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

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"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'.."[1]

"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."[2]

"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."[3]

I. Introduction.

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 the same cultivation techniques, have the same farm sizes, and plant the same crops as in their places of origin.[5]

By 1880 much of the remaining government land for claiming was in the Great Plains, beyond the 100th meridian which ran through the Dakotas, Nebraska and Kansas.[6] Between 1880 and 1925, 1,008,485 original homestead entries were filed to191,941,663 acres in western Kansas, Nebraska, and the Dakotas and eastern Colorado and Montana, 46 percent of all homestead filings and 50 percent of all government land claimed during the period.[7] In this region, climatic conditions were quite different with important implications for agriculture. It was dry. The area had been known in the 1840s and 50s as the Great American Desert. Because average rainfall was 18-24 inches in western Kansas, around the 20 inches thought necessary for unirrigated farming,

the region had been deemed at the margin for farming–one to be endured and crossed, but not settled.[8]

Drought was to take a toll. In eastern states, such as Ohio with average precipitation levels of almost 38 inches, sufficient rainfall typically was not a factor in successfully operating a farm. In the Great Plains rainfall was the critical element. A severe drought during 1893 and 1894 brought homestead failures–between 1890 and 1900 the number of farms and population in the 24 counties of western Kansas fell by 37 percent and 27 percent, respectively.[9] Homesteaders did not learn from this experience. Migrants turned to the northern Great Plains, but the drought of 1917 to 1921 in eastern Montana led to abandonment of perhaps 60,000 of the186,363 original homestead claims filed between 1900 and 1920.[10]

Failures of this scale were unusual in the American frontier experience.[11] Agricultural experts and historians examined these homestead "busts" for an explanation. In the 1930s, USDA and agricultural experiment station officials criticized past federal land policies for encouraging the wrong people (non farmers) to plant the wrong crops (drought sensitive ones and not be sufficiently diversified) on the wrong farm sizes (too small).[12] Historians castigated homesteaders for attempting to transplant farming practices that were only appropriate for more "humid" regions and for failing to recognize that any cycle of wet years was certain to be followed by ones of drought. Homesteaders were asserted to have been misled by the false claims of railroads, developers, and other promoters.[13]

In this paper, we re-examine these homestead failures to determine why they occurred and why the Kansas experience did not bring more cautious settlement on the later Montana frontier. We focus on the weather information problem facing migrants to the Great Plains between 1880

and 1920. We show that knowledge of the climate was primitive and that the underlying mechanisms triggering droughts were not understood. Long-term precipitation records for most sites in the region did not exist. Hence, homesteaders had neither an analytical framework nor sufficient data for predicting fluctuations in rainfall. Further, migration often occurred during wet periods, and there was a sense that rainfall was endogenous to settlement, that cultivation could permanently change precipitation patterns, "rain follows the plow."The Kansas drought may have shaken this notion, but it did not completely dispel it, nor did it detour subsequent migration to the Great Plains.

We also emphasize the role of dryfarming principles in influencing agricultural decisions and the interpretation of weather conditions after the Kansas drought. Dryfarming, or scientific soil culture as it was labeled by its advocates, appeared after 1900 during the settlement of eastern Montana and the western Dakotas. It outlined methods for storing moisture in the soil, and as such, made understanding the climate of the Great Plains and its fluctuating rainfall seem less critical. The labor-intensive practices associated with dryfarming also were attractive because they opened lands for settlement that were unlikely to ever be irrigated. Because intensive cultivation was necessary to store and protect water from evaporation, dryfarming had to be done on a small scale, in homestead plots of 160 or 320 acres. The emphasis of dryfarming on small farms helped block major changes in federal land laws for much larger homesteads in semi-arid regions.

Dryfarming was enthusiastically promoted by agricultural experiment stations, state and local governments, the region's railroads, and Dry Farming Congresses. It received more moderate support from USDA officials. Dryfarming recommendations regarding cultivation, equipment, and crops were communicated aggressively to prospective homesteaders. With virgin

soils and (ex post) comparatively wet conditions through 1916, agricultural yields were high in Montana. This record seemed to validate dryfarming claims, and no strong exceptions to them were raised from any quarter until after the drought of 1917-21.

Hence, homesteaders made migration and farming decisions under very incomplete and even faulty information regarding the weather and the farm sizes and agricultural techniques appropriate semi-arid regions. This information came from credible sources, and the recommendations were remarkably uniform. The resulting information set, however, led homesteaders to establish farms that later were found to be too small, under capitalized, and insufficiently diversified to withstand the drought.

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

Because of their relative aridity, the Great Plains were very different from what confronted settlers on earlier frontiers and nothing in their eastern experience nor that in Europe prepared them for this new environment.[14] The Great Plains were then, and remain today, a climatic transition zone where most North American droughts have taken place.[15] During periods of high precipitation, the area took on the characteristics of sub-humid climates, becoming superficially attractive for the kinds of agriculture more appropriate for such regions.[16]When droughts returned, those agricultural practices were placed at risk.

Drought is a meteorological phenomenon, an extended period of below normal levels of precipitation. We define a severe drought as annual rainfall one standard deviation below the mean. Drought is due to an aberration in atmospheric circulation, but the precise triggering mechanisms are not well identified or very accurately predictable.[17] Until the Great Plains were

settled, droughts were not of overriding concern. In the eastern Midwest dry months could reduce yields and agricultural income in affected areas, but they usually did not mean complete crop failures.[18] Temperatures were followed more closely because frosts were important in determining growing seasons.

The Army Signal Corp began to systematically collect temperature and precipitation data from weather stations and voluntary reporters in 1870 with creation of the U.S. Weather Bureau.[19] By 1890 there were 178 weather stations in the U.S., mostly east of the Mississippi.[20] The major emphasis of early weather data collection was for the Great Lakes, Atlantic and Gulf Coast shipping, which was vulnerable to storms. Agriculture made use of frost and growing season length predictions. Weather services were created in Iowa, Nebraska, Missouri, and Ohio between 1875 and 1882, and by 1891 a special weather and crop service was in operation in most states. The first Weather Bureau crop bulletins began in May 1887.[21] The Weather Bureau was transferred from the Signal Corp to the Department of Agriculture in 1891. Following this move, special forecast services for corn and wheat, cotton, sugar, rice, tobacco, fruit, and truck farms were established. A Division of Agricultural Meteorology to analyze weather patterns was not established until1916.[22]

A particular problem encountered in the late 19th and early 20th centuries in studying droughts was that the mid to upper atmosphere, which housed the jet stream and other key meteorological forces affecting precipitation, was barely accessible to observation. Kites and balloons could go as high as 20,000 feet, but required very favorable conditions to do so. Further, there was no established analytical framework for analyzing the data that were collected.[23] 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: "It is true that suggestions of a faint periodicity have been found in some regions of the globe, but it is still the general belief that the vicissitudes of rainfall, if not wholly fortuitous, are so intermingled with the variations of pressure, temperature, etc., that no satisfactory solution of the problem will be reached until the greater problem of the general circulation of the atmosphere has been solved...We can do not more than present the facts as they exist. The treatment of this subject has necessarily, been superficial, and, in a measure, unsatisfactory. It has not been possible, nor is it believed to be desirable to undertake, with the data available at present, a systematic investigation of the underlying causes of rainfall variation, but rather to carry along such an investigation in connection with other studies of the general atmospheric circulation."[24]

Migrants to the Great Plains after 1880 had especially limited information about the climate of the region. Although the Weather Bureau collected precipitation data for the Great Plains, the data generally were intermittent and incomplete for most of the 19th century.[25] 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.

Under these conditions, "folk" theories emerged regarding the weather of the Great Plains. "Rain follows the plow" was the most influential model for explaining the weather of the region. The theory argued that rainfall was endogenous to human activity. Very early observations suggested that the frequent movement of transcontinental trains stirred the atmosphere and changed the flow of moisture, increasing precipitation in the plains that otherwise would have traveled further east before falling.[26] Planting trees with settlement 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.

Chroniclers of western settlement conditions commented on the proliferation of springs, larger stream and river flows, and new, more luxurious vegetation that accompanied the plowing of the plains. As early as 1844, Josiah Gregg reported that droughts were becoming less oppressive in the West and that rains had increased in New Mexico where he lived. He attributed the climate change to civilization and associated cultivation, including the planting of "shady groves."[27] In1867 Ferdinand Hayden, Director of the U.S. Geological Survey of the Territories informed the Secretary of the Interior that the climate could be changed if each settler planted 10 to15 acres of trees on each 160-acre plot.[28] Bayard Taylor of the New York Tribune wrote in June 1866 that "cultivation" would "subdue" the arid belt between Kansas and Denver.[29] In Nebraska, Samuel Aughey (1880, 40, 42) claimed with rising rainfall that nowhere in North American do conditions exist for "genuine desert conditions"and concluded that "the proofs, therefore, that the rainfall of Nebraska is steadily increasing, are manifold."[30] Charles Francis Adams, editor of The Nation in 1887 stated: "Consequently, there seems no good reason for doubting that the entire area of county west of the Missouri and east of the Rockies will within a few years enjoy a rainfall sufficient to admit of raising of crops without any considerable degree of artificial irrigation."[31]

The notion that rainfall would increase with settlement fit nicely with the optimism and sense of manifest destiny that were associated with the western frontier. The civilizing taming of the wild prairies would lead not only to the establishment of small farms for the "home seeker," but to the benevolent transformation of the climate and the creation of a breadbasket from what

had been a desert.[32]

By the late 19th and early 20th centuries, the idea that cultivation would affect precipitation was dismissed by many, but not all. Some Weather Bureau officials concluded that the climate did not change perceptively due to human activity.[33] In the 1896, irrigation proponent, F. Newell 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."[34] In 1901 Willard D. Johnson of the United States Geological Survey cautioned against "fruitless and demoralizing movements of population" into the Great Plains under the mistaken belief that "a radical change of climate" was taking place.[35] E.C. Chilcott, Chief of the Office of Dry Land Agriculture in the Department of Agriculture rejected the argument that the climate was changing.[36] These skeptics, however, offered 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. Moreover, there was never a concerted effort to change the views of homesteaders who might have thought that rainfall was increasing.[37] As late as the 1909 Dry Farming Congress held in Cheyenne, Wyoming, the issue of a permanent climate change due to cultivation was still debated.[38]

Homesteaders to western Kansas in the late 19th century and to eastern Montana in the early 20th century may or may not have believed that rain followed the plow, but these settlers were risk takers, and they had little basis for making judgements about current or future precipitation levels or to evaluate the likelihood of drought cycles.[39]Even in the 1930s, it was concluded that there was no simple rainfall pattern that lent itself for drought predictions in the Great Plains.[40] Accordingly, migrants to this semi-arid region did not perceive the precarious

condition of the crops they planted or the farms they founded.[41]

Figure 1 illustrates climatic conditions facing homesteaders. It shows precipitation levels for Ohio, western Kansas, and eastern Montana from 1895 through 1947, a period where we have comparable data.[42] The figure shows the disparities that existed between an area of origin for homesteaders and their frontier destination. Notice that precipitation was not only always higher in Ohio, but that when it fell, it remained above that found in western Kansas and eastern Montana. In Ohio, even in 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. 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 Ohio, 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.

Figure 1

Table 1

III. The Kansas Homestead Bust, the First Major Homestead Failure on the High 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."[43]

Farmers could use familiar farming techniques and grow the same 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.[44]

Figure 2 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.[45] 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 26.7 percent and the number of farms declined from 14,311 in 1890 to 8,952 in 1900, a drop of 37.4 percent.[46]

Figure 2

The homestead failure of western Kansas and Nebraska following the drought of 1893-94 did not detour subsequent migrants from settling in small farms in other parts of the 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. Relatively few homesteaders to eastern Montana came from Kansas or Nebraska, so that most settlers did not have direct experience with the drought. Further, there was little systematic means of communicating information to prospective settlers about droughts. 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. Cautions were limited and buried in the optimism about the prospects for settlement in the region. Indeed, most organizations were stressing a different factor, dryfarming technology, that promised to limit the impact of any future drought on agricultural prospects on the Great Plains[47]

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

Dryfarming, or scientific soil culture, gained prominence after 1906. Dryfarming was an agricultural doctrine for cultivation of land in semi-arid regions. The most prominent communicator of dryfarming techniques was Hardy Webster Campbell who published a series of monographs (1902, 1907, 1914, 1916). Besides Campbell, there were other advocates of the new, practical science of dryfarming, including John Widtsoe, (1911), President of the Utah Agricultural College and formerly head of the Utah Experiment Station; B.C. Buffin (1909), Professor of Agriculture at the Universities of Wyoming and Colorado Agricultural College and Director of the Wyoming Agricultural Experiment Station; 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).[48]

These writers emphasized their academic credentials and experience, and presented their recommendations with references to the use of experimental techniques, control plots, precise measurement, data collection, and practical testimonials.[49] 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 principles were examined in USDA bulletins and an Office of Dry Land Agriculture was created in 1905.[50]

Dryfarming was a manifestation of the Progressive Era. It stressed an evolutionary march of progress made possible through the practical adoption of science to advance human welfare: "dry-farming was moving onward to conquer the waste places of the earth."[51] With the introduction of dryfarming, vast areas could be opened for settlement, not only in America, but throughout the world. Arid regions previously thought too hostile for crops without irrigation could be transformed so that farmers could grow wheat and other crops in "the natural habitat of cactus."[52] Food production could be increased at a time when there were concerns of impending shortages of food and various raw materials.[53] Finally, because it was so labor intensive, but promised such high yields, dryfarming encouraged formation of small family farms.[54]

The emergence of dryfarming principles occurred at a time of political conflict over the distribution of the remaining federal estate and whether the land laws should be relaxed sufficiently to allow very much larger homesteads of 1,250 acres or more as advocated by John Wesley Powell.[55] Those who promoted Campbell's dry farming techniques strongly supported the maintenance of the small farm homestead and successfully fought major changes in the land laws. Minimal adjustments were made in 1909 and 1912 to allow for 320 rather than 160 acres and to reduce the residency requirement from 5 to 3 years.[56]The question subsequently encountered was whether such small farms of 160 or 320 acres could be viable during serious drought.

Although the identification and use of adaptable plant varieties were part of dryfarming, the key notion was the use of the soil to store water, some times four to ten feet under ground. The stored water was hypothesized to percolate upward via capillary action toward the surface to

nourish plant roots.[57] 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.[58] The subsurface packer and other specialized implements were recommended by dryfarming advocates.[59] Too much evaporation, rather than too little rainfall was asserted to be the critical problem in semi-arid regions.[60] Diligent adherence to these practices would increase yields in wet years by providing plants with the right amount of moisture and sustain reasonable yields during droughts.[61]

Through the use of scientific dryfarming techniques, sharp fluctuations in agricultural yields were no longer to be the natural consequence of the vagaries of rainfall, but rather the result of a failure of farmers to follow the proscribed practices. It was a choice variable. To achieve the success that could be possible, dryfarming advocates stressed that "eastern farmers must *'unlearn'* what he knows of farming."[62] Close attention to the doctrines promised mastery over nature. The occasional dry year was not considered serious for those who practiced proper farming methods: "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."[63]

The assertions of dryfarming proponents might have been dismissed at an earlier time, but at the turn of the century there was an optimistic faith in the ability of science and technology to remove natural constraints and to eliminate waste and inefficiency in the economy.[64] Dryfarming also was introduced at a time when there were no serious droughts, but rather, relatively abundant rainfall, at least in the upper Great Plains. Hence, its doctrines were not put to test until 1917. Dryfarming principles were so attractive that they were emphasized by virtually every

organization supplying information to homesteaders on the Great Plains between 1900 and 1920.

Agricultural Experiment Stations and Dryfarming.

Dryfarming appeared just as the big homestead boom in eastern Montana and the western Dakotas was getting under way. Its principles were extended and communicated to farmers by the agricultural colleges and their experiment stations in the upper Great Plains.[65] The Montana Agricultural Experiment Station organized Farmers' Institutes to bring together farmers and experiment station personnel. At least one meeting was held in each county annually.[66] During 1901-2, 17 institutes were held, and by 1907, 154 were convened across Montana, with 12,000 farmers in attendance.[67]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 with dryfarming. During droughts, lower, but adequate yields could be maintained[68] 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.[69] The Northern Pacific, Great Northern, Chicago, Burlington and Quincy, and Milwaukee railroads provided demonstration trains and contributed funding for dryfarming investigations.[70] State and railroad support for dryfarming experiments continued to rise between 1909 and 1914.[71]

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.[72]The publications were optimistic in their prescriptions for the success of small dry land homesteads, and they repeated or closely followed the principles advocated by Campbell, Widtsoe, Buffin, and others.[73] Climatic information for Montana stations through 1913 was listed by Cooley (1912) and Linfield (1914). Most of the time series reported began in 1898 or thereafter so that the information record for precipitation was fairly short, ten years or less. Even so, rainfall was taking secondary importance because of the emphasis on moisture conservation through the use of dryfarming technology. Changes in rainfall due to cultivation were not emphasized in experiment station reports, although some other sources of information continued to point to the possibility of a permanent change in climate.

Prospective settlers commonly wrote to the experiment station requesting information on the availability of lands to homestead, land values, the types of crops to plant, cultivation practices, the weather (especially rainfall), the capital requirements to start a new farm, and the location of other sources of information. Judging by the volume of letters in the archives, correspondence was a major activity of agricultural extension station personnel. They not only answered questions, but referred homesteaders to dryfarming books, such as the one by Buffin (1909), the publications of the Dry Farming Congresses, and periodicals like *Dakota Farmer*, *Scientific Farmer*, *Montana Farmer*, and *Western Farmer*, all of which published dryfarming articles.[74] The experiment station also distributed copies of its bulletins describing dryfarming practices as part of its correspondence.[75] Because they actively supplied basic data on the climate and dry farming options, the experiment stations were the most important source of information for homesteaders on the upper Great Plains.

The U.S. Department of Agriculture and Dryfarming.

The Department of Agriculture was more cautious than were the experiment stations in prescribing particular dryfarming practices or crops. 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. For example, summer fallow, which was a central part of dryfarming doctrine, was argued to be costly, effective only under certain circumstances, and conducive to blowing.[76] Further, some USDA experiments did not locate appreciable movement of water in the soil, which was a key claim of dryfarming advocates. E.C. Chilcott, head of the Office of Dry Land Agriculture was Campbell's chief critic.[77] Chilcott, Cole, and Burns (1915) summarized results from 14 field stations in North Dakota, Montana, Nebraska, Colorado, Kansas, and Texas and concluded that unfavorable climatic conditions could result a major yield decline, regardless of crops planted or cultural methods used, a conclusion contrary to the most optimistic claims made by Campbell and others. Even so, the conclusion does not appear to have been widely circulated. Alfred Atkinson of the Montana Experiment Station urged the USDA to be more active in disseminating its studies and to attend the 1910 Dry Farming Congress in Spokane. He argued that the experiment stations and USDA had "not made full provision for getting into the hands of these new farmers the statements regarding the best known methods. Unlike humid agriculture, dry land agriculture demands that the essentials must be observed if success is gained."[78]

Chilcott was not equally critical of experiment station studies that were more narrow in focus with controlled experiments, even though their findings supported dry farm homesteading. Indeed, the USDA saw its role as supplementing the experiment stations, and its technical publications tended to mirror state experiment station reports in emphasizing what was possible

with dryfarming techniques.[79] Further, the Department did not strongly counter dryfarming assertions, 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.[80] Even Chilcott (1910) released the results of USDA dry land investigations conducted after 1906 that recommended alternate cropping and summer tillage. Small homesteads of 160 acres were supported. Hence, the USDA lacked a consistent position on dryfarming, and any homesteader who read the technical reports would have seen little that differed from experiment station publications.[81]

Dry Farming Congresses and Dryfarming.

Dry Farming Congresses were organized to disseminate information about dryfarming techniques and the opportunities they created for homesteaders and to lobby Congress and the states for supportive land policies.[82]They were most active during homestead migration to the upper Great Plains, 1906-1916, which was also a time of high rainfall and success for dryfarming doctrine. Congresses were held 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. They 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.[83]

The information-sharing objective of the congresses was outlined at the Fourth Dry Farming Congress in Billings, Montana, October 26-28, 1909: "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; to encourage the use of methods by which in districts where

rainfall is slight, or irrigation water is limited, the actual productive acreage can be increased, to create closer co-operation between the government and state experts in charge of Dry Farming Experimental work and the actual farmers of the arid districts."[84]The assemblies were addressed by experiment station personnel, leading dry farm proponents like Hardy Webster Campbell and Thomas Shaw, and local politicians, such as the Governors of Colorado, Montana, and Wyoming. The presenters outlined the opportunities afforded through dry farming, new crops to plant, practical information regarding cultivation, the results of experiment station studies, and testimonials from "experienced"dry farmers.[85]As such, the Dry Farming Congresses were another important source of information about dryfarming techniques for homesteaders.

Local Government Agencies and Institutions and Dryfarming.

Prospective homesteaders on the upper Great Plains also received publications from state agencies, such as the Montana Bureau of Agriculture, Labor and Industry, later the Department of Agriculture and Publicity. Until 1904 and the shift of emphasis to dryfarming, the Montana agency stressed irrigation opportunities in the state. With the publication of the 1904 report and the inauguration of a section titled, "Dry Land Farming" and thereafter through 1918, however, the agency promoted the opportunities provided by dryfarming. The 1906 report noted that in 15 years of wheat farming in Cascade County in eastern Montana there had never been an entire crop failure on non-irrigated farms, although droughts could cut yields in half.[86]Beginning in 1908, dryfarming was advertised as the poor man's alternative to expensive irrigation in federal reclamation projects.[87]The agency also provided lists of monthly precipitation, county population, land values, spur railroad lines, and crops to plant, including winter and spring wheat, oats, rye, barley flax, peas, "prolific potatoes,"watermelon, alfalfa, sugar beets, all of which "could be

grown without the hazard of failure even in a dry year, providing they have been planted in season and properly prepared land."[88]Practical information for homesteaders regarding the use of the federal land laws, location and amounts of available federal land, and lists of recent homestead entries were included. Additionally, the reports announced the results of experiment station dryfarming tests, included primers on how to use the Campbell method to conserve soil moisture, and described the prizes won at international agricultural fairs, such as the Panama-Pacific International Exposition in San Francisco where Montana won the grand prize for cereals.[89] Specific reference to recent experiment station publications on dryfarming was made.[90]

Any prospective homesteader who had examined the experiment station and USDA publications and attended or read material from the Dry Farming Congresses would have found confirmation in the agency's publications. There were similar state agencies elsewhere in the Great Plains, such as in North Dakota and Kansas.[91]

Besides state agencies, local communities, land developers, and professional homestead locators advertised the advantages of their dry farming regions to migrants. For example, the Glasgow (Montana) Commercial Club claimed that the local land was "very productive without irrigation and the increased yields by irrigation makes it one of the richest valleys in the world." Developer W.M. Wooldridge's circulated a two-page flier for Hindsdale, Montana, "a new town on the main line of the Great Northern Railway" in April 1904, and E.B. Milburn's flier, "Eastern Montana Farm Lands" summarized crops grown, comparative yields, rainfall, private and government land availability, agricultural prizes won, and testimonials from satisfied farmers "who are glad they came to Montana."[92]

The Railroads and Dryfarming

Most historical accounts of homesteads and their subsequent failure point to the railroads as having misled settlers with extravagant claims about dryfarming prospects.[93] The railroads, however, could not have been mere publicists, indifferent to the outcome of homestead migration. The railroads adopted agricultural development in order to promote the settlement of their service areas, and in the case of the Northern Pacific, to sell land. They had to address the difficult conditions of the region if a sustained population were to be promoted. Widespread failure of agriculture would have reduced the attractiveness of the area and hence, the value of railroad investment in the upper Great Plains. Trains, and particularly, tracks and yards were site-specific capital investments with little alternative uses. Hence, the railroads had a stake in the permanent, not temporary, success of the region. And they had no better information about the weather or dryfarming prospects than did the experiment stations or USDA. Dryfarming offered a solution to the problem of settling their lands, and they invested in experiments, demonstration farms and trains, and publicized its advantages. And through 1916, with abundant rainfall, dryfarming experiments continued to show promise. Only with the drought after 1917, was dryfarming doctrine shown to be an insufficient solution, and after that, railroad promotion was much more cautious.[94]

The Northern Pacific argued in 1911 that "Good farming, good methods of cultivation, intelligent tillage of the soil, should be the slogan of the Northwest. Investigations demonstrate that thorough and intelligent cultivation means *more* than the particular amount of rainfall in regions which are classed as sub-humid or semi-arid. The fact has been demonstrated beyond any reasonable doubt that the yields of the various grains can be greatly increased and often doubled, by the intelligent cultivation of the soil, and not only increased in amount but the yield rendered

sure."[95]

The railroads relied upon both private demonstration farms and the state experiment stations to conduct dryfarming investigations. The railroads hired dryfarming experts like Hardy Webster Campbell and Thomas Shaw to perform experiments and to establish a rapport with farmers for the transfer of practical dryfarming techniques.[96] The Rock Island named Henry M. Cottrell, authority on dry farming and director of the Colorado Agricultural Experiment station and who had been involved in the Colorado Farmers' Institutes to head its agricultural development department in 1914. The results of dryfarming investigations and testimonials from farmers were advertised throughout the Midwest, East, and Europe to substantiate claims that were made about the advantages of homesteading the upper Great Plains.

The railroads provided farmers with cuttings and crop seeds that seemed suited to the northern plains at cost.[97] Immigration departments were created, and immigrant trains provided a low-cost means of transporting household goods and farm equipment and animals for settlement.[98] Free transportation to Farmers' Institutes and demonstration trains were sent out to spread the word about moisture-saving techniques. For example, the Chicago, Burlington, and Quincy sent out a Better Farming Special train to 65 towns in Montana, Wyoming, South Dakota, and Nebraska. Finally, the railroads lobbied Congress to liberalize the land laws for the adjustments in the land laws to allow for shorter residences and somewhat larger homestead claims.[99]

Given the lack of understanding of the region's climate, the apparent advantages made possible by dryfarming, described by virtually all sources of information–the railroads, state and local governments, Dry-Farming Congresses, the USDA, and the experiment stations, and high rainfall and yields through 1916, it is understandable why homesteaders moved to the upper Great

Plains with such optimism. And they continued to arrive even as the onslaught of drought began in 1917.

V. Homestead Settlement, Yields, Precipitation, and Frontier Failure in Eastern Montana: Available Information, Priors, and the Decision Process.

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. Original homestead entries which had averaged 3,874 between 1903 and 1909, jumped to 21,982 in 1910 and remained well above the pre-1910 average through 1921(*change1903 to 1900). After that, homesteading declined considerably so that in 1925 there were only 1,180 new homestead entries. All told, between 1900 and 1921 some 191,796 original homestead claims were filed.[100] With 67,963,057 acres of available government land in 1900, Montana alone had over 7 percent of all unappropriated federal property that could be claimed by homesteaders. And they did so rapidly, reducing unappropriated federal land to only 5,659,879 acres by 1922.[101] 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.[102] Figure 3 describes original homestead entries in Montana during the period 1903 through 1930.[103]

Figure 3

The timing of boom seems due to both the federal land law changes in 1909 and 1912 that doubled the homestead allotment and reduced the waiting period for receiving title, as well as the gradual extension of railroad lines. Although the Northern Pacific and Great Northern Railroads

had crossed Montana in the 1880s, they added to the main and branch lines after 1900 and the Chicago, Milwaukee, and St. Paul Railroad entered Montana in 1907 and 1908. In 1900 there were 2,932 miles of mainline track in Montana. By 1903 that number had increased to 3,131 miles, plus 667 miles of side track. In 1910 there were 4,054 miles of mainline and 1,167 miles of side track, and by 1915 mainline track had grown by an additional 12 percent to 4,589 miles and side track had increased by 19 percent to 1,384 miles.[104]Railroads were the primary mode of transportation. They provided access to potential homesteads and linked those homesteads to markets. New towns along the main and side lines were founded for the anticipated growth in population.[105]Wheat prices (the crop most likely to be grown by homesteaders) rose moderately from 1900 to 1914 and then doubled from their 1914 level by 1917. Wheat acreage (the most valuable crop) expanded from 72,555 acres in 1900 to 3,621,000 acres in 1919.[106] Most of the agricultural expansion occurred in the eastern two-thirds of the state.

The attractiveness of Montana also was stimulated by high wheat yields due to farming previously untapped soils and unusually abundant rainfall during the period 1906 through 1916. Figure 4 describes Montana wheat yields and Table 2 compares them to yields in other states. The table shows that Montana yields were consistently above those of the Midwestern states of Ohio, Illinois, and Kansas until 1917. Montana yields remained above 20 bushels per acre from 1891 through 1914. They began to drop in 1915 with settlement of less favorable terrain, but did not collapse until after the drought of 1917 drove yields to 2.7 bushels per acre by 1919.

Figure 4

Table 2

Figure 5 describes rainfall from 1895 through 1925 in eastern Montana where most

homesteads were located.[107] Except for one-year droughts in years 1904 and 1910, most of the period through 1916 is one of precipitation at or above the mean. The drought of 1917-1921, however, stands out both for the severity of the precipitation shortfall and for its length. 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.[108] When the drought came homesteaders found that despite what they had concluded from the available information, droughts could last longer and be more severe than they had anticipated; that moisture could not be stored in the ground through dryfarming techniques in sufficient amounts for a long enough period to save their crops; that instead, irrigation was necessary to reduce the variability of yields; that their farms were far too small to be viable; that they needed larger, more diversified crop/livestock mixes; and that many would have to migrate again, leaving their abandoned farms as testimony to the importance of rain in a semi-arid region.

Homesteader decisions for migrating to eastern Montana, for establishing small farms of 160-320 acres, and for planting crops each year can be viewed as Bayesian process.[109]Because of the high degree of uncertainty that existed on the frontier, homesteaders evaluated current conditions within the context of their prior beliefs, which were heavily influenced by the information provided them from the agricultural experiment stations, railroads, state agencies, the Dry Farming Congresses, and other farmers, as well as their own experiences. From these sources homesteaders developed opinions about wheat yields, rainfall, homestead sites, dryfarming techniques, and their likely ability to endure droughts. Because a settler would not know the "true" condition at the time of the decision, these priors played an especially important role in

their actions.

A dry year would present a puzzle. If it were viewed as an indication of longer-term deteriorating prospects for yields, migration to the region would be less attractive for new settlers and incumbent farmers would reconsider the returns from remaining on their farms. If it were viewed, instead, as an aberration that could be managed with dryfarming techniques, then migration would still take place and existing farmers would continue to plant. Favorable priors would lead homesteaders to discount a dry year, especially if credible sources reassured them. Their priors would be reinforced if the dry year still brought reasonable yields and was followed by a rebound in rainfall and production. If a dry year, however, were followed by yet another one, priors would be reassessed. If priors were very strongly established, then two or more periods of drought might be discounted, encouraging continued migration and farming, even in the face of observed unattractive returns. Additional poor harvests, however, would lead favorable prior beliefs priors to be down graded, discouraging migration and encouraging farm abandonment.

Accordingly, a Bayesian decision process would have the following framework:

$Priors_t = f(yields_{t-1..n}$, price of $wheat_{t, t-1..n,}$, dryfarming $information_{t, t-1...n})$

$Yields_t = f(precipitation_{t, t-1}$, soil $quality_t)$

Homestead $migration_t = f(priors_t$, available federal $lands_t$, cost of $migration_t)$.

Prior beliefs about the financial returns from dry land wheat farming would be influenced by current and past yields, wheat prices, and dryfarming doctrine. Similarly yields would be determined by precipitation and soil quality. Dryfarming doctrine asserted that past precipitation could be saved for current use. Homestead migration would be a function of prior beliefs, available federal lands for homestead claiming, and the costs of migration.

We have sufficient data to estimate two equations for the period 1895 to 1925 for Montana that are consistent with a Bayesian process:

(1) Original Homesteads$_t$ = b_1 + b_2Federal Land$_t$ + b_3Yields$_{t,\,t-1}$ + b_4Wheat Price$_{t,t-1}$ + b_5Federal Law Change + e,

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

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

where land quality is represented by available surveyed federal land. Of the total federal land available for claiming there was surveyed and unsurveyed land. Absent a measure of soil quality, we assume that General Land Office surveyors would survey the best or most productive lands first because those would be most desirable to homesteaders. We included current rainfall and rainfall from the previous year to test dryfarming claims that past rainfall could be stored to plant use.

Table 3 provides the results of the OLS estimation. In terms of 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 95 percent or better. Total federal lands available for homesteading also encouraged new entries with significance at approximately 90 percent.[110] The current price of wheat and wheat yields also stimulated claiming, although at lower levels of significance. 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. Wheat yields, in turn, are strongly influenced by land quality as proxied and current rainfall. The previous year's rain had little impact on current production, under cutting the dryfarming notion that rainfall could be stored from year to year.

A Bayesian framework also can help explain the lagged response of homesteaders to drought in eastern Montana. The drought appeared with little notice, beginning with a dry spring in 1917.[111] Optimism remained high and there was no initial adjustment in farming practices or settlement. 53,366 additional new homestead entries were filed between 1917 and 1925, with most between 1917 and 1920. 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.[112] The number of farms in Montana also grew between 1916 and 1920 before declining gradually by 1925.[113] By the end of 1919, after three years of drought and after average wheat yields had dropped to 2.7 bushels per acre, down from 26.5 bushels in 1915, however, prior beliefs about the viability of small homesteads were finally revised. Homestead abandonment began. Between 1919 and 1925, some 60,000 homesteaders are claimed to have left the state, with over 11,000 farms failing and approximately 2,000,000 acres of land going out of production.[114]

Dryfarming doctrine did not change until 1919. During the early stages of the drought, the Montana experiment station continued to be optimistic about homesteading prospects. In July 1917 Alfred Atkinson of the 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. He also suggested that the homesteader bring $2,500 to $3,000 to start a farm. 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."[115] No one knew that the drought would continue and become even more severe. 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."[116]

The two short-term droughts in 1904 and 1910 in eastern Montana had been accommodated with little hardship, and this experience validated the claims of dryfarming advocates that the new techniques could successfully store enough water in the soil to carry a small farmer through a drought year. In commenting on the potential for dry-land agriculture in Cascade County in eastern Montana, the Montana Department of Agriculture, Labor, and Industry (1906, 311) minimized the effects of drought claiming that in 15 years there had never been a complete crop failure. A Milwaukee Railroad publication (1912) included a testimonial from a settler in Musselshell, County in the east, who commented on the success of dryfarming after the drought of 1910 : "...Taking into consideration the remarkable dry season we just passed through I am now perfectly satisfied that good paying crops can be raised on the dry land principle..."[117]The head of the Northern Pacific Railroad in 1910 also provided a similar assessment of the ability of farmers to withstand a drought through the use of dryfarming techniques.[118]

In 1918 the dry period continued, but since two years of drought had not been observed

previously (Figure 5), three dry years seemed even less likely.[119] But by 1919, the unusual duration of the drought was finally acknowledged by the experiment station: "Weather conditions beyond the expectation of any student of weather reports the past 40 years in this state have fallen upon Montana..." For the first time, the experiment station indicated doubt about the ability of dryfarming techniques to guarantee at least a moderately successful crop.[120] In a further shift, by 1920 the experiment station was claiming that drought could be expected "rather frequently, "and by 1921 dryfarming doctrine was called into question.[121]Small dry-land homesteads were criticized for having been inappropriate. Experiment Station Director Linfield claimed that the distribution of marginal lands via the homestead acts was 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.[122]

Although dryfarming doctrine had downplayed the importance of annual rainfall in determining the success of dry land farms, the data in Table 4 illustrate how difficult it would have been for homesteaders to have predicted the drought of 1917-1921 and its longevity, based on the rainfall experience of 1906-1916. The table shows the mean and variance of precipitation in eastern Montana for ten-year intervals between 1895 and 1947. The coefficient of variation is significantly different for the period 1906-1916 from the longer period of 1895-1947. A two-tailed t-test shows that there is only a 3 percent probability that sample of precipitation during 1906-1916 came from the same distribution of the 1895-1947.

VI. 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 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 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.

The climate of the Great Plains was not well understood in general, and there was only a primitive understanding of the mechanisms that led to droughts. Early on, there was the hope that rainfall would follow the plow, but the drought of 1893-94 in western Kansas and the abandonment of dry land homesteads tempered that notion. But by 1900, rainfall was seen as less important for small farm success if particular dryfarming techniques were followed. Dryfarming methods to conserve soil moisture were promoted widely by agricultural experiment stations, Dry Farming Congresses, state and local government organizations and private groups, and to a lesser degree, the USDA. The results of experiment station tests as illustrated in demonstration farms and publicized in bulletins and circulars and described at Farmers' Institutes, seemed to validate dryfarming claims. The Montana tests were conducted on comparatively untapped, productive soil during a period of unusually high rainfall, where only one-year droughts were experienced.

Dryfarming promised to extend the frontier by opening lands that previously had been thought beyond the fringe of unirrigated agriculture. At a time when wheat prices generally were rising, dryfarming also meant that small homesteads could share in the wheat bonanza. Small dry-land homesteads were seen as a viable alternative to irrigated farms, and the modifications of the federal land laws to allow for larger homesteads of 1,250 acres or more, were effectively blocked.

When the long and deep drought of 1917-1921 appeared, small dry-land farms failed. In subsequent evaluations by the USDA and other government agencies, U.S. land policy in general and small homesteads in particular were criticized as being inappropriate for 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, 2/3's were below 360 acres, when at least 700 to 800 acres were deemed necessary for minimum cost production.[123] By contrast, 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 some 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.

By the mid 1930s, these "successful" farms represented the outcome of a transitional process of initial homestead consolidation that began in 1917. The costs of this transition included the lost alternative incomes failed homesteaders might have earned while they attempted dry land farming, redundant farm buildings, cultivation of submarginal lands 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. Migrants to the upper Great Plains between 1900 and 1920 made decisions based on the best information at hand. This information was supplied to them from a variety of credible sources with no serious reservation from any quarter. To the degree that there was an agricultural "policy" for the Great Plains

between 1900 and 1919, it was dryfarming, and homesteaders cannot be blamed for following its recommendations. Homesteaders were encouraged to migrate to the region, to found small farms and to focus on wheat production. They continued to do so, even as the drought began in 1917 and a major re-evaluation of prospects did not occur until the end of 1919 after three years of drought and a revision of dryfarming doctrine. Had homesteaders understood the weather better they might not have accepted the claims of dryfarming advocates. And had dryfarming tests occurred under less favorable circumstances, its doctrine might have been more circumspect. Land laws might have been revised and fewer homesteaders might have gone to the Great Plains after the turn of the century.

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