PRAIRIE FORUM 34, NO. 1 (*Spring 2009*): PP. 31–44

THE DRY BELT AND CHANGING ARIDITY IN THE PALLISER TRIANGLE, 1895–2000

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Abstract

Due to its average aridity as well as historical experience with prolonged droughts, the Dry Belt has long been identified as the most vulnerable sub-region within the larger Palliser Triangle in the Great Plains of southwestern Canada. Based upon 105 years of climate data, drought maps are redrawn based upon the historical record of drought within the Dry Belt. The result demonstrates that the size of the Dry Belt expands or contracts dramatically depending on the precise period being analyzed. Given current climate change scenarios, we should not be surprised to see a major expansion in the area of the Dry Belt in future decades similar to what was experienced between 1928 and 1938.

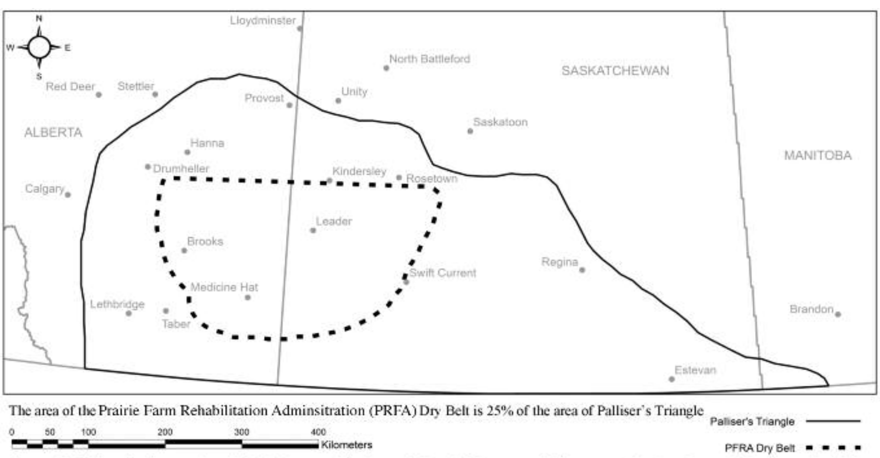
Sommaire

La zone sèche est depuis longtemps reconnue comme étant la sous-région la plus vulnérable du triangle de Palliser des Grandes Plaines du sud-ouest canadien à cause de son aridité moyenne et de son histoire de sécheresses prolongées. C'est en s'appuyant sur 105 ans de données climatiques que les cartes de sècheresse sont revues selon l'historique de sècheresse dans la zone sèche. Les résultats indiquent que l'étendue de la zone sèche augmente ou diminue de beaucoup selon la période spécifique analysée. S'appuyant sur les scénarios de changements climatiques actuels, il ne serait pas surprenant que l'étendue de la zone sèche s'accroisse de façon majeure dans les prochaines décennies par rapport aux cinquante dernières années, rappelant ce qui s'est produit entre 1928 et 1938.

Early History of the Dry Belt

The Dry Belt has long been identified as the most arid portion of the Palliser Triangle. Straddling the border of Alberta and Saskatchewan, this dry core is a prominent geographical and historical feature of the western prairies. Located in the rain shadow of the Rocky Mountains to the west and the Cypress and Sweet Grass Hills to the south, the Dry Belt receives, on average, less than 350 mm of precipitation per year, considerably below the average of the Palliser Triangle. In addition, it is subject to high moisture loss because of the warm and dry winter winds known as Chinooks, as well as summer heat waves of great intensity. Finally, the soils of the Dry Belt are light and have low water retention, thus making the area more sensitive to long periods of moisture deficiency.[1] As the epicentre of drought and depopulation before the Second World War, the Dry Belt is often portrayed as a cursed land, a destroyer of families, livelihoods and dreams, as illustrated in David Jones's classic history of the Dry Belt.[2]

The Dry Belt lies within the Palliser Triangle, itself long recognized for its aridity and limited biodiversity.[3] The Triangle is named after Captain John Palliser, the leader of the British North American Exploring Expedition of 1857–60 sponsored by the British government.[4] Palliser viewed the region as a northern extension of what he called the Great American Desert. His "triangle" is actually more of a parallelogram extending up from the current Canada-U.S. border (Figure 1). Covering more than 200,000 square km of southern Alberta and Saskatchewan (including a tiny bit of southwestern Manitoba), the Palliser Triangle encompasses what is now the single largest expanse of agricultural land in Canada.



Source: J. Palliser, *Exploration-British North America. The Journals, Detailed Reports and Observations* (London: Eyre and Spottiswoode, 1863). W. Namanishen, Drought in the Palliser Triangle: A Provisional Primer (Regina: Prairie Farm Rehabilitation Administration, Agriculture and Agri-Food Canada, 1998), 2.

Figure 1. The PFRA Dry Belt and the Palliser Triangle

Based on his observations of climate, vegetation and soil, Palliser concluded that the entire region was unsuitable for agriculture.[5] His findings were supported by Henry Youle Hind, a professor from the University of Toronto who had explored the western portion of the prairies for the United Province of Canada in 1858.[6] Hind referred to most of the Palliser Triangle as "Arid Plains," but he identified an arc of land directly to the north—"the fertile belt"—which he deemed as suitable for agriculture because it received more rainfall."[7]

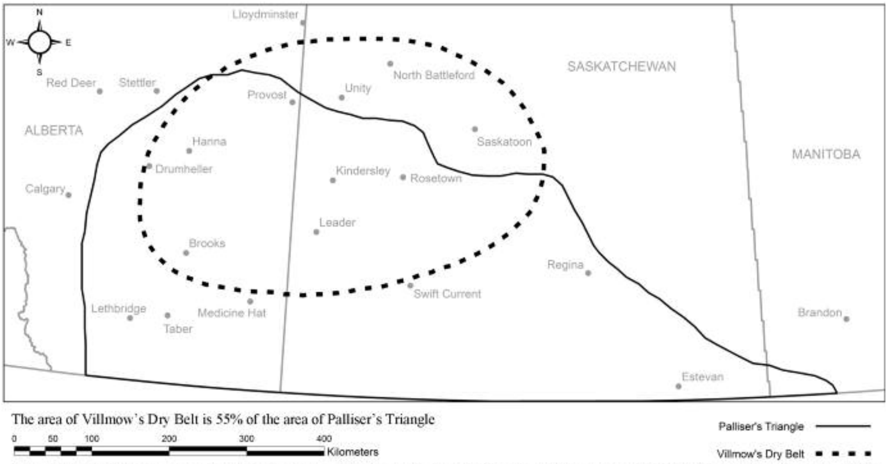
What Palliser and Hind observed, however, was not merely the average aridity of the region, but its worst climatic feature—recurring drought.[8] From the mid-1850s until the mid-1860s, the southern Canadian plains were in the grip of one of the most prolonged droughts of the 19th century.[9] Based upon expedition recordings, the drought, at least during 1859 when Palliser traveled into the heart of the Dry Belt, was most severe in the western part of the prairies.[10]

Although most of the Palliser Triangle was opened for agricultural settlement in the late 19th century, the Dry Belt was settled by ranchers rather than farmers because of its high average aridity and continuing susceptibility to prolonged drought.[11] After the abnormally cold winter of 1905–06 which killed off approximately one-half of the cattle in the region, grain farmers began to move into the Dry Belt.[12] Initially, Dry Belt wheat farmers enjoyed bumper crops. Beginning in 1917, however, grain farmers suffered a series of drought years.

Since farmers on the Alberta side of the Dry Belt suffered the most, the Alberta government was eventually forced to come to the aid of their bankrupt municipalities and help move thousands of drought-stricken farmers out of the Dry Belt, as well as administer the social and physical infrastructure of the region as a Special Area.[13] During the Dirty Thirties, the droughts expanded in size and intensity (at least in Saskatchewan) precipitating a major population exodus.[14] Although there have been severe droughts since the 1930s, in particular in 1961, 1988 and 2001–02, farmers in the Dry Belt have not suffered as prolonged (multi-year) droughts as they experienced from 1917 until the late 1930s.

Villmow's Dry Belt

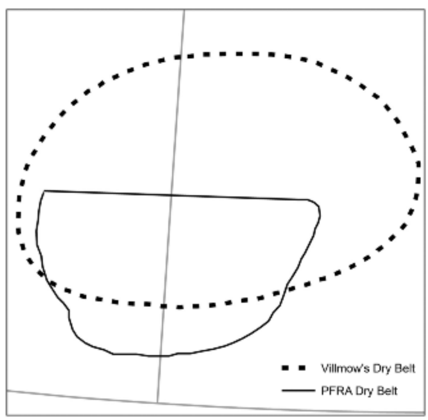
The location of the Dry Belt is not as precise as might be indicated by the Government of Canada's Prairie Farm Rehabilitation Administration (PFRA) in Figure 1.[15] The PFRA refers to the unique moisture characteristics of this region, and defines the boundaries of the Dry Belt based on a 350 mm precipitation isoline averaged over the period from 1961 to 1990. This raises the question of how, in more precise scientific terms, the Dry Belt should now be defined in light of this historical experience.



Source: J. Palliser, *Exploration-British North America. The Journals, Detailed Reports and Observations* (London: Eyre and Spottiswoode, 1863). J.R. Villmow, "The Nature and Origin of the Canadian Dry Belt," *Annals of the Association of American Geographers* 46, no. 1 (1956): 211-32.

Figure 2a. Villmow's Dry Belt and the Palliser Triangle.

In 1956, an American geographer, Jack Villmow, published an article in which he provided an apparently precise description of the Dry Belt (Figure 2a) based on the best climate data available at the time.[16] Villmow analyzed surface meteorological data in a number of ways. He collected data from different climate monitoring stations throughout the region, and mapped out climatic isolines based on 25 to 35 year averages in temperature (T) and precipitation (P) as well as seasonal variability in climate. He also classified the climate of the area following the method developed by the pioneering geographer and climatologist C. Warren Thornthwaite.[17] Of particular interest is Villmow's application of the Thornthwaite model of potential evapotranspiration (PET) to differentiate regions using isolines based on the ratio of PET to P. He found that much of the Dry Belt had a PET to P ratio less than or equal to 1.75, which corresponds to a P to PET ratio less than or equal to 0.57.[18] He was able to combine these results to describe the static boundaries of the dry belt shown in Figure 2a. The boundaries Villmow used for the Dry Belt, how-



Source: J.R. Villmow, "The Nature and Origin of the Canadian Dry Belt," *Annals of the Association of American Geographers* 46, no. 1 (1956): 211-32. W. Nemanishen, *Drought in the Palliser Triangle: A Provisional Primer* (Regina: Prairie Farm Rehabilitation Administration, Agriculture and Agri-Food Canada, 1998), 2.

Figure2b. Villmow's Dry Belt and the PFRA Dry Belt.

ever, differ greatly from those used by the PFRA (Figure 2b). The Dry Belt, as defined by Villmow, has twice the areal extent of the PFRA's version.

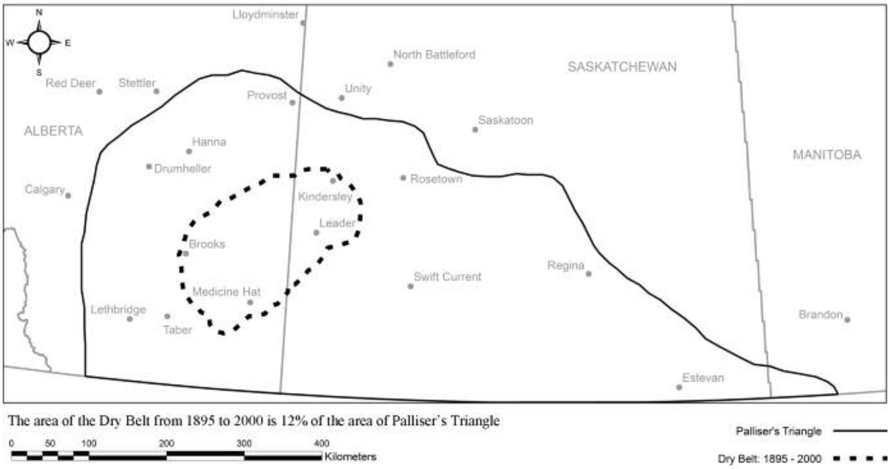
Villmow's work contributed greatly to knowledge of the Canadian Dry Belt. Villmow also acknowledged that "moisture characteristics form the primary basis for the contention that the Dry Belt is a unique and distinctive climatic region."[19] However, moisture characteristics must include both the amount of precipitation distributed both spatially and temporally as well as a measure of temperature as it relates to evapotranspiration (moisture in soil and plant life lost to the atmosphere). As noted by Villmow, both precipitation and temperature vary greatly seasonally, inter-annually and spatially in the area.[20] Since the boundaries of the Dry Belt are defined by these variables, the question addressed below is whether the boundaries vary appreciably over time and space when averaged over different periods.

New Historical Maps of the Dry Belt

As illustrated in Figures 3 to 7, the boundaries of the Dry Belt vary significantly when based on mean conditions of different time periods. Drylands throughout the globe cannot be defined by static borders, and the Dry Belt is no exception.[21] To state the obvious, it is essential to specify the precise time period when mapping the Dry Belt because the boundaries will shift over time.

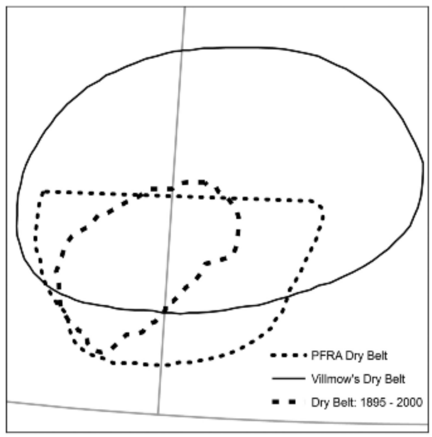
According to the United Nations Environmental Programme's (UNEP) *World Atlas of Desertification,* drylands are areas with an average annual P to PET ratio of less than 0.65.[22] This definition and the P/PET data for the Canadian prairies were used to construct the maps seen in Figures 3 to 6. This definition also corresponds well with Villmow's pioneering work, since he obtained P/PET values within this range for his Dry Belt. PET was calculated using the Thornthwaite method from a gridded climate database of monthly precipitation and temperature produced by Environment Canada.[23] Although this method is simple relative to more complex techniques developed during the past half century since Thornthwaite's work, the method has proven itself in terms of delivering accurate results. As a consequence, it has been employed in similar studies, namely the *World Atlas of Desertification.*[24] The technical aspects of this calculation are provided in Appendix 1.

The map produced by Villmow is difficult to reconstruct given the lack of precise time constraints. Villmow used 25 to 35 year averages, but this varied from station to station. Sometimes, even less than 25 to 35 year averages were used, but this is difficult to determine because Villmow did not provide the exact years that were incorporated into his averages. It almost appears as though Villmow may have assumed that time was unimportant in defining the Dry Belt.



Source: J. Palliser, *Exploration-British North America. The Journals, Detailed Reports and Observations* (London: Eyre and Spottiswoode, 1863).

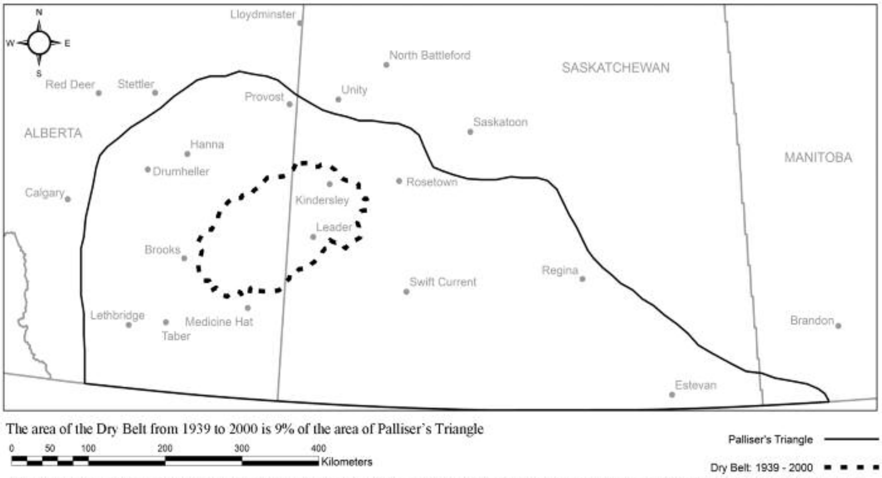
Figure 3a. The Dry Belt based on a P/PET <= 0.65 map for the period from 1895 to 2000 and the Palliser Triangle.



Source: J.R. Villmow, "The Nature and Origin of the Canadian Dry Belt," *Annals of the Association of American Geographers* 46, no. 1 (1956): 211-32. W. Nemanishen, *Drought in the Palliser Triangle: A Provisional Primer* (Regina: Prairie Farm Rehabilitation Administration, Agriculture and Agri-Food Canada, 1998), 2.

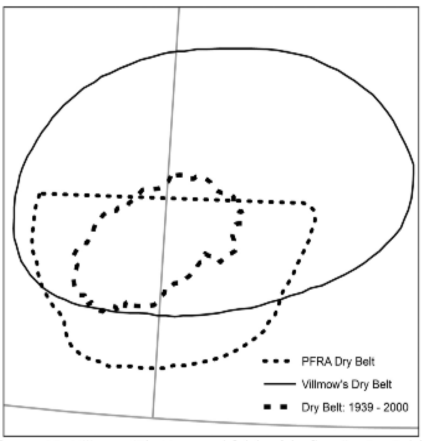
Figure 3b. Dry Belt based on a P/PET <= 0.65 map for the period from 1895 to 2000, Villmow's Dry Belt and the PFRA Dry Belt.

In his study for the PFRA, Walter Nemanishen acknowledges the significance of calculating the boundaries of the Dry Belt over specific time periods, but his exclusive use of precipitation to define the Dry Belt neglects the impact of evapotranspiration from the soil in determining the degree of aridity in the region. The use of the P/PET index accounts for this loss and provides insight into the amount of moisture available at the surface. Moreover, we were not limited to the 25 to 35 years worth of data that were available to Villmow. Our estimates are based upon historical data collected from 1895 until 2000. Different Dry Belt maps were produced corresponding to different periods of interest in the history of the area. Figure 3a illustrates the result for the full period from 1895 until 2000. Figure 3b shows this area in relation to the PFRA's Dry Belt and Villmow's Dry Belt respectively. The area with a P/PET < 0.65 is about half the size of the PFRA's Dry Belt and only about a quarter the size of Villmow's. What is noteworthy, however, is the extent to which the



Source: J. Palliser, *Exploration-British North America. The Journals, Detailed Reports and Observations* (London: Eyre and Spottiswoode, 1863).

Figure 4a. The Dry Belt based on a P/PET <= 0.65 map for the period from 1939 to 2000 and the Palliser Triangle.



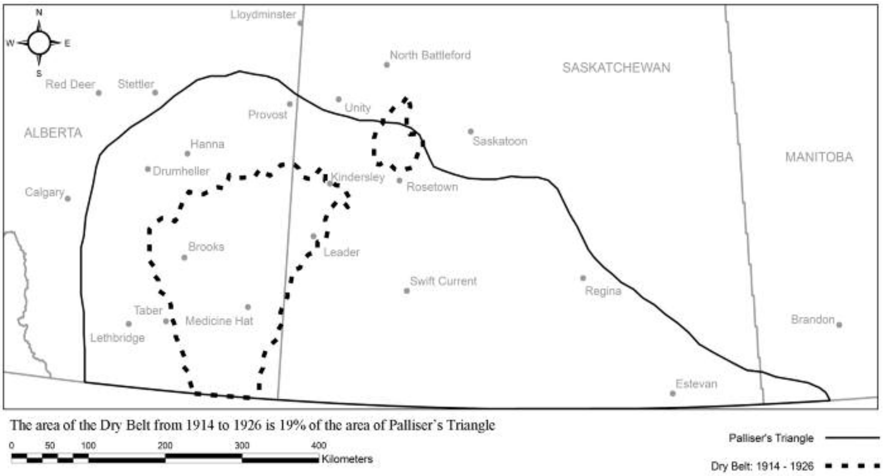
Source: J.R. Villmow, "The Nature and Origin of the Canadian Dry Belt," *Annals of the Association of American Geographers* 46, no. 1 (1956): 211-32. W. Nemanishen, *Drought in the Palliser Triangle: A Provisional Primer* (Regina: Prairie Farm Rehabilitation Administration, Agriculture and Agri-Food Canada, 1998), 2.

Figure 4b. Dry Belt based on a P/PET < = 0.65 map for the period from 1939 to 2000, Villmow's Dry Belt and the PFRA Dry Belt.

Dry Belt remains located almost entirely within the region originally identified by the PFRA and Villmow.

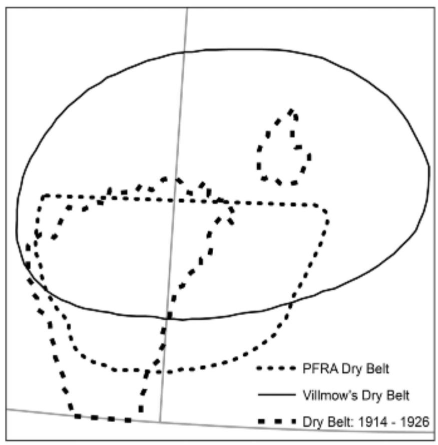
The Dry Belt for the post-Depression years from 1939 until 2000 produces a very similar result—a comparably shaped but slightly smaller region as seen in Figure 4a. Since 1939, this has remained the driest part of the Palliser Triangle, the sub-region least conducive to crop-based agriculture. Although crop farming continues in the region, it is far more restricted. Ranching has again supplanted farming as the dominant form of agriculture within the Dry Belt, particularly on the Alberta side of the border, partly due to the efforts of the Special Areas Board in facilitating the shift from grain farms to ranches or mixed farm-ranches in the 1930s.[25]

The areal extent of the Dry Belt during the post-Depression years is considerably smaller than those proposed by Villmow and the PFRA. It is less than 40% the size of the PFRA's Dry Belt and less than 20% the size of Villmow's. Figure 4b illustrates these differences.



Source: J. Palliser, *Exploration-British North America. The Journals, Detailed Reports and Observations* (London: Eyre and Spottiswoode, 1863).

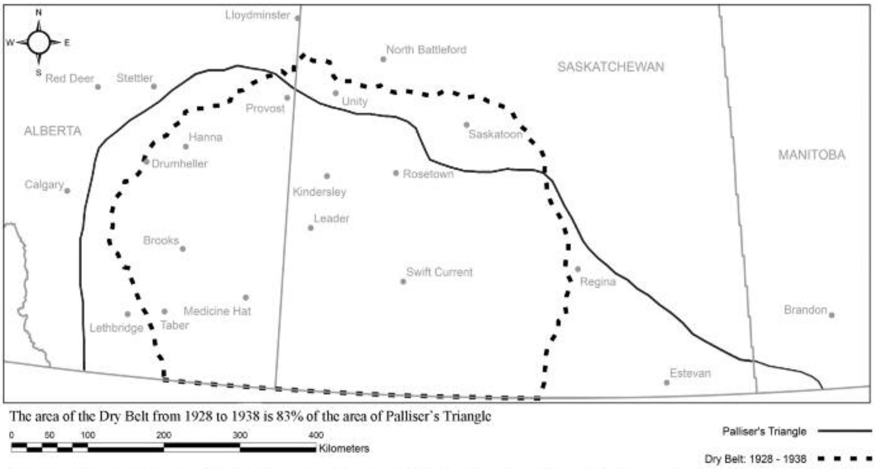
Figure 5a. The Dry Belt based on a P/PET <= 0.65 map for the period from 1914 to 1926 and the Palliser Triangle.



Source: J.R. Villmow, "The Nature and Origin of the Canadian Dry Belt," *Annals of the Association of American Geographers* 46, no. 1 (1956): 211-32. W. Nemanishen, *Drought in the Palliser Triangle: A Provisional Primer* (Regina: Prairie Farm Rehabilitation Administration, Agriculture and Agri-Food Canada, 1998), 2.

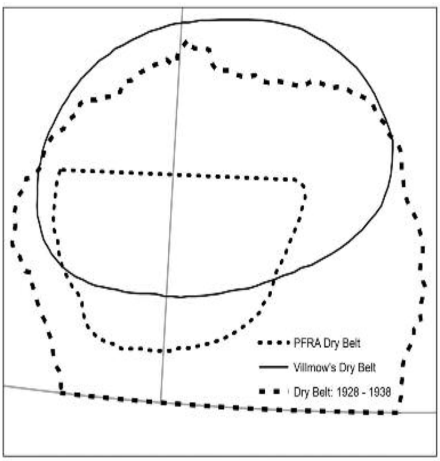
Figure 5b. Dry Belt based on a P/PET <= 0.65 map for the period from 1914 to 1926, Villmow's Dry Belt and the PFRA Dry Belt.

We should also expect the map of the Dry Belt to be quite different for the pre-Second World War era as a consequence of the prolonged droughts which devastated the farm families living in this part of the Palliser Triangle. In this case, it is worth examining the period beginning with the first recorded agricultural drought in 1914, and ending the year before the abnormally moist year of 1927. Figure 5a validates the considerable historical evidence of farmers in southwest Alberta suffering more from prolonged drought than their Saskatchewan neighbours over this time period. The Dry Belt was largely concentrated in southeastern Alberta, from south of Medicine Hat and Taber, Alberta, stopping short of Drumheller and Hanna, although it did swing northeast to include Leader and the region immediately west of Kindersley in Saskatchewan. In addition, the Dry Belt included a small patch in the central part of western Saskatchewan north of Rosetown and southeast of Unity.



Source: J. Palliser, *Exploration-British North America. The Journals, Detailed Reports and Observations* (London: Eyre and Spottiswoode, 1863).

Figure 6a. The Dry Belt based on a P/PET <= 0.65 map for the period from 1928 to 1938 and the Palliser Triangle.



Source: J.R. Villmow, "The Nature and Origin of the Canadian Dry Belt," *Annals of the Association of American Geographers* 46, no. 1 (1956): 211-32. W. Nemanishen, *Drought in the Palliser Triangle: A Provisional Primer* (Regina: Prairie Farm Rehabilitation Administration, Agriculture and Agri-Food Canada, 1998), 2.

Figure 6b. Dry Belt based on a P/PET <= 0.65 map for the period from 1928 to 1938, Villmow's Dry Belt and the PFRA Dry Belt.

The areal extent of our Dry Belt during this period begins to match that of the PFRA's Dry Belt but still is considerably smaller than Villmow's Dry Belt. Figure 5b shows our Dry Belt to be about three quarters the size of the PFRA's Dry Belt and more than a quarter the size of Villmow's Dry Belt. In other words, there are major differences in the delineations of the boundaries between the Dry Belt for this period and these other two conceptions. The concentration of the drought during this period in Alberta, as discussed above, would not be easily inferred from the PFRA and Villmow maps but our map clearly shows the intensity of the drought in Alberta compared to Saskatchewan between 1914 and 1926.

The era of the Dirty Thirties is captured in Figure 6a. We began with 1928, because this was the year that drought returned to the Dry Belt after the unusually wet year of 1927. We ended in 1938 because this is the last recorded year of extreme drought until 1961. The impact of prolonged drought can be seen in the extent of the Dry Belt extending from Saskatoon in the northeast, the U.S. border south of Regina in the southeast and south of Taber in the southwest, almost as far west as Calgary and northwest as Stettler. This huge territory constitutes well over one-half of the area encompassed by the Palliser Triangle. Our map of the Dry Belt covers an area at least three times larger than PFRA's Dry Belt and about one and a half times larger than Villmow's Dry Belt.

Mapping Historical Change in the Dry Belt and Climate Change Implications

When the P/PET calculations are averaged over the entire period—1895 to 2000—the mean position of the boundaries delineated for this period can be used as a reference to which we can compare the magnitude of the changes observed for the other periods, as illustrated in Figure 7. The Dry Belt during the pre-Second World War era was more than one and a half times larger than the Dry Belt during the full reference period. Amazingly, the Dry Belt of the Dirty Thirties is nearly seven times larger than the Dry Belt in the reference period. For the post-Depression period, the Dry Belt shrinks to a point where it is only a little more than three-quarters the size of the reference. Once again, the climate variability of the area becomes apparent through the shifting temporal boundaries of the Dry Belt.

The historical redrawing of the Dry Belt illustrates the extent to which a geographical area determined by climate is not static even within the confines of little more than 100 years of time. Although referred to in the historical literature as a relatively fixed area of geographical space, the Dry Belt has expanded and contracted over the past century. Understanding the

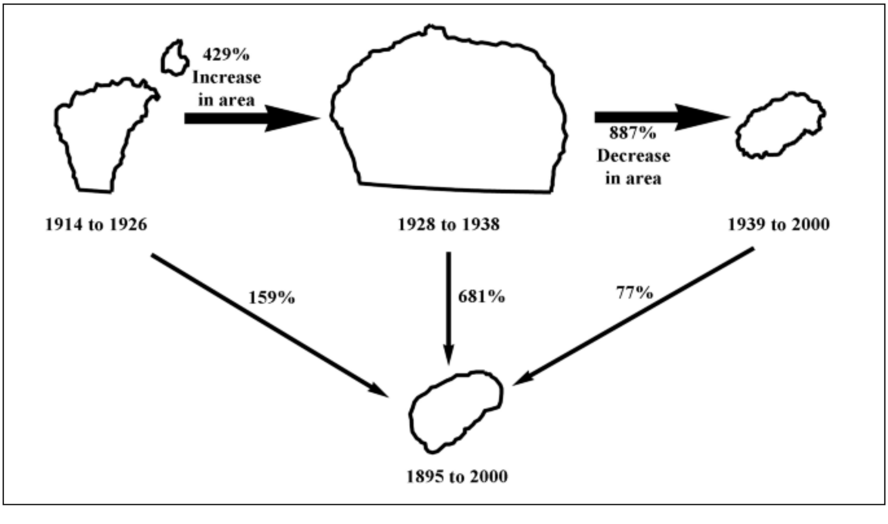


Figure 7. The areal change of the Dry Belt over three time periods relative to the reference period.

shifting nature of the Dry Belt is particularly important given the forecasts of current global climate change models in general, and climate change scenarios for the Great Plains of North America in particular.

Most global climate change scenarios predict increased drying in continental interiors and greater risk of droughts for the 21st century.[26] Based on the expert opinion of the United Nation's Intergovernmental Panel on Climate Change, there is a 66% probability of an increase in the area that could be affected by drought.[27] Using the history of the 20th century as a guide, this could mean that the size of the Dry Belt for a significant period of the 21st century could be as large as that experienced from 1928 until 1938. If this occurs, then almost all the Palliser Triangle would be unsuitable for most types of non-irrigated grain farming, and difficult for ranching without appropriate provision for stored water.

The climate history presented here reveals the Dry Belt to be the vulnerable core of the Palliser Triangle. It should not be surprising if the size of the Dry Belt increases dramatically in the 21st century as a result of climate change. Current climate change scenarios predict higher summer temperatures generating more evapotranspiration. As such, the Dry Belt must be targeted in a larger, risk-mitigation strategy to prepare for the impact of climate change in this century.

Appendix 1. Methodology for Creating the Dry Belt Maps

- The Dry Belt maps were derived from aridity index (P/PET) maps created for the region. A P/PET < 0.65 was used to delineate the boundaries of the Dry Belt. This threshold was chosen based on the UNEP's definition of drylands, which are those with an average annual P/PET < 0.65. (Source: United Nations Environment Programme (UNEP), *World Atlas of Desertification* (Edward Arnold, London, 1992))

- The Thornthwaite method of calculating PET was employed. Thornthwaite's equation is as follows:

$$\mathbf{PET = 1.6\,(10T/I)^a}$$

Where:

- o PET = monthly potential evapotranspiration (cm)
- o T = mean monthly temperature (c)
- o $I = \sum_{m=1}^{n} i_m$, where n is equal to 12 (i.e. i is summed over the 12 months of the year)

- o $i = (T/5)^{1.514}$
- o $a = 6.75*10^{-7}I^3 - 7.71*10^{-5}I^2 + 1.79*10^{-2}I + 0.49$

(Source: C.W. Thornthwaite, "An Approach toward a Rational Classification of Climate," *Geographical Review* 38, no. 1 (1948): 55–94.)

- The PET values were then corrected for latitude by multiplying them by a factor corresponding to each month of the year and different intervals of latitude. (Source: V.M. Ponce, *Engineering Hydrology* (New Jersey: Prentice-Hall, Inc., 1989.)

- Potential evapotranspiration was calculated from mean monthly temperature and precipitation values in the Canadian Gridded Climate Database. This database was interpolated to a 50-km grid from climate station data found in the Canadian Climate Archive. An inverse square distance weighting scheme was applied to obtain the values at a 50-km spatial resolution true at 600N on a polar stereographic secant projection aligned with 1110W. (Source: R. Hopkins, Canadian Gridded Climate Data, Environment Canada (2001.))

- Aridity indices (P/PET) were calculated at a monthly time scale for each grid point and then averaged over the year. Values for each period of interest were then created by averaging the aridity indices corresponding to the particular years of interest. The gridded points were then loaded into a GIS, each with their corresponding values of P/PET. Rasters were interpolated using the P/PET calculations for each original grid point and specific time period as the Z-value. This raster was further interpolated to a spatial resolution of 5 km by Kriging to smooth the boundaries between raster classes.

- The rasters were then classified with a class break at P/PET = 0.65. The resulting maps showed all values below or equal to 0.65 in one color and all values above 0.65 in a different color.

- New polyline shape files were created and loaded into the GIS. These shape files were edited to contain the spatial boundaries of the class break at P/PET = 0.65 for the different periods of interest. The boundaries of the Dry Belt at different temporal resolutions were then completed.

Endnotes

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