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Brian Eddy

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A GIS Methodology for Mapping Regional and Community Vitality for Canada using the CanEcumene 3.0 Geodatabase with Census Data

Brian Eddy [‡, §]

‡ Natural Resources Canada, Corner Brook, Canada
§ Memorial University of Newfoundland, Corner Brook, Canada

Corresponding author: Brian Eddy (briang.eddy@nrcan-rncan.gc.ca)

Abstract

Many ecosystem-based management (EBM) applications require integrating geospatial information about socio-economic conditions of human populated areas within a study area. However, integrating socio-economic data in such a way that it can be related to ecological data is not a trivial process due to issues associated with spatial representation between socio-economic data frameworks, and natural patterns in ecological data. In Canada, this problem is particularly challenging given its large geographic size, diversity of environments, and highly irregular population distribution. Although several indices have been developed for Canada related to well-being and vulnerability, their application for EBM applications is limited. This article presents a GIS-based methodology for mapping *regional and community vitality index* (RVI/CVI) for Canada using standard Census data integrated with the CanEcumene 3.0 Geospatial Database (GDB). The method uses percentile ranks of five sub-indicators of vitality derived from eight primary Census variables. Results reveal a number of notable patterns and trends in socio-economic conditions across the country and across different types of communities and regions.

Keywords

Ecosystem-based Management (EBM), socio-economic, community vitality, regional vitality, well-being, vulnerability, GIS.

Introduction

As part of a comprehensive and inclusive approach to Ecosystems-based Management (EBM), many ecosystem analysis and assessment applications require integrating geospatial information about socio-economic conditions of human populated areas within a study area (Kappel et al. 2006, Eddy et al. 2014). Common examples include natural resource and environmental management (NREM), ecosystems services assessment (ESA), and climate change impact and adaptation (CCA). Socio-economic data used in these applications need to be integrated with bio-physical data for a region to enable analysis of relationships between socio-economic and environmental conditions. Integrating socio-economic data in such a way that it can be related to ecological data is not a trivial process due to geospatial frameworks used to collect socio-economic data do not often align with natural boundaries and patterns in a landscape (Cumming et al. 2006,Eddy et al. 2020).

In Canada, this problem is particularly challenging given its large geographic size, diversity of environments, and highly irregular population distribution. Currently, several high priority policy issues require national level mapping of socio-economic conditions of communities across Canada including climate change adaptation (NRCan 2024), wildfire risk mapping (Erni et al. 2021, Erni et al. 2024), and cumulative effects assessment related to new natural resource development projects (Antwi et al. 2023, IAAC 2024). Ideally, spatial information required for these applications about human populated areas need to capture the overall state of socio-economic conditions and relationships with their environments.

This article presents a GIS-based methodology for mapping *regional and community vitality index* (RVI/CVI) for Canada using standard Census data integrated with the CanEcumene 3.0 Geospatial Database (GDB) (Eddy et al. 2023). First, a review of similar concepts and applications for Canada is reviewed from which an alternative approach is described. Second, a method for mapping both regional and community vitality is described in detail. Third, results are presented and discussed in terms of noteable patterns observed, followed by conclusions that discuss the benefits and limitations.

Background

As with many regions around the world, researchers in Canada are tasked with developing a scientific information base to support decision-making for a host of concurrent EBM issues including, but not limited to, climate change adaptation (CCA) (NRCan 2024), regional and project-level impact assessments (RAs/IAs) (IAAC 2024,Noble and Harriman Gunn 2010), and natural hazards risk analysis and mapping (CFS 2024, Erni et al. 2021, PSC 2024). Although environmental and ecological dimensions may differ, a common requirement among these areas is the need to geospatially map and integrate socio-economic data with spatialized environmental and ecological data.

Different terms and concepts have been used to describe overall socio-economic conditions of communities including well-being, resilience, vulnerability, vitality, and sustainability (Beckley et al. 2002, Dale et al. 2010, Etuk and Acock 2016, Grigsby 2001). How these terms are defined and applied is often contextual depending on the application and scope of analysis, and methods used are diverse. The majority of studies that tend to focus on individual communities and involve qualitative research methods (Beckley et al. 2002, Dale et al. 2010, Etuk and Acock 2016, Grigsby 2001, Lax and Krug 2013, Pearce

2005, Stedman et al. 2004). Studies conducted in other countries that focus on quantitative methods use a variety of definitions and methods depending on the geographic and temporal scope and end user requirements (Ahsan and Warner 2014, Flanagan et al. 2011 , Pravitasari et al. 2018, Wangdi 2022, Zeng et al. 2018). For our purposes, the aim is to develop a quantitative method for mapping socio-economic conditions for over three thousand communities in Canada over multiple time periods, and at a scale that is amenable for integration in regional to national level EBM applications.

Studies that focused on developing such indices for Canada use a variety of methods for different purposes (Table 1). The Canadian Index of Wellbeing (CIW) uses qualitative survey data, but does not provide data for all communities in Canada nor systemically cover multiple time periods (Scott 2016). A similarly named Canadian Well Being Index (CWB) maps all communities in Canada at the census sub-division (CSD) level (ISC 2021). Developed primarily to compare conditions of Indigenous communities with non-Indigenous communities, the CWB is not suitable for integration with environmental and ecological data sets due to its use of standard CSD boundaries, and its lack of a peer-reviewed methodology used in ranking variables (ISC 2016).

Table 1

A Social Vulnerability Index (SoVI) developed by Chakraborty et al. (2020) for flood risk mapping uses dissemination areas (DAs) of the Canadian census framework. The SoVI index is an output of a principal component analysis (PCA) on 49 variables, and although result scores are available, analytical data is not available for evaluation. Similarly, Chan et al. (2015) use PCA on 22 census variables at the DA level to develop a Socio-Economic Status index (SES) for all communities in Canada, but this data was limited to 2006 and was not developed for mapping purposes. Journeay et al. (2022) also use a PCA approach using data derived from the DA and Census tract (CT) level, and mapped using a raster-based human settlement layer, but coverage is only for the year 2016. Although not directly related to community vitality, StatsCan (2019) developed a Canadian Index of Multiple Deprivation (CIMD) using factor analysis on 17 variables but only for the years 2016 and 2021.

In addition to these noted limitations with these sources, it is worth noting while studies that map data at a dissemination area (DA) level data may be suitable for environmental applications (with some modifications), the use of PCA or other factor analysis methods limits accessibility for lay people in terms of their ability to understand how the indices were calculated. Additionally, because statistical distributions and properties of variables change from one census period to another, it may be difficult to normalize indices for time series analysis.

For purposes of integration with EBM applications, several requirements are identified:

1. It would be helpful to have a standardized compound index that captures the overall state of socio-economic conditions of communties, with subdimensions that are easy to disect and understand for lay people and practitioners.

2. Given how communities do not exist in isolation, it would also be useful to compare how communities compare within a region.
3. Another requirement is for such indicators to be provided as time-series to allow changes in sociol-economic conditions to be analyzed over time in relation to environmental changes or changes in economic activity related to natural resource development.

As the studies reviewed above fall short of meeting these requirements, this article presents an alternative approach to meet the stated requirements.

Approach

The approach taken here considers two aspects to ensure adequate integration with EBM and to meet the stated requirements listed above:

1. *Spatial Representation*: pertaining to spatial units used for communities and how they re represented in relation to spatial environmental and natural scientific data, and
2. *Index Composition*: how well an index represents socio-economic conditions, the transparency of the method used, and its understandability and relevance for lay people (public and stakholders, in addition to specialists).

1) Spatial Representation: One of the most critial requirements for EBM is the ability to relate index values to the physical environment of communities and regions, particularly in areas with where there is natural resource development and/or environmental conditions of concern. Integrating socio-economic data in such a way that it can be related to the environment is not a trivial process, and the spatial unit for representing communities is of critical importance (Eddy and Dort 2011, Eddy et al. 2020,Cumming et al. 2006). Studies reviewed above use standard census frameworks as the spatial unit of analysis. This is problematic because the euclidean geospatial frameworks used to collect census data do not often align with non-euclidean natural boundaries and patterns related to the physical geography and environment of regions where communities are situated. Failure to address this issue could result in violating fundamental cartographic principles resulting in misrepresentation of communities and regions, and misinterpretation of results (MacEachren et al. 2005)

To address these aspects, this study makes use of the CanEcumene 3.0 geodatabase (GDB) (Eddy et al. 2023). This database (GDB) was developed using natural boundaries for all communities in Canada (Eddy et al. 2020) (Fig. 1). The spatial unit of analysis in the CanEcumene GDB can be either point or area representations depending of the scale of analysis and requirements. Area representation of communities are represented by natural boundaries derived from satellite DMSP 'night-lights' imagery for the year 2010. Identifiers from Census sub-divisions (CSDs) were attached to each point and polygon feature representing communities thereby providing an alternative spatial framework from which to map and analyze Census variables and derivatives. Data can be mapped using either point or polygon features, but unlike the use of Census polygon features, CanEcumene data does not obscure other environmental data when displayed simultaneously. Additionally, because CanEcumene data contain accurate locations of communities, and in contrast to choropleth mapping with standard Census boundaries, data can be used for spatial interpolation for a more accurate representation of regional patterns.

2) Index Composition: Several aspects are considered in composing indicators and indices for EBM applications. These include: a) how the terms *indicator* and *index* are defined, b) their *purpose,* and how they are used, and c) how they are *constructed*.

a) The term *indicator* has been defined in many different ways in many disciplines, including EBM (Heink and Kowarik 2010). While there may not be a universally accepted definition of *indicator*, most define it in relation to the use of data or measurements that are used to assess or measure the *performance* of some phenomenon (ibid.). It is therefore important to distinguish indicators from *primary measurements* which are defined simply as "*the process of associating numbers with physical quantities and phenomena*" (Encyclopedia Britannica 2023). Primary measurements, or raw data, do not inherently carry decision value, wherease indicators are data that *also* carry decision value.

b) The second aspect consideres the *purpose* or intended usage of the indicator or index along with its user base. Many scientific or technical indicators are developed for analysts and specialists (such as studies listed above), while others are developed for use by the general public and lay people. Indicators and indices aimed for public use require additional consideration with regard to their ease of understanding and decision value for a wider audience (Eddy et al. 2014). This has implications for the choice of analytical method used in that statistical methods need to be transparent and easy to communicate and understand, while remaining scientifically robust.

c) Both a) and b) are carried forward in considering how indicators are *constructed*. This choice of data variables, spatial and temporal coverage, analytical method, and presentation and communication of results all need to be taken into consideration as a whole. From this vantage point, indicators may be composed through either *top-down* or *bottom-up* processes. In a top-down process, indicators and indices are first identified through either an end-user consultation or from another form of decision requirements analysis, followed by the search and collection of required data. In a bottom-up process, indicators are first identified from analysis of existing primary data and defined on the basis of exploratory analysis, such as was done with the studies that incorporate PCA above. The results are then assessed for their decision-value.

Here, a *hybrid* approach is used that involves statistical analysis of existing primary data while keeping in mind end-user needs, which in this case, include both analysts and the public in EBM applications. From an end-user perspective, the requirement is to have a set of indicators and overall index for all communities in Canada, and for multiple time periods, that are representative of key dimensions of socio-economic conditions, and are easy to understand and evaluate. This study benefits from the availability of the CanEcumene 3.0

GDB. In addition to the advantages the CanEcumene offers in terms of spatial representation, this database also contains a selection of eight core socio-economic variables (Table 2) that characterize communities as 'human habitats' (Eddy and Dort 2011). These variables cover census periods from 2001, 2006, 2011, 2016, and 2021, which allows mapping time-series changes in human habitat conditions. Hence, a core objective of this study is to develop and assess a method for mapping an index of *Vitality* for both communities (as a Community Vitality Index, CVI) and regions (as a Regional Vitality Index, RVI) for all of Canada using the socio-economic variables and time periods available in the CanEcumene GDB.

Method

The method developed involves a four step process using community point reference and associated attribute data, a polygonal boundary file that represents the extents of the Canadian ecumene, and the socio-economic tables, all extracted from the recently upgraded CanEcumene 3.0 geodatabase (Fig. 2). The socio-economic tables contain eight variables described in Table 2, and indicated as HHI variables in Fig. 2. GIS and data files are available in Eddy et al. (2023) (CanEcumene 3.0 GDB) and Eddy (2024) (Regional and Community CVI GDB).

Step 1: Deriving Indicator Variables

The first step involves deriving a set of community vitality indicators (CVI) from the HHI variables listed in Table 2. Table 3 provides a list of five indicators along with the fomulas and a rationale for selection. Each indicator represents a sub-dimension of an overall index covering Population Change, Age Structure, Education, Employment, and Economy. All indicators are calculated for each census year from 2001 to 2021 at 5-year intervals to support time-series and trend analyses. A summary of statistical properties for each variable and year is provided in Table 4.

The five indicators represent major dimensions of a communities vitality, all of which are positively oriented whereby lower values are regarded as indicators of lower vitality and higher values are indicative of higher vitality (with the exception of Age in which the inverse values are used to indicatre higher vitality). Pearson-r coefficients show mostly very low to moderate correlation among indicators suggesting they are sufficiently independent (Table 5). This is partly reflected by the variability and direction of skewness of variables, which are observed to shift among Census periods (Table 4). Several trends are worth mentioning. All variables exhibit an increase in mean and median values along with increasing spread of the distribution indicated by increases in minimum, maximum and standard deviation values (Table 4). Overall, although Canada's population is growing, the increase in average age structure ratio beyond values of 1.0 indicates an aging population. Increases in education, employment and residential real estate values/capita indicate continuous growth and development. These statistical characteristics of the data are of critical importance in selecting an appropriate method for standardized scoring of variables when transforming primary data values into indicator and index scores.

Step 2: Calculating Percentiale Ranks (Pr)

Three measures of standard scoring were considered including standardized z-scores (z), and s-scores (s), and percentile ranks (Pr) (Table 6). The benefits of the z-score is it provides a useful standard measure of a value in terms of its positive or negative distance from the mean value. However, for skewed distributions, it is necessary to transform the data to a normal distribution. While it is possible to used z-scores to compare different variables, it is not useful for variables that have skewed distributions that vary over multiple time periods, such as the case with the CVI variables described above. In contrast to z-scores, which provide standard values in the (-4,+4) range, s-scores provide values in the (0,1) interval. However, using standard s-scores results in the same problem when working with distributions that have changing skewness of observations over multiple time periods. It is also not possible to directly compare s-scores calculated from non-normal (skewed) distributions for different variables and over different time periods.

For these reasons, the percentile rank (Pr) measure is deemed most appropriate for our purposes. The rationale in using the percentile rank method is based on the assumption that there is no absolute measure of overall vitality and that it is only possible to compare how communities are performing relative to one another. Pr values range in the (0,1) interval and can be expressed as percentages indicating how a community ranks in terms of its relative position to other communities. A value of 0.25 for variable *M*, for example, means a communties data value is higher than 25% of other communities, and 75% less than the remaining communities. Taking an average of Pr scores from multiple variables will indicate an overall Index score for a particular community. The Pr measure is not sensitive to outliers and does not require normalization. The only caveat with the Pr measure is that ranked values are on an unequal interval. This is deemed to be not a major issue with the data variables described above as few data values are affected due to the skewness of the distributions.

Percentile rank (Pr) scores are first calculated for each indicator and each year and for three categories: *ca* - all of Canada, *pt* - Provinces/Territories, and *pc* - Population Class. Scores are calculated for the three categories to allow for more equitable comparisons based on province or territory and population size classes (from hamlets to major cities) in addition to comparisons of all communities in Canada. For example, a community may score a low value when compared against all other communities in Canada, but may have a higher score for its province or territory, or its population class. This process is repeated for all variables, categories, and census years. Finally, overall CVI Index scores are calculated by taking the average of indicator percentile rank values of the three categories (ca, pt, pc) for each census year.

The result of these first two steps is three new sets of tables (indicators, percentile ranks, and CVI scores) indexed by community for each census year, allowing analysis of scores based on individual categories, or as an aggregate CVI index score. All tables can be related back to the master populated places table in the CanEcumene 3.0 geodatabase for mapping and further analysis using additional descriptive attributes.

Steps 3 and 4: Mapping the Results

The third and fourth steps involve mapping the results in two forms: Step 3) as individual community vitality index (CVI) point maps, and Step 4) as regional spatial (raster) interpolations of CVI point data to produce regional vitality index (RVI) maps. Mapping CVI scores as points simply requires joining the CVI scores tables to the populated places point file in the CanEcumene GDB, then mapping the data according to the preferred legend and style. Mapping regional RVI scores requires performing a spatial interpolation of the point data used in creating the CVI point maps. For this process, the CVI point scores are used as the input into the interpolation, and an ecumene extents boundary file is used to limit the extent of the interpolation. Limiting the extent of the interpolation prevents values from being projected onto geographic regions without permanent settlements or infrastructure. The spatial interpolation parameters used are the same as those used for interpolations in Eddy et al. 2020 (Supplement A). The following section discusses the results using a selection of maps along with statistical graph outputs.

Results

Results are presented in two forms corresponding to Steps 3 and 4 above:

1. a CVI *point* map (Fig. 3), and
2. a RVI *interpolation* map (Fig. 4), supplemented by additional maps and graphs in Suppl. materials 1, 2.

Fig. 3 is a CVI point map that shows individual CVI scores for each community according to percentile ranks in quintiles. In the on-line mapping interface of this data, users may dynamically zoom and pan the map, and query an individual community to retrieve CVI scores for each indexing category (*ca, pt, pc*) plus the average CVI score (Eddy 2024). Although visualizing the results in this form has some limitations due to the overlap of multiple points in the higher populated areas of southern Canada, several patterns can be seen. CVI scores are generally higher in the vicinities of major cities, such as the region between Montreal and Toronto, and southern British Columbia. This is in contrast to northern and remote communities that generally show lower CVI scores, and mixed CVI scores in the rural areas of the prairie and Atlantic regions.

The spatial interpolation map shown in Fig. 4 provides an alternative means of visualizing the results as a Regional Vitality Index (RVI) map. This map reveals an important aspect about community and regional development across the country that generally follows Tobler's law (Tobler 1970), whereby communities that are closer to each other tend to have similar values from those further apart. Many areas show this tendency for regions or clusters of communities to have similar scores illustrating how no community is an island unto itself, but is part of a region of similar socio-economic conditions. This is evident in the higher scores in the vicinity of larger urban areas, while distal and remote regions clearly show significantly lower RVI scores than the southern regions. Regions surrounding Whitehorse, Yellowknife, and Labrador City are noteable exceptions. This pattern is worth noting as many of these northern communities are Indigenous communities located in areas of higher risk to increased wildfire and effects of climate change (Erni et al. 2021, Erni et al. 2024).

As with the points map in Fig. 3, many areas show mixed RVI scores illustrating some variablity in socio-economic conditions. Suppl. material 1 contains RVI maps for all five Census periods (2001-2021) which reveal how RVI values change over time. One pattern worth noting is the decrease in RVI values in the prairie regions and increase in RVI values in the Atlantic regions from 2001 to 2021. It is beyond the scope of this study to comment on reasons for these changes, however they highlight patterns worthy of investigation. Other trends worth noting are shown in box and whisker plots Fig. 5 a number of community dimensions extracted from the CanEcumene Populated Places master table.

As observed in both of the point CVI and the interpolated RVI maps, there is a clear decreasing trend in CVI scores with Ecumene Zones from core economic areas (southern) to distal and remote regions (northern), with a corresponding decrease in the range of values. A similar trend is osbserved with Population Category values where there is a clear decreasing trend from metropolitan and larger cities to small towns, villages and hamlets, although the range in distribution of values increases with this trend. Two other dimensions for Indigenous communities and Forest Zones highlight two categorical differences worth noting. Indigenous communities have noticeably lower CVI scores compared with non-Indigenous communities, and communities categorized as mixed Indigenous and non-Indigenous have similar CVI scores as communities categorized as non-Indigenous. For Forest Zones, communities located in forested areas show slightly lower CVI scores than non-forested communities. Suppl. material 2 contains the same type of plots for all Census years (2001-2021) which remarkably show very little change in these trends over the 25 year period.

Conclusions

The method developed here for mapping a Regional and Community Vitality Index (RVI/CVI) for Canada has both advantages and limitations. One of the main advantages is the method is more straightforward and computationally simpler than comparable methods. It uses only eight primary Census variables that are measured consistently over time to derive five sub-indicators of vitality pertaining to:

1. population growth,
2. age structure,
3. education,
4. employment, and
5. economic wealth.

The use of percentile ranks is a computationally efficient metric that is easily understood by non-experts. RVI/CVI values can be dissected to examine which indicators are performing poorly thereby identifying policy objectives for communities and regions.

The use of the CanEcumene 3.0 GDB with its use of natural boundaries as opposed to administrative or census boundaries ensures a naturalized geospatial representation of communities that is more amenable to integration with environmental and natural scientific datasets. Because the method follows a naturalized approach, regional RVI patterns can be derived from spatial interpolation of CVI values offering a continuous (non-discrete) representation of the variability of socio-economic conditions across Canada. However, as noted in Eddy et al. 2020, the CanEcumene 3.0 GDB may be limited for local scale applications in some regions, and does not provide details *within* major urban centres.

Other limitations are more precautionary than actual limitations as such. It is important to appreciate that RVI/CVI scores are *not absolute* measures of vitality, rather are *relative* indicators. This has implications for how both the data and messaging the maps provide are interpreted. As there is no absolute measure of vitality, it is more appropriate to think of the comparative RVI/CVI scores as *higher or lower* vitality, and not *high* or *low* vitality. Communities and regions with lower vitality scores may exhibit strong vitality in ways that are not captured by the indicators used in this method. Conversely, communities and regions high vitality scores may have weaker vitality in other ways, or locations of lower vitality that are not captured by the scale and resolution of this data.

Most importantly, as with many socio-economic indicators and indices, the RVI/CVI scores are not a measure of *well-being* or *resilience* of communities and regions as these aspects can only be assessed using qualitative methods at a local scale (Beckley et al. 2002, Stedman et al. 2004). However, it is possible the RVI/CVI data and maps may be used as a surrogates for *sustainability* or *vulnerability* in certain contexts. Regions and communities with higher scores are more likely to have the resources to implement sustainability policies and practices. Conversely, RVI/CVI scores may be inversely proportional to the vulnerability of regions or communities in that lower scores are more likely an indication of lower adaptive capacity. In all cases, care must be taken in the interpretation and application of RVI/CVI data and maps.

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Ethics and security

The work herein was conducted under compliance with the Values and Ethics Code of the Government of Canada. This study did not require any ethics clearance.

Author contributions

The author is the principal investigator and conducted all research contained in this article including data collection, analysis, method development, results and writing of the manuscript.

Conflicts of interest

The authors have declared that no competing interests exist.

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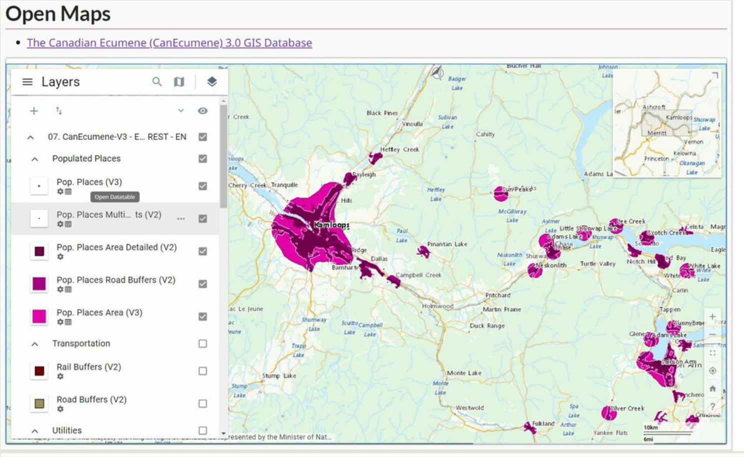

Figure 1.

Detailed view of the CanEcumene 3.0 GDB for an area in southern British Columbia showing both larger and small communties and their spatial representation. Each community is represented by multiple natural boundary types for use with different scales of analysis and representation. (This view captured from the OpenMaps implementation at https://open.canada.ca (search CanEcumene 3.0))

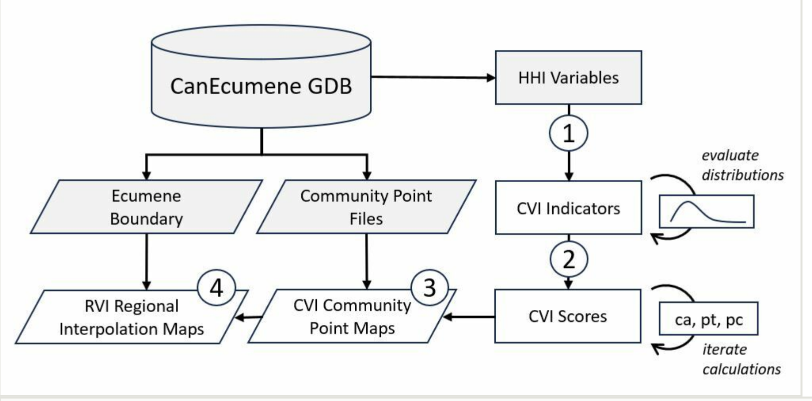

Figure 2.

Process model showing the four (4) steps involved in mapping community vitality index (CVI) and regional vitality index (RVI) data using the CanEcumene 3.0 GDB for Canada. Shaded symbols indicate existing data files, and non-shaded symbols indicate new data files. See text for complete description of processing steps.

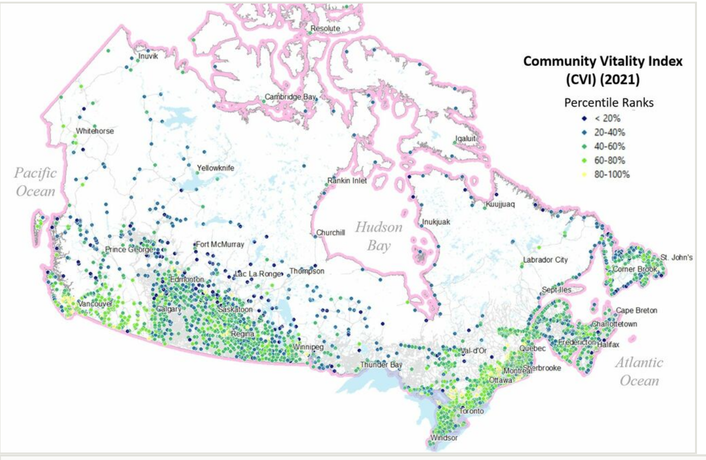

Figure 3.

Community Vitality Index (CVI) 'point map' for all of Canada for Census year 2021. Note: CVI results displayed in quintiles.

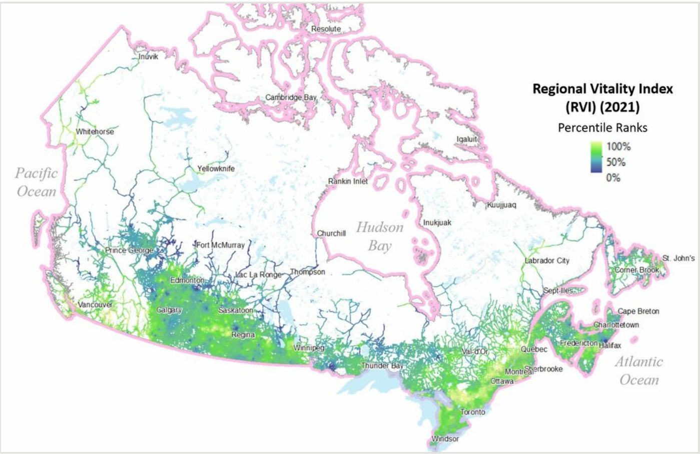

Figure 4.

Regional Vitality Index (RVI) 'interpolation map' of all of Canada for Census year 2021. Note: RVI results displayed as continuous percentile rank values.

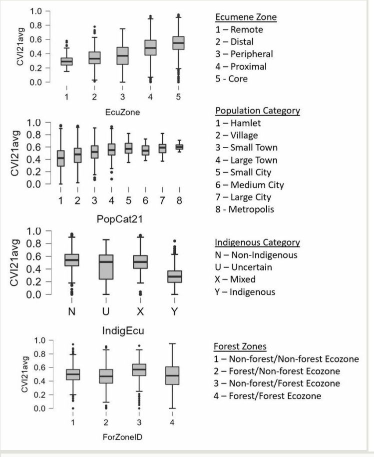

Figure 5.

CVI results for multiple dimensions of community classification displayed as box plots:

1. Ecumene Zone,
2. Population class,
3. Indigenous classification, and
4. Forest Zone.

Table 1.

Summary of recent efforts for socio-economic indiex database development for Canada. See text for discussion. (Note: PCA=Principale Component Analysis, CT=Census Tract, DA=Dissemination Area, CSD=Census Subdivision)

Source	Database/Index	Core Method	Spatial Units	Time Periods	Comments
Chakraborty et al. 2020	Social Vulnerability Index (SoVI)	PCA on 49 variables	CT	2016	Data not available
Chan et al. 2015	Socio-Economic Status (SES) Index	PCA on 22 variables	DA	2006	Data not mapped geographically
ISC 2021, 2016	Canadian Well Being (CWB) Index	Variable Weights	CSD	2016, 2021	Method description incomplete
Journeay et al. 2022	Canadian Social Vulnerability Model (CanSVM)	Hazards of place model	DA/CT	2016	Complex framework for specialists
Scott, K 2016	Canadian Index of Wellbeing (CIW)	Qualitative survey	Limited	various	This index is not mapped for communities
StasCan 2019	Canadian Index of Multiple Deprivation (CIMD)	Factor analysis on 17 variables	DA	2016, 2021	Designed for social analysis

Table 2.

Selected socio-economic variables used to characterize communities as 'human habitats' (after Eddy and Dort (2011)) See this table for derived indicators.

Symbol	Field	Description
P_a	TotPop{PYR}	Total Population (Previous Census Year)
P_b	TotPop{CYR}	Total Population (Current Census Year)
Y	TotYut{YR}	Total Youth (<15 yrs)
S	TotSen{YR}	Total Seniors (>65 yrs)
P	TotPost{YR}	Total Post-Secondary Education
F	TotLForce{YR}	Total Labour Force
U	TotLFUNM{YR}	Total Unemployed
D	TotValDwell{YR}	Total Value of Dwellings

Table 3.

Five community vitality indicators (CVI's) derived from primary HHI variables provided in Table 1, along with formulae and rationale for selection. Note elements of formulas pertain to those listed in Table 2.

Symbol	Indicator	Description	Formula	R
Pop	Pop{YR}	Population (% 5 yr. Change)	= (P_b/P_a)-1	Population growth indica indicates negative vitality
Age	Age{YR}	Age Structure (Seniors/Youth)	= S/Y	Communities with Age > replace seniors (declinin indicate communities wit (increasing vitality). (Not taken in the calculation o
Edu	Edu{YR}	Education (% with Post-Secondary Education)	= P/Pb	A larger proportion of res education indicates posit (negative vitality).
Emp	Emp{YR}	Employment (% Employed)	= 1-(U/F)	Taken as the inverse of u employment rates indica
Eco	Econ{YR}	Economy (Total value of Dwellings/capita)	= D/P_b	The total value of all dwe overall wealth in a comm economic activity. Higher and lower values indicat

Table 4.

Statistical summary of RVI/CVI indicator variables derived from the CanEcumene 3.0 GDB. (Note: Econ values expressed in standardized 2001 $CDN)

	Valid	Median	Mean	Minimum	Maximum	Std. Deviation	Skewness	Std. Error of Skewness
PopCh01	2875	-0.02	-0.01	-0.76	0.98	0.12	1.72	0.05
PopCh06	2794	-0.01	0.00	-0.96	0.98	0.15	0.63	0.05
PopCh11	2819	0.00	0.05	-0.99	17.36	0.62	19.04	0.05
PopCh16	2903	0.00	0.06	-1.00	30.41	0.88	23.77	0.05
PopCh21	2999	0.01	0.05	-1.00	65.51	1.27	46.37	0.04
Age01	2851	0.72	0.80	0.01	6.50	0.56	1.96	0.05
Age06	2819	0.89	0.99	0.02	9.00	0.74	2.95	0.05
Age11	2847	1.07	1.23	0.00	15.00	1.01	4.03	0.05
Age16	2963	1.27	1.54	0.00	79.00	1.92	23.04	0.04
Age21	2941	1.47	1.87	0.00	34.00	1.86	5.06	0.05
Edu01	2892	0.31	0.31	0.02	0.81	0.10	0.22	0.05
Edu06	2836	0.32	0.31	0.02	0.84	0.10	-0.20	0.05
Edu11	2904	0.29	0.25	0.00	0.98	0.17	-0.17	0.05
Edu16	3000	0.37	0.35	0.00	0.88	0.12	-0.56	0.04
Edu21	2987	0.37	0.36	0.00	1.00	0.12	-0.65	0.04
Emp01	2898	0.89	0.85	0.14	1.00	0.14	-1.46	0.05
Emp06	2867	0.92	0.87	0.17	1.00	0.12	-1.59	0.05
Emp11	2276	0.91	0.88	0.17	1.00	0.12	-1.48	0.05
Emp16	2975	0.90	0.86	0.00	1.00	0.11	-1.60	0.04
Emp21	2950	0.90	0.88	0.20	1.00	0.09	-1.75	0.05
Econ01	2536	28,772	33,077	1,776	229,166	18,803	2.29	0.05

Econ06	2504	38,257	47,388	1,029	341,772	32,016	2.56	0.05
Econ11	1916	51,884	60,401	374	353,028	37,851	1.93	0.06
Econ16	2558	76,626	99,230	3,835	2,312,977	102,631	8.01	0.05
Econ21	2570	78,169	107,765	1,456	11,793,103	96,553	4.20	0.05

Table 5.

Pearson r coefficients for five regional and community vitality indicator variables showing low to moderate correlation values.

	PopCh01		**Age01**		**Edu01**		**Emp01**		**Econ01**
1. PopCh01	—								
2. Age01	-0.19	***	—						
3. Edu01	0.01		0.21	***	—				
4. Emp01	0.1	***	0.18	***	0.41	***	—		
5. Econ01	0.4	***	0.01		0.62	***	0.35	***	—
	PopCh06		**Age06**		**Edu06**		**Emp06**		**Econ06**
1. PopCh06	—								
2. Age06	-0.08	***	—						
3. Edu06	0.07	***	0.3	***	—				
4. Emp06	0.06	***	0.08	***	0.4	***	—		
5. Econ06	0.32	***	0.01		0.49	***	0.31	***	—
	PopCh11		**Age11**		**Edu11**		**Emp11**		**Econ11**
1. PopCh11	—								
2. Age11	-0.08	***	—						
3. Edu11	0.02		0.04		—				
4. Emp11	-0.02		0.11	***	0.3	***	—		
5. Econ11	0.07	**	-0.01		0.57	***	0.23	***	—
	PopCh16		**Age16**		**Edu16**		**Emp16**		**Econ16**
1. PopCh16	—								
2. Age16	-0.03		—						
3. Edu16	0.01		0.22	***	—				
4. Emp16	0.03		-0.01		0.43	***	—		
5. Econ16	0.03		0.32	***	0.37	***	0.15	***	—
	PopCh21		**Age21**		**Edu21**		**Emp21**		**Econ21**
1. PopCh21	—								
2. Age21	-0.01		—						
3. Edu21	0.02		0.24	***	—				

4. Emp21	0.01		-0.13	***	0.29	***	—		
5. Econ21	0.06	**	0.19	***	0.36	***	0.13	***	—
* p < .05, ** p < .01, *** p < .001									

https://doi.org/10.3897/arphapreprints.e122783

Table 6.

Common measures used in standard scoring. (Note: x_i = variable value, u = mean, SD = standard deviation, n = number of observations, CF_x = *cumulative frequency of* x_i, F = *Frequency of* x_i).

Measure	**Formula**	**Comments**
z-Score (*z*)	$z = (x_i - u)/SD$	Senstive to outliers, requires normalizatio
Standard Score (*s*)	$s = (x_i - min)/(max - min)$	Sensitive to outliers, may require normal
Percentile Rank (*Pr*)	$Pr = (CF_x-(0.5xF_x))/n$	Not sensitive to outliers, does not require

Supplementary materials

Suppl. material 1: Regional Vitality Index (RVI) Interpolation Maps for Canada (2001-2021)

Authors: BG Eddy
Data type: Maps
Brief description: Series of maps showing spatially interpolated Regional Vitality Index (RVI) values for Canada. These maps illustrate how RVI scores vary by region and proximity to major economic cores, and also show changes over time. Most notable is the significantly lower scores in the peripheral and remote regions north of the high population areas, and the gradual increase in scores for Atlantic Canada and gradual decrease in scores for the praire regions (from Winnipeg to Prince George).
Download file (1.03 MB)

Suppl. material 2: Box and Whisker Plots of CVI Values for Selected Community Dimensions for Census Periods 2001-2021

Authors: BG Eddy
Data type: Charts
Brief description: Series of Box and Whisker plots for a selection of community dimensions showing trends and variations among categories: 1) Ecumene Zone, 2) Population Category, 3) Indigenous Category, and 4) Forest Zones. Interpretive notes provided on each set of graphs.
Download file (489.51 kb)