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Ongoing Soil Degradation in Canada and Its Impacts on the Future of Soil Productivity

As the world becomes more alert on issues such as peak oil and climate change, many neglect the problems arising with soil, one of the most important natural resource and the basic foundation of life. The purpose of this paper is to evaluate different types of soil degradation and its impacts on soil productivity in Canada by focusing on three different regions: British Columbia, the Prairies and the Atlantic provinces



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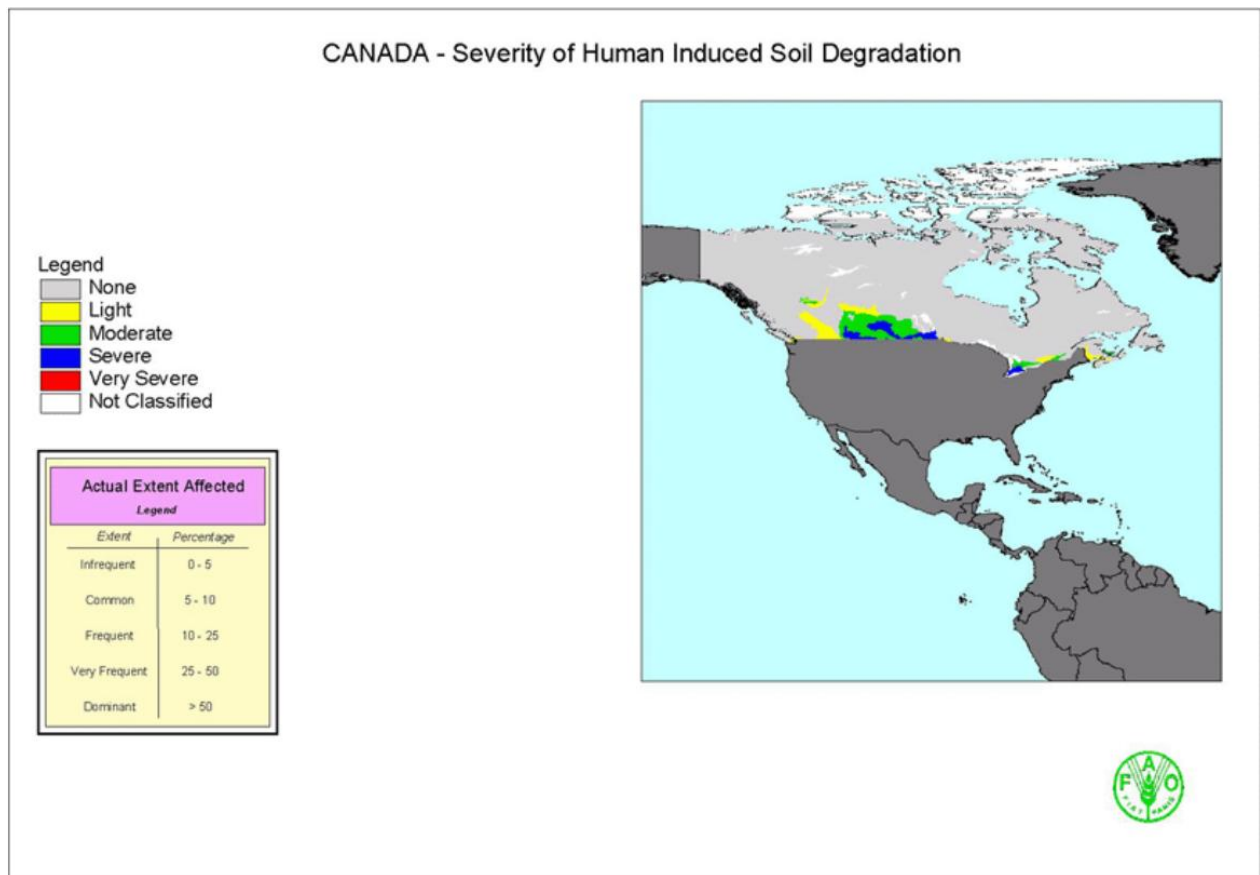
1.0 Introduction

1.1 Our Dependence on Soil

Soil is an important link in providing life on Earth, it accounts for many different functions that humans depend on, from providing resources for food and shelter to sustaining ecosystems enriching the Earth. Each year the global population increases by approximately 80 million people. The response to the increasing demand for food is either through opening up more agriculture lands or through intensified management of existing agricultural lands, however both options could lead to soil degradation (Oldeman, 1999). The Global Assessment of Soil Degradation (GLASOD) defines soil degradation as “a process that describes human induced phenomena which lower the current and/or future capacity of the soil to support human life” (Oldeman, 1999). Soil is an important natural resource and thus should be conserved since our survival depends on it. In 2002, it was estimated that approximately 2 billion ha of land around the world had been degraded (Jie, 2002). Soil degradation will not only hinder human’s quality of life but also the basic functions of natural ecosystems.

Human induced soil degradation in Canada is relatively limited relative to the overall degradation around the world. Figure 1 shows the extent of human induced land degradation in Canada; it is noticeable that area of highest concern is in the Prairies. Northern Canada does not have any soil degradation, due to the fact that the sites are not suitable for any crop production and are generally not used by humans. Approximately 7% of Canada’s land base is used for agriculture (67.5 million hectares) out of the 10% that is suitable for farming, and the Prairies make up 82% of it (Environment Canada, 2008).

Figure 1: An estimate of the human induced soil degradation in Canada (FAO AGL, 2005)



1.2 Land use impacts on soil degradation

There are six main types of soil degradation as classified by the Chinese Academy of Science, these includes erosion, desertification, salinization, pollution, deterioration of soil properties and non agricultural uses (Jie, 2002). In general the six types of soil degradation could potentially lead to soil quantity or quality reduction. Activities that lead to soil quantity reduction include expansion of agricultural production and urbanization. Processes that lead to reduction of soil quality may be due to material loss, mechanical disturbance, and environmental pollution. Different types of soil degradation that decrease soil quality are outlined in Table 1.

Table 1: Types of soil degradation that lead to soil quality reduction (Jie, 2002).

Type of degradation	Examples
Material loss	Soil erosion, desertification
Process disturbance	Nutrient depletion, compaction, acidification
Environmental pollution	Pesticides, heavy metal pollution, radioactive pollution

All the processes mentioned above encompasses a range of activities which also may have one or more forms of soil degradation occurring at a given time (Jie, 2002). A very important component in growing plants is the top layer of the soil or topsoil, which is the most fertile portion of the soil. The top soil as called by Lester R Brown is the foundation of civilization (Brown, 2006). The production of soil does not arise quickly; it takes geologically a long time to form, and as of currently the rate of degradation surpasses the rate of formation (Brown, 2006). The loss of topsoil could lead to distressing results for farmers as it is the most valuable layer of soil for crop production (Franklin Soil and Water Conservation District, 2003).

The impacts of land use on soil degradation are much more rapid compared to natural forms of soil degradation. In many cases land use soil degradation works hand in hand with natural degradation, such as farming will expose soil allowing natural forms of degradation like wind and water erosion to act upon it. One prime example of this was the Dust Bowl that occurred during the 1930s in Canada and US. During World War I there was a dramatic increase in demand for wheat, and large areas of land was ploughed up for the crop with no knowledge of the importance of proper rotation. Several years after severe droughts took place in the Prairies leading to widespread crop failures (Hornbeck, 2009). In addition to the drought, the topsoil became susceptible to wind erosion creating dust storms. Many people feared that the once productive land would soon become a desert; however, the Dust Bowl ended in 1938 when wetter weather returned replenishing the soil and more vegetation grew shielding the soil from natural disturbances; also the implementation of conservation policies and practices were introduced to protect the Prairies from such occurrences again (Hornbeck, 2009). Dust storms as a result of intensive land use are still frequenting around the world and more commonly occur in the developing countries (Brown, 2006)

Overgrazing is another form of land use that may cause soil degradation. Cattle, sheep, and goat forage on two fifth of the Earth's surface that is too steep, too dry, and not fertile enough to produce crops, and as a result half of the grasslands in the world are degraded due to overgrazing (Brown, 2009). Overgrazing tends to lead to desertification as the ruminant mammals engulf all the protective vegetative cover on the land leaving the soil very susceptible to wind erosion and thus converting it into a desert. Currently, overgrazing and desertification is becoming a huge concern in China, many people living in the Northern and Western provinces have been evacuated due to the destruction of the rangeland that is being overrun by drifting sand (Brown, 2009). Overgrazing alters natural habitats of many species as it can dramatically change ecosystems into an unsustainable environment for both flora and fauna.

Deforestation is an ongoing issue especially in developing countries where strict policies are not enforced. One prime example is the ongoing illegal logging in Indonesia. Ever since the Asian financial crisis in 1997, Indonesia's economy has been suffering, illegal logging is much more inexpensive compared to legal logging as there is an increase cost in sustainable management and therefore is not desired (Palmer, 2001). Illegal logging in Indonesia is defined as logging operations outside of the boundaries of their forestry law; these laws are not enforced due to high levels of corruption in the government (Palmer, 2001). Deforestation may be enhanced by other activities such as urbanization, exploitation of resources, poor natural resource management, and overpopulation. Soil degradation as a result of deforestation will lead to different forms of soil erosion and soil compaction.

Desertification is the result of overuse of land and converting the once productive land into a wasteland (Brown, 2006). The Dust Bowl can be classified as desertification as vegetative layer was removed and wind erosion acted upon the unprotected soil causing dust storms. However, the most severe desertification resides in Asia and Africa, one of China's dust storm was so severe it blew all the way to United States, Arizona and in the following year another dust storm from China blew all the way to Korea forcing schools and airlines to close (Brown, 2006)

2.0 Case Studies

2.1 British Columbia

Agriculture and forestry contributed to 2,996 million dollars to British Columbia's (BC) GDP in 2009, which is not that much compared to other sectors such as the service sector (Industry - NAICS Aggregations, 2010). In 2009 it was reported that approximately 34,000 people were employed in the Agriculture sector and 14,000 people in Forestry. The forestry industry has been declining since the 1990s where 26,300 people were once employed and its total share of GDP has now dropped to less than 2%, Agriculture on the other hand has been fairly stable in terms of employment as many people are self employed, however GDP is projected to remain less than 1% in 2017 (Province of British Columbia, 2008). Although these 2 industries are not doing that well, there remains to be issues involving these two sectors that have been promoting soil degradation problems in B.C. The main concern is water erosion. For agriculture water erosion problems range from either having not enough water for irrigation to having an excess supply in the Lower Fraser Valley. Other factors that contribute to soil degradation in B.C are soil compaction and competition over land use (Standing Committee on Agriculture, Fisheries and Forestry, 1984). Table 1 presents various soil degradation processes in B.C and it shows B.C virtually has almost all forms of degradation.

Table 2: Types of Soil Degradation in British Columbia and the Great Plains (Rennie, 1985)

Process	British Columbia	Alberta	Saskatchewan	Manitoba
Wind Erosion		●	●	●
Water Erosion	●	●	●	●
Salinization (man made)		●	●	
Organic Matter Loss	●	●	●	
Acidification	●	●	●	
Drainage	●			
Compaction & Subsidence	●			

Clearcutting is a common harvesting method used in forestry mainly due to its efficiency and simplicity; however, clearcutting poses a huge threat to soil quality especially when terrains are unstable. Terrain instability occurs mainly on steep slopes where debris flows and debris torrents often occur, road construction for logging contributes to adding damages to soil quality. Clearcutting also removes the vegetative cover of the land, so when it snows or rains a large amount of runoff is generated. Road construction and lack of deactivation policies also tend to lead to an increase in the runoff event. Coastal locations in B.C are the most susceptible to debris flows and debris torrents; the reasons being the streams in these areas usually begin on a steep mountain slope and eventually exit into the ocean (McGillivray, 2000). The coasts of B.C have a long history of poor logging practices and as a result much debris has been built up over the years in stream channels forming small dams. When a large volume of rainfall occurs these naturally created dams scour downhill creating gullies (McGillivray, 2000).

The land suitable for agriculture occupies 4% of total land area in B.C. One reason in the past on why B.C has soil degradation problems is due to the competition between urbanization and agriculture pushing the cost of land up, and as a result land holdings tends to be smaller in size forcing farmers in B.C to only produce one crop year after year to as it is more financially feasible for them to do so (McGillivray, 2000). A smaller land holding size has proven to cause soil degradation issue as farmers begin to intensively manage for their one product and thus gradually reducing soil quality; one example is poultry and hog producers, large quantity of manure is produced for this operation but because the size of the farm is too small it is unable to distribute the manure accordingly causing farmers to excessively apply manure over the same plot of land repeatedly resulting in leakage of nitrate (McGillivray, 2000). However this problem has been addressed in 1973 in where Agriculture Land Reserve policy was introduced, this policy promotes agriculture in where suitable land is available and controls non-agricultural uses (Government of British Columbia, 2008)

(Government of British Columbia, 2008). As mentioned before, water erosion is a serious problem in some cases like the Okanagan and lower Fraser Valley where weather is not cold enough to freeze the soil, leaving it unprotected after harvesting of the crops, also in other cases the coast of B.C is known to have high volumes of rainfall and with the increase of urban expansion run off has been increased due to paved developments (McGillivray, 2000).

2.2 The Prairies

The Prairies have are a relatively uniform in plant cover with a lack of trees and dominated by grasses. The Canadian Prairies encompasses three provinces Alberta, Saskatchewan, and Manitoba. Different soil degradation processes that occur within these three provinces are outlined in Table 2. The Prairies are the world's most productive cereal and grain sites, and thus these three provinces are known as the breadbasket of Canada (Standing Committee on Agriculture, Fisheries and Forestry, 1984). Evidence of soil degradation goes back to the history of the first settlement in the Prairies (1870) when the Canadian Pacific Railway was completed speeding up the process of settlement. As more people arrived more land was ploughed, yet people's knowledge of sustainably managing the land was limited. Since soils of this region were very fertile the Prairies were able to provide plentiful crops year after year even with little to no application of fertilizers. In the 1900s, a practice called summerfallow was introduced to aid in the regeneration of the soil as farmers alternated between cropland. Even though this practice was meant to rejuvenate the soil, it soon became the sole reason of the decline in soil organic matter, increased soil erosion and dramatic increase in soil salinity especially in southern part of the Prairies (Standing Committee on Agriculture, Fisheries and Forestry, 1984). In addition due to agricultural practices such as tillage and fertilizer application crop residues are decomposed at a much more rapid rate compared to the native grasses. During fallow years the soil is not being replenished with organic matter leaving it susceptible to wind and water erosion (Standing Committee on Agriculture, Fisheries and Forestry, 1984). Another practice that has contributed to soil degradation is by interfering with the salinity levels in the soils, one example is in the Prairies, the wheat-fallow rotation system disrupts the water cycle dissolving salt that are naturally found in lower depths and bringing it up to the surface making the soil infertile (Standing Committee on Agriculture, Fisheries and Forestry, 1984). The history of soil management in the

Table 3: Estimated historic and current declines of the mixed grass prairies in Canada (Samson, 1994)

Mixed Grass	Historic (ha)	Current (ha)	Decline (%)	Current Protected (%)
Alberta	8,700,000	3,400,00	61.0	<.01
Manitoba	600,000	300	99.9	<.01
Saskatchewan	2,500,00	2,500,00	81.3	<.01

Prairies have caused much damage to soil quality in this region and are still in the process of healing. Table 3 compares the historic and current (1994) areas of grassland in the Great Plains. In all three provinces grasslands have decreased dramatically with little efforts of protection from policies.

2.3 Atlantic Provinces

The Atlantic Region in Canada consists of four provinces, the three Maritime Provinces (New Brunswick, Prince Edward Island, and Nova Scotia) and Newfoundland and Labrador. This region tends to be “ignored” on a national scale in terms of soil degradation due to the fact that compared to other regions in Canada the problem is not seen as serious. However, soil degradation is occurring in these areas with devastating outcomes. The soils in this region are shallow, acidic, and have low productivity, low organic matter, and low clay content. Compared to other parts of Canada, the Atlantic region has the least favorable soil conditions for crop production and therefore intensive agricultural practices need to compensate for the lack of productivity (Standing Committee on Agriculture, Fisheries and Forestry, 1984).

Table 4: The rank of soil degradation issues in the Atlantic Region (Miller,1985)

Form of Degradation	Rank
Soil erosion	1
Soil Compaction	3
Loss of Organic Matter	4
Acidification	2

Table 4 depicts the rank of soil degradation problem in the Atlantic regions of Canada. Water erosion proves to be the leading problem and this includes rainfall, runoff, shoreline, and stream bank erosion (Miller, 1985). Main concerns in Nova Scotia are external to agriculture and are centralized towards more natural causes such as shoreline erosion, stream bank erosion, and flooding. Such erosion is very difficult for farmers to control as it is expensive. Hence, flood prone land should not be cultivated. In New Brunswick and Prince Edward Island the main problem causing water erosion is growing potatoes. Potatoes are harvested in late fall and this leaves exposed soil susceptible to heavy rainfall in fall and winter. Since potato is grown in rows and on slopes enhancing the runoff. Also during winter the exposed soil freezes and when spring arrives the frozen soil melts creating an additional runoff (Standing Committee on Agriculture, Fisheries and Forestry, 1984). In Newfoundland and Labrador main concerns include wind and water erosion, soil compaction, and overgrazing. Similar to New Brunswick and Prince Edward Island, Newfoundland farmers purposely plough up and down the slope so that their crops have time to mature due to the short summers. However, erosion increases as a result. Soils in this province are usually are wet for most part of the

year due to Newfoundland's climate. Consequently, soil compaction proves to be a huge problem in this area. Another problem this province has is livestock overgrazing. Pastureland is very limited and often ranchers tend to overstock their pastures to generate revenue (Standing Committee on Agriculture, Fisheries and Forestry, 1984).

2.4 Comparison of the Three Case Studies

From the West to the East of Canada different regions have different problems. The variability and degree of soil degradation issues is highly dependable on climate, topography, geology, and most importantly type of human practices. Heavy rainfall in B.C and the Atlantic region has shown that implementing poor forestry and agricultural practices can speed up soil degradation. Similarly, in the Great Plains, overexploitation of the fertile soil can lead to disastrous results such as the dust bowl that had occurred in the 1930s. The Coastal areas in B.C and the Atlantic provinces have also presented different problems, with the steep terrain of the B.C coast problems such as debris flows and debris torrents and in the Atlantic region issues such as shoreline and stream bank degradation has created distressing consequences. Although B.C is more populated compared to the Prairies, there are more areas being degraded compared to any other Provinces as we have seen in figure 1, this may be mainly due to large areas being used for agriculture purposes. The practice of agriculture is nationwide, even though in places such as in the Atlantic Provinces where soil is not as suitable for crop production people are still utilizing the soil for farming.

3.0 Conclusion and Recommendations

3.1 Major Findings

Soil degradation is indeed happening in Canada even though Canada has relatively small population Canada should not tolerate irresponsible soil degradation. Farmers may have a tendency to secure their own self interest and contemplate about the consequences later. The same could be said about all land owners in the Atlantic Provinces and the Prairies. Perhaps in many people's mind soil is a unlimited resource which is true to a certain extent, but people's lack of knowledge on the process of soil production and the rate it occurs at could be one important factor on the negligence of sustainable land management. Some things are beyond our control, such as climate and geology of the land but we have to figure out how to work with those elements to produce the most favorable outcomes for both the environment and us.

3.2 Prediction of the Canada's Future Soils

On an international scale Canada is considered miniscule in terms of soil degradation, every soil degradation process occurring in Canada is important as it leads to negative impacts. The future of

Canada's soil is unknown, Nonetheless, if the path of acting out on one's desire continues, the future of Canada's soil looks grim, especially if we project the population of Canada to increase over time. Responsible soil management is a balance between many things, as different factors such as economics and ecology are involved. The physical differences of Canada's land results in a variety of soil degradation types which is difficult for us to control. There is however one tool that can aid in reducing soil degradation and that is to create awareness. The more knowledge people contain about soils the more responsible we will become as we understand that is it a common resource and that we all have a role to maintain it.

3.3 Suggestions for Prevention

Canada is a plentiful country with seemingly endless supply of natural resources. Soil degradation will continue to occur as long as humans continue to have activities on the land, with that being said although we may not be able to stop soil degradation completely we can definitely slow down the processes. In the Soil at Risk report produced by the Standing Committee on Agriculture, Fisheries, and Forestry listed various farming families throughout Canada that has managed to combine conservation tactics within their farming. Each family has taken matters into their own hands to come up with an agriculture system that is suitable for their soil. In one example a potato farmer by the name of Jacques Laforge from New Brunswick. He discovered gullies on the slopes of the potato field realizing that the problem was getting worse every year. He decided that in order to maintain his land for his future generation he needed to act now and to prevent the soil from eroding any further. He began by mapping out each soil type and topography to develop a special engineer system customized for his land's needs. Along with the help of a soil engineer they built terraces and grass waterways. Jacques Laforge also began sowing oats right after harvesting peas to shield the soil from natural erosion. The oats were left until early fall (Standing Committee on Agriculture, Fisheries and Forestry, 1984). The result of this system was highly favorable, it has effectively prevented the soil from forming gullies and not only that higher yields and grades of potatoes were produced. This system has proven it worth as it has done nothing but benefit the farmland. The main problem of such a system is the high cost. Luckily for Mr. Laforge the government was able to provide grants which subtracted about 50% of the cost (Standing Committee on Agriculture, Fisheries and Forestry, 1984). Overall in Jacques Laforge success story, he proved that if you are willing to understand your land you can come up with solutions to save it. In order for projects such Jacques Laforge to become successful one must be informed and most importantly one must have the financial resources. The government should show more support for preventing soil degradation and create more policies to govern this issue.

There are a couple of things in this world humans cannot live without this includes water, oxygen, sunlight, and food. This wonderful matter called soil provides us with so many variety of food. How can the human population possibly survive without understanding its worth? We should be cherishing the soil as we have been highly dependent on soil since our very existence but instead many people are ignorant on the soil degradation processes occurring in the world losing much of our precious soil. We must educate ourselves especially on the history of soil degradation issues in different countries and see how they have overcome problems, a solution can be created but first we need to understand the underlying problem in each situation.

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