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Identifying Neighborhoods at Potential Risk of Food Insecurity in Rural British Columbia

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***Abstract*—**Substantial research has indicated that socioeconomic and demographic characteristics' of neighborhoods are strong determinants of food security. The aim of this study was to develop a Food Insecurity Neighborhood Index (FINI) based on the associated socioeconomic and demographic variables to identify the areas at potential risk of food insecurity in rural British Columbia (BC). Principle Component Analysis (PCA) technique was used to calculate the FINI for each rural Dissemination Area (DA) using the food security determinant variables from Canadian Census data. Using ArcGIS, the neighborhoods with the top quartile FINI values were classified as food insecure. The results of this study indicated that the most food insecure neighborhood with the highest FINI value of 99.1 was in the Bulkley-Nechako (central BC) area whereas the lowest FINI with the value of 2.97 was for a rural neighborhood in the Cowichan Valley area. In total, 98.049 (19%) of the rural population of British Columbians reside in high food insecure areas. Moreover, the distribution of food insecure neighborhoods was found to be strongly dependent on the degree of rurality in BC. In conclusion, the cluster of food insecure neighbourhoods was more pronounced in Central Coast, Mount Wadington, Peace River, Kootenay Boundary, and the Alberni-Clayoqout Regional Districts.

***Keywords*—**Neighbourhood food insecurity index, socioeconomic and demographic determinants, principal component analysis, Canada Census, ArcGIS.

I. Introduction

FOOD security is a vital determinant of population health and wellbeing. The concept was introduced in the mid-1970s, as a movement to combat hunger and food crisis at the global level [1]. Due to multifaceted nature of this concept, many international and governmental organizations defined food security based on specific purposes and policies at national, community, household and individual level [2]. Food security is defined as "access by all people at all times to enough food for an active, healthy life and includes at a minimum: a) the ready availability of nutritionally adequate and safe foods, and b) the assured quality to acquire acceptable foods in socially acceptable ways (e.g., without resorting to emergency food supplies, scavenging, stealing, or other coping strategies)" [3].

BC is known as one of the wealthiest provinces in Canada with its strong socioeconomic and healthcare infrastructures [4]. In spite of these advantages, the rate of food insecurity for average British Columbians has steadily increased over the past decade, reaching 12.7% in 2012 which is relatively high compared to other provinces [5]. Moreover, this situation is more severe among low-income groups in the province such as Aboriginal people, homeless populations, and recipients of social assistance and single mothers with children under age five. Polson [6] noted that despite the advent of food assistance programs in BC, some low-income rural communities, homeless people, and Aboriginal people are still suffering from some degrees of food insecurity. According to Vancouver Coastal Health [7], out of around half-million people struggling with food insecurity, more than 90,000 of whom are suffering from severe food insecurity. Likewise, using 2011-2012 Canadian Community Health Survey (CCHS), Li et al. [8] reported that the rate of food insecurity among female lone-parent households with children under the age of 18 was reported three times more than average British Columbians.

In order to depict a more comprehensive picture of food insecurity among a given community, both supply-side and demand-side key drivers of these phenomena should be investigated. In terms of supply-side drivers, especially at household level, the focus of researchers is mostly on individuals' food environment which refers to the place where people live (e.g. home, school, worksite), the different types of food providers (e.g., grocery stores, restaurants, community gardens, soup kitchens, food banks) in their area, and other physical settings which influence cost and availability, and food distribution [9], [10]. On the other hand, demand-side determinants of food security include socioeconomic and demographic factors, education, and cultural norms which impact on food access [11]-[13].

Measuring food security has always been a source of controversy. Most scholars and organizations use qualitative, quantitative, and mixed methods employing interview, participatory approaches, and pre-defined questionnaires to collect primary data and measure the state of food insecurity mostly at individual and/or household level. Despite the value of collecting primary data to measure and investigate food insecurity, it has some certain shortcomings. One of the main disadvantages of this approach is the lengthy process of data collection. Moreover, this process is very costly and very limited number of individuals can participate in the study. This makes the situation hard for communities and households which are in immediate need of policy interventions especially in vaster with sparsely populated areas such as rural BC.

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Recently, some researchers have used area-level socioeconomic and demographic variables to identify deprived areas where residents are at potential risk of food insecurity. The advantage of using this approach which focus on demand-side determinants of food security is that the data are readily available (e.g., census data) and larger areas can be covered in the analysis. Moreover, all the analysis can be performed over a very short period of time. For example in some studies [14]-[16], area-level income variable was used to identify deprived areas. Several other studies suggest that, aside from income, other socioeconomic factors, such as age, ethnicity, education, car ownership, and housing, should be incorporated in defining deprived areas [17]-[20]. For instance, Jiao et al. [21] and Morris [22] added car ownership and unemployment rate to income criteria to classify deprived rural areas in the United States. Similarly, Hubley [23] used population density and percentage of participation in SNAP factors, in addition to income criteria, to identify problematic rural communities in Maine county.

Few researchers have developed a deprivation index (or score) to produce more accurate results based on a set of socioeconomic and demographic variables in rural areas. In a comprehensive study, Sharkey et al. [24] used unemployment, poverty, education, household crowding, public assistance, vehicle ownership, and telephone service factors to develop a community deprivation index with three categories (low, high and medium) in six rural counties in Texas. Likewise, Gustafon et al. [25] estimated the Neighbourhood Deprivation Index (NDI) in 14 counties in Kentucky with the following criteria: income below poverty line, female headed households, public assistance recipients, unemployment rate, males in management, education attainment, and households with at least two persons per room. By employing PCA technique, they weighted each factor to estimate the final deprivation scores. The deprivation scores were estimated between -4.07 to 4.34. Finally, neighborhoods with the top quartile scores (2.19 to 4.34) were classified as highly deprived neighbourhoods. In order to investigate the deprivation level in rural Grey-Bruce, Ontario, Sadler et al. [26] constructed a composite index by including income, single parenthood, education attainment, and unemployment variables, for DAs. They standardized each variable and summed the related z-scores to calculate the deprivation index for each DA. The results indicated high degrees of deprivation in Arran-Elderslie, Hanover, Owen Sound and in the town of Meaford.

BC is a very vast province with scattered population in rural and remote areas. Despite all the past efforts, the rate of food insecurity and health related outcomes are increasing. Moreover, majority of traditional food security studies are restricted to a few communities in rural and remote areas. Substantial amount of time and financial resources are needed to conduct more studies and investigate the state of food security for rural residents in BC. The main goal of this study is to construct Food Insecurity Neighbourhood Index (FINI) to identify the areas where residents are highly at potential risk of food insecurity in rural BC.

II. Data and Methods

In order to construct the FINI in BC's rural regions, the methodology to categorize deprived areas from Kirishnan [27] study in the province of Alberta was adopted. The advantage of their methodology is that the relative importance (i.e., weight) of each variable was taken into consideration in constructing the FINI. In terms of variable selection, the socioeconomic and demographic variables which were highly correlated with food insecurity across the literature [28]-[31] in Canada were targeted to develop the FINI in rural BC. The selected variable are described in Table I.

TABLE I
The Summary of Selected Variables in Developing FINI

Variable	Description
Elderly Population	Proportion of population 65 years and over
Aboriginal Status	Proportion of Aboriginal Population (First Nations, Inuit and Métis)
Low Income	Proportion of families with a low income after tax in 2005
Unemployment Rate	Population 15 or older unemployed
Lone parents	Proportion of lone-parent families with 3 or more Children
Education	Proportion of population 15 years and over Without Certificate, diploma or degree
Housing	Proportion of Tenant-occupied households spending 30% or more of household income on gross rent
Private Transportation	Total employed labour force 15 years and over without private transportation

PCA was performed to calculate a FINI for each rural DA using the eight variables in Table I. DA is the finest standard geographic area for which all census data (socioeconomic and demographic information) are disseminated in Canada [32]. Moreover, DA was chosen as the unit of analysis to achieve the possible highest level of accuracy by minimizing the Modifiable Areal Unit Program (MAUP) in this study. In the other words, the more disaggregated the unit of analysis, the more precise the statistical results [33], [34]. All of BC is divided by 7471 DAs. Of these, 6020 (80%) are urban and 1451 (20%) were classified as rural DAs by Statistics Canada. Metro Influence Zone (MIZ) which is developed by Statistics Canada was used to classify rural and urban DAs. The proportion of the DAs in urban and rural (MIZ categories) areas is summarized in Table II.

TABLE II
Summary of DA Proportions in Rural BC According to MIZ Categories

	Total Rural	Rural (MIZ)			
		Strong	Moderate	Weak	No
DAs	1,451	160 (11)	334 (23)	560 (38.6)	397 (27.4)

Note: Figures in parenthesis indicates percentages of BC rural DAs in Each MIZ

Canadian Census 2006 socioeconomic data for calculating the Depravation Index was obtained through BC Research Libraries' Data Service. It should be noted that the most recent socioeconomic and demographic data at DA level are available for Canadian Census 2006 but not for Census 2011. Moreover, the National Household Survey (NHS) by Statistics

Canada, which was supposed to supplement the flaws in Census 2011 data collection, has poor data quality especially for small geographic areas [35]. Similarly, Hulchanski et al. [36] asserted that the socioeconomic data in NHS are not valid and using them can significantly alter the results of a study from reality.

A. Index Construction

PCA was used to integrate the selected variables into a single index. PCA is a quantitative technique for identifying a smaller number of uncorrelated variables (i.e., components) from a relatively larger set of observed variables without losing much information [37], [38]. This technique produces a weight for each variable according to its contribution in explaining the differences between DAs. In order to construct the index component scores were estimated for each of the eight variables using regression method. Component scores predict the location of each variable on the component [27], [39]. In the regression model, independent variables are the standardized observed values of the items in the estimated components whilst the component scores are the dependent variables [39]. Then, the percentage of variance associated with each final extracted component (based on eigenvalues of components greater than one) was obtained after running PCA with Varimax rotation. Finally, the summation of each DA's component scores multiplying by respective (unique) explained variance percentage of each component were calculated as Non- standardized FINI (NSFINI) for each DA.

As it is recommended in Krishnan's study [27], for the sake of interpretation and projecting the results on map, the NSFI for each DA was standardized on the scale of 0 to 100 using the below equation:

$$\text{Standardized } (SFINI_i) = \frac{NSFINIi - Min(NSFINI)}{Max(NSFINI) - Min(NSFINI)}$$
$$i = 1,2,\ldots, 1066$$

The greater the SFINI, the more deprived the DA is. In this study, the DAs with the top quartile SFINI were classified as deprived rural communities which are potentially food insecure. All statistical analysis were performed using SPSS Version 22.0 [40].

III. Results

Prior to performing PCA, the Kaiser–Meyer–Olkin (KMO) Measure of Sampling Adequacy and Bartlett's test of sphericity were conducted to determine whether or not PCA was an appropriate technique to construct FINIs. The KMO Measure of Sampling Accuracy tests partial correlations among variables (homogeneity of variables). The KMO statistic ranges from 0 to 1 with a value greater than 0.70 indicating that the PCA produces reliable results [41]. Bartlett's test of sphericity tests the null hypothesis whether the correlation matrix is an identity matrix. The Null hypothesis is desired to be rejected ($P < 0.05$) in favor of an alternate hypothesis in order to proceed with PCA as the appropriate technique for constructing FINIs [42]. The results of both tests are shown in Table III.

TABLE III
Results of Kaiser - Meyer - Olkin (KMO) Measure and Bartlett's Test of Sphericity

KMO Measure of Sampling Adequacy	Bartlett's Test of Sphericity		
	Chi-Square	*df*	P-Value
0.782	2218.19	28	0.001

According to Table III, both the KMO statistics, with acceptable value of 0.782 and Chi-Square value of 2218.19 ($P < 0.001$), indicated the suitability of PCA for constructing FINIs. Therefore, PCA analysis was performed to obtain rotated factor loadings and communalities. These results are shown in Table IV.

TABLE IV
Summary of PCA Results with Varimax Rotation Factor Matrix

Variable	Components		
	1	**2**	**Communalities**
Elderly Population	0.1	**-0.762**	0.591
Aboriginal Status	**0.574**	**0.666**	0.774
Low Income	**0.735**	0.066	0.545
Unemployment Rate	**0.704**	**0.36**	0.625
Lone parents	0.074	**0.466**	0.223
Education	**0.571**	**0.533**	0.61
Housing	**0.71**	-0.242	0.563
Private Transportation	**0.605**	0.146	0.388
Percent of Explained Variance	**38.982**	**14.984**	**53.966**

As indicated in Table IV, two components account for 53.996% of the variance. These were selected to calculate FINIs. The first component explained 38.982%, and the second component accounted for 14.984% of the variance. It should be noted that the component selection was based on the criteria of respective eigenvalues greater than one, which is the common standard in PCA analysis in the literature. According to the component loadings, the first component has a strong positive association with almost all original variables except elderly population and lone parent variables (values in bold). On the other hand, the second component indicated strong positive relationships with Aboriginal status, unemployment, lone parent, and education variables and a strong negative relationship with the elderly population variable. Moreover, the highest communality with value of 0.774 is related to the Aboriginal status variable. In the other words, the extracted components captured 77.4 % of variation in the Aboriginal status variable. In contrast, the lowest estimated communality is 0.223 for the single parent variable indicating that only 22.3% of its variance was explained by extracted components.

In the final step, using the component scores and the percentages of explained variation by each component, FINI for each DA (N=1066) on a scale of 0 to 100 was calculated. The higher the FINI, the higher the risk of food insecurity is. The highest FINI value was 99.1 which is the Bulkley-Nechako (central BC) area whereas the lowest FINI with value of 2.97 was for rural communities in the Cowichan Valley

area. In total, 98.049 (19%) of the rural population of British Columbians reside in deprived areas. In an attempt to illustrate the distribution of FINIs across various types of rural communities, their distribution (based on FINI quartiles) across MIZs is presented in Table V.

TABLE V
THE DISTRIBUTION OF FINI QUARTILES ACROSS MIZS

DI	MIZs				P-value
	Strong	Moderate	Weak	No	
Q1	69 (25.9)	85 (32)	106 (39.8)	6 (2.3)	0.001
Q2	51 (19.2)	90 (33.8)	120 (45.1)	5 (1.9)	
Q3	24 (9)	85 (31.8)	144 (53.9)	14 (5.2)	
Q4	14 (5.2)	52 (19.5)	118 (44.2)	83 (31.3)	

Note: Figures in parentheses indicate percentages

As shown in Table V, of the 267 deprived rural areas with higher prevalence risk of food insecurity, 118 (44.2%) are found in Weak MIZ whilst only 14 (5.2%) of the deprived areas fall into Strong MIZ category. Moreover, the results of Chi-Square test with value of 222.41 ($P < 0.001$) indicated that the distribution of deprived communities (at DA level) is strongly dependent on MIZ category. In the other words, Weak and No MIZ categories are more likely to be classified as deprived areas with higher rate of food insecurity. For better understanding the distribution of deprived communities across rural areas (N=1,066), the FINI quartiles are also shown on a map of BC (Fig. 1). The deprived DAs are shown in red. The cluster of deprived areas with higher probability of food insecurity problems are more pronounced in Central Coast, Mount Wadington, Peace River, Kootenay Boundary, and the Alberni-Clayoqout Regional Districts.

According to Fig. 1, DAs with the FINI between 2 to 19 (colored in yellow) are the least deprived areas. In contrast, DAs with the FINII above 29 (colored in dark red) are the most deprived areas. It should be noted that in terms of geographic hierarchy, in the 2006 Canadian Census, rural BC is divided into 1,451 DAs. Of these 1,177 (81.1%) are residential and 274 (18.9%) are non-residential. As the main focus of this section is to identify food deserts, by definition, there is no interest for the other 274 non-residential DAs. Thus, my analysis is focused on the 1,177 residential DAs in BC. However, Statistics Canada disseminated the socioeconomic and demographic data for only 1,066 (90.6%) of the residential DAs. Therefore, I was only able to construct FINIs for the 1,066 (i.e., 90.6% of residential) rural. It should be noted that Statistics Canada did not disseminate socioeconomic and demographic data for 111 (9.4%) residential DAs because these are very sparsely populated places and dissemination of these data could breach their privacy. Both non-residential (N=274) and suppressed residential DAs (N= 111) are shown as 'no data' (cross hatched areas) on the map.

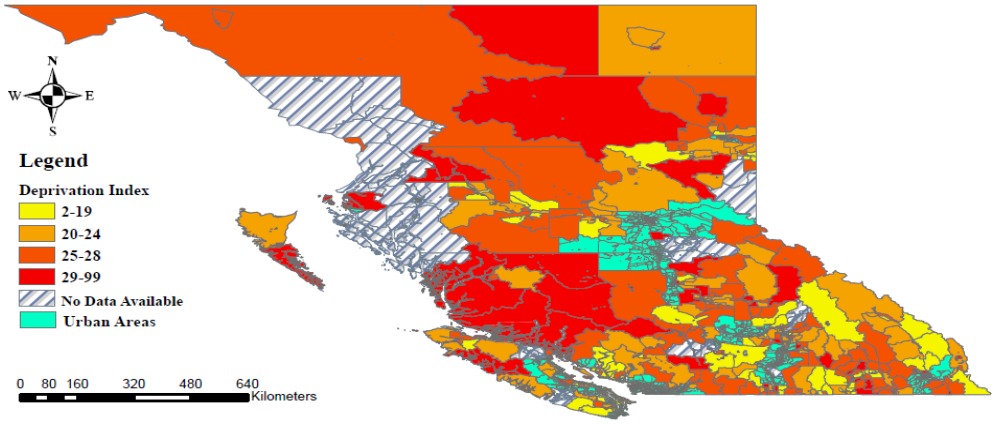

Fig. 1 The Distribution of FINI Quartiles in Rural BC (N=1,066)

IV. DISCUSSION

In this study, FINI was constructed to identify the areas with higher risk of food insecurity at DA level in rural BC. The results based on FINI score was almost consistent with the studies that used traditional approaches (e.g., interview and pre-defined questionnaires) either using primary or secondary data collection methods. For example, in a comprehensive study by Li et al. [8], using 2011-2012 CCHS data, the household food insecurity was reported highest in Northwest regions (18.8%) which fall into the first and second quartile of FINI scores. Moreover, there is convergence about the extent of food insecurity in rural BC in both studies with one major exception. In this study, North Shore/Coast Garibaldi areas falls into the top quartile of FINI score, whereas the prevalence of food insecurity in those regions was reported below the average (8.3% - 11.0%) in Li and colleagues' study. Budd and Moryson [43] reported that Central Vancouver Island areas are has a relatively higher food insecure households compared to average British Columbines. According to FINI scores in this study, those areas are identified as potentially food insecure areas.

Chan et al. [44] conducted a study to measure the state of food security in 21 on-reserve First Nation communities across BC. Using the US Food Security Survey Module developed by the United States Department of Agriculture (USDA), they reported that 41% of BC First Nations are

suffering from some degree of food insecurity. More than two-third of those First Nation communities fall in the food insecure areas which was identify by FINI. Similarly, Kuhnlein et al. [45] found out that residents of Nuxalk First Nation in Bella Coola area were struggling from food insecurity. Their findings are consistent with this study which indicated that Bella Coola area lie in the top quartile of FINI scores.

To date, FINI is one of the few indices which is specifically developed to identify the areas where people are likely to suffer from food insecurity. The results of this study can be highly beneficial to government officials within different jurisdictions and health practitioners to develop or refine food security programs especially toward the areas which were classified as potentially food insecure areas in rural BC. Moreover, researchers and scholar can take advantage of this study finding in identifying food deserts in both urban and rural communities.

The results produced by FINI in this study are subject to the Modifiable Areal Problem (MAUP) despite using DAs as the smallest possible unit of analysis which contains socioeconomic and demographic characteristics of residents. Simply put, MAUP arises when the calculated FINI for a DA is generalized to all the residents of that DA. For example, Ver Ploeg et al. [46] pointed out that a low-income individual might live in a well-off neighbourhood, whereas a high income individual might live in a deprived neighbourhood. Schuurman et al. [47] indicated that MAUP is unavoidable in areas-based deprivation indices due to population data aggregation by Statistics Canada. It should be noted that Statistics Canada does not disseminate individuals' socioeconomic and demographic data for the sake of privacy. Thus, for dissemination purposes, they aggregate the data into different geography levels (e.g., DA, Census Tract, and Census Subdivision) which makes the area-based deprivation indices prone to MAUP.

Future studies needs to investigate the feasibility and efficiency of local and governmental food security programs in problematic areas in rural and remote areas. Moreover, other studies can explore the contribution of traditional food systems in combating food insecurity especially in First Nation communities.

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