ECOCLIMATIC PROVINCES OF CANADA AND MAN-INDUCED CLIMATIC CHANGE[1]

S.C. Zoltai, Canadian Forestry Service, Northern Forestry Centre,
5320 - 122 Street, Edmonton, Alberta T6H 3S5

The establishment of a causal relationship between increased carbon dioxide and other "greenhouse" gases and climate are the subject of intense research. Some climatic changes which occurred during the past century are compatible with the predictions:

1. the earth's surface warmed by about 0.5°C between 1861 and 1984;
2. the temperature of the lower stratosphere decreased by about the same amount between 1975 and 1985; and
3. the diurnal temperature range decreased by about 1°C in the United States.

Critics note that the earth has undergone climatic fluctuations in the past without any assistance from man, and that our climatic records are short and of variable degree of accuracy. A clear "fingerprint" of greenhouse effect has not yet been identified, but anthropogenic changes are expected to exceed natural climatic fluctuations by the end of the twentieth century. In the present study, the currently available predictions of climatic change due to a doubling of atmospheric carbon dioxide levels are used to create a projection of ecoclimatic conditions in Canada under that scenario. Although the accuracy of such a projection is unknown, certain trends are clear which must be taken into account in the long-term planning for the wise use of our land resources.

A number of mathematical models have been generated to forecast the change in climate under various levels of atmospheric CO_2 increase. One of these, produced at the Goddard Institute for Space Sciences (GISS), was used in this study to predict climatic conditions under doubled CO_2 conditions. The GISS model uses general circulation model (GCM) climatic data for temperature projections, but uses normal precipitation values (GISS2) for precipitation projections. The model generates mean monthly temperature and precipitation for grid points located on every 5° longitude, 4° latitude apart.

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1 The "Ecoclimatic Provinces of Canada", which are discussed in this paper and the previous paper, have been extracted from the draft report and map "Ecoclimatic Regions of Canada", which will be published in early 1989 in the Ecological Land Classification Series.

To summarize the effect of possible changes in climate on vegetation distribution, calculated climatic data -- both current and projected -- for the grid points were considered in relation to the ecoclimatic provinces of Canada, as shown in Figure 1. The annual growing degree days (5°C base) were compiled at the 101 grid points located within Canada using a map of growing degree days. Mean annual precipitation at the grid points was derived from the Climatic Atlas of Canada. The mean annual growing degree days under a scenario of doubled CO_2 and the mean annual precipitation were calculated for each grid point from the GISS2 model.

For each ecoclimatic province, ranges of annual growing degree days and annual precipitation were obtained from the climatic maps and then used to locate the boundaries of ecoclimatic provinces under the increased CO_2 scenario, ignoring the effects of climatic extremes. Some of the boundaries were modified to recognize the effect of topographic features.

The use of degree days to locate the generalized position of ecotones shows some promise. The approximate number of annual degree days (5°C base) could be assigned to boundaries where incoming energy plays the greatest role (Table 1).

Table 1: Approximate annual degree days (5°C base) at present boundaries of ecoclimatic provinces

Boundary	Degree days
Arctic/Subarctic	500
Subarctic/Boreal	900
Boreal/Grassland	1350(west)-1600(east)
Arid Grassland/ Transitional Grassland	1500(west)-1900(east)
Boreal/Cool Temperate	1500
Cool Temperate/ Moderate Temperate	2250

This relationship breaks down where precipitation limitations are prevalent, as shown by the difference in degree days in the Grassland ecoprovince. Here, an ecologically meaningful moisture parameter, such as evapotransporation or drought index, would be more indicative of the anticipated moisture conditions.

In general, the boundaries of ecoclimatic provinces would shift northward and somewhat eastward under the increased CO_2 scenario (Figure 2). This means that changes in ecoclimatic conditions would favour the growth of different plant communities. Thus, conditions would be suitable for the expansion of the arctic tree line well into the District of Keewatin and nearly to the Arctic Ocean. However, it does not mean that such changes in the vegetation will in fact take place within the forecast period and that trees will actually grow in this area by 2060 A.D.

Vegetation responds relatively quickly to unfavourable conditions (death of individual plants, failure of regeneration), but it expands more slowly into newly available ecological niches. Slow seed dispersal, unsuitable soil conditions, and long reproductive cycles (especially tree species) tend to delay plant migration. Anthropogenic factors may retard (acid rain, wildfires), or speed up (planting, seeding) this process. However, if CO_2 accumulation continues at present rates, climatic change will continue at a faster pace than vegetation migration in many areas. Thus, the map shows only the projected ecoclimatic conditions at a given CO_2 level for different geographical areas. The adjustment of the vegetation to the changed conditions will take place slowly until all available sites are occupied by vegetation suited to them.

The natural adjustment of vegetation to the changed climatic conditions may be accelerated by importing seeds or plant propagules from the appropriate ecoclimatic province. Agricultural and forestry crops may expand into these areas from the south, taking advantage of the longer growing season.

Some environmental parameters would not change under the changed climatic regime. The length of daylight during various seasons would remain the same, with continuous daylight during the summer above the Arctic Circle, and an absence of daylight during the winter. The degree of incidence of sunlight would also remain the same, with the sun low over the horizon in northern areas. These may limit the northerly migration of southern ecosystems.

Arctic Ecoclimatic Province: The area of this ecoclimatic province will decrease on the mainland. The gridpoints end at 70°, and predictions could not be extended farther north. Only a slight increase in temperature and precipitation is forecast in this province, as the polar ice cap is expected to remain until the summer temperature increases by 4°C. Implications of a longer ice-free period of the Arctic Ocean should be explored.

Subarctic Ecoclimatic Province: Conditions will be favourable for the expansion of the tree line 300-400 km farther north in the east, but only a small change is forecast in the west. Conditions will exist for establishment of spruce-lichen woodlands throughout this ecoclimatic province. Boreal forest conditions will make inroads at the southern boundary.

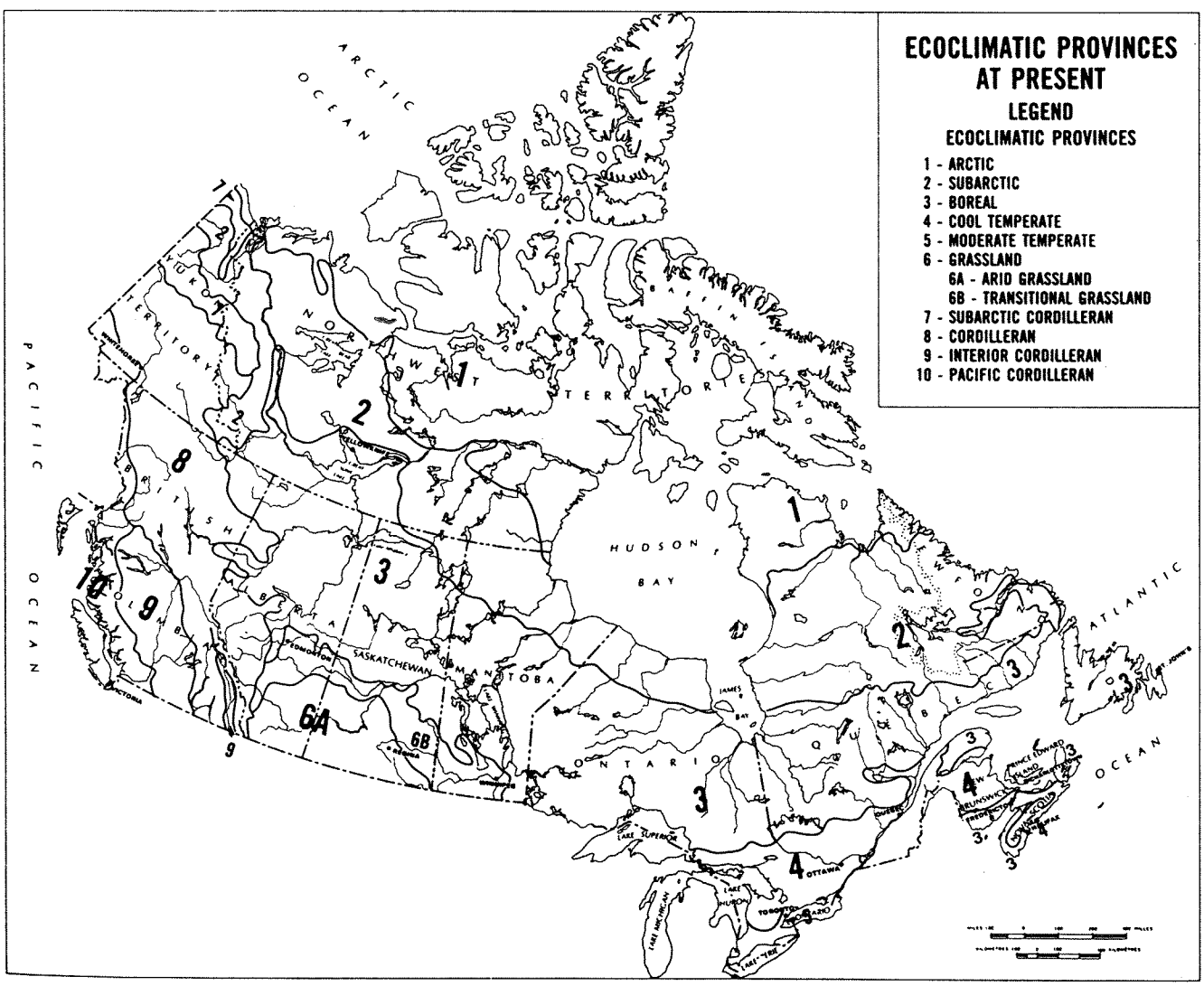
Boreal Ecoclimatic Province: Conditions favourable for coniferous boreal forests will exist some 300-450 km farther north than at the present. However, boreal forest conditions will be displaced along the southern boundary by about the same amount. Increase in sea level due to the melting of polar ice caps may flood large areas around Hudson and James bays.

Cool Temperate Ecoclimatic Province: Conditions favouring a mixture of tolerant hardwoods, white pine, and red pine will exist some 250-300 km farther north than at present. This ecoclimatic province should also expand to the east and west.

Moderate Temperate Ecoclimatic Province: Conditions suitable for the Carolinian hardwood forest, composed of maples, oaks, beech, walnut, tulip tree, etc., will exist some 150 km farther north than at present, as well as along the St. Lawrence River and in New Brunswick.

Grassland Ecoclimatic Province: For the "Transitional" portion of this ecoclimatic province, warmer temperatures with only slightly higher precipitation create conditions for a grassland-aspen parkland vegetation, expanding to the north and east; the boundaries of this portion of the ecoclimatic province would shift some 300 km to the north and east. For the "Arid" portion of this ecoclimatic province, conditions suitable for grassland will dominate, with more arid conditions in the south. This ecoclimatic province would expand some 100-150 km to the north and east, occupying previously aspen parkland regions.

Figure 1:



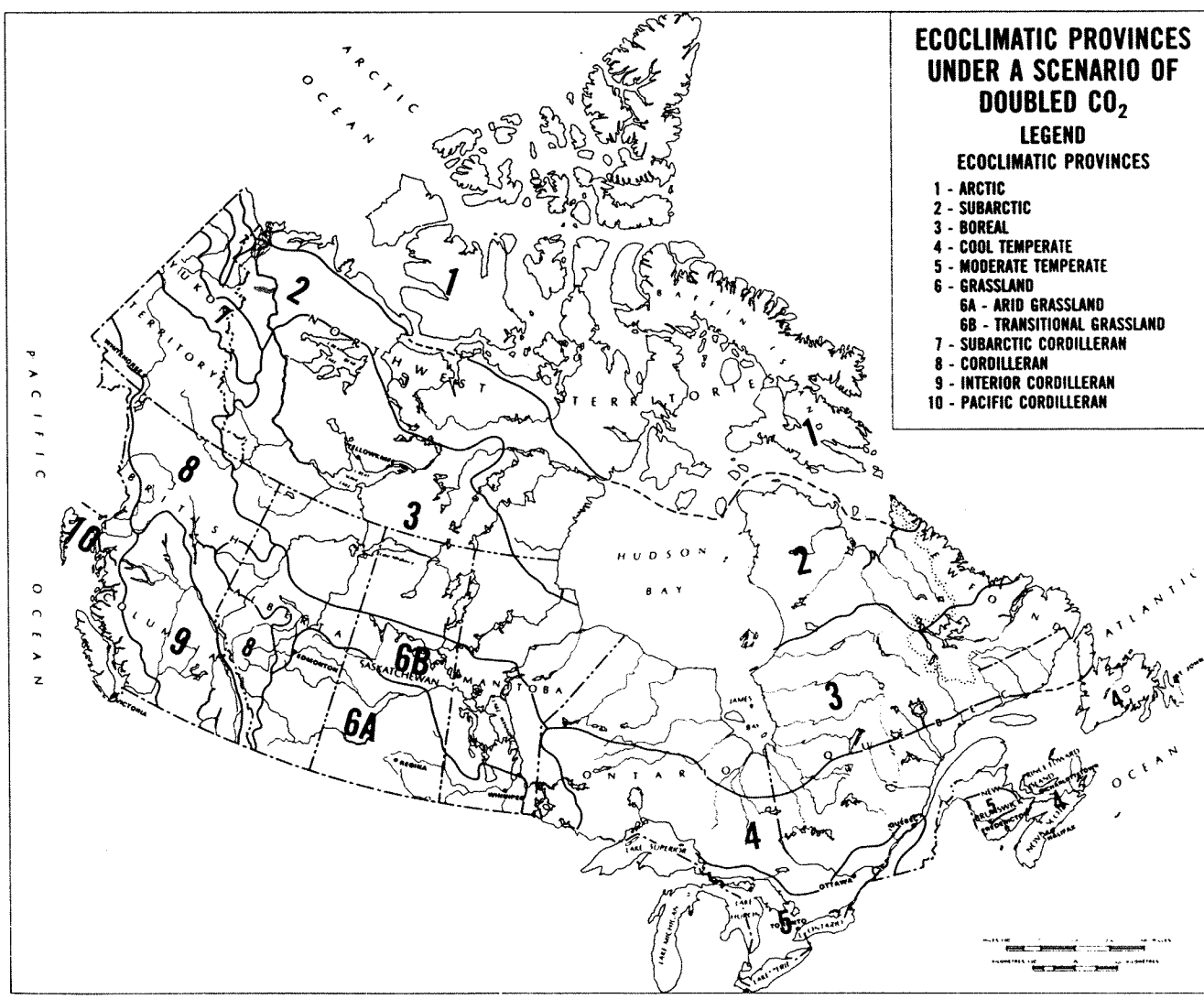
Cordilleran Ecoclimatic Provinces: Due to wide local variations in these mountainous areas, major changes are forecast only in the already arid interior. Here conditions would be drier than at present, creating conditions for grassland and scrublands, in addition to the forests at higher elevations. In the other Cordilleran ecoclimatic provinces the climate would be warmer with an altitudinal expansion of conditions that are now present at lower elevations. Although changes in dominant species may occur, no major changes are foreseen for these areas.

The induced climatic change will result in a general northward expansion of the existing ecoclimatic provinces. The various natural vegetation types will migrate and replace each other relatively slowly. Plants can be imported into the expanded parts of the ecoclimatic provinces for agricultural or forestry purposes. Given the long rotation period for forest trees, growing conditions may change significantly even during the life of a forest stand.

It is not realistic to speculate about "gains" or "losses" of particular habitats, as other conditions may not be the same. Thus, although climatic conditions suitable for agriculture will extend to the north, some of these areas may have limitations to agriculture, such as portions of the Canadian Shield, which have poor and shallow soils over bedrock, or the Hudson Bay Lowlands, which are dominated by wet organic soils.

Climatic change will bring about drastic changes in land use. The sobering fact is that the end is not in sight, as changes may continue beyond the doubling of atmospheric CO_2. We must be prepared for severe changes even within a human lifespan. This is a challenge that has to be faced until we find a way to counteract the deterioration of our atmosphere.

Figure 2:



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