Vulnerability to climate change hazards and risks: crop and flood insurance

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This paper reviews the widely used concepts of risk and vulnerability as they relate to climate and weather hazards, re-conceptualizes these terms in the context of climate change and illustrates this development using crop and flood insurance as examples. Government subsidization of insurance against risks associated with adverse climatic conditions and weather events, such as flood damage and crop loss, may lead to individual decisions that actually increase the susceptibility of people, property and economic activities to those risks. The processes that give rise to this phenomenon are important in understanding the vulnerability of human populations to climate change. In many regions, existing conditions that give rise to flooding or crop failure are likely to be exacerbated by climate change over coming decades. In the climate change field, vulnerability has been conceptualised as a function of exposure to risk and as an ability to adapt to the effects. In this context, crop and flood insurance are possible adaptive measures. This treatment of vulnerability compares with similar concepts in insurance and risk management whereby events that cause loss are known as perils, and physical conditions, such as climate change, that increase the likelihood of a

Cet article fait la critique des concepts très répandus du risque et de la vulnérabilité dans la mesure où ils s'appliquent aux risques météorologiques et propose une reconceptualisation de l'utilisation de ces termes dans le contexte du changement climatique. Les exemples de l'assurance récolte et inondation permettent de retracer cette évolution. La participation gouvernementale aux primes d'assurance contre les risques liés aux conditions climatiques et phénomènes météorologiques défavorables, tels que les dommages causés par les inondations et la perte des récoltes, peuvent mener à des décisions individuelles qui accroissent en effet la sensibilité des individus, des biens immobiliers et des activités économiques face à ces risques. Les processus à l'origine de ce phénomène permettent de comprendre la vulnérabilité des populations humaines exposées au changement climatique. Dans plusieurs régions, les conditions actuelles qui produisent des inondations ou la perte des récoltes seront probablement rendues plus aiguës par le changement climatique au cours des prochaines décennies selon le Groupe d'experts intergouvernemental sur l'évolution du climat. Dans le domaine du changement climatique, la vulnérabilité a été conceptualisée en fonction de l'exposition au risque et la capacité d'adaptation aux effets des changements. L'assurance récolte et inondation, dans ce contexte,

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peril occurring, are known as physical hazards. Human behaviour that increases the exposure of individuals to potential perils is known as morale hazard or moral hazard, depending on the intentions of the person. Vulnerability consequently becomes a function of hazard and responses taken to reduce risk. Examples of crop and flood insurance programs from Canada, New Zealand and the U.S. are used to show how subsidized insurance might create a morale hazard in addition to physical hazards such as short-term weather events and long-term climate change, resulting in a higher level of vulnerability than would otherwise exist. These findings demonstrate that human behaviour affects the formation of both exposure and adaptive capacity in the context of vulnerability to climate change. Responses taken to increase adaptive capacity may in some cases be offset by individual behaviour that increases exposure.

peuvent être considérées comme des mesures d'adaptation potentielles. Ce traitement de la vulnérabilité se rapproche des concepts analogues issus des domaines de l'assurance et de la gestion du risque. Ces domaines appellent risques les phénomènes qui causent des pertes, et appellent risques objectifs (ou matérialité des risques) les conditions physiques, telles que le changement climatique, qui peuvent accroître la probabilité qu'un risque se produise. Les comportements humains qui augmentent l'exposition des individus à des risques possibles sont définis comme un risque moral ou un risque subjectif, variant selon les intentions de l'individu. La vulnérabilité devient alors une fonction du risque et des mesures prises pour réduire le risque. Des programmes en matière d'assurance récolte et inondation au Canada, en Nouvelle-Zélande et aux États-Unis servent d'exemples pour démontrer comment l'assurance subventionnée peut causer un risque moral en outre des risques objectifs tels que les phénomènes météorologiques à court terme et le changement climatique à plus long-terme. Il en résulte un accroissement du degré de la vulnérabilité qu'il en serait autrement. Ces constats mettent en évidence les conséquences des comportements humains sur la formation de la capacité d'exposition et d'adaptation et ce, dans une situation de vulnérabilité au changement climatique. Les réactions qui augmentent la capacité d'adaptation peuvent, dans certains cas, être contrebalancées par des comportements individuels qui augmentent l'exposition.

Introduction

It is increasingly accepted that accumulations of carbon dioxide and other greenhouse gases, in large part, are a result of human activity and are causing significant changes to the Earth's climate, notably increases in average temperatures (Houghton *et al.* 2001). However, the most recent report (2001) of the Intergovernmental Panel on Climate Change (IPCC) also outlines changes in the frequency, spatial distribution and magnitude of a number of climatic conditions, extremes and weather events likely to occur in coming decades (McCarthy *et al.* 2001). Many of these changes, if manifested, pose significant risks to human well-being. Drawing on scholarship in fields such as natural hazards and disaster management, the IPCC suggests that such factors as the extent of exposure, the sensitivity of the systems involved and the adaptive capacity of those exposed influence the vulnerability of human populations. It further suggests that the degree of vulnerability of a given population to risk may be reduced through enhancement of that population's adaptive capacity.

The IPCC notes that many human settlements can be expected to face an increased potential of flooding because of increased heavy precipitation events and sea-level rise (McCarthy *et al.* 2001). Higher maximum temperatures and more hot days are expected to occur over nearly all land areas, and increased summer continental drying and associated risk of summer drought is likely to occur over mid-latitude continental areas (McCarthy *et al.* 2001). Such changes in climatic conditions may be expected to pose concerns for areas of agricultural production (Bryant *et al.* 2000; Reilly *et al.* 2003).

Many human settlements in such environments have long been exposed to the risks of flooding or drought. Such manifestations of climate change can therefore be described as exacerbations of

existing risks to which such communities are already exposed. In other words, the climatic conditions listed above represent potential increases in frequency, extent or magnitude of existing climatic or weather-related risks.

Because the likely manifestations of climate change include exacerbations of risks for which insurance may be obtainable, use of insurance can be considered as one the many possible adaptive options for climate change (Tol 1998; Vellinga and Mills 2001; Smit and Skinner 2002). In affluent societies, insurance is a mechanism that has been formed to assist people in coping with the adverse impacts of a wide range of events, both certain (e.g., death) and uncertain (e.g., automobile accidents). Many types of insurance have developed in response to risks associated with climatic conditions and weather events, such as crop failure and damage to property caused by storms, wind or floods, as well as events such as fire for which climatic conditions may be a contributing factor. While use of such types of insurance may potentially play a role in improving the capacity to cope with climate risks, it will be argued in the following discussion that, in some circumstances, insurance may have the conflicting effect of increasing the exposure of people and economic activities to such risks. Exposure to climate change will be shown to be not simply a measure of changes in biophysical or climatological conditions at a given place and time, but a product of human processes as well.

The aims of this paper are threefold. First, we set forth the concepts of risk and vulnerability from the research literature, which have become central to assessing the potential effects of climate change on human populations. Second, we reveal that although exposure and adaptive capacity are often treated separately, in climate change literature, they are not mutually independent variables and that they are invariably interconnected, and we thus offer a re-conceptualized model of climate-related risk to illustrate more closely these interconnections. This model is pertinent to those seeking to reduce human vulnerability to climate change risks, because actions taken to reduce exposure may cause changes in adaptive capacity—or vice versa. Third, we illustrate these ideas with examples of insurance for crop- and flood-related risks. In many western countries, governments subsidise such insurance, which serves to make the insurance more widely available; thus, more people who experience these types of losses are compensated. While this might seem to increase the ability of these populations to cope with a higher level of risk exposure, subsidization also tends to increase the number of people and economic activities exposed to the very risks that are being insured against.

Human Vulnerability to Climate Change

Many definitions have been offered to describe human vulnerability to natural conditions that may have adverse consequences (Cutter 1996; Clark *et al.* 1998; Liverman 2001; Weichselgartner 2001). Most describe vulnerability as the potential to experience harm or loss from some event or condition, and this potential is related to factors that affect the likelihood of the event or condition occurring and the ability to cope with or adjust to the effects of the event, if and when it occurs.

Human vulnerability to the broad range of risks associated with climate change can be represented with the model (1) (after Smit and Pilifosova 2003):

$$V_{slit} = f(E_{slit}, AC_{slit}) \quad (1)$$

where V = vulnerability, E = exposure, AC = adaptive capacity, s = a given system or community, l = a given location, i = a given climatic stimulus and t = a given period of time. This model acknowledges that the vulnerability of a given community or system to climate change is specific to particular stresses or stimuli at particular locations and periods of time. There are two principal elements of vulnerability distinguished in the model. E refers to the probability or incidence of hazardous conditions relative to the presence of humans at a particular location at a particular time. AC refers to the ability of those exposed to cope with the potential hazardous conditions to which it is exposed. No particular scale is specified in this model, allowing for vulnerability to be characterized at levels from individual households to communities, regions and beyond.

The mathematical form of the relationship (f) is not specified, as it would vary by s, l, i and t; however, the generalized form as it is set forth implies that E is positively related to V, while AC is negatively or inversely related to V.

This model provides a very broad conceptualization of vulnerability. It does not specify the particular interconnections. It is expected that these relationships are likely to be system-, place- and time-specific, and will vary with the specific types of climate change-related risks and potential ways of adapting to such risks. We next reformulate this general vulnerability model to reflect how risk is understood in the fields of insurance and risk management. Doing so will provide insights into how insurance may influence adaptive capacity and may inform policy regarding subsidized insurance in particular applications.

Risk, Peril and Hazard as Defined in the Insurance Industry

The following descriptions of risk and hazard as they are used in the fields of insurance and risk management are derived from Trieschmann *et al.* (2001) and are consistent with those in standard insurers' references such as *Rupp's Insurance and Risk Management Glossary* and the *Field Guide for Property and Casualty Agents and Practitioners*. In the field of insurance, *risk* is synonymous with uncertainty about the occurrence of a given outcome, and an event that is the manifestation of a given risk is known as a *peril*. Risk may be categorized as follows:

Pure risk vs. speculative risk

A pure risk is one where, if the peril occurs, the only possible outcome is a loss to the person experiencing it. For example, a house fire is unlikely to result in any benefit to the owner of the house. A speculative risk is one where, if the peril occurs, the possibility of experiencing either a loss or a benefit exists. Note that the peril itself is not the source of speculation, but the nature of the impact of its occurrence is. A bet placed on a racehorse is an example of a speculative risk.

Static risk vs. dynamic risk

A static risk occurs in an environment that is in a steady state. For example, the probability of death is 100 percent and unlikely to change (Trieschmann *et al.* 2001). A dynamic risk is one where the environment may be subject to change. Starting a new business in a volatile economic environment is an example of dynamic risk.

Subjective risk vs. objective risk

A subjective risk is one where an individual forms a perception regarding the likelihood of a peril occurring. An objective risk is one where the chances of a peril occurring can be quantified. For example, fear of flying is a subjective risk; the frequency of airplane crashes as measured per number of airplane flights is an objective risk.

Using these descriptions of risk, *vulnerability* as it is generally described in climate change literature becomes *pure*, *dynamic risk* using the language of the insurance industry. The *climatic stimuli* that give rise to such risk become *climatic perils*.

Whether the risks are objective or subjective in the context of climate change is in large part related to the perspective of the observer; Slovic *et al.* (2000) have shown how perception of what constitutes risk of harm from environmental perils is influenced by a range of factors and may differ significantly among individuals and institutions. For the purposes of this paper, it is sufficient to recognize the importance of perception in the formation of risk. The existence of crop and flood insurance implies *de facto* that such risks are generally perceived to exist in the jurisdictions where insurance is made available; whether an individual chooses to participate in such insurance plans may indeed be influenced by the perception of those risks (Blanchard-Boehm *et al.* 2001).

Conditions that increase the likelihood of a given peril occurring or that increase the severity of the loss when a peril occurs are known in the insurance industry as *hazards*. Hazards can be categorized as follows:

Physical hazards

A physical hazard is a material condition that increases the chances of a peril occurring, or, in our case, a geophysical, biophysical, atmospheric or hydrological condition. For example, a sudden and intense burst of precipitation is a physical hazard in a floodplain, because it increases the possibility that a watercourse may overspill its banks, thereby increasing the possibility of property damage (a peril) occurring.

Morale hazards

The actions of an individual who disregards or is careless of a given peril is a morale hazard. An

example of this is an individual who builds a house in an area that is frequently flooded and does so with the assumption that a third party will compensate him or her for any losses he or she might experience. It will be shown that subsidized insurance can cause this form of hazard to occur.

Moral hazards

A deliberate action to bring about a peril is a moral hazard. A classic example is the money-losing business owner who deliberately starts a fire to destroy the premises and makes a claim against fire insurance. The distinction between 'moral' and 'morale' is a fine one and relates specifically to the mindset of the individual as evidenced by his/her actions. The distinction may not be crucial in all situations, but it would be a very important distinction to the insurer in the example given here, because deliberate arson committed by a policy holder would probably void the coverage. Were the fire caused, however, by careless storage of flammable materials (i.e., a morale hazard), the insurer might nonetheless be obliged to pay compensation to the policy-holder.

Again, using the language of the insurance industry, events such as crop failure or flood damage are *perils* against which one can purchase insurance. In this context, climate change, with its climate and weather manifestations, can be described as a *physical hazard*, in that it creates a set of conditions, such as more frequent extreme weather events or more frequent dry periods, which in turn increase the likelihood of such perils occurring. Such terminology may seem unusual, particularly to those familiar with natural hazards literature, where it is the manifestations of climate change, and not climate change itself, that are defined as hazards. However, the utility of categorizing risk, peril and hazard in this way becomes apparent when the vulnerability model is reconstructed using the terminology of insurance and risk management.

Re-Conceptualizing the Vulnerability Model

On the basis of the arguments presented so far in this paper, the conceptual model of vulnerability introduced above may be reformulated as follows:

$$R_{slpt} = f(H_{slpt}, A_{slpt}) \quad (2)$$

where R = pure, dynamic risk, H = hazard, A = adaptive response, s = a given community, l = a given location, p = a given peril and t = a given period of time

In this reformulation (2), 'vulnerability of a given system or community to a given climatic stimulus occurring at a given place and time' has been replaced by 'the risk of loss in a given community, in a dynamic environment, due to a given climatic peril occurring at a given place and time'. In doing so, we move from a general conceptualization of the potential for loss or harm due to climate change to a conceptualization that, although still generic in nature, describes the outcomes of particular adaptive measures taken in the context of specific climate- or weather-related events or conditions. The terms 'exposure' (E) and 'adaptive capacity' (AC) have been replaced by H and A, respectively. A, in this model, describes the influence of a particular response or set of actions, such as insurance, against a particular peril (p) and is therefore more measure-specific than adaptive capacity. The term peril (p), which describes the physical manifestation of the risk (R) in question, is considerably narrower than the term 'climatic stimulus' (i) that it has replaced. In other words, the re-conceptualized model seeks to relate specific types or forms of adaptation to specific types of climate- or weather-related risks.

The term 'hazard' includes physical, morale and moral hazards as described above, and its use in this reformulation makes explicit what is implicit in the term exposure used in the more general vulnerability model: that both environmental and human processes influence the level of risk. For instance, different types of hazard might increase the likelihood of flood-related perils in a given location. Climate change, should it lead to more frequent extreme precipitation events, would present a physical hazard. Where the occupier of a building situated in a floodplain uses the basement to store valuable items, not realizing that the building has been flooded in the past, this presents a morale hazard. A builder who deliberately constructs for re-sale, to an unsuspecting buyer, a non-flood-proof building on a piece of land known to be inundated regularly, creates a moral hazard.

In simple terms, this model suggests that hazards (H) serve to increase risk (R), whereas adaptive responses (A) are taken to reduce risk. Consequently, pure dynamic risk (R) associated with climate change may be seen as a function of any hazards that increase the likelihood of a climatic peril occurring and the effects of responses, such as the use of insurance, in reducing that likelihood.

Application of this model may be demonstrated by considering the effects of crop insurance and flood insurance programs on the risks associated with crop failure and flood damage to property. This application indicates that government subsidisation of such insurance programs may create a *morale hazard* that increases climate change-related risks, even though such insurance may be provided as an adaptive response to reduce risk.

Crop Insurance in Canada and New Zealand

In Canada, government subsidies, in the form of income support programs, subsidized crop insurance, disaster financial assistance and *ad hoc* assistance programs collectively form a major part of farmers' strategies to cope with the uncertainty inherent in crop production (Schmitz *et al.* 1994; Smit *et al.* 2000; Wandel and Smit 2000; Smit and Skinner 2002). Crop insurance is a tool used by farmers to reduce the consequence of conditions such as pest outbreaks, adverse weather and crop disease that may adversely affect production (Wandel and Smit 2000). As with most other forms of insurance, by purchasing crop insurance, the farmer shares his/her individual risk of crop failure with a pool of third parties facing similar risks. As the size of the pool increases, the degree of risk faced by the pool as a whole decreases (Trieschmann *et al.* 2001), and those members unfortunate enough to experience crop failure during a given period are compensated from the pool's collective resources.

In Canada, crop insurance programs and uses are based largely on average yield (Smithers 1998). Using the average yield of a given crop over a given number of years, a typical strategy for a farmer participating in a crop insurance plan is to purchase insurance for that portion of his/her crop that must be harvested for the farm business to break even. Should the harvest fall short of that threshold, the insurance plan compensates the farmer for the difference. If yield exceeds the insured amount, the farmer receives no return on the premium paid. In Canada, federal and provincial governments subsidize crop insurance premiums by 50% on average, and governments typically absorb administrative costs and any losses sustained by the insurance plan (Smithers 1998). Because of these subsidies, farmers share their risks not only with other insured farmers but also with the general taxpaying population. This reduces the degree of risk to levels much lower than if only policyholders shared the risks.

Research conducted in New Zealand illustrates the effects of government subsidies on farmer risk-management behaviour. In the early 1990s, the government of New Zealand abruptly removed most existing forms of government subsidy from the agricultural sector, including subsidized crop insurance (Smit 1994; Bradshaw and Smit 1997). Through the various subsidies, New Zealand farmers had shared their individual risks of production with the general taxpaying population, similar to the Canadian situation. The risk-management strategies of farmers showed marked differences after the removal of these subsidies. Previously, there existed a high tendency for farmers to clear marginal land for use as pasture, to use fertilizer indiscriminately and excessively and to maintain high stocking rates for certain types of livestock. When subsidies were removed, the intensity of farming decreased, as did development of new land and the use of fertilizers (Bradshaw and Smit 1997; Bradshaw *et al.* 1998). Crops were no longer grown on land where risk of failure was high, stocking rates fell and lower-yielding but more robust crops and forage grasses were planted (Smit 1994). Farmers diversified as crops and livestock raised, avoided concentrating crop types in one spatial area and diversified their sources of income (Smit 1994; Bradshaw and Smit 1997; Bradshaw *et al.* 1998). The removal of government-subsidized crop insurance spurred increased competition among private insurers to provide crop insurance. However, the much higher premiums for private insurance, especially for areas where risk of crop failure was high, led to a general decline in the use of marginal farmland. It should be noted that the effects of subsidy

removal were not distributed equally among the farming population. The farm-level impacts varied according to a range of factors, including farm size, level of indebtedness, farm family size and age and local incidence of drought conditions (Cloke 1996). Whereas some farmers left farming altogether or took on increased off-farm employment, other farmers with capital to invest benefited from declining agricultural land prices and were able to expand their landholdings.

In summary, when New Zealand farmers were obliged to bear the full costs of potential crop failure and livestock loss, they changed their practices so as to reduce their exposure to physical hazards inherent in farming—unpredictable weather, pests, disease and so forth. The fact that farmers adopted such practices in the absence of subsidies implies that a morale hazard—a higher level of indifference towards conditions that might result in crop failure—existed when subsidies were in place. The abandonment of marginal cropland when confronted with the price of private crop insurance suggests that subsidized crop insurance had created a moral hazard—a deliberate undertaking that increases risk—whereby farmers had been deliberately farming land with a high potential for crop failure.

The New Zealand example illustrates how an alteration of an adaptive response—the removal of subsidies and, in particular, subsidized crop insurance—reduced the morale hazard. Without subsidies, farmers began to choose adaptation options that reduce the likelihood of crop losses and that decrease their potential losses should this peril occur. The overall level of risk of crop failure was thereby reduced.

In addition, the removal of subsidies not only removed those hazards that originated in human behaviour (morale and moral hazards), it also reduced the level of physical hazard. After subsidies were removed, farmers stopped putting marginal land into crop production. Marginal land is, by its very nature, land where physical characteristics such as inadequate precipitation and poor soil quality make raising a crop or sustaining pasture difficult. By avoiding such land, farm operations are concentrated on land where such hazards are lower.

This analysis has focused on the risk to the producer. It may well be that consumers of New Zealand farm products experienced changes in cost, selection or availability because of such structural changes. The purpose here is not to assess the arguments for and against subsidized insurance but to show how such policies, which have economic implications and which represent or contribute to adaptive responses, can also affect the exposure (i.e., the various physical and human-related hazards) of the system to climate-related conditions.

Subsidized Flood Insurance in the United States of America

Approximately 12 percent of Americans live in areas that are subject to periodic flooding (Blanchard-Boehm *et al.* 2001). Over six million buildings exist within 100-year floodplains, and 88 percent of U.S. counties experienced at least one flood in the twentieth century (Burby 2001). In 1968, the U.S. government established the National Flood Insurance Plan to provide subsidized flood insurance for properties in designated high flood-risk areas (Blanchard-Boehm *et al.* 2001). In such areas, it is necessary to purchase this insurance to obtain a mortgage or other forms of property financing from a financial institution but is otherwise not mandatory (Blanchard-Boehm *et al.* 2001). Where flood insurance is not needed for property finance reasons, participation in flood insurance plans, even though subsidized, tends to be low (Pynn and Ljung 1999; Browne and Hoyt 2000; Blanchard-Boehm *et al.* 2001; Burby 2001). The apparent reason is that other forms of government assistance, particularly *ad hoc* disaster relief, are expected and typically delivered when flooding actually occurs. Even where subsidized flood insurance is purchased, the evidence suggests that it creates a morale hazard that results in a higher risk of flood damage than would otherwise occur.

Flood insurance premiums in the United States are on average less than 40 percent of the actual cost of coverage, with the remainder being absorbed by the federal government (Burby 2001). Owners of existing structures in a floodplain are subsidized further by the higher premiums required for new structures (Burby 2001). Premiums are based on a combination of factors, including the value of the property insured and the probability of flooding in that particular area.

The rate of purchase of flood insurance tends to increase with the income of the purchaser (Browne and Hoyt 2000). This may be interpreted in a number of ways; Pynn and Ljung's (1999) research on flood insurance purchase in Grand Forks, North Dakota, suggests that the likelihood of purchase is positively related to the value of the property insured. Indeed, the likelihood of purchase of flood insurance appeared to be more strongly related to the value of the property than to the proximity of the property to the watercourse that is the source of flooding. Consequently, it appears that one effect of subsidized flood insurance is to maintain the presence of higher value properties in areas where the peril of flooding exists—creating a morale hazard.

In fact, the entire premise on which subsidized flood insurance in the United States is based may be considered a morale hazard. The underlying assumption of the National Flood Insurance Plan is that continued occupation and economic activity of floodplains is in American society's interest, notwithstanding that lower intensity use of land in flood-prone areas reduces the numbers of people and properties exposed to the peril of flooding (Burby 2001). Indeed, Burby (2001) finds that subsidized flood insurance actually works against local government planning initiatives to reduce exposure to floods, because it provides an incentive to continue occupation of properties at risk. Moreover, Blanchard-Boehm *et al.* (2001) found that, of those in their study area who purchased flood insurance (whether purchased voluntarily or as a condition of financing), only 3 percent took any other steps to mitigate against flood damage to their property, the attitude being that having insurance precluded the need for any other action—yet another morale hazard.

The authors cited in this section have been concerned principally with investigating why many people who live in flood-prone areas do not purchase any flood insurance, even when it is subsidized. Blanchard-Boehm *et al.* (2001) and Burby (2001) recommend that subsidized flood insurance be compulsory in high-risk areas. However, even if subsidized insurance was mandatory, the peril of flood damage persists. So, too, would the morale hazard persist, for buildings would continue to be occupied and built in areas prone to flooding.

As in the case of New Zealand farmers, this morale hazard will continue so long as insurance subsidies and *ad hoc* relief payments remain in place. And, just like the practice of farming marginal land, continued occupancy of flood-prone areas invites a high level of exposure not only to existing physical hazards that can trigger flooding but also to the physical hazards associated with climate change.

Empirical applications

This conceptualization may be used to help structure other empirical investigations or interpretations of the vulnerability of a range of human systems to climate change, as well as existing climate-related risks. For example, Bryant *et al.* (2000, 184) describe the adaptation of Canadian farmers to climatic variability and change as involving 'purposeful proactive or reactive response[s] to changes or risks'. This description is similar to that of adaptive responses (A) in the conceptualization of risk described above. The authors go on to show that the capacity of agricultural systems to adapt to climatic risks is influenced by a range of human processes, such as government policies, economic conditions and consumer preferences operating at larger scales, and farm size, crop choices and family financial well-being at the individual farm level. A challenge in estimating the capacity to adapt to future climatic conditions is consequently in the interpretation of how such processes constrain or enhance the adoption of adaptive responses. One example given in Bryant *et al.* (2000) concerns farmers' perception of climate risks and how these may or may not be related to their actions. An empirical investigation of the relationship between perceptions and actions might seek to interpret these in the context of physical, morale and moral hazards using the conceptual model introduced here.

This conceptualization of risk has helped guide the development of an empirical investigation of human migration behaviour in rural eastern Oklahoma during a period of repeated crop failures in the mid-1930s caused by alternating years of droughts and floods (McLeman 2004). The model was useful in recognizing that migration could be conceptualized as one of a range of potential adaptive responses to adverse climate conditions or weather events and not simply as a

stimulus–response relationship. On this basis, the research was structured to identify both the physical hazards faced by farmers and the human processes that placed them in differential positions of exposure, leading to particular groups of farmers using migration as an adaptive response.

Conclusion

It is recognized that the decision to provide subsidies and *ad hoc* disaster relief is reflective of political, social and economic considerations, as much as it is of an interest in minimizing future vulnerabilities (Gardette 1998). By re-framing the conceptual model of vulnerability in the context of insurance and risk management, it is evident that the subsidization of crop and flood insurance (possible adaptive responses) may lead to behaviour by those insured that may seem indifferent or contrary to the perils of flood damage and crop failure and, in some instances, places them at higher levels of exposure to such perils. The likely manifestations of climate change include exacerbations of conditions that lead to flooding and crop failure; therefore, the continuance of subsidised insurance plans may cause the hazards posed by climate change to be greater than would otherwise exist.

These examples also provide insight into the role of human behaviour in the construction of vulnerability being developed in the climate change research community. Although vulnerability is presented as being a function of exposure and adaptive capacity, the processes that form exposure and adaptive capacity do not act in isolation from one another. They are not independent variables. Both reflect the underlying social, political, economic, cultural and institutional conditions that guide the nature of human occupance and resource use. Furthermore, programs that are intended to enhance people's ability to cope with environmental risks—that is, to enhance adaptive capacity—may result in behaviour that increases exposure to those very same risks. Exposure to climate change is not simply a measure of the likelihood of changes in biophysical conditions of a given location over time. Rather, both biophysical and human processes determine exposure.

That exposure to hazards is fundamentally related to human behaviour is hardly new; Hewitt (1983), Blaikie and Brookfield (1987), Burton *et al.* (1993) and Sen (1999), among others, have demonstrated the role of human processes in exposing people to natural hazards and environmental degradation. Within the climate change research community, a growing number of researchers have recognized and substantiated the role of human socio-economic processes in the analyses of vulnerability, complementing scholarship that focuses on the biophysical processes of climate change (e.g., Downing *et al.* 1997; Smithers and Smit 1997; Handmer *et al.* 1999; Kelly and Adger 2000; Smit *et al.* 2000; Leichenko and O'Brien 2002; Yohe 2002; Fraser *et al.* 2003; Ford and Smit 2004).

This paper has conceptualized how human behaviour, with respect to measures that might be taken to reduce climate change-related risks, may exacerbate both exposure and adaptive capacity, using examples of *existing* adaptive measures, such as crop and flood insurance, developed in response to *existing* vulnerabilities to climatic conditions. Understanding these relationships as they presently unfold with respect to climate conditions and weather-related events may improve our ability to develop alternative measures that more appropriately support adaptive capacity in coping with *future* manifestations of climate change. Care must be taken when developing adaptation strategies to prevent unintended consequences increasing exposure to the very risks they are designed to avoid.

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