"Rain Follows the Plow" and Dryfarming Doctrine: The Climate Information Problem and Homestead Failure in the Upper Great Plains, 1890-1925

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ABSTRACT

In the late 19th and early 20th centuries, the North American agricultural frontier moved into semi-arid regions of the Great Plains where farming was vulnerable to drought. Farmers who migrated to the region had to adapt their crops, techniques, and farm sizes to better fit the environment. But there was very incomplete information for making these adjustments, and ultimately they were insufficient: too many small, dry-land wheat farms were founded, only to be abandoned in the midst of drought. Two episodes of homestead settlement and collapse in western Kansas in 1893-94 and in eastern Montana in 1917-21 are examined. We go beyond the existing literature by explicitly detailing the weather information problem facing settlers and showing precisely why widespread homestead failure occurred. We present a Bayesian learning model to indicate how new climate information was incrementally incorporated to revise views of agricultural prospects. Primary data are used to show the lagged response of homesteaders to new drought information and to illustrate the differential impact of drought on small farms. Dryfarming doctrine arose as a solution to the problems faced by farmers in the region. Despite its optimistic claims, it was an imperfect response to drought. Indeed, some dryfarming practices increased the likelihood of homestead failure.

"No one need be in doubt about the sharp change in climate that occurs somewhere between the 96th and 100th meridians. It can be felt on the lips and skin, observed in the characteristic plant and animal life, seen in the clarity and/or dustiness of the atmosphere, determined by measurements of rainfall and evaporation, tested by attempts at unaided agriculture. Practically every western traveler in the early years remarked the facts of aridity, though not all used the word 'desert'.." Stegner (1954, 399)

"Dame Nature of the West holds out most alluring charms, and those who woo and win her smile reap a reward beyond compare. The one thing most needed is correct and accurate information." Buffin (1909, 16)

"That dry-farming is a system of agricultural practice which requires the application of high skill and intelligence is admitted; that it is precarious is denied. The year of drought is ordinarily the year in which the man failed to do properly his share of the work." Widtsoe (1911, 412)

I. Introduction.

In the midst of the tragic drought of the 1930s that was driving farmers from the land and exposing dry soil to wind erosion and the Dust Bowl, the Roosevelt Administration established the Great Plains Committee to assess prospects for the region. The Committee was somber in its assessment (1936, 1,3, 7, 40, 42). It concluded that existing conditions "had merely accentuated a situation which had been long developing." Homestead farms were too small to be viable and correspondingly, were too intensively cultivated and too focused on wheat. The Committee recommended unprecedented measures to reduce the number of farms and farmers through resettlement programs and to increase farm size and diversification through consolidation and a shift to livestock and other crops. Past land settlement policies were castigated for encouraging excessive migration to the Great Plains.

Although the drought of the 1930s was one of the most severe and widespread of the 20th century, earlier droughts had also brought homestead "busts" to different parts of the Great Plains. Through each episode, the number of farms gradually declined and farm sizes gradually increased. These clusters of farm failures were unusual in the American agricultural frontier experience, and the obvious question is why small dry-land homesteads were located on the Great Plains in the first place.[1]

In this paper, we examine the weather information problem confronting initial homesteaders. We argue that the lack of accurate information led the Great Plains to be settled too densely in farms that were later found to be too small, undercapitalized and insufficiently diversified to be sustainable. The subsequent waves of homestead busts that swept the region during severe droughts were part of the adjustment toward agricultural techniques, crops, and farm sizes more appropriate for a semi-arid region.

The problems of agriculture on the Great Plains have been examined previously by economic historians, especially with regard to the Canadian prairies. Norrie (1975, 1977, 1980), Lewis (1981), Borins (1982), and Ward (1994) analyze the timing of the Canadian wheat boom between 1880 and 1914 and describe how climate and technology affected early prairie farming. The importance of summer fallow and rapid-growing wheat varieties for extending the range of settlement is discussed. Homesteading on the Great Plains in the early twentieth century also has been examined by historians, such as Gates (1977) for the U.S. and Jones (1986, 1987) for Canada. Farm failure in western Kansas and in eastern Montana is addressed by the U.S. Department of Agriculture (1938), Howard (1959, 189-6), Fite (1966), and White (1991, 142-53). Finally, the broader issue of adaptation to semi-arid conditions is the central theme of the major historical work on the Great Plains by Webb (1931), Hargreaves (1957), and Malin (1944,1947).

Our contribution is to describe more precisely the weather information problem facing all parties in the settlement of the Great Plains--homesteaders, investigators for the U.S. Department of Agriculture and state agricultural experiment stations, local and state government officials, land developers, and railroad officers. We analyze primary data to determine the knowledge that existed regarding rainfall patterns and appropriate agricultural methods. We argue that during homestead settlement there was neither an analytical framework nor sufficient data for predicting fluctuations in precipitation or for interpreting their agricultural consequences. Knowledge of the climate was primitive and the underlying mechanisms triggering droughts were not understood. We present a Bayesian learning model to show how new climate information was incrementally incorporated to modify views of the region and its opportunities for successful agriculture.[2] The resulting adaption process was not smooth or easy. Primary data are used to show the lagged response of homesteaders new drought information and to illustrate the differential impact of drought on small farms. The Great Plains could be either wet and lush or dry and barren, with no particular pattern. These conditions presented unusual learning and adaptation challenges for all parties on the frontier in ways not fully appreciated in the existing literature.

For example, consider assessments of two climate theories that were popular during different stages of migration to the Great Plans: “Rain follows the plow” and dryfarming doctrine. These theories were faulted as implausible, but if they are placed into the context of the limited climate and agricultural information at hand, they are understandable as responses to observed conditions.

On the earlier Kansas frontier, homesteaders relied upon predictions of climate change and increased rainfall due to cultivation. Webb (1931, 375-82) labeled the notion that precipitation would rise with settlement as a “false hypothesis” that grew out of the intense desire of farmers for more rain. But rainfall initially was high as agriculture moved into the region, and observers lacked any compelling reason to deny its possible link to settlement. On the later Montana frontier, settlers were reassured by dryfarming doctrine that proper cultivation could save sufficient moisture to endure dry periods. Throughout her study, Hargreaves criticizes the dryfarming movement for making excessive claims: "that it had been promoted by a highly organized propaganda is the most obvious conclusion; that it has been an effort largely without guidance in the public interest becomes equally apparent"(1957, 23).[3] As we show, however, dryfarming doctrine was tested during periods of (*ex post*) abnormal rainfall, and it too seemed a remedy for the semi-arid conditions of region.

Both theories emerged at a time when the practical science of cultivation seemed to offer the means for bending nature to meet human needs. The drought of 1917-21 in Montana finally dashed these notions. We examine changes in dryfarming doctrine and assess which tenets held up and which ones had to be significantly modified or jettisoned. We also show that the recommended 160 to 320-acre homesteads were the farms most likely to fail during drought.

II. Homesteading on the Great Plains and the Information Problem Facing Settlers Regarding the Weather.

Between 1863 and 1880, the northern U.S. agricultural frontier moved across the Midwest from Ohio, Indiana, and Illinois through Iowa, Wisconsin and Minnesota to the eastern parts of Kansas, Nebraska, and the Dakotas.[4] In following the frontier, migrants encountered similar climatic and growing conditions. This situation allowed settlers to use familiar cultivation techniques, crops, and farm sizes as in their places of origin.[5] By 1880, however, much of the remaining government land for claiming was in the Great Plains. Between 1880 and 1925, 1,078,123 original homestead entries were filed to 202,298,425 acres in western Kansas, Nebraska, and the Dakotas and eastern Colorado and Montana, 45 percent of all homestead filings and 48 percent of all government land claimed during the period.[6]

Figure 1

When migrants crossed the 100th meridian into this region (Figure 1), they encountered climatic conditions that were quite different from what they had experienced in the East or in Europe. It was dry. Early explorers had labeled it the Great American Desert.[7]

Figure 2 illustrates climatic conditions facing settlers. It shows mean precipitation levels for three Midwestern states that were origins for many homesteaders–Minnesota, Illinois, and Ohio, as well as for western Kansas, and eastern Montana, from 1895 through 1947, a period for which we have comparable regional data.[8] The figure shows the rainfall disparities that confronted homesteaders at their frontier destination. Notice that precipitation was always higher in the Midwest, and even when it fell, it remained above that found in western Kansas and eastern Montana. In the Midwest, during a dry period, rainfall generally was sufficient for crops at lower yields. But in western Kansas and eastern Montana agriculture was always on the margin. When rainfall was at or above the mean, yields would be plentiful, but when rainfall was below the mean, yields and agricultural income would fall.

Figure 2

Table 1 reports the mean precipitation levels for the three regions, the coefficient of variation, and the correlation coefficients between the regions. Not only did western Kansas and eastern Montana have lower average precipitation than in the Midwest, but the coefficient of variation measures show that rainfall was more variable, making weather prediction more difficult in those states. Further, the correlation coefficients indicate that the weather experience a farmer might have had in Ohio provided little useful information for predicting rainfall patterns in either frontier area.

Table 1

Our definition of a severe drought is rainfall one standard deviation below the mean. An annual rainfall distribution calculated for the state of Montana over a 88-year period, 1895 to 1982, reveals that severe droughts, with precipitation of 13 inches or less, occurred 16 percent of the time. Precipitation above the mean, with precipitation between 16 and 22 inches, was found during 40 percent of the period. Annual rainfall of 20 inches or less was the threshold used by Webb (1931, 17) to define the Great Plains. A similar distribution calculated for the Midwest, however, shows that even during severe droughts, annual rainfall never fell below 25 inches. In the Great Plains, then, low mean precipitation, coupled with high variability, presented a new threat for agriculture, and drought was to take a toll.[9]

The weather information problem facing migrants was especially acute because of the climatic conditions on the Great Plains, the lack of systematic data to describe them, and the absence of an analytical model for interpreting available information. The Great Plains are a climatic transition zone where most North American droughts occur.[10] During periods of high precipitation, the area takes on the characteristics of the East and is attractive for the kinds of agriculture that take place there.[11] When droughts occur, however, those farming practices are placed at risk since rainfall levels are far too low to sustain crops that require more moisture.

Drought is a meteorological phenomenon, an extended period of below normal levels of precipitation. It is due to an aberration in atmospheric circulation, but the precise triggering mechanisms even today are not well identified or very accurately predicted.[12] In the late 19th and early 20th centuries studying droughts was made more difficult because of very limited access to the mid and upper atmosphere, which housed the jet stream and other key meteorological forces affecting precipitation. Further, there was no established framework for analyzing the data that were collected.[13] The Weather Bureau's Bulletin D, issued in 1897 outlined the primitive state of knowledge about precipitation and admitted that there were few observed patterns regarding droughts (U.S. Department of Agriculture, Weather Bureau,1897, 18, 24). Only sparse rainfall data for the Great Plains were available for analysis by prospective homesteaders. Although the Weather Bureau collected some precipitation data for the region, the data generally were intermittent and incomplete for most of the 19th century.[14] Precipitation and temperature records often were collected at military posts, but the stations were widely scattered and temporary. Many areas had no precipitation records until the 20th century.

Until the Great Plains were settled, droughts were not of overriding concern to migrants. In the Midwest dry months could reduce yields and agricultural income in affected areas, but they usually did not mean complete crop failures. Temperatures were followed more closely because frosts were important in determining growing seasons. The Army Signal Corp only began to systematically collect temperature and precipitation data from weather stations and voluntary reporters in 1870 with creation of the U.S. Weather Bureau.[15] A Division of Agricultural Meteorology to analyze weather patterns was not established until1916.[16]

With a very imperfect understanding of the region's climate, "folk" theories emerged regarding the weather of the Great Plains. "Rain follows the plow" was the most influential early model for explaining the weather of the region (Smith, 1947, 169-93; Malin, 1953, 211). The theory argued that rainfall was endogenous to human activity. The frequent movement of transcontinental trains was thought to change the flow of moisture, increasing precipitation in the plains. Planting trees also was hypothesized to make the air more humid with the release of oxygen and water vapor and hence, more likely to support rainfall. But the most critical factor was cultivation, whereby the hard prairie soil which previously caused water to run off, was broken down to become more absorptive and a subsequent source of moisture for evaporation and following the cycle, for rainfall.

After the Kansas drought of 1893-94, the idea that cultivation would permanently affect precipitation began to be dismissed. Some Weather Bureau officials concluded that the climate did not change perceptively due to human activity. Irrigation proponent, F. Newell (1896, 172) argued that "farmers have deluded themselves with the belief that with the breaking the soil...and bringing civilization, the climate was becoming more favorable to their operations." E.C. Chilcott, Chief of the Office of Dry Land Agriculture in the Department of Agriculture and others in the USDA rejected the argument that the climate was changing (Chilcott, 1908, 451; Sullivan, 1909, 289-90). There was, however, no alternative explanation for precipitation fluctuations, such as the relatively high levels of rainfall enjoyed in western Kansas in the early 1880s and in eastern Montana between 1906 and 1916. Even as late as the1930s, a leading researcher of climate in the region, Warren Thornthwaite (1936, 219), concluded that there was no simple rainfall pattern that lent itself for effective drought predictions on the Great Plains.[17]

III. The Kansas Homestead Bust: the First Major Homestead Failure on the High Plains.

Homestead failure in Kansas illustrates how severe drought modified initial views of farming prospects on the central Great Plains. Eastern Kansas, Nebraska, and the Dakotas were settled beginning in the late 1850s and early 1860s, largely by emigrants from Ohio, Indiana, and Illinois. Rainfall and soil conditions were relatively similar to what they had experienced before and the settlers "felt at home"(Fite, 1966, 13). Farmers used the same farming techniques and grew crops of corn and small grains. The agricultural frontier continued to move westward across Kansas through the early 1890s. A major drought, however, led to an exodus of homesteaders as their crops and farms failed. This was the first major homestead "bust" on the Great Plains.[18]

Figure 3 presents rainfall data for western Kansas, beginning in 1883. Mean precipitation for the region was 24 inches, and although 1890 was a dry year, with 17 inches, 1891 and 1892 were wet with 35 and 23 inches, respectively. But 1893 and 1894 were very dry, with rainfall at 19.6 and 15.9 inches, and these were the years that brought about farm failure. As yields collapsed, farm families migrated from the region. The population of the 24 counties of Kansas that lie west of the 100th meridian fell from 68,328 in 1890 to 50,118 in 1900, a decline of 27 percent and the number of farms declined from 14,311 in 1890 to 8,952 in 1900, a drop of 37 percent. By contrast, eastern Kansas did not experience a drought and between 1890 and 1900, and the number of farms and population grew by 10 percent and 19 percent, respectively.[19]

Figure 3

By the end of the drought and the associated revision of expectations, western Kansas was less attractive to new homesteaders. There were 2,385 original homestead entries in 1892, the year before the drought, and even more, 3,083, in 1893, the first year of the drought. But then they fell to 907 in1894 and averaged only 471 new entries annually through the end of the century.[20] The drought also brought agricultural adjustment in western Kansas through farm consolidation and diversification with combined livestock and grain production. Between 1890 and 1900 average farm size in the region doubled from 221 acres to 468 acres and rose to 504 acres by 1920. Larger farms were better able to withstand drought. By contrast, farm consolidation in eastern Kansas where rainfall was higher was much more modest. Average farm size in eastern Kansas was 169 acres in 1890, 186 acres in 1900, and 197 acres in 1920, only a 17 percent increase between 1890 and 1920.[21]

The homestead failure of western Kansas and Nebraska following the drought of 1893-94, however, did not deter subsequent migrants from settling on small farms in other parts of the semi-arid Great Plains, especially in eastern Montana and the western Dakotas between 1905 and 1920. The Kansas experience does not appear to have loomed large in the information set used by settlers. Most homesteaders in eastern Montana did not have direct prior experience with the drought, and there was little means of systematically communicating weather information from other regions to prospective settlers on the upper Great Plains. Although the USDA published bulletins on farming in the Great Plains, it does not appear to have actively disseminated the publications to migrants, nor did it or any other agency strongly warn of droughts.[22] Indeed, most organizations were stressing a different factor, dryfarming doctrine, that promised to limit the impact of any future drought on agricultural prospects in the region.[23]

IV. Dryfarming Doctrine or "Scientific Soil Culture" as a Progressive Era Solution to Drought: 1900-1916.

Dryfarming doctrine, or scientific soil culture, gained prominence after 1906. The most influential communicator of dryfarming doctrine was Hardy Webster Campbell who published a series of monographs (1902, 1907, 1914, 1916). Other major dryfarming proponents had credible academic credentials and agricultural experience, such as John Widtsoe, President of the Utah Agricultural College and formerly head of the Utah Experiment Station and B.C. Buffin, Professor of Agriculture at the Universities of Wyoming and Colorado Agricultural College and Director of the Wyoming Agricultural Experiment Station.[24] Their recommendations to farmers were presented in a scientific manner, with discussion of the experimental techniques used, designation of control plots, use of precise measurement in data collection, and accompanied with practical testimonials.[25] Their prescriptions for arid regions were repeated in agricultural experiment station bulletins and circulars, state and local government publications, proceedings of Dry Farming Congresses, and railroad immigration pamphlets. Further, dry farming doctrine was examined in USDA bulletins, and an Office of Dry Land Agriculture was created in 1905. Dryfarming doctrine offered a remedy for drought. With proper cultivation, soil moisture could be saved and yields could be smoothed. Dryfarming doctrine made failure a choice variable.[26] Farmers who followed its precepts could expect to succeed during periods of short rainfall, whereas those who did not could expect to fail.

Dryfarming doctrine reflected the Progressive Era's belief in the practical use of science to advance human welfare: "dry-farming was moving onward to conquer the waste places of the earth."[27] Since its techniques were so labor intensive, but promised such high yields, dryfarming also encouraged formation of small family farms.[28] This was important because the emergence of dryfarming principles coincided with political conflict over the size of homesteads to be allowed on federal lands. In 1878, John Wesley Powell had proposed allocations of 2,560 acres in semi-arid regions. Such large allocations were controversial because they threatened to reduce the total number of settlers who could obtain land on the frontier.[29] Those who promoted Campbell's dryfarming techniques strongly supported the maintenance of the small-farm homestead. Dryfarming's promises may have influenced the political debate because only minimal adjustments were made to federal land laws in 1909 and 1912 to allow for 320 rather than 160 acres and to reduce the residency requirement from 5 to 3 years. The question subsequently encountered was whether such small farms of 160 or 320 acres could be viable during serious drought.

The key element of dryfarming doctrine was the use of the soil to store water, sometimes four to ten feet under ground. The stored water was hypothesized to percolate upward via capillary action toward the surface to nourish plant roots (Campbell, 1902, 6). Water was to be captured through persistent cultivation, deep fall and spring plowing to capture moisture, surface mulching with a harrow after every rain to create a 2 ½ to 3 inch mulch to retard evaporation, subsurface soil packing to promote percolation, and summer fallow and tillage on alternating years to build up moisture and nutrients.[30] The subsurface packer and other specialized implements were recommended by dryfarming advocates.[31] Too much evaporation, rather than too little rainfall was asserted to be the critical problem in semi-arid regions (Campbell, 1902, 42). Close attention to the principles promised mastery over the vagaries of nature: "the farmer will always have a crop: in the wet years his crop will be large; in the driest year it will be sufficient to sustain him" (Widtsoe, 1911, 402).

Dryfarming experiments were conducted at a time when there were no serious droughts, and its claims were not really put to test until1917. Lacking the perspective of long-term precipitation and farming data, its advocates, however, did not appreciate how dependent their conclusions were on the unusual rainfall of the period.

Dryfarming's possibilities were so attractive that it was emphasized by virtually every organization supplying information to homesteaders on the Great Plains after the turn of the century. Dryfarming doctrine molded how settlers formed expectations for agricultural success on the Great Plains and how they interpreted new evidence regarding changes in rainfall.

A chief source of information was the agricultural experiment station. The Montana Agricultural Experiment Station organized Farmers' Institutes to bring together farmers and experiment station personnel. The Farmers' Institute assured prospective homesteaders that even in eastern Montana where annual rainfall was about 13 inches, irrigation was "not necessary" in many places and that good crops could be grown even during dry periods by adhering to dryfarming doctrine (Montana Farmers' Institutes (1903, 201-3). Besides Farmers' Institutes, demonstration farms were set up to showcase new crops, equipment, and cultivation practices, and by1910,13 dry farm substations had been set up to conduct dryfarming tests in eastern Montana.[32]

Publications of the Experiment Stations in Montana, North and South Dakota, Nebraska, Wyoming, and Colorado provided specific information to settlers about precipitation levels in various areas, crop types to plant, new varieties under consideration, cultivation and tillage techniques, the best timing for cultivation and planting in each region, results of crop rotation experiments, expected yields and costs, returns from use of summer fallow, and necessary farm equipment.[33] The publications were optimistic in their prescriptions for the success of small dry-land homesteads, and they often repeated or closely followed the principles advocated by Campbell, Widtsoe, Buffin, and others.[34] In this literature, rainfall levels were of secondary importance because of the emphasis on moisture conservation through the use of dryfarming doctrine.

The U.S. Department of Agriculture also disseminated dryfarming information, but was more hesitant than were the experiment stations in drawing strong conclusions about its success throughout the Great Plains.[35] Department personnel argued that regional differences had to be considered before making broad recommendations, and they criticized Hardy Webster Campbell's assertion that dryfarming techniques could be applied everywhere to improve yields. Indeed, E.C. Chilcott, head of the Office of Dry Land Agriculture was Campbell's chief critic (Chilcott, 1908, 1910, 1912).[36] Even so, the Department did not strongly counter the assertions of dryfarming doctrine, and other USDA publications described the results of dry farm experiments and recommended cultivation to enhance water storage in a manner consistent with Campbell's arguments.[37]

Another source of information were Dry Farming Congresses. At least ten Dry Farming Congresses were held between1907 and 1916 in cities throughout the Great Plains "to discuss and compare methods by which the great area of arid land can be profitably utilized under thorough tillage by which the natural rainfall can be conserved"(Dry Farming Congress, Board of Control, 1909, 3-4).[38] The meetings were popular. 500 delegates attended the third Congress in Cheyenne, February 23-25, 1909, and in 1912, the Dry Farming Congress was alleged to have 15,000 members.[39] The assemblies were addressed by experiment station personnel, leading dryfarming proponents like Hardy Webster Campbell, and local politicians, such as the Governors of Colorado, Wyoming, and Montana.

Prospective homesteaders on the upper Great Plains also received publications on farming prospects from state agencies, such as the Montana Bureau of Agriculture, Labor and Industry (1900-1912), later the Department of Agriculture and Publicity (1914-1924) and from local communities, land developers, and professional homestead locators. These parties were confident of the future of agriculture in the region. They described the benefits of dryfarming and provided other practical information on precipitation, county population, land values, and spur railroad lines.

The railroads were yet another source of weather and agricultural information for migrants. They have been criticized form misleading settlers with extravagant claims about homestead prospects (Hargreaves, 1957, 224; Howard, 1959, 167-82; Toole, 1959, 233-5). It is not accurate, however, to describe the railroads' promotion of homesteading as mere propaganda. Railroads could not have been indifferent to the outcome of migration. Agricultural development was necessary to promote the settlement and economic growth of the region. Its failure would reduce the attractiveness of the area to migrants and hence, the value of railroad investment. Trains, and particularly, tracks and yards were site-specific capital investments with few alternative uses. The railroads had a stake in the permanent, not temporary, success of the region, and they had no better information about the weather or farming opportunities than did the experiment stations or USDA. Dryfarming doctrine offered a solution to the problem of settling their lands, and they invested in experiments, demonstration farms and trains, and publicized its advantages.[40] "Big business" too could make faulty decisions.

Following the experience of the drought of 1917-21, however, dryfarming doctrine was significantly modified by all parties. We have reviewed publications of the experiment stations, the USDA, the railroads, and the Montana state government to assess which concepts were dropped or changed based on new drought information.

Dryfarming doctrine's emphasis on moisture conservation was retained, but the strong conclusions that it would maintain yields even under the driest conditions were eliminated. Dryfarming no longer was viewed as a panacea, but rather as a means of improving yields during periods of reasonable rainfall (McKee, 1922, 37; Wilson, 1923, 73). Many older arguments were dismissed altogether. Deep water storage and capillary action were found to have no empirical basis. Deep plowing and soil packing, once emphasized, were not recommended. Instead, more limited cultivation was advised to avoid wind erosion and excessive evaporation (McKee, 1922, 3; Wilson, 1923, 41-48; 74-81). Summer fallow, strip cropping, and inter-tillage of crops became the primary methods for conserving soil moisture and raising yields (Seamans, 1921, 4-6; Wilson, 1923, 25, 36, 41-8, 67-9, 81). Previously favored, small homesteads were not advocated, except for irrigated farms. Where possible, irrigation was suggested as a means of protecting yields and supporting crops like alfalfa (Montana Department of Agriculture and Publicity, 1919, 35; 1920, 20, 35; Chicago, Burlington & Quincy, Northern Pacific, and Great Northern Railroads, 1924, 51; Morgan and Seamans, 1920, 18). Irrigation's reach in this dry area of few streams, however, was recognized as limited. Farmers were urged to diversify to other crops beyond wheat and to livestock. Melons and potatoes were no longer touted as suited for the region, and drought-resistant wheat varieties, like Kubanka and Marquis spring wheat and Kharkov winter wheat were given more attention (Morgan and Seamans, 1920, 9, 13; Seamans, 1921, 21; Wilson, 1923, 41-48; Chicago, Burlington & Quincy, Northern Pacific, and Great Northern Railroads, 1924, 31). These were major adjustments in prescriptions for successful agriculture in a semi-arid region, and they had important implications for farming in the upper Great Plains. Before examining those effects, we turn to the record of initial homestead settlement.

V. Homestead Settlement and Drought on the Upper Great Plains, 1900-1925.

The homestead boom in the northern Great Plains began gradually after 1900 with the major increase in settlement occurring in 1910 and thereafter through 1921. Figure 4 describes original homestead entries in Montana per 100,000 acres of available federal land during the period 1903 through 1930.[41] Original homestead entries that had averaged 3,495 between 1900 and 1909, jumped to 21,982 in 1910 and remained well above the pre-1910 average through 1921. After that, homesteading declined considerably so that in 1925 there were only 1,180 new homestead entries. All told, between 1900 and 1921 some 197,388 original homestead claims were filed.[42] As a result the rural population of Montana grew from 158,775 in 1900 to 376,878 people in 1920, with the eastern counties growing from 83,762 in 1900 to 250,330 in 1920.[43]

Figure 4

The timing of the homestead boom was due to federal land law changes in 1909 and 1912 that doubled the homestead allotment and reduced the waiting period for receiving title, the gradual extension of railroad lines, rising wheat prices, and the extravagant yields possible on the upper Great Plains. Wheat prices rose moderately from 1900 to 1914 and then doubled from their 1914 level by 1917. Wheat acreage expanded from 72,555 acres in 1900 to 3,621,000 acres in 1919 (Montana Department of Agriculture, Labor, and Industry, 1928, 125). Between 1900 and 1915 Montana wheat yields averaged 25.5 bushels per acre, well above the average of 15 bushels per acre possible in the Midwestern states of Ohio, Illinois, and Kansas.[44]Yields were high because soils had accumulated nutrients that had not been leached away by precipitation in the dry climate. Further, the period 1906 through 1916 was one of unusually abundant rainfall as shown in Figure 5. The figure describes rainfall from 1895 through 1925 in eastern Montana where most homesteads were located. Except for one-year droughts in years 1904 and 1910, most of the period through 1916 is one of precipitation well above the mean.[45]

Figure 5

We have been unable to locate farm-level data during the peak settlement period, 1906-1916, to analyze what a homesteader might have expected to earn from migrating to the region prior to the drought. We have, however, found a sample of farms surveyed in 1921-2 by the Montana Agricultural Experiment Station. The survey collected data on farm size, crop acres, production, sales, and expenses for 27 homesteads of 320 acres or less and 97 farms larger than 320 acres in the eastern Montana counties of Hill, Toole, Pondera, Cascade, Carter, Teton, Liberty, and Chouteau.[46] We use these survey data to approximate what the average homestead farm would have earned from wheat production in 1916, the year before the drought.

Using mean farm size and mean wheat acres from the survey, the1916 Montana average wheat yield of 19.3 bushels per acre and wheat prices of $1.43, and converting1921 mean current and total expense estimates from the survey to1916 values, we estimated gross and net wheat income for the average homestead. The exercise is shown in Table 2.

As indicated, the mean gross wheat income for a homestead was $2,650; wheat income net of current expenses was $2,365; and net of total expenses was $2,225.[47] Although these are only suggestive figures, they compare very favorably with average U.S. per farm gross income of $2,104 in 1920 or mean total farm receipts for the western U.S. of $2,322 in 1922.[48] The sample data indicate why homesteading in the upper Great Plains was such an attractive prospect in the early part of the twentieth century, given the very high wheat yields that were possible from untapped soil.

Table 2

To further examine the motivating factors for homesteading we estimated two equations for the period 1895 to 1925 for Montana:

(1) $\text{Yields}_t = c_1 + c_2 \text{ Land Quality}_t + c_3 \text{ Rain}_{t,\ t-1} + e$,

where land quality is represented by available surveyed federal land. Of the total federal land available for claiming, there were surveyed and unsurveyed lands. Absent a time-series measure of soil quality, we assume that General Land Office surveyors would have surveyed the best or most productive lands first because those would have been most desirable to homesteaders.[49] As homesteaders claimed the best lands, the supply of available high quality surveyed land declined. We included current and previous year's rainfall to test for their effects on yields.

(2) Original $\text{Homesteads}_t = b_1 + b_2\text{Available Surveyed Federal Land}_t + b_3\ \text{WheatYields}_{t,\ t-1} + b_4\text{Wheat Price}_{t,t-1} + b_5\text{Federal Law Change} + e$,

where a dummy for changes in federal land laws to reduce the costs of acquiring land is entered beginning in 1909.

Table 3

Table 3 provides the results of the OLS estimation. Wheat yields were strongly influenced by land quality as proxied and current rainfall. The previous year's rain had a positive, but statistically insignificant impact on yields. These findings underscore the importance of current precipitation on plant growth in a semi-arid region.[50]

For annual original homesteads filed, changes in federal land law that reduced the occupancy requirement and doubled the amount of land that could be claimed to 320 acres and lagged wheat yields, reflecting information on expected returns from wheat farming have the expected positive signs and are significant at approximately the 5 percent level. Surveyed federal lands available for homesteading and real wheat prices, both current and previous year's, also encouraged new entries although at lower levels of significance.[51] Migrants, then, were attracted to the region by the availability of government land, which after 1909 could be claimed more easily, by knowledge of previous high wheat yields, and the price of wheat.

VI. Limited Climate Information, Dryfarming Doctrine and Learning: Drought and Homestead Failure.

Because settlers were moving into a very different region from what they had experienced, they would not know the "true" conditions for agricultural prospects at the time of the migration or farming decision. When making their decisions, they would have to decide how to weigh observed conditions, relative to their prior beliefs about the area. A Bayesian decision process would involve updating prior assessments whenever new information about precipitation, yields, and prices appeared, leading homesteaders to form new posterior judgements about the true state of agricultural opportunities in the upper Great Plains. Hence, settlers would begin with limited information about farming opportunities obtained from previous homesteaders or publications from railroads, state and local governments or other sources. After migration, they would annually update their prior opinions based on their actual experiences, leading to a more complete judgement about farming opportunities.

This Bayesian process has been described as adaptive learning (Cyert and DeGroot, 1989). If the possibility of serious drought in the region had been appreciated and the linkage between precipitation and farm production well understood, farmers would have reacted differently than they did. Observations of very dry weather when the drought began in 1917 would have led homesteaders to modify their prior opinions, formed during years of relatively high rainfall, and to adjust farming practices–delaying or changing migration plans for prospective migrants and reducing planting by existing farmers. Because of their size, larger farms would have been preferred because they could produce more, devote additional land to moisture-conserving fallow, and diversify into other crops and livestock that could better withstand drought.[52]

But, the climate was not understood and appropriate farm practices and sizes had not been determined. Dryfarming doctrine argued that annual rainfall was not essential and that small farms could be successful under adverse conditions. This limited and ultimately faulty information was used in the assessment of weather conditions and their implications for agriculture.

Given a high degree of uncertainty, homesteaders relied upon heuristics that heavily weighted past information, gained from the experiment station and from their own experience, in making judgements about farming prospects when they received new rainfall information.[53] We argue that the previous wet period and the strong claims of dryfarming doctrine led homesteaders to discount observations of dry weather and to place more weight on past opinions about the ability of the small farms to withstand droughts. Discounting drought prospects would lead to continued migration and farming, even in the face of currently observed unattractive returns. This decision rule would be reinforced if past dry years had been followed by a rebound in yields because that experience would have validated the claims of dryfarming doctrine. If a dry year, however, were followed by longer periods of drought and low yields, then eventually prior beliefs would be adjusted toward a more pessimistic view of homesteading opportunities. Accordingly, a migration and farming decision rule strongly influenced by the past assertions of dryfarming doctrine would result in a lagged response to a serious drought.

As Figure 5 shows, the drought of 1917-1921 stands out both for the severity of the precipitation shortfall and for its length. It was certainly an unusual event for the recently-arrived population. For five years, precipitation remained below average, and in 1917 and 1919 rainfall was more than one standard deviation below the mean. Nothing like this had been experienced in Montana since 1895, the period in which historical data were available for consideration by homesteaders. As shown in the figure, there were two short-term droughts in 1904 and 1910. These had been accommodated with little hardship, and this experience gave confidence that new dryfarming techniques could successfully store enough water in the soil to carry a small farmer through a drought year.[54]

Although we do not have individual homestead data to directly test the prediction of a lagged response to drought due to the claims of dryfarming doctrine, we have state and county-level data that are instructive. The data in Figure 4 show that original homestead entries in Montana continued at their high level through1922. 53,366 additional new homestead entries were filed between 1917 and 1925, with most between 1917 and 1922. 15,197 original homestead entries were made in 1917 (more than in 1916), and they gradually declined, but even 1920 and 1921, the last two years of the drought, 13,235 homestead claims were entered.[55] The number of farms in Montana grew by 7,700 between 1916 and 1920 before declining gradually by 1925.[56] At the county level, Table 4 shows the number of farms by two size categories, 320-acre homesteads and farms 641 acres and larger, in Prairie County, in eastern Montana between 1916 and 1919. As indicated in the table, the number of 320-acre homesteads continued to grow and the homestead share of total farms remained stable from 1916, the year before the drought, through 1919. There is no evidence of a shift to larger farms over 640 acres that subsequently were viewed in experiment station publications as most likely to be sustainable in a semi-arid climate.

Rising wheat prices between 1915 and 1920 provided motivation for settlement because they offered some offset for the 90 percent decline in wheat yields between 1915 and 1919. But had climate knowledge been more complete, the response to higher wheat prices would have been more through expanded farm sizes in the face of drought rather than through settlement in small farms by additional homesteaders.

Table 4

Experiment station personnel also failed to anticipate the severity of the drought and urged continued migration to the region. For example, in July 1917 Alfred Atkinson of the Montana Experiment Station and later, President of Montana State College of Agriculture and Mechanical Arts, warned a prospective homesteader that the supply of good land was dwindling. In an August 1917 letter to another homesteader, Atkinson claimed that "Dry land crops are raised successfully in practically all parts of Montana....The great dry farming area in Montana lies in the eastern part of the state. There is practically no place in the state where they do not receive sufficient rainfall in normal years to produce a crop."And in December 1917, the experiment station claimed that: "there are very few points in Montana where they cannot raise crops successfully."[57] The drought would continue and become even more severe, yet Atkinson examined available precipitation data from 1898 through 1916 and concluded that there was "a tendency for two dry years, but in very few cases for three dry years in succession."[58]

By 1919 the unusual duration of the drought was finally acknowledged by experiment station personnel, and for the first time, there was doubt about the ability of dryfarming doctrine to guarantee at least a moderately successful crop. In a further shift, in 1920 the experiment station claimed that drought could be expected "rather frequently (Montana Agricultural Experiment Station, 1920, 8; 1921, 7; 1922, 57).

Beginning in 1920, after three years of drought and after average wheat yields had dropped to 2.7 bushels per acre in 1919, down from 26.5 bushels in 1915, prior beliefs about the viability of small homesteads finally were being revised downward. Experiment station and railroad officials, as well as current and prospective homesteaders, began to modify their views of the region. Homestead abandonment began. Between 1919 and 1925, some 60,000 homesteaders are claimed to have left their farms, with over 11,000 farms failing (one out of five) and approximately 2,000,000 acres of land going out of production.[59]

Montana became less attractive to migrants. As shown in Figure 4, the number of new homesteads declined in 1921 and 1922 and fell sharply in 1923.

The impact of the drought on farm incomes was dramatic, and it undercut the viability of small homesteads in particular. The effect of drought on large and small farms is illustrated by the survey data in Table 2. In rows 2 and 3, we show gross and net wheat income in 1919 at the peak of the drought for the average small and large farm. The figures are calculated using the wheat acreage data from the 1921 survey, 1919 statewide mean yields of 2.7 bushels per acre, and the 1919 mean wheat price of $2.16 per bushel. We converted 1921 reported expenses to 1919 values. For homesteads listed in row 2, 1919 net wheat income was $108, less than one-twentieth of 1916's income of $2,365. Mean wheat income in 1919 net of current expenses, mortgage costs and depreciation was -$114.00. As shown in row 3, larger farms could withstand the drought somewhat better. Gross wheat income was $1,213, income net of current expenses of $491, and income net of mortgage and depreciation costs of $ 84. The drop in yields due to the drought hurt farms of all sizes, but larger farms still had more than four times the net wheat income of homesteads and had positive earnings to service mortgage debt.[60]

The experiment station and USDA literature after 1920 is uniformly critical of small homesteads as not being viable for agriculture in the semi-arid upper Great Plains. Experiment Station Director Linfield claimed that the earlier distribution of lands via the homestead acts had been a mistake and that much larger farms, "two to four times the area of the land named in the National Homestead Acts" were necessary for successful farming in dry areas (Montana Agricultural Experiment Station, 1924, 8; 1926, 6).[61] Smaller farms not only produced less, but they also had higher costs per bushel. Using the survey data, mean 1919 current expenses per bushel were $1.74 and $1.29 for small and large farms, respectively, a difference of over a third or $.45 per bushel.[62]

Although variation in land quality and human capital may have influenced the ability of some farms to survive the drought, we do not have data for successful and unsuccessful farms to examine their relative contribution. The available evidence, however, suggests that they likely played a secondary role in the differential failure of small farms. While the earliest homesteaders had access to better lands than did those who arrived later, land quality was generally high throughout the region (Morgan and Seamans, 1920, 2; Wilson, 1923, 8-11). Further, most homesteaders appear to have had farming experience.[63] Farm size was emphasized because when yields fell due to drought, farms of 320 acres or less could not produce enough to cover costs and sustain a family (Wilson, 1923, 94; Eckert and Maughan, 1939, 23).[64] There were at least some economies of scale in grain production, and 360 acres was below the minimum efficient size for dry-land agriculture (Wilson, 1923, 108-9; Eckert and Maughan, 1939, 15-23). Additionally, small farmers may have been less likely to practice summer fallowing, which was strongly recommended for retaining moisture and maintaining yields.[65] With limited acreage, small farms may not have been able to afford to leave much land in fallow. Finally, small farms did not diversify into other crops and especially into livestock, as was suggested as another means of better withstanding drought (Wilson, 1923, 41, 108-9; Oakley and Westover, 1924, 50).[66]

Data assembled by the experiment station to analyze foreclosures on farm loans also shows the vulnerability of small homesteads to the drop in yields that occurred with the drought. The data are described in Table 5.

Table 5

Of the 381 loans examined, 107 were to homesteaded farms with an average size of 291 acres. Most foreclosed loans were made between 1917 and 1921. 70 percent of the loans to homesteaded farms were foreclosed, by far the largest percentage of all farm categories. By comparison, the 127 farms acquired through purchase from non-relatives with an average size of 544 acres had foreclosure rates of 28 percent, the next highest category. All larger farms had lower foreclosure rates. They were less likely to default on loans during drought because they had more production to draw from and other products beyond wheat to sell.[67] The entire wheat-growing region of the Midwest was hurt by the fall in wheat prices in 1921, but the drought in the upper Great Plains exacerbated the problem. Across the region, farm failure was most common among the small homesteads of eastern Montana (Rich, 1923; Renne, 1938, 20; 1939, 17).

Survey data from later in the 1920s and early 1930s reinforce the conclusion that small homesteads were not viable on the Great Plains. Halcrow's (1938) study of 503 "unsuccessful" farms in eastern

Montana, using data for 1928-1935, found that they were undiversified and small, two-thirds were below 360 acres, when at least 700 to 800 acres were deemed necessary for minimum cost production.[68] Cochrane's (1938) examination of 314 farms, using data for 1934-36, found that the most productive farms (measured by net income) were twice the size of the average farm, at approximately 1,100 acres, focused on wheat cultivation with diversification into livestock production, did not invest appreciably more in buildings, but used more machinery, and were more likely to practice summer fallow than were their less productive counterparts.

VII. Conclusion.

In the late 19th and early 20th centuries the North American agricultural frontier moved for the first time into semi-arid regions where farming was vulnerable to drought. Farmers who migrated to the Great Plains had to adapt their crops, techniques, and farm sizes to better fit the environment. But there was very incomplete information for making these adjustments. The use of decision rules that were heavily influenced by first, the optimistic notion that the climate was changing, and then by the strong claims of dryfarming doctrine led too many to migrate to the region and settle on too many small dry land wheat farms. Our sample homestead data indicate that so long as rainfall and yields remained high, early homesteads were viable, providing farm incomes comparable to what could be earned elsewhere. But when rainfall sharply declined, small farms were especially vulnerable. Many were abandoned subsequently in the midst of drought.

Two waves of major homestead failures took place, first in the central Great Plains of western Kansas and Nebraska and eastern Colorado and then, almost 25 years later in the northern Great Plains of eastern Montana and the western Dakotas. These homestead failures and corresponding farm consolidation were part of a necessary transition process toward larger, more viable farms in the Great Plains. Although it is beyond the scope of this paper to estimate the costs of this transition, they surely included the lost opportunity income of homesteaders during the five-year drought period, redundant farm buildings, intensive cultivation that subsequently contributed to wind erosion and the Dust Bowl of the 1930s, excessive county infrastructure that was designed for larger populations, and disruption to the banking system by wide-spread mortgage defaults by small farmers and corresponding bank failures.

The transactions costs, however, were probably unavoidable given the limited information available about the climate of the Great Plains and appropriate agricultural techniques and farm sizes for a semi-arid region. Had homesteaders better understood the weather they might not have accepted the claims of a changing climate or of dryfarming doctrine. And had dryfarming tests occurred under less favorable circumstances, its doctrine might have been more circumspect, with less encouragement for small farmers. Land laws might have been revised and fewer homesteaders might have gone to the Great Plains around the turn of the century.

Census data provide a glimpse of the adjustment in farm size that was necessary to bring about more sustainable agricultural establishments. In 1910, during the midst of the homestead boom in the upper Great Plains, average farm size in eastern Montana was 612 acres, a figure that included homesteads and larger established farms and ranches. By 1920, average farm size was 696 acres, and by 1925, after the effects of the drought had been felt and farm consolidation had occurred, average farm size was 783 acres, an increase of 28 percent from 1910.[69] Moreover, the share of small farms, 499 acres or smaller, declined between 1910 and 1925 from 84 percent of total farms to 59 percent, whereas the share of larger farms, 500 acres and up, increased from 16 percent to 41 percent. The dispersion of observed farm sizes also declined. The coefficient of variation for farm sizes in eastern Montana fell from 1.35 in 1910 to 1.01 by 1925.[70] Farm sizes continued to expand after 1925 with adoption of mechanization and associated changes in economies of scale in grain production. The droughts of 1893-94 in the central region and 1917-21 in the north, however, dashed the small-farm ideal of the homestead acts and initiated the move to more viable, larger farms on the semi-arid Great Plains.

Figure 1
100th Meridian and the Start of the Great Plains

Figure 2

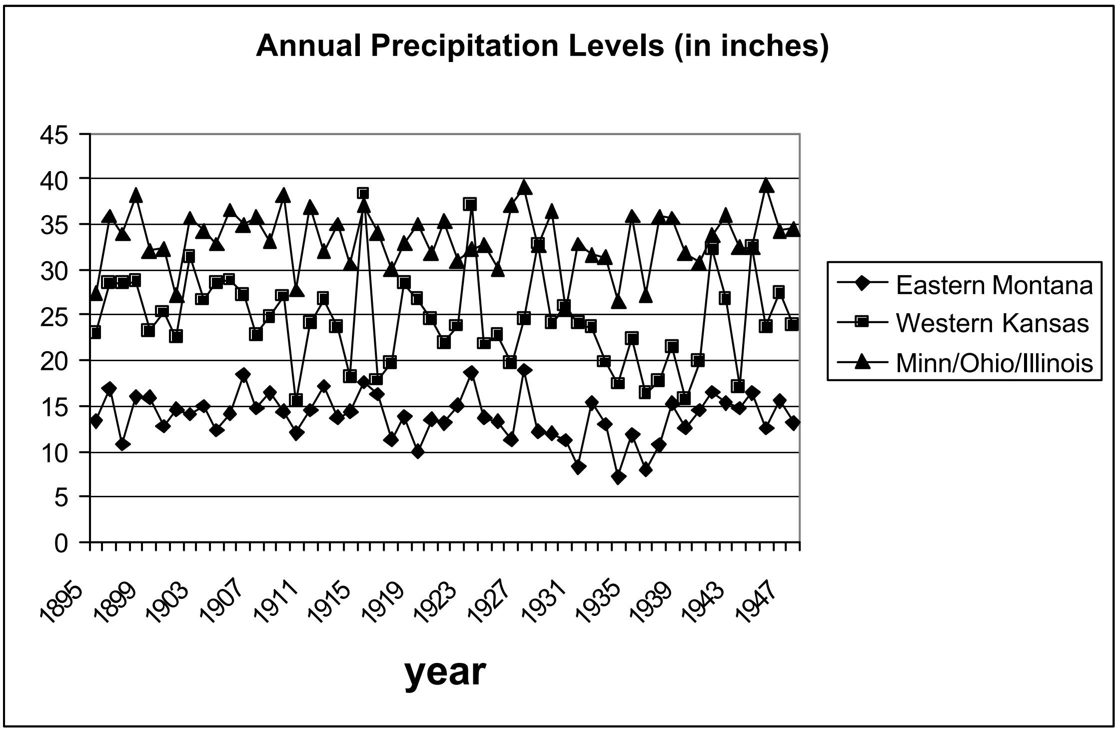

Annual Precipitation Levels (in inches)
45
40
35
30
25
20
15
10
5
0
1895
1899
1903
1907
1911
1915
1919
1923
1927
1931
1935
1939
1943
1947
year
Eastern Montana
Western Kansas
Minn/Ohio/Illinois

Figure 3

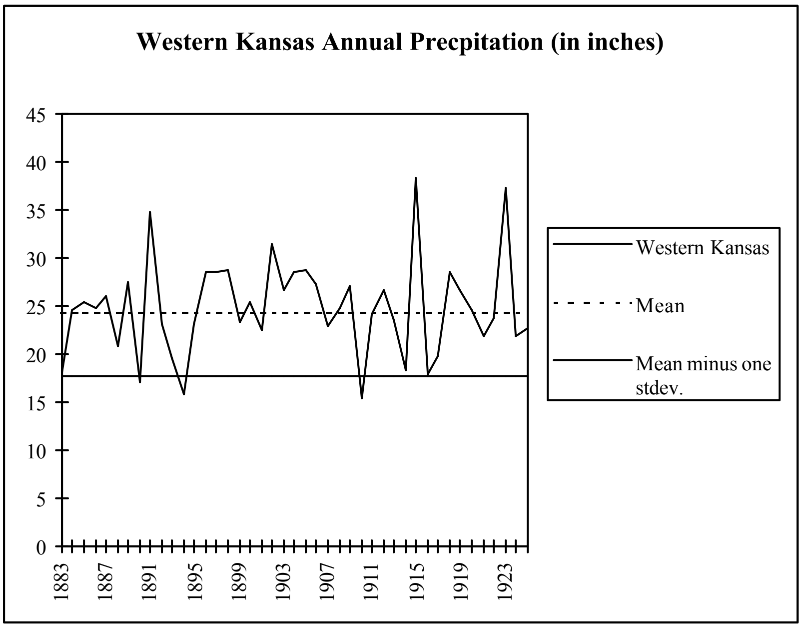

Western Kansas Annual Precpitation (in inches)
45
40
35
30
25
20
15
10
5
0
1883
1887
1891
1895
1899
1903
1907
1911
1915
1919
1923
Western Kansas
Mean
Mean minus one stdev.

Figure 4

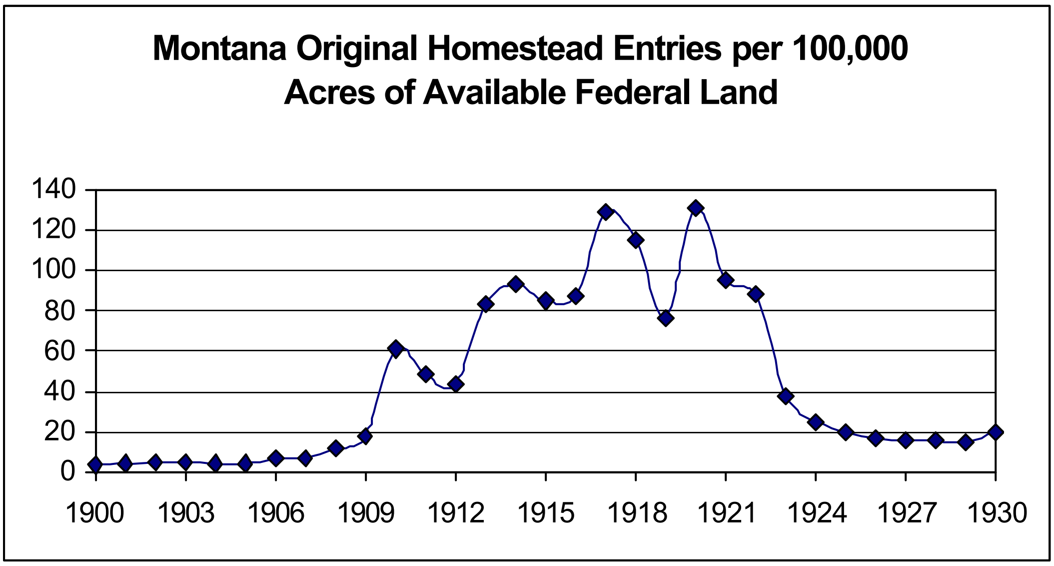
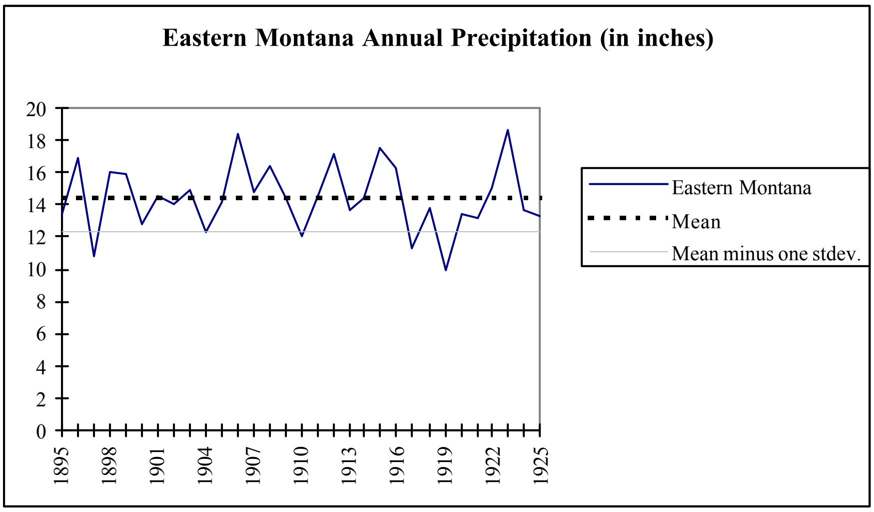

Montana Original Homestead Entries per 100,000 Acres of Available Federal Land
140
120
100
80
60
40
20
0
1900
1903
1906
1909
1912
1915
1918
1921
1924
1927
1930

Figure 5



Eastern Montana Annual Precipitation (in inches)
20
18
16
14
12
10
8
6
4
2
0
1895
1898
1901
1904
1907
1910
1913
1916
1919
1922
1925
Eastern Montana
Mean
Mean minus one stdev.

Table 1
Rainfall Patterns

	Western Kansas	Eastern Montana	Minnesota, Ohio, Illinois
Mean	24.5	13.8	33.3
Coefficient of Variation	0.21	0.19	0.10
Correlation Coefficient with	1	0.45	0.34
Correlation Coefficient with	0.45	1	0.34
Correlation Coefficient with	0.34	0.34	1

The precipitation data are for the years of 1895 through 1947

Table 2
Estimated Farm Income, 1916 and 1919

	Mean Farm Size (acres)	Mean Wheat Acres*	Mean Current Expenses	Total Expense**	Gross Wheat Income	Income-current expenses	Income-total expense
Sample of 27 Homestead Farms, 320 Acres or Smaller							
1916 Montana Wheat Yield (19.3 bu/acre) and Price ($1.43/bu)	310	96	$285	$425	$2,650	$2,365	$2,225
1919 Montana Wheat Yield (2.7bu/acre) and Price ($2.16/bu.)	310	96	$452	$674	$560	$108	-$114
Sample of 97 Farms Larger than 320 Acres							
1919 Montana Wheat Yield (2.7 bu/acre) and Price ($2.16/bu)	825	208	$722	$1,130	$1,213	$491	$84

*Total farm size included wheat acres, pasture, fallow, land in other crops, and waste.

**Mean Expenses + Mortgage and Depreciation. 1921 expense data are converted to 1916 and 1919 values using the cost of living index in U. S. Department of Commerce, Historical Statistics (1976, 211).

Table 3
Yield and Migration Analysis

Dependent Variable: Montana Wheat Yield		
Variable	Coefficient	t-ratios
Constant	-6.75	-1.30
Land Quality (Proxy)	0.93 E-03	9.58
Montana Annual Rainfall, t	0.76	2.87
Montana Annual Rainfall, t-1	0.24	0.96
Durbin-Watson: 1.71 Adjusted R-squared: .79 Number of Observations: 34 (1895-1929)		

Notes: The proxy that is used for the land quality is available surveyed land in Montana (in terms of 1,000 acres)

Dependent Variable: Original Homestead Entries in Montana		
Variable	Coefficient	t-ratio
Constant	-24032.60	-5.20
Available Surveyed Federal Land	0.19	0.54
Montana Wheat Yield, t	153.81	0.78
Montana Wheat Yield, t-1	366.24	1.94
Price of Wheat, t	1564.71	1.13
Price of Wheat,t-1	1850.09	1.32
Dummy (Law change of 1909)	11680.06	4.70
Durbin-Watson: 1.41 Adjusted R-squared: .61 Number of Observations: 34 (1895-1929)		

Notes: Montana wheat yields relative to the annual wheat yields in Ohio give similar results. Total available federal land is in terms of 1,000 acres. Real wheat prices are calculated using nominal prices and the consumer price index (U.S. Department of Commerce, 1976, Historical Statistics, 211).

Table 4
Farms by Size Category, Prairie County Montana

Year	Total Number of Farms	Number of 320-Acre Homesteads	Number of Farms Above 640 Acres
1916	933	292	106
Percent of Total		31%	12%
1917	1079	357	155
Percent of Total		33%	14%
1918	1384	481	191
Percent of Total		33%	14
1919	1563	522	198
Percent of Total		33%	13%

Source: Prairie County Tax Records, Montana Historical Society, Helena

Table 5
Analysis of Loan Foreclosures According to Method of Farm Acquisition

Method of Acquisition	Number of Loans (Farms)	Percent Foreclosed	Average Amount of Loan	Farm Appraisal	Farm Size (Acres)
Homestead	107	70%	$2,023	$5,636	291
Purchase from Non-Relatives	127	28	5,621	14,522	544
Purchase from Relatives	32	22	6,753	16,709	788
Homestead and Purchase	82	27	5,741	15,894	826
Other	33	24	7,079	21,100	1,102

Source: Montana State Experiment Station, Bozeman, Merrill G. Burlingame Special Collections, Montana State University Bozeman, Group 73039, Box 12.

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Endnotes

1. For analysis of some American frontier experiences and the comparative ease of frontier farming, Danhof (1969), Ferrie (1994), and Galenson and Pope (1989).

2. For discussion of decision making under uncertainty, the use of heuristics, and the biases that can result, see Kahneman, Slovic, and Tversky (1982), El-Gamal and Grether (1995), and Camerer (1995).

3. Hargreaves (1957) provides a very broad and complete study of agriculture in the upper Great Plains, and we have benefited from her analysis. See also, Hargreaves (1958, 1977). Although she recognizes the information problem facing settlers, she labels the spread of dryfarming doctrine as "propaganda," less concerned with the spread of viable farm practices and more concerned with development. See, for example, 1957, pages 33, 78, 83, 97, 121, 125, 220, 223, 234, 238, 328. We interpret dryfarming doctrine differently, based on our analysis of experiment station studies and precipitation levels during the major homestead period. As we show later in the text, there were two one-year droughts between 1904 and 1910. The rest of the period was the wettest in the 20th century, a perspective that no party had at that time. Dryfarming doctrine worked well for the two short droughts, but was unable to conserve enough soil moisture to sustain

farms when the long-term drought set in after 1916. As we view it, all of the parties involved in development, homesteaders, real estate agents, railroad officers, dryfarming movement leaders, experiment station investigators, and state and local government officials, had a stake in successful long-term agricultural settlement.

4. Between 1863, the year after the Homestead Act was passed, and 1880, 469,882 original homestead entries were filed covering 55,667,035 acres of federal government land (Annual Reports of the Commissioner of the General Land Office). The average claim size was 118 acres. 59 percent of the claimed acreage was in the Midwest, in Ohio, Indiana, Illinois, Michigan, Iowa, Wisconsin, Minnesota, eastern Kansas and Nebraska.

5. For instance, 1880 census data show similar agricultural patterns across northern states: Average farm size was 99 acres in Ohio, 124 acres in Illinois, and 134 acres in Iowa; Ohio, Illinois, and Iowa devoted 13 percent, 29 percent, and 27 percent of farm land to corn and 10 percent, 10 percent, and 6 percent, respectively, in wheat. See U.S. Department of the Interior, Census Office (1883, 26-7, 102-3, 177, 212, 250-1). Farmers did have to make adjustments for different temperatures and soil types. Olmstead and Rhode (2000) examine the process of biological innovation that occurred in American agricultural development that was in part stimulated by migration to new areas with different growing conditions.

6. Annual Reports of the Commissioner of the General Land Office for the Fiscal Years, 1880-1925. The calculations are for state totals.

7. Ranges of mean annual precipitation, calculated 1941-1970 for western Kansas are provided in Self (1978, 58).

8. National Climatic Data Center (1983) for Minnesota, Illinois and Ohio. Eastern Montana precipitation data through 1913 from Burke and Pinckney (1914) and for 1914-47 from USDA Weather Bureau, "Summary of the Climatological Data for the United States by Section, published annually. Our classification of eastern Montana follows that used by Hargreaves (1957). Western Kansas data from a website: cdiac.esd.ornl.gov/r3d/ushcn/state/KS. These data are for stations in the western 24 counties. Stations were identified from NOAA, National Climatic Data Center, Asheville, 1983, "Climatological Data Annual Summary, Kansas" Vol 97 (13), map, p. 34.

9. For an assessment of the critical importance of precipitation on the Great Plains, see Starch (1939, 114). When rainfall occurred also was critical. Rainfall during the growing season, April-June, was most important. For discussion, see Burke and Pinckney (1919).

10. Bark (1978, 11), Riefler (1978, 66), Diaz (1983), Karl and Koscielny (1982).

11. Warrick (1975, 11-27; 1980) points out that although there is no general agreement on how normal circulation patterns are disrupted to cause droughts, the arid Southwest and Great Plains are most susceptible in North America. There are no well-defined drought cycles. Smith (1920b, 81-2, 101) provides an early discussion of the climate of the Great Plains, giving charts of climate types according to annual rainfall and charts of crops.

12. Felch (1978, 25-42). The American Meteorology Society defines drought as a period of abnormally dry weather sufficiently prolonged for a lack of water to cause serious hydro-logic imbalance in the affected area. See also, Schneider (1978, 163), Warrick (1975, xiii, 3-11), Bradley (1976, 2-15), and Trewartha (1961, 259-61, 279-87) for discussion of drought. Smith (1920b, 25) indicates that the study of weather was still relatively new early in the twentieth century.

13. See Abbe (1908, 1909) for discussion of the state of meteorological science at the turn of the 20th century.

14. U.S. Department of Agriculture, Weather Bureau (1897, 18-19) noted that "the local distribution of rainfall is exceedingly erratic," so that individual registers "often afford doubtful and conflicting information respecting the yearly fall of one and the same region." A few stations had longer term data. See U.S. Department of Agriculture, Bulletin C, (1894) for data on annual precipitation, beginning with the earliest records, in the U.S. at various cities. Riefler (1978, 63-77) discusses the drought in the early 1890s in western Kansas and Nebraska and notes that records on the drought are

sparse.

15. Smith (1920a, 281), Whitnah (1961, 4-8) describes early crude mapping of storm movement, theories of wind and pressure formation in the 1840s-70s. The location of weather reporting stations is shown in the Annual Reports of the Chief Signal Officer through 1890. For example see map and lists in The Report of the Chief Signal Officer of the Army, (U.S. Department of War, Chief Signal Officer, 1881, 304). The reports also provide summaries of the year's weather at observation posts. See also, Hughes (1970, 36-9). Craft (1998) provides discussion of the use of weather information in Great Lakes shipping.

16. Smith (1920a, 281); Weber (1922, 7-12) describes early weather activities in the 1870-80s that included limited forecasts, river observations, flood warnings, and some meteorological investigation.

17. Ausubel and Biswas (1980, 93-123) discuss the impact of droughts on agricultural yields.

18. Fite (1966, 126-131), Self (1978, 58), Baltensperger (1977), and Riney-Kehrberg (1989). Stegner (1954, 296) argues that drought conditions began to appear in 1886. Rainfall data, however, indicate a series of one-year droughts in the 1880s with rebounds in precipitation. The 1893-94 drought was not only deeper but lasted longer.

19. 21 of the 24 counties lost population. Calculated from U.S. Agricultural and Population Censuses 1890, 1900. See also Fite (1966, 131).

20. Homestead entries are for the entire state of Kansas, but most settlement was in western Kansas. The average is for 1895-1899. Annual Reports of the Commissioner of the General Land Office.

21. Calculated from U.S. Agricultural Census, 1880, "Report on the Production of Agriculture," 115-6; 1890, "Report on the Statistics of Agriculture," 209-9; 1920, Vol. 6, Pt. 1, 732-41. Western Kansas counties are those west of the 100th meridian and eastern Kansas counties were those to the east. Discussion of drought adaptation in Kansas is in Fite (1966, 131-4), Saarinen (1966), and Malin (1944).

22. There was an unsuccessful effort to persuade Chilcott and other USDA staff members to be more active in the Dry Farming Congresses. See exchanges involving F.B. Linfield and Alfred Atkinson of the Montana Agricultural Experiment Station and E.C. Chilcott and other USDA officials during 1910 and 1911 regarding USDA involvement in the congresses and in disseminating USDA publications and views. Merrill G. Burlingame Special Collections, Montana State University, 00004, Box 3, Files AA-F6, AC-F4, AF-F4, AF-F4A, AF-F4B, AF-F5.

23. This "failure" to learn from the Kansas experience has been criticized by observers who have commented on the riskiness of agriculture in the Great Plains. For example, see Johnson (1901), Thronthwaite (1936), Great Plains Committee (1936), and Warrick (1980). There also was no sharing of weather information between ranchers and Native Americans who had lived in the region for some time and prospective homesteaders. Ranchers and Native Americans, however, had different experiences. They used very large tracts of land either to graze animals or to follow and hunt them, and hence, did not face the same constraints that subsequently confronted small homesteaders.

24. Other advocates included E.R. Parsons, (1913), who was credited with 40 years of experience and scientific training; Thomas Shaw (1911), Professor of Animal Husbandry at the University of Minnesota; V.T. Cooke (1907), whose work was published by the Wyoming Dry Farming Commission, and Professor Murray E. King (1911). For discussion of other dryfarming adaptations, see Merk (1978, 484-94).

25. For example, see discussion of control plots and other experiments in Campbell (1914, 20-24; 1916, 25-7).

26. Widtsoe (1911, 399-410) described how a drought was successfully handled by those who practiced dryfarming.

27. Widtsoe (1911, 361). Notice also, Buffin (1911, 11-2): "Evolution always leads towards greater perfection."See Sullivan (1928, 6105), Noble (1958, 5-6), Hays (1959, 265-6; 1995, 15-8), Diner (1998, 3-4) for discussion of the ideology of the Progressive Age and the optimistic assessments of the role of science and technology for human progress.

28. There was a considerable bias toward small homestead farms in the dryfarming doctrine literature because they offered an alternative to more costly irrigation or larger-scale ranching. Larger farms were also considered wasteful. See Campbell (1902, 5; 1907, 1914, 1916) and Buffin (1909, 36).

29. See Stegner (1953,* 219-42) and Pfeffer (1951, 8-62, 135-68) regarding the political controversy over homestead farm size and efforts to adjust the federal land laws.

30. Parsons (1913, 17, 44), Campbell (1902, 34; 1914, 57-65).

31. Campbell (1902, 12-5), Widtsoe (1911, 301), Buffin (1909, 35-7).

32. The actions of the county agents and the experiment stations in disseminating dryfarming doctrine are described in Merrill G. Burlingame Special Collections, Montana State University, 00004, Box 1,AA-F8, 00002, Box 22, File T-10, and collection 78036.

33. For example, Linfield and Atkinson (1907) identified the Montana regions, some 12 to 14 million acres where dryfarming promised the greatest success, and Atkinson and Nelson (1908), described viable grain types and cultivation practices and concluded that dry farming would be successful in many parts of Montana. Climatic information for Montana stations through 1913 was listed by Cooley (1912) and Linfield (1914). Other experiment station publications that outlined dryfarming techniques include Cooley (1907), Atkinson and Cooley (1910), Atkinson and Wilson (1915), and Atkinson (1915).

34. To illustrate, see the correspondence between Agricultural Experiment Station personnel and prospective homesteaders in the Merrill G. Burlingame Special Collections, Montana State University, 00004, Box 1, File AC-F4. In one letter to B.D. Bundy from Alfred Atkinson of the experiment station, May 30, 1916, Atkinson asserted that 160 acres could give fine returns.

35. For example, see Chilcott, Cole, and Burns (1915).

36. However, Hargreaves (1948) concludes that the differences between Chilcott and dryfarming promoters were more of degree than of substance.

37. For example, in a USDA bulletin, Failyer (1906) makes arguments very similar to those outlined by Campbell.

38. They met in Denver, 1907, Salt Lake City, 1908, Cheyenne, 1909, Billings, 1909, Spokane, 1910, Colorado Springs, 1911, Lethbridge, 1912, Wichita, 1914, Denver,1915, and El Paso, 1916.

39. Quisenberry (1977, 220) claimed that 20,000 attended the 1912 Dry Farming Congress in Lethbridge. Other sources claim that the Dry Farming Congress had 15,000 members at the time (Merrill G. Burlingame Special Collections, Montana State University, 00004, Box 3, File AF-F4A).

40. The Northern Pacific Railroad echoed the claims of drying farming doctrine in its pamphlet (1911), "Western North Dakota: Being a Description of a Land of Great Promise and the Opportunities it Holds for Homeseekers," Montana Historical Society Collections. For additional discussion on the role of the railroads in the region, see Overton (1965, 283-85) and Scott (1985, 35).

41. We scale the number of homestead entries by total federal land available for claiming in order to control for the effect

of the declining federal estate. Original homestead claims and total federal land available for claiming are compiled from the Annual Report of the General Land Office for the years of 1903-1930.

42. Annual Reports of the Commissioner of the General Land Office.

43. 1900 and 1920 U.S. Population Census.

44. Yields are from the USDA Yearbook of Agriculture, 1900, 769; 1910, 516-7;1920, 565-6; 1925, 746; 1930, 600-1. Mean yields between 1900 and 1915 were 15.39 bushels per acre for Ohio, 15.63 bushels for Illinois, and 14.15 for Kansas.

45. Rainfall data compiled from Burke and Pinckney (1914) and USDA, Weather Bureau, "Summary of the Climatological Data for the United States, by sections, Montana," various years. Eastern Montana counties included follow the designation used by Hargreaves (1957), Big Horn, Blaine, Carbon, Carter, Cascade, Chouteau, Custer, Daniels, Dawson, Fallon, Fergus, Garfield, Golden Valley, Hill, Judith Basin, Liberty, McCone, Meagher, Musselshell, Park, Petroleum, Phillips, Pondera, Powder River, Prairie, Richland, Roosevelt, Rosebud, Sheridan, Stillwater, Sweet Grass, Teton, Toole, Treasure, Valley, Wheatland, Wibaux, Yellowstone.

46. Farm Survey Records, 73039, Box 12, Files A-28, T-27, T-42, T-43, T-89, Merrill G. Burlingame Special Collections, Montana State University, Bozeman. The "Farm Survey Record" for each farm included county; date; operator; address; acres--owned, operated, in crops, fallow, pasture, in various types of crops; crop sales; livestock; livestock sales; livestock product sales; other sources of income; seed; current expenses– for hired labor, machinery repairs, seeds, fertilizers, taxes, and horseshoeing, and other miscellaneous costs; machinery and equipment (number, type, value); depreciation rates on machinery; real estate; farm finance; unpaid labor; and demographic data. We did not include the farms surveyed in Yellowstone County. These were small irrigated farms, not the dry-land farms of concern to us.

47. Current expense reported in the table is that described in the survey. Total expense includes current expenses plus depreciation on machinery and buildings and the interest cost on mortgages and short term loans. The survey reported the value of machinery and buildings, mortgage and other loans, loan interest rates, and depreciation rates. Since some farmers did not report depreciation rates, we used the mean rates for them, which were 7 percent for buildings and 10 percent for machinery. The table reports only wheat sales revenues using reported wheat acreage, 1916 Montana yields (USDA, Yearbook of Agriculture, 1920, 555-6), and wheat prices (U.S. Department of Commerce, Historical Statistics, 1976, 208).

48. The average U.S. farm income figure for 1920 was calculated by using 1920 gross farm income as reported in the USDA, Agricultural Statistics (1936, 338-39) $13,566,000,000 and total number of farms in 1920 of 6,448,343 (USDA, 1922 Agricultural Yearbook, "Agricultural Statistics," 1923, 1008). The 1922 USDA Agricultural Yearbook, "Agricultural Statistics" (1923, 1160) report $2,322 as gross receipts for western farms.

49. As we have indicated, soil quality in the upper Great Plains was generally high (Hargreaves, 1957, 6; Wilson, 1923, 8-10). Land in Montana was classified into quality categories by L.F. Gieseker. We did not use this classification in the regression. The data are not in time series form.

50. Descriptive statistics:

Variable	Mean	Std. Deviation	Min	Max
Surveyed Land	12,472,154	6,231,027	3,335,963	21,024,719
Montana Annual Rainfall	15.77	2.39	10.88	21.12

51. We converted nominal wheat prices to real prices using the CPI index (1967 base year) from U.S. Department of Commerce, U.S. Historical Statistics (1976, 211). Descriptive statistics:

Variable	Mean	Std. Deviation	Min	Max
Surveyed Federal Land	12,472,154	6,231,027	3,335,963	21,024,719
Montana Wheat Yield	20.89	7.35	2.7	32.5
Real Price of Wheat	2.91	0.81	1.82	5.34

52. The advantages of larger farms became a dominant theme of the experiment station literature after the drought of 1917-21. See, for example, Seamans (1921), Wilson (1923), and Clawson, Saunderson, and Johnson (1940).

53. See Kahneman, Slovic, and Tversky (1982, 11) for discussion of the "availability" heuristic. Basically, individuals assess the probability of an event by the ease in which previous instances can be brought to mind. Past experiences or information are relied upon in decision making, especially if they have credibility. El-Gamal and Grether (1995) also discuss undue reliance on past information as "conservatism"whereby decision makers require more evidence to update their priors than the Bayesian rule would imply.

54. For instance, see claim by Lewis Cameron, Sr., Martingsdale, Montana August 20, 1910, quoted in Chicago, Milwaukee and Puget Sound Railroad pamphlet, "The Musselshell Country," Montana Historical Society, Helena. See also, "An Address by Howard Elliott, President of the Northern Pacific Railway Company, Delivered at the Interstate Fair, Bozeman, September 1, 1910" Montana Historical Society, Helena.

55. Annual Reports of the Commissioner of the General Land Office.

56. Http://www.nass.gov/mt/historic/general/farmnumber.htm. The numbers do not correspond with those for original homesteads. Some new homesteads were combined with existing farms. Moreover, as new homesteads were being entered, farms were being abandoned by 1919. The number of farms rose from 50,000 in 1916 to 57,700 in 1920, declining gradually to 50,000 once again in 1925.

57. Letters by Alfred Atkinson to Gibson McKneight, July 9, 1917; Atkinson to J.L. Ambrose, August 21, 1917, both in 00004, Box 1, File AF-F0. Letter to B.H. Hibbard, December 4, 1917, 00004 Box 1, File AB-F1, Merrill G. Burlingame Special Collections, Montana State University.

58. Alfred Atkinson, "The Agricultural Outlook," 00004, Box 1, File AB-F1, Merrill G. Burlingame Special Collections, Montana State University.

59. Toole (1959, 238), Howard (1959, 207-8) Fulton (1977).

60. 1919 Montana yields from USDA, Yearbook of Agriculture, 1920, 555-6) and wheat prices (U.S. Department of Commerce, Historical Statistics, 1976, 208). In related work, we are attempting to determine the characteristics of farms that survived versus those that failed.

61. The problem of small farms remained on the Great Plains. After the droughts of the 1930s, Clawson, Saunderson, and Johnson (1940, 41-7) argued that there were too many small farms of 320 acres or less and they called for the number of farms to be cut in half.

62. These production cost differences under state the likely true difference between surviving large farms and failing small ones. The 1921-22 survey necessarily included only farms, large and small, that survived the drought.

63. Wilson's (1923, 124-5) discussion of 550 homesteaders farmers in north central Montana finds that 278 were farmers

prior to homesteading, with other occupations related to farming (laborer, ranch hand, rancher, sheep herder) accounting for 30 more. 78 were listed as unclassified, and he states that the total number of prior occupations other than farming was 63.

64. Eckert and Maughan (1939, 23) concluded that farm size was the single most important factor in obtaining satisfactory income.

65. Wilson (1923, 39) points out that successful farms were more apt to use summer fallow.

66. For further analysis of the relative disadvantage of small farms during this period see Starch (1935), Renne (1938, 1939), Montana Agricultural Experiment Station (1939), and Clawson, Saunderson, and Johnson (1940).

67. Data on relation of farm operator's method of acquirement of farm to foreclosure, Montana State Experiment Station, Bozeman, Merrill G. Burlingame Special Collections, Montana State University, 73039, Box 12. See discussion in Eckert and Maughan (1939).

68. Halcrow (1938) defined unsuccessful farms as those with less than $1,000 average annual gross farm income and whose operators received relief assistance from the Farm Security Administration. He also found that unsuccessful farms were on less productive soil, and used less summer fallow than did other farms in the area.

69. Data from 13th U.S. Census, 1910, Volume VI Agriculture, 958-60, and 15th Census of the U.S., 1930, Agriculture, Volume II, Part 3, 118-22. We included the counties listed in footnote 111, which are the counties identified by Hargreaves as eastern Montana. Average farm size is the mean of the average farm sizes by county.

70. Data are from 13th U.S. Census, 1910, Volume VI Agriculture, 958-60; 14th U.S. Census, Agriculture, Volume IV Part 3, The Western States, 106-110; and the 1925 U.S. Census of Agriculture, Part III, The Western States, 82-89. The farm size categories listed in the census were combined to 0-99, 100-259, 260-499, 500-999, 1,000-4,999, and 5,000 and larger. To calculate the coefficient of variation, the number of farms in each size category was assumed to have the mid point size. A weighted mean was calculated and a standard deviation around the mean for 1910, 1920, and 1925.