Modelling Urban Forest Structure and Services Using the Urban Forest Effects (UFORE) Model

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Abstract

Urban forests offer a variety of services, values and benefits to communities. Urban forest resource values include air quality improvements, carbon storage and sequestration, increased property values, energy savings for homeowners and a variety of environmental services. Effective urban forest management for these services and values requires at the very least an understanding of the structure, composition and state of urban forests. The Urban Forest Effects (UFORE) model uses urban forest inventories or sampling data to quantify urban forest structure. The forest structure data is then used to estimate pollution removal, carbon sequestration, pollen allergy ratings, and the effects of shading on building energy use within the urban forest. This paper outlines the UFORE model and its applications for urban forest managers and then discusses a series of recommendations. These include; the incorporation of additional output values in an expansion of the UFORE model; use of new technology to increase accuracy, efficiency and decrease cost of input data collection processes; and potential application of the UFORE model in Canadian cities

Keywords: Urban forestry, urban forest management, Urban Forest Effects Model, air quality, pollution removal, carbon storage and sequestration, urban planning

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1.0 Introduction

"Urban forestry is a specialized branch of forestry that has, as its objective the cultivation and management of trees for their present and potential contribution to the physiological, sociological, and economic well-being of urban society" (Kielbaso, 2008). An urban forest is roughly defined as a population of trees within the jurisdiction of a municipality. This includes street trees, trees on private property and in parks, natural stands and reserves within management jurisdiction of municipalities. In Canada over 80% of the population live in urban areas (Government of Canada, 2011) and rely on the several benefits and services provided by trees. The population growth rate within metropolitan areas is 2% above the national average (Government of Canada, 2011) further demonstrating the importance of urban forests now and for the future. With an increase in urban development, several advances in urban forest management strategies have occurred and organizations focused on improving urban forest management have been created. Tree Canada, a not-for-profit organization focused in providing education, technical advice and resources to promote care for and expansions of urban forests was established in 1992. Tree Canada runs an annual conference in order to promote collaborative efforts to improve Canadian urban forest management practices.

There is a broad range of values, services and benefits associated with urban forests. Despite advances in urban forest management, it is common that the core values governing specific urban forestry programs and departments differ from one another (Kielbaso, 2008). Trees in the urban forests offer aesthetic, economic, and environmental values and services most of which are not mutually exclusive. Urban forests require several measurements and modelling systems to quantify various benefits in some form of an economic or nominal rating.

Street trees are most frequently recognized for their aesthetic value and contribution to the character or "feel" of a neighbourhood. As stated by Kielbaso (2008), street trees provide a sense of well-being, stateliness and charm. These aesthetic values are difficult to quantify monetarily as they are subject to personal tastes and preferences. Having said that, research conducted by Payne and Strom (1975) indicates the presence of mature trees contributes to faster home sales and a potential increase in home value between 5 and 10 %.

Environmental values and services of trees in urban forests are numerous and in most cases less apparent to the general public. Trees are attributed to providing improvements in air quality through transpiration by reducing air temperatures; removing air pollutants such as carbon monoxide (CO), nitrogen dioxide (NO^2), ozone (0^3), sulphur dioxide (SO^2) and particulate matter less than 10 µm (PM10) by intercepting airborne particles and through stomata absorption; and reduction of building and consequent power plant emissions through temperature reductions from tree shade and temperature increases by shielding cold winter winds (Nowak et al. 2006). Nowak et al. (2006) reported that US urban trees have an annual air pollution removal of 711,000 metric tons with value of $3.8 billion USD. This study was based on 55 US cities and used median monetized dollar per ton externality values from previous energy-decision-making studies.

Trees act a carbon sink through the fixation of CO^2 in photosynthesis whereby excess carbon is stored as biomass (Nowak & Crane, 2002). Not only does this process reduce atmospheric concentrations of greenhouse gasses countering the effects of climate change but it provides an economic opportunity for urban forest managers with the emergence of carbon markets. The environmental functions of trees are directly attributed to improvements in human health and environmental quality, providing social and economic incentive for management of these functions within urban forests.

Trees in urban forests are valuable for their effects on urban hydrologic processes specifically interception and slowing the flow or precipitation which reaches the ground (Nowak & Dwyer, 2007).Hydrologic studies indicate that a tree canopy of 22% cover percentage can reduce runoff by as much as 7% (Sanders, 1986).

In order to effectively manage an urban forest and to accurately model the physiological, sociological and economic benefits they provide, inventories or statistically accurate samples of urban forests are required. This paper has identified the environmental, sociological and economic benefits provided by urban forests and will address advantages, disadvantages and applications of forest inventories and urban forest sampling. This paper will then apply these concepts in order to provide an outline of the Urban Forest Effects (UFORE) model and its applications for urban forest managers. The UFORE model uses field data to quantify urban forest structure, pollution removal, carbon sequestration, pollen allergy ratings, and the effects of shading on building energy use. The UFORE model should be used to prepare, update and evaluate management plans for North American urban forests using output data as indicators of performance with respect to management objectives.

2.0 Urban Forest Inventories

An urban forest inventory is a complete collection of data for an entire population. Inventories are useful management tools for individual trees and small populations (Nowak, et al 2003). A complete urban forest inventory of correct measurements paired with appropriate modelling software will allow land managers to quantify urban forest structure, benefits, and services with a high degree of certainty**.** In many cases, due to the size of an urban forest population, it is very unlikely development of a complete inventory is actually possible. Traditionally inventories are prepared using direct field data collection which is an expensive, time-consuming process for large scale applications and almost always infeasible (Nowak, et al 2003). Inventories are difficult to prepare for urban forests as municipalities frequently do not have jurisdiction or permission to measure trees located on private property.

With the maturation of technologies such as remote sensing including Light Detection and Ranging (LiDAR), preparation of accurate forest inventories for large scale regions is possible (Jones, 2011). These methods resolve issues of measuring trees located on private property and significantly reduce the cost and time required for data collection, but skilled professionals for interpretation and application of data are still required (Nowak & Duggin, 2006, Jones, 2011). Remote sensing and LiDAR are limited in the range of measurements that can be taken and the absence of specific measurements, for example diameter at breast height (DBH), will limit the potential modelling applications for these inventories. It is yet to be seen, but likely, that a combination of remote sensing and or LiDAR data with permanent sampling for field parameters is the most economical means by which to prepare statistically accurate and dynamic urban forest inventories.

When sampling a randomly chosen portion of a larger population, estimation of parameters for the entire population can be produced within some bound of certainty (McCullagh, 2007). The accuracy and cost to prepare estimations for population parameters are positively correlated to the number of trees sampled from the urban forest population. Nowak et al. (2003) reported that as a general rule approximately 200 (0.04 ha) fixed area plots are required in order to yield approximately 10% standard error to estimate a measurement of the entire urban forest such as the total number of trees or species composition. The UFORE model discussed in this paper uses sampling or inventories, if they are available, to report population level estimates of forest structure and function for the urban forest in question.

3.0 Urban Forest Effects Model (UFORE)

The UFORE model was developed by scientists from United States Department of Agriculture (USDA) Forest Service in the 1990's in conjunction with the State University of New York (SUNY). It was developed as a means by which urban forest managers could accurately quantify forest structure and functions (Nowak & Crane, 1998). The system uses field measurements, tree cover, meteorological and air pollution data to produce metrics of forest structure, volatile organic compound emissions, carbon storage and sequestration and hourly air pollution removals. The UFORE model uses comprehensive results from a series of research projects conducted by its developers to produce output parameters useful for urban forest managers (Nowak et al., 1996, Nowak & Crane, 2002, Nowak et al., 2006).

3.1 Model Requirements

The UFORE model requires several input parameters: field data, forest cover data, meteorological data, and air pollution concentration data (Nowak et al., 2003). The specific requirements for each will be outlined in this section.

3.1.1 Field Data

Field data is required for all analyses using UFORE. Prior to the collection of data the boundaries of the urban forest or region of interest must be clearly defined. Users have the option to stratify the study area into smaller units for regional analysis and can choose between sampling and inventories for field data measurements. In most cases urban forest inventories are not available or realistic to prepare, for these reasons sampling is most common. As stated by Nowak et al., (2003) the core variables to be sampled for each tree within a plot that are required for all UFORE analyses are:

- tree species
- dbh
- height to base of live crown
- total tree height
- crown width
- crown light exposure
- percent canopy missing
- crown dieback
- distance and direction to nearby building

Table 1 outlines the applications of these metrics for modelling purposes, an x in a cell indicates the use of its associated measurement to model the above output value.

Table 1: Modeling applications of core variables in UFORE model

Measurement	Structural	Air pollution removal	Carbon Sequestration	VOC Emmisions	Energy Conservation	Pollen Index
Tree Species	x	x	x	x	x	x
DBH	x		x			
Height to base of live crown	x	x		x		x
Total tree height	x	x	x	x	x	x
Crown width	x	x		x		x
Crown light exposure	x		x			
Percent canopy missing	x	x		x		x
Crown dieback	x		x		x	
Distance and direction to nearby building					x	

Data are collected from inventories, random sampling or stratified random sampling. Managers must decide whether or not plots are long term and planned to be revisited in the future to assess changes over time. Mangers have the option to measure ground cover data to estimate the amount and distribution of ground cover types within the region. Managers also have the option to collect shrub data in order to estimate the pollution removal and VOC emissions from shrubs within the urban forest land-base (Nowak et al., 2003).

The UFORE data collection manual (2003) makes a series of recommendations with respect to field data collection techniques to ensure adequate data and acquired so that modeling scenarios provide accurate results. Nowak suggests that there be a minimum 200 (0.04 ha) fixed area plots for an entire city, while a minimum of 10 plots are to be found within each stratum. Random selection of plot location is necessary in order to avoid bias in sampling design arising from preferred sampling locations. Random sample locations are determined using either a GIS tool with a random location finder or paper maps and random number generator and grid overlays on the map (Nowak et al., 2003).

Nowak states (2003) that if the urban forest region has been stratified a number of plots proportional to the tree cover percentage for each stratum should be randomly distributed within each stratum, otherwise plots need to be randomly distributed in the entire urban forest land base (Nowak et al., 2003). To reduce variance within strata Nowak recommends that they be classified into homogenous land use units. To determine tree cover percentage for a specific stratum, managers should refer to aerial photography and satellite imagery; otherwise managers are instructed to refer to the details given in Table 1 (Nowak et al., 1996) which outline average tree cover for various land use types. The data for Table 1 is from a 1996 study which analyzed several US cities of three different potential natural vegetation (PNV) types and found mean tree cover figures for the listed land use types (Nowak et al., 1996). Finally Nowak (2003) suggests that for managers to deal with access issues where sampling crews are unable to sample trees because of private property, they should plan to take an extra 10 plots per strata as a rule of thumb.

Table 2: Mean percent tree cover by land use type and standard error (Nowak et al., 1996).

	Forest PNV		Grassland PNV		Desert PNV	
Land Use	Mean	SE	Mean	SE	Mean	SE
Park	47.6	5.9	27.4	27.4	11.3	3.5
Vacant/wildland	44.5	7.4	11	2.5	0.8	1.9
Resendential	31.4	2.4	18.7	1.5	17.2	3.5
Institutional	19.9	1.9	9.1	1.2	6.7	2
Other*	7.7	1.2	7.1	1.9	3	1.3
Commercial/Industrial	7.2	1	4.8	0.6	7.6	1.8
* Includes agriculture, orchards, transportation (eg freeways, aiports, shipyards), and misc						

3.1.2 Meteorological Data

The UFORE model uses local hourly meteorological data from the United States National Climatic Data Centre (NCDC) digital records for its VOC emissions, air pollution mitigation and pollen index analyses (Nowak & Crane, 1998). The UFORE model links regional climatic data to species composition, height to live crown, tree height, crown width and percent canopy missing records for each stratum in order to determine total VOC emissions and air pollution mitigation values.

3.1.3 Air Pollution Data

In order to model air pollution removal by the urban forest, the UFORE model requires hourly pollution concentration data from the U.S. environmental Protection Agency's (EPA) Aerometric Information Retrieval System (AIRS Database) (Nowak & Crane, 1998). If the sampling region is not from within the United States, hourly air pollution data is required for the following fields; year, month, day and hour that pollution data is recorded, the name of pollutant being monitored (CO, NO^2, O^3, $S0^2$ and PM10), the concentration of that pollutant in (parts per million (ppm) or $\mu g/m^3$), and the complete address and location of the pollution monitor (Nowak et al., 2003).

3.2 UFORE Output

In this section the output measurements from the UFORE model are summarized. The UFORE model currently produces outputs for urban forest structure, pollution removal, carbon sequestration, pollen allergy ratings, and the effects of shading on building energy use.

3.2.1 UFORE-A: Anatomy of the Urban Forest

Using the field data collected from inventories or sample plots UFORE-A produces a series of means and standard errors for each strata and entire urban forest of the following measurements: number of trees, species composition, tree density, diameter and condition class distribution, leaf area index (LAI) and leaf biomass (Nowak & Crane, 1998). The number of trees, species composition, tree density, DBH and condition class distributions are calculated using simple statistical analyses based on field data measurements while the LAI values use regression equations based on height to crown width ratios and crown light exposure measurements for deciduous species (Nowak & Crane, 1998). Coniferous species use corresponding deciduous values for trees of the same height and are multiplied by species relational shading coefficients (Nowak & Crane, 1998). LAI estimates are used to calculate tree leaf biomass using species specific measurements for grams leaf dry weight per m^2 of leaf area (Nowak et al., 1996). These measures are useful to urban forest managers as they outline a clear picture of entire urban forest population. They may be important metrics used by urban forest managers to inform the public or members of municipal governments of the state of urban forests. "An understanding of urban forest structure and how it impacts functions can lead to better urban forest management" (Nowak & Crane, 1998).

UFORE-A calculates a series of more specific values including; species richness, Shannon-Wiener diversity index values, percent native species, ground cover type distribution, and proportions of various susceptibility classes for gypsy moth and Asian long horned beetle (Nowak & Crane, 1998). These values are strong indicators for specific objectives frequently found in urban forest management plans and of great importance to urban forest managers (Nowak & Dwyer, 2007).

3.2.2 UFORE-B: Volatile Organic Compound (VOC) Emissions

Through a series of physiological processes trees emit volatile VOC's such as isoprene and monoterpenes that contribute to the formation of ozone and carbon monoxide (Nowak & Crane, 1998, Nowak et al., 2006). Emission levels of VOC's are a function of tree species, leaf biomass, temperature and other climatic factors such as relative humidity. A study by Geron et al. (1994) produced specific factors for VOC emissions from varying genera of trees at 30^{o}C in full sunlight along with correction factors for varying temperature and sunlight. These factors are multiplied by the species leaf biomass produced in UFORE-A, and then modified according to the hourly CNDC meteorological data to produce UFORE-B output (Nowak & Crane, 1998). The results are presented as hourly emissions of specific VOC's on a per species basis for the entire urban forest or within strata. It is important that land managers have the opportunity to monitor atmospheric VOC emission data for urban forests specifically on a per species basis within strata. Using UFORE-B data land managers can evaluate planning decisions with respect to species selection and planting location to reduce and monitor VOC emissions within strata and across the entire urban forest land base.

3.2.3 UFORE-C: Carbon Storage & Sequestration

Trees fix carbon dioxide, a dominant greenhouse gas, into growth tissue or biomass through the process of photosynthesis (Gifford et al., 1981). The UFORE-C model calculates the total metric tons of stored carbon for trees using species-specific biomass equations that require measurements of DBH and tree height (Nowak & Crane, 1998). In instances where species-specific equations do not exist, equations from different species within the same genera are used. For trees greater than 97 cm DBH volumetric equations and wood density information is used to estimate total biomass (Nowak & Crane, 2002). Corrections are applied to values that have not accounted for below ground biomass; values found using forest-derived biomass equations that are used to estimate biomass of for larger open-grown maintained trees; and for standing dead trees with no leaf mass (Nowak and Crane, 1998). The results of carbon storage for sampling plots are extrapolated for the entire urban forest using U-FORE A estimates of species composition and diameter distributions.

The UFORE-C model provides estimates for the gross amount of carbon sequestered annually by the entire urban forest and within each stratum. These results for stored carbon are presented in metric tonnes of carbon per year. Carbon sequestration rates are calculated using genera and region specific diameter growth curves to estimate the annual change in biomass (Nowak and Crane, 2002). These growth curves are modified for trees grown in stands, park structures and open grown situations (Nowak and Crane, 1998, 2002)**.** Further reductions are made to growth rates based on crown dieback field measurements greater than 25% (Nowak & Crane, 1998).

Land managers can use carbon sequestration and carbon stock data from UFORE-C for various applications. In certain jurisdictions such as British Columbia municipalities, commitments to maintain carbon neutrality in municipal operations exist (Parfait, 2010). Municipalities may expand urban forests to increase carbon sequestration capacity to offset emissions from public sector infrastructure. If carbon neutral requirements do not exist, urban forest managers can expand urban forests to increase carbon sequestration and storage to create offset credits to sell in voluntary carbon markets (Wouters et al., 2007.

3.2.4 UFORE-D: Dry Deposition Pollution Removal

Dry-deposition is the removal of gaseous particulate matter from the atmosphere through processes of absorption in stomata and gravitational sedimentation (Sehmel, 1967)**.** The UFORE-D model calculates annual dry-deposition of CO, NO^2, O^3, $S0^2$ and PM10 during precipitation free periods. The output hourly pollutant flux (grams per m^2 of tree canopy per hour) is calculated as the product of the deposition velocity (meters per second) and pollutant concentration (grams per m^3) (Nowak & Crane, 1998).

The deposition velocity is the inverse of the sum of aerodynamic resistance (m/s), quasi-laminar boundary resistance (m/s) and canopy resistance. Aerodynamic resistance and quasi-laminar resistance are calculated using a series of complex fluid equations (Nowak & Crane, 1998). The canopy resistance is calculated using the following measurements from the NCDC meteorological data: photosynthetic active radiation, air temperature, carbon dioxide concentration and absolute humidity (Nowak & Crane, 1998). Canopy resistance measures are reduced significantly during fall and winter leaf off seasons due to fact that absorption rates are significantly less and a majority of gravitationally deposited particles are re-suspended into the atmosphere (Nowak & Crane, 1998). Nowak reports (1998) that average deposition velocities are 0.0064 m/s for the leaf-on season and 0.0014 m/s for the leaf-off season.

Hourly pollutant concentrations for the project area from the EPA pollutant input data, measured in ppm, are converted to (g/m^3) and multiplied by deposition velocity in order to determine the pollutant flux. When any of the pollutant or meteorological data is missing, values are estimated by extrapolating existing data (Nowak & Crane, 1998). To calculate total hourly pollutant removal, the pollutant flux is simply multiplied by LAI values calculated in UFORE-A. These values can then be multiplied by median externality values for each of the pollutants in order to determine an estimated economic value of total pollution removal. Economic values can then be divided between species, strata or pollutants.

Urban forest managers can use UFORE-D output data to plan planting expansions and maintenance schedules. Species that are shown to have high pollution removal capacities in specific climates may be targeted as preferred species for planting expansions. Managers can also pin-point urban forest strata that have poor pollution removal capacities and focus maintenance and planting within these regions if appropriate.

3.2.5 UFORE-E: Energy Effects on Buildings

The UFORE-E model provides estimates of energy use reductions resulting from trees heating and cooling building by means of shading in warm climates and wind shielding in cold climates (Nowak & Dwyer, 2007). The UFORE-E model uses measurements from field data of the direction and distance trees to buildings, crown dieback, species and tree height in regression equations used to estimate total energy savings resulting from heating and cooling (Nowak & Crane, 1998). UFORE-E output provides urban forest managers the opportunities to examine benefits resulting from strategic tree planting expansion design. Managers can use UFORE-E data to select appropriate species and planting locations with respect to slope aspect and main direction of incident sunlight to reduce heating and cooling costs for residents and public sector buildings.

3.2.6 UFORE-F: Pollen Concentrations

The UFORE-F model produces estimates of the species specific seasonal pollen concentrations per cubic meter of air within strata or for the entire project area. These estimates are classified by species and converted to a nominal scale from 0 to 10, where higher values represent higher concentrations. UFORE-E calculates these values based on the value of total leaf biomass per species calculated in UFORE-A, and meteorological data to project periods of high pollen concentrations (Nowak & Crane, 1998). Pollen concentrations are useful measurements to assist members of the public with allergies so they may plan outdoor activities for low concentration periods. Additionally managers can interpret the pollen index readings over time potentially to identify strata with too much of a certain allergenic species and prompt removal of some trees or a cease in planting of that species.

4.0 Discussion

As outlined in this paper urban forest ecosystems are extremely valuable to communities due to the variety in, and quality of services and benefits they provide. In order to prepare comprehensive urban forest management plans the desired outcomes of urban forests must be determined by managers. Managers should be focused on maximizing the net benefits from urban forests and be aware of available tools and strategies to accomplish these objectives. By altering urban forest structure through species selection and planting locations or arrangements, managers have the capacity to target strategies specific to single or multiple urban forest services in select areas of the urban forest. The UFORE model is a tool that can be used to provide feedback on previous urban forest management and to evaluate current and prepare future management strategies and plans for urban forests.

The UFORE system has potential to be expanded and used to model other aspects of urban forests. The model has opportunities for expansion to examine additional urban forest attributes including forest health, projected mortality, water quality effects, human comfort ratings and inspection schedules. For these outputs additional qualitative and previously non-essential measurements such as condition class, pest and disease presence and location to infrastructure such as power lines are required. The same projective principles will be applied in these scenarios using species specific regression equations developed from historical data and new research projects.

Forest health projections may be one the most important potential additions to the UFORE model. Urban forests are regularly subject to large scale health issues resulting from invasive insects and disease. This statement is validated by the severe impacts of urban forest health threats from the past few decades including but not limited to; *Ophostoma ulmi* (Dutch elm disease); *Agrilus planipennis* (Emerald Ash Borer); *Cryphonectria parasitica* (Chestnut Blight); and *Anthronomus aeneotinctus* (Asian longhorn beetle). The UFORE model should be expanded to identify high risk strata for forest health threats identified in or near the urban forest. The UFORE model has the potential to predict spread of forest health issues within an urban forest. These outputs may then be used to outline and specify management strategies to reduce the rate of spread, decrease number of susceptible hosts and plan for future urban forest resiliency. The UFORE model should then incorporate estimates for the effects of a specific forest health concern to run a series of analyses with existing output UFORE measurements, such as carbon sequestration, to identify potential losses due the identified forest health threat.

Inspection schedules for regions of urban forests may also be a viable option to incorporate into the UFORE model. Metrics for species composition, condition class, estimated age, crown condition and, proximity to buildings and infrastructure such as power lines can be used to infer species and strata with higher priority maintenance requirements. A UFORE output of a maintenance requirement ranking for strata and species could possibly be made available to urban forest managers. This would enable managers to update existing maintenance schedules to ensure that adequate inspection and maintenance activities such as pruning and crown thinning are scheduled accordingly. This addition to the UFORE model will increase public safety by promoting improved street condition and likely reduce management costs associated with the maintenance of municipal trees.

Data collection measures can be enhanced through incorporating new handheld electronic devices which can be synced directly to urban forest databases. The benefits of this idea are countless for urban forest managers including but not limited to: continuous updates of UFORE output estimates over time; significant reductions in data processing time relative to the alternative of filling out data collection sheets and converting results manually to the database; reduction in the sampling error attributed to incorrect transfer from data collection in the field or in office; reduced paper consumption and storage costs of field data collection sheets; potential increases in productivity of field measurement crews; increased ease of documenting and finding exact location of plots using built in GPS capacities of several devices; and assistance determining tree species when data collection team is unsure.

The UFORE model has been applied to several cities within the United States and should be considered by urban forest managers in Canada. To date in Canada both Calgary and Toronto have run UFORE analysis with high degrees of success. Canada is an ideal location for expansion of the UFORE model since the majority of species in Canadian urban forests are also found in the US. The UFORE model incorporates a series of species specific relationships from research conducted specifically for US tree species. Since Canadian urban forests share these species crossover is possible. In international regions outside North America, application of the UFORE model will require incorporating additional research for species not included in the UFORE model. For Canadian application, the data source for meteorological data and pollution concentrations requires attention. The CNDC and EPA data sets do not contain records for Canadian cities; however, Environment Canada provides open access to the National Climate Data and Information Archive (NCDIA) and pollutant monitor data used to prepare Air Quality Health Index (AGHI) can easily be applied to the model. It is recommended that the UFORE model be employed for Canadian urban forest analysis and used by managers as a tool to prepare and update existing management plans and strategies.

The state of urban forest management in several Canadian municipalities lacks in comparison to the vast majority of the United States. The majority of Canadian municipalities do not have strategic management plans in place let alone effective inventories of their urban forests. There are few provincial and federal incentives that promote professional management of Canadian urban forests. Proper education and training in urban forest management is limited within Canada and is dwarfed by institutions and programs focused in wildland forest management. This paper recommends; creation of programs and opportunities for professional training in the field of urban forest management in Canada; federal and provincial incentives to promote proper urban forestry practices; and national adoption of the use or development of a model such as, or similar to UFORE in Canadian urban forests.

5.0 Conclusions

To effectively manage urban forests for the benefits and services they provide, urban forest managers must take advantage of available tools like the UFORE model in order to analyze past, current and future management practices. This paper has attempted to demonstrate the importance of urban forests and to outline the principles, tools, and strategies that can be used to assist urban forest managers. This paper outlined the definition, importance and basic management requirements of urban forests. Environmental, sociological and economic benefits provided by urban forests have been identified and the advantages and disadvantages of forest inventories and urban forest sampling have been addressed. These concepts were then applied in an outline of the UFORE model (Nowak & Crane, 1998). Input measurements and output capacities of the model were then identified. The output measures include urban forest structure, pollution removal, carbon sequestration, pollen allergy ratings, and the effects of shading on building energy use. Urban forest managers can use these output parameters to identify strengths and weaknesses in management strategies, potential value of urban forest services, identify ideal species and locations for planting expansions; and to inform the public and government of the importance of urban forests to communities. Recommendations for developments to the UFORE model and suggestions for the application of this or a similar model in Canadian cities have been presented. This paper can be used as a basis by which urban forest managers can further understand benefits and services of urban forest and to consider the UFORE model as a potential tool by which they can develop urban forest management plans.

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