

Population Distribution Modeling and Scenario Forecasting

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Reducing Canada's vulnerability to climate change

Objectives

The objectives of developing a population distribution model across Canada are: a) to provide simulation of future population distributions at the level of communities and drainage sub-basins, for the purpose of estimating climate change impacts and adaptation costs, and b) to provide a population distribution model across Canada for other research and applications.

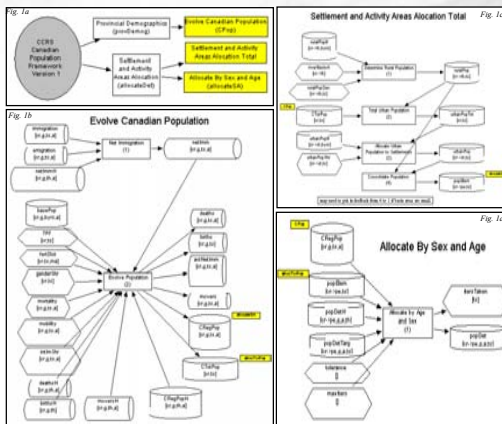
Model Description

Model structure – the conceptual view

A cohort model is used to simulate population by province/territory (13), sex and age (0-90+ in 1 year age steps). Internal as well as international migration is also considered. This provincial total population is then allocated to sub-basins (256) and settlements (2035) as follows: 1) rural population of a sub-basin is calculated as density x area of each sub-basin; 2) urban population of a settlement is calculated by allocating some of the remaining provincial population to urban and some to rural according to a share variable, and the rural portion is assigned to adjacent sub-basins; and 3) population by age and sex is then simulated via bi-proportional adjustment. A time variable seed for this calculation is the main simulation parameter. Settlements have been chosen in such a way that they can be considered as unconstrained points of population. In this way we avoid, in this version of the simulator, having to consider the built economy constraints that would come into play if we had used a finer geographical aggregation. Fig.1a-d show the structure of the model. Fig. 1a is the top level model structure. There are three calculators which 1) produce the total population distribution and evolution by province, sex and age (Fig. 1b - Evolve Canadian population (CPop)); 2) allocate the population to sub-basin and settlement within province (Fig. 1c - Allocate the total settlement and activity areas (allocTotPop)); and 3), allocate provincial population to sub-basins and settlements by sex and age (Fig. 1d - Allocate by sex and age).

Software Components – the system view

The model is implemented in the Whatif software package, which is a system modeling and scenario analysis tool from Robert Associates. The software comes with three main components: the documenter, which is used to design and document the model; the SAMM, which is used to create, manage and compare scenarios; and the server, which stores all data files. The model itself consists of two components: the calibrator and the simulator. Calibration involves assembly of the data sets identified in the design phase, conversion and standardization, parameter estimation, and estimation of missing data. The simulator implements the actual model physics and algorithm. It is quickly implemented using the documenter of Whatif.

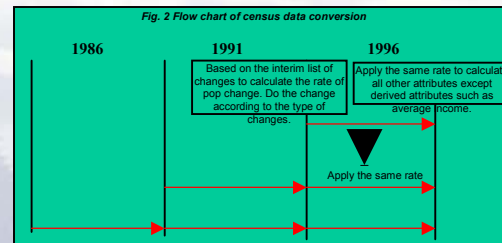


Development of Calibrator

The model was calibrated over historical time using the Statistics Canada population census and the vital statistics (birth, deaths, and migration) for 1972 to 2000 with a one year step. This gives an historical trajectory for all simulation parameters.

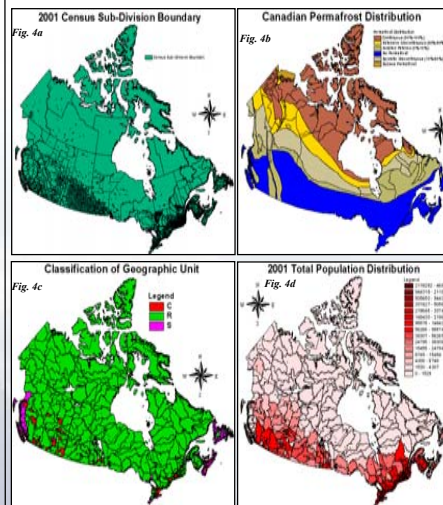
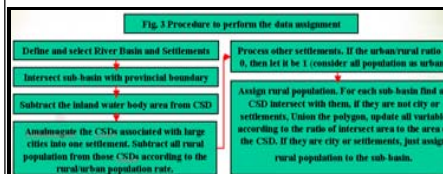
Census data conversion

In different census years, the Census Sub-Division (CSD) boundary, the CSD identifier, attributes, and data format vary. We need to convert all census data to a consistent CSD boundary and data format (based on 2001 census year). Fig. 4a shows the 2001 census boundary. The basic algorithm to do the conversion is shown in Fig. 2.



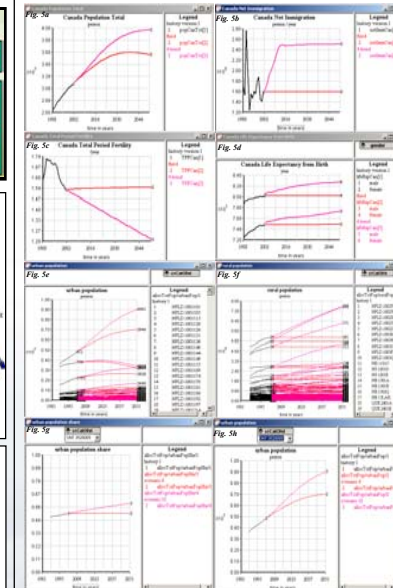
Data Assignment

Assigning historical CSD level census data to sub-basins and settlements is the major task to build the calibrator. The criteria to select settlements are as follows: 1) Divide Canada into South and North based on permafrost distribution (Fig 4b, from Atlas). All non-permafrost area is considered to be South. All other permafrost areas are considered to be North; 2) For North: population > 50, and population density > 700/km²; 3) For South: total population > 100, and population density > 30000 km²; 4) Amalgamate CSDs associated with large cities into one settlement. The procedure to perform the data assignment is shown in Fig 3. Fig 4c shows the classification of geographic units used in the model. We assigned urban population into Class C (city) and S (settlement). They are both actually settlements in the model but are treated in different ways for data assignment. Class R (rural) is assigned the rural population for sub-basins. Fig. 4d shows 2001 population distribution after assignment.



Scenario Analysis and Sample Outputs

Users can use SAMM, the scenario builder and manager of the Whatif software, to create, manage, and compare as many scenarios as they want. We created two scenarios: a fixed scenario and a scenario following the historical trend. The two scenarios have different parameters for immigration and emigration rate, mortality rate, mortality, total period fertility, rural population density and urban population share. Fig. 5a-h displays some sample outputs at different levels. In Fig. 5a-h, the pink line and the red line represent results of historical trends and fixed scenarios, respectively. Fig 5e and 5f show all population distributions by sub-basin (rural) and settlements (urban). Fig. 5g shows the urban population share of the Greater Toronto Area (GTA), which is one of the input parameters (assumptions) for the scenario. Fig. 5h shows the population evolution of GTA.



Acknowledgements

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