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Boom Bust Economy and Social-ecological Systems

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Abstract

This paper reports on the changing dynamics of a small town's social-ecological system (SES) concerning oil and gas industry boom-bust economic cycles. It explores both the vulnerability and resilience of the town over the past 30 years. With the goal to understand how resource-based single industry economies impact social-ecological systems, we developed indicators of human and environmental well-being and assessed them. Seven indicators were used including labor force distribution, education, oil price, household income, water quality, air quality, and land cover land use. Over this period, Drayton Valley, Canada quadrupled in size, with more than 20% of the population working in the oil and gas sector. Median income rose to 42% above the national average despite the population lagging behind national benchmarks for educational attainment. There have also been dramatic fluctuations in levels of fluoride, phosphorus, and other chemicals in water quality samples, implying a correlation with fossil fuel extractive activities over this period. Land cover land use change analysis shows a decreased area of water bodies, wetland, and forests, and increased built capital and agricultural land. While economic boom cycles have led to cash inflows, an exclusive focus on the benefits of the oil and gas industry may leave those dependent on the industry vulnerable to social and environmental risk factors during bust cycles that are beyond their control in the everchanging global oil economy. This phenomenon, which has been referred to as the "resource curse", suggests the need to anticipate cyclical (or more sustained) periods of low levels of oil and gas production. These results also point to the impact of single industry boom-bust economies on social-ecological systems. Therefore, a sustainable development plan that comprehensively considers not only economic growth, but also diversification, environment protection, and strategic land use planning is indispensable to ensure the long-term development of communities that depend upon extractive industries.

Keywords: Boom bust economy, Resilience, Single industry, Social ecological system, Sustainable development

1. Introduction

Extractive industries offer precipitous influx of revenue that can serve as a valuable development asset to be translated to multisector economic prosperity and improved social wellbeing during "boom" cycles (Chindo, Naibbi et al. 2014). However, real-world examples have demonstrated that many resource rich countries/regions (e.g., Angola and the Democratic Republic of Congo) experienced only temporary economic growth which was followed by long-term economic vulnerability and social problems (Boschini, Pettersson et al. 2007, O'Leary and Boettner 2011, Jacquet and Kay 2014), which is the widely recognized "resource curse" phenomenon (Wright 2001). Though little agreement exists on why "resource curse" happen, two perspectives are often mentioned in the literature (Findlay and Lundahl 1999, Findlay and Lundahl 2017). The first is an economic perspective. It considers that sudden influx of resource-based wealth disincentivizes other industries so that these countries/regions risk their economic prospects by overly relying on a vanishing resource before it is too late to diversify economically (Corden and Neary 1982, O'Leary and Boettner 2011). The second perspective involves political and economic theories and argues that the lack of institutional management of resource revenue could turn the potential of resources to boost the economy of countries/regions into barriers for diverse and long-lasting economic strategies (Boschini, Pettersson et al. 2007, Holden 2013).

Socioeconomic changes as a result of boom and bust cycles can be seen in many social indicators, including population growth, health and income equality, employment opportunities, and education attainment (Schrecker, Birn et al. 2018). Extractive industries worldwide have been found to have varying degrees of impact on human health including a toxic work environment (Cartwright 2016) and environmental exposure (e.g., water and air contamination) (Eisler and Wiemeyer 2004, London and Kisting 2015). An energy boom-bust study in Western Canada found that(Timoney and Lee 2001) boom-induced labor demands placed greater impacts on the earnings and employment within energy extraction industries than in other industries and widened the income gap (Marchand 2012). The counties in West Virginia, U.S that heavily relied on mining and enjoyed an economic surge during boom periods also experienced higher poverty rates, lower median incomes, and worse health outcomes during bust years than their surrounding resource-poor counterparts (O'Leary and Boettner 2011). Further, investment in education was found to be inversely related to the share of natural resource capital in national revenue across countries (Gylfason 2001). On the other hand, the resource curse can be avoided, though very rarely, with appropriate institutional management. Norway is a successful demonstration of the possibility of turning oil endowment into long-term economic and societal prosperity (Boschini, Pettersson et al. 2007, Holden 2013).

Besides being susceptible to oil and gas price fluctuations, the communities/regions relying on extractive industries also face challenges associated with degraded ecological systems, including landscape fragmentation, environmental pollution, biodiversity disturbance, and species endangerment (Lambin and Meyfroidt 2010, O'Leary and Boettner 2011, Houghton, House et al. 2012, London and Kisting 2015, Kirshner, Castan Broto et al. 2019). Specifically, the way the oil and gas industry disrupts socioeconomic conditions and causes changes to forests and agricultural land (Timoney and Lee 2001, Breslow, Sojka et al. 2016), along with the potential for pollution (Kelly, Short et al. 2009, Breslow, Sojka et al. 2016, Landis, Edgerton et al. 2018) have all been independently studied but need to be synthesized through interdisciplinary investigation.

Drawing from existing research on boom and bust economies and their impact on SES, wherein studies tend to separately focus on economic, social, or environmental impacts, our research assesses the interactions between all these system components using an oil town in Canada as the case study. Our main research question guiding this study was: how have the boom and bust cycles of the oil and gas industry impacted social and ecological systems in communities relying on resource extractive industry? This paper is organized as follows: first, we introduce the study site, with a focus on its historical economic development and its physical geography; next, we chart historical changes in socio-economic conditions that correspond with fluctuations in boom-bust cycles, before analyzing water quality, air quality, and land cover land use (LCLU). The final section discusses our results and their implications for industry, the local municipality, and provincial and federal governments that seek to support a more sustainable and resilient future for communities with a mono-product economy.

Social-ecological indicator selection

Research on resilience/wellbeing of SES often takes the form of indicator/index development. For instance, a study on coastal community SES developed indicators of socioeconomic, institutional, physical, and coastal management aspects of human and environmental systems (DasGupta and Shaw 2015); on a larger scale, the Canadian Index of Wellbeing includes, but is not limited by, indicators of education, environment and living standards (University of Waterloo 2016). Our study developed the indicators we used following an approach that combines indicators from the literature and local context (Bergamini, Dunbar et al. 2014, Sterling, Ticktin et al. 2017). Drawing from around 40 indicators identified from the literature (Reed, Dougill et al. 2008, Cabell and Oelofse 2012, Bergamini, Dunbar et al. 2014, Eaton and Charette 2016, Dong and Hauschild 2017, Town of Drayton Valley 2017), we decided on indicators that are representative of social, economic, and ecological systems in the Drayton Valley, Canada case study with input from local stakeholders through our network of advisory committees (Ungar, McRuer et al. 2020).

With the goal to understand how resource-based single industries impact social-ecological systems, we emphasized indicators that directly or indirectly link to the oil and gas industry, such as labor force distribution across industries (this indicator was adopted because it mirrors local industrial structure and working population profile). Past research has found that job creation within the energy extraction industry during boom periods help generate jobs within non-energy industries, i.e., every ten jobs created within the energy sector lead to around three construction jobs, two retail jobs, and four and half service jobs (Marchand 2012). Therefore, labor force distribution across industries is an important social indicator to contextualize our research and could reveal the proportion of labor force in each industry and the degree of their reliance on each industry (Kemi 2016). The second indicator of social system functioning is education achievement as it reflects people's knowledge, skills, earning prospects, and capacity to adapt during periods of economic fluctuation. On an individual level, it is a predictor of health, living standards and democratic participation (University of Waterloo 2016). On a societal level, education directly increases the proportion of educated and trained labor force that can support a more productive economy (Radcliffe 2019).

For economic indicators, past research found oil and gas price historically reflected worldwide supply and demand of these goods. Thus, oil price has been considered a barometer of the stability of the energy industry (Marchand 2012). Moreover, the price of oil often follows similar boom and bust cycles as an economy that relies on an extractive industry (Helliwell 1989, Marchand 2012). Therefore, oil price was adopted as an economic indicator to capture the economic ups and downs in Drayton Valley. With oil price chosen as a community level economic indicator, household income was chosen as a household level economic indicator to reflect the financial status of households. Shifting attention to household level allows for the examination of wealth distribution as well as identification of income inequality within the community (O'Leary and Boettner 2011).

For ecological indicators, we chose air and water quality because they are essential aspects of an ecosystem, critical to human wellbeing, and could be impacted by human activities. A large body of research measured environment quality by measuring the contamination in environmental media and the built environment (Jakubowski and Frumkin 2010); some scholars investigated the influence of air quality on the environment (Frank, Sallis et al. 2006, Fiore, Naik et al. 2012). LCLU change has long been considered as a significant driver of socioecological changes because LCLU could impact the biodiversity of the landscape. Human activities were found to play a big role in causing LCLU changes (Jingan, Jiupai et al. 2005, Barton, Ullah et al. 2012, Dorresteijn, Loos et al. 2015). Other research has explored the interrelationship between LCLU change and its environmental impacts (Lambin and Meyfroidt 2010, Arima, Richards et al. 2011, Houghton, House et al. 2012, Bateman, Harwood et al. 2013). The present study applied remote sensing to quantify and analyze LCLU changes to provide a more accurate and reliable measure of the changing landscape (Natural Resources of Canada 2008, National Oceanic and Atmospheric Administration 2020).

2. Study Site and Methods

The town of Drayton Valley is in central Alberta, Canada, and is known for its vast oil fields (Figure. 1). Located between the North Saskatchewan River to the south and the Pembina River to the north and surrounded by large areas of provincial parkland and recreation areas Drayton Valley is home to various land use types

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including forest, wetland, agriculture, water bodies, and urban development. Drayton Valley also resides in Treaty 6 Territory, the traditional home of the Plains Cree and Metis peoples. In the early 20th century, the area was colonized by European settlers on account of the area's abundance of natural resources. Farming and logging were the main economic activities for a half-century until the discovery of one of the Canada's largest and most prolific oil fields in 1953 (The Canadian Encyclopaedia 2010).

Drayton Valley was chosen as our study community on account of its resource-based economy and reliance on oil and gas extraction/production. As a result, it is a community with a high propensity to be affected by SES changes related to this industry. As shown in Figure 1, oil wells and pipelines are densely located throughout the region, regardless of whether the land use type is forest, agriculture, or wetland, indicating the potential for social-ecological impacts.

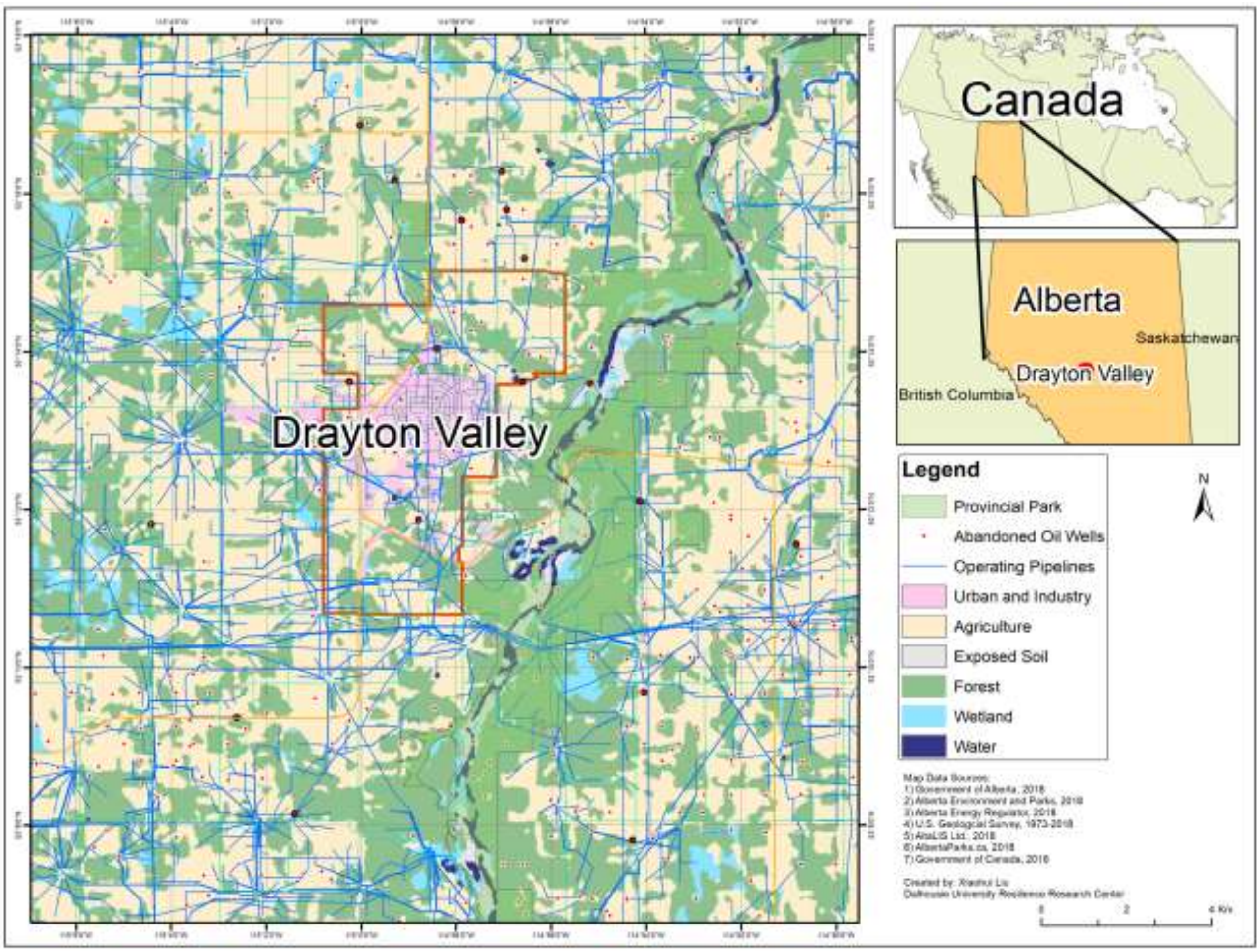

Figure 1: The geographic profile of Drayton Valley, Canada

3. Changes to Social Conditions

In determining the temporal scale of analysis, this research selected significant years linked to the oil industry boom and bust turning points that provided good data availability (i.e., satellite imagery and the population census). The years were 1986, 1996, 2001, 2006, 2011, and 2016. (Depending on data type and availability, some of these years required data to be substituted from adjacent years).

Over 30 years, from 1986 to 2016, the town of Drayton Valley increased from 8 km^2 to 30.72 km^2, and the population increased at an average rate of 6.56% from 5,290 to 7,235 (Statistics Canada 1986, 1996, 2001,2006, 2011, 2016).The average household income in Drayton Valley changed dramatically during these years. As

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seen in Figure 2(a), there was a steadily decreasing number of households in the *Under $20k*, *$20-50k*, and *$50-80k* annual income brackets; an unchanged number of households in the *$80-100k* group; and a rapidly increasing number of households in the *$100k and over* income bracket. Nearly half of the households had an annual income of over $100k, and the median household income in 2016 was $100,034, which was 42% above the national average. As for education (Figure 2(b)), there has been a steady decrease in the number of people aged 15 years and over with no degree or certificate, and a slow increase in people having at least a high school diploma or postsecondary degree or certificate. Despite this, the 2016 census shows only 38% of Drayton Valley residents aged 25-64 have a postsecondary degree or certificate, compared to 50% of Albertans and 54% of Canadians.

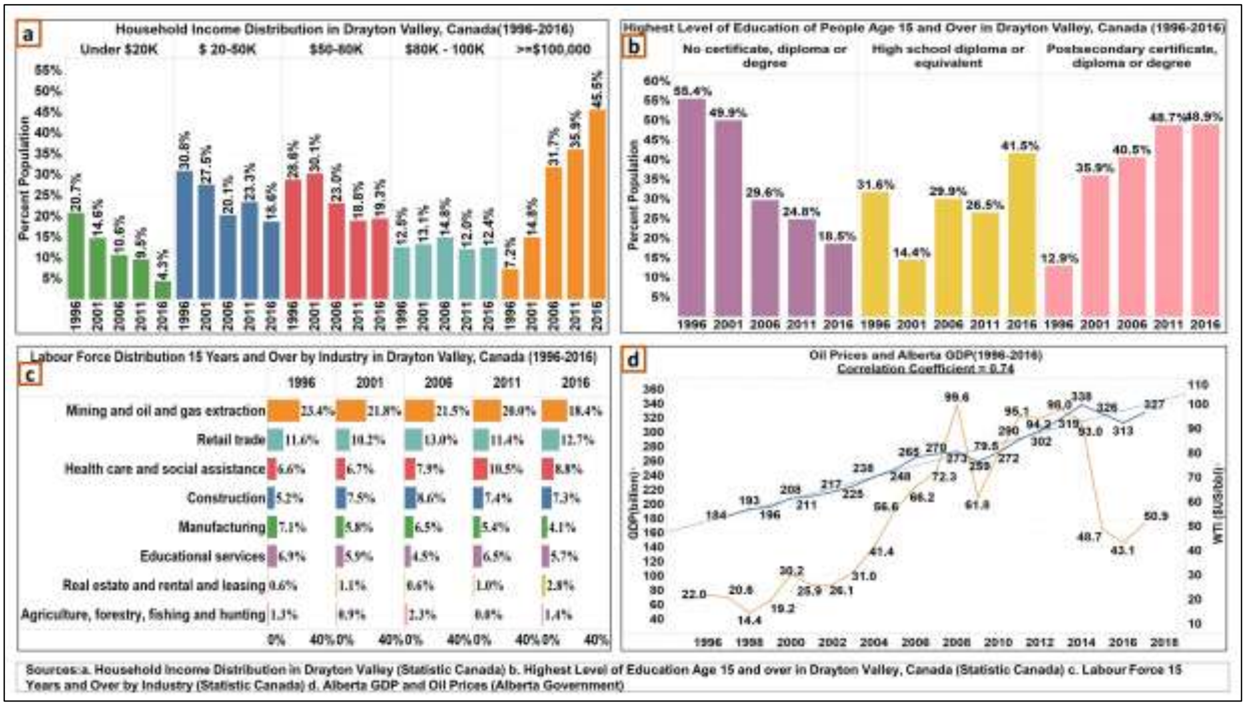

Figure 2: Socioeconomic profile of Drayton Valley, Canada

The town's labor force distribution among major industries is shown in Figure 2(c), with the mining, oil, and gas industries being consistently the largest employer. Notably, however, from 1986-2016 there was a decrease in the percentage of the population working in mining and oil and gas extraction industries, hitting a historical low of 18.4% in 2016. The percentage of the population engaged in manufacturing has also declined from 7.1% in 1986 to 4.1% in 2016. Meanwhile, real estate has seen a slight increase over time, while other industries such as agriculture, forestry, fishing, and hunting display a fluctuating labor force. To understand this pronounced decline in the labor force for the oil, gas, and manufacturing industries, we infer that global market influences and Gross Domestic Product (GDP) decline are the most likely causes. As shown in Figure 2(d), Alberta's GDP correlates strongly (correlation coefficient = 0.74) with a sharp decline in the price of West Texas Intermediate (WTI), a grade of crude oil used as a benchmark in oil pricing. This correlation implies that the bust of a global oil-based industry not only has a stark impact on the provincial economy but also on industry structure and labor force redistribution at the local municipal level. Figure 2(d) shows an overall booming oil economy from 1996 to 2007, but two bust periods occurred around 2008 and 2016, with the latter bust continuing into 2019. A further discussion on the boom and bust cycles as well as its impacts on SES will be presented later in this paper.

A comparison of average percent labor force distribution among major industries across Canada, Alberta, and Drayton Valley is shown in Figure 3 (Statistics Canada 1986, 1996, 2001,2006, 2011, 2016). Notably, Drayton

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Valley had nine and three times higher percent of the labor force than national and provincial levels, respectively, in the mining and oil & gas extraction industry. Conversely, Drayton Valley had the lowest percent labor force in all other major industries, including agriculture, forestry, fishing and hunting, manufacturing, and health care and social assistance.

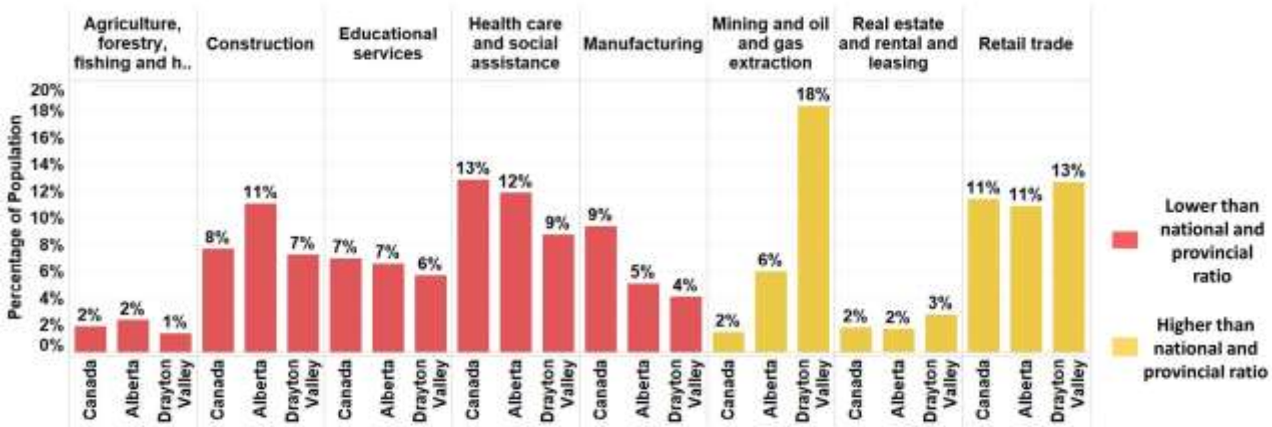

Figure 3: Comparison of average labor force distribution ratio among major industries across Canada, Alberta, and Drayton Valley

4. Water Quality Conditions and Changes

4.1 Water Quality

Alberta Environment and Parks' Long Term River Network (LTRN) project (Gov. of Alberta and Parks 2017) takes monthly samples for most water quality variables at 29 sample stations along the major rivers province-wide. To screen water quality more relevant to Drayton Valley, data between the years 1985 and 2015 were analyzed from stations within a 200km radius, and through which the North Saskatchewan River runs. Commonly measured water quality variables were averaged to show the historical annual trend. As shown in Figure 4, the concentration of most variables had small fluctuations throughout that time with two exceptions: 1) fluoride and phosphorus showed a vibrant fluctuation over the past 30 years, and 2) the years of 1990, 2004, and 2009 saw a spike in the concentration of all chemicals (marked by an red line).

The main source of fluoride is unprocessed, industrial by-products of the phosphate fertilizer industry, as well as outputs from hydrogeological processes in certain environments (Oram 2014). Levels of fluoride vary from 0.02 to 1.2 ppm in Canada (Boyle and Chagnon 1995). The recommended maximum fluoride level in drinking water is 0.7 ppm (World Health 2017, Safe Water 2018) and 2 ppm for agriculture and grazing (Scholz, Kopittke et al. 2015). The range of fluoride in the Drayton Valley region was 0 ~ 0.15 ppm, thus met the recommended safety levels, despite fluctuations. Phosphorus levels also went through significant fluctuations, which could be the result of organic pesticides containing phosphates, or soil erosion related to deforestation or urbanization (Oram 2014, Survey 2018, Survey 2018). The level of phosphorus in Drayton Valley region water samples exceeds the recommended aquatic safe phosphorus level of 0.1 ppm (US Environmental Protection Agency 1986) in the years 1990, 2004, and 2009, posing risks to biodiversity and wetland stability.

Though other water quality variables (e.g., sulphate, chloride, chlorophyll) fluctuated less than that of fluoride and phosphorus, abnormally high levels occurred between 2004 and 2009. Substantial literature revealed the impacts of energy production on water quality in rivers and groundwater, including the massive amount of water consumption and pollution in northern Alberta's Athabasca River region and central Alberta's North Saskatchewan River region (surrounds Drayton Valley) (Griffiths and Woynillowicz 2009). Direct causality has

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not, however, been found between energy production and water pollution possibly due to complex hydrogeological reasons and inadequate water monitoring techniques.

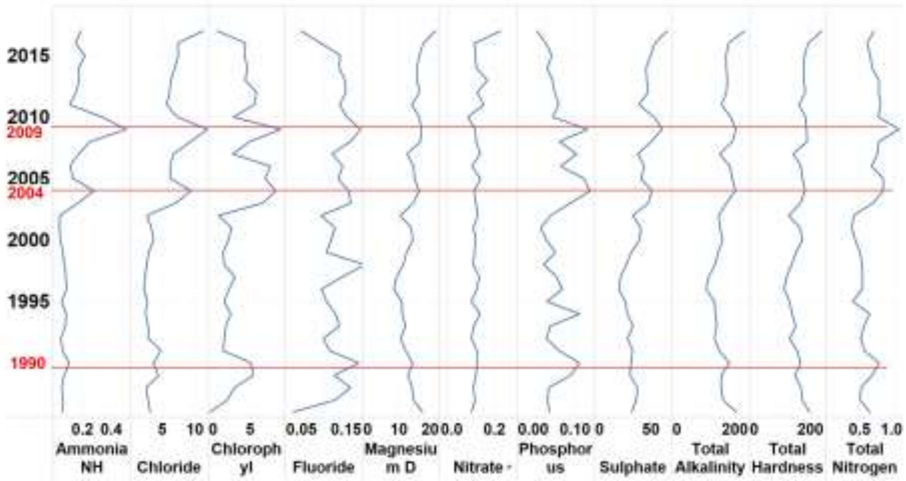

Figure 4: Water Quality of River Stations in Drayton Valley Region

4.2 Air Quality

For this study we included fine particulate matter (PM2.5) data from the Drayton Valley region collected between 2005 and 2015 to retrospectively understand air quality trends (The World Air Quality 2018). Monthly average PM2.5 in Drayton Valley had significant fluctuations throughout the years 2011, 2013, and 2014 which witnessed huge monthly average PM 2.5 spikes (Figure 5) and approached the World Health Organization's ceiling of 25 µg/m^3 (World Health 2005). These fluctuations could be signs of air quality disturbances due to human activity and industry operations. The three big troughs of PM 2.5 levels could be the result of local traffic or fire smoke; however, a direct causal relationship cannot be established without enough tracked records to accurately locate the source of air pollutants. To augment historical data, we installed an air quality monitor in an open green space close to the center of the town where roads traverse. Besides being a supplementary air quality data source for research purpose, this air quality monitor can serve as an educational tool to raise environmental awareness while providing real-time air monitoring for the community.

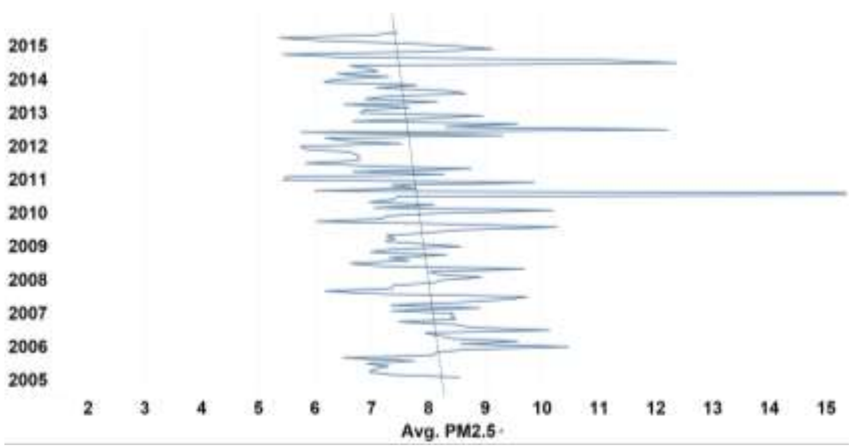

Figure. 5 Air Quality in Drayton Valley (2005-2015)

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5. Land Cover and Land Use Change

Using multiple satellite images from the U.S. Geological Survey website, we quantified, analyzed, and visualized historical LCLU change (US Geological Survey 1986) . For the years without available satellite images, data from adjacent years were used (i.e., years 2002, 2014, and 2018 were replaced by 2001, 2011, and 2016 respectively). Satellite images with a spatial resolution of 30 meters are obtained from Landsat 4 and 5. The satellite images were analyzed in ArcGIS Pro and supervised classification was applied to generate LCLU maps (Senseman, Bagley et al. 1995, Thomlinson, Bolstad et al. 1999, Foody 2008).

Figure 6 shows maps of the spatial distribution of five LCLU categories: waterbodies, built-up/urban, barren and wetland, forest, and agriculture. Figure 7 shows the area trend of each LCLU type across selected years. As is shown in Figure 6, the area of water (e.g., lakes and rivers), barren and wetland areas (e.g., unused open area), and forest decreased, which could be evidence of land reclamation and deforestation. However, built-up (e.g., urban and industrial sites) and agriculture land increased.

The impact of the oil and gas industry on LCLU lies in two main aspects: the size of land converted from other LCLU types to industrial land, and land reclaimed from industrial operations. An oil or gas drilling well occupies at least 30 square meters of land (Oil Education 2019), and as of 2016, there had been approximately 15,000 wells drilled in the Drayton Valley area (Town of Drayton 2016), which makes the total impacted land area to be at least 450,000 square meters or 111 acres. As for land disturbance, researchers argue that even though ex-situ (e.g., pumpjack) or in situ extracting methods (e.g., deep underground steam injections) require less land per unit production than surface mining operations (e.g., oil sands), their spatial footprints are more scattered and collectively leading to widespread land fragmentation (Jordaan, Keith et al. 2009).

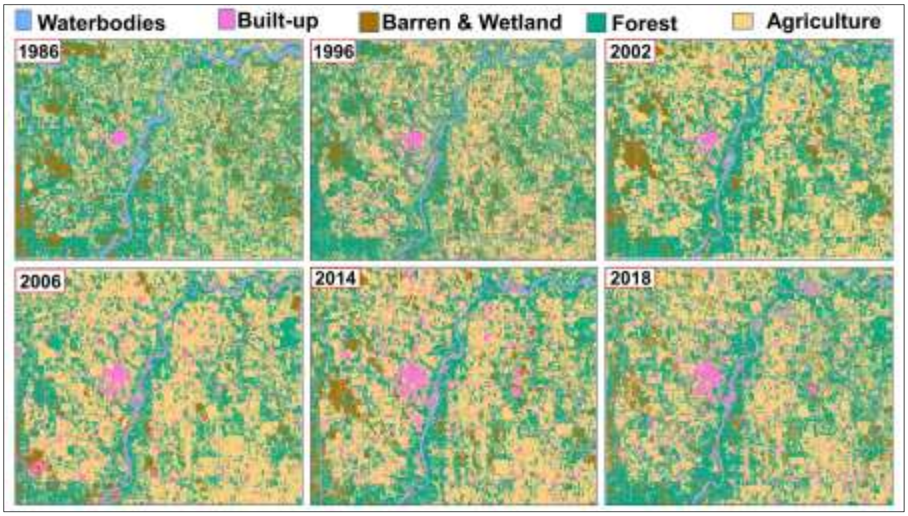

Figure 6 Land cover land use types and changes in Drayton Valley

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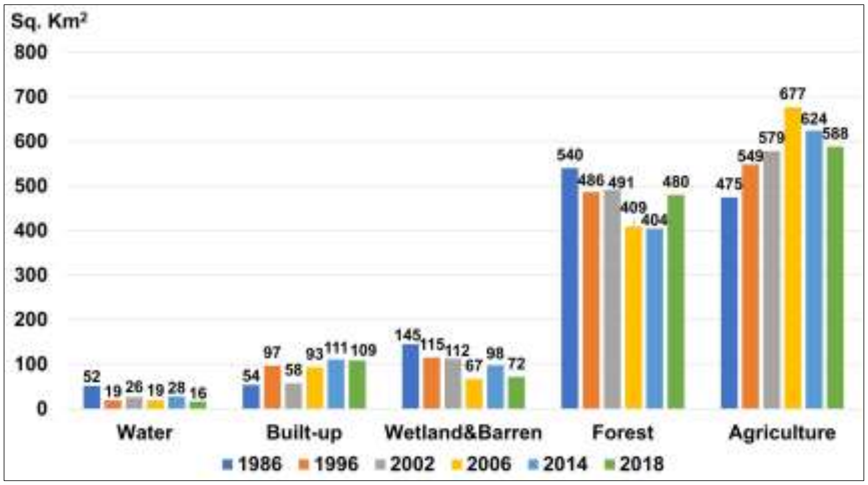

Figure 7: Area of land use land cover change in Drayton Valley

6. Impacts of boom and bust cycles

Oil price was used as a proxy indicator of the boom and bust economic cycle to explore its potential impacts on SES, and its correlation with average household income, household debt, and various LCLU types. Oil price referred to West Texas Intermediate (WTI) crude oil prices per barrel (Macrotrends 2019). Drayton Valley's average household income is strongly and positively correlated with oil price (correlation coefficient =0.73) (Figure 8(a)) and has been rapidly increasing. Debt service ratio at the household level is a measure of the household's ability to produce enough income to cover its debt payments, and thus can serve as an indicator of the stress level that directly relates to the wellbeing of household members (Canada 2017). A correlation coefficient of 0.78 between oil price and household debt service ratio (Figure 8(b)) indicates that oil prices positively correlate with Albertans' debt level, implying that people tend to have more debt as the oil economy booms, and therefore take more loan risks and are likely to suffer more stress when the oil economy experiences a downturn.

Figure 8(c) indicates that the built-up area (i.e., urban expansion) of Drayton Valley has been rapidly increasing with the growth of the oil economy. Notably, however, a significant decline in the growth of the built-up area occurred in the year 2000, almost three years after a bust period in the global oil economy. This indicates a lag in the increase of the built-up area in response to oil prices, which may relate to construction project continuance despite market influence. Figure 8(d) shows that agricultural expansion is, unexpectedly, positively correlated with the price of oil, with steady growth amount of land under cultivation despite a small decline during oil industry boom periods. This correlation may be due to agriculture supporting a larger population or it may be a sign of diversification efforts taking advantage of a better economy to incentivize new industries. Unlike the other variables we assessed, the areas of wetland, barren area, and forests, however, show a negative correlation with the oil price, namely, they have decreased while oil prices experienced boom and bust cycles and built-up areas increased in size (Figure 8 (e, f)).

These results suggest that boom-bust cycles in Drayton Valley are closely correlated to many aspects of SES. When Alberta oil price is used as the proxy for the condition of the economy, the correlation coefficients between oil price and other variables are as follows: average household income (0.73), debt service ratio (0.78), area of built-up land (0.68), area of agriculture (0.77), area of wetland and barren areas (-0.59), and area of forest (-0.93). On one hand, these correlations imply that sole dependence on the oil and gas economy helped the town advance urbanization and financial status, and on the other hand increased the town's debt and decreased wetland and forest areas.

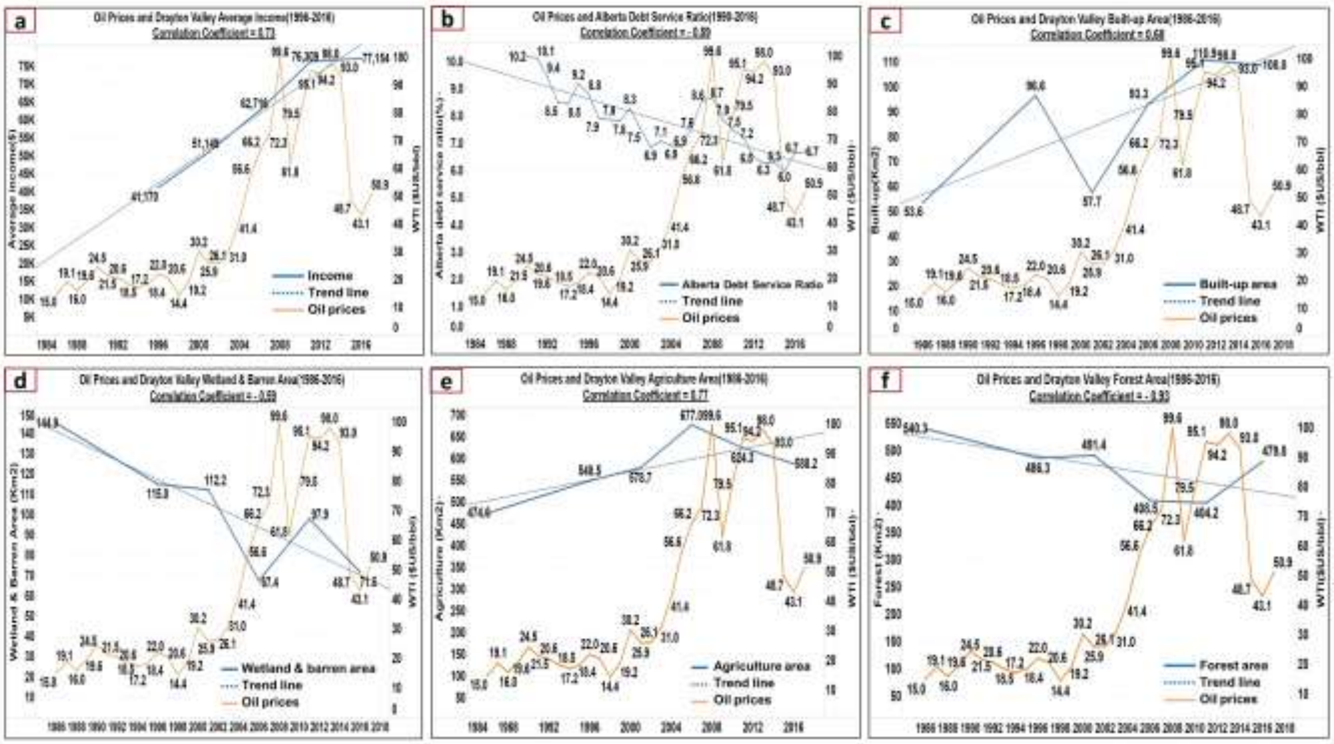

Figure 8 Indicators’ correlation with oil price

Discussion

Every type of economy is bound to have positive or negative, and strong or weak impacts on local SES. This relationship, however, has been more theorized than empirically tested. The present study demonstrates how multiple data sources can be brought together to track co-occurring changes in SES and their relationship with economic fluctuations. We believe tracking these changes will be particularly relevant to oil and gas industry-dependent towns which are experiencing stress as global demand and price for these resources changes rapidly. Although Drayton Valley shares some common impact characteristics with other resource-rich regions, it also has unique qualities. Similar to what has been found in the literature regarding resource-dependent economies, Drayton Valley displays educational attainment scores lower than the national average, a widening rich-poor gap, very little diversification of its local economy, and the gradual degradation of its ecological environment (Sachs & Warner 1995; Timoney & Lee 2001; Boschini et al. 2007; Murshed & Serino 2011; Breslow et al. 2016). Although other resource extraction economies tend to have lower economic growth, Drayton Valley has, however, enjoyed more than 50 years of mostly oil booms and occasional busts contributing to many social benefits for the local population, including well-paying employment opportunities for those holding lower educational qualifications (Sachs and Warner 1995, Heidenreich 2018). Due to the susceptibility of oil prices fluctuating with global production and demand, geopolitics, and other factors at the global level, populations at the local level relying on an extraction-based economy are becoming more vulnerable to industry boom-bust cycles (Freudenburg 1992, Breslow, Sojka et al. 2016). Interestingly, what has made Drayton Valley’s situation seem different from other resource extraction communities (i.e., Angola and the Democratic Republic of Congo) is the fact of more boom and fewer bust cycles across a smaller timescale. If viewed on a larger timescale (e.g., over a century), Drayton Valley may expect similar economic growth patterns to other resource extraction-based economies.

These patterns are most evident when multiple social and ecological factors are tracked at the same time, contributing to the complex multisystem models which have been defined as panarchy (Berkes and Ross 2016).

In this study, we have focused on labor force distribution, education, the price of oil, household income, education, water quality, air quality, and LCLU change. The integration of secondary data from government and other sources proved to be effective in tracking changes to the SES. However, one major concern identified from this research is that the current environmental monitoring systems are not adequate to provide complete, clear, and frequent data related to water, air, biodiversity and land use. For instance, there are insufficient number of province-wide river monitoring stations, which are not enough to monitor the quality of major tributaries that run through areas in higher need of water quality monitoring, e.g., high industry zones (Gov. of Alberta 2017). Despite this shortcoming, our examination of environmental indicators like water quality in the region shows that levels of fluoride, phosphorus, and other chemicals fluctuate dramatically, which suggests a possible correlation with fossil fuel extractive activities. LCLU change analysis shows a decreased area of water bodies, wetland, and forest and increased area of built-up and agricultural land, which is evidence of land reclamation and deforestation for development, particularly related to growth in the oil and gas industry.

Reviewing patterns in our data, we find support for efforts to decrease the impact of oil and gas extracting activities on ecological environments through the implementation of initiatives like the pre-defined land-use frameworks developed by the Government of Alberta that delineate different land use zones to minimize interference (Gov. of Alberta 2008). The Government of Alberta released a new Land Use Framework (LUF) in 2008, which divides Alberta into seven regions to achieve Alberta's long-term social, economic, and environmental development goals (Jordaan 2012). Although the LUF calls for a regional plan for each of the seven regions, only two regions have developed plans to date and Drayton Valley is in neither of those two regions.

An analysis of 30 years of satellite images using remote sensing techniques shows the importance and significance of understanding LCLU change in terms of the size and spatial distribution of each LCLU type. Such visualizations are helpful and necessary when comparing LCLU types to the dynamics of a boom-bust economy. For future research direction, remote sensing analysis, specifically texture analysis, can be further applied to detect oil and gas operation sites more accurately, and thus offer an in-depth understanding of the expansion of the oil and gas industry as well as its impact on the surrounding environment.

Conclusion

This paper focuses on the changing dynamics of SES in Drayton Valley by analyzing seven key indicators of human and environmental well-being throughout economic boom-bust cycles during the past 30 years. With the help of a flourishing oil and gas industry, Drayton Valley quadrupled in size, raised its median income well above the national average, and attracted more than 20% of the population into oil and gas sectors, yet failed to reach national education attainment scores. An analysis of labor force distribution and GDP reveals a strong economic dependence on the oil and gas industry, and an absence of diversified development in other industries. The lower than the national average educational attainment scores, widening rich-poor gap, and debt service ratio dependent upon the oil economy all support the notion that Drayton Valley may be beginning to experience the effects of the "resource curse", leaving those who are heavily dependent on the oil and gas industry to become even more vulnerable to future economic downturns.

Given the complex and interdependent relationship between SES and boom-bust cycles in single-industry towns, it is vital to develop sustainable development plans that comprehensively consider economic growth and diversification, social wellbeing, environment protection, and strategic land use planning. Towns like Drayton Valley do not need to turn away from the 'blessings' they receive from their rich resource extraction industries but do need to explore other sectors and interests that will benefit them in the future. As our study has shown, the effects of boom-bust cycles are measurable through a variety of indicators, and therefore long-term and cross-dimensional monitoring of SES using more accurate tools are needed to gauge impacts of boom and bust periods and inform future social and environmental policies.

References

Arima, E. Y., P. Richards, R. Walker and M. M. Caldas (2011). "Statistical confirmation of indirect land use change in the Brazilian Amazon." Environmental Research Letters **6**(2): 024010.
Barton, C. M., I. I. T. Ullah, S. M. Bergin, H. Mitasova and H. Sarjoughian (2012). "Looking for the future in the past: Long-term change in socioecological systems." Ecological Modelling **241**: 42-53.
Bateman, I. J., A. R. Harwood, G. M. Mace, R. T. Watson, D. J. Abson, B. Andrews, A. Binner, A. Crowe, B. H. Day and S. Dugdale (2013). "Bringing ecosystem services into economic decision-making: land use in the United Kingdom." science **341**(6141): 45-50.
Bergamini, N., W. Dunbar, P. Eyzaguirre and K. Ichikawa (2014). "Toolkit for the indicators of resilience in socio-ecological production landscapes and seascapes."
Berkes, F. and H. Ross (2016). "Panarchy and community resilience: Sustainability science and policy implications." Environmental Science & Policy **61**: 185-193.
Boschini, A. D., J. Pettersson and J. Roine (2007). "Resource curse or not: A question of appropriability." Scandinavian Journal of Economics **109**(3): 593-617.
Boschini, A. D., J. Pettersson and J. Roine (2007). "Resource Curse or Not: A Question of Appropriability*." The Scandinavian Journal of Economics **109**(3): 593-617.
Boyle, D. R. and M. Chagnon (1995). "An incidence of skeletal fluorosis associated with groundwaters of the maritime carboniferous basin, Gaspé region, Quebec, Canada." Environmental Geochemistry and Health **17**(1): 5-12.
Breslow, S. J., B. Sojka, R. Barnea, X. Basurto, C. Carothers, S. Charnley, S. Coulthard, N. Dolšak, J. Donatuto and C. García-Quijano (2016). "Conceptualizing and operationalizing human wellbeing for ecosystem assessment and management." Environmental Science & Policy **66**: 250-259.
Breslow, S. J., B. Sojka, R. Barnea, X. Basurto, C. Carothers, S. Charnley, S. Coulthard, N. Dolšak, J. Donatuto, C. García-Quijano, C. C. Hicks, A. Levine, M. B. Mascia, K. Norman, M. Poe, T. Satterfield, K. S. Martin and P. S. Levin (2016). "Conceptualizing and operationalizing human wellbeing for ecosystem assessment and management." Environmental Science & Policy **66**: 250-259.
Cabell, J. F. and M. Oelofse (2012). "An indicator framework for assessing agroecosystem resilience." Ecology and Society **17**(1).
Canada, S. (2017). "Debt service indicators of households, national balance sheet accounts.", 2018, from https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1110006501.
Cartwright, E. (2016). Mining and Its Health Consequences. A Companion to the Anthropology of Environmental Health**:** 417-434.
Chindo, M., A. Naibbi and A. Abdullahi (2014). "The Nigerian Extractive Economy and Development." Human Geographies - Journal of Studies and Research in Human Geography.
Corden, W. M. and J. P. Neary (1982). "Booming Sector and De-Industrialisation in a Small Open Economy." The Economic Journal **92**(368): 825-848.
DasGupta, R. and R. Shaw (2015). "An indicator based approach to assess coastal communities' resilience against climate related disasters in Indian Sundarbans." Journal of Coastal Conservation **19**(1): 85-101.
Dong, Y. and M. Z. Hauschild (2017). "Indicators for Environmental Sustainability." Procedia CIRP **61**: 697-702.
Dorresteijn, I., J. Loos, J. Hanspach and J. Fischer (2015). "Socioecological drivers facilitating biodiversity conservation in traditional farming landscapes." Ecosystem Health and Sustainability **1**(9): 1-9.
Eaton, B. and T. Charette (2016). Drivers, Stressors, and Indicators of Wetland Change in Alberta's Oil Sands Region-Potential for Use in Wetland Monitoring, Alberta Biodiversity Monitoring Institute.
Eisler, R. and S. N. Wiemeyer (2004). Cyanide Hazards to Plants and Animals from Gold Mining and Related Water Issues. Reviews of Environmental Contamination and Toxicology. G. W. Ware. New York, NY, Springer New York**:** 21-54.
Findlay, R. and M. Lundahl (1999). Resource-Led Growth-A Long-Term Perspective, World Institute for Development Economic Research (UNU-WIDER).
Findlay, R. and M. Lundahl (2017). Resource-led Growth—A Long-term Perspective: The Relevance of the 1870–1914 Experience for Today's Developing Economies. The Economics of the Frontier, Springer**:** 315-366.
Fiore, A. M., V. Naik, D. V. Spracklen, A. Steiner, N. Unger, M. Prather, D. Bergmann, P. J. Cameron-Smith, I. Cionni and W. J. Collins (2012). "Global air quality and climate." Chemical Society Reviews **41**(19): 6663-6683.
Foody, G. M. (2008). "Harshness in image classification accuracy assessment." International Journal of Remote Sensing **29**(11): 3137-3158.

Frank, L. D., J. F. Sallis, T. L. Conway, J. E. Chapman, B. E. Saelens and W. Bachman (2006). "Many pathways from land use to health: associations between neighborhood walkability and active transportation, body mass index, and air quality." Journal of the American planning Association **72**(1): 75-87.
Freudenburg, W. R. (1992). "Addictive Economies: Extractive Industries and Vulnerable Localities in a Changing World Economy1." Rural Sociology **57**(3): 305-332.
Gov. of Alberta. (2008). "Land-use framework." from https://open.alberta.ca/publications/9780778577140#summary.
Gov. of Alberta, A. E. and Parks (2017). Long Term River Network Data.
Griffiths, M. and D. Woynillowicz (2009). Heating Up in Alberta: Climate Change, Energy Development and Water.
Gylfason, T. (2001). "Natural resources, education, and economic development." European Economic Review **45**(4): 847-859.
Heidenreich, P. (2018). "Large rally in central Alberta town calls for immediate construction of new pipelines." from https://globalnews.ca/news/4729634/drayton-valley-pipeline-rally-alberta-oil/.
Helliwell, J. F., MacGregor, M.E., McRae, R.N., Plourde, A. (1989). Oil and gas in Canada: the effects of domestic policies and world events. C. T. Foundation.
Holden, S. (2013). "Avoiding the resource curse the case Norway." Energy Policy **63**: 870-876.
Houghton, R. A., J. House, J. Pongratz, G. Van Der Werf, R. DeFries, M. Hansen, C. Le Quéré and N. Ramankutty (2012). "Carbon emissions from land use and land-cover change." Biogeosciences(12): 5125-5142.
Jacquet, J. and D. L. Kay (2014). "The Unconventional Boomtown: Updating the impact model to fit new spatial and temporal scales." Journal of Rural and Community Development **9**(1).
Jakubowski, B. and H. Frumkin (2010). "Environmental metrics for community health improvement." Prev Chronic Dis **7**(4): A76.
Jingan, S., N. Jiupai, W. Chaofu and X. Deti (2005). "Land use change and its corresponding ecological responses: A review." Journal of Geographical Sciences **15**(3): 305-328.
Jordaan, S. M. (2012). Land and water impacts of oil sands production in Alberta, ACS Publications.
Jordaan, S. M., D. W. Keith and B. Stelfox (2009). "Quantifying land use of oil sands production: a life cycle perspective." Environmental Research Letters **4**(2): 024004.
Kelly, E. N., J. W. Short, D. W. Schindler, P. V. Hodson, M. Ma, A. K. Kwan and B. L. Fortin (2009). "Oil sands development contributes polycyclic aromatic compounds to the Athabasca River and its tributaries." Proceedings of the National Academy of Sciences **106**(52): 22346-22351.
Kemi, A. O. (2016). "Diversification of Nigeria economy through agricultural production." Journal of Economics and Finance **7**(6): 104-107.
Kirshner, J. D., V. Castan Broto and I. Baptista (2019). "Energy landscapes in Mozambique." The role of extractive industries in a post-conflict environment: 1-21.
Lambin, E. F. and P. Meyfroidt (2010). "Land use transitions: Socio-ecological feedback versus socio-economic change." Land use policy **27**(2): 108-118.
Landis, M. S., E. S. Edgerton, E. M. White, G. R. Wentworth, A. P. Sullivan and A. M. Dillner (2018). "The impact of the 2016 Fort McMurray Horse River Wildfire on ambient air pollution levels in the Athabasca Oil Sands Region, Alberta, Canada." Science of The Total Environment **618**: 1665-1676.
London, L. and S. Kisting (2015). "The Extractive Industries: Can We Find New Solutions to Seemingly Intractable Problems?" NEW SOLUTIONS: A Journal of Environmental and Occupational Health Policy **25**(4): 421-430.
Macrotrends. (2019). "Crude Oil Prices - 70 Year Historical Chart." 2019, from https://www.macrotrends.net/1369/crude-oil-price-history-chart.
Marchand, J. (2012). "Local labor market impacts of energy boom-bust-boom in Western Canada." Journal of Urban Economics **71**(1): 165-174.
National Oceanic and Atmospheric Administration. (2020). "What is the difference between land cover and land use." from https://oceanservice.noaa.gov/facts/lclu.html.
Natural Resources of Canada. (2008). "Land Cover & Land Use." from https://www.nrcan.gc.ca/node/9373. .
O'Leary, S. and T. Boettner. (2011). "Boom and bust: the impact of West Virginia's energy economy." from https://wvpolicy.org/wp-content/uploads/2018/5/BoomsBusts072111.pdf.
Oil Education. (2019). "Energy Education." from https://energyeducation.ca/encyclopedia/Oil_well.
Oram, B. (2014). "Phosphates in the Environment." from https://www.water-research.net/index.php/phosphates-in-the-environment.
Radcliffe, B. (2019). "How Education and Training Affect the Economy." Investopedia.

 doi:10.20944/preprints202009.0368.v1

Reed, M. S., A. J. Dougill and T. R. Baker (2008). "Participatory Indicator Development: What Can Ecologists and Local Communities Learn from Each Other." Ecological Applications **18**(5): 1253-1269.
Sachs, J. D. and A. M. Warner (1995). Natural Resource Abundance and Economic Growth, National Bureau of Economic Research.
Safe Water, O. (2018). Water Fluoridation in Canada.
Scholz, L. M., P. M. Kopittke, N. W. Menzies, S. A. Dalzell, D. C. Macfarlane and J. B. Wehr (2015). "Use of Fluoride-Containing Water for the Irrigation of Soil–Plant Systems." Journal of Agricultural and Food Chemistry **63**(19): 4737-4745.
Schrecker, T., A.-E. Birn and M. Aguilera (2018). "How extractive industries affect health: Political economy underpinnings and pathways." Health & Place **52**: 135-147.
Senseman, G. M., C. F. Bagley and S. A. Tweddale (1995). Accuracy Assessment of the Discrete Classification of Remotely-Sensed Digital Data for Landcover Mapping, CONSTRUCTION ENGINEERING RESEARCH LAB (ARMY) CHAMPAIGN IL.
Statistics Canada. (1986, 1996, 2001,2006, 2011, 2016). "Census of Population, 1986-2016: Census Subdivision(CSD)." 2018, from http://datacentre.chass.utoronto.ca/cgi-bin/census/.
Sterling, E., T. Ticktin, T. Kipa Kepa Morgan, G. Cullman, D. Alvira, P. Andrade, N. Bergamini, E. Betley, K. Burrows, S. Caillon, J. Claudet, R. Dacks, P. Eyzaguirre, C. Filardi, N. Gazit, C. Giardina, S. Jupiter, K. Kinney, J. McCarter, M. Mejia, K. Morishige, J. Newell, L. Noori, J. Parks, P. a. Pascua, A. Ravikumar, J. Tanguay, A. Sigouin, T. Stege, M. Stege and A. Wali (2017). "Culturally Grounded Indicators of Resilience in Social-Ecological Systems." Environment and Society **8**(1).
Survey, U. G. (2018). "Phosphorus and water: The USGS Water Science School.", 2018, from https://water.usgs.gov/edu/phosphorus.html.
Survey, U. S. G. (2018). "Phosphorus and water: The USGS Water Science School."
The Canadian Encyclopaedia. (2010). "Drayton Valley." 2018, from https://www.thecanadianencyclopedia.ca/en/article/drayton-valley.
The World Air Quality, I. (2018). "Drayton Valley Real-time Air Quality Index (AQI)." aqicn.org.
Thomlinson, J. R., P. V. Bolstad and W. B. Cohen (1999). "Coordinating methodologies for scaling landcover classifications from site-specific to global: Steps toward validating global map products." Remote Sensing of Environment **70**(1): 16-28.
Timoney, K. and P. Lee (2001). "Environmental management in resource-rich Alberta, Canada: first world jurisdiction, third world analogue?" Journal of Environmental Management **63**(4): 387-405.
Town of Drayton, V. (2016). "Drayton Valley Community Profile."
Town of Drayton Valley. (2017). "Drayton Valley Community Sustainability Plan.", 2018, from https://www.draytonvalley.ca/community-sustainability/.
Ungar, M., J. McRuer, X. Liu, L. Theron, D. Blais and M. A. Schnurr (2020). "Social-ecological resilience through a biocultural lens: a participatory methodology to support global targets and local priorities." Ecology and Society **25**(3).
University of Waterloo. (2016). "Canadian Index of Wellbeing." 2018, from https://uwaterloo.ca/canadian-index-wellbeing/home.
US Environmental Protection Agency. (1986). "National Recommended Water Quality Criteria - Aquatic Life Criteria Table." 2018, from https://nepis.epa.gov/Exe/ZyPDF.cgi/00001MGA.PDF?Dockey=00001MGA.PDF.
US Geological Survey. (1986). "1986 High Resolution Landsat Images.", 2018, from https://earthexplorer.usgs.gov/.
World Health, O. (2005). World Air Quality Index.
World Health, O. (2017). "Guidelines for drinking-water quality, 4th edition, incorporating the 1st addendum."
Wright, G. (2001). "Resource-based growth then and now." Processed. Stanford University.