# Understanding the Formation of Local Agri-Environmental Institutions: Historical Evidence from Soil Conservation Districts in the Great Plains*

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**Abstract**

Recent theoretical work on local institutions and natural resource management suggests that, by identifying the factors that drive people to cooperate, we may enrich our understanding of local institutions. I test this theory by compiling a novel database from the archives for a long-lasting local institution in the Great Plains, soil conservation districts (SCD), and estimate the effects of climatic and ecological uncertainties, placement of demonstration plot, and agricultural characteristics. Using the dataset for the period 1936 - 1957, and employing multilevel discrete survival models, I find that the likelihood of creating an SCD is higher in counties with higher ecological uncertainties, and counties near the demonstration plots.

**Keywords:** Conservation, Climate, Duration Analysis, Institution, Agriculture
**JEL Codes:** N22, N52, Q15, Q24

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# 1 Introduction

Uncertainty and other spatial heterogeneity may trigger collective action in places where people face common socioeconomic distress. Collective action under a shared threat and condition has been particularly well-documented in the literature related to civil war (Bauer et al., 2016), urban crime (McCarthy, Hagan, and Cohen, 1998; Reid, Roberts, and Hilliard, 1998), and labor movement (David, 2008; Olzak, 1989; Olson, 2009). Can this hypothesis be extended to climate or ecological uncertainties? In the face of increasing climate uncertainty, it is important to understand the capacity of local institutions and collective action; so that federal, state and local climate policies can be designed accordingly (Bréchet et al., 2012; Dryzek, Norgaard, Schlosberg, et al., 2011; Raihani and Aitken, 2011). Due to the limited budget and limited technical support available from the central governments, understanding and capitalizing on the conditions under which collective action may occur at a local level is vital to climate policy making.

Collective action or local natural resource management is critical in the current climate-related policy debate. For example, the Intergovernmental Panel on Climate Change (IPCC) recommends strengthening local institutions to reduce biodiversity loss (Mbow et al., 2017). Many developing countries started planning for local institutions to combat climate change (Sultana and Thompson, 2010), and strong local institutions have been asserted as a tool for ensuring climate resilience (Agrawal, 2008). Early studies in institutional economics have documented that the collective action model is an important instrument to manage small-scale local natural resources or commons (Commons, 1931; McCay and Acheson, 1990; Veblen et al., 1898). As economies develop, private ownership starts to dominate (Shleifer, 1998; Linke et al., 2015), but some local resources, however, still depend on a collective management system under increasing climate uncertainty.

While on the one hand, classical theory shows how rational economic modeling predicts over-exploitation of natural resources or 'tragedy of the commons' (Hardin, 1968), several scholars have argued that people cooperate to manage local resources under certain conditions and social norms (Poteete, Janssen, and Ostrom, 2010; Ahn, Ostrom, and

Walker, 2003).[1] Findings of these studies suggest that isolating the factors that drive people to cooperate can enrich our understanding of local institutions and, subsequently, their capacity to complement federal support. In this paper, I ask these questions: what are the underlying heterogeneities that determine the speed of the formation of local agri-environmental institutions related to farmland conservation activities? How do climate and ecological uncertainty play a role in that formation? Do public investment in knowledge-generating programs help landowners to realize the necessity of these institutions to conserve farmland? Understanding these dynamics may help us design better local and global agri-environmental policies.

I use a historical context from the American farmland conservation experience. One crucial implication of common-pool resource management is farmland conservation and topsoil erosion control activities. Topsoil is a natural resource that flows over different plots, and farmers need to take joint decisions to take care of their land; this is especially true where wind erosion is high (McConnell, 1983, Barbier, 1990). The on-site and off-site costs of high topsoil erosion include foregone future productivity, productivity loss in congruent plots, health hazards, and in extreme cases, a natural disaster like the Dust Bowl. Dust Bowl was a series of severe dust storms that caused significant damage to American and Canadian prairies during the 1930s. Blowing topsoil from excessive farming and grassland destruction in the Great Plains created this situation.

One of the essential agrarian institutional changes that were implemented after the Dust Bowl was the development of a farmer-governed institution to manage topsoil and to reduce the impact of wind erosion on farmland. Soil Conservation Districts (SCD), a widespread local institution that manages topsoil erosion in the United States farmland, has evolved in the American landscape following the devastating experience of the Dust Bowl. This paper creates a novel database from the national archives and draws evidence from the numerous SCDs that are operating in the USA to empirically test the theoretical hypotheses around the formation of local institutions under climate

[1]The tragedy of the commons is a situation in a common-pool resource management where individual users behave contrary to the common good of all users by depleting or spoiling that resource. The theory originated in an essay written in 1833 by the British economist William Forster Lloyd. The concept became widely known as the "tragedy of the commons" due to an article written by Garrett Hardin.

and ecological uncertainty.

Main empirical challenge in answering research questions around the formation of local institutions is that there is no existing, available dataset about their formation and community involvement from the beginning. Thus, to answer this research question, I compile a primary dataset on the Soil Conservation Districts utilizing the annual reports of the SCDs deposited in the National Archives and Record Administration at College Park (Helms, 1992). Following the Dust Bowl in 1937, the federal government instructed states to organize local soil conservation institutions. In 1937, the Soil Conservation and Domestic Allotment Act was passed, and this federal law directed all states to have state-specific regulations to support soil conservation in the farmland. Within a couple of years, each state passed its new legislation following the federal policy suggestions. However, the time it took to set up SCDs on a county-by-county basis in the Great Plains ranged from 1 to 40 years. Using empirical evidence, I study the determinants of the speed of formation of these federal-backed yet locally-organized institutions and shed light on the theoretical puzzles discussed in collective action literature (Ostrom et al., 1999). The extent of the Dust Bowl as an ecological disaster, the involvement of the federal government to support local institutions, and the spatial scale of the SCDs make this a perfect fit to understand questions related to the agricultural and environmental collective action.

I study counties affected by the Dust Bowl in the eight states of the Great Plains: Montana, South Dakota, North Dakota, Wyoming, Kansas, New Mexico, Oklahoma, and Nebraska. I primarily study the effects of three sources of spatial heterogeneity on the formation of SCDs: a) ecological heterogeneity: Soil Erosion Index issued by the USDA in 1933 that gives a measurement of high, medium, and low erosion counties (Hornbeck, 2012), b) placement of demonstration plots: USDA established demonstration plots across the Great Plains to teach farmers about conservation activities, and d) agricultural characteristics such as tenancy, access to irrigation, access to shelterbelt programs, number of farms, etc.

To guide the empirical framework, I build a simple economic model showing how climatic and ecological uncertainty may influence the initiation of the SCDs. The model identifies the key externalities and shows how they can be addressed through cooperative activities by farmers. The model predicts that: 1) visual experience of soil erosion affects the decision, 2) heterogeneity in farming characteristics influence the decision and, 3) building public infrastructure like demonstration plots may help to reduce the knowledge gap among farmers and help to create SCDs. As the outcome variable is in time, I use a duration framework to estimate the effects of the covariates on the timing of the formation of the SCDs. SCDs are organized inside a state, and I do not observe state-level unobservables like state agricultural policies. For that, I use a flexible multi-level Discrete proportional hazard survival model to capture the state-level unobservable heterogeneity (Friedman et al., 1982, Austin, 2017). This model can handle cluster-specific random effects and can vary baseline hazard function across clusters.

The results confirm the hypothesis that higher ecological variation, captured by the Soil Erosion Index, exerts a significant influence on the SCD formation process. Higher erosion areas are almost twice as likely to form an SCD than medium and low soil erosion areas. Meanwhile, medium erosion areas are more likely to form an SCD compared with lower erosion areas. I also find placement of demonstration plots create a significant difference in landowners' decision about soil erosion and conservation. I also find first decade after the Dust Bowl was more effective compared to second decade in the decision process. Other factors such as total farm area, population density and access to other conservation activities also influence the probability of an SCD being formed. Having a higher percentage of tenant farmers in an area decreases the likelihood of an SCD being formed there. Using the coefficient estimates from my preferred model, I show how marginal effects of climate and ecological heterogeneity change over space. These results confirm that having a good understanding of local institutions is important in the context of climatic and ecological uncertainties. In considering spatial factors, one may reduce the current federal fiscal burden to prevent and address regional climatic damage.

This paper makes several contributions to the literature. First, I show how the strengthening of local institutions may be effective in public policy. Early studies on institutional mechanisms state how public policy should be designed to provide an efficient public good (Samuelson, 1954). The continuous decline of natural grazing systems in the West has generated an intellectual debate around the effective management of natural resources (Gordon, 1954; Hardin, 1968; Gilles and Jamtgaard, 1981). Other early neoclassical economics studies also find that bargaining and property rights can mitigate the problem of overuse and exploitation of natural resources (Coase, 1960).[2] I contribute to this literature by showing a new dimension related to climatic and ecological uncertainty that fosters communities to cooperate to manage farmland and to define property rights through coordinated farmland conservation plans.

Second, this paper contributes to the debate around collective action management. Ostrom(2002) outlines two theoretical puzzles: the size of the collective action group and the heterogeneity in the resource management institution's performance. Due to the lack of empirical evidence, this pre-existing established theoretical literature cannot predict when people can, or will, create local institutions. Theoretical studies identify the relative importance of the different factors which underlie the formation of local institutions, and call for empirical studies to be undertaken so that we might understand the heterogeneity (Ostrom, 2002; Dietz, Ostrom, and Stern, 2003; Agrawal and Gibson, 1999; Schlager and Ostrom, 1992, Ostrom, 1992; Bromley, 1990; Blomquist et al., 1992; Banerjee, Iyer, and Somanathan, 2007).[3] Multiple forces are involved in the formation of land-related institutions, identification of the effect is challenging, and it is not surprising that empirical studies have, hitherto, been sparse and inconclusive. Case studies like this paper should provide ideas on which variables have an impact on the formation of local

[2]Property rights are the social institutions that define the range of privileges granted to individuals to specific assets, such as parcels of land or water. For example, the Coasian bargaining theorem states how well-defined property rights can sustain the system. Transaction cost theory suggests that institutional settings may help to reduce the transaction cost and make the contract work (Williamson, 1979, Ayres, Edwards, and Libecap, 2017). Because of their important social role, the survey of economics and economic history states how arrangements of property rights affect wasteful resource management through the establishment of local institutions (North, 1991; North, 1984).

[3]Under the leadership of Elinor Ostrom, a group of social scientists collected rich case studies from 5000 examples from different disciplines about CPR management all over the world to explain the structure of the resource system, the attributes, and behaviors of the appropriators, the rules that the communities are using, and the outcomes resulting from the behavior. Ostrom has outlined the principals of local resource institutions: clearly defined boundaries, congruence, arrangement, monitoring, sanction, conflict resolution mechanism, defined rights, and payoff distribution.

institutions that manage topsoil erosion and farmland conservation, as well as how to design incentive policies to mitigate the possibilities of inequality. There is also a growing literature on demonstration plot that use randomized controlled trials to understand learning mechanism by farmers (Maertens, Michelson, and Nourani, 2021).

Finally, I contribute to the growing literature by showing how common shocks may foster a spirit of cooperation. Political scientists and economists study how war and conflict encourage collaboration and cooperation (Bellows and Miguel, 2009; Bellows and Miguel, 2006; Blattman, 2009; Voors and Bulte, 2014). Using evidences from recent wars, these papers prove that war fosters cooperation. For example, recent African pieces of evidences state how people cooperate amidst civil conflicts in Sierra Leone (Bellows and Miguel, 2006, Glennerster, Miguel, and Rothenberg, 2010) and Burundi (Voors and Bulte, 2014). People exposed to violence tend to behave more cooperatively because people tend to become more pro-social after facing similar shocks (Bauer et al., 2016), Balcells and Torrats-Espinosa, 2018). Other papers also show the implication of violence on the provision of public goods such as, for example, public voting behavior (Blattman, 2009, Jakiela and Ozier, 2019). I contribute to this literature by exploring a different shock generated from climatic and ecological uncertainties and show how climate shocks may also foster cooperation.

The paper proceeds by providing background information in Section 2. I develop a conceptual model to demonstrate where gains are likely to be high in section 3. Section 4 is on the data construction. Section 5 is on empirical framework. Section 6 demonstrates the results and discussion. Concluding remarks are in Section 7.

# 2 Background on the Soil Conservation Districts

To understand the implications of ecological destruction and climate uncertainty on the concepts, and enactment, of collective action and joint management, I needed to find a place where climate uncertainty and ecological destruction create immense spatial heterogeneity. In my search, I identified the unique situation created after the Dust

Bowl in the 1930s. The federal government took action to decentralize natural resource management systems. We can use this special case to study how the intensity of the soil erosion, and the accompanying climate shock, affected the creation of local institutions.

Land conservation processes, activities, and organizations in the United States of America can be traced back to Yellowstone National Park, established in 1871. These early efforts were, however, motivated by both wildlife and nature conservation. Farmland, or soil conservation, was not on the priority agenda (Hays, 1999). The conservation of working land (or soil conservation) first came into federal discussion in 1914 with the introduction of the Smith-Lever Act. The Act gave power to land-grant universities to disseminate knowledge of farmland conservation by publication of bulletins and reports by the Agricultural Extension Service. However, this law had a negligible impact on farmers. In order to, primarily, meet the high demand for wheat in Europe – and under the conditions of the Homestead Act – farmers continued to uproot native grassland from the Great Plains region. Grassland is an essential component of the Great Plains ecosystem, and the uprooting of native grassland consequently disturbed the biological soil organic system (Webb, 1959). The result was, sadly, the slow destruction of the ecology.

In the 1930s, the Dust Bowl influenced farmers to prioritize soil conservation activities. The chief USDA soil scientist, Hugh Bennett (1928), suggested that taking marginal land out of production would offer a two-pronged solution to control production as well as soil erosion. Under Bennett's leadership, the USDA conducted a detailed soil survey to try to understand the implications of erosion in 1931-1933. Franklin D. Roosevelt was elected to office in 1933 and, in the first 100 days of his presidency, he established the First New Deal. Land utilization policies (such as regarding the purchase of submarginal, eroded farmland) were a key component of the Agricultural Adjustment Act of the New Deal in 1933. The initial plan to conserve soil had two main areas of focus: a) to buy submarginal land (set-aside program); b) to show farmers soil conservation techniques through demonstration plots.

In the first couple of years, the USDA realized that a crucial line of communication between farmers and the Soil Conservation Service was missing. Therefore, to make farmers more concerned about their soil, the USDA proposed establishing local institutions in each community at which farmers could create a group, develop management plans – with the help of Soil Conservation Service (SCS) technicians – and employ technicians in the fields. The federal government would be responsible for providing the technical and financial aid necessary for farmland management. SCS established demonstration plots to teach farmers how to take care of the soil. Eventually, different states started to adopt the law, beginning in 1937.[4] The creation of the SCDs was democratic and referendum-based; only landowners were eligible to vote for the SCDs. Three external institutions were involved in the process of helping the SCD farmers: a) The SCS of USDA (with technical assistance); b) the Extension Service (with educational programs); c) the Work Projects Administration (with financial aid). The USA currently has more than 3000 SCDs; for the most part, SCDs coincide with county administrative borders.

SCDs are still the primary local units to disseminate knowledge of soil conservation techniques in the counties. The primary purpose of SCDs is to design conservation surveys of the farm plots, assign and suggest essential conservation techniques (for both short-term and long-term use) based on the surveyed soil type, and help with structural conservation techniques. The districts have obtained funds from assessments and private contributions and earnings through equipment operations and from state and county appropriations. It is important to remember that SCDs does not define a right to topsoil, nor can they restrict farmers from the overexploitation of soil. SCDs are, rather, responsible for monitoring the arrangement of the soil conservation, teaching farmers how to undertake heavy practices, and coordinating farmers for ongoing and future planning.

# 3 Conceptual Framework

In this section, I lay out a conceptual model for farmers' production decisions that closely follows previous agricultural economics literature regarding the effects of soil

[4]On April 27, 1935 Congress passed Public Law 74-46, in which it recognized that "the wastage of soil and moisture resources on farm, grazing, and forest lands . . . is a menace to the national welfare," and it directed the Secretary of Agriculture to establish the Soil Conservation Service (SCS) as a permanent agency in the USDA. The Department published a model state law in May 1936 which would authorize farmers to organize soil conservation districts.

erosion (McConnell, 1983 and Barbier, 1990). Under the regularity assumptions of the production function, it is possible to predict the effects of spatial and temporal climatic uncertainty, and farm characteristics, on the formation of a local institution. I start with an open-access model for farmers, showing how ecological uncertainty may affect the production decisions through excessive topsoil erosion, and then consider the nature of negative externalities resulting from the topsoil erosion. Next, I extend the model to include the possibilities of institutional arrangements to solve the problems of these externalities.

Farmers maximize personal farm profit. Land is divided into $n$ parcels, $i = 1, 2, 3, ..., n$. Without loss of generality, we assume that only one crop is produced. $q = f(z, x)$ is the production function with $z$ input package where some inputs are soil conserving; $x$ is soil depth. $r$ denotes the discount rate. Farmers use their part of the soil depth and transfer that to the next plot. The level of wind erosion (climatic uncertainty) is unknown. This is what we capture by incorporating production uncertainty. $\pi$ is farm profit. $\widetilde{\pi(Z, X)}$ shows that profit is uncertain and a function of input package and soil depth.

Without any institutional arrangement, for a single farmer the value function is the present discounted profit over time. Constraint in this optimization function denotes the evolution of soil depth over time, and show how that depends on both the production input package and previous topsoil extraction.

$$\max V_t = \sum_{t=0}^{\infty} r^{-t}[\widetilde{\pi(Z, X)}]dt \tag{1}$$

subject to

$$X_{t+1} = g(z_t, X_t) \tag{2}$$

The most important insight from this framework is that the first-order condition and optimal soil extraction path under open access would depend on $\frac{\delta f}{\delta z}$, $\frac{\delta f}{\delta x}$, $\frac{\delta g}{\delta z}$ and $\frac{\delta g}{\delta x}$: how the farmer's yield function changes with soil health and input use, and how the soil transition from one plot to another plot changes with input use and soil health.

There are two different social problems from this open-access model: a) farmers' current soil extraction may have a negative impact on his own future profit (on-site cost) and; b) there is a neighborhood effect of soil erosion from one plot to another (off-site cost) (Hansen and Libecap, 2004; McConnell, 1983). Previous literature has identified that a key barrier to internalizing this negative externality is the conservation knowledge gap experienced by farmers. Some soil conservation techniques are labor- and skill-intensive, and farmers need assistance and support in order to learn them (McConnell, 1983). The USDA provided technical support through the establishment of demonstration plots.

An SCD forms only when collective action will give more aggregate benefit than the private action undertaken by individual farmers (as in Equation 1). For an optimal management plan at the social level, the decision to extract soil includes all of the nearby parcels of land. There is a cost attached to this coordination and we can denote that by $c$; the cost varies over the plots. In accordance with the existing body of scholarship, we can call this "transaction cost" or "coordination cost." There is $M$ number of farmers. The social planner chooses the optimal soil extraction path that distributes maximum benefit among the participants.

$$\max V_M = \sum_{t=0}^{\infty} \sum_{m=1}^{M} r^{-t}[\pi\widetilde{(Z, X)} - c]dt \tag{3}$$

subject to

$$X_{t+1} = g(z_t, X_t) \tag{4}$$

Farmers will participate in creating a local institution to internalize the negative externality only if the aggregate benefit is more prominent than the individual benefit (individual rationality or participation constraint). The likelihood of agreement between institutions at any point of time depends on a number of factors. All things being equal, the greater the size of the anticipated aggregate benefits of institutional change, the more likely that new property rights will be sought and adopted (Libecap and Wiggins, 1984).[5] There are three sets of variables that may influence this adoption: climatic and ecological variables which influence the production uncertainty; farm characteristics that influence

[5] SCD cooperators get some financial assistance to adopt conservation practices too. From that sense, SCD is a mixture of Pigouvian subsidy model and Coasian bargaining models.

the transaction cost or coordination cost, and; access to demonstration plots to learn the importance of conservation activities.

Firstly, climatic and ecological variations affect the production uncertainty as well as baseline knowledge and experiences about soil erosion. Higher levels of uncertainty may foster the formation of SCDs. Alternatively, higher uncertainty may push the farmers below survival level and lower the probability of cooperation. Next, farmers may understand the importance of conservation and form SCDs faster if they live near demonstration plots established by the USDA. Next, farm characteristics that may influence the transaction costs of coordination include farm size, number of farms, and access to alternatives, e.g., irrigation or windbreak. Land tenure may also play an important role in decision-making. Landowners may vote for SCDs, meaning that a higher percentage of tenancy may have a negative impact. Alternatively, SCDs need extra labor; percentage of tenancy may have a positive impact. Heterogeneity in the population, such as population density or racial composition, may delay the adoption process. The empirical strategy and data construction sections of this paper introduce a strategy that may be used to identify these aforementioned factors that may affect the decision to establish an SCD.[6]

# 4 Data Construction and Summary Statistics

To disentangle the relative contribution of different factors toward the formation of SCDs, I have constructed a dataset that involves both primary data extraction from the National Archives at College Park and the compilation of explanatory factors from various secondary sources. The empirical analysis is based on a sample of 594 counties in the Great Plains. I have chosen to focus upon the eight Great Plains states: Montana, North Dakota, South Dakota, Nebraska, Kansas, New Mexico, Oklahoma, and Wyoming. The area of study is shown in Figure 1. To have consistent observation units over time, I have followed Hornbeck (2012) in adjusting all data to 1910 boundaries. Figure-1 plots the study area.[7]

[6]From the 1970s, water quality also became a large part of the decision process in the soil conservation. Our study period ended in 1957, so we do not include "distance to water bodies" as a potential variable.

[7]ICPSR provides this agricultural census data after geographic adjustment.

## 4.1 Data from the Annual Reports of SCDs

My main primary data sources are the annual reports of SCDs from the National Archives at College Park. The USDA asked all SCDs to submit annual reports to them, showing detailed and significant soil conservation progress. The reports are arranged to show the progress of and future plans for soil conservation activities. The reports have been deposited in the National Archives at UMD-College Park (RG 114).

The SCD boundaries mostly overlap with county boundaries. This overlapping was not required by any federal- or state-level laws. However, in the evolution over the next decades, SCDs have followed existing administrative boundaries. Some counties initially had more than one SCD, but these were eventually consolidated into just one in any given area. In these instances, and to remain consistent with my other explanatory variables, I consider the first SCD in the county border for my sample purposes.

As states started with the policy at different stages, I have collected relevant data relating to state policies' timing - from the state-specific Soil Conservation and Domestic Law reports. Table 1 shows the various times at which the eight states adopted the policy in my dataset. Kansas, Oklahoma, North Dakota, South Dakota, and Nebraska passed the law in 1937, while Montana passed it in 1939, New Mexico in 1938, and Wyoming adopted it in 1941. I introduce multi-level discrete choice models to deal with this hierarchical system at the state level in econometric modeling.

## 4.2 Climate and Ecological Variables

I have taken data on soil erosion from Hornbeck (Hornbeck, 2012). Counties are divided into medium, low and high erosion areas. The data shows the proportion of areas in any county, which are experiencing different levels of erosion. This dataset omits some counties, and for those, I impute the erosion index from state-level averages.

One alternative method that has been used to increase soil moisture is the planting of shelterbelts (agroforestry). The Prairie Forestry Project was targeted to improve the shelterbelts (1936 -1942). Data on areas that are under shelterbelt is not readily available. I have collected and manually extracted county-level areas, listed under 'Great Plains

Shelterbelt Project', from the project reports that have been deposited in the regional archives in Missouri city, Kansas (RG 114).

### 4.3 Placement of Demonstration Plots

The USDA established demonstration plots across the states to help farmers learn about soil erosion and farmland conservation activities. Narrative literature says that placement of demonstration plots created an inequality as some farmers did not get the technical help from the plots (Sampson, 1985). I collect a historical map for the placement of demonstration plots from the National Archives at the College Park and digitize the map to create a distance variable for every county (Fig 2). Farmers used to travel across neighboring counties to see the demonstration, so I used counties 100 miles around any demonstration plot as "near demonstration plot" counties in the regression framework.

### 4.4 Data from Agricultural Census

Explanatory variables relating to farming characteristics have primarily been taken from the Census of Agriculture, the Census of Population, and county data books. These include the percentages of farms that have been operated under tenant farmers, farm sizes, total number of farms, proportion of area under farmland, the proportion of area under cropland failure, the proportion of area under irrigation, etc. Furthermore, I have used population density from the Population Census. The agricultural census has been collected every four years. I use the data from 1935 to 1957. I have used 'ipolate' command in STATA to extrapolate annual variables with linear interpolation.

Table 2 displays the names and sources of the variables used in the paper. I show the mean of all census years in Table 3. As Table 3 suggests, the Great Plains indicate a very low percentage of black population in our sample. Moreover, the tenancy rate is decreasing over time while the farm size is increasing. Population density is, meanwhile, stable over time. The distribution of SCDs across soil erosion types are not homogeneous. Also, crop failure shows substantial variation over space. Table 4 suggests that an average SCD takes 79 months – in terms of total time – to form in the Great Plains.

# 5 Empirical Framework

The duration model has been widely used in land economics in order to understand the variations in the timings of events (Ando, 1999; Wrenn, Klaiber, and Newburn, 2017; Bulan, Mayer, and Somerville, 2009; Dawkins, Shen, and Sanchez, 2005). This paper draws upon, and extends, this previous literature by placing the duration framework within the context of collective action in farmland conservation in the USA. In accordance with the analytic framework, we are interested in estimating the effects of covariates on the creation of an SCD in the Great Plains.

I use the gap in the timing between the policy (state law) and time of the formation of the SCDs (event) to study the factors behind temporal variations in the policy-to-event. I record the initial length (spell) in months. The final sample for this paper consists of 519 counties in eight states, who started to have an SCD in the period 1937 to 1956. From the initial date of the policy, I follow the counties until their date of formation, and record the length of their duration in units of months.

Using this database, I examine several quantities of interest related to the formation of SCDs. The formation distribution, in months, is plotted in the histogram (Figure 2). The distribution shows that there is sufficient variation in the timing; it is important to understand the causes of the variation in the speed of this formation. I use non-parametric Kaplan-Meier estimates in order to explore the shape of the overall hazard function. However, it must be noted that Kaplan-Meier is a descriptive way to explore hazard function, and therefore cannot estimate the effects of covariates.

I use hazard function in order to approximate the probability of the formation of an SCD within a short interval, conditional on surviving up to the starting up to the interval which is the essence of an optimal stopping investment decision (Dixit and Pindyck, 1994). I allow hazard function to depend on both time-varying and time-invariant covariates. In each period,$t$, the landowners come together and decide whether or not to start an SCD to reduce the soil erosion. In this analysis, $T$ is the length of time before the SCD occurs. $t$ denotes a particular value of $T$. The cumulative distribution function of $T$ is defined by:

$$F(t) = P(T \leq 0); \quad t \geq 0$$

The survivor function is defined by,

$$S(t) = 1 - F(t) = P(T > t)$$

Given that the spell has lasted until time t, this is the probability that it will end in the next interval of time. As we are assuming T to be continuous, we can identify the probability density function. Denote the density of T by $f(t)$

$$P(t \leq T < t + h | T \geq t)$$

is the probability of forming an SCD in the interval. The hazard function is defined by:

$$\lambda(t) = \lim_{h \to 0} \frac{P(t < T < t + h)}{h} = \frac{f(t)}{S(t)}$$

where $f(t)$ denotes the density of T. The $\lambda(t)$ represents the rate of conversion of the collective action group (SCD) occurring in the time interval $dt$ given that it has not occurred prior to that time. All probabilities can be computed using this hazard model. In the models that follow, we define f(t) and S(t) to be functions of independent variables (X) and parameter $\beta$, and choose $\beta$ to maximize the log of the following likelihood function, L($\beta$).

$$L(\beta) = \prod_{i=1}^{n} f(t_i, X\beta)^{\lambda_i} \prod_{i=1}^{n} [(1 - S(t_i, X\beta)]^{1-\lambda_i}$$

Because unobserved characteristics of the states may affect the outcome, I use multilevel mixed-effect duration models to include group-level random effects in my model (Austin, 2017). The assumption is that counties in the same state are correlated because they share common state-level random effects. I use a proportional hazard (PH) model where covariates have a multiplicative effect on the hazard function. The discrete survival model with the cloglog link approximates the PH model with mixed effect and is frequently used to include random effects (Austin, 2017). When random effects are incorporated in the Cox model, these random effects denote increased or decreased hazard for distinct groups (states). This yields the model:

$$h(t_{ji}) = h_0(t_{ji})exp(x_{ji}\beta + z_{ji})$$

The counties are nested in states, j = 1,....,8. Baseline hazard function, $h_0(t)$, is assumed to be parametric. The vector $z_{ji}$ contains the covariates corresponding to the random effects. I use "mecloglog" command in STATA 16 with shared frailty.

I use the discrete time duration model in the PH model so as to incorporate unobserved heterogeneity (fragility). My outcome variables are measured in years, so a discrete choice model is a better fit than the continuous time survival models. Cox (1972) proposed an extension of the PH model to discrete time by working with the conditional odds of dying at each time $t_j$ given survival up to that point. Specifically:

$$\frac{\lambda(t_j|x_i)}{1-\lambda(t_j|x_i)} = \frac{\lambda_0(t_j)}{1-\lambda_0(t_j)}exp(xb)$$

Here $\lambda(t_j|x_i)$ is the hazard at time $t_j$ for an individual with covariate values $x_i$, $\lambda_0(t_j)$ is the baseline hazard at time $t_j$, and $exp(xb)$ is the relative risk associated with covariate values $x_i$. Taking logs, we obtain a model on the logit of the hazard or conditional probability of dying at $t_j$ given survival up to that time,

$$logit\lambda(t_j|x_i) = \alpha_j + xb \tag{5}$$

where $\alpha_j = logit\lambda_0(t_j)$ is the logit of the baseline hazard and $x_i\prime\beta$ is the effect of the covariates on the logit of the hazard. Note that the model essentially treats time as a discrete factor by introducing one parameter $\alpha_j$ for each possible time of formation $t_j$. Interpretation of the parameters $\beta$ associated with the other covariates follows along the same lines as in logistic regression. I use a complementary log-log transformation of the baseline hazard model.

$$log(-log(1-\lambda(t_j|x_i))) = \alpha_j + xb; \alpha_j = log(-log(1-\lambda_0(t_j))) \quad (6)$$

# 6 Results

My discussion of the results starts with some descriptive analyses. I use non-parametric Kaplan-Meier estimates to explore the shape of the hazard functions and survivor functions. Figure 3 shows the fraction of counties without any SCDs for a certain number of months. Figure 4 presents the survivor function for the full sample and Figure 5 shows these disaggregated by the states. We can see that the speed slows down over time and displays a significant variation over time. I also present the failure function and Nelson-Aalen Cumulative Hazard Function. These show that the hazard rate is increasing over time. This might be a case of increasing levels of knowledge dissemination – or increasing levels of cooperative behavior – among the SCDs. These figures suggest that SCDs were created at an increasing rate; the last SCD in our sample took 188 months to be established.

One limitation of non-parametric Kaplan-Meier curves is that they cannot analyze the effects of covariates. In order to do so, we need to move to the regression model to estimate covariate-adjusted survival. The outcome variable is the duration measured by years between state policies and the formation of an SCD in the county. We use discrete choice proportional hazard models to estimate the impact of the time-varying and time-invariant covariates. In my model, total farm area, percentage of tenants, population density, failed cropland, and total number of farms, are all time-variant. Furthermore, Soil Erosion Index, crop failure, and area under irrigation are time-invariant and measured in 1934 (collected from the agricultural census of 1935). Also, I use the historical placement of demonstration plots, and create a distance to the nearest demonstration plot variable. This is also time invariant variable. The erosion variables are continuous. These variables count the proportion of area, in any county, that is experiencing low, medium and high erosion levels. The summation of these proportions must add up to one.

Table 5 presents the results. Discrete model coefficients and odds ratios show that increases in erosion increase the probability of SCD formation. One unit increase in higher erosion areas increases the probability of formation by a factor of 2.5, which is higher than in the medium and low erosion areas. This means that higher erosion regions are 2.5 times more likely to form an SCD compared to low erosion areas. Moreover, medium erosion areas are 1.62 times more likely to form an SCD compared to lower erosion areas. These results corroborate our intuition about the effects of visual experiences encountered as a result of erosion levels of that county. High erosion decreases farm productivity, and so landowners may use SCD as a coping mechanism. Also, visual inspection of higher erosion may foster collective action.

Next, we see that counties around USDA-established demonstration plots have 1.3 times higher chances to create a SCD. Placement of demonstration plots increased knowledge about conservation activities, and so landowners were more likely to form SCD if they see demonstration plots around their counties.

Next, the Dust Bowl experience created in 1930s may fade away over time. I create a decade dummy to capture that effect. We see that 1950 decade dummy has a lower effect compared to previous decade.

Our theoretical framework shows that agricultural farm capacity constraints also influence the decision-making process to form an SCD. Farmers with lower capacity and higher transaction costs will not be able to form an SCD. We see from Table 5 that one unit increase in log total farm area leads to an increase by a factor of 1.24. More farmland creates more capacity to put effort into conservation activities. More farmland also means that the counties are more farming-dependent, and farm populations consequently have more political agency to pass legislation accordingly, and have better access to extension service. Furthermore, log (failed cropland) highlight a decreased probability of creating an SCD. This may be an indicator that the dry regions do not tend to form SCDs quickly. The main restrictions are often poverty and a lack of the capital needed to create SCDs.

As the theory suggests, an increase in levels of farm tenancy serves to decrease the probability of an SCD being formed. According to the legislation, only landowners are permitted to vote for the formation of an SCD. Also, tenants have fewer incentives to create a permanent institution to take care of soil. An increase in tenants, therefore, decreases the probability of SCD formation. A single unit change in tenancy decreases the probability by 3

Next, we see that the increase in population density increases the odds of forming an SCD. This is understandable as more than 25 landowners are required to come together before a referendum may be issued. Population density also decreases the transaction costs of coming together and of organizing collective action and activities.

An increase in total shelterbelt plantation under 'The Great Plains Forestry Project' increases the probability of forming an SCD by a factor of 1.003. The presence of shelterbelts signals further collective joint actions around environmental stewardship. SCS technicians were also more readily available at the shelterbelt project locations.

Next, the area under irrigation in 1934 has seemingly no significant effect on SCD formation, but the probability magnitude is low. This may be a reflection of the fact that, in 1934, irrigation levels were low. Next, total number of farms decreases the probability of forming a SCD. This is intuitive as cooperation breaks down if size is bigger. A similar analysis, using a continuous survival model, shows that the results are similar across models (here, duration is measured in months). I have also produced a Bayesian estimation as we have small numbers of groups. The results are similar to those that have been presented in this paper.

# 7 Conclusion

Local institutions play a significant role in coordinating the management of natural resources and in helping communities to reduce the uncertain effects of environmental shocks. Understanding the determinants in the formation of local SCD institutions helps us to identify the probability of the success of an institution in a particular setting. This paper takes advantage of a federal-backed local institution to conserve farmland, and studies how public infrastructure, ecological heterogeneity, and agrarian structure affect the formation process.

Libecap and Hansen addressed wind erosion in the Great Plains as a common-pool resource problem, and also mentioned that the negative externality from erosion has partly been solved by the creation of SCDs (Hansen and Libecap, 2004). Several other narratives also indicate that SCDs are a major instrument for farmland conservation in the USA (Morgan, 2013). However, detailed analysis of SCDs has not been undertaken because of data limitations. This paper produces primary data on SCDs across the Great Plains, and explores the underlying factors that can influence their formation. I find that soil erosion levels have a significant impact on SCD formation. I also show that demonstration plots play an important role in the formation. I have also shown how several farming characteristics, and population density, affect the formation of SCDs, especially the size of the farmland area and the percentage of non-owner farmers.

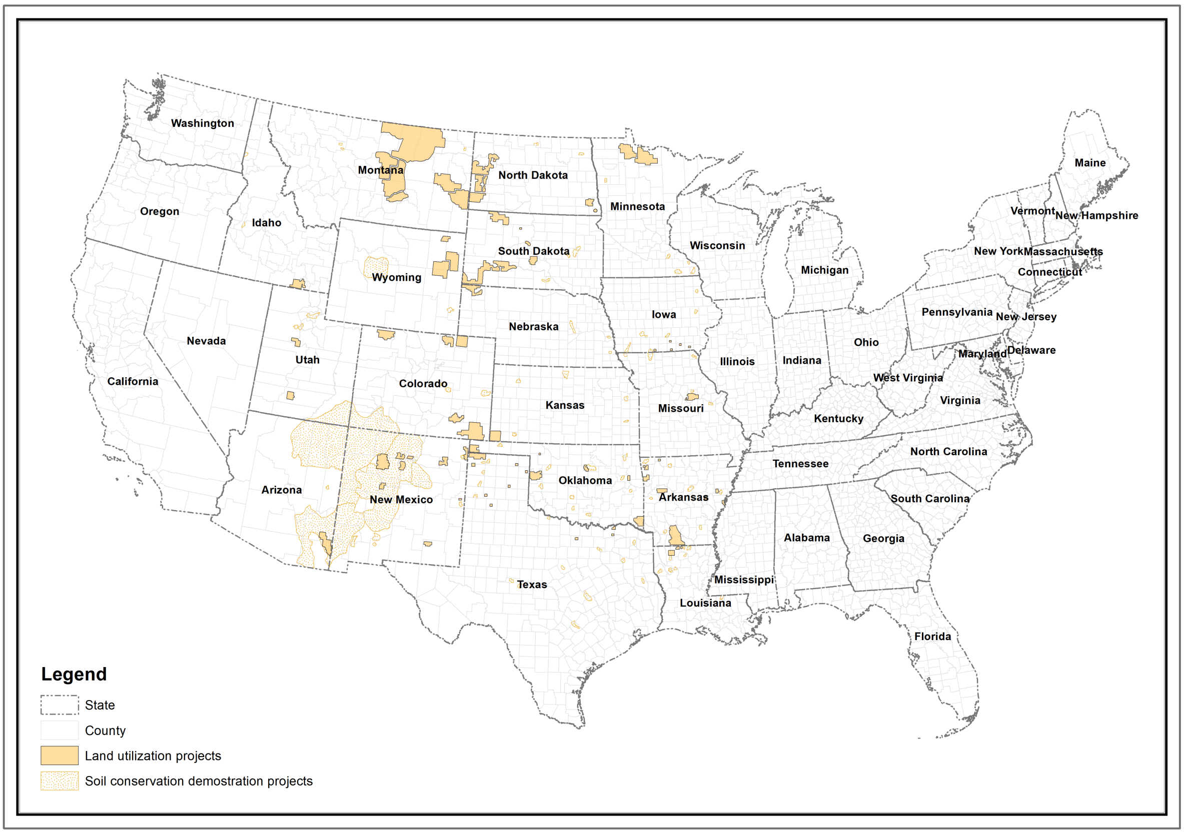
It has been difficult to empirically examine how variations in the ground variables may affect collective action. This paper contributes to the existing body of scholarship by providing empirical evidence on the relative importance of different covariates: both economic and ecological. The findings of this paper can mainly be used in two dimensions in order to design conservation policies: firstly, existing knowledge about the spatial heterogeneity in formation may be used to design better policies in order to nudge landowners. Policy makers may try to utilize demonstration plots to teach methods related to soil conservation. Secondly, the micro-level variations in farm characteristics may help us to understand the distributional consequences of SCDs. The USA's Environmental Quality Incentive Programs (EQIP) still disseminate technical services, primarily through SCDs. The knowledge dissemination process – if dependent upon some pre-established spatial heterogeneity in land institutional management – may have long-term ecological and economic consequences.

# 8 Maps

Figure 1: **Study Area: The Great Plains**


Note: Eight states are included: Nebraska, North Dakota, South Dakota, Montana, Kansas, Oklahoma, New Mexico and Wyoming

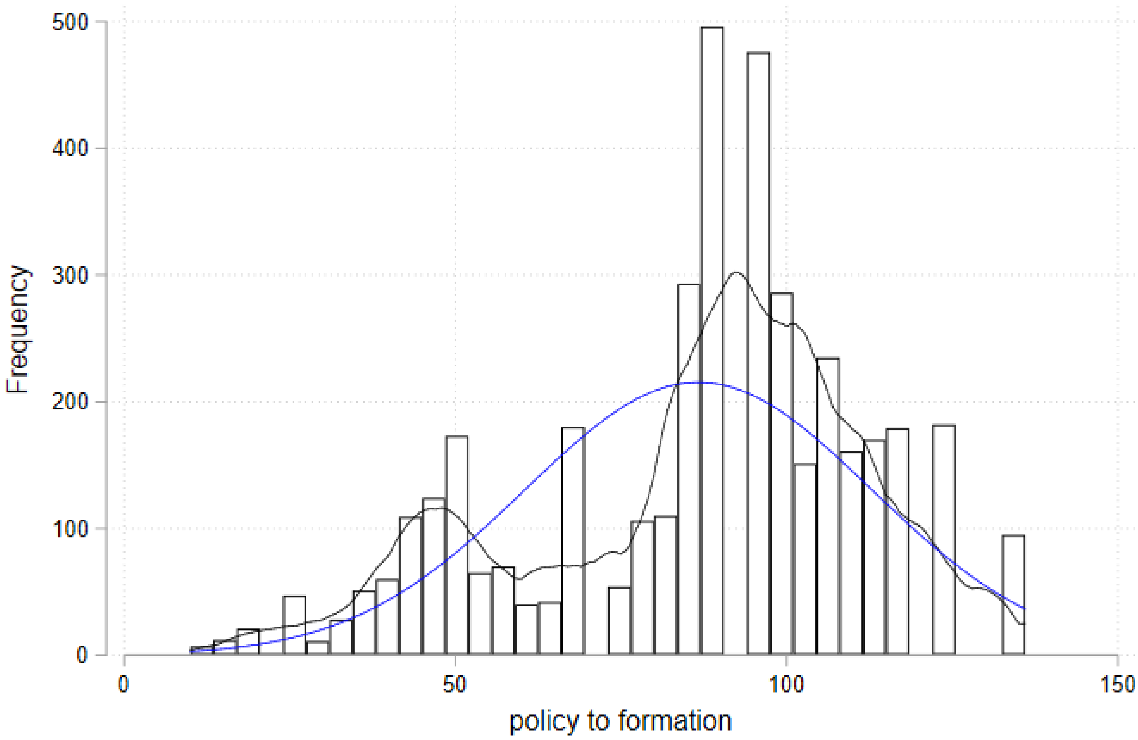
Figure 2: **Soil Conservation Demonstration Plots**




Soil Conservation Demonstration Plots established by the United States Department of Agriculture. Map obtained and digitized from the National Archives at College Park.

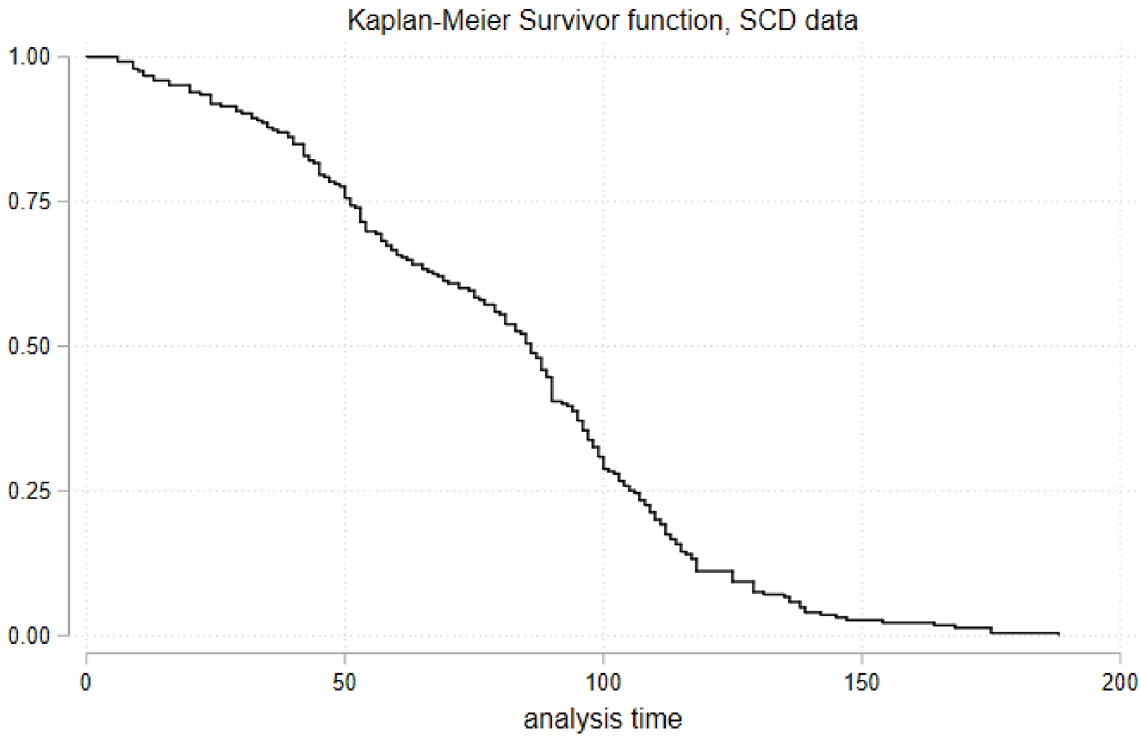
# 9 Graphs

Figure 3: **Distribution of Policy to Formation**



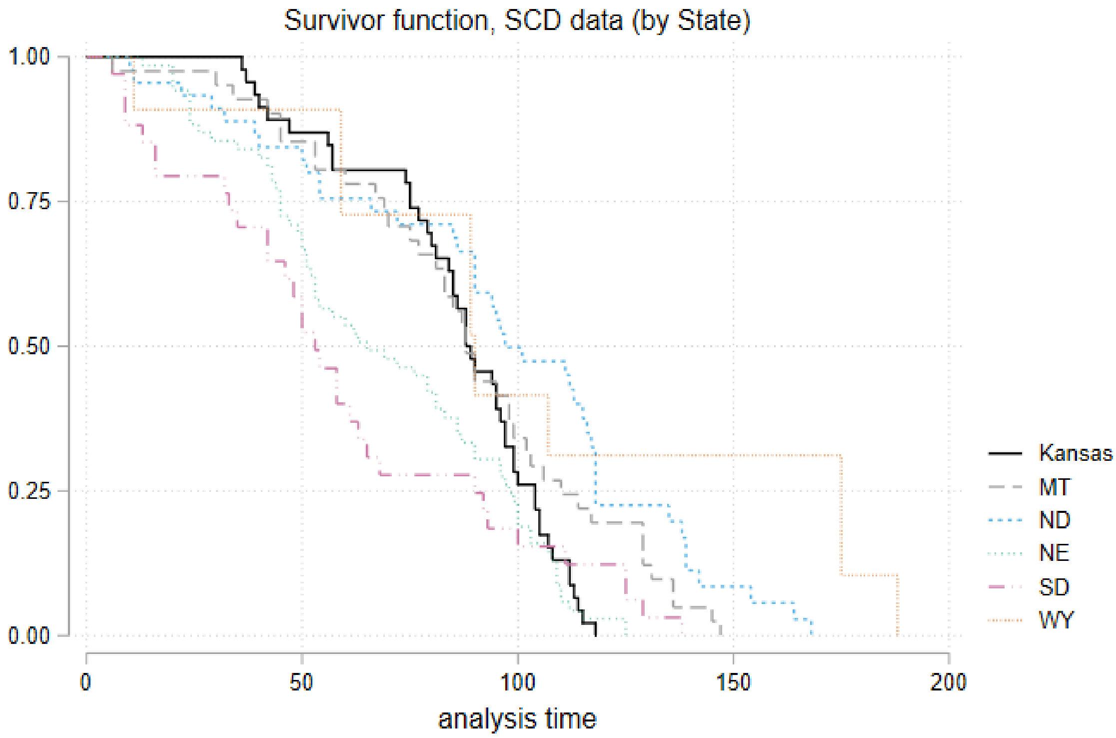

Note: Data on formation and referendum collected from the annual reports of Soil Conservation Districts.

Figure 4: **Kaplan-Meier Survivor Function**




Note: Data manually collected from the annual reports of Soil Conservation Districts deposited in the National Archives and Records Administration. This data covers 1936 to 1957 formation of the SCDs.

Figure 5: **Survivor Function by State**




Note: Data manually collected from the annual reports of Soil Conservation Districts deposited in the National Archives and Records Administration. This data covers 1936 to 1957 formation of the SCDs.

# 10 Tables

Table 1: Timeline: Soil Conservation and Domestic Allotment Act

| | |
|---|---|
| 1936 | Federal Law "Soil Conservation and Domestic Allotment Act" |
| 1937 | Kansas, North Dakota, Nebraska, South Dakota |
| 1938 | New Mexico |
| 1939 | Montana |
| 1941 | Wyoming |
| $t > 1941$ | Formation of Districts continues |

Manually collected

Summary statistics is available in Table 2. In the duration analysis we will try to explore if this variation can explain the duration gap.

Table 2: Description of the Variables used in Duration Analysis

| Variable Name | Description | Data Source |
|---|---|---|
| SCD Time | Year, Date, Month | SCD Annual Reports |
| SCD Size | Initial size | SCD Annual Reports |
| SCD Location | Location in the county | SCD Annual Reports |
| Tenancy | Percentage of Tenants | Agricultural Census |
| Landowners | Proportion of landowners | Agricultural Census |
| Proportion Black Farms | Black Farms/Total Farms | Agricultural Census |
| Proportion White Farms | White Farms/Total Farms | Agricultural Census |
| Farm size | Average farm size | Agricultural Census |
| Number of Farms | Total Number of Farms | Agricultural Census |
| Population Density | Population/acre | Agricultural Census |
| Soil Erosion | Soil Erosion Index | Reconnaissance Erosion Survey (Hornbeck (2012)) |
| Shelterbelt plantation area | Acreage, Own collection | Kansas Regional Archives |
| Distance to the Demonstration Plot (mile) | Own Calculation from historical map | National Archives at College Park (RG 114) |

[a] SCD reports are manually collected from RG114 at National Archives and Records Administration at College Park.

[b] A SCD location inside the county is not determined.

Table 3: Summary Statistics

| | (1) 1935 | (2) 1940 | (3) 1945 | (4) 1950 | (5) 1954 | (6) 1959 |
|---|---|---|---|---|---|---|
| Total Population | 26515.1 | 25611.6 | 25674.7 | 26590.4 | 26656.2 | 29317.6 |
| | (127800.1) | (122718.4) | (122863.4) | (127999.5) | (128151.4) | (143401.4) |
| Total Number of Farms | 2687.2 | 2373.6 | 2177.3 | 2069.9 | 1930.4 | 1708.1 |
| | (12519.7) | (11154.7) | (10220.4) | (9670.9) | (8991.5) | (7941.1) |
| Total Farm Area | 1217379.3 | 7833504.7 | 1347917.6 | 136172177.1 | 139011090.5 | 1411940.5 |
| | (4989332.7) | (40448471.3) | (5520360.5) | (557725592.7) | (569320285.5) | (5787021.3) |
| Average Size of Farms | 633.1 | 396.1818 | 1011.7 | 1129.7 | 1204.8 | 1391.5 |
| | (652.8) | | (1247.4) | (1609.6) | (1513.1) | (1848.3) |
| Percentage of Tenants | . | 43.29 | 32.47 | 26.70 | 26.13 | 23.86 |
| | (.) | (13.00) | (12.99) | (10.79) | (11.09) | (10.20) |
| $N$ | 407 | 407 | 406 | 405 | 404 | 403 |

mean coefficients; Standard Deviation in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

[a] Data extracted from USDA Agricultural Census.

Table 4: Parametric Survival Distribution

| Category | Total | Mean | Median | Max |
|---|---|---|---|---|
| N | 319 | | | |
| Time at Risk | | 79.60 | 85 | 188 |
| (final) exit time | | 79.60569 | 85 | 188 |
| Failures | .975 | 1 | 1 | |
| Incidence Rate | .0122 | | | |
| Survival Time | 51(25%) | 86(50%) | 106(75%) | |

[c] Weibull model has lowest AIC.

Table 5: Discrete Proportional Hazard Model with Mixed Effect

| VARIABLES | (1)<br>Model Coefficient | (2)<br>Odds ratio |
|---|---|---|
| Medium Erosion | 0.487** | 1.628** |
| | (0.229) | (0.373) |
| High Erosion | 0.918*** | 2.503*** |
| | (0.275) | (0.689) |
| Near Demonstration Plot | 0.269* | 1.309* |
| | (0.138) | (0.181) |
| 1950 Dummy | -1.222*** | 0.295*** |
| | (0.287) | (0.0847) |
| Log(Total Farmarea) | 0.216*** | 1.241*** |
| | (0.0393) | (0.0488) |
| Percentage of Tenants | -0.0318*** | 0.969*** |
| | (0.00678) | (0.00657) |
| Population Density | 1.110 | 3.034 |
| | (0.772) | (2.344) |
| Total Shelterbelt | 0.00194* | 1.002* |
| | (0.00102) | (0.00102) |
| Log (Crop Fail, 1934) | -0.0126 | 0.988 |
| | (0.0505) | (0.0499) |
| Total Irrigated, 1934 | -2.15e-06 | 1.000 |
| | (4.26e-06) | (4.26e-06) |
| Total Farm number | -0.000638** | 0.999** |
| | (0.000261) | (0.000261) |
| Sq(TotalFarm number) | 1.17e-07* | 1.000* |
| | (7.06e-08) | (7.06e-08) |
| var(_cons[State]) | 0.584* | 1.793* |
| | (0.341) | (0.612) |
| Constant | -3.621*** | 0.0268*** |
| | (0.819) | (0.0219) |
| Observations | 2,416 | 2,416 |
| Number of groups | 8 | 8 |

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

[a] Mixed Effect Discrete Choice Model. First column shows the probability of forming a SCD in a county. Second column shows the respective odds ratio.

Table 6: Discrete Proportional Hazard Model with Mixed Effect

| VARIABLES | (1) Marginal effects |
|---|---|
| Medium Erosion | 0.0686** |
| | (0.0345) |
| High Erosion | 0.129*** |
| | (0.0456) |
| Near Demonstration Plot | 0.0402* |
| | (0.0232) |
| 1950 Dummy | -0.121*** |
| | (0.0331) |
| Log(Total Farmarea) | 0.0304*** |
| | (0.00823) |
| Percentage of Tenants | -0.00448*** |
| | (0.00131) |
| Population Density | 0.156 |
| | (0.113) |
| Total Shelterbelt | 0.000273* |
| | (0.000154) |
| Log (Crop Fail, 1934) | -0.00177 |
| | (0.00710) |
| Total Irrigated, 1934 | -3.02e-07 |
| | (6.20e-07) |
| Total Farm number | -8.98e-05** |
| | (4.04e-05) |
| Sq(TotalFarm number) | 1.65e-08 |
| | (1.17e-08) |
| Observations | 2,416 |

Standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

[a] Mixed Effect Discrete Choice Model. Column shows the marginal effects at mean from Table 5.

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