EcoHealth

10.1007/s10393-004-0055-0

Original Contributions

Health Consequences of Drought on the Canadian Prairies

Karen E. Smoyer-Tomic[1], Justine D.A. Klaver[2], Colin L. Soskolne[2] http://www.springerlink.com/media/E3GHUHQTRNLCEB6QNQ96/Contributions/K/R/W/F/KRWFHMJCYTE7B3DW_html/fulltext.html - ContactOfAuthor3 **and Donald W. Spady[2, 3]**

(1)
Department of Earth and Atmospheric Sciences, University of Alberta, 1-26 Earth Sciences Building, Edmonton, Alberta T6G 2E3, Canada

(2)
Department of Public Health Sciences, University of Alberta, 13-103 Clinical Sciences Building, Edmonton, Alberta T6G 2G3, Canada

(3)
Department of Pediatrics, University of Alberta, Edmonton, Alberta, Canada

Colin L. Soskolne
Email: colin.soskolne@ualberta.ca

Published online: 4 November 2004
Abstract Population pressures and expanding agricultural and industrial development, with their resulting environmental degradation and demand for water, are likely to increase drought

vulnerability on the Canadian Prairies. Coupled with increases in drought expected under climate change, the health and well-being of prairie populations may be compromised. However, little is known about the health effects of drought in this region or of possible adaptation strategies. This article assesses the available information on the health effects associated with drought and uses this information to develop an ecosystem health framework for outlining how drought may affect the prairie ecosystem and the health and well-being of Canadian Prairie populations. The article identifies multisector mitigation and adaptation strategies for reducing the harmful effects of drought on the prairie ecosystem and its populations. The literature review revealed that drought is associated with crop failure, increased atmospheric dust, and intensifying forest fire frequency, with health effects ranging from respiratory illnesses from inhaling dust or smoke, to mental health concerns arising from economic stress, particularly among farmers. Future research is needed on: the health effects associated with drought more specific to the Prairie region; the mental well-being of farmers and agricultural communities; the health effects from exposure to forest fire haze; and the health effects of reduced water supply and quality. Reducing drought vulnerability requires multisectoral collaboration, starting at the community level, to identify more sustainable water use, diverse health risks of drought, and ways of adapting to drought conditions.

Keywords prairie ecosystem - human health - drought - Canada

INTRODUCTION

Humans live and participate in ecosystems, comprised of complexes of organisms and their physical environment interacting as a functional unit. Whether on a global, regional, or local level, humans are linked to their biophysical, social, and economic environments (*Lebel, 2003*). Healthy ecosystems are resilent to stressors but, as ecosystems are degraded, their ability to respond diminishes. Humans are remarkably adaptable despite causing extreme disruption to the ecosystems they inhabit. But, over time, the ongoing effects of unsustainable activity tend to have negative consequences for human health.

Our focus here is on the Canadian Prairie ecosystem, and the effects of drought, a naturally recurring stressor, on population health of residents of the area. The Prairie region has received little attention in the environment and health literature, yet is an important social and economic region within Canada that relies heavily on water-intensive primary resources, such as agriculture, livestock, forestry, and energy production. Water-intensive land use and increasing population demands for water will exacerbate the effects of increased climatic variability and drought expected in the prairies under climate change, leading to heightened drought vulnerability, which can impact ecosystems and locally important economic sectors. Disruptions to these could jeopardize the health and well-being of prairie populations, particularly if health risks and adaptive strategies are not identified.

Our objectives in this article are: (1) to assess the available information on the health effects associated with drought, particularly on populations in the Canadian Prairies; (2) to use this information to develop an ecosystem health framework for outlining the complex ways by which drought may affect the prairie ecosystem, and how these impacts may affect the health and well-being of Canadian Prairie populations; and (3) to identify multisectoral mitigation and adaptation strategies for reducing the harmful effects of drought on the prairie ecosystem and its populations.

CANADIAN PRAIRIE REGION

A regional perspective of the health effects of drought recognizes that every region will have its own set of challenges stemming from its unique environmental, economic, and social characteristics. Canadas Prairie region is home to 5.3 million people (16.8% of the Canadian population), and encompasses the provinces of Alberta, Saskatchewan, and Manitoba. Population growth in the region is highly variable, with Saskatchewan gradually losing population, Manitoba growing slowly, and Alberta growing faster than any other province in Canada (*Statistics Canada, 2004a*). The economy is centered on primary resources—agriculture, ranching, forestry, oil, gas, and mining (Environment Canada, 1996). The prairies are home to 46.5% of all Canadian farm operators (Statistics Canada, 2004b),

and employ 61.4% of Canadas mining and oil extraction and production workforce (*Statistics Canada, 2004d*). The combination of water-intensive industry and a growing population results in increased water demand.

The two dominant ecozones in the region are the Prairie grasslands and the Boreal Plains. Almost 85% of the population lives in the Prairie ecozone, where all major urban centers are located. Human activity is increasingly disrupting this ecozone. In the Boreal Plains, approximately 84% of the land is forested, whereas 70% of the land in the Prairie ecozone is devoted to ranching and agricultural operations. Much of the oilsands development is occurring in Albertas Boreal Plains, entailing not only increasing water demands, but causing additional land use change that can disrupt the hydrological cycle.

DROUGHT AND ITS IMPLICATIONS FOR THE CANADIAN PRAIRIES

Drought can be defined as unusually low water supply, due to reduced rainfall, reduced snowmelt, or low levels of streams (*Oliver and Hidore, 2002*, p 394). Ecosystems experience cycles of precipitation and evapotranspiration of differing periodicity, with drought occurring when the balance between the two is disrupted for long periods of time. Drought is a relative concept, in that nearly all climates undergo periods where precipitation is substantially below long-term average conditions. Drought, however, is not just a natural phenomenon—it is also a function of water demand, which in most ecosystems has a societal component (National Drought Mitigation Center [NDMC], 2002a).

Transformation from nondrought to drought conditions within an ecosystem can have a negative impact on population health. Even long before the industrial revolution, when human activity began to cause global environmental impacts, abrupt changes in climate towards drought have been cited as contributors to major declines in Old World and New World societies (*DeMenocal, 2001*). Understanding the natural and anthropogenic causes of drought at

both the macro- and micro-levels, as well as identifying the potential health consequences of drought, are important for mitigating activities that contribute to drought as well as for adapting to drought conditions.

Macro-level Causes of Drought

Climatic variability is the underlying driver of drought. Variability reduces the amount, intensity, and frequency of precipitation, and disrupts the timing of precipitation events. These conditions can lead to reduced infiltration, run-off, deep percolation, and ground water storage. High temperatures, low relative humidity, high solar insolation, minimal cloud cover, and high winds all increase surface evaporation and transpiration in plants, and thus exacerbate the potential for drought. Once normal rainfall returns to an area, the meteorological drought may be over, but the effects of local drought conditions can cause reduced stream flow throughout entire watersheds. These conditions, known as hydrological drought, can be long-lasting and affect wetlands and wildlife habitat outside of the immediate area experiencing meteorological drought (*NMDC, 2002a*).

Climate variability and change have both natural and anthropogenic components. Climatic shifts varying in scale and intensity have occurred naturally and frequently over time (*Nkemdirim, 1991*). However, human influences on climate change have become much greater over the last century (Pollack and Huang, 2000), particularly from the release of greenhouse gases (GHGs) from burning fossil fuels (IPCC, 2001). With the continued release of GHGs into the atmosphere, the IPCC predicts a 1.4–5.8°C global mean surface air temperature rise over this century (IPCC, 2001).

Climate change projections call for increased temperatures and decreased soil moisture in the Canadian Prairies (*Government of Canada, 2004*), and increased summer continental drying and drought potential (IPCC, 2001). On the Canadian prairies, drought is expected to be a significant marker of climate change (Herrington et al., 1997).

Micro-level Causes of Drought

Land use and development practices that increase surface run-off and evaporation and that disrupt the hydrological cycle, coupled with continued high water demand leading to unsustainable surface and aquifer water use, are anthropogenic contributors to drought. Urban sprawl, population growth, deforestation, excessive irrigation, industrial activity, and increasing resource consumption, place great demands on water supplies that may outstrip the hydrological cycle. Even when precipitation levels are within the expected range for an area, they may no longer be adequate for increased societal needs in particular areas, leading to the possibility of frequent or even perpetual drought-like conditions with supply not meeting demand.

Agriculture is the third largest consumer of water in Canada (*Statistics Canada, 2004c*), and nonirrigated crops are especially vulnerable to a lack of rain and high temperatures. Land use practices such as ploughing crops during dry, windy conditions can exacerbate drought effects on farmlands and ecosystems by increasing soil erosion. Deforestation and overgrazing also remove topsoil, exposing it to additional evaporation and soil erosion. The combined effects of these practices can compound drought, causing ecosystem damage in areas not directly affected by precipitation deficits.

As people continue to migrate from rural to urban locations, and prairie populations grow, vegetated surfaces are paved over, increasing surface run-off and evaporation, and reducing water percolation into underground aquifers. Increased global and local energy demand is leading to continued development and extraction of fossil fuels, particularly in Albertas oilsands. In the Prairie region, large amounts of water from the same source are used by both industry and municipalities, and it must be shared. Compounding pressures from increasing and competing societal water demand is that prairie rivers are fed by Rocky Mountain glaciers. These glaciers have been receding rapidly, with the lowest glacial cover in 10,000 years presently being recorded. Continuation of this trend will exacerbate downstream water flow shortfalls (*Natural Resources Canada, 2002*).

Assessing the Health Effects of Drought

To assess the health effects of drought, particularly on Canadian Prairie populations, we conducted an extensive review of the literature, emphasizing the linkages between drought and one or more human aspects. A broad key word search of the literature published in English was conducted within four databases: a) EMBASE; b) MEDLINE; c) PubMed; and d) Web of Science. The gray literature was not included.

The main inclusion criteria were that each article include an ecological or climate component, and a health, sociological, or adaptation component. Since drought can encompass other ecological conditions that impact health, the research reviewed included key words like dust, soil dryness, water quantity, uncontrolled natural disaster, air quality, and wildfire.

In most cases, we excluded articles from lesser developed countries facing different challenges than Canada, unless we deemed these differences did not affect the study results. The purpose of the literature review was to gather sufficient information to create a putative causal web of health effects from drought. While this procedure cannot be easily replicated, it serves the purpose of a review article.

Drought and Population Health

Drought is associated with crop failure, increased atmospheric dust, and greater forest fire frequency. These, in turn, will have immediate health consequences for prairie communities. This article is organized into four categories of health outcomes associated with drought: farming and mental health, dust and respiratory health, fires and respiratory health, and other health outcomes.

Farming and Mental Health

Farming is one of the most stressful occupations in society (*Robertson, 1980*), and drought conditions will only exacerbate the problem. In the Prairie region, drought has the potential to decrease the average crop yield by 10–30% and move agriculture northward (Herrington et al., 1997). While corporate agricultural enterprises have greater resources to buffer agricultural losses, family farmers do not. Increased drought incidence will disproportionately affect family farmers and ranchers (U.S. National Assessment Synthesis Team, 2000).

The effect of drought on mental health outcomes, such as depression, stress, and anxiety, was rarely studied in peer-reviewed literature. *May (1990)*, in a review article, outlined many potential health and safety hazards associated with farming, yet only touched on the causes of stress in farming, such as weather and economic pressures.

It is well-known that financial concerns are strongly associated with stress among farmers (*Olson and Schellenberg, 1986*; Walker et al., 1986; Geller et al., 1988; May, 1990; Ehlers et al., 1993; Deary et al., 1997; Simkin et al., 1998; Booth and Lloyd, 1999), and this stress can be exacerbated by economic markets, added bureaucracy, financial concerns, and time pressures. Stress is well-established in the causal pathway of many additional health problems, such as coronary heart disease (Wasserman et al., 2000).

In a study from the United Kingdom, *Deary et al. (1997)* found that farmers rated the highest causes of stress to be: filling in government forms, bad weather, adjusting to new government regulations and policies, machinery breakdown at busy times, complying with environmental regulations, and too much to do in too little time. Principal component analysis identified six stress categories: farming bureaucracy, finance, isolation, acts of God (uncontrollable natural forces), personal hazards, and time pressure; with women reporting significantly higher levels of stress than men from uncontrollable natural forces, finance, farming bureaucracy, and time pressure.

Olson and Schellenberg (1986) found that financial difficulties, or

events associated with financial loss, are most often reported by farmers as integral to their stress levels. However, financial stress is compounded by additional familial and extra-familial stressors, such as policy and market forces, which are unique to each farm family and situation.

Often, in times of drought, financial worries and farming bureaucracy increase. Farmers need to complete and submit insurance forms, which may not result in adequate compensation to meet their financial needs. This results in the further need to apply for aid or other types of financial assistance from government.

Dust and Respiratory Health

Dust generation is directly related to climatic processes. The Prairie Provinces are often dry (*Sauchyn and Beaudoin, 1998*), and when combined with large-scale agricultural practices or in the event of drought, atmospheric dusts result. For example, the 1930s were dubbed the dirty thirties in the prairie provinces because a lack of water created dry soil conditions, leading to soil erosion and dust storms (*NDMC, 2002b*).

Farming activities generate most of the aerosolized particulate matter in south-central farming regions of Alberta, with total suspended particulates (TSP) peaking at times of spring and fall maximal farming activities (*Green et al., 1990*). The major component of dust within Alberta farming communities was mineral (e.g., silicates), but depending on the type of crop grown, organic material was also present (Green et al., 1990). Organic dust contains molds, pollen, plant material, animal-derived particles, bacteria, fungi, mites, insect fragments, and dusts generated in barns, silos, and grain elevators (do Pico, 1992; Lang, 1996). The biological activity of organic dusts in the atmosphere depends on the type and concentration of the dust (mainly owing to the industry type), in addition to the regional weather conditions, product source, state of decomposition, and temperature (do Pico, 1992). Inhaled particles (i.e., particulate matter [PM] 2.5 m in diameter) can reach the terminal end of the bronchioles, causing airway inflammation, and can eventually manifest as respiratory illnesses including rhinitis, bronchitis, and

asthma (*Lang, 1996*).

In general, the major health effect from PM inhalation is airway inflammation, which can manifest in acute or chronic forms of asthma, allergic rhinitis, bronchitis, hypersensitivity pneumonitis (*do Pico, 1986*; Rylander, 1986; Lang, 1996; Simpson et al., 1998), and organic dust toxic syndrome (do Pico, 1986; Rylander, 1986; Simpson et al., 1998). Although windblown dust may be most noticeable in rural communities, urban populations may also experience added atmospheric dust of rural origin (Haller et al., 1999).

Eight studies investigated the health outcomes associated with dust and/or soil dryness (*Pappagianis and Einstein, 1978*; Unger, 1985; Gomez et al., 1992; Hefflin et al., 1994; Kwaasi et al., 1998; Prospero, 1999; Rutherford et al., 1999; Schwartz et al., 1999), but only one specifically investigated drought (Fisher et al., 2000). Respiratory illness was a theme in seven studies (Pappagianis and Einstein, 1978; Unger, 1985; Gomez et al., 1992; Hefflin et al., 1994; Prospero, 1999; Rutherford et al., 1999; Fisher et al., 2000), and death in one study (Schwartz et al., 1999). One study considered health outcomes associated with windblown dust such as aeroallergens in Saudi Arabia (Kwaasi et al., 1998).

Seven studies were primary research linking dust and health outcomes (*Unger, 1985*; Gomez et al., 1992; Hefflin et al., 1994; Kwaasi et al., 1998; Prospero, 1999; Schwartz et al., 1999; Fisher et al., 2000). However, only one originated in the Prairie region. Gomez et al. (1992) investigated the potential adverse respiratory health effects among residents living near the desiccated Old Wives Lake in Saskatchewan from blowing alkali salt and dust. The study concluded that cough, wheeze, and both nasal and eye irritation were significantly greater in Old Wives Lake residents than in the control group.

Kwaasi et al. (1998) noted that during sandstorms in Saudi Arabia, agar plate counts for bacteria and fungi were 100% and 40% higher, respectively, than in nonsandstorm dust. In addition, IgE (an indicator of allergic reactions) reactivity for sandstorm dust in humans was noted in both normal and atopic (i.e., allergic

hypersensitivity) individuals.

Fisher et al. (2000) investigated a 1991–1994 epidemic of coccidioidomycosis (a fungal microorganism found in the soil) in California, which they hypothesized was a result of either a new pathogenic strain of *Coccidioides immitis* or a change in environmental conditions that favored pathogen reproduction. The researchers concluded that the epidemic was related to the duration of drought (the most sustained since 1956) prior to a rainfall event and that the timing as well as amount of the rainfall was important.

Fires and Respiratory Health

Drought is also expected to increase the number of forest fires in the Prairie Provinces. In Canada, under a twofold increased CO_2 projection, there will be an increase in the area at risk of extreme forest fire, a lengthening of the forest fire season, and more frequent and severe forest fires (*Natural Resources Canada, 2000*). The direct consequences of wildfires (e.g., evacuation and loss of property and lives) will cause more hardship and need for social assistance, as well as raise insurance costs.

Another health consequence of fire is smoke haze and smoke inhalation. *Emmanuel (2000)* found that 94% of haze particles are inhalable and can aggravate the respiratory tract. Several studies investigated respiratory health effects associated with wildfire or agricultural smoke. In studies of smoke haze affecting Singapore and Indonesia in 1997, significant increases in respiratory disease and in accidents and emergency room attendance were noted, as well as acute respiratory infection, bronchial asthma, diarrhea, eye irritation, and skin disease (Aditama, 2000;]\Emmanuel, 2000). Other haze-related conditions included conjunctivitis, acute upper respiratory tract infection, allergic rhinitis, acute bronchitis, asthma, eczema, and exacerbations of chronic obstructive pulmonary disease (COPD), ischemic heart disease, pneumonia, and emphysema (Emmanuel, 2000). In California counties most affected from smoke during a 1987 forest fire, significantly more patients were treated for asthma in the emergency department than would have been expected (Duclos et al., 1990).

Three studies investigated respiratory symptoms from agricultural burning (*Jacobs et al., 1997*; Long et al., 1998; Roberts and Corkill, 1998). Long et al. (1998), the only study specific to the Prairie region, examined individuals in Winnipeg who had well documented preexisting obstructive respiratory disease prior to the burning residue episode. The authors found that those with underlying phlegm production, dyspnea (i.e., shortness of breath), wheezing, or asthma were more likely to have increased symptoms of cough, wheeze, chest tightness, and/or shortness of breath associated with the agricultural residue burning episode.

In their investigation of the effects of exposure to the seasonal burning of Kentucky bluegrass in Spokane over more than 30 years, *Roberts and Corkill (1998)* found the citys self-reported rate of asthma, emphysema, and chronic bronchitis to be higher than the national rate. Hospitalization rates for asthma in the state-licensed hospitals also were higher in Spokane County than in Washington State. *Jacobs et al. (1997)* suggested that an increase in hospitalization for asthma could be associated with rice stubble burning in Butte County, California, although they noted less than one hospitalization for asthma per day.

No studies investigated the impact of death or economic cost to society from infrastructure losses, in areas devastated by fire. This gap may primarily be because of successful fire suppression capability and the timely evacuation of vulnerable populations.

Mims (1996) found that biomass burning in Brazil significantly reduced solar UV-B intensity. Through a literature review, *Mims (1996)* noted that a reduction in UV-B could decrease the suns bactericide capabilities, decrease photosynthesis, and provide better survival conditions for mosquito vectors.

Other Health Outcomes

Other health outcomes associated with drought include: increased incidence of spinal cord injury from diving in shallow water (*Anonymous, 1998*; Raymond, 1988; Samples, 1989); increased

incidence of diarrhea in children with restricted water access (Burr et al., 1978); silo gas exposure in farm workers from drought-induced grain fermentation (Pavelchak et al., 1999); higher levels of food and feed mycotoxin contamination (Wood, 1992); and an outbreak of leptospirosis in a swimming hole (Jackson et al., 1993).

Concern about water- and vector-borne diseases is important to this discussion and have been addressed in depth in the thesis upon which this article is based (*Klaver, 2002*). In summary, the vector- and rodent-borne diseases significant to the Prairie region are hantavirus pulmonary syndrome, Rocky Mountain spotted fever, Western equine encephalitis, Lyme disease (Klaver, 2002), and West Nile virus (Epstein, 2001).

In the Prairie region, drought may compromise water quality through increased toxin and pathogen concentrations in water. Flash flooding, which can occur at the end of a drought period, can lead to water-borne diseases (e.g., *E. coli*, *Cryptosporidium*, and *Giardia*) associated with the large number of intensive livestock operations in the Prairie Provinces (*Klaver, 2002*; Statistics Canada, 2004b). Toxins and biological organisms in water bodies must be monitored to track threats to water quality.

Discussion of Drought/Health Literature

Many of the articles reviewed were able to provide a general perspective on the potential health effects from drought. However, drought or associated ecological changes were not the primary focus of these articles, nor was the region of investigation the Canadian Prairies. Thus, these studies might neither be applicable to the Canadian Prairies, nor be representative of health impacts of drought-like conditions expected under climate change. Nonetheless, the results of the literature review provide a starting point for anticipating possible health impacts of drought that may affect Canadian Prairie populations.

We found several studies that investigated the possible direct or indirect mental health outcomes associated with ecological changes, but none took into account changing weather, drought periods, or

water availability as possible correlates of increased financial pressures on farmers and agricultural-based industry and, hence, on mental health. This gap is important to fill because the link between financial stress and negative mental health in farmers has been well-documented.

Suicide, as it relates to stress from drought conditions, was not investigated. Suicide in farm owners, managers, and tenants is highly correlated with depression in the year before death, which, in turn, is correlated with financial pressures (*Malmberg et al., 1997*). Suicide could possibly increase under drought conditions or under other extreme climate phenomena when farmers face decreased yields, greater financial pressures, and stress.

There is also a lack of prairie-based research assessing the impact of drought and soil dryness on air quality and, subsequently, on human health. Although *Green et al. (1990)* and Haller et al. (1999) have linked weather variables, farming activities, and aerosolized PM, the connection to health outcomes is lacking.

Studies of exposure to wildfire or agricultural smoke show that these can be harmful to human health. Forest fires, which can inflict great loss of personal belongings and infrastructure, also can be associated with mental health outcomes. However, very little research has been conducted on the mental health aspects of communities affected by fire.

Despite the limitations of the drought literature, we found that it did provide a useful starting point for developing an ecosystem approach to exploring the effects of drought on the health of Canadian Prairie populations.

Ecosystem Approach to Human Health

The ecosystem approach provides a human-centered evaluation of human health that recognizes the direct link between human exploitation of the environment and subsequent negative health effects (Fig. 1). Population health ultimately entails a healthy

environment. With this approach, ecosystem management revolves around finding an optimal balance for all the ecosystems inhabitants, placing equal importance on plants and animals as on humans (*Lebel, 2003*). This balance is often difficult to establish in practice, as many stakeholders inherently put human priorities first. Only through recognition of the importance of ecosystem health to human health and well-being will environmental needs begin to be addressed.

Figure 1. An anthropogenic view of macro- and micro-level human influences on ecosystems and drought, and their affect on human health. *Not all variables possible for investigation have been listed. The dotted line represents the direct health effects from climate variables, such as heat, which are not discussed here.

Figure 1 depicts a human-centered model of the linkages between macro- and micro-level ecosystem changes (i.e., towards drought) and their effect on human health. For example, humans contribute to drought through GHG emissions and dependence on the Canadian Prairie ecosystem for agriculture, forestry, and oil and gas economies. These effects feed back to the human population—drought negatively affects these economies by decreasing air and water quality on which prairie populations rely, thus leading to stresses on health and well-being. Individual adaptive behavior can reduce drought impacts as well as threats to personal health, such as reducing water use or seeking out mental health services.

Although our research investigates the health effects from drought alone, several environmental changes could work synergistically and compound the health consequences anticipated under drought (e.g., drought and a heatwave occurring simultaneously).

Input from community members and stakeholders, researchers, and decision-makers is essential for representing diverse needs in ecosystem management planning to protect ecosystem health (*Lebel, 2003*), and to respond to health effects of drought. The following subsections outline how each of these groups can contribute to viable solutions for minimizing the health impacts of drought.

Community Members and Stakeholders:

Local Adaptation and Participation

Ecosystem-based approaches entail communities assessing their risks from various ecosystem changes (in this case, drought), and estimating for individual communities their health consequences. Community participation is needed to identify potential harms and solutions in order to adapt to the negative health consequences of future environmental change, considering that more than one environmental change may work synergistically (e.g., drought and a intense rainfall event). People who are invested in their community are often the most motivated to protect it and often better understand the challenges posed by environmental change than nonlocal experts or decision-makers, and can identify adaptations best suited to their communities.

Adaptation to drought could encompass small changes, such as educating agricultural workers to wear respiratory masks during windy days, monitoring air quality, and warning rural and urban populations when ambient dust could affect respiratory health. A community effort to educate agricultural workers about the signs of stress, its implications, and where to obtain help also could be implemented. This effort could lessen the public stigma attached to depression and stress.

Adaptation could also encompass taking advantage of potential opportunities from drought. Communities could discuss potential economic markets as a way of adapting to negative economic consequences of drought. For example, summer recreation and associated economic opportunities could increase, as could research and development of water conservation technologies, especially in sectors that use large amounts of water. These efforts could help to reduce anthropogenic contributions to drought.

Researchers: Knowledge Gaps

Drought and human health research could be expanded in four areas. First, there is a need to investigate the health effects associated with drought more specific to the Prairie region and its populations,

especially the elderly, and rural and remote communities, which may be particularly vulnerable. Research should include inventorying the communitys capacity to cope with drier conditions, as well as identifying needed adaptations. Second, more research is needed on drought and the mental well-being of farmers and agricultural communities. A third research gap entails mental health in communities affected by fire. Under climate change conditions, the fire season could lengthen, subjecting large regions to prolonged forest fire haze stemming from fires spread throughout the prairies. Finally, transdisciplinary research is needed to determine the direct and indirect health risks associated with major decreases in prairie water supplies, and also to determine sustainable alternative water sources to support major populations and industry demands. These research areas will require substantial input from both qualitative and quantitative researchers, in addition to community stakeholders, industry, and government officials, to assess societal contributors to drought, related health outcomes, and the capacity of infrastructure to cope with and adapt to drought.

Decision-makers: Role of Government

As noted above, the rapid loss of Rocky Mountain glaciers, the origin of many prairie rivers, is expected to increase with climate change. Prairie populations depend on this water source, as do agriculture and oil and gas extraction industries. With potentially substantial decreases in flow to glacier-fed rivers, municipalities and industry will find it difficult to meet their water demands. Because the government controls the uptake and use of water in the Prairie region, policy needs to be implemented at all levels to ensure an adequate and sustainable water supply to all users. Government actions need to involve water conservation, drought assistance, and water use quota enforcement among competing sectors. The Alberta Government is currently addressing the water situation (*Government of Alberta, 2003*), although not the health implications of water shortages, which require multidisciplinary study.

CONCLUSIONS

The linkages between human activity, its effects on the prairie ecosystem in terms of drought vulnerability, and the ensuing health impacts, are complex. Identifying the ways in which human activity affects ecosystems, and the intricate pathways by which ecosystem health is linked to human health, is the first step in awareness needed for mitigating harmful activities and in adapting to ecosystem stresses resulting from these activities. We found sufficient information in the literature to enable us to develop an ecosystem health framework for investigating health effects from drought. Few studies specifically examined how drought affects health, and even fewer examined health outcomes from a Canadian prairie perspective. Thus, we have identified knowledge gaps to be filled through research.

The causes and consequences of drought in the prairie ecosystem need to be investigated from both a regional and an environmental change perspective. An integrated approach will provide a starting point for community participation in mitigating practices contributing to drought, adapting to the negative health outcomes of drought, and seizing possible economic opportunities arising from drought. Open and transparent dialogue between researchers, communities, industry leaders, and decision-makers through public forums is necessary for protecting ecosystem health, for ensuring infrastructure for adaptation needs, and for promoting population health.

Résumé

La pression démographique et la progression du développement agricole et industriel, avec la dégradation de lenvironnement et la demande deau qui sensuivent, contribueront selon toute vraisemblance à accroître la vulnéerabilité à la sécheresse des prairies Canadiennes. Associées à la siccité quengendrent les changements climatiques, elles auront pour effet de compromettre la santé et le bien-être des habitants des prairies. Dans cette région, on connaît mal les effets sur la santé de la sécheresse et des stratégies dadaptation possibles. Cet article évalue les données disponibles relativement aux effets sur la santé associés à la sécheresse et utilise cette information pour concevoir un cadre de santé de lécosystème et extrapoler les impacts de la sécheresse sur léecosystème des prairies ainsi que

sur la santé et le bien-être de la population qui y vit. Lauteure détermine des stratégies multisectorielles datténuation et dadaptation permettant de réduire les effets délétères de la sécheresse sur lécosystème des prairies et ses habitants. Lexamen de la documentation a révélé que la sécheresse est associée aux mauvaises récoltes, à laugmentation de la poussière atmosphérique et aux incendies de forêt plus fréquents, les effets sur la santé allant des affections respiratoires consécutives à linhalation de poussières ou de fumée aux troubles de santé mentale provoqués par le stress économique, notamment chez les agriculteurs. Des recherches futures savèrent nécessaires pour étudier les effets sur la santé associés plus particulièrement à la sécheresse dans la région des prairies, le bien-être mental des agriculteurs et des collectivités agricoles, les effets sur la santé de lexposition aux brumes provenant des incendies de forêt et les effets sur la santé dun approvisionnement en eau réduit et de qualité moindre. Réduire la vulnérabilité à la sécheresse exige une collaboration multisectorielle commençant au palier communautaire afin de déterminer des utilisations plus durables de leau, les divers risques pour la santé attribuables à la sécheresse et les mécanismes dadaptation.

Mots clés écosystème des prairies – santé humaine – sécheresse – Canada

Resumen

Es probable que las presiones que conllevan el aumento de la población y la expansión del desarrollo agrícola e industrial incidan en una mayor vulnerabilidad asociada con sequías en la región de las praderas de Canadá. La consiguiente degradación ambiental y mayor demanda de agua son presiones que, sumadas al incremento esperado de sequías por cambios climáticos, podrían afectar la salud y bienestar de la población de las praderas. Poco se sabe, sin embargo, acerca de los efectos de la sequía en esta región y de las posibles estrategias de adaptación. Este artículo evalúa la información disponible al respecto y la utiliza para desarrollar un marco ecosistémico a la salud que describe la manera en que la sequía podría afectar al

ecosistema de la región de las praderas Canadienses y la salud y bienestar de sus pobladores. El artículo identifica estrategias multisectorales de mitigatión y adaptación destinadas a reducir los efectos nocivos de la sequía a nivel de ecosistema y de población. Los estudios consultados revelaron que la sequía está asociada con pérdida de cosecha, aumento de polvo atmosférico y una intensificación de la frecuencia de incendios forestales, con efectos a la salud que van desde las enfermedades respiratorias causadas por inhalatión de polvo o de humo, hasta inquietudes relacionadas con la salud mental por el estrés que causan las condiciones económicas adversas, especialmente entre los agricultores. Se necesita realizar más investigación específica a la región de las praderas sobre los efectos de la sequía en la salud, el bienestar mental de los agricultores y comunidades que viven de la agricultura, los efectos de la exposición a la bruma causada por el humo de incendios forestales y los efectos para la salud de una reducción del suministro y la calidad del de agua. Para reducir la vulnerabilidad aparejada con la sequía se requiere colaboración multisectoral, comenzando por la comunidad, con el fin de identificar usos más sustentables del agua, los diversos riesgos a la salud asociados con la sequía, así como maneras de adaptarse a las condiciones de sequía.

Palabras claves ecosistema de las praderas – salud humana – sequía – Canadá
Acknowledgments Funding for this research was provided by Natural Resources Canada Climate Change Action Fund (CCAF), and Prairie Adaptation Research Cooperative (PARC).

References

Aditama, TY (2000) "Impact of haze from forest fire to respiratory health: Indonesian experience" Respirology 5: 169-174 http://chemport.cas.org/cgi-bin/sdcgi?APP=ftslink&action=reflink&origin=springer&version=1.0&coi=1%3ASTN%3A280%3ADC%2BD3M3pvFOmtA%3D%3D&md5=ead6764e4d9d5f31de5b910f6b9765bbhttp://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=10894107

Anonymous (1998) "Diving-associated spinal cord injuries during

drought conditions-Wisconsin, 1988" MMWR. Morbidity and Mortality Weekly Report 37: 453-44

Booth, NJ, Lloyd, K (1999) "Stress in farmers" International Journal of Social Psychiatry 46: 67-73

Burr, ML, Davis, AR, Zbijowski, AG (1978) "Diarrhoea and the drought" Public Health 92: 86-87
http://chemport.cas.org/cgi-bin/sdcgi?APP=ftslink&action=reflink&origin=springer&version=1.0&coi=1%3ASTN%3A280%3ACSeC2MfnsFc%3D&md5=903a42820a6764a936f0231e13409e10http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=644021

Deary, IJ, Willcock, J, McGregor, (1997) "Stress in farming" Stress Medicine 13: 131-136
http://dx.doi.org/10.1002/(SICI)1099-1700(199704)13:2%3C131::AID-SMI727%3E3.3.CO;2-K

DeMenocal, PB (2001) "Cultural responses to climate change during the late Holocene" Science 292: 667-673
http://dx.doi.org/10.1126/science.1059827http://chemport.cas.org/cgi-bin/sdcgi?APP=ftslink&action=reflink&origin=springer&version=1.0&coi=1%3ACAS%3A528%3ADC%2BD3MXjt1elsrk%3D&md5=d314aac258622ef2724f0c7bfc491406http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=11303088

do Pico, GA (1986) "Report on disease" American Journal of Industrial Medicine 10: 261-265
http://chemport.cas.org/cgi-bin/sdcgi?APP=ftslink&action=reflink&origin=springer&version=1.0&coi=1%3ASTN%3A280%3ABiiD38zgtlA%3D&md5=6327e921626fef5097117e4add313d7bhttp://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=3766553

do Pico, GA (1992) "Hazardous exposures and lung diseases among farm workers" Clinics in Chest Medicine 13: 311-328
http://chemport.cas.org/cgi-bin/sdcgi?APP=ftslink&action=reflink&origin=springer&version=1.0&coi=1%3ASTN%3A280%3ABy2A2sbpvFQ%3D&md5=f89eb41280cb1b4974a8eb92a888ff0dhttp://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=1511556

Duclos, P, Sanderson, LM, Lipsett, M (1990) "The 1987 forest fire disaster in California: assessment of emergency room visits" Archives of Environmental Health 45: 53-58
http://chemport.cas.org/cgi-bin/sdcgi?APP=ftslink&action=reflink&origin=springer&version=1.0&coi=1%3ASTN%3A280%3ABy%2BC1MjivFQ%3D&md5=4570b858d747c1c8b7d7d255b4b99a94http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=2180383

Ehlers, JK, Connon, C, Themann, CL, Myers, JR, Ballard, T (1993) "Health and safety hazards associated with farming" AAOHN Journal 41: 414-421
http://chemport.cas.org/cgi-bin/sdcgi?APP=ftslink&action=reflink&origin=springer&version=1.0&coi=1%3ASTN%3A280%3AByuD1c3nslM%3D&md5=adca2fb13a05b0836c44fbd4a1af3ea9http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=8259943

Emmanuel, SC (2000) "Impact to lung health from forest fires: the Singapore experience" Respirology 5: 175-182
http://dx.doi.org/10.1046/j.1440-1843.2000.00247.xhttp://chemport.cas.org/cgi-bin/sdcgi?APP=ftslink&action=reflink&origin=springer&version=1.0&coi=1%3ASTN%3A280%3ADC%2BD3M3pvFOmtQ%3D%3D&md5=393fc2e7371ef6b4e61c53610fef8525http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=10894108

Environment Canada (1996) *The State of Canadas Environment—1996*. Ottawa: Government of Canada

Epstein, PR (2001) "West Nile virus and the climate" Journal of Urban Health 78: 367-371
http://chemport.cas.org/cgi-bin/sdcgi?APP=ftslink&action=reflink&origin=springer&version=1.0&coi=1%3ASTN%3A280%3ADC%2BD3MzlvFWruw%3D%3D&md5=c24601a762a39f827a221dee7601b5dehttp://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=11419587

Fisher, MC, Koenig, GL, White, TJ, Taylor, JW (2000) "Pathogenic clones versus environmentally driven population increase: analysis of an epidemic of the human fungal pathogen Coccidioides immitis" Journal of Clinical Microbiology 38: 807-813

http://chemport.cas.org/cgi-bin/sdcgi?APP=ftslink&action=reflink&origin=springer&version=1.0&coi=1%3ASTN%3A280%3ADC%2BD3c7it1CltA%3D%3D&md5=c2cad955dd6623c4b01eb3ea02a6ec4dhttp://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=10655389

Geller, JM, Bultena, G, Lasley, P (1988) "Stress on the farm: a test of the life events perspective among Iowa farm operators" Journal of Rural Health 4: 43-57

Gomez, SR, Parker, RA, Dosman, JA, McDuffie, HH (1992) "Respiratory health effects of alkali dust in residents near desiccated Old Wives Lake" Archives of Environmental Health 47: 364-369
http://chemport.cas.org/cgi-bin/sdcgi?APP=ftslink&action=reflink&origin=springer&version=1.0&coi=1%3ASTN%3A280%3AByyD2svhtlc%3D&md5=c1ab16285ef5a2f65c2e655ee22b56b4http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=1444599

Government of Alberta (2003) *Water for Life: Albertas Strategy for Sustainability*, Edmonton: Government of Alberta. Available: http://www.waterforlife.gov.ab.ca [accessed January 9, 2004]

Government of Canada (2004) Canada Country Study: Summary, Ottawa: Government of Canada. Available: http://www.climatechange.gc.ca/english/publications/ccs/ [accessed July 8, 2004]

Green, FHY, Yoshida, K, Pick, G, Paul, J, Hugh, A, Green, WF (1990) "Characterization of airborne mineral dusts associated with farming activities in rural Alberta, Canada" International Archives of Occupational and Environmental Health 62: 423-430
http://chemport.cas.org/cgi-bin/sdcgi?APP=ftslink&action=reflink&origin=springer&version=1.0&coi=1%3ASTN%3A280%3ABy6D28%2FislU%3D&md5=b6f02dec28f2d104a089275fb2d6c9d8http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=2246059

Haller, L, Claiborn, G, Larson, T, Koenig, J, Norris, G, Edgar, R (1999) "Airborne particulate matter size and distributions in an arid urban area" Journal of Air Waste and Management Association 49: 161-168
http://chemport.cas.org/cgi-bin/sdcgi?APP=ftslink&action=reflink&origin=springer&version=1.0&coi=1%3ACAS%3A528%3ADyaK1MXhvF2hsr4%3D&md5=3d9591ef8d9723edcf6b59c25b466892

Hefflin, BJ, Jalaludin, B, McClure, E, Cobe, N, Johnson, CA, Jecha, L et al. (1994) "Surveillance for dust storms and respiratory diseases in Washington State, 1991" Archives of Environmental Health 49: 170-174
http://chemport.cas.org/cgi-bin/sdcgi?APP=ftslink&action=reflink&origin=springer&version=1.0&coi=1%3ASTN%3A280%3AByuB2c7nvVU%3D&md5=d6090ccf97a4844d9af6be8af5fccf29http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=8185387

Herrington R, Johnson BN, Hunter FG (1997) Responding to global climate change in the prairies. In: *The Canada Country Study: Climate Impacts and Adaptations—Vol III*, Adaptation and Impacts Section, Atmospheric Branch, Environment Canada, Prairie and Northern Region, Ottawa, Canada, pp 19–35

IPCC (2001) *Climate Change 2001: The Scientific Basis. Summary for Policy Makers*, Geneva: IPCC Secretariat. Available: http://www.ipcc.ch [accessed January 9, 2004]

Jackson, LA, Kaufmann, AF, Adams, WG, Phelps, MB, Andreasen, C, Langkop, CW et al. (1993) "Outbreak of leptospirosis associated with swimming" Pediatric Infectious Disease Journal 12: 48-54
http://chemport.cas.org/cgi-bin/sdcgi?APP=ftslink&action=reflink&origin=springer&version=1.0&coi=1%3ASTN%3A280%3AByyC3cbnvFc%3D&md5=6387dd06294af206e50ce83e58c78642http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=8417426

Jacobs, J, Kreutzer, R, Smith, D (1997) "Rice burning and asthma hospitalizations, Butte County, California, 1983–1992" Environmental Health Perspectives 105: 980-985
http://chemport.cas.org/cgi-bin/sdcgi?APP=ftslink&action=reflink&origin=springer&version=1.0&coi=1%3ASTN%3A280%3AByiH2cjoslw%3D&md5=e169ea73a90d8e67de96511589539452http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=9300924

Klaver, JDA (2002) *Climate Change and Human Health: A Canadian Prairie Perspective* (MSc Thesis), University of Alberta, Edmonton, Canada

Kwaasi, AA, Parhar, RS, al-Mohanna, FA, Harfi, HA, Collison, KS, al-Sedairy, ST (1998) "Aeroallergens and viable microbes in sandstorm dust. Potential triggers of allergic and nonallergic respiratory ailments" Allergy 53: 255-265
http://chemport.cas.org/cgi-bin/sdcgi?APP=ftslink&action=reflink&origin=springer&version=1.0&coi=1%3ASTN%3A280%3ADyaK1c3gtlOgsA%3D%3D&md5=f92403ab08df6eafc6d3022e59a7e37dhttp://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=9542605

Lang, L (1996) "Danger in the dust" Environmental Health Perspectives 104: 26-30
http://chemport.cas.org/cgi-bin/sdcgi?APP=ftslink&action=reflink&origin=springer&version=1.0&coi=1%3ASTN%3A280%3ABymH3s7nslE%3D&md5=0ee52b018538cd30a745782f2b01fbcbhttp://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=8834857

Lebel L (2003) In Focus: Health an Ecosystem Approach, Ottawa, Canada: International Development and Research Centre. Available: http://network.idrc.ca/ev.php?ID=29393_201&ID2=DO_TOPIC [accessed July 12, 2004]

Long, W, Tate, RB, Neuman, M, Manfreda, J, Becker, AB, Anthonisen, NR (1998) "Respiratory symptoms in a susceptible

population due to burning of agricultural residue" Chest 113: 351-357
http://chemport.cas.org/cgi-bin/sdcgi?APP=ftslink&action=reflink&origin=springer&version=1.0&coi=1%3ASTN%3A280%3ADyaK1c7ktVOqsA%3D%3D&md5=5bf0cb6db7d1396a0b1dfb0d6d4dec1fhttp://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=9498951

Malmberg, A, Hawton, K, Simian, S (1997) "A study of suicide in farmers in England and Wales" Journal of Psychosomatic Research 43: 107-111
http://dx.doi.org/10.1016/S0022-3999(97)00114-1http://chemport.cas.org/cgi-bin/sdcgi?APP=ftslink&action=reflink&origin=springer&version=1.0&coi=1%3ASTN%3A280%3AByiH3cblslI%3D&md5=256181011a84b9a6a738d17355db5a6bhttp://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=9263937

May, JJ (1990) "Issues in agricultural health and safety" American Journal of Industrial Medicine 18: 121-131
http://chemport.cas.org/cgi-bin/sdcgi?APP=ftslink&action=reflink&origin=springer&version=1.0&coi=1%3ASTN%3A280%3ABy%2BA1cnhs1Y%3D&md5=fc988471bae29c1cbd76f98c4fb6679dhttp://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=2206045

Mims, FM (1996) "Significant reduction of UVB caused by smoke from biomass burning in Brazil" Photochemistry and Photobiology 64: 814-816
http://chemport.cas.org/cgi-bin/sdcgi?APP=ftslink&action=reflink&origin=springer&version=1.0&coi=1%3ACAS%3A528%3ADyaK28XntVClsrs%3D&md5=6e0f39345eae02ef5b2498683d991a24http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=8931379

National Drought Mitigation Center (NMDC) (2002a) *What Is Drought? Understanding and Defining Drought*, Lincoln, NB, Canada: National Drought Mitigation Center. Available: http://www.drought.unl.edu/whatis/concept.htm [accessed July 7, 2004]

National Drought Mitigation Center (NMDC) (2002b) *What Is Drought? Drought in the Dust Bowl Years*, Lincoln, NB, Canada: National Drought Mitigation Center. Available:

http://www.drought.unl.edu/whatis/dustbowl.htm [accessed January 9, 2004]

Natural Resources Canada (2000) *Sensitivities to Climate Change in Canada*. Ottawa: National Resources Canada. Available: http://adaptation.nrcan.gc.ca/resource_e.asp [accessed January 9, 2004]

Natural Resources Canada (2002) *Climate Change Impacts and Adaptation. A Canadian Perspective*. Ottawa: National Resources Canada. Available: http://adaptation.nrcan.gc.ca/app/filerepository/511B461E4DF64FCBA4C4ED6578050A74.pdf [accessed July 8, 2004]

Nkemdirim, L (1991) *Sources of Proxy Meteorological Data for the Canadian Prairies*, Saskatoon, Canada: Atmospheric Environment Service, National Hydrology Research Centre

Olson, KR, Schellenberg, RP (1986) "Farm stressors" American Journal of Community Psychology 14: 555-569
http://chemport.cas.org/cgi-bin/sdcgi?APP=ftslink&action=reflink&origin=springer&version=1.0&coi=1%3ASTN%3A280%3ABiiD1MjhsVE%3D&md5=dfc57fcbee7e557ef992d3542e7c86e3http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=3799552

Oliver, JE, Hidore, JJ (2002) Climatology: an Atmospheric Science, 2nd ed., Prentice Hall, Upper Saddle River, NJ

Pappagianis, D, Einstein, H (1978) "Tempest from Tehachapi takes toll or Coccidioides conveyed aloft and afar" Western Journal of

Medicine 129: 527-530
http://chemport.cas.org/cgi-bin/sdcgi?APP=ftslink&action=reflink&origin=springer&version=1.0&coi=1%3ASTN%3A280%3ACSaD1Mbgtlw%3D&md5=fdbf597f26a3cd1b3b23fe8a918e8cebhttp://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=735056

Pavelchak, N, Church, L, Roerig, S, London, M, Welles, W, Casey, G (1999) "Silo gas exposure in New York State following the dry growing season of 1995" Applied Occupational & Environmental Hygiene 14: 34-38

Pollack, HN, Huang, SP (2000) "Climate reconstruction from subsurface temperatures" Annual Review of Earth and Planetary Sciences 28: 339-365
http://dx.doi.org/10.1146/annurev.earth.28.1.339http://chemport.cas.org/cgi-bin/sdcgi?APP=ftslink&action=reflink&origin=springer&version=1.0&coi=1%3ACAS%3A528%3ADC%2BD3cXlsFOnt7Y%3D&md5=3971b4167657b4cf3b9f1e413f88cdb9

Prospero, JM (1999) "Assessing the impact of advected African dust on air quality and health in the Eastern United States" Human and Ecological Risk Assessment 5: 471-479

Raymond, CA (1988) "Summers drought reinforces divings dangers" JAMA 260: 1199-1200
http://chemport.cas.org/cgi-bin/sdcgi?APP=ftslink&action=reflink&origin=springer&version=1.0&coi=1%3ASTN%3A280%3ABieA3c%2Fps10%3D&md5=f2762fb8aeb840799cedd773f3ffde8c

Roberts, RA, Corkill, J (1998) "Grass seed field smoke and its impact on respiratory health" Environmental Health 60: 10-16

Robertson L (1980) Farming and stress. Psychiatric Nursing May–June:12–13

Rutherford, S, Clark, E, McTainsh, G, Simpson, R, Mitchell, C (1999) "Characteristics of rural dust events shown to impact on asthma severity in Brisbane, Australia" International Journal of Biometeorology 42: 217-225
http://dx.doi.org/10.1007/s004840050108http://chemport.cas.org/cgi-bin/sdcgi?APP=ftslink&action=reflink&origin=springer&version=1.0&coi=1%3ASTN%3A280%3ADyaK1M3kvVynsg%3D%3D&md5=841f663f3c56ee13f262b2183d67a34ehttp://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=10232058

Rylander, R (1986) "Lung diseases caused by organic dusts in the farm environment" American Journal of Industrial Medicine 10: 221-227
http://chemport.cas.org/cgi-bin/sdcgi?APP=ftslink&action=reflink&origin=springer&version=1.0&coi=1%3ASTN%3A280%3ABiiD38zgtlQ%3D&md5=da11b762e83fb2c62e88c4179559057fhttp://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=3766549

Samples, P (1989) "Spinal cord injuries: the high cost of careless diving" Physician & Sportsmedicine 17: 143-148

Sauchyn, DB, Beaudoin, AB (1998) "Recent environmental change in the southwestern Canadian plains" The Canadian Geographer 42: 337-353

Schwartz, J, Norris, G, Larson, T, Sheppard, L, Claiborne, C, Koenig, J (1999) "Episodes of high coarse particle concentrations are not associated with increased mortality" Environmental Health Perspectives 107: 339-342
http://chemport.cas.org/cgi-bin/sdcgi?APP=ftslink&action=reflink&origin=springer&version=1.0&coi=1%3ASTN%3A280%3ADyaK1M3ivVKmsQ%3D%3D&md5=ec11d2f8a0d993a9a1f6081659193067http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=10210688

Simkin, S, Hawton, K, Fagg, J, Malmberg, A (1998) "Stress in

farmers: a survey of farmers in England and Wales" Occupational and Environmental Medicine 55: 729-784
http://chemport.cas.org/cgi-bin/sdcgi?APP=ftslink&action=reflink&origin=springer&version=1.0&coi=1%3ACAS%3A528%3ADyaK1cXnt12ls7k%3D&md5=357691a994e82d0868986821a5890346http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=9924448

Simpson, JCG, Niven, RM, Pickering, CAC, Fletcher, AM, Oldham, LA, Francis, HM (1998) "Prevalence and predictors of work related respiratory symptoms in workers exposed to organic dusts" Occupational and Environmental Medicine 55: 668-672
http://chemport.cas.org/cgi-bin/sdcgi?APP=ftslink&action=reflink&origin=springer&version=1.0&coi=1%3ASTN%3A280%3ADyaK1M7ivV2nug%3D%3D&md5=3daed56c6cf78b9cc822bcd923ff8769http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=9930087

Statistics Canada (2004a) Canadian Population: Provinces and Territories. Available: http://www.statcan.ca/english/Pgdb/demo02.htm [accessed July 8, 2004]

Statistics Canada (2004b) Census of Agriculture. Farm Operators by Type: Provinces. Available: http://www.statcan.ca/english/Pgdb/econ121a.htm [accessed July 8, 2004]

Statistics Canada (2004c) Environment: Water. Major Withdrawal Use of Water. Available: http://www.statcan.ca/english/Pgdb/envir05.htm [accessed July 8, 2004]

Statistics Canada (2004d) Primary Industries. Employment in the Logging, Forestry, Mining, Quarrying and Oil Wells Industries. Available: http://www.statcan.ca/english/Pgdb/prim04a.htm

[accessed July 8, 2004]

Unger, DL (1985) "Immediate effects of a sandstorm on asthma and other respiratory problems" Chest 87: 543-544
http://chemport.cas.org/cgi-bin/sdcgi?APP=ftslink&action=reflink&origin=springer&version=1.0&coi=1%3ASTN%3A280%3ABiqC2Mzkslw%3D&md5=f537330a561cf9ca75650855b535de5fhttp://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=3979147

U.S. National Assessment Synthesis Team (2000) *Climate Change Impacts on the United States: the Potential Consequences of Climate Variability and Change*, Washington DC: US Global Change Research Program. Available: http://www.gcrio.org/NationalAssessment/overpdf/overview.html [accessed January 9, 2004]

Walker, JL, Walker, LS, MacLennan, PM (1986) "An informal look at farm stress" Psychological Reports 59: 427-430
http://chemport.cas.org/cgi-bin/sdcgi?APP=ftslink&action=reflink&origin=springer&version=1.0&coi=1%3ASTN%3A280%3ABiiD28fgvFc%3D&md5=8ab13e13221d86ffbbfb2c125f88d09ahttp://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=3786615

Wasserman, JR, Whitmer, W, Bazzarre, TL, Kennedy, ST, Merrick, N, Goetzel, RZ et al. (2000) "Gender-specific effects of modifiable health risk factors on coronary heart disease and related expenditures" Journal of Occupational and Environmental Medicine 42: 1060-1069
http://dx.doi.org/10.1097/00043764-200011000-00005http://chemport.cas.org/cgi-bin/sdcgi?APP=ftslink&action=reflink&origin=springer&version=1.0&coi=1%3ASTN%3A280%3ADC%2BD3Mzgtlansg%3D%3D&md5=f2b71092c841591327446ed0cc1fa148http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=11094784

Wood, GE (1992) "Mycotoxins in foods and feeds in the United States" Journal of Animal Science 70: 3941-3949
http://chemport.cas.org/cgi-bin/sdcgi?APP=ftslink&action=reflink&origin=springer&version=1.0&coi=1%3ACAS%3A528%3ADyaK

3sXnvFGitQ%3D%3D&md5=f2a245928ca201c4bb7fc245b88763b2http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=1474031