Western Geography

Highwood Pass Hwy40, AB June2023

Glencoe Kwatsech Park, Saanich BC Feb2023

Volume 25 | 2023

Western Geography is the official open access academic refereed journal of the Western Division of the Canadian Association of Geographers. The objective of the journal is to publish original scholarly work including research notes on geographical themes or topics that emphasize western Canada and adjacent areas, or that are written by geographers from this region.
The editor and editorial board invite manuscripts of a methodological, empirical, theoretical, or philosophical nature that fall within this objective.

(*Western Geography*'s predecessors were the *Occasional Papers in Geography* published by the British Columbia (BC) Division of the Canadian Association of Geographers (CAG) and *BC Geographical Series*.)

As with the first volume of *Western Geography* under the editorship of Michael Edgell, and continued by Jim Windsor, Neil Hanlon and Craig Coburn, submissions from students are encouraged.
Papers presented at the WDCAG conferences are also encouraged.

(Volume 25 cover photos by Editor)

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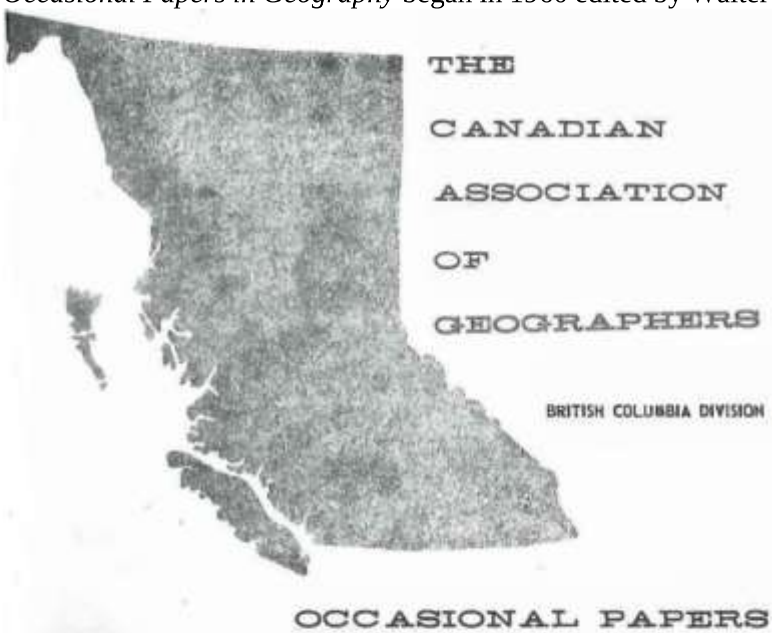
Editorial: The Illustrious pedigree and importance of *Western Geography.*

Western Geography is the open access academic scholarly journal of the Western Division of the Canadian Association of Geographers (WDCAG). This editorial argues that although times have changed and some question *Western Geography* continuing in the 2020s, this editor and others, contend *Western Geography* should press on. *Western Geography* has an esteemed pedigree of publishing and is important to faculty, students, the public and western geography.

Western Geography was formally created in 1990 when Michael Edgell, then Chair of the University of Victoria (UVic) Geography department, wanted to establish a ‘high impact’ journal specific to the Pacific Northwest. *Western Geography*’s predecessors were the *Occasional Papers in Geography* published by the British Columbia (BC) Division of the Canadian Association of Geographers (CAG) and *BC Geographical Series*. This editorial will not cover the entire history of these three publications but will briefly summarize them to highlight their long-standing lineage.

Occasional Papers in Geography began in 1960 edited by Walter G. Harwick; see below:



OCCASIONAL PAPERS IN GEOGRAPHY, Numbers 1, 2, 3, 4

Published in Vancouver, Canada
for the
Canadian Association of Geographers,
British Columbia Division
at the
Department of Geography,
The University of British Columbia,
Vancouver 8, B.C., Canada.

1st Printing - Number 1 - 1960
Number 2 - 1961
Number 3 - 1962
Number 4 - 1963

2nd Printing - Number 1-4 - 1965

Walter G. Hardwick
Editor
Vancouver
April, 1965

Harwick wrote that in six years the BC Division of CAG had developed into one of the major regional associations of geography.

As far as this editor is aware, *Occasional Papers in Geography* has not been digitized but is available in many university libraries with outstanding content specific to Pacific northwest geography as shown by the example Tables of Contents below:

OCCASIONAL PAPERS IN GEOGRAPHY #1 (May, 1960)

OCCASIONAL PAPERS IN GEOGRAPHY #2 (June, 1961)

Around 1963/1964 *BC Geographical Series* began and its numbering system sometimes overlapped with the *Occasional Papers in Geography*, see below:

GEOGRAPHY OF THE FOREST INDUSTRY OF COASTAL BRITISH COLUMBIA

OCCASIONAL PAPERS IN GEOGRAPHY, NUMBER 5

by

WALTER G. HARDWICK, Ph.D.

DEPARTMENT OF GEOGRAPHY
THE UNIVERSITY OF BRITISH COLUMBIA

B.C. GEOGRAPHICAL SERIES

BOX 4248, VANCOUVER 9, CANADA

#1 A GEOGRAPHY OF THE FOREST INDUSTRY OF BRITISH COLUMBIA -- W. G. Hardwick, 1964

#2 PORT OF BRITISH COLUMBIA: DEVELOPMENT AND TRADING PATTERNS -- D. E. Kerfoot, 1966

#3 GEOGRAPHICAL DIALOGUE: UNIVERSITY VIEWPOINTS FOR TEACHERS -- W.G. Hardwick & George Tomkins, editors, 1966

#4 RESIDENTIAL LOCATION AND THE PLACE OF WORK -- John R. Wolforth, 1965

#5 WORLD RESOURCE PRODUCTION: 50 YEARS OF CHANGE -- Harry V. Warren and E. F. Wilks, 1966

#6 SPECIALTY-RETAILING: A GEOGRAPHIC ANALYSIS -- Roger Leigh, 1966

#7 THE GEOGRAPHER AND THE PUBLIC ENVIRONMENT, Occasional Papers, B. C. Division, C.A.G. -- Julian V. Minghi and Edward C. Higbee, editors, 1966

#8 GEOGRAPHICAL PERSPECTIVE: A NORTHWEST VIEWPOINT, Occasional Papers, B. C. Division, C.A.G. -- George Tomkins, editor, 1967

#9 LOWER FRASER VALLEY: THE EVOLUTION OF A CULTURAL LANDSCAPE -- Alfred Siemens, editor, 1968

#10 SPATIAL DYNAMICS OF GASOLINE SERVICE STATIONS -- R. J. Claus, 1969

#11 AMENITY AGRICULTURE -- Robert M. Irving, 1970

#12 CONTEMPORARY GEOGRAPHY: WESTERN VIEWPOINTS, Western Division, C.A.G. -- Roger Leigh, editor, 1971

There has been exceptional regional geographic content throughout the years but only some examples are presented in this editorial as shown in the following pages.

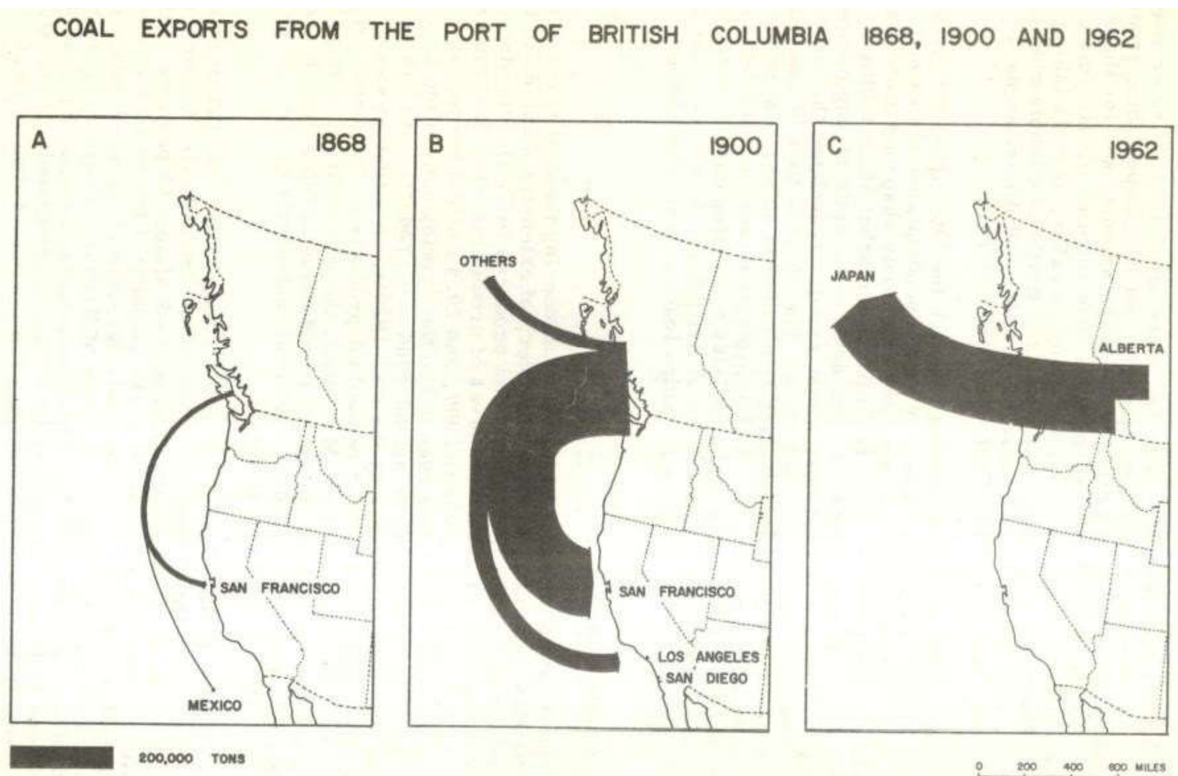
PORT OF BRITISH COLUMBIA:

DEVELOPMENT AND TRADING PATTERNS

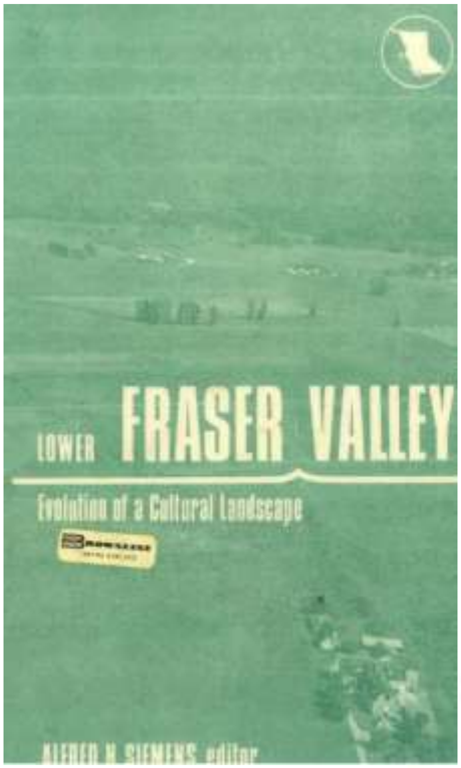
B.C. GEOGRAPHICAL SERIES, NUMBER 2

DENIS E. KERFOOT, M.A.

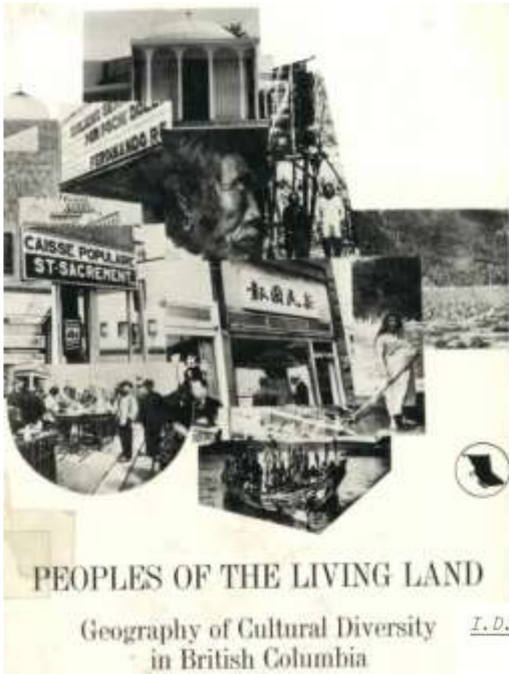
Department of Geography
University of British Columbia
Vancouver 8, Canada



BC Geographical Series No.2, 1966



BC Geographical Series No.9, 1966



BC Geographical Series No.15, 1972

I.D. Anderson, M.A., Simon Fraser University: Ph.D. candidate in Geography, Simon Fraser University, Burnaby, B.C.

Allen R. Astles, M.A., Simon Fraser University: Instructor of Geography, University of Victoria, B.C.

George Cho, M.A., University of British Columbia; Assistant Lecturer in Geography, University of Malaya, Kuala Lumpur.

James Cromwell, M.A., Simon Fraser University; Lecturer in Geography, Selkirk College, Castlegar, B.C.

L.J. Evenden, Ph.D., Edinburgh University; Associate Professor of Geography, Simon Fraser University, Burnaby, B.C.

Donald Gale, B.A., (Hons.), Simon Fraser University; M.A. Student in Geography, Simon Fraser University, Burnaby, B.C.

K.F. Grant, M.A., University of British Columbia.

Paul M. Koroscil, Ph.D., University of Michigan; Assistant Professor of Geography, Simon Fraser University, Burnaby, B.C.

Roger Leigh, Ph.D., University of London; Assistant Professor of Geography, University of British Columbia, Vancouver, B.C.

Ann McAfee, M.A., University of British Columbia; Ph.D. candidate in the Urban Studies Programme, University of British Columbia, Vancouver, B.C.

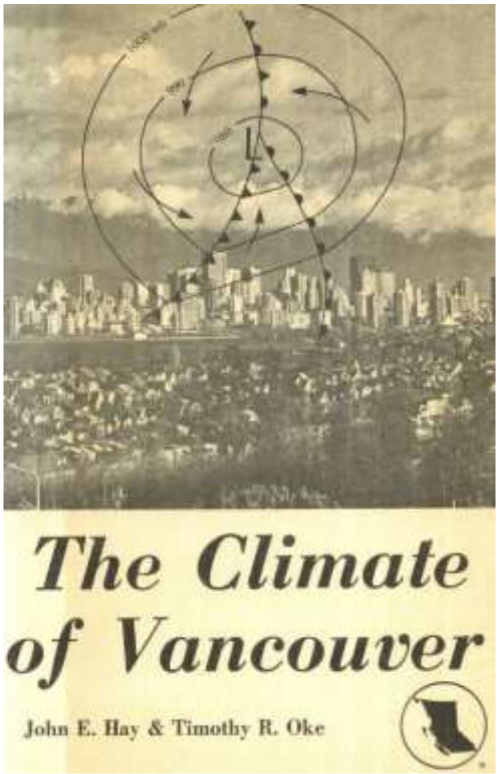
Julian V. Minghi, Ph.D., University of Washington; Associate Professor of Geography, University of British Columbia, Vancouver, B.C.

Dennis Rumley, M.A., Newcastle University; Ph.D. candidate in Geography and Canada Council Fellow, University of British Columbia, Vancouver, B.C.

Kernial Singh Sandhu, Ph.D., University of London: Associate Professor of Geography, University of British Columbia, Vancouver, B.C.

Paul Y. Villeneuve, Ph.D., University of Washington; Assistant Professor of Geography, Université Laval, Quebec City, Quebec.

Philip L. Wagner, Ph.D., University of California at Berkeley; Professor of Geography, Simon Fraser University, Burnaby, B.C.



BC Geographical Series No.23, 1976
with superb figures and graphics.

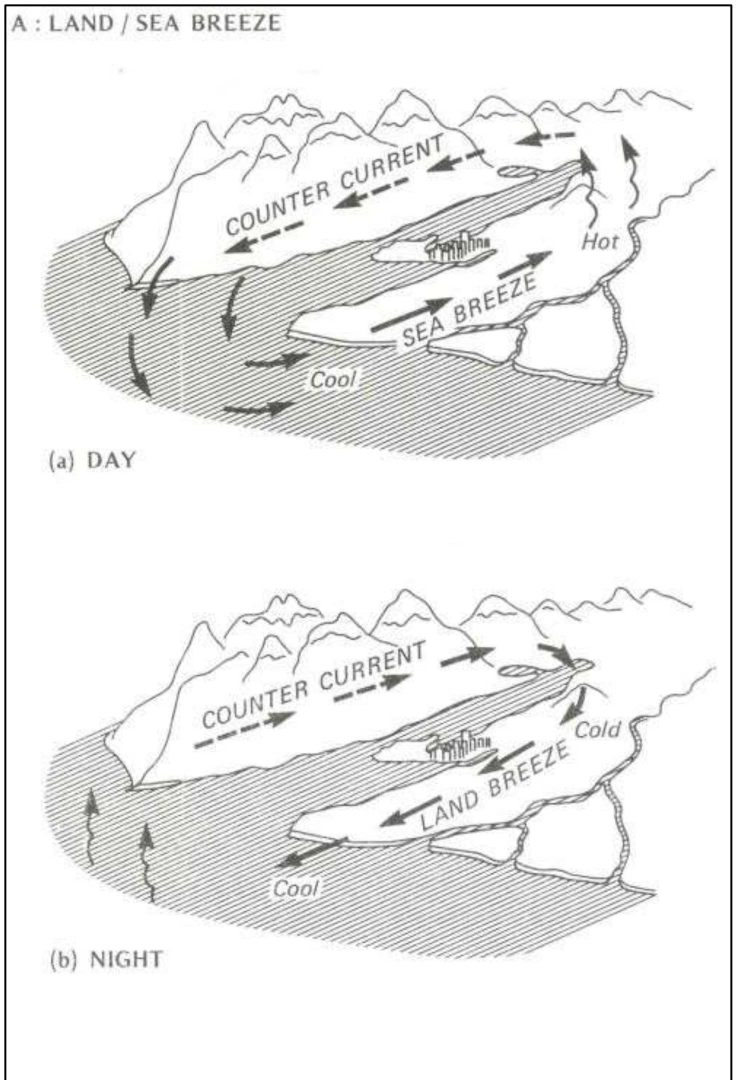


Figure 17a. *Schematic diagram of wind flows over Vancouver. Land/Sea Breeze.*

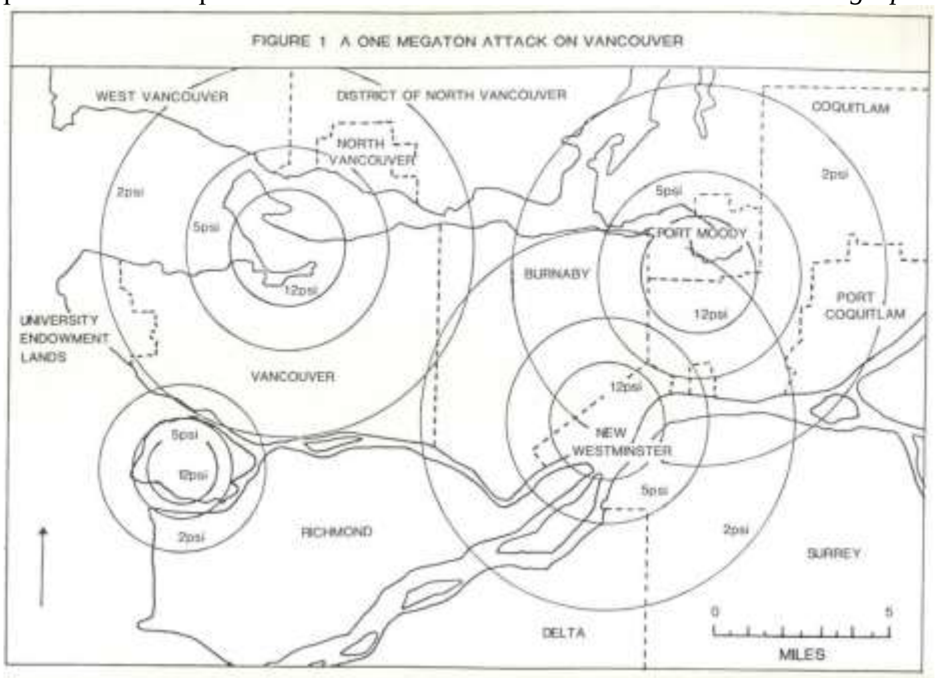
Prior to *Prairie Perspectives*, the open-access peer-reviewed publication of the Prairie Division of the Canadian Association of Geographers that began in 1998, *BC Geographical Series* No.26, 1980 published at least two issues on Canadian prairies themes as shown below:

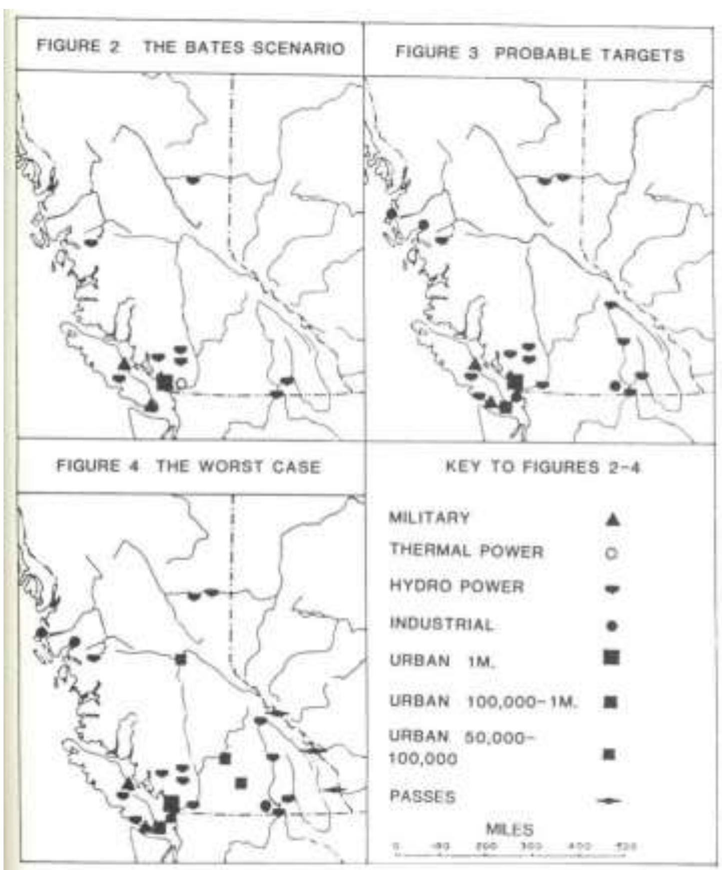
BC Geographical Series No.26, 1980

Among the contributors was Tommy C. Douglas; see below.

David Elliott	Calgary, Alberta
Victor Howard	Department of English Michigan State University
David McGinnis	Department of History University of Calgary
Michiel Horn	Department of History Glendon College, York University
Dick Harrison	Department of English University of Alberta
David Jones	Department of Educational Foundations University of Calgary
Patricia Bovey	Assistant Curator Winnipeg Art Gallery
Keith Clifford	Department of Religious Studies University of British Columbia
Tim and Patricia Rogers	Department of Psychology University of Calgary
T. C. Douglas	Member of Parliament, Ottawa

During the 1980s and just before the 100,000 person 'Peace' rally in Vancouver against nuclear weapons in 1986, Simon Dalby at the time at SFU (and later at Carleton and Wilfrid Laurier Universities, published the impactful 'British Columbia in a Nuclear War' in *BC Geographical Series* No.41, 1985.





BC Geographical Series No.41, 1985

The final issue or volume of *Occasional Papers in Geography* and *BC Geographical Series* was in 1988 as shown below.

OCCASIONAL PAPERS IN GEOGRAPHY:
CASTLEGAR
1988

B.C. GEOGRAPHICAL SERIES, NUMBER 46

Edited by

MICHAEL C.R. EDGELL
Department of Geography
University of Victoria

To read more regarding *Occasional Papers in Geography* and *BC Geographical Series* and their numbering, Leonard J. Evenden, Emeritus professor from Simon Fraser University (SFU) Geography discusses these in Three decades of publishing: A guide to the annual publications of the Western Division of the Canadian Association of Geographers in *Western Geography* 8/9, 1998/1999 and summarized at https://www.lib.sfu.ca/help/research-assistance/subject/geography/western-div-geographers

In 1990 Michael Edgell, Emeritus professor and former Chair of UVic Geography established *Western Geography*. See also the above-mentioned article by Evenden and Michael Edgell's perspective in 'Geography at the University of Victoria' in *Yearbook of the Association of Pacific Coast Geographers* 52(1).

WESTERN GEOGRAPHY

Volume 1, Number 1, Spring 1990

B.C. GEOGRAPHICAL SERIES, NUMBER 47

WESTERN GEOGRAPHY

(formerly OCCASIONAL PAPERS)

The first three volumes of *Western Geography* were published in paper/print only and are available in some university libraries. *Western Geography* also broadened its scope of contents accepting articles that addressed issues outside the Pacific northwest but most of its contributors were based in the Pacific northwest.
As an example, see volume 3 Table of Contents below.

WESTERN GEOGRAPHY
Vol. 3, 1993

CONTENTS

Western Geography Vol.3, 1993

It is also important to note the journal publishing context and scene in the late 1980s and early 1990s. There were approximately only 16 academic journals in human and physical geography in Canada in 1987. (Worldwide, there were roughly 325 human and physical geography journals.) Today in 2023, there are approximately 51 academic journals in human and physical geography in Canada and more than 1000 worldwide. (data from *Ulrich's Periodicals Directory*, 2023)

In other words, academics and other writers have much more choices of where to publish than in the 1990s. However, *Western Geography* is proudly an open access (double blind refereed) journal that allows anyone, or any institution, to access and read its contents. In these days of ever escalating journal subscription fees by large journal publishers, open access academic scholarly publishing is more important than ever.
Western Geography moved to a partial electronic on-line format in 1994 and fully on-line in 1995.
See https://wdcag.geog.uvic.ca/publications.htm#P20
1994 was the last year of Michael Edgell as Editor of *Western Geography*.

In 1995 *Western Geography* had a new Editor with Jim Windsor from the College of New Caledonia in Prince George until volume 17 in 2007 and was at that time fully on-line. Other *Western Geography* Editors were Neil Hanlon, UNBC, 2007-2009; Damian Collins, (University of Alberta) and Darryl Carlyle-Moses, (Thompson Rivers University), 2011 to 2013; Craig Coburn, (University of Lethbridge), Tom Waldichuk, (Thompson Rivers University), Pamela Shaw, (Vancouver Island University) 2014-2015; Craig Coburn, (ULeth), Tom Waldichuk, (TRU) 2016; and Craig Coburn, (ULeth), along with Joanne Moyer, (King's University) from 2017-2022.
For a list of *Western Geography* editors and editorial board members over the years, see https://wdcag.geog.uvic.ca/publications.htm#P20

Michael Edgell also envisioned a venue for 'student' writing in 1990 when *Western Geography*'s editorial policy specifically stated 'Submission from graduate students are particularly encouraged' and *Western Geography* continues this policy to this day.
The highest cited *Western Geography* paper was written by a student from at the time, Cariboo College, (now Thompson Rivers University-TRU) under emeritus professor Gilles Viaud:
Petherick, N. (2000). Environmental design and fear: The prospect-refuge model and the university college of the Cariboo campus. *Western Geography* 10(11) 89-112.
(The second highest cited paper is:
Edgington, D.W., & Hutton, T.A. (2000). Multiculturalism and local government in Vancouver. *Western Geography* 10(11), 1-29.
The highest cited physical geography paper is:
Laroque, C.P., Lewis, D.H., & Smith, D.J. (2000). Treeline dynamics on southern Vancouver Island, British Columbia. *Western Geography* 10(11), 43-63.)

After discussion with former *Western Geography* editors, and current researchers, scholars, and teaching professors in 2022-2023, *Western Geography* will also welcome papers from Honours students and winning students' papers and posters from the annual WDCAG conference meetings. This volume includes the winning Masters poster by Rabecca Thiessen (along with Philip Bonnaventure and Caitlin Lapalme) and the winning undergraduate poster by Kathleen Moore (with Crystal Huscroft).

Western Geography fills a niche in the academic publishing world with its focus on the geography of western North American with such informative articles as
Smith, D. (1997). Those magnificent men and their flying machines: Aerial reconnaissance in the Alberta Rocky Mountains during the 1920s. *Western Geography* 7, 73-96
http://www.geog.uvic.ca/wcag/smith.pdf Where else would this be published?

Thus, let us all participate by contributing to the academic open access double blind peer refereed journal *Western Geography* in the years to come following the continuum that began with *Occasional Papers in Geography* and *BC Geographical Series.* Over the years contributors predominately were geographers but also included historians, politicians, and archivists. Some contributors were as aforementioned but were working outside of universities and colleges. Open access academic scholarly publishing and Pacific northwest geography all remain essential, important and relevant in the 2020s.

Sincere thanks to all previous authors, editors and referees and to authors, referees and guest referees of this current volume.

Managing Editor
daniel Brendle-Moczuk
University of Victoria, (Canada)

Youth perspectives on healthcare careers: contextual influences, supports and constraints

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[2]MSc student, School of Health Sciences, Faculty of Human and Health Sciences, 3333 University Way, Prince George, BC, V2N 4Z9, Canada

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Funding:
This study was supported by a Distributed Medical Education (DME) Research Grant from the Centre for Health Education Scholarship, University of British Columbia (CHES; https://ches.med.ubc.ca)

Disclosures:
All authors declare that they have no competing interests

Abstract

Recent literature suggests that experiential forms of learning are an effective means to promote healthcare careers as options for youth in secondary school, and that such efforts are especially important in recruiting youth from groups underrepresented in the healthcare workforce. Yet, little is known about how youth obtain information about career options, nor about the influence that contextual factors, such as rural or smaller population centres, have on the formation of career aspirations. This study reports on results of an online survey questionnaire distributed to students in the mid-senior years of high school (i.e., Grade 10) at four high schools across British Columbia during the 2020-21 academic year. Students were generally aware of a range of healthcare career opportunities, but desired additional exposure and information. They obtained information about these career options from an array of sources (i.e., family, friends, teachers, popular culture, social media). Students in small centres appear to have more reservations about their own abilities to pursue healthcare careers. The cost of post-secondary education was the most cited barrier to pursuing a healthcare career across all populations and students suggested that costs should be lowered or eliminated to increase the number of youth working towards a career in healthcare. Finally, our data suggest that youth impressions about healthcare career planning and opportunities were largely unaffected by COVID-19, at least in the early stages of the pandemic, though students in small centres were more likely to be shy of a healthcare career due to the pandemic. In light of our findings, we offer recommendations to educators and policy makers.

Key words: youth, career choice, healthcare education outreach, health workforce, rural population, smaller urban settings.

Introduction

Successful healthcare career pathways require considerable investment of time and effort on the part of students, beginning with planning and preparations necessary to gain entry into relevant post-secondary education and training programs. There is growing evidence that greater levels of support and encouragement from parents, educators, and mentors each play an important role in guiding youth to healthcare careers (Zayas & McGuigan, 2006; Holden, et al., 2014; Gerard & Booth, 2015; Oomen, 2016).

The future diversity of the healthcare workforce requires that efforts be made to promote healthcare education and training to students in traditionally underrepresented social circumstances and contexts, such as low-income neighbourhoods, Indigenous students, and rural areas (Brownrigg, et al., 2020; Fonseka, 2018). Rural youth may be less likely to have confidence that they can get into medical school, and face greater barriers (Rourke, 2005; Whalen, et al., 2016). Importantly, in the context of current and historical rural healthcare provider shortages, there is strong evidence that healthcare professionals who were raised in rural and smaller urban settings are more likely to practice and remain in such settings (Cosgrave, et al., 2019; Hughes, et al., 2005; Maurice, et al., 2019; Rourke, 2008; Rourke, 2010; Malatzky, et al., 2020).

For these and other reasons, it is important to ensure youth are informed about healthcare education and career options, and to do so as early as possible for high school students, particularly among groups that are historically underrepresented in the healthcare workforce (Rourke, 2005; Lauver, et al., 2011). In spite of this urgency, there is little consideration in the healthcare human resources literature about how youth from underrepresented social categories perceive healthcare careers as personal options. Likewise, little is known about the influence of contextual factors such as family, peers, schools, popular and social media, and current events, on the career aspirations and planning of youth.

In British Columbia (BC), Canada, in response to a persistent maldistribution of physicians, the province's lone metropolitan-based medical school expanded its annual intake of students and added three regional medical campuses over several phases of growth, beginning in 2004 (Snadden, et al., 2005). New admissions processes were developed to increase the numbers of rural, Indigenous and Black medical students (Fabian, 2008; University of British Columbia). However, there remains a physician maldistribution with half as many physicians per capita practicing in rural vs urban environments (Snadden & Kunzli, 2017). Similar challenges exist with respect to other health professions and the COVID-19 pandemic has only exacerbated pre- existing workforce shortages and healthcare provider burnout (Maurice, et al., 2019; MacLeod & Place 2015; Manahan, et al., 2009; Murthy 2022). Clearly, more concerted efforts are needed to recruit future medical and allied health professional students from traditionally underrepresented populations.

In this study, we surveyed high school students in a sample of schools throughout the province of BC. The schools were located in a range of settings, two in small population centres, one in a medium population centre, and one in a large urban population centre. Each of the schools are in communities served by the three regional medical campuses of the province's distributed medical education program (Figure 1). Our objective was to obtain baseline data from youth in each region and in different sized population centres, about healthcare career options. We wanted to provide an opportunity for youth to share their knowledge and impressions of healthcare opportunities, where and how they receive information about healthcare career options, whether they and/or their peers are considering post-secondary education and training in the healthcare field, and what barriers they perceive to such education and training. We were also interested in whether these views and impressions were influenced by contextual factors such as location and size of population centre. We distributed the survey during COVID-19, so we included questions about the impact the pandemic had on their impressions of healthcare careers.

Figure 1. Map of the province of BC, Canada, with the UBC medicine main campus and regional campuses shown, along with provincial health authorities (note the province also has a First Nations Health Authority, but it is not limited to a particular geography so is not shown here).

Methods

We created and pilot tested an online questionnaire on youth attitudes and awareness of healthcare career opportunities. We chose to use Qualtrics software as this tool was flexible for our purposes, straightforward to use, and compliant with the BC Freedom of Information and Protection of Privacy Act (QualtricsXM, https://www.qualtrics.com). The questionnaire was intended as an exploratory tool to solicit input from students in mid-upper secondary education (ISCED level 3 (UNESCO, 2011)), namely grade 10 students in BC, across a range of populations in the province. This cohort was chosen in order to hear from youth who are expected to be in the early stages of considering future education and career opportunities, when “career-life interests and possibilities start to become meaningful considerations” for many (Government of British Columbia, 2021). In terms of location, our primary interest was students in schools in different sized population centres, served by one of the three small sites of the provincial distributed medical education program.

We ran the Qualtrics survey from mid-December 2020 until late April 2021. We initially had commitments from six schools to help us recruit participants and distribute the questionnaire to an audience of 150 – 200 in each population. Four of the six schools were in small population centres (populations 1,000 to 29,999), one school was located in a medium population centre (population 30,000 to 99,999) and one was located in a large urban population centre (100,000 or greater) (Statistics Canada, 2022). Two of the schools in small centres later withdrew from the research. For reasons of confidentiality, the names of participating schools are withheld and their locations are reported at the regional health authority level. As reported in Table 1, we received a total of 71 completed surveys, with approximately 28% (n=20) of the respondents located in the large centre, 37% (n=26) located in the medium centre, and 35% (n=25) located in small centres. While the objective was to survey grade 10 students, one respondent was in grade 11 and we chose to include their responses.

Table 1. Schools attended by respondents

Regional Health Authority	Setting Type	Count	%
Interior	Small centre	12	16.9
Northern	Medium centre	26	36.6
Northern	Small centre	13	18.3
Vancouver Island	Large centre	20	28.2

The gender self-identification of respondents is summarized in Table 2. The majority of respondents identified as female (65%), followed by males (30%), and non-binary (3%). Two respondents (3%) chose not to answer. The higher rate of replies from females was consistent across all three populations.

Table 2. Gender identification of respondents

Gender	Total (N=71)		Small centre (n=25)		Medium centre (n=26)		Large centre (n=20)	
	N	%	N	%	n	%	n	%
Male	21	29.6	9	36.0	6	23.1	6	30.0
Female	46	64.8	14	56.0	18	69.2	14	70.0
Non-binary	2	2.8	1	4.0	1	3.9	0	0.0
Prefer not to answer	2	2.8	1	4.0	1	3.9	0	0.0

The sample size prevented us from undertaking any multivariate analysis of the data. The questionnaire included open-ended questions that enabled respondents to add additional insights, and these data were coded using NVivo for Mac version 11.4.3 which allowed us to code and organize the qualitative responses, and identify themes in the data (QSR International, https://www.qsrinternational.com). Where appropriate, we include excerpts of open-ended responses to add depth to findings, but the data were insufficient to undertake thematic analysis. All quotes are anonymized and only information about population type (small, medium, or large centre) is included.

Ethics approval

Following buy-in from teachers and/or counsellors at the schools, we gathered administrative support from the 6 schools between August 2019 and October 2020. This study received approval (H20-00837) from the University of British Columbia, the University of Victoria, and the University of Northern British Columbia research ethics boards.

Results

The findings concerning sources of information for respondents are presented in Table 3. Respondents were instructed to select as many responses as they deemed relevant. Overall, family members (80%) and various forms of entertainment media (75%) were the most common sources of information to learn about healthcare careers. The next most commonly cited sources of information were social media, friends, and teachers (approximately 60% of respondents).
Guidance counsellors, on the other hand, stood out as being much less commonly cited sources of information for these youth.

In terms of the influence of setting type, the number of responses per respondent was higher in the small and medium centre settings, whereas students in the large centre setting tended to cite a lower number of information sources. The responses from students in the large centre setting differed in other ways. For instance, the large centre was the only setting in which popular media was more frequently cited than family. Likewise, the frequency with which friends were cited as information sources was lower in the large centre setting.

Table 3. Sources of healthcare career information

Source	Total (N=71)		Small centre (n=25)		Medium centre (n=26)		Large centre (n=20)	
	N	%	N	%	N	%	n	%
Family	57	80.3	21	84.0	22	84.6	14	70.0
TV Shows, movies, books	53	74.7	20	80.0	17	65.4	16	80.0
Social Media	44	62.0	15	60.0	19	73.1	10	50.0
Teachers	44	62.0	15	60.0	18	69.2	11	55.0
Friends	43	60.6	18	72.0	17	65.4	8	40.0
Guidance Counsellors	10	14.1	4	16.0	4	15.4	2	10.0
Other	6	8.5	0	0.0	3	11.5	3	15.0
Total citations			93		100		64	
Citations per respondent			3.7		3.8		3.2	

In terms of sources of inspiration to pursue a healthcare career (Table 4), family was cited most frequently (58%) as a source of inspiration and encouragement. Students in the medium centre were particularly likely to cite family as a source of inspiration. While the proportion of family citations was much lower in the other settings, this category was still the top choice in these settings. Otherwise, most other sources of inspiration received between 24% and 40% (depending on population type), with the exception of guidance counsellors who were cited very sparingly.

Table 4. ***Sources of inspiration to pursue a healthcare career***

Source	Total (N=71)		Small centre (n=25)		Medium centre (n=26)		Large centre (n=20)	
	N	%	N	%	n	%	n	%
Family	41	57.8	12	48.0	21	80.8	8	40.0
Friends	26	36.6	7	28.0	14	53.9	5	25.0
TV Shows, movies, books	24	33.8	9	36.0	7	26.9	8	40.0
Teachers	22	31.0	6	24.0	11	42.3	5	25.0
Social Media	20	28.2	8	32.0	7	26.9	5	25.0
No options selected	9	12.7	6	24.0	2	7.7	1	5.0
Other*	7	9.9	2	8.0	3	11.5	2	10.0
Guidance Counsellors	5	7.0	3	12.0	2	7.7	0	0.0

**Other (N=7): no information provided (6), Google (1)*

We were interested in collecting views about pursuing post-secondary education generally, and healthcare education programs in particular. The responses to these survey items are presented in Table 5. Most respondents were intending to attend a college or university in the future, although there was marginally lower support for this view among students in the small centre settings.

Approximately 30% of respondents indicated an interest in healthcare education and training, with the highest proportion recorded among students in the medium centre (42%) and the lowest proportion among the students in the small centre setting (20%). Respondents who indicated they had no desire to pursue offered a range of reasons. A few indicated that they already had other career goals in mind or indicated that they felt in one way or another not suited to a healthcare career. For instance, four respondents expressed some aspect of queasiness, such as “I don’t do well around blood” [record 19, large centre], “I’m a very anxious person” [record 21, large centre], and “It is a very good career choice in my opinion, but I get light-headed at the sight of blood and most needles” [record 44, medium centre]. Others expressed feelings that they weren’t personally equipped to handle the stress of healthcare; in the words of one student from the medium centre context, “I’m unsure of whether or not healthcare would be a thing that I would be comfortable doing due to the nature of such jobs and some of the risks that may come with it” [record 40, medium centre]. Others cited the lack of interpersonal skills, confidence, or qualifications, “I am not very good at math so I wouldn’t be able to be one” [record 30, small centre]. Approximately one-third of respondents indicated “maybe or undecided” to the question about healthcare education, and this was consistent across the three school setting types.

Table 5. ***Desire to go to College or University or to pursue a healthcare career***

College/University	Total (N=71)		Small centre (n=25)		Medium centre (n=26)		Large centre (n=20)	
	N	%	N	%	n	%	N	%
Yes	56	78.9	17	68.0	22	84.6	17	85.0
No	3	4.2	1	4.0	1	3.9	1	5.0
Maybe/ Undecided	12	16.9	7	28.0	3	11.5	2	10.0

Healthcare Career	Total (N=71)		Small centre (n=25)		Medium centre (n=26)		Large centre (n=20)	
	N	%	N	%	n	%	N	%
Yes	21	29.6	5	20.0	11	42.3	5	25.0
No	27	38.0	11	44.0	8	26.9	8	40.0
Maybe/ Undecided	23	32.4	9	36.0	7	30.8	7	35.0

We were especially interested in student perceptions about the feasibility of pursuing a healthcare career for themselves and their peers (Table 6). The most common response to both questions was “yes,” although less than a majority expressed this view about themselves, while the majority of students across all settings felt that this was feasible for other youths in the community. Students in the medium centre were the most positive about these questions (58% concerning themselves and 85% concerning their peers), whereas students in the small and large centre settings were more mixed in their responses between yes or uncertain.

A quarter of the students felt that a career in healthcare was not a practical possibility for them. The view that a healthcare career was not in the cards was most prevalent in the small centre setting (36%), and least so in the medium centre setting (15%). Students in the two small centres were also most likely to indicate they were “unsure” about their own prospects for a healthcare career.

Table 6. ***Views about the feasibility of a healthcare career***

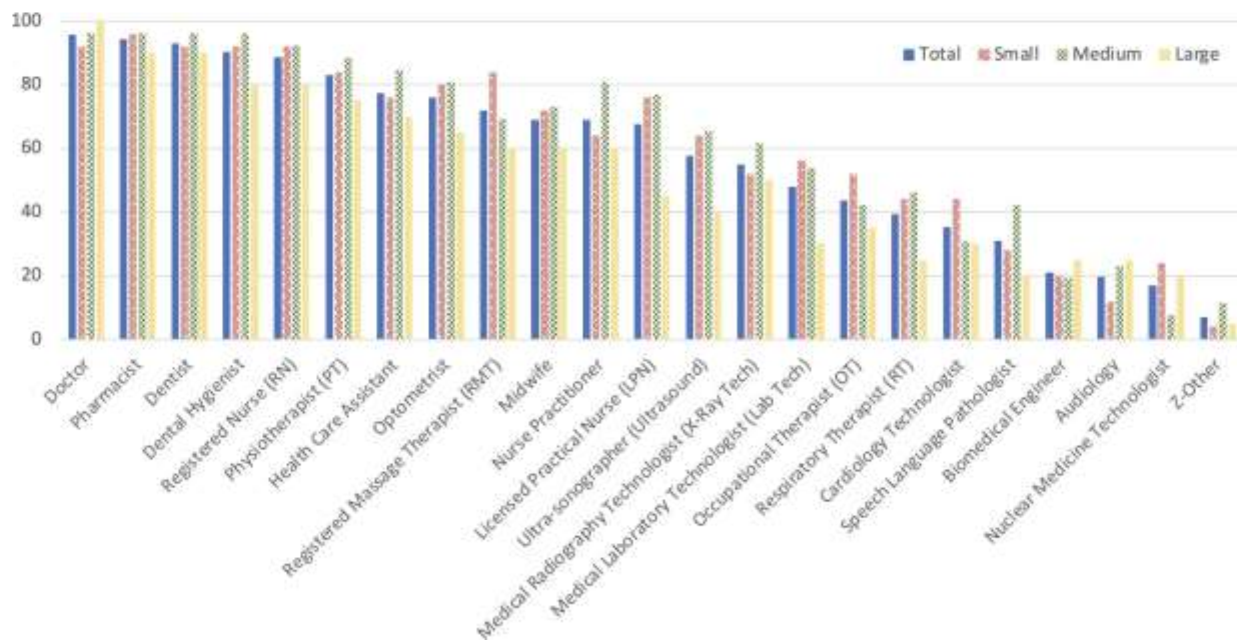
For Self	Total (N=71)		Small centre (n=25)		Medium centre (n=26)		Large centre (n=20)	
	N	%	N	%	N	%	N	%
Yes	30	42.3	7	28.0	15	57.7	8	40.0
No	18	25.4	9	36.0	4	15.3	5	25.0
Unsure	23	32.4	9	36.0	7	26.9	7	35.0

For Others	Total (N=70)		Small centre (n=24)		Medium centre (n=26)		Large centre (n=20)	
	N	%	N	%	N	%	N	%
Yes	44	62.9	12	50.0	22	84.6	10	50.0
No	5	7.1	3	12.5	1	3.9	1	5.0
Unsure	21	30.0	9	37.5	3	11.5	9	45.0

Note: **the N value of the bottom table is different from other tables in this report because there is a missing answer from one small centre student*

We asked respondents to identify how many healthcare careers they were aware of, from a list provided. Most respondents had heard of doctor, pharmacist, dentist, dental hygienist, and registered nurse (≥80%), and many had heard of a variety of other healthcare careers as shown in Figure 2. The responses were largely similar across populations, indicating that students have heard these career titles before, to a greater or lesser extent.

Figure 2. Awareness of healthcare careers



However, students also described a lack of awareness about healthcare careers saying "... I know very little about healthcare careers because [we] receive little to no exposure at school or in the community" [record 26, small centre], indicating that the awareness of different careers in healthcare may be fairly superficial and not sufficient for making a decision about a potential career.

Views about personal barriers to a healthcare career are summarized in Table 7. Many of the more commonly cited reasons related to economic barriers (e.g., cost of education, moving to a city, cost of application, number of years involved). Some of the more commonly cited barriers related to perceived personal shortcomings (e.g., not smart enough, not qualified). In these cases, students in small centres appear more apt to list these perceived shortcomings as barriers. Only a small percentage of respondents indicated that they did not want to live or work far from home, with the proportions inversely related to settlement type (i.e., population size). Finally, about one-third of respondents cited lack of personal healthcare experiences and connections as a personal barrier, with those in the medium centre setting most likely to cite this as a barrier.

Table 7. ***Personal barriers to pursuing a healthcare career***

Barriers	Total (N=71)		Small centre (n=25)		Medium centre (n=26)		Large centre (n=20)	
	n	%	N	%	n	%	n	%
Cost of education	41	57.8	16	64.0	12	46.2	13	65.0
Number of years I would need to be in college/university	33	46.5	14	56.0	8	30.8	11	55.0
Don't think I am smart enough	31	43.7	14	56.0	11	42.3	6	30.0
Cost of moving to a city to study	27	38.0	10	40.0	8	30.8	9	45.0
Cost of application	24	33.8	12	48.0	5	19.2	7	35.0
Lack of personal experiences or connections with others in the healthcare field	23	32.4	6	24.0	11	42.3	6	30.0
Don't think I would qualify	20	28.2	11	44.0	7	26.9	2	10.0
Don't want to live or work far from home after I finish high school	14	19.7	6	24.0	5	19.2	3	15.0
Other	11	15.5	3	12.0	6	23.1	2	10.0
No options selected	4	5.6	1	4.0	1	3.9	2	10.0

Other (N=11): No (4); I don't like blood/needles (2); Competitive field (1); Not a priority (1); Lack of interest (2); Stress/Anxiety (1).

Respondents were also asked to indicate barriers facing their friends, and these data are summarized in Table 8. Overall, patterns of response were similar to those concerning personal barriers as reported in the preceding table, with not much variability between settlement type, although the frequency of citations was generally higher for this question. That is, various economic barriers again emerged as the most commonly cited responses (i.e., approximately 40% to 70%). One important difference was that, just as respondents from the small centre setting appeared more likely to feel they would not be smart enough or would not qualify for a healthcare career, they also appeared more likely to feel their friends would not be smart enough or would not qualify for a healthcare career.

Table 8. ***Views about barriers friends face to pursuing a healthcare career***

Barriers	Total (N=71)		Small centre (n=25)		Medium centre (n=26)		Large centre (n=20)	
	N	%	n	%	n	%	n	%
Cost of education	47	66.2	18	72.0	17	65.4	12	60.0
Cost of moving to a city to study	40	56.3	15	60.0	15	57.7	10	50.0
Number of years they would need to be in college/university	38	53.5	15	60.0	10	38.5	13	65.0
Cost of application	30	42.3	13	52.0	9	34.6	8	40.0
Lack of personal experiences or connections with others in the healthcare field	28	39.4	10	40.0	10	38.5	8	40.0
Don't want to live or work far from home after finishing high school	26	36.6	10	40.0	10	38.5	6	30.0
Don't think they would qualify	23	32.4	12	48.0	7	26.9	4	20.0
Don't think they are smart enough	22	31.0	11	44.0	6	23.1	5	25.0
Other	6	8.5	3	12.0	2	7.7	1	5.0
No options selected	4	5.6	2	8.0	1	3.9	1	5.0

Other (N=6): no (3), Yes (1), Probably not (1), I don't know (1)

When asked to elaborate on perceived barriers, students emphasized that they had concerns about the costs of post-secondary education and suggested “Maybe not have it be as expensive,” [record 11, large centre], “Make secondary education free or low of cost,” [record 15, large centre], or “Make it more affordable,” [record 70, small centre]; and expressed that the cost of the education was not justified for such a demanding job: “Traditional healthcare is high stress and odd hours, as well as requiring long and expensive schooling” [record 26, small centre].

When we asked students what could be done to encourage more rural youth to go into healthcare careers, they articulated the importance of providing more exposure and information: "Introduce the healthcare careers and give lessons on what they do and how to pursue them. It is difficult to know this information and would make it easier if we were taught about them. We need resources to know if it's what we are looking for and if it is, then we need information on how to create that path" [record 46, medium centre]. Others shared similar sentiments: "If the school systems keep on encouraging the medical occupations, I think the youth of this generation would continue to be interested in going to find what healthcare positions interest them most" [record 49, medium centre] and "I think that if we were taught more about all of the different aspects and careers in the healthcare field, there would be more kids that are interested in those jobs" [record 9, large centre]. Other respondents suggested that their own schools should do more to promote healthcare careers, such as the following statement: "If there would be more teaching in schools, they teach a little bit about health care but I don't think they do enough. I think kids should get put into programs that you have to take about healthcare because in my opinion that would get more kids interested, and also encouraged" [record 51, medium centre]).

Respondents who had been exposed to such experiential activities attested to the efficacy of these efforts. For instance, one student in a small centre setting stated, "I've done many healthcare workshops and I can see myself pursuing nursing as a career" [record 67, small centre]. Similarly, other students said, "a career in healthcare would be a practical possibility for me because I have done a lot of projects on this subject and it interests me," [record 57, medium centre] or "Yes, a career in healthcare is something I have been looking at for quite a while now. I have been doing things to set myself up to be able to pursue a career in healthcare such as keeping my grades up, being active in my community by volunteering, doing many extracurriculars like air cadets and music lessons, and more," [record 52, medium centre].

The final section of the survey asked students to share their impressions about the impact that COVID-19 has had on their educational and career aspirations and planning. In consideration of the fact that some may not have wanted to answer these questions, we created a screening question to ask if respondents wished to deal with COVID-related questions. A large majority of students (81%) chose to proceed, with not much variability in response according to settlement type (Table 9).

Table 9. ***Willingness to answer questions about the impacts of COVID***

Answers	Total (N=70)		Small centre (n=25)		Medium centre (n=26)		Large centre (n=19)	
	n	%	N	%	n	%	n	%
Continue to COVID-19 Related Questions	57	81.4	20	80.0	23	88.5	14	73.7
Skip the COVID-19 related question section	13	18.6	5	20.0	3	11.5	5	26.3

Students were then asked about the impact of COVID-19 on their career decision making in general (Table 10). The majority of the 57 students who completed the COVID questions suggested that their decision making had not been affected, or else only a little. These responses were consistent across the three types of school settings. In terms of decision making about healthcare careers, the most common response was that students felt "about the same" about a healthcare career as they did prior to COVID. Here, however, there was less agreement from students in small centres, with half of small centre respondents indicating they would be somewhat or much less inclined to enter healthcare because of the pandemic.

Table 10. ***Impact of COVID-19 on career decision making***

Various Careers	Total (N=57)		Small centre (n=20)		Medium centre (n=23)		Large centre (n=14)	
	n	%	N	%	n	%	n	%
A great deal	2	3.5	1	5.0	1	4.4	0	0.0
A lot	4	7.0	2	10.0	0	0.0	2	14.3
A moderate amount	6	10.5	2	10.0	4	17.4	0	0.0
A little	19	33.3	6	30.0	6	26.1	7	50.0
None at all	25	43.9	9	45.0	11	47.8	5	35.7
Prefer not to answer	1	1.8	0	0.0	1	4.4	0	0.0

Healthcare Careers	Total (N=57)		Small centre (n=20)		Medium centre (n=23)		Large centre (n=14)	
	n	%	N	%	n	%	n	%
Much more	2	3.5	1	5.0	0	0.0	1	7.1
Somewhat more	8	14.0	4	20.0	3	13.0	1	7.1
About the same	26	45.6	5	25.0	14	60.9	7	50.0
Somewhat less	11	19.3	6	30.0	3	13.0	2	14.3
Much less	8	14.0	4	20.0	2	8.7	2	14.3
Prefer not to answer	2	3.5	0	0.0	1	4.4	1	7.1

We then probed students a bit more closely about the impact of COVID on their considerations of a healthcare career (Table 11). Approximately half of those responding to the question felt that COVID had not affected their decision making at all. Approximately 28% expressed fear of contracting COVID, although this response was considerably more common among the students in the small centre settings and least so among students in the large centre setting. It was generally more likely that respondents would be less rather than more inclined to enter a healthcare career because of the pandemic. Here again there is a fairly pronounced urban gradient, with reservations about a healthcare career tending to increase as the setting size decreases.

Several students indicated that they were especially grateful for healthcare workers during the pandemic, stating “I really admire the healthcare workers, I really admire their patience and their courage to facing the virus,” [record 8, large centre], and “... I would just like to say that my family and I are so thankful to have healthcare workers in this covid-19 pandemic,” [record 22, large centre].

Table 11. ***How COVID has affected decision making for healthcare careers***

Answers	Total (N=57)		Small centre (n=20)		Medium centre (n=23)		Large centre (n=14)	
	n	%	N	%	n	%	n	%
COVID-19 has not affected my decisions	29	50.9	9	45.0	13	56.5	7	50.0
Fears of contracting COVID-19 if I work in healthcare	16	28.1	9	45.0	5	21.7	2	14.3
Because of COVID-19 I am less likely to go into healthcare	11	19.3	6	30.0	4	17.4	1	7.1
I am motivated to help solve and work through COVID-19	10	17.5	3	15.0	5	21.7	2	14.3
Prefer not to answer	5	8.8	2	10.0	2	8.7	1	7.1
Because of COVID-19 I now want to go into healthcare	3	5.3	1	5.0	2	8.7	0	0.0
Other	4	7.0	2	10.0	1	4.4	1	7.1

Other (N=4): no (1), Never considered Healthcare (1), Did not affect opinion (1), Kind of scared away but still willing to do (1)

Discussion

The findings reported here were intended to provide baseline data about healthcare career aspirations in school districts served by UBC's distributed medical education program, and to inform current and future university-high school outreach initiatives. The timing of the survey distribution, a year into the COVID pandemic, was clearly a factor in the lower levels of school and student participation than we had anticipated. The small sample size precludes us from providing rigorous statistical or thematic analysis of results beyond a descriptive analysis and basic proportions, but there were enough responses to warrant some attention about healthcare career aspirations among groups of students historically underrepresented in healthcare education seats and practice. Where possible, we share anonymized excerpts of comments and cursive notes shared by respondents at various points in the online survey questionnaire to offer additional insight about the topics explored.

The data suggest that students have a fairly broad understanding of healthcare career options and receive information and encouragement about healthcare career options from numerous sources. Students appear at least as likely to learn about healthcare careers from teachers and family members as they were from arguably less reliable sources such as social media and entertainment venues. We are mindful not to presume that the information and impressions imparted by parents and educators are necessarily accurate and evidence-based, or that media and popular culture representations are necessarily distorted. But we do posit that enhancing access to career counselling programs and experiential forms of career guidance are a means to compliment other sources of information and insight, and are most likely to help youth make better-informed decisions about higher education and career planning.

Our data show that only a small number of students in the early senior years of high school receive information about career options from their guidance counsellors at the high schools we surveyed. This may well be because counsellors are not asked to play a major role in career and post-secondary education planning until students are in their final year of high school.
Alternately, it may be that in many schools guidance counsellors are part-time positions, and teachers who have these roles also teach other classes, and thus some students may think of them more as teachers. Nevertheless, the findings suggest that guidance counsellors may be underutilized in efforts to promote healthcare careers amongst youth. In that case, there is an opportunity to engage guidance counselors in providing more accurate and evidence-informed information about healthcare career options at critical stages of youth career development.

Respondents also appear to believe that they would benefit from more educational outreach and professional mentorship programs that teach them about healthcare career opportunities and options. Such activities might emphasize the attainability of healthcare careers, especially for those schools serving social groups that are traditionally underrepresented in the healthcare workforce (e.g., rural, lower-income households, Indigenous self-identification). There is a growing literature that suggests that the promotion of healthcare careers in schools serving underrepresented groups is important to overcoming perceived or experienced barriers (Brownrigg, et al., 2020; Lauver, et al., 2011). Such programs should be designed to expose students to the full range of career opportunities in healthcare, and not just those in the medical and nursing professions (Maurice, et al., 2019; Berk, et al., 2014).

Across all three types of population centre, students felt strongly that the cost of post-secondary education collectively was a significant barrier. Participants suggested that lowering the cost or even having post-secondary education be free, would go a long way to getting more students to pursue healthcare careers. Here too, guidance counsellors may be in a position to make students aware of what financial opportunities exist in the forms of scholarships, governmental programs, grants or other such opportunities; and this education is likely more important for youth from groups underrepresented in healthcare.

Interestingly, the COVID pandemic did not seem to have much impact on career decision making, although it did appear to promote positive views of, and appreciation for, healthcare providers. This seems to support the notion that career aspirations and plans are fairly robust and not easily altered, whether that be those who have a career in mind or those who are uncertain.
As with our findings more generally, however, we must be careful what is inferred from the responses to this questionnaire. For instance, while most students chose to respond to COVID questions, we should be mindful that some or all of the 13 respondents who chose not to answer the questions about COVID might in fact be deeply impacted and troubled about their future in the midst of the pandemic.

We did note some trepidation from students in rural settings, and the responses we received from students in these settings suggest that more might be done to help boost confidence and self- esteem in rural schools. Career aspirations are often closely associated with a greater sense of self-efficacy, hopefulness and overall healthier behaviour (Dudovitz, et al., 2016). The larger barrier for students in smaller centres, however, appears to be concerns about the money and time required to complete post-secondary training, as well as a sense of unworthiness (feeling not smart enough or not qualified), as has previously been reported (Whalen, et al., 2016; Aird, et al., 2007). This speaks to the need for greater encouragement and outreach to youth in these less populous settings. We should also note that teachers and guidance counsellors more generally might play an important role in addressing the underlying anxieties (e.g., queasiness, intellectual inadequacies) expressed by our respondents.

A sizeable segment of the respondents indicated they were interested in pursuing a career in healthcare. In fact, the ~30% of survey respondents interested in a career in healthcare is proportionate to the share of the total Canadian workforce engaged in healthcare. There is a well- established literature demonstrating that those with close family or friends in the medical profession are positively predisposed to pursue a healthcare career, for instance because they enjoy various types of “insider” knowledge about medical school entry (Simmenroth-Nayda & Gorlich, 2015). At the same time, there is growing evidence that the presence of “weak ties” of social capital are also an effective means to extend the advantages of knowing a healthcare insider (Nicholson & Cleland, 2017). Beyond positively influencing career choices, the amount of informal interaction a youth has with healthcare professionals or providers is likely to determine the accuracy and realism of the youth’s impression of the field. This might include, for instance, impressions and expectations about course requirements, entrance examinations, and the importance of gaining extra-curricular experiences that are highly valued in securing placement in competitive programs.It has been shown that students are greatly influenced by parental views about the importance of post-secondary education, including as a means for youth to make long-term contributions to rural development after graduation (Abbott-Chapman, et al., 2014). The compliment of this is that efforts should be made to bridge the gap for those students who do not enjoy the benefits of a close family member or family friend in the field, perhaps by means of providing career mentoring and guidance services in schools serving students from traditionally underrepresented household and geographical contexts (e.g., low-income households, Indigenous households, rural and small-town settings).

Conclusion

It is important to hear from youth about their career aspirations and how they gather information that helps them choose a particular path. It is equally important to know more about how youth obtain information about healthcare education and career options. The findings reported here reinforce the notion that youth are influenced by a variety of sources, each with their own strengths and limitations. If nothing else, this speaks to an important role for educators to help ensure that youth have access to accurate and realistic information about career options, whether these relate to healthcare or other sectors. Our findings also offer support for the importance of taking context into consideration when designing and delivering career counselling and higher education recruitment exercises, particularly when the aim is to encourage greater diversity in future healthcare workforces.

If there is interest in promoting healthcare as a career option to youth in rural and smaller centres, our findings suggest that greater use might be made of the services and programming offered by guidance counsellors, especially for students in the early senior years of high school (i.e., grade 10). The data we collected suggest an interest in having more workshop programming, outreach (e.g., healthcare education "roadshow" events) and experiential opportunities (e.g., day visits to hospitals, job shadowing events) to learn more about healthcare careers. Schools in smaller and more remote regions, as well as those serving lower-income areas and Indigenous communities, often face a number of barriers and challenges in offering such programs and opportunities. This should give pause for school administrators and school district planners to consider ways in which various forms of communications technology and/or added resources and specific programming might be employed to close these gaps in access.

Limitations of this study include the small sample size which limits our ability to make generalizations beyond the populations studied. Additionally, we used a convenience sample, so the study was subject to selection bias because we relied on youth who chose to participate.

Finally, we would be remiss not to comment on the potential impact of COVID on youth attitudes and aspirations concerning healthcare careers. A majority of the youth we heard from had apparently not altered their career interests one way or the other, at least at the pandemic's one year mark. However, youth from small centres were more likely to have been turned away from a healthcare career because of the pandemic. It is also worth noting that 1 in 6 of our respondents chose not to answer questions about COVID, and we have no way of knowing the reasons for not wanting to do so. As of the writing of this manuscript, the evolving COVID pandemic is still on our minds. It would be wise to continue monitoring closely the impact that COVID may have on future educational and career aspirations of youth, especially among groups traditionally underrepresented in the healthcare workforce.

Recommendations

Given the importance of expanding our health workforce and increasing the numbers of healthcare providers from traditionally underrepresented groups, we offer the following policy recommendations:

1. School district officials and secondary school administrators should seek to enhance access to career counselling programs and experiential forms of career guidance.
2. Guidance counsellors and teachers should be encouraged and supported to develop or enhance educational outreach and professional mentorship programs to provide greater exposure to diverse healthcare careers.
3. Federal and provincial governments should consider ways to reduce or eliminate the costs of post-secondary education, and/or improve financial assistance options and enhance awareness of these options.

In each case, an emphasis on rural and Indigenous communities is needed to help youth from these traditionally underrepresented groups overcome potential barriers to healthcare career pathways.

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Solar energy considerations in urban planning:

The tension between solar potential and densification

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Abstract

In this paper we explore the relationship between solar potential and the built urban environment. Solar potential across the urban landscape is uneven, in part, because it is affected by the surrounding texture of the urban form. Increasingly, the integration of solar energy considerations into urban planning and design is considered a crucial step in the transition from fossil fuels toward more renewable energy sources. Given the impact of the urban form, a key challenge may be the tension between solar potential and policies that promote densification.

Other studies have noted how the built environment may significantly decrease solar potential. We suggest in this paper that solar potential should be more adequately considered in pre- planning phases with emphasis on the effects of building design on solar potential. The urgency may be heightened because increasing density with taller buildings has been embraced and widely implemented as part of many cities' urban sustainability agendas. Using the City of Calgary as a case-study, we explore its solar potential. A spatial modelling tool in a GIS environment was used to assess the solar potential of the central business district and surrounding neighborhoods. The results show that Calgary's central business district has significantly lower solar potential than the surrounding neighborhoods. Importantly, current land-use regulations do not cover the potential impact of taller buildings on the area's solar potential. We suggest that there should at least be acknowledgement of this issue in urban planning practices and that solar potential should be incorporated as one variable in the urban planning process.

Keywords: GIS; solar potential; urban planning; densification

Introduction

Increasing the amount of renewable energy sources, especially from solar power, is considered a vital part of achieving sustainability goals, especially as a key part of efforts to combat global climate change (Rogelj et. al. 2018). In addition to generating significantly less greenhouse gas emissions and reducing the use of fossil fuels, increasing the energy from solar sources may also foster greater "energy security" (Proskuryakova 2018). There is evidence that advances in solar energy systems enhance the stability of electrical grids and offers greater resilience during natural disasters (Pagliaro 2019).

Solar potential is unevenly spread across the urban landscape. One factor that has been shown to have a significant impact on the solar potential of a building is the surrounding texture of the urban form. Recent studies have examined the relationship between solar potential and various aspects of the urban texture (Lobaccaro & Frontini, 2014; Cheng, et.al., 2006; Kanters & Horvat, 2012; Zhang et.al., 2019). Save the modelling by Kanters and Horvat (2012), few studies have explored the relationship between solar potential and the potential impact of changes in urban form, especially in its densification. They suggested that increased densification, especially in urban cores, could decrease solar potential by as much as 75%, primarily due to complicated overshadowing effects. Unlike their study, our case-study of Calgary, Alberta, uses an existing urban form, not a model, to quantify the reduction in solar potential resulting from increased densification.

Employing geospatial modeling within a Geographic Information System (GIS) we ascertained that Calgary's urban core exhibits lower solar potential compared to its surrounding neighborhoods. The limits of the available techniques make it impossible to isolate the various causes of this difference such as the built form alone. Instead, we had to highlight the pattern in Calgary in which buildings in the urban core receive less solar radiation than buildings in the neighborhoods that surround it. The main cause, we suggest, is the contrasting-built forms, which is stark, where the central business district (CBD) has a much taller landscape. Building height has been shown to impact an area's solar energy potential, largely because of how shadowing reduces the area's solar radiation, and we suggest shadowing from taller buildings is the most plausible explanation for this difference.

In Calgary, as in other cities, this issue of building height is especially pertinent. As we note at the end of this paper, increasing densification in the areas that surround the CBD and increasing the solar potential of these areas are both central to Calgary's urban sustainability agenda. Yet, the current land-use regulations and urban planning policies fail to account for the relationship between the built environment and urban solar potential. The findings we believe show that there is tension between policies that promote greater density from land-use intensification and the potential benefits from the more widespread adoption of solar energy.

Calgary's CBD is a small area of the city, but its built form is unique in Calgary. As a percentage of the City of Calgary – the CBD is less than 10 km^2 – while the city's territorial jurisdiction is more than 800 km^2 – it is less than 10% Calgary's total area. What is most important for this study is that the CBD has much taller and ridged landscape than the rest of the city. Although our results do show that the ability of the CBD to provide its own solar power has been decreased, it is important to clarify that this was not the primary objective of this research. Instead, this research aimed to explore the potential loss of solar potential in other areas should the urban form change to more resemble the landscape of the CBD. Our contention is that contrasting the two areas illuminates the issue of the relation between solar potential and the characteristics of built-up environment and may help to prevent a loss in power generation in other areas of the city where there is pressure, especially, to build taller buildings.

Background:

Urban Sustainability, Urban Solar-Power Generation, and the Urban Landscape

Cities are increasingly targeted for their vital role in achieving sustainability goals. We live in an urban age, and any solution to meeting ecological goals must involve cities, the retrofitting of existing urban fabric, and the implementation of new technologies. Since the 1980s, a suite of planning and policies, under the banner of urban sustainability, the meshing together of urban development with environmental and social goals, has been championed as necessary (Beatley, 2008). For decades, policy and design frameworks such as smart growth or new urbanism, especially in North America, have located the central problem with North American cities as urban sprawl, highlighting its negative environmental consequences and advocating for more compact, transit-oriented, and denser communities (Checker et.al, 2015). One approach to arresting sprawl is a redevelopment model, like that advocated by journalist David Owen (2010), which is to enact policies that promote more intensification of land-use and taller buildings, especially for residential uses. Although this is not the only possibility to achieving greater urban residential density without very tall buildings (it could be achieved by utilizing 4-6 storey blocks as seen in the old urban quarters in Paris, Barcelona, and Copenhagen), cities in North America have largely embraced the approach of larger and taller buildings (Keough and Ghitter, 2021; Graham 2016). More recently, urban sustainability has also come to encompass the widespread adoption of urban solar energy systems. The experience of Freiburg, Germany, is a salient and popular example because the city adopted a highly incentivized solar power development strategy that proved highly successful (Keough and Ghitter, 2021).

Following the more recent trends in urban solar energy adoption, researchers began investigating the relationship between solar potential and urban planning. Over the past two decades, extensive large-scale initiatives have sought to identify and analyze optimal practices in solar urban planning, contributing to a substantial body of knowledge. These efforts have aimed to establish a more systematic set of planning practices, fostering the effective integration of solar energy into urban landscapes, and advancing sustainable development goals. The European Union, for example, since 2009, has had a program, EU POLIS, which focused on five European cities. The program examined and identified the best practises in solar urban planning as a part of a strategy to mobilize greater solar potential in the region. Another program, TASK 51, launched in 2013 was a specific taskforce within the International Energy Agency's Solar Heating and Cooling (IEA SHC) project. Looking at thirty-four case studies across the world, its goals were to figure out how to better support urban planners in integrating solar photovoltaics in urban areas (Lobaccaro, et.al. 2019). The TASK 51 project also highlighted several case studies showing the usefulness of conducting preliminary analysis to compare the current situation with the proposed planning alternatives regarding solar accessibility, potential, daylight, and energy generation.

A separate, more technical literature, has shown the influence of urban texture on solar potential, offering valuable insights into ways that urban density may influence solar potential and suggesting possible solutions. In particular, what the more technical literature shows is that with appropriate planning especially in the early design phases urban form could be designed to better maintain an area's solar potential. Zhang, et.al. (2019) argued that addressing specific factors in the urban form with appropriate design could increase the solar potential by up to 200%. In a case-study of Sao Paulo, Brazil, Cheng et al. (2006) found that solar potential is negatively correlated with plot ratio (i.e., the ratio of total floor area to site area). High site coverage combined with a random vertical layout, resembling those commonly found in CBD's as illustrated in Figure 1, they found, is disadvantageous because it causes overshadowing on rooftop areas resulting in a considerable proportion (30-80%) of low-level solar radiation (0-200 kWh/m^2) (Cheng, et.al., 2006).

Researchers have also explored solar access rights as a means to address diminished solar potential in urban settings, this may be especially valuable for areas experiencing increased densification. Solar access rights have not traditionally focused on the impact to active solar systems such as solar panels, rather it has been concerned with the effect on passive systems.

Addressing solar access rights, however, would indirectly bring attention to active solar energy system concerns. A common method of addressing solar access rights is by using a solar envelope, which is defined as the "volumetric limits to development that will not shadow neighbours," is meant to prevent overshadowing of neighbouring buildings during critical times throughout the day (Knowles, 2003). Although solar access may be most prevalent in highly built-up areas, where the urban form was constructed and oriented without concern for solar access, implementing more appropriate frameworks during the redevelopment of neighborhoods or sites can achieve a solution for this issue. Moreover, protecting solar access has complex legal challenges. Many jurisdictions still lack statutory recognition of solar rights and in these locales, other legal mechanism must be used such as easements, restrictive covenants, or purchasing airspace above neighbouring properties (particularly, in the UK and US) (Kauffman, 2019). The lack of policy creates uncertainty, potentially, stymieing, the more widespread use of solar technologies (Krivitsky, 2010).

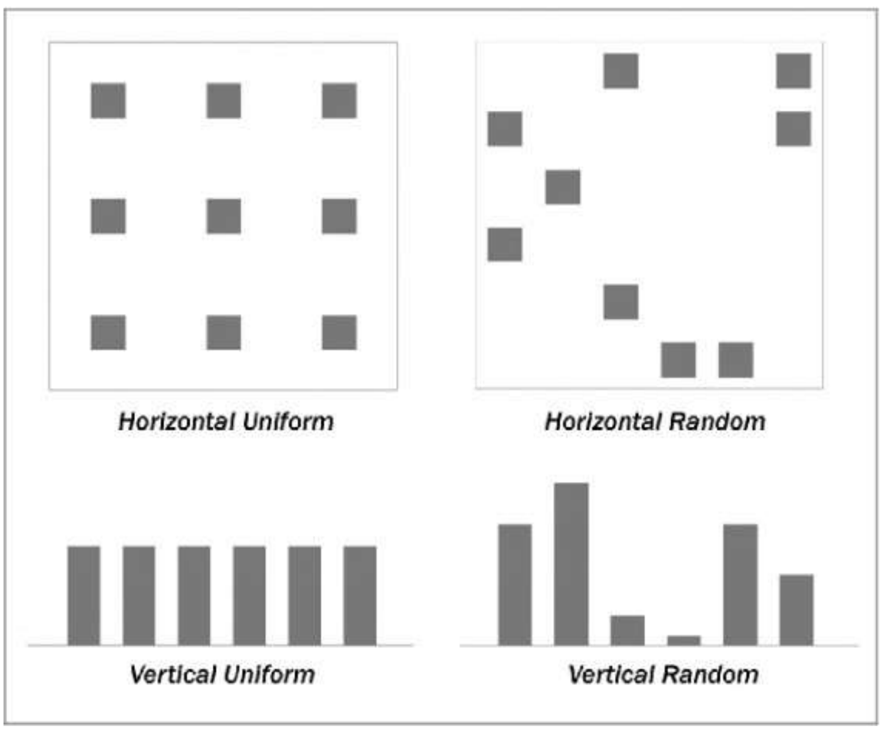

Figure 1: Horizontal and vertical urban layouts (Cheng, et.al., 2006). Both a horizontal and vertical random layout is seen in Calgary's downtown core whereas a horizontal and vertical uniform layout is more seen more in the surrounding neighborhoods.

Methods

Solar mapping allows the quantification of a city's solar energy production potential (Santos, et.al., 2014). The mapping and modeling of urban solar potential and the evaluation of specific sites, such as buildings, has been made more accurate by advances in geographic information sciences such as GIS and remote sensing (Dominguez, et.al., 2015).

In this study, three distinct sources of data were utilized to conduct a comprehensive analysis. The first dataset, acquired from Natural Resources Canada's High-Resolution Digital Elevation Model (DEM) database, consists of a 1-meter spatial resolution Digital Surface Model (DSM) of Calgary. It is important to note that while a DSM represents the Earth's surface, including all features like buildings and vegetation, and provides heights for both terrain and objects, a DEM focuses exclusively on the bare Earth's surface. A DEM excludes objects above the ground and is typically used for applications emphasizing topography. As seen in figure 2, which compares the difference between a DEM and a DSM, given our specific interest in rooftop solar potential for this project, a DSM is considered the most appropriate choice. The DSM layer was created from the Canadian federal government's airborne Lidar data, with an aggregate nominal pulse density exceeding 2 pulses per square meter (pls/m^2) (Government of Canada, 2019). The second dataset encompasses a city-wide 3D buildings layer and building footprint layer, both sourced from the City of Calgary. These layers provide essential information about the structural landscape of the urban environment. The final data source utilized in this study is a city-wide Dissemination Block Polygon layer obtained from Statistics Canada. A dissemination block refers to a bounded area enclosed on all sides by features such as roads or rivers, providing a valuable geographical unit for our analysis.

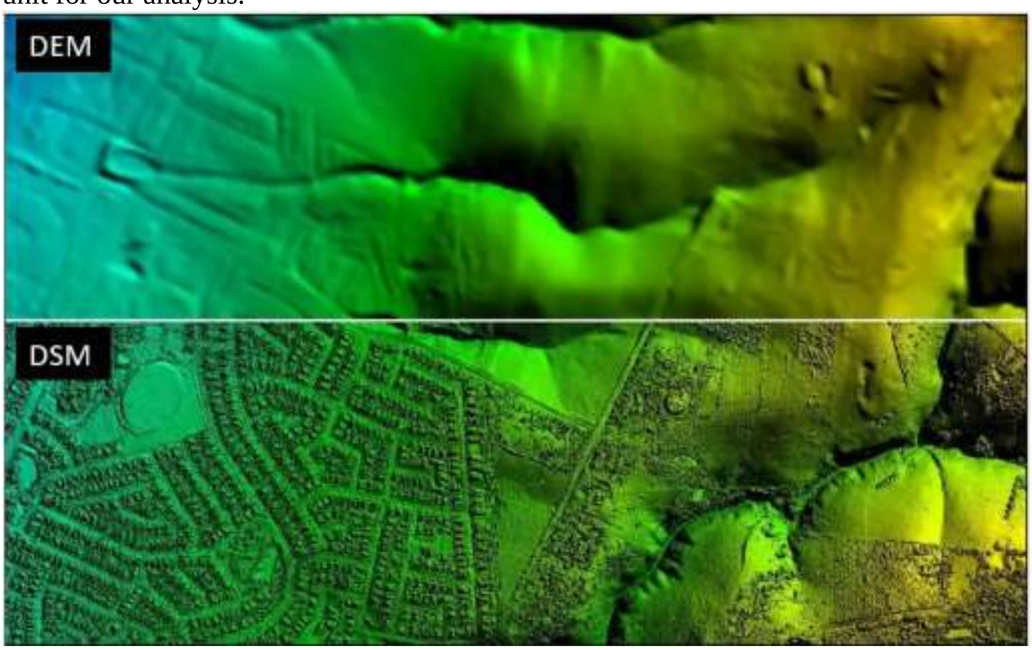

Figure 2: Comparison showing the difference between a DEM and a DSM (Singh, 2013). A DEM shows changes in bare ground elevation. It does not capture any features on the ground. A DSM shows the surface of the earth including features such as buildings and trees. For this research, given we are interested in rooftop solar a DSM is the appropriate choice to use in the analysis.

The study employed the ArcGIS Pro's area solar radiation tool with specific input parameters detailed in Figure 3. This tool generates an upward-looking hemispherical viewshed based on a DSM and is suitable for high spatial resolution scale analyses (Kodysh et al., 2013). The viewshed algorithm, part of the ArcGIS Pro Solar Analyst toolbox, involves three initial calculations—viewshed, sunmap, and skymap—and a final calculation that utilizes the results to estimate solar radiation values for each location on the DSM (Kodysh et al., 2013). In customizing key input parameters for the solar radiation tool, considerations such as sky size resolution, time intervals, and number of calculation directions were examined.

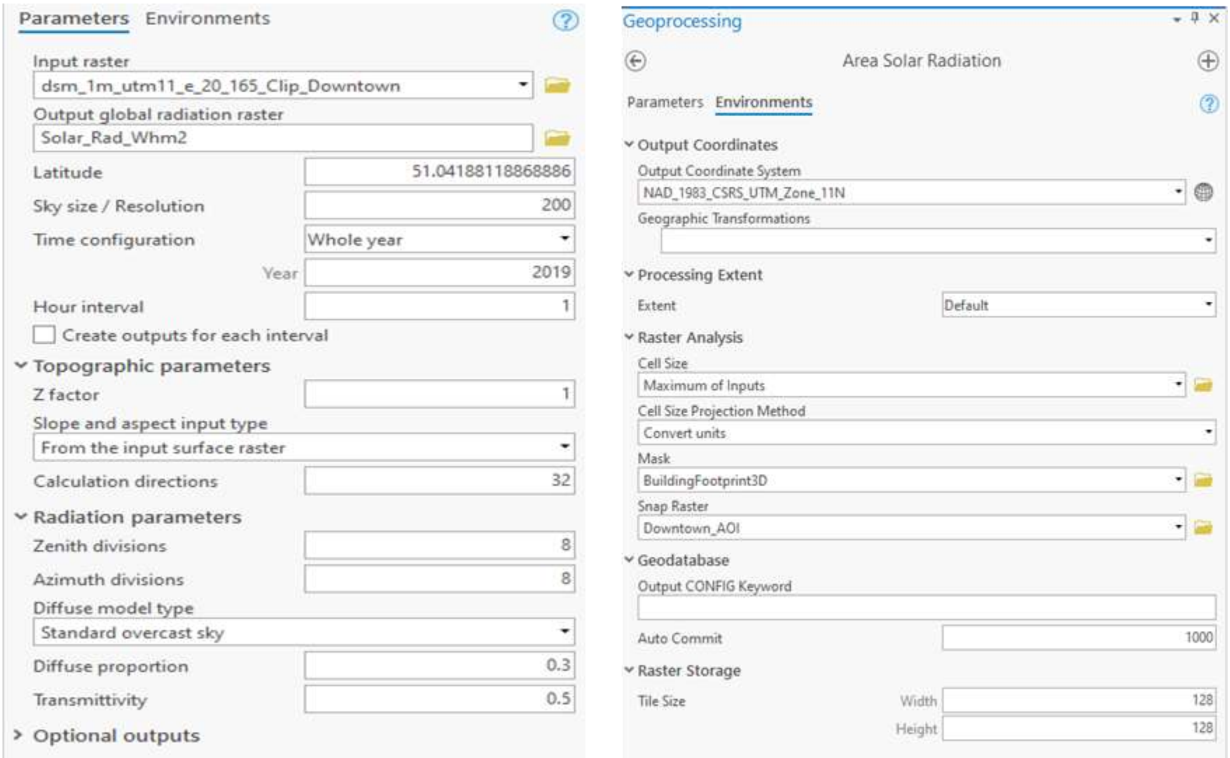

Figure 3: Inputs for ArcGIS Pro's "area solar radiation" tool. The input raster was a DSM collected from Natural Resources Canada. The solar potential was calculated as an average over an entire year. 32 directions were used to calculate the solar radiation input for each 1 m pixel. Diffuse proportion and transmissivity values were used to estimate average cloud coverage seen in Calgary.

The sky size, determining the resolution for viewshed, sunmap, and skymap rasters, significantly affects calculation accuracy and time (Esri, n.d.). Although increasing sky size enhances accuracy, it also extends calculation time. Typically, for entire DSMs with day intervals exceeding 14 days, a value of 200 is sufficient (Esri, n.d.). Given that this project assessed solar potential throughout an entire year, using monthly intervals, a sky size value of 200 was appropriate to balance detail and computation time.

Viewshed calculations determine the angular distribution of sky obstructions for each cell in the DSM, considering shadow obstructions impacting solar potential (Fu and Rich, 1999). The viewshed is determined by searching a specified number of directions around the location of interest to ascertain the maximum angle of sky obstruction, known as the horizon angle; for the remaining unsearched directions, horizon angles are calculated using interpolation (Fu and Rich, 1999). The number of calculation directions are linked to the DSMs spatial resolution. High spatial resolution DSMs, especially with human made structures require an increased number of directions (Esri, n.d.).

Direct solar radiation calculations utilize the sunmap, displaying the sun's position at designated time intervals, and are based on the study area's latitude and time configuration (Esri, n.d.). The skymap calculates diffuse radiation, incorporating atmospheric components.
Atmospheric conditions, crucial for accurate calculations, are approximated using average diffusivity and transmissivity values. Default values of 0.3 for diffusivity and 0.5 for transmissivity were used, aligning with generally clear skies in Calgary.

The standard overcast sky option was chosen to account for zenith angle variation in relation to incoming diffuse radiation flux, particularly relevant for Calgary's varying sun angles throughout the year. The choice of the standard overcast sky option is not intended to account for shadows but rather to simulate the variation in incoming diffuse radiation flux based on the zenith angle. This option specifies the type of diffuse model used. The options are standard or uniform. The uniform overcast sky option means that the amount of incoming diffuse radiation will be considered the same from all sky directions. The standard overcast sky option means that the incoming diffuse radiation flux varies with the zenith angle. At higher zenith angles, sunlight has to pass through more of the Earth's atmosphere, leading to increased scattering and reduced radiation reaching the surface. This is the correct choice given Calgary’s latitude and it does not impact the shadowing calculation.

After researching these inputs, the tool was initially run without a mask (Figure 4) and subsequently with a building footprint layer mask (Figure 5) to assess overall and building rooftop solar potential.

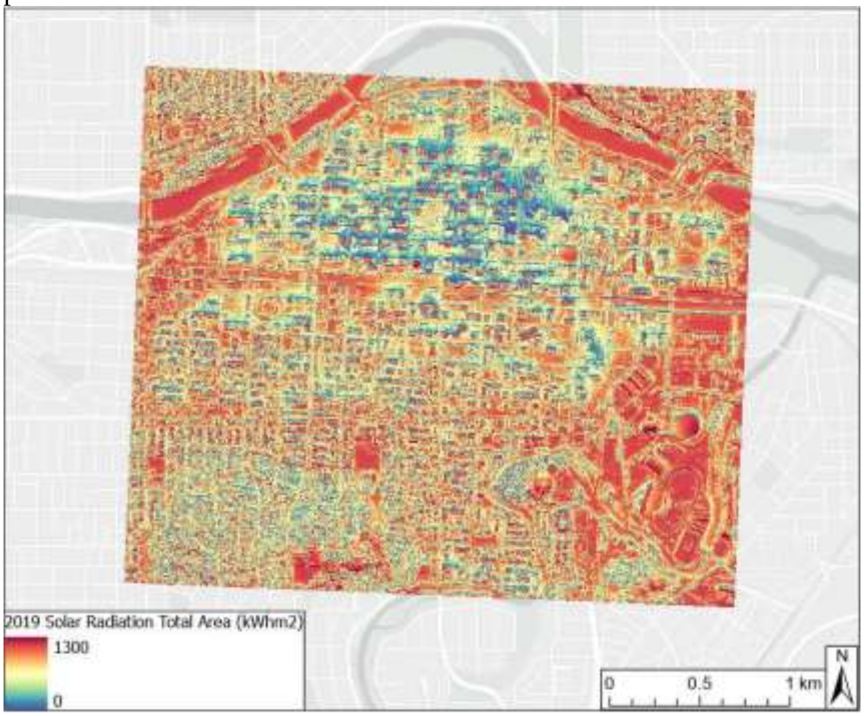

Figure 4: Calculated solar radiation from ArcGIS area solar radiation tool. Pixel size is 1 m. Areas of lower solar radiation/potential (shown by blue colours) in the downtown core are the result of overshadowing by tall buildings.

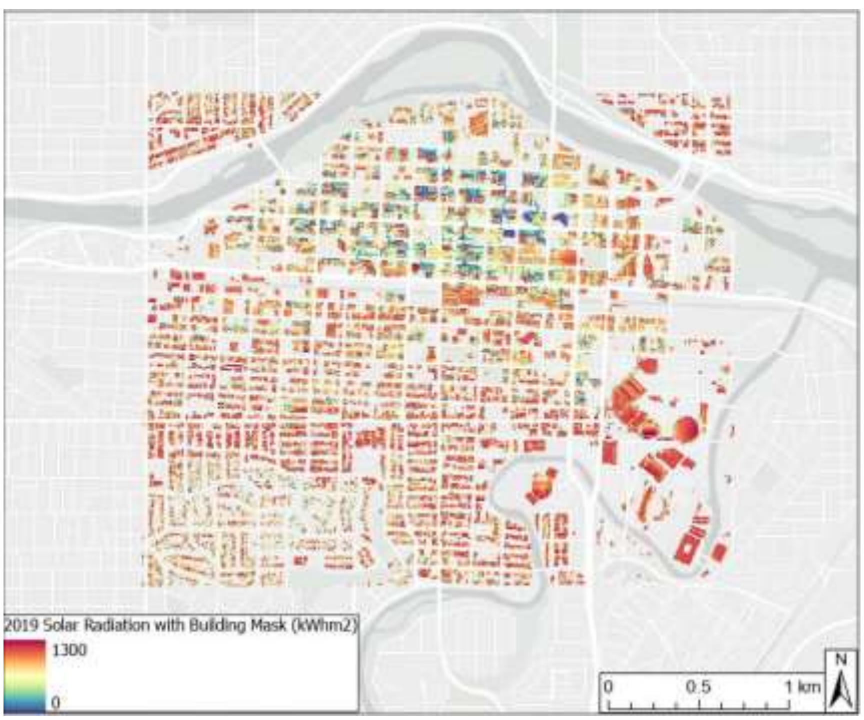

Figure 5: Calculated solar radiation from ArcGIS area solar radiation tool. Showing only rooftop results. Pixel size is 1 m. Areas of lower solar radiation/potential (shown by blue colours) in the downtown core are the result of overshadowing by tall buildings.

For this study, area density and its solar potential were joined. Building volume, cubic size of a building, was chosen as a reasonable proxy for density. It was calculated using the buildings footprint layer and the following equation.

((rooftop elevation (z) – ground elevation (z)) * shape area)

Equation 1: Calculation for above ground building volume, used to quantify density.

After calculating each buildings volume, a spatial join was performed that linked the dissemination block polygons and the buildings layer, then these building volumes were dissolved into each dissemination block (Figure 6). To calculate the mean solar potential for each dissemination block, a zonal statistics tool was used and joined to the building volume for each dissemination block. From there the data was exported into a table and building density was recalculated as the sum of the volume of all buildings for each dissemination block. For the analysis only a sub-set, comprising a spatial coherent area which included Calgary's CBD and adjacent areas to the south (as shown on Figure 6), of the dissemination blocks was used.

Figure 6: Dissemination blocks (black outlines) and building polygons (yellow blocks) included in correlation analysis. Excludes areas to the east as they comprise of light industrial and stampede ground areas. Excludes areas south of the elbow river comprising of green spaces and parks. Over 200 blocks included.

Given the non-linearity observed in the dataset, as illustrated in Figure 7, Spearman's rank correlation coefficient was employed. Spearman's rank correlation analysis was chosen as it does not assume a linear relationship between the variables. This analysis provided a quantitative measure of the relationship between solar potential and building density.

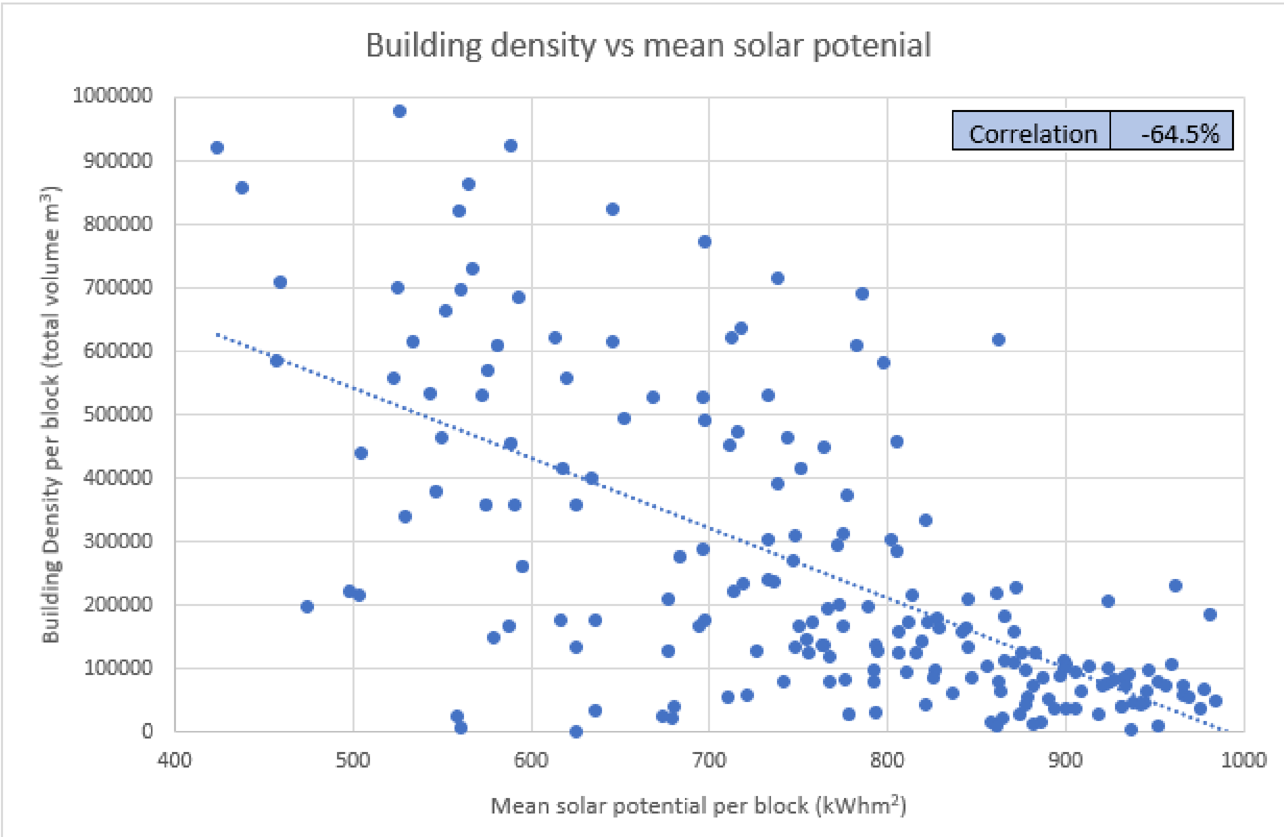

Figure 7: Building Density vs mean solar potential. Excludes 10 outliers with extremely high building density and varying solar potential. Includes a line of best fit. The Spearman's rank correlation coefficient is -64.5%, indicating a strong negative correlation between the two variables.

An examination of Calgary's urban planning regulations was also conducted to see if it contained information which addressed solar potential, strategies to increase densification, and measures to address the potential tension between solar potential and densification. In particular, Calgary's municipal development plan was consulted. It is the core planning document, updated in 2020, which shapes the city's long-term planning priorities. Further, a search for policy and regulations regarding solar access rights was conducted.

Results

Figures 3 and 4 show the calculated solar potential for the study area and shows starkly that Calgary's CBD has significantly lower solar potential (cold colours) than its surrounding neighbourhoods (hot colours). To provide a more precise assessment, the average solar potential for buildings in the downtown commercial core was determined and juxtaposed with the average solar potential for buildings in the surrounding areas. Notably, the downtown core demonstrated an average solar potential 33.5% lower than that of the surrounding regions.

The scatterplot of density (building volume) and mean solar potential, represented in Figure 7, clearly depicts a negative correlation between these two variables and the spearman's rank correlation coefficient of -64.5% further confirms this. In correlation analysis the sign of the coefficient indicates the direction of the relationship. A positive coefficient suggests a positive monotonic relationship (as one variable increases, the other tends to increase). A negative coefficient suggests a negative monotonic relationship (as one variable increases, the other tends to decrease). The magnitude (absolute value) of the Spearman's rank correlation coefficient indicates the strength of the relationship. A coefficient close to 1 (positive or negative) suggests a strong monotonic relationship. A coefficient close to 0 suggests a weak or no monotonic relationship. In this case, the calculated coefficient of -0.645 shows a moderately strong negative correlation.

The potential impact on solar panel installations is evident and, potentially troubling because, in practical terms, lower overall solar potential decreases the number of suitable rooftops. Several factors are used to determine suitability for solar panels such as the amount of incident solar radiation, facing direction, individual building energy usage, roof size, and slope. In this study a general analysis of suitable rooftops was conducted using a minimum amount of incident solar radiation criteria generally accepted to be >800 kWh/m^2 (Bujarkiewicz et. al. 2018).

Discussion

ArcGIS Pro’s area solar radiation tool has been shown to be accurate and robust, specifically by Giannelli et.al. (2022), who compared six different solar radiation modelling tools and real-world weather data, showing that ArcGIS only had a 0.2% difference, and a root mean square error of 0.91, when compared with yearly weather station data. However, despite its strengths, the tool has limitations that may impact the accuracy of solar maps. One notable limitation is its reliance on an internal radiation model, preventing users from providing their own weather data files, thus potentially reducing accuracy (Giannelli, et.al., 2022).

Another potential limitation of using this tool is that it does not include reflected radiation in the calculations. This does not have a large effect as reflected radiation is considered to be only a small proportion of the total radiation. However, reflected radiation can be affected by different surface conditions such as snow cover or different building material types. While this was not explored in this research it may be an interesting future direction of study to consider the impact of building materials on solar potential.

In Calgary, we found the denser urban core has significantly lower solar potential than the less densely developed surrounding areas. Despite that we show this, we are not able to isolate the various causes of the difference. We suggest that the main cause of reduced solar potential is due to overshadowing of suitable rooftops by tall buildings.

The negative correlation identified between solar potential and urban densification may have important ramifications for Calgary as solar energy generation becomes more common and a key part of how Calgary meets its carbon reduction targets. A key recommendation emerging from this research is to formally acknowledge the tension between densification and solar potential in urban policy. An increased awareness of the tension between the adoption of a large- scale urban solar network and increasing urban density would allow for sounder objectives to be developed that would not undermine either. Our recommendation here is supported by recent literature, which shows that solar power has become a more important element of urban sustainability and that appropriate planning, especially in the early design phases, could better maintain the solar potential of areas in a city. Failure to incorporate solar potential in urban planning policies, may impact the solar potential across entire urbanized areas and it appears this could be minimized. This is an unforeseen missed opportunity that will be much more manageable and inexpensive to address in the pre-planning phase.

The problem is especially evident when examining the City of Calgary's municipal development plan, updated in 2020. Outlining a myriad of goals and objectives, the plan put a great deal of emphasis on the urgency of increasing density in Calgary's existing urbanized areas as a way to arrest sprawl and increase municipal housing supply (City of Calgary, 2020). While the plan does not specify what types of building will help accomplish this goal, the trends in redevelopment in Calgary have been to permit more high-rise buildings. Although the plan briefly mentions solar considerations, these are limited to maximizing passive solar gain through street design and building orientation, ensuring solar penetration throughout a block, and reducing shadowing to public sidewalks on the North side of streets. The plan does not mention the suitability of solar panels and active solar potential, and therefore, does not envision the potential impact of a densification strategy that prioritizes taller buildings. The results of this study suggest that addressing this potentially significant and costly omission is crucial to maximize the goals of densification and solar production in future developments. Further, as of 2021, in Alberta, there is no legal acknowledgement of solar access rights (Kauffman, 2021).
This lack of policy creates uncertainty, potentially, stymieing, the more widespread use of solar technologies (Krivitsky, 2010).

The omission of active solar in the plan is especially surprising in Calgary. The City of Calgary has made significant commitments to maintaining high solar coverage in other contexts - specifically, preventing shadowing of pathways along the Bow River pathways to preserve the sunlight and warmth in and along pedestrian corridors. The results of this policy on solar potential are seen in Figure 4. Applying this approach more broadly would encourage better design of buildings that could maximize their solar potential and increase the desired building density more effectively.

Conclusion

In conclusion, a forward-thinking approach to urban planning should incorporate solar potential considerations from the design phase. The study recommends modeling solar potential under various design scenarios to ensure the consideration of trade-offs early in the design process when implementing changes is less costly. This proactive approach would prevent the wasteful loss of the city's urban solar potential and foster a balance between the goals of densification and solar production. Acknowledging and addressing the tension between these objectives in urban policy is crucial for sustainable and effective city planning. The study underscores the importance of adopting a comprehensive approach that takes solar potential into account, fostering the design of buildings that not only maximize solar efficiency but also align with the objectives of achieving desired building density.

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Cataloguing of rock glaciers in dissimilar regions of the Mackenzie Mountains: Testing for possible semi-automated detection of rock glaciers using topographic data

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We acknowledge that The University of Lethbridge is located on the traditional territory of the Blackfoot Confederacy. We recognize and honor the past, present, and future generations of Indigenous peoples who have lived on this land since time immemorial.

ABSTRACT

Rock glaciers have been the subject of extensive research in recent years, due to their potential to serve as indicators of past and present climate conditions and their potential impacts on water resources. Compilation and analysis of collected data on the location, size, and characteristics of rock glaciers within the Mackenzie Mountains was used to build a rock glacier catalogue that will serve as a valuable resource for future research and monitoring efforts. The research also aims to map the spatial distribution of rock glaciers using optical imagery and to develop a semi-automated detection model using Generalized Additive Models (GAMs) in R. The model will incorporate attribute data, such as solar radiation, aspect, topographic position index, slope, elevation, and lithology as controls for rock glacier development. Topographic data was collected in multiple regions of the Mackenzie Mountains and extracted using a 30m digital elevation model (DEM). The results of this study have the potential to improve our understanding of rock glacier distribution and dynamics in the Mackenzie Mountains and could also be applied to similar mountainous regions.

Figure 1: Three defined regions within the Mackenzie Mountains, which border the NT and YT in northern Canada. Each region is approximately 5000 km^2.

OBJECTIVES

1. Identify rock glaciers in selected study regions within the Mackenzie Mountains using previously developed classification methods.
2. Analyze rock glacier morphological attributes, extracted from digital elevation models (DEMs)
3. Test a potential semi-automated detection model using a statistical approach. Striving for a semi-automated model that will determine the likelihood of rock glaciers in adjacent regions.

METHODS

The international permafrost association (IPA) has established guidelines for the inventory and mapping of rock glaciers, which provide a framework for the use of optical imagery in the identification of rock glaciers (RGIK, 2022). The morphological features discussed in this study, follow these guidelines, and include utilizing identification criteria including vegetation patterns, color, ridge, and furrow features. This framework was implemented to manually identify rock glaciers from satellite imagery, within an ArcGIS Pro 2.9.3 environment (ESRI Inc. 2021), Google Earth 7.3.6 (Google Earth 2022) Pro and Sentinel Hub.

Features confidently identified as rock glaciers were recorded using datapoints labeled RG (Rock glacier) while features that were identified as debris covered glaciers (DCGs), embryonic rock glaciers, protalus lobes, protalus ramparts, talus cones and rockslides were recorded as features of interest (FOI). To overcome subjectivity issues a consensus-based method was used (Way et al, 2021).

The spatial distribution of rock glaciers can be modeled using generalized additive models (GAMs) in R (R version 4.2.2). In this study multiple GAM models were created in R with restricted maximum likelihood (REML) method. These models help to better understand the spatial distribution of rock glaciers as a binary dependent variable, '0' and '1' absence and presence, respectively. In the stepwise GAM model termed ‘StepGAM1,’ six independent variables were included: 'slope,' 'eastness,' ‘northness,’ 'topographic position index,' 'elevation,' and 'solar radiation.” To prevent issues with maintaining consistency among variables that are distributed radially, the aspect was transformed into two linear variables that represent the direction of "northness" and "eastness” (Pearson et al, 2007). Lithology was not included in the StepGAM1 model as a predictor variable because including categorical predictors with many levels, such as lithology, can lead to overfitting, which can result in poor model performance on new data (Wood, 2017). A second GAM model ‘StepGAM2’ was created to test the differences between the models when including the lithology variables.

Figure 2: Active rock glacier, SA3, ESRI World imagery base layer (ArcGIS Pro, version 2.9.3) with defined, steep terminus and lateral margins. Ridge and furrow topography indicative of flow also apparent, 1:10,000.

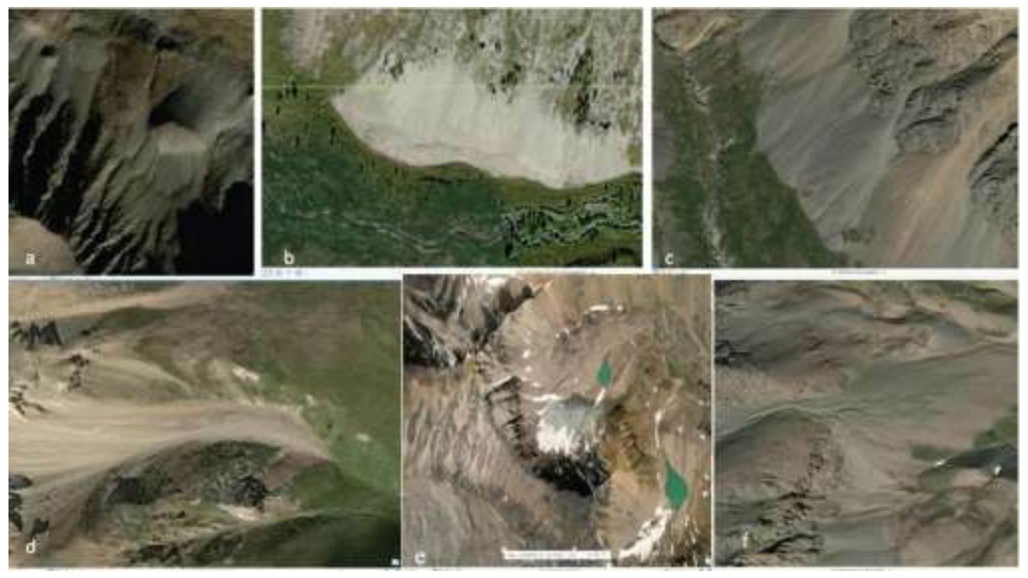

Figure 3: Landforms found in periglacial environments that can be considered embryonic rock glaciers (a) FOI; embryonic rock glacier (protalus lobe) from SA3, northern Mackenzie Mountains. ESRI world imagery base layer (EWIBL), 1:10,000 (b) protalus rampart, SA2,(EWIBL), 1:5,000; features that can be mistaken for rock glaciers (c) talus cones, SA1, ESRI World Imagery Base Layer, 1:5,000 (d) rockslide, SA2, ESRI (WIBL), 1:5,000 (e) debris covered glacier, SA1, ESRI (WIBL), 1:15,000 and (f) fluvial erosion over a talus slope,SA1, ESRI WIBL, 1:5,000. (ArcGIS Pro, version 2.9.3).

RESULTS

StepGAM1

variable	AIC	R2	Step
Sol_Rad	1018.683	-0.00125	1
Sol_Rad+SLOPE	919.728	0.135434	2
Sol_Rad+SLOPE+Eastness	898.9516	0.158932	3
Sol_Rad+SLOPE+Eastness+Northness	900.9068	0.157878	4
Sol_Rad+SLOPE+Eastness+Northness+ELEV	865.4432	0.195075	5
Sol_Rad+SLOPE+Eastness+Northness+ELEV+TPI	517.6669	0.551742	6

	Predicted Positive	Predicted Negative
Actual Positive	122	34
Actual Negative	26	130
Total Diagnol	252	
Total	312	
Accuracy (%)	80.77	

StepGAM2:

variable	AIC	R2	Step
Sol_Rad	1018.683	-0.00125	1
Sol_Rad+SLOPE	919.728	0.135434	2
Sol_Rad+SLOPE+Eastness	898.9516	0.158932	3
Sol_Rad+SLOPE+Eastness+Northness	900.9068	0.157878	4
Sol_Rad+SLOPE+Eastness+Northness+ELEV	865.4432	0.195075	5
Sol_Rad+SLOPE+Eastness+Northness+ELEV+TPI	517.6669	0.551742	6
Sol_Rad+SLOPE+Eastness+Northness+ELEV+TPI+Lithology	501.8854	0.590138	7

	Predicted positive	Predicted Negative
Actual Positive	120	36
Actual Negative	25	131
Total Diagonal	251	
Total	312	
Accuracy (%)	80.45	

The rock glacier inventory results show that there are a total of 536 rock glaciers total within the three regions. 477 categorized as active and 59 as inactive. The area covered by rock glaciers in each study region is 121.62 km2 in region 1, 60.66 km2 in region 2, and 88.07 km2 in region 3. The mean elevation of rock glaciers in all regions is 1608.6 meters, with a mean slope of 17.6 degrees and a mean aspect of 168.7 degrees. The mean TPI (Topographic Position Index) is -40.3, indicating that rock glaciers are generally lower in elevation than their surroundings. The mean solar radiation is 231.2 W/m2, which may contribute to the formation and maintenance of rock glaciers. The occurrence of different types of geology in each study region is also presented, with sandstone, dolostone, and siltstone being the most common rock types among the rock glaciers while shale, dolostone and limestone are the most predominant rock types of the entire study area.

CONCLUSIONS

In conclusion, the catalogue results provide valuable information for understanding the distribution and characteristics of rock glaciers in the study regions, as well as their potential impacts on the surrounding landscape. The generalized additive model with a binomial family and a logit link function provides significant predictors for the outcome variable and explains a moderate amount of variance in the data. The inclusion of lithology as a predictor in the model provides additional information that helps explain more of the variation in the response variable compared to the second model that does not include lithology. However, the second model still explains a substantial portion of the variation in the response variable. The confusion matrices show that both models have similar accuracy and F1 scores, but Model 1 has a higher precision score indicating better performance in correctly identifying positive cases. It may be worthwhile to further evaluate the model's performance through cross-validation or other methods, such as a random forest model. The data collected will also be used to create a probability surface in ArcGIS Pro. This surface will provide a visual representation of the model's results and better illustrate the probability of different outcomes. The probability surface is created by overlaying the model results on a geographic map, in order to see the spatial distribution of the model predictions. This information can be invaluable in making informed decisions and identifying areas of higher likelihood of rock glacier presence, therefore reducing the time, and labor constraints, as well as subjectivity that are currently encountered when composing a rock glacier inventory at large regional scales.

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Retreat of an Unnamed Glacier in Stave River Watershed, Garibaldi Provincial Park, British Columbia

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Abstract

The retreat of glaciers in southwestern British Columbia is happening at an alarming rate. An unnamed cirque glacier lies on the northeast slope of Galaxy Peak within the Stave River watershed in southeastern Garibaldi Park, British Columbia. A comparison of Google Earth Engine Timelapse imagery reveals that the glacier has been retreating at an average of 5.5±.7 m a^{-1} between 1988 and 2020. If the glacier were to continue retreating at this same rate, the glacier would take approximately 232 years to disappear completely. The position of terminal moraines using high-resolution satellite imagery indicates that the approximate length of the glacier during the maximum of the Little Ice Age was 2.2 km. If measured from the end of the Little Ice Age until 2020, the glacier would have retreated at an average rate of 5.1±.2 m a^{-1}. Additionally, analysis of sentinel-2 imagery from 2022 indicates the accumulation area ratio (AAR= 0.3) is below the equilibrium accumulation ratio (AAR_0) required for the survival of glaciers between 1 and 4 km^2. Other evidence such as rock islands appearing in the accumulation zone and lakes forming on the east margin indicates a low likelihood of survival for this glacier in our current climate.

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Figure 1. Water drainage from Galaxy Peak Glacier (red arrows indicate Galaxy Peak glacier, yellow arrow indicated ultimate base level of the streams draining the glacier) Source: Sampled from https://river-runner-global.samlearner.com/ by K. Moore.

Introduction

Unofficially named "Galaxy Peak Glacier" is located within the unceded territory of the S'ólh Téméxw, In-SHUCK-ch, Sƚáƚimc Tmicw, Kwantlen and Cayuse, Uma;lla and Walla Walla First Na;ons peoples.[2] This glacier is located 65.2 km northeast of Vancouver, BC and 52 km southeast of Whistler, at (49.740742°N 122.534747°W). The glacial meltwater flows into Stave River for 98km, flows into Stave lake, then into the Fraser River for 71 km, and finally ends up in the Salish Sea. Galaxy Peak Glacier is located within the Pacific Ranges.

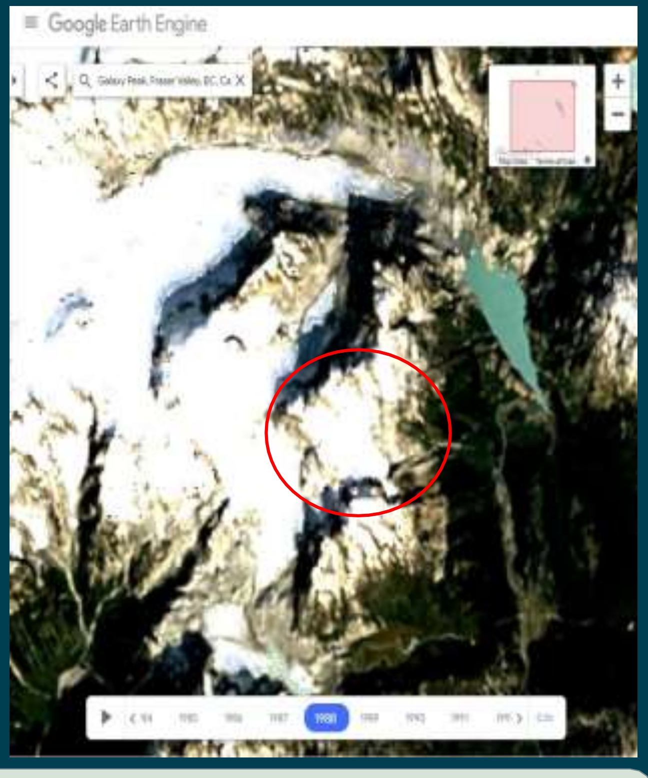
Figure 2. Toporama Map of Galaxy Peak Glacier (red arrow indicates highest elevation) Source: Sampled from The Atlas of Canada-Toporama by K. Moore. Used in accordance with Government of Canada non-commercial reproduction terms of use.

Methods

- Retreat since the Little Ice Age was calculated by using the location of terminal moraines from the Little Ice Age identified using Google Earth imagery. The age of maximum extent of the Little Ice Age was assumed to be 1850.
- Retreat from 1988 until approximately 2020 was calculated by comparing the farthest estimated extent of the toe in 1988 identified using Google Earth Timelapse and the most recent image on Google Earth Web.
- Accumulation Area Ratio (AAR) was determined by examining Sentinel hub Playground imagery as well as a paper written by Kern and László (2010) that states glaciers between 1 and 4km^2 should have an AAR of 0.54 ± 0.07.[1]

Results

- Retreat from the Little Ice Age until 2020 is about 5.1±.2 m a^{-1}.
- Retreat from 1988 until 2020 is about 5.5±.7 m a^{-1}.
- The accumulation Area Ratio is approximately 0.5 which is within the bounds of what it should be for a glacier this size.



Figures 5 (left) & Figure 6 (right). Figure 5 depicts the Galaxy Peak glacier in 2020. Figure 6 depicts the Galaxy Peak glacier in 1988. (Red circles indicate where the glacier is) source: Google Earth Engine Timelapse – glacier Sampled from Google Earth by K. Moore and used in accordance with Google Earth terms and conditions.

Discussion

Inspection of the Sentinel-2 imagery from late in the melt season of 2022 indicates:

- Thinning in the accumulation zone is suggested by the emergence of the rock island towards the top of the glacier. It has grown larger compared to the photo in 1988, and another island is evident to the left of the first one.
- However, 2022 Sentinel imagery indicates a large accumulation area that Kern & László (2010) would suggest would be associated with a positive mass balance for that year. If large annual accumulation like that of the 2021-22 mass balance year were to continue, the glacier could survive the warming climate, although this is unlikely due to the overall recent and longer-term glacier recession.

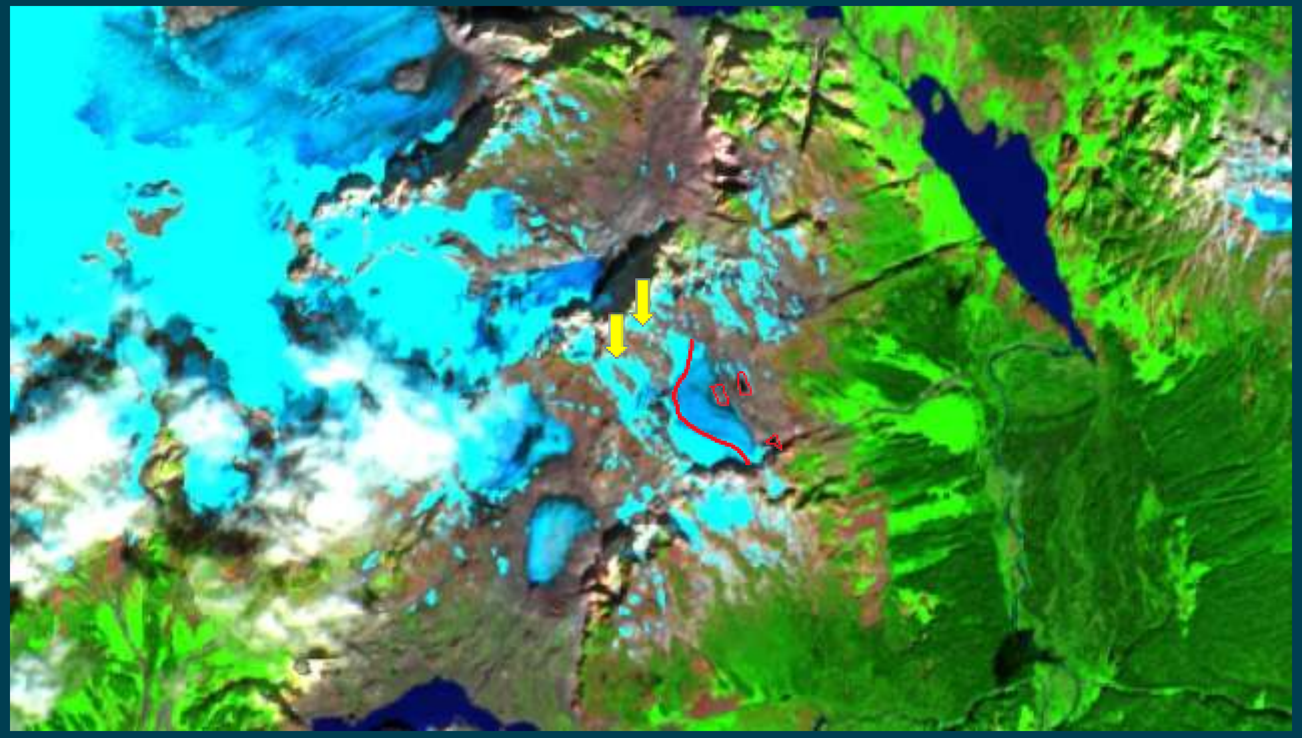


Figure 7. Sentinel 2 imagery taken mid-September 2022 (red line indicates accumulation zone, red shapes indicate lakes and the yellow arrow points to the rock islands) Source: Sampled from Sentinel Hub EO Browser by K. Moore. Materials are shared under CC BY 4.0 license.

Conclusion

Galaxy Peak Glacier has a low chance of survival in the current warming climate. Comparison from the Little Ice Age and the 1988 toe show the retreat has increased from 5.1±.2 m a^{-1} to 5.5±.7 m a^{-1}. If the glacier were to continue retreating at 5.5±.7 m a^{-1} it would take about 232 years to fully disappear although, I hypothesise the rate of retreat will continue to increase further. Additionally, the mass balance in mid-September 2022 showed to be positive but for the glacier to survive it would need to maintain a positive mass balance for many consecutive years, this is unlikely due to the warming climate. Galaxy Peak Glacier has a low likelihood of survival.

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