Small Farms, Externalities, and the Dust Bowl of the 1930s

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We provide a new and more complete analysis of the origins of the Dust Bowl of the 1930s, one of the most severe environmental crises in North America in the twentieth century. Severe drought and wind erosion hit the Great Plains in 1930 and lasted through 1940. There were similar droughts in the 1950s and 1970s, but no comparable level of wind erosion. We explain why. The prevalence of small farms in the 1930s limited private solutions for controlling the downwind externalities associated with wind erosion. Drifting sand from unprotected fields damaged neighboring farms. Small farmers cultivated more of their land and were less likely to invest in erosion control than larger farmers. Soil conservation districts, established by the government after 1937, helped coordinate erosion control. This "unitized" solution for collective action is similar to that used in other natural resource/environmental settings.

> In the morning the dust hung like fog, and the sun was as red as ripe new blood. All day the dust sifted down from the sky, and the next day it sifted down. An even blanket covered the earth. It settled on the corn, piled up on the tops of the fence posts, piled up on the wires; it settled on roofs, blanketed the weeds and trees. [John Steinbeck, *The Grapes of Wrath* (1939, p. 6)]

> One man cannot stop the dust from blowing but one man can start it. [Farm Security Administration, September 12, 1937][1]

I.   Introduction

The Dust Bowl of the 1930s was one of the most severe environmental crises in North America in the twentieth century.[2] Severe drought and damaging wind erosion hit in the Great Plains in 1930 and lasted through 1940. Strong winds blew away an average of 480 tons of topsoil per acre, degrading soil productivity, harming health, and damaging air quality. The leading historian of the Dust Bowl, Donald Worster, described it in the following way: "In no other instance was there greater or more sustained damage to the American land, and there have been few times when so much tragedy was visited on its inhabitants. Not even the Depression was more devastating, economically … in the decade of the 1930s the dust storms of the plains were an unqualified disaster" (1979, p. 24).

Similar droughts and wind occurred later in the 1950s and 1970s in the Great Plains, but there is a general consensus among soil conservationists that there was no comparable level of erosion.[3] Excessive cultivation of land in the 1930s, exposing dry soil to the wind, is the standard explanation for the Dust Bowl.[4] The issue to be explained is why cultivation was more extensive and use of erosion control techniques more limited in the 1930s than later in the twentieth century.

Our contribution is to analyze wind erosion as a common-pool prob-

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[1] Farm Security Administration, "The Great Plains Yesterday, Today and Tomorrow," M. L. Wilson Files, Merrill G. Burlingame Special Collections, 00002, box 32, Montana State Univ., Bozeman.

[2] See Bonnifield (1979), Worster (1979), Hurt (1981), and esp. Gutmann and Cunfer (1999). Contemporary wind erosion is examined by Colacicco et al. (1989), Ervin and Lee (1994), and Pimentel et al. (1995).

[3] See Borchert (1971, p. 5), Rosenberg (1980, p. 121), Hurt (1981, pp. 145–54), and Changery (1983, p. 1). Data analyzed by Stout (2001) for Lubbock, Texas, indicate a long-term decline in wind erosion from 1961 through 1982 and 1999.

[4] See Kellogg (1935), Bennett (1939, pp. 729, 738–42), Johnson (1947, pp. 135–54), and Worster (1979). More generally, cultivation practices are viewed as important contributors to erosion (Lee, Wigner, and Gregory 1993; Lee and Tchakerian 1995).

lem. We focus on the effects of numerous small farms on the Great Plains in the 1930s for combating erosion during the Dust Bowl. In contemporary erosion research, farm size is shown to be an important factor in soil conservation (see Frey 1952; Korsching et al. 1983; Lee and Stewart 1983; Rahm and Huffman 1984; Norris and Batie 1987). Small farms are associated with more intensive cultivation, less frequent use of conservation practices, and greater soil erosion.[5]

   We concentrate on the downwind externalities from a farmer's failure to shield cultivated fields. Blowing sand from an unprotected farm smothered the lands and crops of leeward farms, lowering their productivity and reducing returns from their erosion control investments. These cross-farm effects were intensified by the presence of many small farms in an erosion-prone region. There were differential incentives according to farm size for investing in conservation practices, such as strip cropping and fallow. We examine the effect of cultivation intensity associated with farm size on observed variation in the severity of erosion across the Great Plains. The optimal farm size for productive efficiency was smaller than for wind erosion control, and hence, coordination among farmers was necessary. The "unitized" solution for collective action was provided by soil conservation districts adopted after 1937.[6] Our analysis provides a new and more complete explanation for the origins of the Dust Bowl.[7]

II.   The Dust Bowl

A drought that was unprecedented in the twentieth century began in the northern plains in 1930 and gradually spread south, covering the entire region through 1940. Strong winds, characteristic of the area, blew across dry, cultivated soil, generating dust storms of unparalleled number, duration, and scale. Many dust storms were local, defined by topographical boundaries, including erodible soil texture, watersheds, and hills, but very intense weather systems also brought huge blasts that covered hundreds of miles and lasted 10 hours or more (Clements 1938).

   Some figures illustrate the extent of wind damage in the Great Plains. Light, fertile topsoil became airborne and was carried far away. This

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[5] See Gross and Taves (1952), Marsh and Coleman (1955), Pampel and van Es (1977), Napier et al. (1984), Ashby (1985), Nowak (1987), Camboni and Napier (1993), and Napier and Sommers (1994). See also the development literature (Berry and Cline 1979; Cornia 1985; Feder 1985).

[6] The analogy is to oil field unitization (Wiggins and Libecap 1985; Libecap and Smith 1999).

[7] Economists have not examined the Dust Bowl as a common-pool problem. We use the term "Dust Bowl" to describe wind erosion throughout the Great Plains in the 1930s, rather than focusing on a particular area of intense erosion.

material was critical for dryland wheat farming, which dominated the plains. Each loss of soil from successive windstorms removed more plant nutrients, until the remaining ground was heavy and relatively sterile (Stallings 1957, pp. 203–4). Samples of soil carried 500 miles from Texas to Iowa had 10 times as much organic matter, nine times as much nitrogen, 19 times as much phosphoric acid, and 45 percent more potash as compared to the soil that remained (Thornthwaite 1936, p. 240; U.S. Department of Agriculture 1938, p. 71; Bennett 1939, p. 118). In his book on the Dust Bowl, Vance Johnson (1947, pp. 194–95) estimated that in 1935 alone, 850 million tons of topsoil had blown away from 4,340,000 acres. Soil erosion surveys by the Soil Conservation Service (SCS) in 1934 indicated that 65 percent of the total area of the Great Plains had been damaged by wind erosion and 15 percent severely eroded. By 1938, the agency claimed that 80 percent of the land in the southern plains had been subject to wind erosion, with 40 percent to a serious degree. As much as 10,000,000 acres had lost the upper 5 inches of topsoil, and 13,500,000 acres had lost 2.5 inches, with an average loss of 480 tons of topsoil per acre. Hugh Bennett (1939, p. 11), the first director of the SCS, estimated productivity losses from erosion at $400 million annually.

Other costs of wind erosion included destruction of nearby crops and farmland from the localized deposit of heavier eroded material (sand); damage to livestock, buildings, household goods, and merchandise; and health problems associated with inhalation of dust particles. Claims of greater incidence of pneumonia, asthma, influenza, and eye infections were reported from Dust Bowl counties in Colorado, Kansas, New Mexico, Oklahoma, and Texas.[8] Similarly the chambers of commerce of towns located in the region estimated that the costs of damage wrought by blowing sand and dust from each storm ranged from $50,000 (Liberal, Kans.) to $288,228 (Tucumcari, N.M.).[9]

Figure 1 illustrates the range of wind erosion across the Great Plains in 1934, based on soil erosion surveys conducted by the SCS. The figure also shows the extent of sheet erosion from heavy rainfall. Efforts to combat water-based sheet erosion, however, did not involve the broad externalities and coordination problems found in addressing wind erosion. As indicated on the map, there was considerable variation in the severity of wind erosion across the region, with bands of severe damage in the Texas and Oklahoma panhandles, southeastern Colorado and southwestern Kansas, north central Nebraska, the eastern and central Dakotas, and parts of Montana. We make use of this variation in our

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[8] See Worster (1979, pp. 21–23) and "The District Program of the Western Baca County Soil Erosion District," National Archives, Record Group 114, MLR 1176(A1), box 93.
[9] See National Archives, Record Group 114, MLR 1, box 72.

Legend:

- Erosion unimportant except locally
- Moderate sheet and gully erosion serious locally
- Moderate to severe erosion; includes mesas, mountains, canyons, and badlands
- Severe sheet and gully erosion
- Slight wind erosion moderate sheet and gully erosion
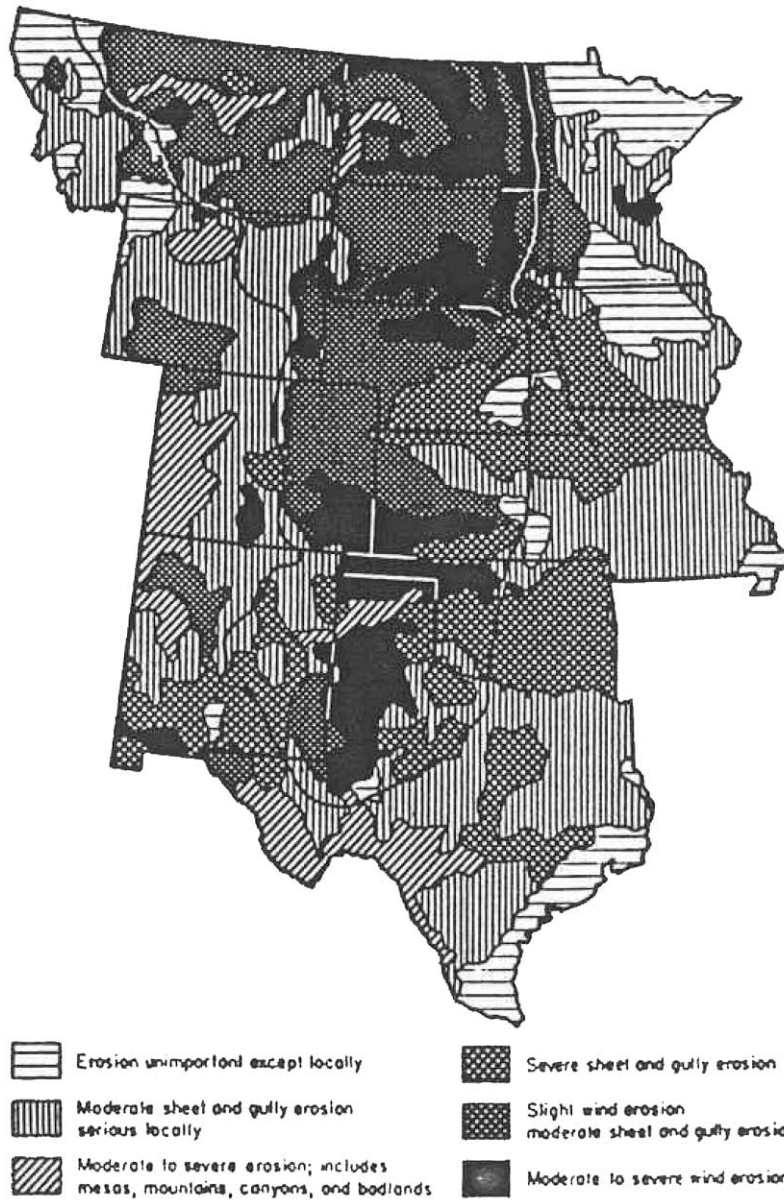- Moderate to severe wind erosion

Fig. 1.—Wind erosion in the Great Plains in the 1930s. An irregular line bounds the Great Plains region as delimited by the Great Plains Committee. Source: Adapted from "General Distribution of Erosion" (U.S. Dept. Agriculture, Soil Conservation Service, August 1936).

analysis of the effect of farm size on efforts to combat wind erosion in the Dust Bowl.

III.   Wind Erosion, Externalities, and Differential Incentives According to Farm Size

A.   *The Dynamics of Wind Erosion and Potential Externalities*

Drought and extensive cultivation in the 1930s raised soil erodibility across the Great Plains. Except in the far western plains, where grass pasture was more common, providing some ground cover, the soil was exposed, dry, and pulverized from repeated tillage. There was limited moisture to make the soil cloddy and rough, and there were few obstacles to block the flow of wind.[10] We describe the dynamics of soil erosion in some detail in order to demonstrate the nature of the externalities involved and the collective action problems encountered among farmers in the 1930s in combating erosion.

There were three types of soil movement in wind erosion—suspension, saltation, and creep—and each had different cross-farm effects. Suspension involved very fine topsoil particles, less than 0.1 millimeter (mm) in diameter, that were blown high into the air as dust and could be carried hundreds of miles if the storm were strong enough. Suspension accounted for 3–40 percent of soil movement. A key benefit of any farmer's erosion control investments was limiting the loss of topsoil via suspension. In 1933 it was estimated that topsoil losses reduced annual productivity from 15 to 25 percent, and when the soil was fully stripped, fields became unproductive or "barren."[11] The external effects of suspended dust were felt quite a distance from the source, and the topsoil could be beneficial for receiving farms. The negative effects were damage to buildings and the health of livestock and people from inhaling blowing dust.

Saltation and creep involved larger particles, 0.1–0.5 mm in diameter for the former and 0.5–1.0 mm for the latter. Saltation and creep brought the most localized externalities through the formation of hummocks and sand drifts up to 40 feet high that smothered downwind crops. Saltation accounted for 50–80 percent of total soil movement, and creep 7–25 percent. These heavier particles fanned out, destroying stable soil crusts and vegetation, and exposing more soil to erosion. This type of erosion was compared to an epidemic disease or avalanche that,

[10] Soil erodibility is discussed in Johnson (1947, p. 193), Chepil (1959), and Woodruff et al. (1972).

[11] Memo to the Secretary of Agriculture, August 22, 1933, National Archives, Record Group 114, MLR 1, box 74, and memo to Hugh H. Bennett, Soil Erosion Service, June 5, 1934, box 4.

if not contained at its source, would spread rapidly. The leeward area affected depended on soil texture and moisture as well as wind speed. It could be several thousand acres or more, but adjacent fields and farms were most vulnerable (Thornthwaite 1936, p. 237; Stallings 1957, pp. 71–83, 129–39, 195–219; Hurt 1981, p. 18; Papendick 1997, pp. 11–12; Toy, Foster, and Renard 2002, pp. 44–70, 101, 229). Limiting the damage from blowing and drifting sand was the other major benefit of a farmer's efforts to combat erosion.

The two leading erosion control methods in the 1930s were strip cropping with strip fallow and windbreaks of trees or brush.[12] Both provided barriers to lower surface wind velocity and carrying capacity, but the former was more prevalent because trees could not be grown in many parts of the plains. Strip fallow also had the advantage of building up soil moisture and roughness, which reduced erodibility, whereas tree windbreaks actually absorbed moisture from surrounding ground (Greb and Block 1961). Strip fallow involved creating alternating bands, placed perpendicular to the wind, of wheat and fallow (usually with wheat stubble) or bands of wheat or cotton and drought-resistant crops such as sorghum (Kell and Brown 1938, pp. 30–32; Chepil 1959; Craig 1959; Held and Clawson 1965, pp. 25–27). Breaking fields into bands of cultivated areas and stubble reduced the exposed area over which the wind passed. Fallow strips were part of crop rotations, which at maximum involved one-third to one-half of a farm's total crop acreage in three- or two-year rotations.

The barriers provided by tree windbreaks or wheat stubble could protect downwind fields for distances 10–20 times their height depending on the porosity and shape of the obstruction, wind speed, soil type, and moisture, especially if used in combination with other erosion control methods, such as stubble mulch (Stallings 1957, pp. 238–65; Fryrear 1963; Woodruff et al. 1972, pp. 4, 13). Stubble mulch involved leaving plant residue in the cultivated areas between fallow strips. If wheat stubble were 1 foot high, for example, then around 20 feet downwind could be sheltered if the soil were very sandy and over 300 feet if the soil were heavy, clay loam. In the 1930s, recommended fallow strips ranged from 1 to 10 rods or 16.5–165 feet (Bennett 1939, pp. 361, 763; Chepil 1957, pp. 5–11; Stallings 1957, pp. 250–55; Norwood and Herron 1977). Through investment in erosion control, a farmer could reduce topsoil losses and shield downwind crops from being smothered by saltating and drifting particles. He also could maintain the viability of fallow strips and windbreaks in combating erosion, which otherwise would be cov-

[12] Erosion control is addressed in Duley (1951), Fryrear (1963), Heady and Vocke (1978), Moldenhauer et al. (1983), Fryrear and Skidmore (1985), and Bilbro, Fryrear, and Zobeck (1987, pp. 114–20).

ered by sand and made ineffective. A major externality in the 1930s occurred when sand from one farmer's unprotected fields drifted across the fallow strips and fields of his downwind neighbor, eliminating any of the productive benefits of those investments.

Depending on the size of the unprotected area, wind speed, soil type, and amount of soil moisture, the absence of erosion control on one field or farm could lead to the degeneration of all erosion control in the region. Similarly, if an isolated farm were strip fallowed but bordered upwind by exposed land, the treated farm would gradually succumb as drifting and saltating soil particles overwhelmed successive fallow strips and crops.

B.   *Wind Erosion, External Effects, Farm Size, and Collective Action*

To completely combat regional erosion, all the cultivated acreage in a topographical area of similarly erodible soil would have to be included in a "wind erosion unit" of 50,000–500,000 acres or more. The optimal farm sizes for addressing wind erosion and production, however, were not the same. Most estimates by agricultural economists and extension agents in the 1930s of appropriate production sizes for the region suggested two sections of land, 1,280 acres, depending on location in the plains. Few scale economies could be realized beyond that size.[13] Nevertheless, in the 1930s, most farms were smaller than the prescribed levels for optimal production. The Great Plains was covered by hundreds of thousands of small farms. This condition was largely a legacy of the Homestead Act, which limited claims to 160–320 acres when the region was settled between 1880 and 1925.

Table 1 shows the prevalence of small farms in all 362 Great Plains counties in our sample, as well as in the counties of the Great Plains in which crop acres as a share of total farmland were at least 40 percent. We make this distinction because the Great Plains included areas that specialized in cattle raising with natural grass pasture, as well as areas of extensive wheat cultivation. These croplands were the most vulnerable to wind erosion. Since available farm size categories in the agricultural census do not exactly match the 160 and 320 acres in homesteads, we present census data on the share of farms below 180 and 500 acres.

Small farms were checkerboarded across the land, surrounding somewhat larger farms, a condition that increased the potential for exter-

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[13] See Cochran (1938); Halcrow (1938); Starch (1939); U.S. Department of Agriculture, Bureau of Agricultural Economics (1941), "Cheyenne Project, Roger Mills County, Oklahoma, National Archives, Southwest Division, Record Group 114, Sp.14, SCS; and Miller, Rodewald, and McElroy (1981, pp. 20–22). Using more contemporary data, Allen and Lueck (1998, 2000) argued that labor monitoring costs rose rapidly in farm sizes beyond what could be operated by family members.

TABLE 1
SMALL FARM PROLIFERATION IN GREAT PLAINS COUNTIES ACROSS TIME

	PERCENTAGE OF FARMS SMALLER THAN 180 ACRES		PERCENTAGE OF FARMS SMALLER THAN 500 ACRES	
	All Great Plains Counties	Great Plains Counties with Total Crop Share ≥40%	All Great Plains Counties	Great Plains Counties with Total Crop Share ≥40%
1930	27	26	65	68
1935	30	30	67	71
1940	28	27	62	66
1945	22	22	54	61
1950	20	19	51	56
1954	18	18	48	52
1959	15	15	42	46
1964	15	14	39	42

SOURCE.—U.S. Agricultural Census, 1930–64.
NOTE.—Great Plains counties includes the 362 eastern counties of Montana, Colorado, and New Mexico; all of North Dakota; those west of the ninety-seventh meridian in South Dakota; most of those west of the ninety-eighth meridian in Nebraska, Kansas, and Oklahoma; and west Texas counties in the Panhandle to 32 degrees latitude.

nalities from those farms that failed to practice erosion control.[14] As shown, the share of small farms decreased dramatically between 1930 and 1964. Although approximately two-thirds of farms were below 500 acres in the 1930s, only about one-third were that small by 1964.

Accordingly, collective action among farmers was necessary to address wind erosion. In commenting on strip cropping and recognizing the externalities involved, Charles Kellogg of the Bureau of Chemistry and Soils stated that "such a practice, to be most effective, must be adopted on a community basis. Isolated farmers following this practice are not greatly benefited if the adjoining land is allowed to blow badly" (1935, p. 5). The large number of small farms on the Great Plains, however, raised the costs of coordination. Indeed, Roland Renne of the Montana Agricultural Experiment Station noted that "dealing with thousands of different owners slows up the adoption of a planned land use program" (1935, p. 429).

Private motivation to invest in strip fallow was reduced when farmers did not internalize the externalities.[15] The problem was accentuated for small farm owners. Each farmer had to consider the benefits of strip fallow with the opportunity costs of lost production.[16] Because small farmers captured *fewer* of these leeward effects, they were less likely to

[14] See, e.g., the property distribution for Musselshell County, Mont., in Renne (1935, p. 425).
[15] Hannah (1950) and Hines (1952) note a lack of farmer incentive to fallow lands to reduce soil erosion when there were off-site effects.
[16] Costs are discussed in Barbarika (1987), Crowder and Young (1987, pp. 177–87), and Stults and Strohbehn (1987).

have any fallow rotation, leaving their land in cultivation and their fields exposed to wind.[17]

The excessive tillage practices of small farms were noted by the U.S. Great Plains Committee (1936, pp. 3, 40–46, 75), appointed by President Franklin Roosevelt, "although we now know that in most parts of the Great Plains a farm of this size [homestead] … [was] required to put this land under plow, regardless of whether or not it was suited to cultivation." M. R. Cooper et al., of the Bureau of Agricultural Economics, claimed that farms "are so small that the establishment of a system of farming that will conserve soil and produce a desirable family income is practically impossible" (1938, p. 146). Geographer Warren Thornthwaite of the SCS concluded that "the type of tillage which, because of its low cost, gives the farmer his only advantage is the primary cause of wind erosion so destructive in nature that it eventually renders the land unfit for cultivation" (1936, p. 242).

IV.   Empirical Analysis of Farm Size, Investment in Erosion Control, and Wind Erosion

In this section, we first summarize the parameters that influenced a farmer's decision to invest in erosion control in the 1930s. We then present quantitative evidence on the importance of farm size and externalities in that decision. In the empirical analysis, we focus on the fallow decision because it is the only soil conservation variable continuously reported in the agricultural census, and strip fallow was the primary means of combating wind erosion recommended by the SCS.

We assume that farmers sought to maximize profits by determining the share of their cropland to place into strip fallow. Strip fallow increased productivity by conserving moisture and reducing the losses of wind erosion. There were opportunity costs from lost production on fallowed land. Farmers had to balance those costs with the productive benefits on land that remained in crops. The productivity gain, however, depended on the fallow actions of neighboring farmers—on the aggregate fallow share of total cropland in a wind erosion zone, due to cross-farm effects.

When there is only one farm in an erosion-prone region, all externalities are internalized and the socially optimal fallow share is achieved. When there is more than one farm, however, farmers will not adopt this

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[17] See Bennett and Fowler (1936, p. 4), Stephens (1937, p. 751), Bennett, Kenney, and Chapline (1938, pp. 68–76), Boatright (1938), Kimmel (1940, p. 264), U.S. Department of Agriculture (1940*b*, p. 409), Huffman and Paschal (1942), and Kraenzel (1942, pp. 583–86) for complaints about small farmers. Very small farmers with mortgages or tenant payments also may have had less incentive to invest in erosion control because placing land in fallow may have placed them below their budget constraints.

share. Moreover, smaller farms have even greater incentives to deviate from the optimal share because their opportunity costs from lost production are higher relative to the productivity benefits from fallow.[18] Accordingly, in the presence of many small farms, the total fallow share is lower than socially optimal, and this, in turn, reduces the fallow share selected by every farmer, large and small alike.

This framework suggests the following implications for empirical analysis of wind erosion on the Great Plains in the 1930s:

a. Small farms should have lower fallow shares.
b. The presence of many small farms in a region should reduce fallow incentives on larger farms, implying that the greater the variation in farm size, the lower the fallow share of cropland on all farms.
c. Regions with lower fallow shares of cropland (greater fully cultivated shares) should have more intense wind erosion when natural factors are controlled for.

In the following section we use these implications to guide our analysis of the effects of farm size on fallow, cultivation, and the intensity of wind erosion damage across the Great Plains. Three other testable implications are presented here for use in our analysis of collective action in Section V.

d. The presence of many small farms and positive transaction costs should require formal, coercive government institutions to promote rapid collective action to address wind erosion.
e. Such government institutions should be adopted first in regions in which wind erosion was most severe.
f. Larger farmers should be the major advocates of collective action, and subsidies to small farms would be required to offset the production losses of increased fallow shares.

We now turn to examination of the relationships among farm size, fallow, cultivation, and the intensity of erosion damage.

A.   Farm Size and Fallow Share

There are very limited farm-level quantitative data that allow for comparison of the fallow share of cropland for farms of different size. One data source that provides this information is a 1936 Resettlement Administration survey of 263 farms in nine townships in Morton, Slope, Bowman, and Hettinger Counties, North Dakota. This was a mixed farming/ranching area in which more of the land was used for crop pro-

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[18] The model is flexible enough for zero fallow shares on some farms, most likely on very small farms.

TABLE 2
FALLOW SHARE OF TOTAL CROP ACRES, NORTH DAKOTA, 1936

	FARM SIZE (Acres)							
	2,051 and Over	1,041–2,050	881–1,040	721–880	561–720	401–560	241–400	240 or Less
Fallow share	.22	.18	.20	.11	.11	.13	.15	.09

SOURCE.—1936 U.S. Resettlement Administration, Sample Surveys of Farms, U.S. Department of Agriculture, National Agricultural Library.

NOTE.—The survey was done across 263 farms in nine townships in Morton, Slope, Bowman, and Hettinger Counties, N.D. Fallow share is defined as idle or fallow land as a share of total crop acres. This is the same definition used in the econometric analysis of fallow share.

duction, as indicated by 1935 agricultural census data. The percentage of total farmland devoted to crops in the four counties ranged from 41 to 73 percent, with an average of 54 percent. The survey included mean crop and mean fallow acres across eight farm size categories. The calculated fallow shares of cropland are shown in table 2, and as predicted, the fallow shares generally increased with farm size.

The shares can be placed into broader context by referring to the 1935 agricultural census, which indicates that the mean fallow share of cropland for those four counties was approximately 15 percent when the average farm size was 675 acres. As shown in the table, farms that were larger than 880 acres had fallow shares above the county mean share and about twice that of smaller farms. Further, the fallow shares for farms of all sizes were below the one-third to one-half shares recommended by SCS officials. This finding is consistent with the notion that the presence of small farms with their limited fallowing would have reduced the fallow shares of larger farmers. It is instructive to note that as farm size grew over time and soil conservation districts (SCDs) were put into place in the Great Plains after 1937 to coordinate farmer anti-erosion efforts, fallow shares in these North Dakota counties increased. By 1964, the mean fallow share calculated from the census was 28 percent, closer to the range recommended by soil conservation officials.[19]

In our econometric analysis we use county-level agricultural census data from 1930–64. Discussion of the definitions and the comparability of the data across time are provided in the Data Appendix. We examine the relationship among farm size and fallow share of cropland using census data for the counties in the Great Plains most vulnerable to erosion, where the share of crop acres was at least 40 percent of total farmland. This sample allows us to avoid including ranching counties of mostly pastureland in which neither crops nor fallow was a major option because of poor soil quality.

[19] Government commodity policies and other factors may have influenced fallowing decisions. As described later, fallow shares increased generally after the SCDs were created.

The relationship that we estimate is

$$f_i = a + b_1 s_i + b_2 s_i^2 + b_3 d_i + e_i,$$

where f_i is the share of strip fallow acres of total crop acreage in each county i, s_i is average farm size (land in farms divided by number of farms), s_i^2 is farm size squared, and d_i is the estimated standard deviation in farm size in each county. The share of fallow acres is expected to rise with farm size but decline with a greater deviation in farm size. The existence of both small and larger farms in a county would raise cross-farm effects and weaken individual incentives to invest in wind erosion control.

Table 3 reports the regression results. Since we have data from each agricultural census between 1930 and 1964, we estimated the fallow relationship separately for each census year, as well as pooled across the entire period.[20] As indicated in the table, the estimated coefficient on the farm size variable is positive and statistically significant each year. The fallow share increases with farm size at a decreasing rate, and the marginal effects of farm size on the fallow share, calculated at the sample mean farm size (shown in boldface in the table), are stable through the years, with largest impacts in 1935 and 1940. Further, during early census years, the standard deviation of farm size in a county exerts a negative and statistically significant effect on fallow share. Where there was a considerable range of sizes with failure of small farmers to invest in wind erosion control, the overall use of strip fallow was reduced. As average farm size increased over time, the variation in farm size tended to decline, and the effect of the standard deviation of farm size diminished.

Column 9 of table 3 shows the results from the estimation of a panel regression model with county and time fixed effects. Time effects control for factors such as wheat and cattle prices, federal farm programs, and other institutional and technological factors. The county fixed effects allow us to use within-county variation to estimate our model. The results of the fixed-effects panel model further indicate the strong impact of farm size on the use of strip fallow. The negative and significant coefficient on the farm size deviation variable points to the role smaller farms played in inhibiting investment by all farms in strip fallow. Large,

[20] We take farm size as exogenous in examining the fallow decision and later in determining the effects of cultivation on wind erosion. Other productivity factors, such as relative factor prices, nonfarm income, and technology, were the major determinants of farm size (Kislev and Peterson 1982). Initial farm sizes largely were set by the Homestead Act. After 1937, SCDs, which subsidized and occasionally forced the adoption of erosion control, reduced any potential effect of wind erosion and erosion control investments on farm size. We tested for endogeneity of farm size using farm population per 1,000 farm acres in 1930 as an instrument for the same sample used in the regression reported in table 3. The result of the Durbin-Wu-Hausman test indicates no evidence of endogeneity or inconsistency in the ordinary least squares (OLS) estimates.

TABLE 3

ANALYSIS OF THE RELATIONSHIP BETWEEN AVERAGE FARM SIZE AND FALLOW SHARE IN GREAT PLAINS COUNTIES

Dependent Variable: Fallow Share (as a Percentage of Total Crop Acres)

	1930	1935	1940	1945	1950	1954	1959	1964	1930–64
Mean of dependent variable	5.42	14.13	17.75	11.32	14.87	16.58	19.32	24.06	15.14
Average farm size	.023**	.062***	.083***	.043**	.051**	.033**	.043**	.043**	.020***
	(.008)	(.104)	(.015)	(.016)	(.022)	(.010)	(.018)	(.016)	(.004)
Average farm size squared	−6.3E−6**	−2.0E−5***	−2.8E−5***	−1.2E−5**	−1.4E−5*	−6.8E−6	−9.1E−6*	−8.9E−6*	−2.4E−6**
	(2.5E−6)	(3.0E−6)	(5.4E−6)	(3.7E−6)	(6.5E−6)	(3.9E−6)	(4.4E−6)	(4.3E−6)	(1.0E−6)
Marginal effect of farm size[a]	**.016**	**.041**	**.048**	**.027**	**.031**	**.022**	**.027**	**.026**	**.017**
Standard deviation of farm size	−.007	−.026***	−.033***	−.003	−.007	.001	−.011	−.011	−.005**
	(.004)	(.007)	(.008)	(.134)	(.016)	(.020)	(.016)	(.015)	(.002)
Observations	285	252	260	210	225	225	226	218	1,901
R^2	.203	.369	.415	.366	.352	.354	.345	.316	.409

SOURCE.—U.S. Agricultural Census, 1930–64.

NOTE.—The sample at each year includes Great Plains counties in which the county-level total crop acre percentage is at least 40 percent of the total farmland. OLS estimates are given for each census year, and Huber-White robust standard errors allowing for clustered errors by state are in parentheses. The panel regression includes county fixed effects and time dummy variables. The county fixed effects are jointly significant at the 1 percent level, and time dummy variables are positive and statistically significant relative to the left-out year dummy of 1930. The results are similar with statistically significant and larger coefficients on all variables when the pooled model is estimated. Fallow share includes fallow and idle land during 1930–45 and includes only summer fallow acres during 1950–64. Average farm size is defined as total farmland divided by total number of farms in a given county. For the construction of the standard deviation of farm size and the discussion on comparability of variables over time, see the Data Appendix.

* Statistically significant at the 10 percent level.

** Significant at the 5 percent level.

*** Significant at the 1 percent level.

[a] The marginal effect of farm size is calculated at mean farm size. Mean farm size for each year is reported in col. 1 of table 4.

TABLE 4
ESTIMATED FALLOW SHARE AT DIFFERENT FARM SIZES

	A		B		C	
	Mean Farm Size (1)	Fallow Share (%) (2)	Farm Size at the Mean Plus One Standard Deviation (3)	Estimate of Fallow Share (%) (4)	Estimate of "Peak" Farm Size (5)	Estimate of Fallow Share (%) (6)
1930	557	5	874	10	1,857	17
1935	512	14	758	24	1,526	36
1940	631	18	976	34	1,479	41
1945	635	11	1,004	21	1,754	28
1950	721	15	1,135	27	1,794	34
1954	778	17	1,227	26	2,378	35
1959	883	19	1,375	33	2,391	42
1964	968	24	1,473	37	2,410	45

NOTE.—Fallow share calculations are based on the coefficient estimates presented in table 3. Panels A and B show the fallow share as a percentage of total crop acres calculated at the mean farm size and at the farm size of mean plus one standard deviation, respectively. Col. 5 in panel C gives the estimates of the peak farm size based on the coefficient estimates of the average farm size and average farm size squared. These are estimates of farm size beyond which no increase in fallow share is expected as farm size increases. Col. 6 presents the fallow share values based on these peak farm size estimates.

positive coefficients on the census year fixed-effect variables relative to 1930 (not reported in table 3) indicate the growing use of strip fallow over the period.

Using the estimated coefficients for each year, we can show the potential increase in fallow share as farm size increased. The results are given in table 4. Panel A shows the change in the fallow share of cropland over time as mean farm size grows. Panel B reports the estimated effect of a one-standard-deviation increase in average farm size on the fallow percentage for each census year. In 1935, the fallow share is estimated to be 24 percent at a farm size of 758 acres, but it is only 14 percent at the mean size of 512 acres. Since approximately two-thirds of farmland was used as cropland in 1935 in our sample, this one-standard-deviation increase in farm size implies a 166-acre increase in cropland, of which an estimated 75 acres (or 45 percent of the increase in cropland) would have been put in fallow, with no change in crop share.

Column 5 in panel C shows the estimated "peak" farm size based on the coefficient estimates of average farm size and farm size squared. These peak farm size estimates can be interpreted as the size beyond which no increase in fallow share is expected as farm size increases. Column 6 displays the fallow share that corresponds to this peak farm size. In 1935, the fallow share is estimated to be 36 percent at the peak size of 1,526 acres. This difference of over 1,000 acres in farm size from the mean of 512 acres implies an increase of 685 acres in cropland, based on the ratio of two-thirds cropland to total farmland. Of this

increase in cropland, an estimated 323 acres (47 percent) would be placed in fallow. Column 6 also shows that for farm sizes closer to those recommended as optimal for production by agricultural economists in the 1930s, the fallow share estimates approach the suggested one-third to one-half ratio for fallow share of cropland.

These estimates suggest that an increase in farm size from 512 acres to 1,526 acres in 1935 would have raised fallow shares to their recommended levels. Larger farmers had approximately three times the cultivated acreage of average farmers and therefore could internalize more of the returns from investing in erosion control. Their farms were large enough to better control the drift of heavier saltating and creeping soil particles that otherwise would have smothered their fields and strip fallow investments. If coordination problems are ignored and complete compliance by all farms in a wind unit is assumed, the results in panel C for 1935 indicate that if all farms had been 1,526 acres, they would have internalized most of the externalities of erosion control, especially those associated with the drift of heavier saltating and creeping particles. Small farmers, however, captured fewer of these benefits and placed less of their cropland in fallow. Where their cultivation practices prevailed, wind erosion damage should have been more severe. We now examine this issue.

B.   Farm Size, Cultivation Shares, and the Intensity of Wind Erosion across the Great Plains

As indicated in figure 1, the intensity of wind erosion varied across the counties of the Great Plains. The literature on erosion and our analytical framework suggest that this variation should be a function of differences in drought conditions, wind velocity, sand content of the soil (erodibility), and the extent of cultivation (cropland minus strip fallow) across the counties. The effect of small farms on erosion control should be reflected in the cultivation measure.

In 1934, the SCS conducted reconnaissance erosion surveys throughout the United States. State and national maps were prepared in 1934 and 1935 detailing locations of wind and water erosion of different intensities, ranging from no erosion, slight, moderate, severe, and very severe erosion. We use these maps to assign erosion index values to each county in the Great Plains in 1934 and estimate the following relationship:

$$WE_i = f(r_i, \ t_i, \ w_i, \ c_i),$$

where WE_i is the wind erosion index measure for county i, ranging from zero to three for no, light, moderate, and severe erosion; r_i is the deviation in rainfall from normal levels during 1930–35; t_i is the percentage

TABLE 5
Wind Erosion Analysis across Great Plains Counties
Dependent Variable: Wind Erosion Index

	OLS with State Fixed Effects		Ordered Probit	
	All (1)	Crop Share ≥ 40% (2)	All (3)	Crop Share ≥ 40% (4)
Cultivation share[a]	.017***	.021***	.023***	.024***
	(.003)	(.003)	(.009)	(.008)
Annual wind speed	.201***	.327***	.046	.102
	(.050)	(.055)	(.149)	(.175)
Deviation in rainfall	−.006	−.006	−.024**	−.025**
	(.005)	(.006)	(.010)	(.011)
Soil sand percentage	.028***	.027***	.022***	.029***
	(.003)	(.004)	(.007)	(.008)
Observations	362	285	362	285
R^2	.510	.559		
χ^2			71.5***	55.5***

Source.—Rainfall deviation is taken from Cronin and Beers (1937, table 8, pp. 41–54). Annual average hourly wind velocity is taken from Chepil, Siddoway, and Armbrust (1962, p. 163). Sand percentage by county is taken from a STATSGO data set graciously provided to us by Geoff Cunfer from the Great Plains Population and Environment Database, 2001 (ICPSR, University of Michigan). Cultivation share is calculated from 1930 Agricultural Census county-level measures of farmland, cropland, and fallow acres.

Note.—The wind erosion index ranges from zero to three, indicating no erosion to severe erosion. Huber-White robust standard errors are in parentheses. Standard errors of ordered probit specification are adjusted for clustered errors by state. The threshold parameters of the ordered probit are correctly ordered and precisely estimated. Cols. 1 and 3 show estimates based on all the Great Plains counties, and cols. 2 and 4 show results from Great Plains counties in which the county-level total crop acre percentage is at least 40 percent of the total farmland. OLS models include state dummy variables, all of which are positive and statistically significant relative to the left-out state of Oklahoma. For the detailed descriptions of variable definitions and construction, see the Data Appendix.

[a] We use the term "cultivated" acres to describe crop acres that do not include fallow or idle land. Cultivation share is the percentage of total county farmland in cultivation (i.e., total cropland minus fallow or idle land divided by the sum of total cropland, including fallow or idle land, and pasture).

** Statistically significant at the 5 percent level.

*** Significant at the 1 percent level.

of sand in county soil; w_i is average annual hourly wind velocity by county; and c_i is the percentage of total county farmland in cultivation (i.e., total cropland minus fallow divided by the sum of total cropland, including fallow or idle land, and pasture). The Data Appendix describes the details of variable construction. Controlling for these variables, as well as state fixed effects, we examine the impact of cultivation intensity as determined by farm size on wind erosion.

Table 5 summarizes the results of the statistical analysis. Columns 1 and 2 report the coefficient estimates of the OLS model with state fixed effects in the full and truncated samples of Great Plains counties, respectively. Columns 3 and 4 present ordered probit estimates, utilizing the ordinal nature of the dependent variable. The regression results indicate that the counties with higher cultivation shares of total farmland faced more severe wind erosion. The coefficient estimates for the other variables have the expected signs, and most are statistically significant.

Table 6 shows the observed cell frequencies and the predicted probabilities for different levels of wind erosion. The results are based on

TABLE 6
PREDICTED PROBABILITIES AT DIFFERENT VALUES OF CULTIVATION SHARE

	CULTIVATION SHARE[a]			CELL FREQUENCY
	65.7% (1)	50.8% (2)	100% (3)	(4)
Prob($WE = 0$)	.10	.18	.02	.13
Prob($WE = 1$)	.35	.42	.15	.33
Prob($WE = 2$)	.28	.24	.25	.25
Prob($WE = 3$)	.26	.16	.58	.29

NOTE.—Predicted probabilities are based on coefficient estimates of the ordered probit model for the truncated sample of 285 Great Plains counties as reported in table 5.
[a] Cultivation share is the percentage of total county farmland in cultivation (i.e., total cropland minus fallow or idle land divided by the sum of total cropland, including fallow or idle land, and pasture).

the coefficient estimates of the ordered probit model at various cultivation share values from the truncated sample estimation. Column 1 reports the predicted erosion probabilities that are calculated at the mean values for all the variables. The predicted probabilities of the model are similar to the observed cell frequencies, indicating the model's ability to predict correctly. Columns 2 and 3 are calculated at the mean values for the variables, except that in column 2, the cultivation share is assumed to be 50.8 percent, one standard deviation below the mean share, and in column 3 the cultivation share is assumed to be 100 percent of farmland. If the average county cultivation share is 50.8 percent, the predicted probabilities of no or light wind erosion (i.e. Prob($WE = 0$) and Prob($WE = 1$)) increase from those associated with the mean cultivation share, whereas the probabilities of moderate and severe erosion decrease. In contrast, if we assume that farmers in a county put all their farmland into cultivation (cultivation share is 100 percent), which was not unlikely for very small homesteads of 160–320 acres, the predicted probability of severe wind erosion jumps from .26 to .58 and the predicted probability of no wind erosion practically disappears. These calculations indicate the important effect of cultivation intensity and farm size on the magnitude of the wind erosion damage in a county.

V.   A "Unitized" Response for the Control of Externalities: The Formation of Soil Conservation Districts

A.   *Farm Size Effects and Private Efforts to Address Wind Erosion*

With all farms in the 1930s below the size necessary to fully combat wind erosion and internalize the externalities involved, coordinated actions were required. Private efforts to contain the blowing and drifting of soil would have posed a formidable bargaining problem, even if farmer incentives had been aligned. Hence, a difficult collective action

problem existed in the Great Plains in the 1930s. And given the magnitude and severity of the problem, there were important reasons for moving quickly to reduce the costs of wind erosion. Unfortunately, the drought began in 1930, but an effective institutional response did not emerge until after 1937.

In the early 1930s, the expectation was that the drought would end and that short-term private efforts to combat erosion would be sufficient. Even so, the challenge of coordinating action among farmers was understood clearly. In a 1936 report to Hugh H. Bennett, chief of the SCS, J. T. Reece, soil conservation supervisor in Littlefield, Texas, argued that "the premier problem in establishing a constructive erosion control program in this camp is securing adequate cooperation from the farmers and land owners, for without this, no conservation program is possible."[21]

To encourage coordinated investment in erosion control, the SCS, starting in 1934, developed 79 demonstration areas to show farmers the benefits of various conservation practices (Chilcott 1937; Bennett 1939, pp. 742, 747; Simms 1970). Reflecting the size necessary to address regional erosion, these demonstration areas were large, ranging from 24,960 to 169,000 acres in Colorado, 30,000–114,000 acres in Kansas, and 30,000–114,000 acres in Nebraska.[22] Given the mixed incentives to participate in erosion control, the response to calls for voluntary collective action was limited.[23] Indeed, the SCS noted a lack of voluntary farmer participation in the erosion control programs outlined in the demonstration projects. In 1935, Bennett reprimanded F. L. Duley, regional SCS director in Mankato, Kansas, stating that "frankly, it is somewhat disappointing to note that such a small portion of your project is being retired from cultivation and that you are not using any strip-cropping measures whatsoever … we have been considering that strip-cropping would make up one of our principal means of erosion control."[24]

An examination of records for demonstration areas in Colorado, Kansas, New Mexico, and Texas in 1936–37 reveals differential actions in erosion control among "cooperators" and "noncooperators." Data on fallow and strip cropping across farms show that for cooperators the fallow and strip-cropping share of total cultivated land was 25 percent,

[21] Annual report, July 1, 1935–June 30, 1936, Erosion Control Work Camp, 15-T, Littlefield, Texas, J. T. Reece, Conservation Superintendent, National Archives, Record Group 114, MLR 1176 (A1), box 28.

[22] National Archives, Ft. Worth, Record Group 114, WG 1(A), box 1, August 1935.

[23] For discussion of demonstration farms and the lack of farmer enthusiasm, see Bennett (1939, pp. 361, 737) and Helms (1990, pp. 13–15).

[24] Record Group 114, Soil Conservation Service, box 6, letter Bennett to Duley, August 20, 1935. See also Bennett (1939, pp. 315–22). Held and Clawson (1965, pp. 49) discuss the problem of noncooperating farmers.

whereas for noncooperators the share was 14 percent.[25] Other evidence suggests that the smallest farmers in the demonstration areas were the noncooperators. Records from two erosion control projects in Dalhart and Dublin, Texas, in 1937 and 1939 identify cooperators and noncooperators according to farm size. Although the data set is small, in both cases cooperating farms were somewhat larger than noncooperating farms. In Dalhart, located in the Texas Panhandle, the mean size of cooperating farms was 629 acres, whereas the mean size of noncooperators was 418 acres. In Dublin, located in central Texas, the mean size of cooperating farms was 145 acres, whereas the average size of noncooperating farms was 118 acres.[26]

B.   Government Intervention to Address the Collective Action Problem: Soil Conservation Districts

More direct and coercive government intervention came in 1937 with the inauguration of soil conservation districts that had the authority to force farmer compliance and the resources (subsidies) to cover the costs of erosion control. The SCDs were local government units and required state legislation for establishment. A model statute was drafted by Department of Agriculture Assistant Secretary M. L. Wilson and Assistant Solicitor Philip M. Glick and submitted by President Roosevelt to the state governors for legislative adoption in February 1937 "for the discontinuance of land use practices contributing to erosion and the adoption and carrying out of soil conservation practices and to provide for the enforcement of such programs and regulations. … The failure by any land occupier to conserve the soil and control the erosion upon his lands causes a washing and blowing of soil, of water, from his lands on to other lands, makes the conservation of soil and the control of erosion of the other lands difficult or impossible" (U.S. Department of Agriculture 1936, p. 1; Helms 1992).

  We expect the states with the greatest wind erosion problems to be the first to adopt legislation to promote cooperation among farmers. Indeed, Kansas, Oklahoma, and Texas, at the center of the Dust Bowl, enacted wind erosion laws in 1935, earlier than other Great Plains states (U.S. Great Plains Committee 1936, pp. 105–7; Wehrwein 1936; Hockley and Walker 1938). In all three states, district officials were authorized to enter private property to combat erosion and to fine noncomplying

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[25] Files for Cheyenne Wells, Colo.; Liberal, Kans.; Clayton, N.M.; and Dalhart, Hereford, Stratford, and Vega, Texas, at the Southwest Regional National Archives, Ft. Worth, Record Group 114, SP 6 (0), box 20.

[26] Green Creek Project, TEX-8, Dublin, Texas, 1937; National Archives, Record Group 114, MLR 1001, box 65; and Dalhart, Tx Project, TEX-3, 1939, National Archives, Record Group 114, MLR 1154, box 1. There are no figures as to the size distribution of the farms.

owners.[27] In Colorado, another central Dust Bowl state, assessments were levied against farmlands to fund erosion control, and SCDs had the power to block new cultivation plans with "sod land ordinances" (U.S. Department of Agriculture 1937, p. 14; Colorado Soil Conservation Act, Colorado Laws 1937, c. 241).

The conservation districts were even larger than the demonstration areas. For example, districts in Kansas in 1941 ranged from about 250,000 acres to nearly 600,000 acres.[28] The district sizes reflected the areas necessary to encompass an erodible region or wind zones. Districts typically covered entire counties, and they clearly focused on externalities. The land use ordinances applied only where neglect on one farm caused damage or hindered conservation treatment "on adjacent lands." The 1939 *Extension Service Review* noted that "individual farmers have been practicing measures of erosion control for years, but they have learned that it is a difficult if not a losing single-handed fight. … As the forces of wind and water are not halted by the section line or fence row, erosion becomes a community problem, and community problems require community action" (Partain 1939, pp. 357–58).

Within the districts, individual farmers entered into contracts with the SCS to cooperate in reducing soil erosion for five years. The SCS provided equipment, seeds, fencing, and personnel for erosion control. Erosion control ordinances imposing land use regulations on all farmers could be adopted upon a favorable vote of a majority of the farmers in a district. Under the statute, the district supervisors could occupy parts of farms and begin erosion control with the costs plus 5 percent levied by court order against the farmer (Parks 1952, pp. 14–15; Held and Clawson 1965, pp. 47–49; Hurt 1981, pp. 74–77; Helms 1990, pp. 47, 49). Further, farmers who did not comply were ineligible for SCS assistance. Moreover, beginning in 1938, the Agricultural Adjustment Administration (AAA) required that "every cooperator handle his land by using practices which are effective in preventing wind erosion" (U.S. Department of Agriculture 1940*a*).

Subsidies were provided. Thirty percent of AAA payments to a farm were to be earned by carrying out soil conservation practices. The payments to the farmer, however, were to be reduced by $1.00 per acre for each acre of land on which approved practices were not implemented. If it were deemed that the farmer's land had become "a wind erosion hazard to surrounding farmers in the community," the farmer would not receive any funds under the 1939 Agricultural Conservation Pro-

[27] Letter to Hugh H. Bennett, chief SCS, September 4, 1935, National Archives, Record Group 114, MLR 1, box 13. See also Wehrwein (1936, pp. 312–13) and Hockley and Walker (1938).

[28] Soil Conservation District Records, National Archives, Record Group 114, MLR 1001, box 12. See also Morgan (1965, pp. 45–51, 333–38, 358–70).

TABLE 7
FARM SIZE COMPARISONS FOR SCD PETITIONERS WITH COUNTY AVERAGES

Soil Conservation District	Average Size of Petitioners (Acres)	Average Farm Size in County (Acres)
Fallon County SCD	2,889	1,511 (1940)
Cascade County SCD	1,452	1,241 (1945)
Powder River SCD	3,533	3,381 (1950)

SOURCE.—SCD petitioners, Farm Service Agency files, Helena, Mont.; U.S. Agricultural Censuses, 1940–50.

gram (ACP). These funds were significant to a farm family, amounting to $162 per applicant in 1939 (U.S. Department of Agriculture 1940a). Districts could acquire lands "for purposes of conservation" and receive 1939 ACP funds and loans from the Farm Security Administration (FSA). Finally, the FSA was authorized to make loans for erosion control investments to be repaid with ACP allocations. Other FSA loans were to assist farmers to "obtain a proper-size operating unit" (U.S. Department of Agriculture 1939).

The available evidence also suggests that larger farmers, who bore more of the costs of cross-farm erosion externalities, were the major proponents of SCDs. Data from Farm Service Agency files in Helena, Montana, include information on the size of farms owned by individual farmers who petitioned for the establishment of three SCDs in Montana: the Little Beaver SCD (formed January 27, 1942), the Cascade County SCD (approved June 17, 1946), and the Powder River County SCD (organized December 17, 1953). A comparison of the average farm size of the petitioners with census data on the average farm size in the county allows us to test the hypothesis that political support for SCDs would come from larger farmers. As indicated in table 7, the petitioning farmers had somewhat larger farms, on average, than the mean farm size in the county. Especially in Fallon County, the average farm size of petitioners was one standard deviation larger than the mean farm size in 1940.

VI. Conclusion

In this paper we reexamine a well-known environmental disaster, the Dust Bowl of the 1930s, and emphasize the important role that farm size and externalities played in both contributing to severe wind erosion and inhibiting corrective action. Best possible wind erosion control would have required farms that would have been productively inefficient. We argue that farmers were more likely to adopt wind erosion control, such as putting part of their cropland to strip fallow, if they were operating at sizes closer to recommended production levels. At those sizes, they internalized more of the benefits of fallow relative to

the opportunity costs of lost production. Farm-level data and our empirical analysis using county census data provide evidence that larger farms had greater fallow shares. Further, our analysis shows that erosion across the Great Plains was more severe in those counties in which cultivation shares were greater.

Soil conservation districts, which could be as large as 600,000 acres, eventually were implemented in order to coordinate and enforce farmer actions to combat regional wind erosion. Within these districts, individual farmers entered into contracts with the SCS to cooperate in more complete erosion control.

The results reported here are consistent with more contemporary analyses of the sources of wind erosion that emphasize the importance of land use practices relative to natural geologic and climatic conditions. Field personnel of the SCS recognized the problem of small farms in the 1930s, but this issue has been lost in subsequent work on the Dust Bowl by historians, agricultural economists, and engineers. Regulations within SCDs, along with the gradual consolidation of farms, led to changes in cultivation practices that better shielded the soil so that when droughts affected the Great Plains in the 1950s and 1970s, the region was less vulnerable to wind erosion.[29]

The Dust Bowl illustrates a classic common-pool problem. Exacerbated by the existence of many small farms in the Great Plains, it was not solved until larger units were created that aligned the incentives of the individual parties. In this sense, addressing the problem of widespread wind erosion required actions similar to those necessary to reduce losses in competitive oil extraction, fishery exploitation, and aquifer drawdown.[30]

Data Appendix

The qualitative and quantitative evidence presented in the paper comes from many sources as indicated in the notes. This Appendix describes the quantitative evidence presented in the tables and used in the econometric analyses.[31]

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[29] Nace and Pluhowski (1965, pp. 15–21) report that the 1950s drought was as severe as or more severe than that of the 1930s, but that wind erosion in the 1930s was much more extensive and damaging.

[30] For a summary of common-pool problems, see Libecap (1998).

[31] Data were provided by Geoffrey Cunfer and Myron Gutmann from the Great Plains Population and Environment Database. Erosion analysis was provided by Thomas E. Gill and Rick Zartman of Texas Tech University; Gary Tibke and Larry Hagan of Kansas State University; Kent Matsutani, district conservationist, South Platte National Resource District; Dale Pekar, National Water Management Center, Little Rock, Ark.; Nebraska State conservationist Steve Chick; and Donald Fryrear, Big Spring, Texas; recommendations for archival sources were provided by Douglas Helms, senior historian, Natural Resources Conservation Service, U.S. Department of Agriculture.

A.   Agricultural Census Data Definitions and Comparability across Time

The census data are electronically available from the Great Plains Population and Environment Database, 2001, Inter-University Consortium for Political and Social Research (ICPSR), University of Michigan (http://www.icpsr.umich.edu/plains), and from the U.S. Historical Census Data Browser (http://fisher.lib.virginia.edu/census/). When necessary we supplemented these sources using the print versions of agricultural census data.

Farmland.—The land in farms includes all cropland harvested, all land on which crops failed, all cropland idle or fallow, all cropland used only for pasture, all woodland, and all other land including all wastelands, house yards, barnyards, feed lots, lanes, roads, ditches, and so forth. This variable is quite comparable across years, although there were changes in the inclusion of "nonagricultural" land, which is only a small portion of farmland.

Total crop acres.—Includes cropland harvested, land on which crops failed, cropland idle or fallow, and cropland used for pasture. This variable is consistent across years, but the specific definition of "cropland for pasture" differs slightly in 1945.

Fallow acres.—Fallow or idle land as defined by the census during 1930–45, and summer fallow as defined during 1950–64. This is the most comparable definition of fallow, although the latter years' fallow acres are more restricted than the years of 1930–45.

Fallow share (constructed variable).—100 × (fallow acres/total crop acres).

Crop share (constructed variable).—100 × (total crop acres/farmland).

Cultivation share (constructed variable).—100 × (total crop acres − fallow acres)/farmland.

Standard deviation in farm size (constructed variable).—The agricultural census provides farm size categories and the number of farms in each category. We constructed the following categories, which are comparable over the years, and used these data to calculate an approximate standard deviation: 0–49 acres, 50–99 acres, 100–179 acres, 180–259 acres, 260–499 acres, 500–999 acres, and over 1,000 acres. The standard deviation of farm size was calculated on the basis of the difference between average farm size and the midpoint of each category, weighted by the number of farms in each category. In order to choose the midpoint for the open-ended category of farms over 1,000 acres, we first estimated the farmland in farms over 1,000 acres and calculated the average farm size in this category. We used this calculated average size as the midpoint if it was between 1,000 and 3,000 acres. If the estimated average farm size was smaller than 1,000 acres, we used the lower limit of 1,000 acres as the midpoint. Otherwise, the upper limit of 3,000 acres was used as the midpoint. The formula for weighted variance is

$$\text{variance} = \sum_i \left(\frac{N_i}{N_T}\right)(M_i - \bar{F})^2,$$

where N_i is the number of farms in a category for a county, N_T is the total number of farms in a county, M_i is the midpoint of a size category, and $\bar{F}$ is the average farm size in a county.

B.   Data Used in the Wind Erosion Analysis

Wind erosion index.—State erosion reconnaissance survey maps prepared in 1934 by the SCS for Montana, North and South Dakota, Nebraska, Kansas, Colorado,

Oklahoma, Texas, and New Mexico are available at the National Archives, Record Group 114, Cartographic Collection. See Kifer and Stewart (1938, p. 9) for a 1934 map; a 1935 U.S. erosion reconnaissance survey map is available in Joel (1937). We consider only wind erosion as indicated on the maps and do not assign values for water erosion. The maps are color coded and shaded to identify locations of different erosion intensity. A county was assigned a value from zero to three on the basis of dominant erosion conditions indicated in the maps. Generally, a county's erosion index value was based on the condition that characterized 50 percent or more of the county. In cases in which severe erosion conditions were widespread within the county, but the total appeared to cover less than 50 percent of the land area, the county was still assigned the severe index value, three. The indication that severe erosion was widespread and not localized warranted the higher value.

Rainfall deviation.—This is the average percentage departure from normal by county, 1930–35, from Cronin and Beers (1937, table 8, pp. 41–54).

Wind velocity.—Annual average hourly wind velocity in miles per hour 30 feet above the ground is taken from Chepil et al. (1962, p. 163). They provide a map of the United States with isobars of similar wind speeds. These are used to map onto county locations. For the Great Plains, the minimum wind speed was 9 miles per hour (mph) and the maximum was 14. Each county was assigned one of the following wind velocity values: 9 mph = 0, 10 mph = 1, 11 mph = 2, 12 mph = 3, 13 mph = 4, and 14 mph = 5.

Percentage of sand in soils.—Soil erodibility in a county is indicated by percentage of sand, since sandy soils are highly erodible. Percentage of sand by county is taken from a STATSGO data set graciously provided to us by Geoff Cunfer from the Great Plains Population and Environment Database, 2001, ICPSR, University of Michigan.

Definition of the sample.—Our definition of the Great Plains is based on the map of the region in Kifer and Stewart (1938, p. 9). Their designation of the Great Plains includes the 362 eastern counties of Montana, Colorado, and New Mexico; all of North Dakota; those west of the ninety-seventh meridian in South Dakota; most of those west of the ninety-eighth meridian in Nebraska, Kansas, and Oklahoma; and west Texas counties in the Panhandle to 32 degrees latitude. The results described in the text do not appear to be sensitive to our definition of the Great Plains. Dropping far eastern counties in North and South Dakota, for example, does not change our results.

In our analyses, we also used a truncated sample of Great Plains counties in which crop acres as a share of total farmland were at least 40 percent (285 in 1930, variable after that). We make this distinction because the Great Plains included areas that specialized in cattle raising with natural grass pasture and areas of extensive wheat or cotton cultivation. Croplands were the most vulnerable to wind erosion.

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