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ARTICLE

Adaptive Capacity for Climate Change in Canadian Rural Communities

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ABSTRACT It is widely acknowledged that promoting the long-term sustainability of rural areas requires an assessment of their capacity to handle stress from a host of external and internal factors such as resource depletion, global trading agreements, service reductions and changing demographics, to name but some. The sustainability literature includes a number of approaches for conducting capacity evaluations but is sparse regarding effective methods and empirical examples. This article provides one approach for assessing community capacity and gives results from its application to a specific Canadian rural community. The authors use general capacity variables and indicators to focus on a particular stress, namely impacts from climate change, and on one type of capacity, namely the capacity to adapt (to such climatic change). A basic framework and profiling tool ('amoeba') for describing the resources underlying community adaptive capacity are offered. The researchers provide a set of indicators reflecting social, human, institutional, natural and economic resources and relate them to climate change adaptation at the community level. Although the indicators cannot be replicated exactly for other rural communities, the essentials of the framework and the profiling tool can. In fact it is hoped that the ideas and example found in this article will encourage researchers to enhance and improve on the methods and results for work on community capacity.

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Introduction

Since the UN Framework Convention on Climate Change was signed in 1992, interest in climate change has been as variable as the weather itself. As with many issues involving social, economic and environmental concerns, arguments pro and con climate change are regularly debated and rarely resolved. While there is growing acceptance that the climate is in fact changing and that it continues to be influenced by human activity, directions for future policy, programmes and related actions are largely shrouded in controversy with a good measure of confusion (Oreskes, 2004).

It is possible to identify two distinct responses to the impacts from a changing climate. One is to take steps to slow down and moderate the pace of change. Such actions are generally called 'mitigation' and have been designed to lessen emissions from activity generating carbon dioxide, methane and nitrous oxide (the most common greenhouse gases) (Smit & Pilifosova, 2003). Mitigation is the topic that receives most of the attention when people refer to the Kyoto Protocol.

Another response to impacts from climate change is to focus on the ability or capacity of individuals, communities and nations to handle the impacts and/or take advantage of opportunities from altered conditions. Such actions are usually referred to as 'adaptation measures'. Developing and implementing adaptation strategies for climate change impacts is a specific element in formal international agreements (for example, the UN Framework Convention for Climate Change). However, the climate change adaptation research, policy and programmes necessary for encouraging adaptation have been largely disregarded, despite the growing awareness that many regions and groups are increasingly vulnerable (Burton et al., 2002; Pielke & Sarewitz, 2003).

This article advances our understanding of climate change adaptation at the community level and in doing so contributes to a larger or more generic discussion of community capacity. The authors draw from established community capacity indicators to create a framework for assessing adaptive capacity for climate change; they provide an empirical example of applying that framework to a specific Canadian rural community; and they offer a tool for displaying results that can be useful in two distinct ways. One is to engage rural community residents in assessing and enhancing their ability to deal with climate change. The other is to provide policy-makers with some indication of local response to climate change in different regions.

The article begins by reviewing some of the impacts from recent weather and climate conditions on rural Canadian communities and considers a number of factors that may limit community responses to them. The authors then turn to more conceptual material, define key terms and point out the linkages between adaptive capacity and elements of sustainability, resilience and community capacity. Variables and indicators for adaptive capacity to deal with climate change are then outlined and categorized into a framework. The article goes on to incorporate substantive material from an application of the framework to a specific rural community, using data and profiling tools ('amoebas') from research conducted through the NRE2 project.[1] The paper concludes with an assessment of the adaptive capacity framework and how it might be used.

Approaches for Understanding Climate Change Impacts

Climate change impacts and adaptation for rural Canada include challenges from adverse conditions (such as increases in variability and extreme events) and opportunities (such as extended growing seasons and increased temperatures). Research into the topic can be divided into studies employing 'top-down' and 'bottom-up' approaches (Dessai & Hulme, 2004). The former usually begin with macro-scale conditions based on future projections and then narrow the focus to potential impacts on a particular region or phenomenon. Possible adaptation strategies are assumed and tested for limiting or taking advantage of the projected effects from climate change. Canadian agricultural research in this vein includes work assessing impacts on crop production, farming systems and regional economies (Wall et al., 2004). Top-down analysis frequently points to potential benefits for the agri-food sector if warmer temperatures and adequate moisture allow production to extend northward (Mendelsohn et al., 1994). But such an outcome is conditional on producers having the capacity to take adaptive actions, a factor that is not always taken into account.

Studies employing a bottom-up approach do focus on adaptive capacity and vulnerability, and tend to be less optimistic about future climate change effects on Canadian rural community sectors, such as agriculture. This line of inquiry generally has a smaller-scale focus, namely the system of interest, and often begins by documenting current adaptive responses to a number of stresses (including weather and climate conditions) as the basis for understanding future capacity to adapt to climate (Belliveau et al., submitted; Bradshaw et al., 2004; Venema, 2005). With its focus on current community capacity, the research results reported here fit within the bottom-up approach for understanding climate change impacts and adaptation.

Recent Impacts from Climate and Weather Conditions on Rural Canada

A comprehensive report detailing the impacts from drought conditions across Canada in 2001 and 2002 points out that rural agricultural regions were especially hard hit (Wheaton et al., 2005). For instance agricultural production dropped an estimated C$3.6 billion; water supplies (previously considered reliable) were negatively affected and several failed to meet requirements; soil erosion, deterioration of grasslands, and herd reductions were evident. In addition the drought was responsible for net farm income being negative or zero in several provinces for the first time in 25 years (Wheaton et al., 2005). Subsequent to 2001–2002, climate and weather impacts have continued to challenge rural and remote Canada. In some cases the impacts remain direct such as damage due to persistent droughts, flooding, or violent storms; in other cases they are indirect, for instance, pest infestations linked to warmer winters. The latter example has been particularly problematic for British Columbia forest communities, where mountain pine beetle damage combined with extreme heat and dryness to create numerous serious forest fires during 2003 and 2004.

Since most rural communities are economically dependent on natural resources, impacts from climate change on those resources will create substantial challenges for residents' and community well-being. Davidson et al. (2003) provide a summary of characteristics that make northern Canadian forest-based communities particularly vulnerable to climate-related impacts. Several of their points are true for rural communities in general. For instance they note that community adaptability is constrained by recent political changes (such as municipal amalgamations) where local governments have lost control and resources for dealing with challenges of all kinds. As well they point to limited human capital and highly specialized skill sets that reduce rural residents' ability to move into forms of employment outside resource sectors. Another set of factors suggesting forest-based communities are compromised in their ability to adapt to climate change revolves around risk perception. In this case, Davidson et al. (2003) point out, rural residents may not acknowledge climate change is a serious problem because they associate the topic with 'environmentalism' and take a position counter to those they think of as an urban-based radical opposition. Denial of climate-related problems is not conducive to implementing strategies and tools that may help individuals adapt to altered conditions. As well, corporate and government messages have not been consistent and/or emphatic about the need to take climate-based risk management seriously. In fact, the message may be the opposite, namely that technological solutions will continue to solve any and all resource-based production problems.

Accompanying these constraints on rural community adaptability for climate change is the additional fact that impacts and risks from climate change are not experienced or conceived of in an isolated manner (Shackley & Deanwood, 2002). Instead they are perceived and treated in connection with ongoing economic and environmental concerns (Allman et al., 2004; Bryant et al., 2000; Wall et al., 2004). A Canadian Senate report recognizes that the potential biophysical impacts from climate change combined with already highly stressed social, economic and environmental systems means rural communities are poorly equipped to handle the challenges from a changing climate (Senate Standing Committee on Agriculture and Forestry [SSCAF], 2003). The question in many minds is 'What is to be done?' Is there capacity in rural communities (and the larger society) to deal with ongoing and escalating climate and weather impacts? And, if the capacity is lacking, how can it be restored and/or built up?

Allman et al. (2004) address elements of this question in their study of local authorities in England and Wales. They conclude that community-level success in adapting to climate change and mitigating greenhouse gas emissions is enhanced by looking for opportunities related to innovative responses to the problem; having strong political, professional and technical support; and working in partnerships with different groups to raise the necessary financial resources. These features are quite specific and could be understood in broader terms as 'community resources'. For instance focusing on the benefits of dealing with climate change in a timely manner might fall under community leadership or human resources. Having strong political, professional and technical support is an aspect of the institutional resources available. Working in partnerships could reflect the strength of established social resources as evidenced in the density of networks in, and level of commitment to, the community.

This more general categorization of community capacity and how to assess it is pursued in the balance of the discussion offered here. With adaptive capacity for climate change as a specific focus for assessing community capacity, the authors provide a capacity framework based on identifying community resources and selecting appropriate indicators for measuring them. Before such a framework is presented, a number of basic terms and concepts are reviewed to provide the rationale for the elements chosen.

Terms, Concepts and Approaches

With respect to recent climate change research, 'adaptation' refers to adjustments in management strategies to actual or expected climatic conditions or their effects, in order to reduce risks or realize opportunities (Smit & Pilifisova, 2003). Adaptation takes many forms, can occur at different scales and is undertaken by different agents (for example, in the case of agriculture these would be producers, agribusiness, industry organizations and governments) (Bryant et al., 2000). The capability to adapt is a fundamental determinant of how vulnerable a specific system is to external or internal stresses (Keskitalo, 2004). For climate change, this attribute is referred to as 'adaptive capacity', defined as 'the ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences' (McCarthy et al., 2001, p. 21). Easterling et al. (2004) suggest a more appropriate term is 'proactive adaptation', which moves a system beyond resilience. That is, it may be preferable for a system to do more than return to an initial state. Instead the system needs to be able to reorganize to accommodate change or expected change and thereby becomes something 'new' in the process.

Adaptive Capacity

Scholarly work on adaptive capacity is linked closely to vulnerability assessments (Clark et al., 2000; Smit & Pilifosova, 2003). Systems are considered more or less vulnerable depending on two factors: the severity of the specific stressful event (for example, a prolonged drought) and the degree of adaptive capacity (that is, the ability to cope with the impacts from such an event). Adaptive capacity is considered inherent to the system (Smithers & Smit, 1997; Kandlikar & Risbey, 2000). It is a set of characteristics that allows a given system to perceive change or threatening circumstances, evaluate them, decide on a solution path and both develop and adopt processes and tools to manage the risk, thereby maintaining itself throughout (Kandlikar & Risbey, 2000; Berkes & Jolly, 2001; Klein, 2002). Because adaptive capacity resides in the system, it does not require the stress condition to be in place. As noted, a community's vulnerability depends on both the severity of the climate event per se (or other stress source) *and* how the social system has organized its relation to its resource base, its relation with other societies and amongst its members, and the larger context of historical and structural processes (Oliver-Smith, 1996; Kandlikar & Risbey, 2000). 'If a society cannot withstand major damage and disruption by a predictable feature of its environment, that society has not developed in a sustainable way' (Oliver-Smith, 1996, p. 304).

Adaptive Capacity Framework

Frameworks are useful for analysing systems and issues so that a fuller understanding of the components and their relationships can be attained. The literature is replete with documents referring to frameworks for community sustainability and capacity development (Ivey et al., 2004), often with a policy orientation (for example, see Institute for Research in Innovation and Sustainability [IRIS], 2005; Chaskin, 2001). There has also been considerable interest in developing frameworks for assessing vulnerability to climate change impacts by exploring the notion of adaptation itself (Smit et al., 1999); by focusing on political and institutional capacity (MacKendrick & Parkins, 2004); by integrating output from different modelling exercises (Ileka et al., 2004); and by identifying elements of adaptive capacity (Adger et al., 2004; Ivey et al., 2004), among others.

Adaptive capacity exists at different scales, from the individual through family, community, region and nation. It is fundamentally dependent on access to resources (Easterling et al., 2004; Adger et al., 2004); not only must these exist in adequate quantities, but the system requiring resources must also be able to mobilize them effectively. The framework proposed here is directly related to resource levels. Resource availability represents the sine qua non of adaptive capacity and as such forms a fundamental platform on which to pursue further understanding of the process of adaptation, namely, the collective action required to handle climate impacts. For the purposes of adaptive capacity studies, resources can be represented as: social, human, institutional, natural and economic. Basic definitions for each type of resource and the associated variables are found in Table 1 and draw on work completed by Mendis et al. (2003).

While it is relatively straightforward to identify the resources underlying adaptive capacity (Smit & Pilifosova, 2001), devising measurements or indicators for the variables is a major challenge. In an attempt to enhance the validity of their measures, MacKendrick and Parkins (2004) base some of their indicators for forest community sustainability on interview and focus group data from residents. By revising the measures for assessment

Table 1. Framework for adaptive capacity: resources, definitions and related variables

Resource	Definition	Variables
Social	People's relationships with each other through networks and the associational life in their community	Community attachment Social cohesion
Human	Skills, education, experiences and general abilities of individuals combined with the availability of 'productive' individuals	Productive population Education infrastructure Education levels
Institutional	Government-related infrastructure (fixed assets)—utilities such as electricity, transportation, water, institutional buildings and services related to health, social support, and communications	Political action Utilities infrastructure Emergency preparedness Health services Communications services
Natural	Endowments and resources of a region belonging to the biophysical realm, including forests, air, water, arable land, soil, genetic resources, and environmental services	Potable water quality Potable water quantity Surface water Soil conditions Forest reserves Fish reserves
Economic	Financial assets including built infrastructure as well as a number of features enabling economic development	Employment levels and opportunities Economic assets

according to how relevant the indicators were to the residents, their approach is typical of integrated assessments (Keskitalo, 2004). As Keskitalo notes, such approaches are now being used more often in climate change adaptation policy development. Integrated assessments that include stakeholders (i.e. those who stand to lose or gain as a result of some kind of change) attempt to balance contributions from scientists and other specialists with information from individuals whose livelihoods are fundamentally dependent on the phenomenon under study.

An effective stakeholder engagement, however, requires specific skills, time and resources to be available from researchers and local agents (Mayers, 2001; Nichols, 2002; Pahl-Wostl, 2002). Thus, such an approach has drawbacks for studies conducted with limited resources and for research objectives that include comparisons across a range of communities. The authors of this article had access to data collected for one of the NRE2 research sites and were able to build on that resource for their adaptive capacity framework (see Table 2).

Indicators listed in Table 2 constitute a set of measures that provide a snapshot of how well or poorly a given rural community scores with respect to resource levels underlying adaptive capacity. While not exhaustive, the variables and indicators are offered as *one* possible way to profile a variety of resources that have relevance for communities' ability to handle climate change impacts. Thus the indicators listed may not be replicated exactly

Table 2. Framework for adaptive capacity with possible indicators

Resource	Variable	Indicator
Social	Community attachment	Buckner scale
	Social cohesion	Trends in mobility rates
		Number of community events
Human	Productive population	Trends in dependency ratios
	Education infrastructure	School/institutional availability measure
	Education levels	Trends in years of schooling completed
Institutional	Political action	Elected representation
	Utilities infrastructure	Age and condition
	Emergency preparedness	Number of programmes available
	Health services	Services available
	Communications services	Availability of local radio/TV/ARES
Natural	Potable water quality	Frequency of contamination
	Potable water quantity	Frequency of shortage measure
	Surface water	Quality/quantity assessment
	Soil conditions	Percentage of class 1 land
		Erosion/quality measure
	Forest reserve	Diversity/age measure
	Fish reserves	Quality/quantity measure
Economic	Employment levels and opportunities	Trends in job diversity
		Trends in employment rates
	Economic assets	Trends in income level
		Trends in home ownership rates
		Local business ownership rates

for other rural community studies, although the logic behind their choice can. It is assumed that researchers working in the field of community capacity could take the framework and approach presented here and modify them to suit the communities and resources available to them.

Methods

As Table 2 implies, sources for the indicator measurement may vary from those readily available as secondary data (for example from Statistics Canada), to primary data collected as an integral part of projects conducted under NRE2. In the latter case, some of the information was gathered from key informants in the sites through interviews and reviewing published site reports. Differences in types of data collected for each indicator have to be resolved to make results comparable. For example dependency ratios rely on quantitative data while assessing utilities infrastructure requires qualitative data. To achieve some commonality, initial assessments for each indicator were transformed into scores based on a Likert scale (0–10). Details on how researchers arrived at Likert scores for each indicator are available in the Appendix. In general, the extremes of 10 and 0 were applied, respectively, to the most and least desirable conditions regarding capacity. Situations

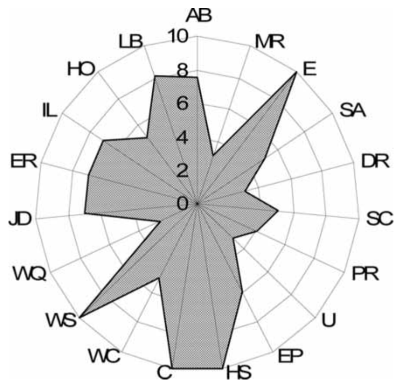

Figure 1. Amoeba profile of resource levels underlying adaptive capacity for climate change.

falling in between the two extremes were scored accordingly. In cases involving qualitative data, decisions regarding the scores were based on the researchers' judgment and experience in the community.

Using a common metric such as a Likert score also allows the results to be represented graphically in 'amoeba' profiles (see Figure 1). The term 'amoeba'[2] has been used for displaying output from profiling exercises for environmental, economic and human health assessments (Smit et al., 1998). Amoeba profiles are in essence vector diagrams, created with radar charts (Connell & Wall, 2004). Other terms for summarizing results in this manner are 'sustainability polygons' (Steiner et al., 2000) and, in the case of human health indicators, 'wellness appraisal index graph' (Dever, 1991).

Social Resources

Social resources exist in relationships between and among individuals, groups and organizations within (and without) a community. The importance of social networks during times of stress is well established for both communication and facilitating collective action (Oliver-Smith, 1996; Scheffer et al., 2002; Adger, 2003).

In terms of climate- and weather-related events with damaging impacts, communities with strong social resources are in a good position to handle related challenges. Recent studies confirm this statement. For instance, during a severe ice storm in eastern Canada (1998), the fire chief for the city of Kingston (badly affected by the ice storm) remarked, 'I think the success of what we got through and how we got through this was people helping people, as much, and in some cases more than, emergency services' (quoted in Purcell & Fyfe, 1998). Likewise, in British Columbia, after the disastrous season of forest fires in 2003, the role of social networks and attachment were noted as fundamental to efforts for restoring community amenities (Stuart, 2004).

Two variables are used to represent the level of social resources existing in a community. *Community attachment* relies on averaging scores from the Buckner scale of cohesion and includes psychological sense of community, attraction to community, and neighbourly behaviour, based on Wilkinson (submitted). The implicit understanding is that the stronger the attachment, the greater the social resource. Researchers also consider social resources in terms of *social cohesion* and use measures reflecting trends in mobility rates for assessing how cohesive a given community may be. In this case, it is argued that communities with high turnover rates create environments where it is more difficult to form strong social networks compared with those where the population is stable (Government of Canada, 2003). Also considered important for developing social cohesion is the number of community events held, since these provide opportunities for residents to meet, socialize and strengthen their relationships.

Human Resources

Human resources encompass the collective skills, knowledge and life experience of individuals within a community as well as their level of physical capability (Yohe & Tol, 2002; International Institute for Sustainable Development [IIDS], 2003). The greater the human resources available, the more likely it is that people will be able to respond to risks, challenges and opportunities facing their communities. With respect to climate- and weather-related impacts, those communities with educated populations capable of 'productive' activity may have a better chance of acting on climate risk management strategies, coping with severe weather events and seeking out potential benefits from altered conditions.

An important aspect of human resource levels is the distribution of population according to age. Relatively speaking, having a smaller rather than a larger *productive population* (defined as residents of 'working age') may be problematic for climate change adaptation. In some cases younger and older individuals are limited with respect to income and information that might be needed for climate change adaptation; they also may place additional demands on the 'working' population, thereby reducing the latter's time and energy available for dealing with stresses affecting the community (Downing et al., 2001). In the event of a hazardous weather event (for example, an extended heatwave), older and younger individuals may suffer disproportionately and thereby weaken overall community resilience (Lemmen & Warren, 2004).

Indicators for human resources include those related to *education infrastructure* (school availability in or close to the community) and *education level* (years of schooling completed). The opportunity to attend an educational institution enhances one's chances for increasing knowledge and therefore one's ability to appreciate and prepare for future situations such as climate change impacts. At the same time, the institutions themselves may support different learning processes (schools, universities, research centres) that provide additional impetus for enhancing skills and knowledge (Adger, 2003).

Institutional Resources

Institutions exist as both formal and informal entities, and are significant for the general planning of a community (Smithers & Smit, 1997; Streets &

Glantz, 2000; Handmer, 2003). The very capacity of social groups to act in their collective interest depends on the quality of the formal institutions under which they reside (Woolcock & Narayan, 2000; Adger, 2003). The role of institutions in determining adaptive capacity for climate change is widely recognized (Willems & Baumert, 2003) and subject to a variety of conceptualizations. Ivey et al. (2004) use qualitative assessments and focus on institutional arrangements for managing climate-related risks associated with water quantity. Their concern is with understanding whether representatives of government agencies involved in risk management are aware of their roles and responsibilities, have sufficient support to take necessary action and are able to work with local agencies responsible for implementing desired changes.

The research underlying this article treated institutional resources in broad terms and developed a range of quantitative indicators including: political connections, material conditions for utilities, emergency preparedness, and the availability of health and communication services found in a community. The first is an assessment of the potential for getting *political action* directed at the community of interest. Docherty (1997) notes that, although the significance for local service appears to be more of an issue in the United States, Canadian political representatives are keenly aware of its importance, especially in rural ridings. Markland (1998) refers to lobbying for projects, grants or contracts for the constituency as 'allocative responsiveness' and identifies it as one of many obligations political representatives can have. For the research reported on in this article, the authors make the assumption that, having elected representatives belonging to the party in power will be beneficial to the community in terms of its ability to gain access to state initiatives and programmes. In terms of climate change impacts, these might include: flood control measures, irrigation projects, coastal protection and/or alternative employment opportunities.

A second aspect of institutional resources is some assessment of *utilities infrastructure* (water, electricity and transportation). In Canadian municipalities responsibility for such infrastructure is in the domain of various levels of governments. Some assessment of the current condition for such infrastructure is relevant to understanding potential negative impacts from climate and weather stress (Hersh & Wernstedt, 2002). If such infrastructure has been built and maintained to standards that will withstand future climate and weather stress then the community is in a better position than one where such assets are in poor condition.

Also important is a third factor, the level of a community's *emergency preparedness* (often the responsibility of institutionally based programmes and policies). Future climate and weather conditions include those that may lead to an increase in various types of disaster (forest fires, flooding, the spread of infectious diseases). Because of recent challenges in Canada from natural disasters and human health issues 'emergency preparedness planning' has become a priority and the federal government now has a new department, Public Safety and Emergency Preparedness Canada (PSEPC) (Government of Canada, 2005).

Communities that have implemented emergency planning will be in a better position to deal with climate change impacts than those that have not.

Related to emergency preparedness is a fourth issue, namely the availability of public *health services*. If and when climate-change-related health concerns appear (for instance, new infectious diseases, emotional stress from experiencing storm damage, and ill-effects from increased smog and heat), a community with well-established health and medical facilities will be in a good position to deal with the resulting challenges. A fifth institutional aspect that is important for handling climate change impacts is the level of *communications services* and their capacity to disseminate important information in a number of ways (Purcell & Fyfe, 1998). During the ice storm in eastern Canada (1998) the volunteer activity of the Amateur Radio Emergency Service (ARES) was invaluable (Samsom, 1998). The ARES could make connections when normal communications means did not work. They have developed a network of contacts with hurricane, cyclone and other weather links, together with the major official emergency services, that allows them to contribute to emergency action, especially in rural and remote communities (ARES, 2004a; 2004b).

Natural Resources

Given rural communities' historic connection to a natural resource base, it has become axiomatic to define sustainability in terms of the presence of sufficient natural resources to support present and future human settlement (Millennium Ecosystem Assessment, 2005). Not only are there immediate needs for clean air and water but there are also requirements for a substantial resource base to support related economic activity (for example, forestry, fisheries, agriculture and tourism). As well, natural resources provide amenities for enhancing quality of life related to aesthetic appeal and proximity to the natural world (Gunderson, 2000; Berkes & Jolly, 2001; Mendis et al., 2003).

At the present time, climate change is credited with having impacts on many types of natural resources and therefore negatively affecting many rural and remote communities. In Canada, changes in the arctic ice conditions, extreme variability and extended drought in the prairie regions, and extreme weather events across the country have all been related to climate change (Lemmen & Warren, 2004). Natural resources are implicated in each of these examples. Ice conditions affect the movement of caribou and polar bear populations; some prairie farmers have had to disband their family operations due to impossible growing conditions for several consecutive years; and some coastal communities face substantial property damage and disturbance in their fishing activity.

Measuring natural resources for a community is challenging for a number of reasons, including determining which natural resources should be assessed and finding appropriate indicators for the resource levels. Several natural resources are considered in Table 2 to offer a range of possible variables and indicators that could be chosen for a specific community study on adaptive capacity for climate change. Not all of them would be used for one community. The exception is water, since all communities need to have a secure water source for human settlement. Thus *potable water* might be assessed in terms of *quality* (trends in the number of contamination incidents) and *quantity* (trends in the number of times shortages have existed).

Beyond the universal need for clean water, other natural resource indicators used will depend on the dominant industry in the rural community studied. For instance, in addition to water used for personal and industrial needs, some communities rely on the amenities provided from *surface water* (lakes, streams, rivers, oceans) for their tourist industry (sport, recreation, leisure and aesthetics). Likewise agricultural communities are reliant on *soil conditions* (perhaps measured in terms of percentage of high-quality soil and lack of erosion). Forest-based communities depend on a healthy *reserve* of trees and fishing communities rely on ample, well-managed *fish stocks*. Appropriate indicators for the latter two types of natural resources would have to be developed for their adaptive capacity assessments.

Economic Resources

Economic resources in communities are among the most frequently studied elements of community capacity and sustainability. They are implicated in climate change issues in several ways. If *employment levels* show increasing trends then it is more likely that residents will have some financial resources to draw upon should a climate or weather event disturb income generation. Residents with secure jobs may be able to invest in preventive and adaptive strategies and perhaps withstand periods of financial hardship more easily than those with no reserves. Likewise, a diversity of *employment opportunities* indicates more choice for individuals should their jobs be adversely affected by climate and weather conditions. However, if community employment is largely dependent on one resource base, the chances of adapting by moving to another sector are limited.

Adaptation to climate change is enhanced when individuals have increasing *economic assets*. If trends indicate rising income levels and home ownership rates then a community's residents will be better prepared for economic stress related to a climate or weather impact (such as a reduction in tourism related to fish habitat disappearing with climate-induced changes in lakes and rivers). As well, the economic assets in community business enterprises are more likely to benefit the residents if ownership is local than if it is not. Such resources may facilitate the recovery from external damaging impacts in a number of ways.

Applying the Adaptive Capacity Framework

Researchers applied the adaptive capacity framework to a rural community site in central Canada (with the pseudonym of Herrington) using primary and secondary data sources. Herrington is a community with a population of approximately 1500 and serves as a service centre for agricultural operations in the surrounding settlements while building its tourism potential. Herrington has the look of a typical rural village in central Canada, situated on a main road with an attractive landscape featuring rolling hills, rocks, lakes and wetlands. Its manufacturing and service industries continue to change with pressures from both global and local developments and conditions. Recent attempts to build a tourism economy include joining forces with neighbouring villages and hamlets to market the region as a desirable vacation destination.

As in many central Canadian rural communities, a river runs through Herrington; it provided a power source and transportation route in the past. Today the river's contribution is more aesthetic although there is some discussion of its potential for generating electricity. Because the village is within easy commuting distance to larger urban centres, it is a challenge to maintain viable retail outlets in Herrington. Most residents travel outside the community for work, shopping and other services. The loss of some government offices, community schools and industrial firms presents continuing challenges for Herrington. As well, there are concerns regarding pollution levels in ground and surface water that have resulted from mine sites close to the community but no longer operational. Despite (or perhaps because of) these stresses, there is a strong sense of pride in the community and a number of very active organizations.

It is conceivable that climate change could have several impacts on future biophysical and socioeconomic conditions in Herrington. What adaptive capacity does the community have to deal with such impacts? This question needs to be addressed in two parts. First, climate change projections and their possible effects on the region including Herrington are presented. Second, the results from applying the adaptive capacity framework to Herrington are discussed in light of the potential impacts.

Climate Change Projections for Herrington

Climate change scenarios have been generated for southern Ontario. Projections for the 21st century include a 3–8°C average annual warming, leading to fewer weeks of snow, a longer growing season, less moisture in the soil and an increase in the frequency and severity of droughts and other extreme weather events. As a result there may be more days when heat stress and air pollution adversely affect people's health. There may also be substantial changes to aquatic ecosystems and alterations to wetlands. Water levels in the Great Lakes could decline to record lows by the latter part of the 21st century, affecting conditions in neighbouring communities (Canada Country Study, 1998).

Given Herrington's proximity to Lake Ontario (approximately 50 km), projected conditions for the Great Lakes Basin are of particular interest. According to Kling et al. (2003), southern Ontario's climate is projected to become warmer and probably drier during the 21st century, especially in the summer. By 2030, summer in the region may resemble that currently found in upstate New York. Further changes by 2095 could be more extreme, as summer conditions might become more like those today in Virginia. The *Great Lakes Regional Assessment* (Andresen et al., 2000) portrays a similar picture, noting that future climate in southern Ontario may have fewer cold air outbreaks and less lake-effect snow in winter, combined with warmer summers and more chances of extreme precipitation events, although 'average' conditions may be drier.

Possible impacts from these projected conditions include a variety of challenges and some opportunities including:

- A warmer climate and longer frost-free seasons may permit the spread of new diseases from warmer climates, such as Lyme disease, malaria and West Nile virus. This could lead to problems for community health and vulnerable populations.
- Droughts and reduced ice cover may increase evaporation and cause surface water levels to decline, thereby affecting tourist/recreational activity as well the effectiveness of water and sewage treatment.
- Bridges, roads and buildings may come under more stress related to flooding, washouts and increased temperature extremes.
- There could be some agricultural benefits from longer growing seasons and warmer temperatures but these may be offset by moisture stress and increased diseases and pests.
- With extended droughts, forests may suffer from various impacts related to dry conditions, such as increased pests and more frequent fires.

Herrington's Adaptive Capacity

The adaptive capacity framework described in Table 2 was populated with data from Herrington (see Table 3) and forms the basis for an amoeba to show the results (see Figure 1).

Table 3 summarizes the indicator scores for the five types of resources and reflects the fact that Herrington scores above 5 out of 10 on approximately half of them. The community appears to be in a relatively strong position in terms of its social resource levels. The exception is mobility rates, which are substantial, thereby lessening the chances for social cohesion. Otherwise, one would expect a strong community response to an extreme weather event such as a flood or prolonged heatwave that might harm the community's infrastructure and/or vulnerable populations. Human resources are less robust, especially with respect to dependency ratios. Herrington's working age residents might be over-burdened with the demands of the young and elderly when responding to the effects from weather conditions that result in new infectious diseases and/or damaged infrastructure.

According to the data, some institutional resources are in very good shape (namely health services availability and communications). This bodes well for dealing with health impacts related to adverse climate and weather conditions and for communicating information regarding responses to hazards resulting from extreme weather events. However, only water-related utilities (which are in need of upgrading) were included for this aspect of institutional resources.[3] A more complete assessment of other utilities and infrastructure would improve the assessment presented here. Natural resources also have some challenges in this community given substantial pollution threats to water sources from earlier mining activity in nearby areas. This could present

Table 3. Assessment of Herrington resources

Resource	Indicator	Score	
		Code	
Social	Averaged Buckner score (psychological sense of community; attraction to community; neighbourly behaviour)	AB	7.5
	Mobility rates	MR	3
	Number of community events	E	10
Human	School availability measure	SA	5
	Dependency ratio (trends)	DR	3
	Years of schooling completed (trends)	SC	5
Institutional	Political representation	PR	4
	Age and condition of utilities	U	3
	Emergency/disaster relief programmes availability	EP	6
	Health services availability	HS	10
	Radio/TV/ARES	C	10
Natural (water)	Frequency of contamination	WC	5
	Frequency of shortage	WS	10
	Quality/quantity assessment	WQ	2.5
Economic	Job diversity (trends)	JD	7
	Employment rates (trends)	ER	7
	Income level (trends)	IL	7
	Home ownership (trends)	HO	5
	Local business ownership	LB	8

problems under climate change conditions where the extremes of flooding/washouts and droughts are both possible. Economically, Herrington is in a reasonable position to withstand stress from job loss related to climate or weather conditions and the need for financial resources for rebuilding or sustaining livelihoods should a weather event create problems.

The amoeba profile (portrayed in Figure 1) provides an alternative method for depicting the data and may be useful for engaging community residents, who can see at a glance their overall resource assessment underpinning their adaptive capacity for climate change. If there is interest in a community, these amoebas could be created for past and future years, thereby providing the basis for a visual comparison over time and a quick and relatively straightforward indication of whether things are improving or not. As well, comparisons with other communities in the region or across a wider territory could be made effectively if they all had amoeba profiles. Such assessments might be useful for provincial or state governments interested in regional variation in adaptive capacity.

Conclusion

This article began by noting that, despite the need for progress, little has been accomplished regarding the development and implementation of adaptation strategies for the impacts of climate change. A discussion then followed in which the resource elements of adaptive capacity and a framework for defining and assessing those resources were presented. An additional feature is the use of amoeba profiles for depicting the results from applying the framework so that stakeholders, including policymakers and researchers, can see fairly quickly where adaptive capacity might be strong or lagging.

Among the objectives of the article are raising awareness about climate change adaptation issues and demonstrating how the topic is closely aligned with work on community capacity, sustainability and resilience. The framework and amoeba profiling exercise are offered as one way to achieve those objectives with the added aim of encouraging researchers to improve their methods and therefore the quality of results. Thus both those interested in community capacity and those dealing with community responses to climate change can benefit from the discussion.

The variables and indicators used in the adaptive capacity framework were selected based on literature reviews and data availability. Researchers adopting this framework for assessing community capacity in the future could make improvements in the thoroughness of their assessments if they had access to larger, reliable data sets. There are no limits to the number of variables and indicators that can be included in the structure offered here. It is possible, and might be preferable for some, to generate a framework and amoeba for each of the five resources, thereby providing a much more detailed examination of a community's adaptive capacity. Hypothetically there is no shortage of indicators; realistically it is problematic to find ones that can be quantified and included in the profiles.

Although the adaptive capacity framework presented here is quantitative, it is not necessary to use numeric measurements to achieve reliable assessments. Generating a more qualitative version of the framework requires a different approach, one that would involve stakeholders more directly and at the formative stage of research process. In this case, community residents would join researchers in determining the resources that underlie their community capacity and agree on a slate of indicators that reflect resource levels. Instead of Likert scores, they might prefer to use high–medium–low designations based on their experience in and knowledge of the community. The results could still be portrayed in a version of the adaptive capacity framework and amoeba presented here. In fact, it would be interesting to compare a quantitative assessment based on numeric, 'objective' data with a more qualitative assessment based on individual perceptions.

Using the framework and amoeba profiles to communicate findings to researchers and community residents has always been highly successful. The results presented here were made available to some residents of Herrington in a 2004 public meeting. They expressed keen interest in the description of their community, especially the findings on water quality, since there are sensitivities about having a community labelled as below standard. Otherwise, the residents did not appear too concerned about what the capacity assessment might mean for future climate change but were more intrigued about how well or poorly their community appeared to outsiders.

From the reaction of Herrington residents (among other attendees at the meeting), the amoeba profile conveys results in an appealing and readily understandable form. It is possible to use the amoeba as a tangible focal point for discussing next steps while in other instances it can be used as a baseline to measure future progress. Whether the issue is adaptive capacity for climate change or some other aspect of community sustainability and capacity, the approach will support many possible applications and uses. It is valuable for a number of different groups including researchers striving to understand forces and factors underlying community capacity, government agents challenged with assisting in community capacity building, policy analysts seeking comparative assessments among different communities and regions and individual residents working to sustain themselves and their communities.

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Notes

[1] The New Rural Economy Project Phase 2 (NRE2) is a research and education programme studying rural Canada since 1998. It is a collaborative undertaking bringing together rural people, researchers, policy analysts, the business community and government agencies at all levels to identify and address vital rural issues. It is conducted at the national level with historical and statistical data analysis, and at the local level with case studies involving community and household surveys. The NRE's mandate has been extended through 2006 with the help of a major grant from the Initiative on the New Economy Program (INE) of the Social Sciences and Humanities Research Council of Canada. For more information on the NRE, visit <http://nre.concordia.ca/nre2.htm>.

[2] The irregularity of the overall shape and the fact that it can change from year to year (if repeated assessments are completed) has led to calling this form of graphing an 'amoeba' approach (ten Brink, 1991).

[3] Data on the state of roads, bridges and electrical infrastructure were not readily attainable so could not be included in this assessment.

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Appendix. Transforming Indicators into Likert Scores

Indicator	Explanation and source	Likert scoring
Averaged Buckner scale (AB)	Data available through NRE household survey results (2003)	No transformation needed, since it exists as a 1–10 scale
Trends in mobility rates (MR)	Trends in the percentage of movers relative to the total population over past 20 years (Source: Census Canada 1981, 1986, 1991, 1996 and 2001)	10 means site MR is <15% and steady 7 means site MR is 15–25% and decreasing 5 means site MR is 25–50% and decreasing 3 means site MR is 25–50% and steady 0 means site MR is >50% and steady
Number of community venues/events (E)	Number of annual events recorded for 2004. Number of annual events in site compared with the average for 22 NRE sites. (Source: NRE Communications Report 2004)	10 means site E is > other NRE sites 5 means site is = other NRE sites 0 means site E is < other NRE sites
Trends in dependency ratios (DR)	Trends in dependency ratios over past 20 years. DR calculated as {(% under 15) + (% over 64) / % between 15 and 64} × 100 (Source: Census Canada 1981, 1986, 1991, 1996 and 2001)	10 means site DR is 50 and stationary trend (i.e. 34–40% of dependents) 7 means site DR is <65 to >50 and decreasing 5 means site DR is < 65 to >50 and stationary 3 means site DR is >65 to <100 and increasing 0 means site DR is >100 and increasing
School/institutional availability measure (SA)	Presence of educational institutions in the site (Source: NRE site profiles 2003)	10 means site has college + 7 means site has up to high school 5 means site has up to junior school 0 means site has no school on site
Trends in years of schooling completed (SC)	Trends in residents' average number of completed years of schooling over past 20 years (Source: Census Canada 1981, 1986, 1991, 1996 and 2001)	10 means site SC is increasing 5 means site SC is stationary 0 means site SC is decreasing

Political representation (PR)	Political representation for the riding in federal and provincial parliament in past 20 years. (Source: Legislative Assembly of Ontario (2004) and Government of Canada (2004) websites)	10 means site has always had government representation (federal and provincial) 0 means site has never had government representation (federal and provincial level). Scores between 0 and 10 reflect situations varying from either extreme
Age and condition (water and sewer utilities) (U)	Estimate the condition for water and sewage treatment (Source: interviews with municipal personnel responsible for infrastructure)	10 means site U has recent upgrading, continuous monitoring 7 means site has U monitored, continues to upgrade and has no areas of concern 5 means site has U monitored, continues to upgrade and has areas of concern 3 means site has U monitored, is not currently upgrading and has some concern areas 0 means site has no U upgrading since original installation
Number of emergency programs available (EP)	Determine the existence of programmes/ARES (Source: Primary research in site; NRE Profiles 2003)	Each of the following is scored on the basis of 10 for existence and 0 for non-existence: • programs in the province • programs in the region • programs in the site • presence of ARES • emergency health services Score out of 10 reached by dividing total by 5
Health services available (HS)	Ten services were considered (hospitals, ambulance, emergency services, doctors, nurses, home care visits, social workers, public health nurse, food bank, and drop-in centres (Source: NRE Services Report 2003)	10 means all HS are within 30 minutes of the site (by vehicle) 0 means no HS are within 30 minutes drive (by vehicle) Scores between 0 and 10 reflect situations varying from either extreme

(*Table continued*)

Appendix Continued

Indicator	Explanation and source	Likert scoring
Local radio/TV/ ARES availability (C)	Existence of local communication tools (Source: NRE Communication Report 2003)	10 means site has radio/TV/ARES 0 means site has none of them Scores between 0 and 10 reflect situations varying from either extreme
Frequency of water contamination (WC)	Review history of potable water issues (Source: Herrington Annual Report 2003)	10 means site has no contamination events and monitors continuously 5 means contamination is a possibility, but monitors continuously 0 means site has high rate of contamination events
Frequency of water shortage measure (WS)	Review history of potable water supply (Source: Herrington Annual Report 2003)	10 means site has no shortage 5 means site has occasional shortage 0 means site has no water availability
Surface water quality/quantity assessment (WQ)	(Source: Diverse reports on water management for the relevant county and industry from Herrington Annual Report 2003)	10 means site has water availability/no threat of contamination 5 means site has water availability/low degree of contamination 0 means site has water availability/high degree of contamination
Percentage of class 1 land	N/A	N/A
Erosion/quality measure for soils	N/A	N/A

Diversity/age measure for forest reserve	N/A	N/A
Quality/quantity measure for fish stocks	N/A	N/A
Trends in job diversity (JD)	Trend in job diversity over the past 20 years in the site and in those communities within 60 km commuting distance from the site (Source: Census Canada 1986, 1991, 1996 and 2001)	10 means site has dominant industry; steady situation 7 means site has one or two dominant industries (>20%); decreasing dominance 5 means site has one dominant industry (>30%); decreasing dominance 3 means site has one dominant industry (>30%); increasing dominance 0 means site has one dominant industry (>50%); increasing dominance
Trends in employment rates (ER)	Trends in level of unemployment over past 20 years (Source: Census Canada 1986, 1991, 1996 and 2001)	10 means site has decreasing unemployment 5 means site has steady employment 0 means site has increasing unemployment
Trends in income level (IL)	Trends in income levels over past 20 years (Source: Census Canada 1986, 1991, 1996 and 2001)	10 means site has increasing income levels 5 means site has steady income levels 0 means site has decreasing income levels
Trends in home ownership rates (HO)	Trends in the percentage of the population owning home over the past 20 years. (Source: Census Canada 1986, 1991, 1996 and 2001)	10 means site has increasing home ownership 5 means site has steady home ownership 0 means site has decreasing home ownership
Local business ownership rates (LB)	(Source: Herrington—business retention and expansion survey report, 2004)	10 means site has 100 per cent of businesses owned locally 0 means site has no businesses owned locally Scores between 0 and 10 reflect situations varying from either extreme