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Background & Objectives

Climate change is a global trend that imposes great consequences on society. Because of their small population size and relatively simple industrial structures, rural communities were more susceptible to social change caused by climate change compared to cities within the same period. This project aims to reveal the relationship between climate and social change in the last 40 years through the analysis of census data and climate records from 65 Quebec villages.

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Patterns of community and climactic change in Rural Quebec

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Hypothesis

As average temperatures around the globe rise, the number of frost days (define as the number of days in a year whose maximum temperature is lower than 0℃/32ºF) begins to diminish. As for rural Quebec communities, the global warming trend extends growing season and increases ease of transportation, which benefits the inhabitants of these. The population might positively correlate to average temperatures and negatively correlate to the number of frost days. Furtherly, the warmer climate would have influence on occupation structures: people may involve more in primary industry, including cultivation and fishing. More employments would be created in local communities, becoming a motivation for population increase and economic development.

Methods

1. Choosing the study area

By offering transportation and infrastructure support, cities can include near villages into their system so that interference the social changes of the villages. Thus, to study patterns of community and climatic change of Quebec rural area, the research focuses on 65 Quebec villages that are at least 100km away from cities.

2. Collecting census data

The Canadian census is collected every 5 years. Starting from 1981, there are 8 census years of data that record social data up to 2016. All are available from the Chass Data Centre [1]. It is a platform run by the University of Toronto which renders convenient access to census data provided by the Statistics Canada. From here we extract data that relate to social changes—including population, number of people that finished certain levels of education, income, mobility status, occupation structure [2], and household data. As the research went further, due to reasons like records missing, some social parameters proved incompatible with our analytic models, thus were abandoned.

3. Processing climate records and generate panel data

The climatic data which covers daily temperature records of the villages was inherited from Dr.Sarah May Harris' postdoctoral thesis. The success of agricultural production is dependent on the number of frost days in Canada. Thus, the number of frost days is used as a climate parameter, along with annual average maximum and minimum temperatures. Using Excel, climate and social data were sorted respective to years and communities to form a data frame and prepared for exportation to R for analysis

4. Fitting in the regression models and visualization work

R is utilized to analyze the data. Due to space limitations, the poster cannot present every graph, only examples are shown.

Firstly, goem_smooth in 'ggplot2' package was used to generate trend lines to show change of climate, population of the 40-year period(shown in fig. ①, take Aguanish as an example).

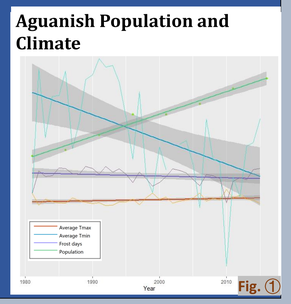

Fig. ①

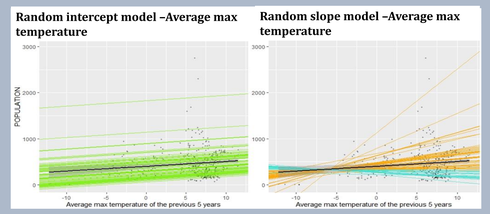

Fig. ②

Secondly, considering the characteristics of the unbalanced panel data, the Fixed Effects (FE) Model and Multilevel Model were used for analysis. In the FE model, the 'plm' package in R was used to generate a whole view of the correlation over all communities the 'plm' package was used to generate a whole view of the correlation over all communities. In the Multilevel Models, the clustered data of each community was fitted into random intercept and random slope regression models using the 'lme4' package [3] in R. Moreover, in order to observe the models better, line plots (fig. ②) and summary tables were generated (fig. ③, ④).

	Average_Tmax RI			Average_Tmax RS		
Predictors	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*
(Intercept)	407.53	313.05 – 502.00	**<0.001**	398.20	322.79 – 473.61	**<0.001**
Avg_Tmax	9.24	-3.18 – 21.65	0.145	12.30	1.06 – 23.53	**0.032**
Random Effects						
σ^2	21980.02			21757.49		
τ_{00}	66327.86 $_{Location}$			39041.36 $_{Location}$		
τ_{11}				249.87 $_{Location.Avg\_Tmax}$		
ρ_{01}				0.55 $_{Location}$		
ICC	0.75			0.76		
N	65 $_{Location}$			65 $_{Location}$		
Observations	403			403		
Marginal R^2 / Conditional R^2	0.017 / 0.755			0.029 / 0.770		

Fig. ③

	POPULATION			POPULATION			POPULATION		
Predictors	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*
Frost_2	0.26	-0.50 – 1.02	0.498						
Avg_Tmax				6.72	-13.90 – 27.34	0.523			
Avg_Tmin							0.16	-5.73 – 6.04	0.958
Observations	404			403			403		
R^2 / R^2 adjusted	0.001 / -0.191			0.001 / -0.191			0.000 / -0.193		

Fig. ④

The 'ggmap' package [4] in R projected slope values onto the map to visualize the correlation between climate and population of each community were visualized (fig. ⑤) [5].

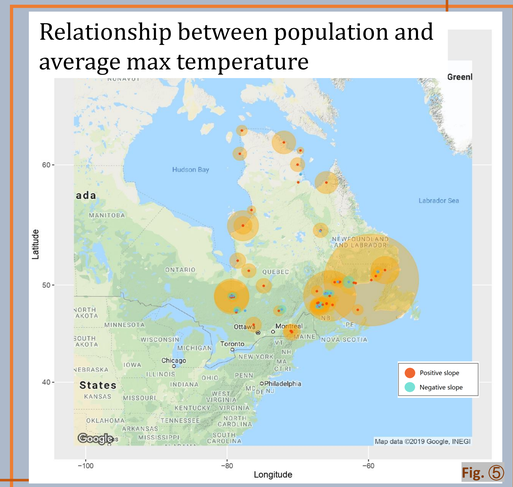

Fig. ⑤

Results

- From the trend line plots we can see not all communities experience a warmer climate, and the population changes vary greatly.
- The summary tables of the Fixed Effects models suggest that the three climate parameters positively relate to population.
- **In the map and line plots of Multilevel Models, the heterogeneity across communities is observed. The population – climate relationship is mediated by many factors, not all of which are able to be presented in the models here.**
- Most negative correlations concentrate along the estuary of the St. Lawrence river and Quebec-Ontario provincial boundary.
- Many of the strongest positive associates seem to be in more isolated communities, and many are coastal. However, since 45 out of 65 communities are located in these two areas, it is difficult to determine a clear pattern.
- In the full multilevel models including occupation data, the correlation between occupation structure and population is quite weak (~ 0.00).
- Most models failed to find statistically significant association, especially after controlling for other socio-economic variables.

Conclusion

Our analysis fails to confirm the *simple* hypothesis that community population is positively associated with average temperature and negatively associated with the number of frost days. We offer three possible explanations in order of what we think are increasing plausibility:

1. There were events caused greater influence than climate change but they were difficult to be presented by census data (e.g. construction of infrastructure, nature disaster, policies, economic opportunism, etc.).
2. Rural communities in Quebec may not be especially vulnerable to climate change.
3. Our sample does not cover a long enough period of time to see the effects of climate change clearly.

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