the three toolkits. The co-benefits charts included in each toolkit are derived directly from this model.

The three intervention toolkits that follow are part of a larger set created in 2015-2016 by a group of students in the Faculty of Environmental Studies at York University. All of the toolkits use a common template which identifies key fields relating to each intervention. Most notably, co-benefits to humans and ecosystems were the focus of the research. These are specifically identified in a matrix based upon the cascade model of ecosystem services that shows the progression from an intervention causing a change in the ecosystem to a benefit for human society.

Visualization of Cascade Model of Ecosystem Services



From Haines-Young & Potschin 2010, with help in adaptation from Alvaro Palazuelos

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Toolkit I1: Nutrient Management Plans

Overview

1. *Description*

Adopting best/beneficial management practices (BMPs) regarding fertilizer handling and storage involves soil testing for existing nutrients, carefully choosing when and where to apply fertilizers, and adopting practices such as fertilizer injection in order to minimize the volume of fertilizer used. A Nutrient Management Plan (NMP) is an document prepared by the operator of a farm that identifies where fertilizer is needed or unneeded, and "outlines nutrient application in farm fields, crop rotation … and other management approaches to optimize the utilization of nutrients by the crops" (OMAFRA, 2016). Two other comparable instruments are known as Non-Agricultural Source Material Plans (NASM) and Nutrient Management Strategies (NMS). The former is similar to an NMP but it deals with the management of a wider range of nutrient sources that might be applied to a farm field, for example sewage biosolids or food processing washwater (OMAFRA, 2016).

2. *Key issues faced by the watershed that can be mitigated through this intervention*

Poor practices regarding the application of nitrogen-rich fertilizers to crops cause (a) water quality issues, (b) soil quality issues and (c) air quality issues in the watershed.

(a) Poor practices regarding fertilizer application, handling and storage can cause excess amounts of nitrates, phosphates and other nutrients to infiltrate groundwater and surface water. High levels of nitrogen accelerate the process of eutrophication in waterways.

Eutrophication directly affects water quality but also has secondary effects which are detrimental to human health such as "noxious algal blooms (including some toxic ones), decreased water clarity, and low dissolved oxygen." (Rabalais 2002, p. 106)

Phosphorus is the key nutrient that drives the process of eutrophication in fresh water systems. (Rabalais 2002)

As the urban area expands northward in the Credit River watershed, more and more people will rely upon groundwater as their source of drinking water. This is already the case in the northern, rural areas of the watershed. The growing rate of urbanization in this area combined with groundwater pollution is particularly concerning because fertilizer chemicals that enter groundwater can remain there for many years before reaching a well. This means that the effects of poor fertilizer management practices will linger far into the future.

Surface water can also become acidified when there is too much nitrogen present in an ecosystem. Health effects include the "direct mortality of acid-sensitive fish from acidic waters" and enhanced mercury accumulation in fish, which directly impacts humans who consume the fish. Ultimately, surface water acidification, driven by the presence of excess nitrogen will result in a "decrease in the survival, size and density of fish and in the loss of fish and other aquatic biota from lakes and streams." (Rabalais 2002, 106)

(b) Excess amounts of nitrogen in the soil will cause acidification of the soil over time as the nitrogen gets nitrified into nitrous acid (HNO_2) and nitric acid (HNO_3).

Excess nitrogen gets absorbed into the air when ammonia (NH_3) is applied to farm fields as fertilizer. The dispersal and deposition of this excess atmospheric nitrogen affects the functioning of a variety of ecosystems. In temperate forests it "can lead to increased productivity but loss of biodiversity." (Rabalais, 2002, p. 106)

(c) Nitric acid (HNO_3) is a major cause of acid rain. When ammonia (NH_3) is used as a fertilizer, excess nitrogen gets emitted into the atmosphere. This nitrogen forms nitrites (NO_2^-) and nitrates (NO_3^-) and combines with Hydrogen to form Nitric acid.

(d) Moreover, excessive levels of these chemicals in drinking water will cause adverse health effects for humans. "NO_3 in water is toxic [to humans] at high concentrations" (Carpenter, 1998, p. 562).

3. *Policy Context*

The storage and handling of fertilizer in Ontario is currently regulated by the *Nutrient Management Act, 2002* and the corresponding set of regulations (O. Reg 267/03). In situations where the application and management of fertilizer poses a threat to drinking water sources, the *Clean Water Act*, *2006* contains policies that must be adhered to. There exist regulations governing the control and application of fertilizer in Intake Protection Zones (IPZs) as well as Wellhead Protection Areas (WHPAs).

Policies can also be designed to better reflect the environmental costs of large-scale applications of fertilizer, particularly in order to create disincentives.

There are already several regulations that require farms of a certain size to prepare NMPs. These revolve primarily around the size of the farm, which is measured using a common scale of "Nutrient Units" (NU). Farms below a certain threshold can choose to develop a NMP, and it is often in their economic interest to do so.

Criteria for both Nutrient Management Strategy & Nutrient Management Plans

NMS = mainly dealing with livestock and their manure

NMP = crop rotation & nutrient application to farm fields

It is *obligatory*, under the Nutrient Management Act, 2002, to develop a Nutrient Management Strategy (NMS) if:

- Farms that are already ≥ 300 nutrient units (NU) or plan on increasing to ≥ 300 NU
- Operations occur on land located within 100m of a municipal well
- The property owner wishes to build new livestock housing and/or a manure storage facility (a NMS must be in place before the building permit can be issued)
- If there is a change in ownership or control of a farm operation that had a previously approved NMS, but the change will affect the capacity to implement the existing NMS
- Farms that receive off farm material (e.g. commercial food processing by-products), that are used in an anaerobic digester (AD).
- A farm unit that will house ≥ 5 NU in new livestock

These farms are "phased in" to nutrient management legislation.

The primary criteria for deciding whether or not a NMS should be implemented depend on the size/expansion plans for the farm.

Source: Nutrient Management Act, 2002.

The design criteria for the implementation of a nutrient management plan are listed in the chart below:

SUITABILITY CRITERIA TO CONSIDER
Proximity to municipal well
Agricultural operations within 100m of a municipal well

Agricultural operations within an intake protection zone (IPZ)
Proximity to field tiles
Proximity to surface water
Presence of On-Site anaerobic digester (AD)
Soil permeability
Size of farm in nutrient units (NU) – Categories Defined By NMA, 2002
≥ 300 NU
150 ≤ NU < 300
5 ≤ NU < 150
≤ 5 NU
Height of water table
Soil chemistry (existing levels of nutrients present in the soil)

4. Main Stakeholders Involved

Federal Government (Agriculture and Agri-Food Canada)

Provincial Government (Agriculture, Food and Rural Affairs)

Upper and lower tier municipalities

Conservation Authorities

Drinking Water Source Protection Authorities

Farming Industry

Horticultural Industry

Fertilizer Industry

- Manufacturers
- Wholesalers
- Retailer

Co-Benefits: Achieving a double dividend

Common issues that can be addressed through the adoption of Nutrient Management Plans (NMPs)

Reduce the threat of toxic algal blooms that are stimulated by excessive Potassium. (Carpenter, 1998, p. 362). This is a phenomenon that occurs when excessive amounts of nutrients are applied to agricultural fields, or applied in a manner that causes them to run off before being adequately absorbed by the plant matter.

Reduce the amount of NO_3 in water which is toxic to humans at high concentrations. (Carpenter, 1998, p. 362) thus reducing strain on municipal water filtration systems and ensuring access to clean, healthy water bodies for recreation such as swimming and fishing.

Prevents and reverses processes of eutrophication which directly affect humans because of:

Decreases in water transparency
Decreases in the perceived aesthetic value of water bodies
Taste, odour and water treatment problems
Reductions in harvestable fish and shellfish

(Carpenter, 1998, p. 561)

Run-off from farm fields can be caused by excessive use of fertilizer, heavy rainfall, wind conditions or overwatering. It ultimately leads to “nutrient enrichment that encourages the growth of toxic algal species.” (Faber, 2012, p.3)

Nutrient loading and algal blooms affecting healthy food supply

In British Columbia algal blooms pose a major public health concern in the form of paralytic shellfish poisoning (PSP). PSP is caused by the ingestion of the neurotoxin 'saxitoxin' which is naturally produced by certain algae and plankton. Excess nitrogen in marine environments causes a massive proliferation of these harmful algae. These events are known as "red tides" or Harmful Algal Blooms (HAB) (Farber, 2012, p. 3). Filter feeders such as clams and oysters concentrate this toxin which is then passed along to humans when the shellfish are consumed.

The Department of Fisheries and Oceans in Canada often prohibits the commercial and recreational harvesting of certain species of shellfish when it records high levels of toxins present in the shellfish caused by red tide. These reports are updated daily for the entire BC coast (DFO, 2012). Moreover, it is estimated that US shellfish fisheries on the Pacific Coast can lose $6 million from one PSP outbreak (Faber, 2012, p. 4-5).

Capacity of Agricultural fields

When developing strategies to reduce fertilizer use, one considerable advantage to human health and ecosystem health is the increased capacity for the farmland and surrounding ecosystem to metabolize its own nutrients. With proper timing of nutrient application and in proper quantities, any nutrients that do not get utilized by the plants on the farm will be absorbed and metabolized by surrounding marshes and wetlands. One common mistake that prevents this action is the application of nutrients too late in the growing season, which does not allow them adequate time to be absorbed before the fields freeze for the winter. These excess nutrients then get washed away into waterways with the spring thaw (from discussions with agricultural experts at CVC).

Co-Benefits: Cascade Framework Chart

Structural and/or Landscape Change		Ecosystem Function Affected	Ecosystem Service(s) Affected	Final Benefit	Well-Being Domain
Before	After				
Fertilizer applied routinely, regardless of soil conditions or existing nutrients in the soil. Large volumes of chemical fertilizer indiscriminately applied to agricultural fields	**Nutrient Management Plans Developed -** Lesser volumes of chemical fertilizers applied to agricultural soils at controlled times depending on weather and soil conditions	Nutrient Cycling – Smaller volumes of nutrients (Nitrogen, Phosphorous) cycling through the ecosystem. Does not overload the existing ecosystem with synthetic nitrogen	a. Water Storage and Regulation **(Regulating)** b. Water Filtration **(Regulating)** c. Food **(Provisioning)**	More secure access to clean water Reduces strain upon water filtration systems Reduces excess nitrogen entering the water system leading to eutrophication	Health Basic material for good life

Structural and/or Landscape Change		Ecosystem Function Affected	Ecosystem Service(s) Affected	Final Benefit	Well-Being Domain
Before	After				
Unused agricultural fields are still maintained and managed for aesthetic purposes or for potential future cultivation (e.g. mowed and/or ploughed but not planted)	**Natural Area Enhancement and Creation** – Strips of uncultivated land adjacent to active agricultural fields are deliberately managed to convert them into protected naturalized areas and conservation lands **Increased Biodiversity** – Greater variety of flora and fauna active close to agricultural operations	**Habitat** – More opportunities for bird and mammal habitats Naturalized areas can become refuges for native plants and pollinators	Food **(Provisioning)**	Pollination – More wild pollinators in the ecosystem leads to greater crop yields with fewer managed human inputs	Basic Material for good life

Structural and/or Landscape Change		Ecosystem Function Affected	Ecosystem Service(s) Affected	Final Benefit	Well-Being Domain
Before	After				
Horticultural Operations Nutrient-rich leached feedwater is mixed with other wastewater, released into municipal sewers, discharged into septic systems or disposed directly into surface water.	Feedwater is stored on-site after use. Excess sediments, nutrients and pathogens are removed through a combination of buffer strips, grassed waterways and/or constructed wetlands. The nutrient-rich leached feedwater is captured after use in greenhouse operations and applied to croplands	Nutrient cycling Nutrient absorption	a. Water Storage and Regulation **(Regulating)** b. Water Filtration **(Regulating)**	More secure access to clean water Reduces strain upon water filtration systems	Health Basic material for good life
Golf course users expect the playing field to be green and intensively maintained regardless of climatic	Education programs promote play on naturalized courses.	Water Cycling	Water storage and regulation **(regulating)**	More secure access to clean water Reduces strain upon	Health

Structural and/or Landscape Change		Ecosystem Function Affected	Ecosystem Service(s) Affected	Final Benefit	Well-Being Domain
Before	After				
conditions. This is achieved through liberal application of chemical fertilizers and the installation of "wall-to-wall sophisticated irrigation". (Graves and Cornish, 1998, p. 21)	Reduce the intensity of irrigation and allow the turf to dry out when there is less rainfall. Golfers get used to the feel of playing on harder dirt courses as opposed to soft, well irrigated turf.			water filtration systems	

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Toolkit I2: Wetland Plantings

Overview

1. *Description*

   Wetlands are tremendous sources of life and biodiversity. Moreover, they play a significant role in regulating water levels, filtering water and absorbing water from large rainfall events. This role has been ignored for decades in traditional city building approaches. Historically, marshes have been seen as sources of insects and of little aesthetic value to a city. Toronto has dredged countless hectares of marshland in order to build entire neighbourhoods and beaches in areas that were once productive, thriving marshes.

2. *Key Issues Faced By The Watershed That Can Be Addressed Through Constructed Wetlands*

   Peel region is the main urban jurisdiction within the Credit River Watershed. It is experiencing rapid urban growth into areas that were previously forested or agricultural. As a result, porous lands are being paved over and replaced by impervious surfaces. Pervious surfaces provide many regulating ecosystem services that mitigate the impact of heavy rainfall events. In order to replicate some of the ecosystem services that have previously been lost, engineered wetlands and recreated wetlands are an important, albeit cost prohibitive, approach to improving the health of the local watershed ecosystem. This can include small projects such as bioswales, which simultaneously prevent excess storm water run-off into local waterways as well as reproducing some of the ecosystem services provided by wetlands (water filtration, evapotranspiration, etc). In addition to focusing on recreating riparian landscapes and their corresponding ecosystem services through natural approaches (e.g. planting) and engineered appraoches (bioswales, green roofs), it is important to focus on interventions that will improve the tree canopy cover and the urban forest in the Credit Valley. Trees will be able to stem stream-bank erosion as well as contribute to evapotranspiration and cool road surfaces that would otherwise emit heat and worsen the urban heat island effect.

3. *Policy Recommendations that Encourage Wetland Creation*

The most important drivers of wetland creation policies are the 26 conservation authorities in Ontario. In Southern Ontario, the two largest and most influential conservation authorities are the Toronto and Region Conservation Authority (TRCA) as well as CVC. Both of these organizations have published visions that encourage the creation of more wetland areas in the province. It will be on a case-by-case basis that the larger governmental authorities will be persuaded to protect greater areas for marshland.

4. *Main Stakeholders Involved*

Provincial Government

Landowners

Conservation Authorities

Environmental NGOs

Co-benefits: Achieving a Double Dividend

One of the primary benefits to human health from a greater area of wetland habitat will come in the form of improved flood resistance of human settlements. Another key will be improved groundwater quality. As mentioned above, the upper reaches of the Credit River Watershed already rely upon groundwater as their primary source of drinking water. This primarily includes sparsely populated agricultural zones, but it does include the large population centre of Orangeville. The recent provincial efforts to create a regime of groundwater protection through the Clean Water Act, 2006, and the subsequently developed source protection plans, speak directly to the need to use natural ecosystems to protect groundwater sources. The CTC Region (Credit River, Toronto, Central Lake Ontario) has developed a source protection plan that heavily flags water quality around Orangeville as a major concern. This is witnessed in the charts below:

Table 1: Permitted Water Uses in the Credit River Watershed
Source: Credit Valley Conservation Authority, 2007

Number of Permitted Users in the Credit River Watershed (Fall, 2006)

PTTW Category	PTTW Purpose	Total Number of Permits	Groundwater	Surface Water	Both
Agricultural	Market Gardens / Flowers	1		1	
Agricultural	Nursery	3		2	1
Agricultural	Other - Agricultural	1	1		
Commercial	Aquaculture	1	1		
Commercial	Bottled Water	5	5		
Commercial	Golf Course Irrigation	13	2	10	1
Commercial	Other - Commercial	1	1		
Commercial	Snowmaking	2		1	1
Construction	Other - Construction	1		1	
Dewatering	Construction	5	5		
Dewatering	Other - Dewatering	2	2		
Dewatering	Pits and Quarries	2	2		
Industrial	Aggregate Washing	11	10		1
Industrial	Other - Industrial	2	2		
Institutional	Schools	1	1		
Miscellaneous	Heat Pumps	1	1		
Miscellaneous	Pumping Test	16	16		
Miscellaneous	Wildlife Conservation	3		3	
Remediation	Groundwater	3	3		
Remediation	Other - Remediation	2	1	1	
Water Supply	Communal	2	2		
Water Supply	Municipal	24	24		
Water Supply	Other - Water Supply	1	1		
	Total	**103**	**80**	**19**	**4**

Table 2: Known Agricultural Water Uses in Credit River Watershed
Source: Credit Valley Conservation Authority, 2007

Summary of Known Agricultural Water Uses

Database	Category	Number
Water Well Record	Livestock	484
Water Well Record	Irrigation	86
Permit to Take Water	Market Gardens / Flowers	1
Permit to Take Water	Nursery	3
Permit to Take Water	Other – Agriculture	1

Table 3: Identified Groundwater Quality Issues in Credit River Watershed
Source: Credit Valley Conservation Authority, 2007

Summary of Identified Groundwater Quality Issues

Issue	Location	Identification Source	Description
Nitrate	West Orangeville	Raw Water Quality Data	Although nitrate concentrations have not risen above the regulatory limit (10 mg/L in groundwater), concentrations in several wells show a gradual upwards trend.
Chloride	West Orangeville	Raw Water Quality Data	Chloride concentrations within several wells have increased with a sharp trend since 1999, and the trend appears to be continuing.
Sodium	West Orangeville	Raw Water Quality Data	Sodium concentrations within several wells have increased with a sharp trend since 1999, and the trend appears to be continuing.
Nitrate	Acton	Raw Water Quality Data	Nitrate concentrations at Davidson wells have shown a significant upwards trend since 1995, but have remained steady over the past 5 years. Further monitoring may be warranted to better understand chemistry in recharge areas to predict longer term impacts and the potential for adversely affecting the sustainability of the water supply.
Nitrate	Alton	Raw Water Quality Data	Although there is no upwards trend in Alton wells 3 and 4, there is a potential for nitrate impacts to those wells, particularly given the fact that wells 1 and 2 were taken off line due to nitrate impacts. Further work is warranted to better understand the potential risks to the water supply.
Chloride, Sodium	Alton	Raw Water Quality Data	Chloride and Sodium concentrations show an upwards trend over the past 15 years. However, the trend appears to be lessening over the past several years. The trend should be monitored as part of the long-term management of the water supply and to understand the potential for chloride concentrations to increase above levels that are unsuitable for water distribution.
Chloride, Sodium	Acton	Raw Water Quality Data	Chloride and Sodium concentrations show a continuous upwards trend over the past 15 years. The trend should be monitored as part of the long-term management of the water supply and to understand the potential for chloride concentrations to increase above levels that are unsuitable for water distribution
Nitrate	Georgetown	Raw Water Quality Data	Although they are below regulatory limits, nitrate concentrations at the Princess Anne and Lindsay Court wells have shown steep upward trends over the past 5 years. Further work may be warranted to better define nitrate concentrations in the capture zones and recharge areas to better understand any risks to the water supply.
Chloride, Sodium	Georgetown	Raw Water Quality Data	Chloride and Sodium concentrations show a continuous upwards trend over the past 15 years. The trend should be monitored as part of the long-term management of the water supply and to understand the potential for chloride concentrations to increase above levels that are unsuitable for water distribution

Co-Benefits: Cascade Framework Chart

Structural and/or Landscape Change		Ecosystem Function Affected	Ecosystem Service(s) Affected	Final Benefit	Well-Being Domain
Before	After				
Riparian zones that do not have an adequate forest buffer Currently the riparian zone in the Credit River watershed is 37% forested [Credit Valley Conservation, 2013]	50% of the riparian zone in the Credit River Watershed is forested in order to meet Conservation Ontario guidelines Strict controls are in place to protect the tree canopy in riparian zones	**Bank Stability** The root structure from the forested area in the riparian zones stabilizes the banks of waterways preventing rapid erosion during peak flows. **Carbon Capture** The increased tree canopy in riparian zones captures and stores carbon from the atmosphere. [Newell, 2000] **Shade & Cooling** Increased vegetation in riparian zone provides shade and cools the	Natural hazard mitigation *(regulating)* Erosion control *(regulating)* Carbon storage and sequestration *(regulating)* Micro-climate regulation *(regulating)* Opportunities for recreation *(cultural)*	Protection of people and property from slope instability and riverbank erosion Climate Regulation – Mitigate the impacts of global climate change More comfortable temperatures More possibilities for active and passive recreation (e.g. fishing, learning about fish)	Security Health & Security Health Health

Structural and/or Landscape Change		Ecosystem Function Affected	Ecosystem Service(s) Affected	Final Benefit	Well-Being Domain
Before	After				
		temperature of the water. **Wildlife Habitat** Cooler water provides good habitat for many native fish species (e.g. Brook Trout)			
Overland flow washes excess fertilizer, pesticides and pathogens directly into waterways	Denser buffer plantings intercept: a. fertilizers b. pesticides c. pathogens before they enter surface water.	a. **Nutrient cycling** – there are lower levels of phosphorous in waterways because the nutrient is absorbed by the buffer plants b. **Pesticide Removal** Chemical pesticides are trapped and broken down by wetland buffer plantings before entering surface	Access to fresh water (provisioning) Disease regulation (regulating) Water purification (regulating)	More secure access to clean drinking water	Health Basic material for good life

Structural and/or Landscape Change		Ecosystem Function Affected	Ecosystem Service(s) Affected	Final Benefit	Well-Being Domain
Before	After				
		water ways c. **Pathogen control** Pathogens such as *E. coli* are trapped within the buffer plantings and become inactive before reaching sources of drinking water			
Fewer shoreline plants create a weak structure that is quickly eroded. Sediment flows downstream and collects at the mouth of the river.	Dense root system created by trees and aquatic plants along the shoreline stabilize soils and create "natural traps" that catch sediment and prevent it from building up at the mouth of the waterway.	**Sediment Control** Lower levels of turbidity leading to lower water temperatures and higher levels of dissolved oxygen in the waterways, creating healthier fish habitat. [Credit Valley Conservation]	Aesthetics and Spiritual *(cultural)*	Fishing Opportunities	Health

Structural and/or Landscape Change		Ecosystem Function Affected	Ecosystem Service(s) Affected	Final Benefit	Well-Being Domain
Before	After				
No transition zone between open waterways and agricultural/urban lands. Water flows quickly along a straight path.	30-100m buffer of densely planted aquatic vegetation creates transition between terrestrial and aquatic ecosystem. Diversity of aquatic plants, shrubs and trees slows down the flow of water and causes the watercourse to meander.	**Fish and Wildlife Habitat** The abundance of diverse plants provides habitat and spawning grounds for many different species of fish [Diana et al., 2006, p. 268]	Opportunities for recreation *(cultural)*	More possibilities for active and passive recreation (e.g. fishing, learning about fish)	Health
Road runoff including heavy metals, oil, gasoline sand and road salt are washed into drainage ditches and fed directly into surface waterways or leached into	Road runoff gets captured and filtered through buffer plantings **Increased Biodiversity** Fewer opportunities	**Water Cycling** Water spends a longer time cycling through the ecosystem and getting filtered in the process. Storm run-	**Water Filtration** The buffer plantings filter water, taking pressure off of man-made water filtration systems.	**Clean Water (Quality)** Lower chloride concentrations measured in municipal wells.	Health

Structural and/or Landscape Change		Ecosystem Function Affected	Ecosystem Service(s) Affected	Final Benefit	Well-Being Domain
Before	After				
groundwater	for salt-resistant invasive species such as *Phragmites Australis* to dominate the ecosystem [Richburg et al. 2001]	off does not immediately infiltrate surface waterways and wells			

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Toolkit I3: Cover Crops

Overview

1. *Description*

This intervention is also focused on changing accepted agricultural practices in favour of adopting practices that will be less resource intensive, create less disturbance for local ecosystems, and ultimately produce greater outcomes for human health and well-being. As opposed to a standard crop rotation that mixes wheat, corn, and soy beans over a three year period, cover crops are planted and then left in the field without being harvested. Common cover crops include Red Clover, Oats, Rye, Radish and Winter Wheat (Schipanski et al., 2014). Winter wheat, for example, is planted right after the final harvest of the season and left to nourish the fields under the snow.

Many cover crops are known as "nitrogen scavengers" because of their capacity to find and capture nitrogen in the soil that was left behind after previous harvests. The nitrogen is stored in these crops, whose detritus is then consumed by the next generation of crops, thus making the previously locked nitrogen accessible.

1. *Common issues that can be addressed through the adoption of Cover Crops*

The primary benefits to using cover crops relate very closely to adopting Nutrient Management Plans. In this sense, the agricultural field is being developed into a self-sustaining system that does not need external energy inputs (fertilizers) in order to be productive. Also known as nitrogen "catch crops" (e.g. oilseed radish and rye) these plants take up the nitrogen that has been left behind by the main crop or from manure applications. This means that the excess nitrogen does not get leached into groundwater. This benefit is most notable if there is a shallow aquifer (Schipanski, 2014). According to the Ontario Ministry of Agriculture, Food and Rural Affairs, cover crops "reduce the potential for the contamination of shallow aquifers by nitrates" (OMAFRA, 2016).

2. *Main Stakeholders Involved*

Farm operators
Fertilizer Producers
Water Quality Managers
Conservation Authorities
OMAFRA (Ontario Ministry of Agriculture, Food and Rural Affairs)

3. *Policy Context*

A great challenge is that planting cover crops remains an entirely voluntary exercise on the part of the farm operator. There is a growing body of academic research showing the ecological and financial benefits of planting cover crops and purchasing and applying less fertilizer. However, there are currently no policy tools in place that require the planting of cover crops. Conservation authorities are left to conduct voluntary workshops and information sessions in an effort to increase the level of knowledge and education surrounding the use of cover crops.

Co-Benefits: Achieving a double dividend

The greatest advantage to planting cover crops is reduced reliance upon added fertilizers to produce healthy crops. Cover crops take advantage of energy and nutrients that are already present in the system, thus producing a more efficient agricultural loop.

Another challenge is the economic context in which there is a powerful emphasis on growing only cash crops (rotating soybeans, corn, wheat) and then leaving the fields bare in the winter months. The erosive potential is high in the winter months and cover crops could

Co-Benefits: Cascade Framework Chart

Structural and/or Landscape Change		Ecosystem Function Affected	Ecosystem Service(s) Affected	Final Benefit	Well-Being Domain
Before	After				
Standard Crop Rotation Corn-Soy-Wheat over three years (Schipanski et al., 2014)	Nitrogen Scavengers such as radish and winter wheat are planted after the final harvest	Nutrient Cycling – Previously locked nitrogen is captured by nitrogen scavengers, and becomes available to the next generation of plants when the scavengers are left in the soil.	a. Food (**Provisioning**) b. Water Filtration **(Regulating)**	Fewer external nutrient inputs are required to produce the same crop yield, thus lowering cost of food and decreasing levels of added synthetic nitrogen. Lower overall levels of added nitrogen in the ecosystem reduce the amount that leaches into groundwater or flows into surface water.	Health Basic Material for good life

Structural and/or Landscape Change		Ecosystem Function Affected	Ecosystem Service(s) Affected	Final Benefit	Well-Being Domain
Before	After				
Fertilizer applied routinely, regardless of soil conditions or existing nutrients in the soil. Large volumes of chemical fertilizer indiscriminately applied to agricultural fields	**Cover Crops Planted Over Winter –** Existing nitrogen is captured and stored in the soil by the decaying cover crops, thereby making itself available for the next generation of crops. No additional fertilizer is needed.	Nutrient Cycling – Smaller volumes of nutrients (Nitrogen, Phosphorous) cycling through the ecosystem. Does not overload the existing ecosystem with synthetic nitrogen	a. Water Storage and Regulation **(Regulating)** b. Water Filtration **(Regulating)** c. Food **(Provisioning)**	More secure access to clean water Reduces strain upon water filtration systems Reduces excess nitrogen entering the water system leading to eutrophication	Health Basic material for good life

Structural and/or Landscape Change		Ecosystem Function Affected	Ecosystem Service(s) Affected	Final Benefit	Well-Being Domain
Before	After				
Agricultural Fields left bare over the winter months because it is not possible to plant and harvest profitable cash crops in winter. This greatly increases rates of erosion as there is no root structure present to protect the barren fields from high winds.	Winter wheat or root vegetables such as oilseed radish are planted after the final harvest in the autumn. This creates a deep and stable root structure in the soil that protects the fields from erosion.	**Bank Stability** The root structure stabilizes the banks of waterways if the fields are located next to a watercourse. **Sediment Reduction** Less eroded material gets washed into the local waterways, thus reducing turbidity. This creates clearer and more aerated water bodies that are more visually appealing and provided healthier fish habitat.	Natural hazard mitigation *(regulating)* Erosion control *(regulating)* Opportunities for recreation *(cultural)*	More possibilities for active and passive recreation (e.g. fishing, learning about fish) because of the greater aesthetic appeal of clearer water bodies Protection of people and property from slope instability and riverbank erosion	Health and Security

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