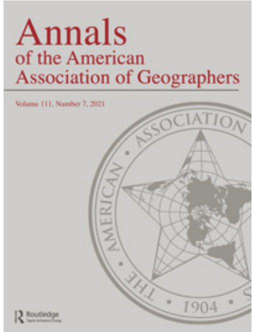

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Footprints from the Dust Bowl: Using Historical Geographic Information Systems to Explore Land and Resource Access, Use, and Survivability in "No Man's Land," Cimarron County, Oklahoma

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Despite the importance of land legacy effects on land use/land cover change (LULCC), historical data remain underutilized in analyses of social–environmental systems (SES). Drought, a slow-onset disaster, serves as an ideal case study to examine how multitemporal LULCC provides context for contemporary land use patterns. We use historical geographic information systems (HGIS) to analyze land ownership change, resource access, and land use in Cimarron County, Oklahoma, the epicenter of the Dust Bowl. We digitize archival county plats covering 1931 through 2014 into an HGIS. Through analysis of ownership information, we trace changes in familial and corporate landholdings during this period, exploring how different landowner types have changed over time. Aerial photography analysis helps to quantify the adoption of irrigation in relation to family survivability. Results show that families with larger landholdings in the 1930s were significantly more likely to persist through the Dust Bowl and continue owning land in the present. Access to the Ogallala Aquifer also increased the duration of land ownership. Corporate operators were most aggressive in adopting irrigation. Results raise questions of sustainability and uneven access to resources. We argue that land legacy has profound impacts nearly a century later. Further, SES studies can benefit from incorporating HGIS into their repertoire. *Key Words: Dust Bowl, historic GIS, land legacy, land use/land cover change, social–environmental systems.*

Agriculture sustains civilization but is also a primary driver of global land use/land cover change (LULCC; Lambin and Geist 2006). Agricultural LULCC is particularly acute in drylands, areas characterized by water scarcity and limited soil moisture, which nonetheless support 50 percent of the world's livestock and 44 percent of the world's crops (Safriel et al. 2005). Both the extent and aridity of drylands is projected to increase as the climate changes (Schlaepfer et al. 2017), which will place new pressures on agriculturalists in dryland regions and the global food systems they support (Verburg et al. 2013; Vadjunec et al. 2018). Understanding how future shifts in agricultural practices and LULCC will affect the social–environmental systems (SES) in drylands depends on understanding how historic LULCC processes develop over long periods of time (Coomes, Takasaki, and Rhemtulla 2016). The historic roots of LULCC remain understudied in SES research, however, particularly in dryland studies.

The nuanced historical context of the human and ecological components of SES is gaining increasing attention (Beymer-Farris 2013). The Global Land Programme (2016, 12) identified "long-term histories of land-use change" as a key priority, because historical land ownership and use clearly influences present-day patterns (Coomes, Takasaki, and Rhemtulla 2011). Quality historic land cover data prior to the advent of remote sensing can be difficult to obtain, though. Records of past agricultural practices and relationships among people altering the landscape are often lost with the passage of time. Leaving important information about social historical context out of SES analyses disregards (1) the importance of how a land system was originally designed, (2) how the ecological system was being used, (3) who was benefiting from that system and, by extension, (4)

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how people relying on the system could be affected in the future (Michon 2011; Beymer-Farris and Bassett 2012).

Drought, as a slow-onset disaster (Cutter 2004), serves as an ideal scenario for studying the impacts of historic LULCC on SES. Management practices during drought directly alter the function of environmental services, household use of natural resources, and landowner vulnerability (Kasperson, Kasperson, and Turner 1996). Poor management practices during drought could increase land degradation through leaching, soil erosion, decreases in biodiversity, woody plant encroachment, and aquifer drawdown (McGuire 2014; Archer et al. 2017). There is often a scalar mismatch, though, between data collected on households affected by drought and the remotely sensed data measuring drought (see Rindfuss et al. 2004; Frazier et al. 2019). In these cases, long-term historic data sets such as historical maps can add necessary context (Cousins 2001; Petit and Lambin 2002).

To demonstrate how history can be better integrated into SES studies, we use historical geographic information systems (HGIS) to analyze the hidden histories of Cimarron County, Oklahoma, a county with a history of severe recurrent drought, including the 1930s Dust Bowl. Although many agriculturalists migrated from the Great Plains during this period, a popular romantic notion maintains that others outlasted the Dust Bowl through "true grit," or attachment to place (Worster 2004). Agriculturalists remaining in the region offer a different story: Their families were "too poor to leave." Yet, evidence suggests a more nuanced LULCC process rooted in familial histories and the need to survive. The work of Coomes, Takasaki, and Rhemtulla (2011), for instance, found that Amazonian households with larger landholdings were more likely to increase the area of their cultivated land than those with smaller landholdings. Further, they identified a "dynasty effect" where households receiving land from previous generations were less likely to live in poverty. Rather than using poverty as a direct proxy, we focus on a family's vulnerability to losing land and resource access, and their survivability in a region of cyclical drought.

We identify Dust Bowl "survivors"—those whose familial land ownership outlasted the environmental disaster—in Cimarron County, Oklahoma, and use HGIS to analyze their long-term family histories and impacts on the landscape. These long-run processes are not often at the forefront of traditional SES studies of LULCC or resilience (Redman and Kinzig 2003). Here, we explore what bringing a deeper and more nuanced land history can offer SES research. In illustrating what HGIS can offer to SES studies through a case study example in the southern Great Plains, more specifically, we address three subquestions:

1. How has the type of landowner and land use changed in tandem over time and space in Cimarron County, Oklahoma, between 1931 and 2014?
2. How do resources (e.g., groundwater access or historic homestead sites) affect landowner resilience?
3. Based on the notion of dynasty effect, are families with a larger initial geographic footprint more likely to "survive" through multiple generations?

In the following sections, we discuss the use of HGIS in agricultural and LULCC studies and the challenge of incorporating qualitative data into HGIS. Additionally, we explore the complex social-ecological history of Cimarron County, Oklahoma, followed by a discussion of our mixed-methods approach. After presenting and discussing our results, we provide concluding remarks on both the dynasty effect of drought survival with implications for social–ecological resilience of a land system and the promise and perils of HGIS in SES research.

Historical Geographic Information Systems: Evolving Methods and Challenges

Geographers have a tradition of using historical and archival data to better understand spatial phenomena (Pearson and Collier 1998; Knowles 2002; Cunfer 2005; Bonnell and Fortin 2014; Szabó et al. 2015). As GIS became a primary tool for analyzing spatial patterns, researchers working in history-focused traditions fused historic data sets with GIS tools (I. N. Gregory and Healey 2007; Schlichting 2008). The outcome, HGIS, is a flexible, dynamic, and analytically rigorous spatial analysis system, capable of handling large and complex data sets from multiple perspectives and providing insight into the causes of historical events, patterns, and processes (Knowles 2002; Knowles and Hillier 2008; Sprague 2013).

Using HGIS in a mixed methodological approach can strengthen knowledge claims and facilitate interdisciplinary research (Schlichting 2008). HGIS allows researchers to reimagine historical landscapes and events from a "geographical perspective" (Knowles and Hillier 2008, 269). For example, Hillier (2003) used an HGIS to fuse census and property surveys and conduct spatial regression analyses that show that areas with African American residents were subject to mortgage redlining practices. Medley, Pobocik, and Okey (2003) similarly used a combination of GIS and historical archival analysis to reveal the historical changes in forest cover based on land use change and land ownership dynamics.

Most frequently, quantitative historic data such as digital elevation models and land granting documents (e.g., Hunter 2014) or county plats and aerial photography (e.g., Medley, Pobocik, and Okey 2003; see also Sylvester et al. 2013) are used to capture land cover and land use characteristics in HGIS. To strengthen the credibility of inferences about LULCC processes, HGIS analysis might incorporate qualitative data that facilitate triangulation and the improved interpretation of results (e.g., Longley, Webber, and Lloyd 2007; O'Kelly 2007; Simon 2014). Examples of such qualitative data include personal letters and tax reports from the U.S. Civil War (Ayers and Thomas 2003) and ethnographic interviews (Cope and Elwood 2009). Additionally, some qualitative data could be transformed into quantitative data through time and space, expanding the potential for more robust analyses (Pearson and Collier 1998).

HGIS has been widely implemented in agricultural and land use studies (Campbell 2000). For example, Cunfer (2008; see also Cunfer 2005) constructed an HGIS-based database detailing social–ecological characteristics of counties affected by the Dust Bowl. Cunfer's analysis demonstrates how natural weather patterns created or catalyzed the Dust Bowl, challenging prior Dust Bowl narratives, which described the event as mainly a "human ecological failure" (Cunfer 2008, 101; see also Worster 2004). Taking a longer temporal perspective, Hunter (2014) used archival Spanish land-granting documents, digital elevation models, and GIS to analyze historical land use change in New Spain (Mexico). Similarly, Fagin and Hoagland (2014) analyzed repeat Public Land Survey System data to examine historical patterns of LULCC following European-American settlement in south-central Oklahoma.

More broadly, HGIS is increasingly used in the spatiotemporal analysis of LULCC (see I. N. Gregory and Southall 2002; McLeman et al. 2010). Although useful as a platform for mixed-methods analysis, any HGIS project is simultaneously subject to the sets of uncertainties that accompany historic data and geographic representation. As imperfect representations of real-life phenomena, spatial data have a degree of uncertainty that could be amplified when working with historical or qualitative information. Spatial or temporal uncertainties can emerge during the conceptualization, measurement, analysis, and representation of the geographic entity through investigator bias or historical inaccuracy of a phenomenon (Plewe 2002; Knowles 2005). Assumptions about location, time, and shape of an entity can all introduce error. Further, because historical data are often ephemeral, investigators are left with little knowledge regarding the quality, efficacy, intent, or provenance of the data. Consequently, HGIS studies might be widely susceptible to error and suffer many of the same pitfalls of other archival methods (Hay 2005).

At the same time, HGIS can serve as a powerful tool for visualizing and conveying complex themes in an easily digestible format (Owens 2007). HGIS can also be used to help to uncover data inaccuracies at multiple spatial and temporal scales (Carrion et al. 2016). Moreover, some forms of qualitative data (e.g., relatively simple county plats) can be transformed into quantitative data using the storage, analysis, and visualization capabilities of GIS, thus expanding the potential for more robust analyses (Pearson and Collier 1998). Ultimately, HGIS will continue to evolve with the growth of "digital humanities" (Cope and Elwood 2009; Travis and von Lunen 2016).

Social and Ecological History of Cimarron County, Oklahoma

Cimarron County, Oklahoma (Figure 1) is located in the southern Great Plains, a region known as the "breadbasket of the United States" and, more recently, "the breadbasket of the world" (Sanderson and Frey 2014). Despite its agricultural importance, Cimarron County has endured six major drought events over the past 120 years, including the Dust Bowl of the 1930s (Worster 2004). The county comprises one third of the Oklahoma Panhandle, a

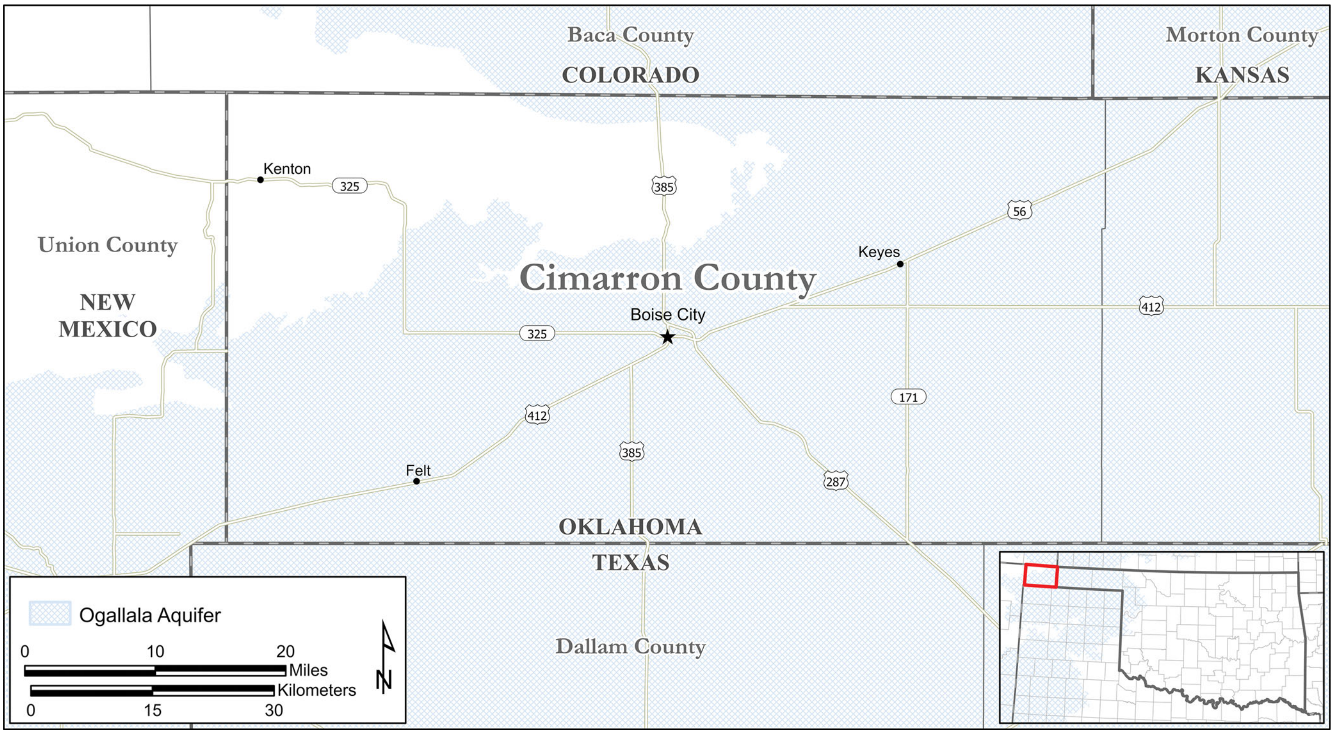


Figure 1. Location of the study area in historic "No Man's Land": Cimarron County, Oklahoma.

region once known as "No Man's Land," because it was unattached to any state or territorial government from 1890 to 1907. Cimarron County epitomizes No Man's Land given its extreme location ("the end of the tail of the dog"), low population density, sparse services, antagonistic underdog identity, and complex history (Vadjunec and Sheehan 2010). Moreover, a participatory mapping project by Porter and Finchum (2009) identified Cimarron County as the epicenter of the Dust Bowl. Cimarron County is also the only county in the United States that touches four other states. Known as the Five States Area, it is representative of the region in terms of history, socioeconomics, and agricultural and western lifestyle.

Cimarron County is located at an ecological crossroads, where the shortgrass prairie–dominated High Plains merge into the dissected plains, canyons, and mesas of the Southwestern Tablelands (Woods et al. 2005). The county has a semiarid cold steppe climate (Köppen BSk) with normal annual precipitation averaging 438.4 mm (17.26 inches) and average maximum temperatures of 21.6°C (71°F) and minimum temperatures of 4.4°C (40°F; Oklahoma Climatological Survey 2020). There is a distinct southeast to northwest gradient in both precipitation and temperatures, with both slightly decreasing along the gradient.

Agriculture has long been the predominant land use in the county and remains so today, with 1,097,472 acres (93 percent) in production in 2017, of which 402,669 acres (~37 percent) were classified as cropland. These croplands are primarily associated with the rolling, irregular High Plains, whereas pasturelands dominate the more rugged Southwestern Tablelands. The primary crops grown include wheat (~24 percent of the total cropland acreage), grain sorghum (~18 percent of the total cropland acreage), and corn (~5 percent of the total cropland acreage), and cattle are the primary livestock raised (~97.7 percent of total livestock inventory). According to the 2017 Census of Agriculture, Cimarron County is ranked second in the state and in the top 10 percent nationally in overall agricultural market products sold (U.S. Department of Agriculture National Agricultural Statistics Service 2019).

On Oklahoma's statehood in 1907, Cimarron County was a mosaic of scattered large historic ranches along the Dry Cimarron and predominantly small, quarter-section farms (160+ acres; Vadjunec and Sheehan 2010), with a population of 5,927 (U.S. Census Bureau 1996). Population steadily decreased in the following decades, however (U.S. Census Bureau 1996, 2018a), most notably in the environmental and economic disaster of the "Dirty Thirties."

A number of factors have been implicated in the massive 1930s outmigration from the Great Plains. The "Okie Migration" of agriculturalists from Oklahoma and surrounding areas saw about 400,000 migrants move to California (J. N. Gregory 1989). Even in areas not directly affected by the Dust Bowl, increased agricultural mechanization such as use of tractors reduced the demand for family labor and allowed land to be consolidated into larger, more efficient operations owned by fewer people. Regional demand for farm labor was further reduced by the Agricultural Adjustment Act of 1933, which offered subsidies to landowners for taking land out of production (Rasmussen, Baker, and Ward 1976). Often, tenants operating these lands were forced off by landowners (J. N. Gregory 1989). Unable to purchase land, many former tenants left. Of the Oklahoma farmers lucky enough to own land, 10 percent faced foreclosures between 1931 and 1933 (Mullins n.d.).

The decision to leave home was not easy. Often the hardest hit families were presented with an impossible choice: stay put and risk further impoverishment or invest in the costly journey west with no guarantee of work (Manes 1982). As the situation worsened, migration from the region increased dramatically, peaking in 1938. Despite the promise of fertile fields in the West, many "Okies" faced challenging circumstances in their new home, a fate novelized by Steinbeck (1939) in his iconic *The Grapes of Wrath*. Likewise, those who dug their heels in and persisted through blackout conditions in almost daily dust storms struggled immensely. Some of these survivors were helped financially by federal assistance programs until precipitation returned in 1938 (Weisiger 1995).

In Cimarron County, severe drought is a common, recurrent, cyclical event. The Dust Bowl of the 1930s is the best known of these events, with 95 percent of the southern Great Plains experiencing severe drought and associated economic hardship at its peak (Wilhite 2018). Evidence suggests, however, that the Dust Bowl was but one severe drought event in a series (Woodhouse, Lukas, and Brown 2002; Gallo and Wood 2015). Since the Dust Bowl, the area has been racked with periods of exceptional drought, including a drought in the 1950s described as "one of the more severe of record in the Southwest and southern Great Plains" (Nace and Pluhowski 1965, 50). Recently, the region experienced an extreme drought that lasted from approximately 2000 to 2015 and, at its peak, was described as "more intense than the Dust Bowl era droughts" (Freedman 2013).

One adaptation to become "drought proof" is to irrigate. Beginning in the 1950s, following another extreme drought event, there was a steady increase in both the number and area of irrigated farms, with the technology first introduced in neighboring Dallam County, Texas (Wenger, Vadjunec, and Fagin 2017). A large portion of the county is underlain by the High Plains (Ogallala) Aquifer system (see Figure 1). The Ogallala helped foster the rapid growth of center-pivot irrigation (CPI), a mechanized irrigation method in which large equipment rotates around a central pump tower connected to a water source; here, groundwater. Although beneficial for farmers in the short term, CPI has been linked to rapid loss of groundwater resources, threatening the long-term sustainability of agriculture (Basso, Kendall, and Hyndman 2013).

Another important adaptation to drought is to procure more land (own, lease, or crop share). Land tenure in Cimarron County is a matrix of private and public ownership. Private lands, occupying 78 percent of the county's total land area, include those owned by individuals, families, and trusts, as well as limited liability companies (LLCs) and other corporate entities. The county also has a significant (relative to other counties in the state) amount of public lands. These lands include federally owned multipurpose lands, such as the Rita Blanca National Grasslands, located in the southwestern portion of the county and covering approximately 1.33 percent of the county's total area, and a state park and wildlife management areas, covering less than 1 percent of the county's area (Oklahoma Natural Heritage Inventory 2020). Other public lands include city properties, as well as state and federally maintained roadways. The public lands that get the most attention in the county, however, are state school trust lands, which cover approximately 20 percent of the county's total area (Fagin et al. 2016) and are leased by producers to expand operations. Although these lands are vital to many of the county's producers, they are also contentious (see Vadjunec and Sheehan 2010).

Under the Enabling Act of 1906, which paved the way to statehood, sections 16 and 36 in each township were set aside for common education, and section 13 was set aside for colleges and universities (Commissioners of the Land Office of the State of Oklahoma 2015). Money from leases of these state school lands is distributed to public schools and colleges and universities throughout the state. The law stipulated equivalency, however, or "in lieu of lands" for lands already homesteaded. The sparsely populated Panhandle became the ideal place for the "in lieu of lands" (Hodge 1937), with Cimarron County receiving a disproportionate share of these state school lands. Because these lands are state owned, they do not generate regular ad valorem tax for the county, and much of the revenue they generate through leases goes to support "downstate" schools. Nonetheless, many agriculturalists in the region rely on state trust lands to sustain and expand their operations. Although some families have relied heavily on state land leases to meet their farming and ranching needs throughout several generations, changes in land governance and the introduction of an open bidding system have forced some lessees off their land and even out of the county (Vadjunec and Sheehan 2010). Overall, the complex social and ecological history of the region continues to shape both the residents and the landscape.

Mixed-Methods Research and HGIS

The analysis, framing, and conceptualization of this article draws from an ongoing mixed-methods field project in the region (Vadjunec and Sheehan 2010; Vadjunec et al. 2018; Colston, Vadjunec, and Fagin 2019), started in 2008 in conjunction with the Oklahoma Oral History Research Program. Although our larger project focuses on farmer and rancher adaptation to the most recent drought (2000–present), a strong underlying historical component to our research surfaced through our relationships with the Oklahoma Oral History Research Program and local museums.

Plat Acquisition, Digitizing, and HGIS Construction

We constructed an HGIS from a combination of secondary data sources, archival evidence, and field-based ethnography. Our archival work focused on locating and digitizing historical maps and documents detailing Cimarron County land ownership dating back to the 1930s. Among the most important assets in our analysis were county plats, which were produced each year for use by the Cimarron County Clerk's office. These wall-size posters mapped each parcel of land in the county and recorded mainly qualitative data, including the parcel's owner, section location, and, at times, mineral rights ownership (Figure 2). Plats are annually produced ephemeral data that were not meant to be saved. An encounter with a badly water damaged plat from 1931 in a local museum sent us on a county- and state-wide hunt for a more complete set.

In a sustained, piecemeal effort, we acquired archival plats from the years 1931, 1946, 1954, 1963, 1983, 1998, 2007, and 2014 from various sources, including the Cimarron Heritage Center, the County Clerk's office, and family archives of historic landowners. Some of the plats were printed with a production date, and we dated others by consulting historical deed records for the county to triangulate a one- to two-month window in which the plats' landowners matched the deed timelines. Additionally, we sourced historical maps from the basement of the county courthouse depicting early homesteads from 1845 to 1889 (Figure 3).

For each plat, we captured a digital image either through use of a large-format scanner (when possible) or high-resolution photography (captured in tiles in the field). Images were mosaiced, imported into ArcMap 10.4 (Esri, Redlands, CA, USA), and georeferenced according to a master vector base map of county sections. We manually digitized polygons for each parcel and entered feature attribute data, including the owner's name, the owner type (family, public, corporate, etc.), township, range, and section. Plats were digitized in chronological order, with the vector data from earlier decades copied to the following decade and then edited to reflect any changes. This methodology ensured consistency of nonchanging landowners over time. We calculated the area of each parcel and totaled each landowner's holdings.

Although plats listed the first and last name of each owner, we observed ambiguity or typographical errors over time that complicated our ability to individually identify owners by their first name and trace their land ownership over time. For example, it was not always possible to determine whether the names John Smith, John P. Smith, and Jon Smith represented the same person, or perhaps a father and son,

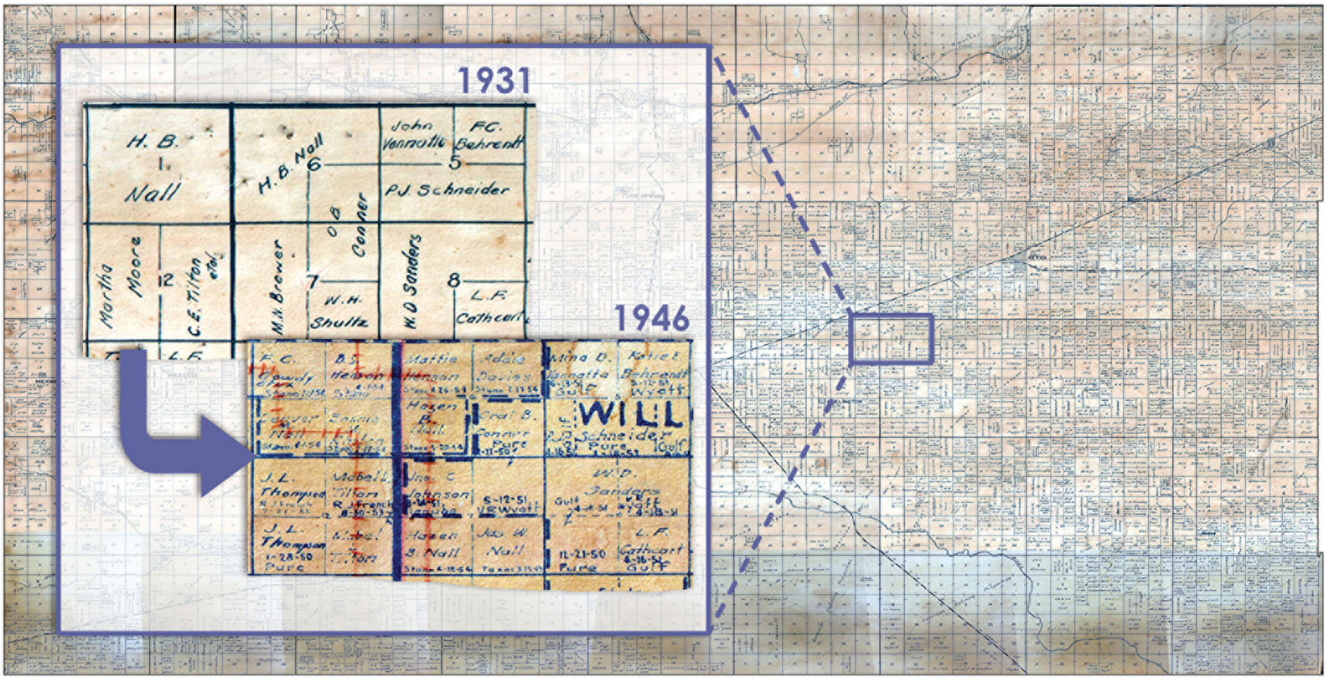


Figure 2. Historic plat example. A 1931 plat shows handwritten landowner information for every parcel of land in the county (background). The subset illustrates the change in landowners and parcels between the 1931 and 1946 plats (foreground).

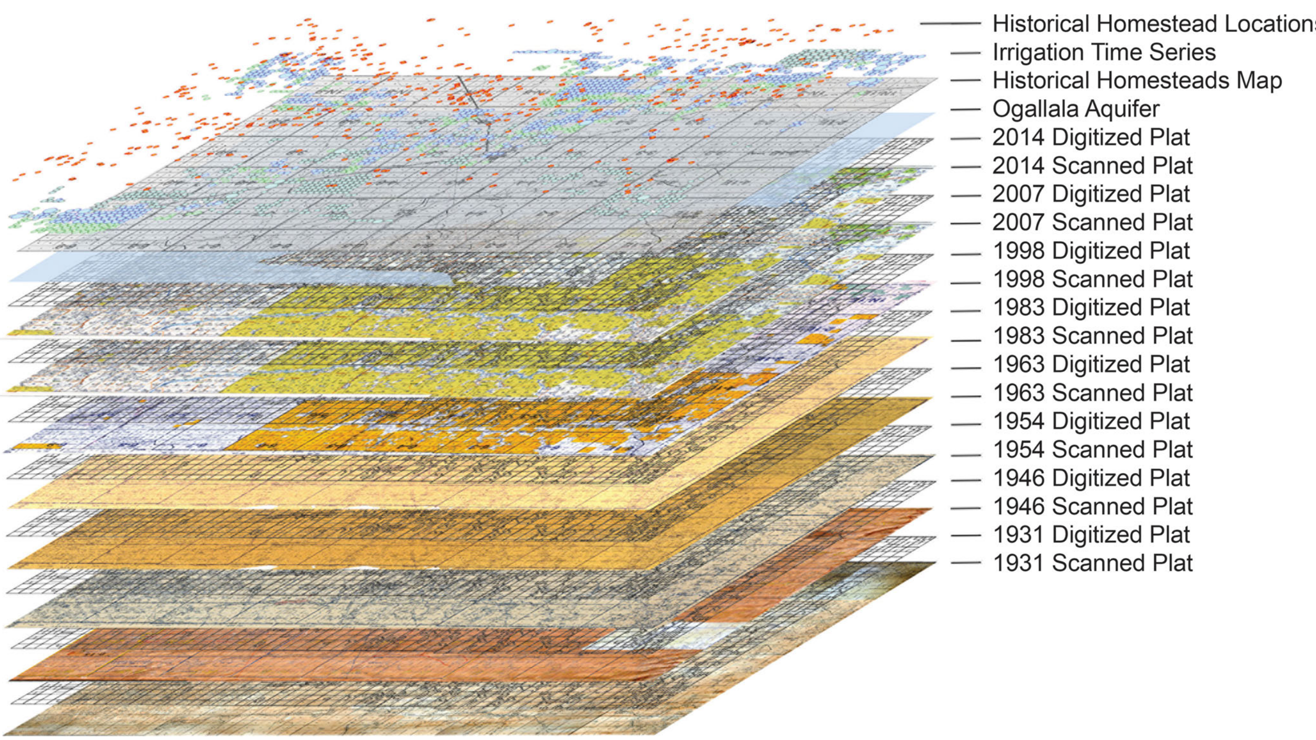


Figure 3. HGIS layers. The HGIS incorporated eight scanned historical plats (1931–2014) and digitized polygons representing each parcel on the historical maps. Additional layers included the footprint of the Ogallala Aquifer, locations of historic homesteads, and a time series of center pivot irrigation footprints from 1985, 1995, 2005, and 2015. HGIS = historical geographic information system.

and so on. For the purposes of the analyses presented here, we have calculated the total landholdings from each year for each family surname, corporation, or government entity. Using surnames only, we found little ambiguity or noted error. At the same time, in using last names as a proxy for familial relationships, we acknowledge that not all Smiths or Johnsons might be related, although our experience in the region shows strong and deep kinship ties. Still, we found great value in the ability to measure the survival of entire families despite the death, name change, or emigration of individual family members. Further, we hypothesized that a relationship might exist between a family's collective landholdings or number of family members and their ability to persist through the decades.

Triangulation Using Primary and Secondary Data Sources

To provide context, we drew on agricultural census data, ethnographic fieldwork, participant observations, and key informant interviews conducted with Cimarron County residents each summer from 2010 to 2017 (Vadjunec and Sheehan 2010; Sheehan and Vadjunec 2012; Wenger, Vadjunec, and Fagin 2017). This laid the foundation for conceptualizing and developing our HGIS analysis, as we set out to triangulate the factors that appeared to allow some families to survive the Dust Bowl and Depression, even as others were forced to leave. For instance, perceptions of "corporations as competition" is a recurring theme garnered from interview data (Vadjunec and Sheehan 2010). We also know from extensive discussions with Dust Bowl survivors that people either made bold "risk taker" moves to start, such as buying more land immediately after their neighbors left the area, or they hung on to what they had in case things got worse ("steady" survivors). Additionally, time spent in the records of the county clerk's office furthered our understanding of early corporate oil speculation in the region. Hence, our approach to measuring survivability is based on our understanding of their stories.

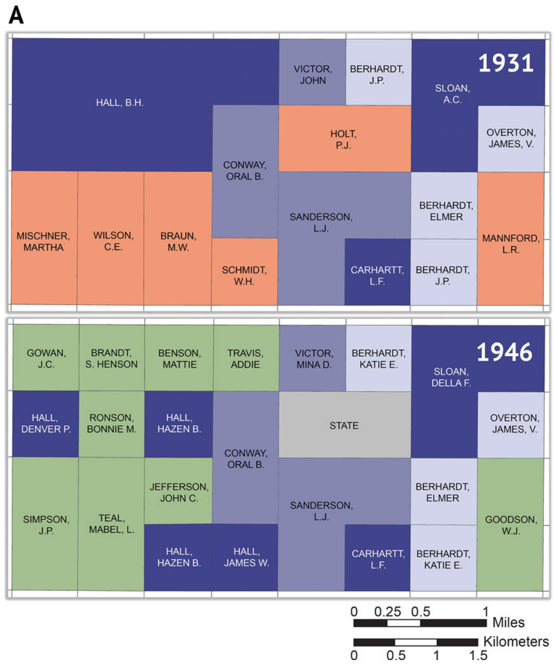
We also drew on secondary data sources from the U.S. Census Bureau and U.S. Department of Agriculture (USDA) Census of Agriculture between 1930 and 2018 (USDA 2018). Combined, these data are used to provide further context for the results elucidated by our HGIS.

Landowner Analysis

To gain insights on the trends of landholders throughout the decades, we established a typology to categorize families according to how their landholdings changed after the 1930s (Figure 4; Table 1). We classified each family as an emigrant, survivor, or latecomer. We defined a category of emigrants as those whose last name appeared on the 1931 plat but not the 1946 plat (although some later returned). Note that emigrants constituted entire families who left; our analysis does not account for individual migrations. By contrast, survivors were defined as families who owned land in both 1931 and 1946 (and often other subsequent decades).

Within the survivor category, we established three subcategories, based in part on our ethnographic experience in the region, to describe the family's landholding changes: (1) declining survivors, who decreased their landholdings by greater than one acre per year from 1931 to 1963; (2) steady survivors, who changed their landholdings by less than one acre per year over the same period; and (3) risk-taking survivors, who acquired new land at a rate of greater than one acre per year from 1931 to 1963. This time frame and typology were selected to explore the long-term impacts of land legacy years after surviving an extreme event. As such, we identified the type of survivor (declining, steady, or risk-taking) by their landholding changes in the years (1946–1963) directly after the Dust Bowl through the equally devastating drought of the 1950s (known locally by some as the "double whammy"). Finally, the latecomer category included families who did not appear on the 1931 plat but owned land in at least one subsequent decade (see Table 1). Similarly, trends in acreage were calculated for each corporation and different types of public lands (e.g., state, federal, etc.).

Additionally, using 100-year-old historical homestead maps, we determined how many historical homestead footprints were located within each family's 1931 landholdings. Building on work by Coomes, Takasaki, and Rhemtulla (2011, 2016), we hypothesized that agriculturalists on older, more established homesteads would also likely have more quality infrastructure on their property, as well as access to nearby surrounding infrastructure (i.e., paved roads, better services and utilities, etc.). Environmentally, the lands can be seen as representing speculators' "first choice" in terms of access to



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FAMILY NAME	ACREAGE 1931	1946	1954	1963	1983	1998	2007	2014	TYPE
BENSON	0	160	0	0	0	0	0	0	LATECOMER
BERNHARDT	480	480	1280	2560	2560	2560	5760	5760	RISK-TAKING SURVIVOR
BRANDT	0	160	160	160	640	640	640	1280	LATECOMER
BRAUN	320	0	0	0	0	0	0	0	EMIGRANT
CARHARTT	160	160	0	0	0	0	0	0	DECLINING SURVIVOR
CONWAY	320	320	320	320	320	320	0	0	STEADY SURVIVOR
GOODSON	0	320	320	0	0	0	640	0	LATECOMER
GOWAN	0	160	160	160	320	640	640	640	LATECOMER
HALL	1120	640	640	160	160	0	0	0	DECLINING SURVIVOR
HOLT	320	0	0	0	0	0	0	0	EMIGRANT
JEFFERSON	0	160	160	0	0	0	0	0	LATECOMER
MANNFORD	320	0	0	0	0	0	0	0	EMIGRANT
MISCHNER	320	0	0	0	0	0	0	0	EMIGRANT
OVERTON	160	160	640	640	640	0	0	0	RISK-TAKING SURVIVOR
RONSON	0	160	160	0	0	0	0	0	LATECOMER
SANDERSON	480	480	480	480	480	0	0	0	STEADY SURVIVOR
SCHMIDT	160	0	0	0	0	0	0	0	EMIGRANT
SIMPSON	0	320	320	320	0	0	0	0	LATECOMER
SLOAN	480	480	480	0	0	0	0	0	DECLINING SURVIVOR
TEAL	0	320	320	320	640	1280	1280	0	LATECOMER
TRAVIS	0	160	160	160	160	160	160	160	LATECOMER
VICTOR	160	160	160	160	160	640	160	0	STEADY SURVIVOR
WILSON	320	0	0	0	0	0	0	0	EMIGRANT

Figure 4. Example of plat analysis. Total acreage for each family was cross-tabulated by decade and analyzed over time to create a landowner typology. For illustrative purposes only, family names and locations changed to protect human subjects. (A) Transition between 1931 and 1946 defined emigrants and survivors. (B) Individual land holdings over time based on typology.

Table 1. Landowner typology definitions

Type	Definition
Emigrants	Family name found on 1931 plat but not 1946 (although some later returned).
Declining survivors	Family name found on both 1931 and 1946 plats. Decreased landholdings by greater than one acre per year from 1931 to 1963.
Steady survivors	Family name found on both 1931 and 1946 plats. Changed landholdings by less than one acre per year from 1931 to 1963.
Risk-taking survivors	Family name found on both 1931 and 1946 plats. Increased landholdings by greater than one acre per year from 1931 to 1963.
Latecomers	Family name not found on 1931 plat.
Public	Landowner name listed on plat as federal, state, county, or city lands.
Corporate	Landowner name listed as business (e.g., limited liability company, limited partnership, corporation, etc.).

land, water, and other natural resources. Further, a homestead's entrenched social–environmental histories (e.g., a longer agricultural production and credit history, etc.) might serve to provide a head start and a firm footing for families initiating farming and ranching operations in the area.

We calculated county-wide descriptive statistics to examine changes in private, public, and corporate landholding patterns over time. Additionally, we examined individual landowners' acreage to identify changes in landholding inequality. Further, to elucidate differences between families based on their 1931 landholding footprint (i.e., their "dynasty"), we grouped families into four subsets: (1) those owning a quarter-section (160 acres) or less, (2) those owning between a quarter-section and a full section (161 – 640 acres), (3) those owning between one and four sections (641 – 2,560 acres), and (4) those with greater than four sections. By examining each individual landowner's acreage, we were able to identify those with the greatest swaths of Cimarron County's land and relate these data to broader trends of survival or emigration.

Table 2. Decrease in landowners over the decades

	1931	1946	1954	1963	1983	1998	2007	2014
Number of unique landowners on plat	2,023	1,661	1,529	1,541	1,609	1,316	1,241	1,236
Average acres per unique landowner (excluding public lands)	473	542	559	593	576	709	752	754
Average parcels per landowner (excluding public lands)	2.2	2.7	2.1	2.8	2.8	3.1	4.0	4.1
	1930	1940	1950	1960	1980	1990	2000	2010
U.S. Census population	5,408	3,654	4,589	4,496	3,648	3,301	3,148	2,475

Note: Census data are sourced from U.S. Census Bureau (1996, 2018a, 2018b).

Center Pivot Irrigation Analysis

We also investigated the adoption of CPI, which became more common in the region beginning in the 1970s, with the technology expanding dramatically in subsequent decades. About 80 percent of the county falls within the footprint of the Ogallala Aquifer, meaning that landowners with property outside of the aquifer boundary typically do not have adequate groundwater resources to operate CPI. We digitized areas of irrigated cropland throughout the county for the years 1985, 1995, 2005, and 2015 using USDA aerial photography and Landsat imagery (see Wenger, Vadjunec, and Fagin 2017). Although the chronology of the CPI time series is a slightly imperfect match, it is based on quality and availability of imagery. Further, due to the high costs of CPI installation, change tends to be much more incremental than land tenure changes. We then performed overlay operations to determine the underlying land ownership type for each CPI circle in the county, using ownership information from the plat chronologically closest to the year each imagery data set was captured (Figure 3).

We calculated descriptive statistics for CPI adoption to determine the rates and time frame of adoption among different landowner types (private, corporate, and public). We examined how private landowners' Dust Bowl survival history, landholding size, and position of landholdings within the Ogallala Aquifer might have influenced their readiness to implement CPI, as well as the extent of their CPI installations.

Results

Landowner Analysis

The number of unique landowners in Cimarron County (including individuals, corporations, and government entities) decreased consistently, from 2,023 landowners in 1931 to only 1,236 in 2014 (Table 2, Figure 5). The largest dip in landowners occurred in the period between 1931 and 1946. During that fifteen-year period the number of unique landowners decreased by 18 percent, as both families and corporations left the county in the midst of the Dust Bowl and Great Depression. This decrease in landowners observed on the plats mirrors the population change recorded over the same period by the U.S. Census (U.S. Census Bureau 1996, 2018a). Whereas the 1930 county census population exceeded 5,000, this decreased to just 2,475 by 2010 (Table 2).

Average acres per landowner (including public lands) followed an inverse pattern, increasing from 583 acres (0.9 square miles) in 1931 to 954 acres (1.5 square miles) in 2014. Large average holdings, however, are influenced by a small number of landowners owning vast stretches of property (a growing gap between haves and have-nots). In 1931, half of the land in the county was held by only 3.7 percent of the unique landowners. This observation had not changed in 2014, when only forty-seven landowners (3.8 percent) owned half the county's acreage. When excluding public-owned landholdings, we observed that the ownership inequality in Cimarron County has become more exaggerated in recent decades. In 1931, half of the nonpublic land belonged to 280 landowners (14.0 percent). By 2014, the same share of the acreage was held by only 100 individuals or corporations, comprising just 8.1 percent of the county's nonpublic landowners listed on that year's plat.

Median corporate acreage also increased dramatically over the decades. Although the 1931 value of 384 acres was relatively high, median acreage for corporations plummeted to 159 acres in the following decade—lower than median acreage for individuals. By 1998, however, this value had nearly

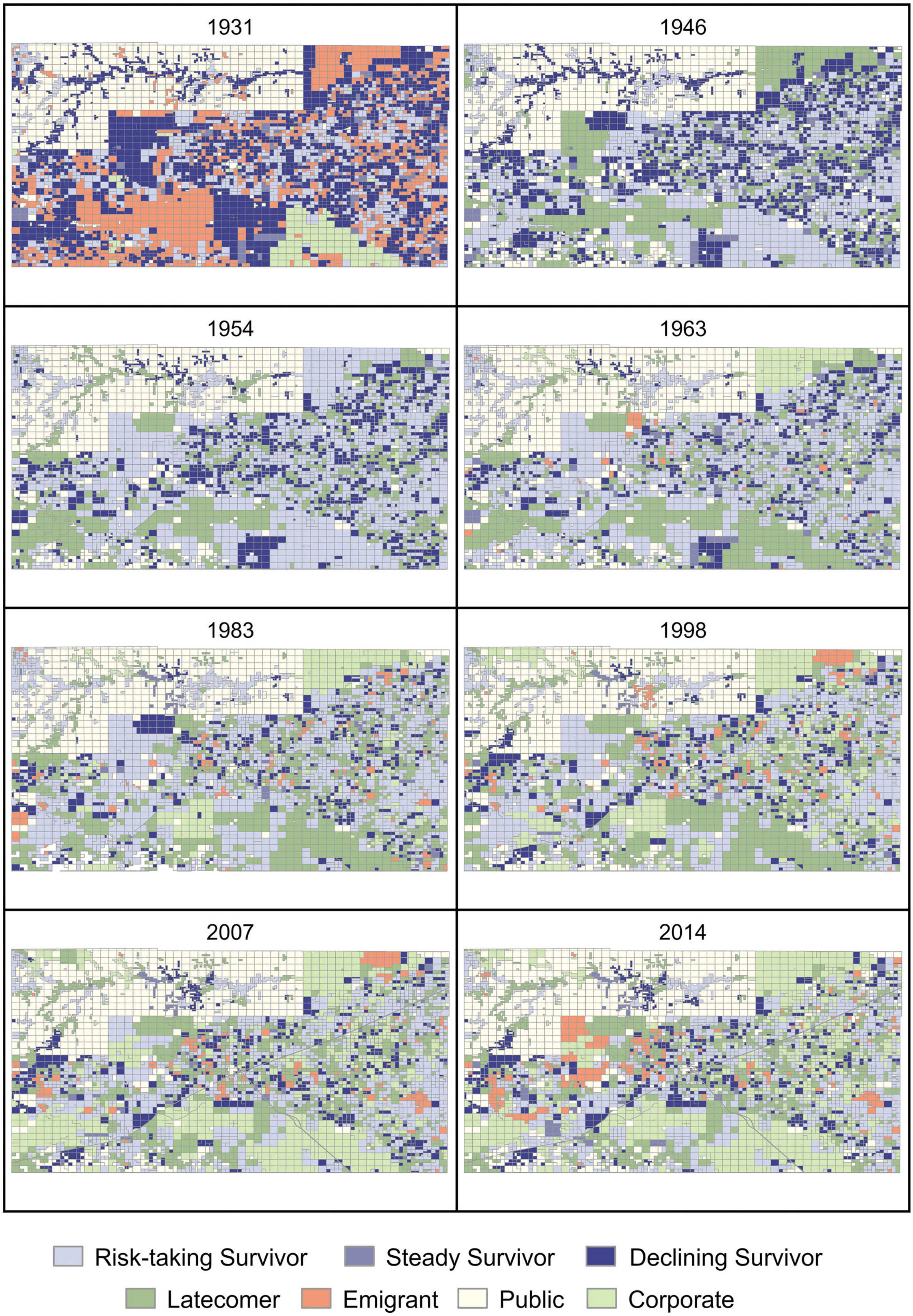

Figure 5. Changes in parcel-level landowner typology, 1931 to 2014.

Table 3. U.S. Department of Agriculture Census of agriculture data

Year	No. farms	Farms (acres)	Irrigated farms	Irrigated lands (acres)
1910	1,307	293,296	—	—
1925	761	633,383	—	—
1930	867	1,067,348	—	—
1935	975	913,020	—	—
1940	605	929,453	—	—
1945	560	1,034,520	—	—
1950	616	1,101,417	20	46,083
1954	559	1,097,216	28	58,510
1959	505	1,010,266	58	171,588
1964	502	1,082,737	107	271,805
1969	600	1,086,377	217	83,986
1974	475	1,034,710	154	63,273
1978	490	1,069,953	167	344,035
1982	458	1,080,087	113	289,476
1987	458	1,006,430	129	292,560
1992	446	1,034,980	123	314,612
1997	481	1,077,004	132	338,393
2002	545	1,121,690	114	339,297
2007	557	1,044,528	94	234,471
2012	554	1,157,186	75	286,679

Source: U.S. Department of Agriculture (2018).

quadrupled to 600 acres, remaining roughly the same in the following two decades.

During our study period, the average number of parcels per landowner nearly doubled. The typical individual or corporation of 1931 held 2.2 parcels of land ($\mu = 473$ acres), but this number had increased to 4.1 parcels by 2014 ($\mu = 754$ acres). This increase is due to two major factors: (1) the decrease in the number of unique landowners in the county, which resulted in each remaining or new landowner being able to take a greater share of the overall acreage, and (2) fragmentation of large 640-acre parcels into smaller lots as they were sold or as mineral leases were granted. The average parcel size decreased by 14 percent over the decades, from 270 acres to 233 acres, suggesting increased fragmentation.

Similarly, the number of farms decreased according to the USDA Census of Agriculture. The 1910 agriculture census (U.S. Census Bureau 1913) indicated that there were 1,307 farms in Cimarron County covering 293,296 acres. These farms produced 23,374 head of cattle as well as principal crops of corn, wheat, milo, and forage. By 1925, the number of farms in Cimarron County had dropped to 761, although the area of farmland increased to 633,383 acres. Numbers of cattle changed little in

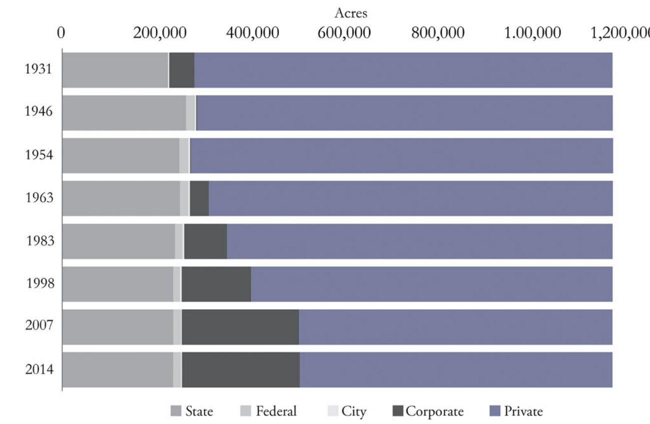

Figure 6. Total acreage by landowner type, 1931 to 2014.

1925 and principal crops remained consistent. By 1940, on the heels of the prolonged and severe drought of the Dust Bowl, the number of farms in Cimarron County had dropped to 605. Although the number of head of cattle had dropped to 14,876 by the 1940 enumeration, the actual area of farmland in Cimarron County had increased to 929,453 acres with an average farm size of 1,563 acres despite the Dust Bowl. The trend of fewer, albeit larger, farms continued during the proceeding enumeration periods and various drought cycles (Table 3). The actual land area dedicated to farming and ranching began to level off by the 1945 agricultural enumeration, however. Even as the land area in agricultural production remained relatively constant, the number of calves and cows increased during the following decades, going from 30,438 in 1945 to well over 100,000 by the 1992 agricultural census (U.S. Department of Agriculture 2018).

As the total number of residents in the county decreased, so too did the share of the county's acreage owned by family (nonpublic, noncorporate) landowners (Table 3; also see Figures 5–6). These private landowners were the only group to lose acreage, demonstrating a 25 percent reduction in landholdings from 1931 to 2014, much of which shifted to corporate ownership. State and city landholdings were largely unchanged, whereas federal and corporate ownership increased.

Throughout this time, ~20 percent of Cimarron County's land was held as state school trust lands, generally occupied by private and corporate lessees. Federal landholdings saw a major spike from 1931 to 1946, as the government began acquiring eroded cropland and rangeland in establishing the Rita Blanca National Grasslands (Lewis 1989; Fagin and

Table 4. Corporate versus family land ownership trends

	1931	1946	1954	1963	1983	1998	2007	2014
Total number of landowners	2,023	1,661	1,529	1,541	1,609	1,316	1,241	1,236
Number of corporations	16	9	5	14	53	101	135	156
% of landowners that were corporations	<1	<1	<1	<1	3	8	11	13
Mean corporate acreage	3,420 (11,396)	184 (137)	454 (1,634)	2,991 (10,047)	1,755 (4,726)	1,486 (3,333)	1,867 (6,242)	1,862 (5,938)
Median corporate acreage	384	159	160	160	318	600	614	614
Mean family acreage	773 (2,506)	942 (2,823)	1,080 (3,025)	1,089 (2,906)	1,157 (3,216)	1,271 (3,396)	1,120 (2,273)	1,217 (2,651)
Median family acreage	319	319	404	321	325	399	324	323

Note: Standard deviations are shown in parentheses where applicable.

Wikle 2012). Afterward, however, federal acreage decreased slightly (Figure 6).

Among the most prominent shifts we observed in land ownership was the rapid corporatization in Cimarron County (Table 4). Although corporate acreage in 1931 was relatively high (~55,000 acres), corporate owners during this period appeared to be managing fallout related to the Great Depression. A majority of corporate landowners in 1931 were banks, which frequently appeared to be repossessing land from defaulted mortgages and failed oil speculation. County Clerk deed records during this period indicate that land was rapidly changing hands, in some cases with multiple transfers in the same month. By 1946, corporate land ownership had plummeted. Only nine corporations, including financial, oil, and agricultural ventures, maintained landholdings in the county. By 1983, however, this number increased to fifty-three corporations and spiked to 156 corporations by 2014. At the end of our study period, over one fifth of county land was held by corporations. As with privately held lands, the distribution of acreage across corporate owners was remarkably skewed. Over half of corporate land in 2014 was held by just five companies.

A list of all unique last names found on plats during our study period contained 2,062 names. Nearly a quarter of these were classified as emigrants (Table 5). Seventy-two emigrant families returned to Cimarron County after a 1946 absence, a majority of whom expanded their landholdings through the decades. From interviews, we know that in some cases ranchers with money temporarily rented public lands in Arizona and elsewhere, and others went to California, Oregon, or Washington to work but returned after the dust settled, both literally and financially. Another 31 percent of families owned land in both 1931 and 1946 and were classified as survivors of the difficult decade following the Dust Bowl and Great Depression. Of these 654 families, the greatest subcategory was declining survivors, those who sold off portions of their land during the period from 1931 to 1963. By contrast, about one third of survivors were who we defined to be land-amassing risk-takers (Figure 7).

A majority (56 percent) of the study's 2,062 families were already established in the county in 1931. The remaining 44 percent were classified as latecomers, who might have sought to acquire the abundant, cheap land left in the aftermath of the 1930s. In fact, nearly one third of all latecomers first appeared on the 1946 plat, with the remainder trickling in over the following decades. Turnover for all types of families was remarkably high during our study period. Of the 2,062 unique families we identified, 40 percent owned land in only one decade's plat; 56 percent appeared on only two decades' plats. In examining the 1,157 families shown on the 1931 plat specifically, more than half had emigrated by the following decade.

Land legacy, or family acreage in the early 1930s, proved to be a major factor affecting Dust Bowl survival. Median acreage for survivors was 407 acres, whereas emigrants held a median of just 166 acres.

Continuing a theme of landholding inequality, three fourths of all 1931 families owned less than a

Table 5. Family survival traits through 2014 based on initial 1931 landholdings

Acreage class	Quarter section or less	Quarter to full section	One to four sections	More than four sections
Acres	≤160	161–640	641–2,560	>2,560
Number of families in class	460	408	239	43
% survivors	51	63	83	89
Mean acres per family member	151 (28)	251 (140)	275 (122)	323 (121)
Mean 1931 family acreage	153 (25)	413 (140)	1,262 (478)	8,156 (10,427)
1931 landowning family members	1.0 (0.7)	1.5 (0.6)	2.7 (1.5)	6.6 (6.2)
Mean 1946 family acreage	105 (480)	396 (2,393)	1,085 (1,214)	4,526 (4,963)
1946 landowning family members	0.5 (0.6)	0.8 (1.0)	0.9 (1.0)	5.7 (5.3)
% families with historical homesteads	6	26	57	91
Mean decades family remained in county	2.4 (1.9)	3.3 (2.5)	5.0 (2.5)	2.6 (5.9)
% surviving to 2014	3	14	38	48

Note: Standard deviations shown in parentheses where applicable.

section (640 acres) of land, although there was a positive correlation between family acreage and number of family members. Of families owning just a quarter-section in 1931, nearly all were comprised of just one landowner. By contrast, there was an average of 6.6 landowning family members for the class of families owning four or more sections.

Families in the largest 1931 landholding class (owning four or more sections) were one third more likely to survive the Dust Bowl than smaller landholders. For these families with the largest landholdings, the average family member owned 323 acres. Meanwhile, families owning one to four sections owned 275 acres per member. For families in the smallest 1931 landholding class (owning a quarter-section or less), the average family member owned just 151 acres.

As an added effect of land legacy on family Dust Bowl survival, we observed that the locations of historical homesteads, or embeddedness, were associated with greater survival rates. One third of survivors owned 1931 landholdings that overlapped with a historic homestead site, whereas only 17 percent of emigrants held property with a historic homestead. Of the families owning four or more sections in 1931, more than 90 percent owned land that overlapped historical homestead locations. On average, these larger landholding families had 3.5 historical homesteads on their collective property. By contrast, just 6 percent of quarter-section families were located on homestead footprints ($\mu = 0.1$ homesteads per family).

These homesteads, which might have had more thorough improvements or better "first choice" access to natural and other resources for agricultural or domestic uses than nonhomesteaded lands, likely provided a significant advantage to larger, wealthier families with deeper connections to the county's history (Figure 8).

Center Pivot Irrigation Analysis

Because access to the Ogallala Aquifer might increase agriculturalists' resilience in the face of drought, and therefore affect their chance of survival, we analyzed whether household location within the aquifer, or total holdings within the aquifer, produced greater odds of survival. Because CPI did not become widely available until the 1960s, we tallied landowning families on the 1963 plat and tracked their survival through 2014. Overall, families with 1963 landholdings within the Ogallala boundary were 30 percent more likely to survive to 2014 than those without access to the Ogallala. By 2014, these surviving families with aquifer access had increased their landholdings by 185 acres on average.

Early adoption of CPI was spearheaded predominantly by corporate owners. By 1985, over 18 percent of corporate-owned land in Cimarron County was under CPI, compared to less than 7 percent of noncorporate private land. Of the 44,000 acres of irrigated cropland in 1985, 38 percent was corporate owned—dramatic growth considering the corporate share of landholdings in 1983 was just 8 percent. As time progressed, however, CPI ownership by noncorporate landowners increased; two thirds of the county's CPI was noncorporate by 1995, increasing to 71 percent by 2015. Whereas corporations in the 1980s owned far more irrigated acres than their overall proportional

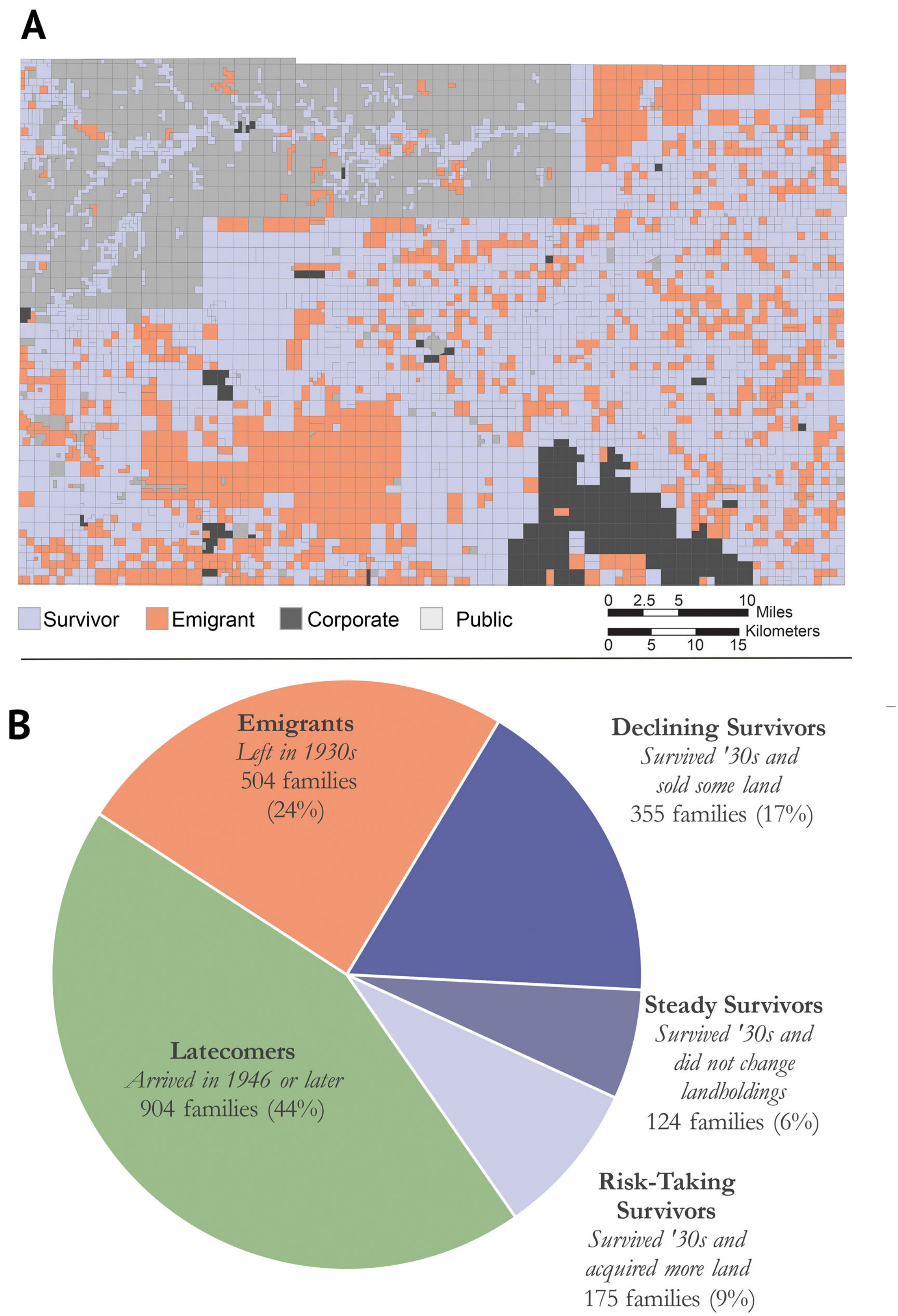

Figure 7. Landowner typology. (A) Orange parcels indicate emigrant families whose names appeared in 1931 but no longer appeared on the 1946 plat. Survivors, by contrast, were identified on both the 1931 and 1946 plats. (B) We identified 2,062 unique last names when examining plats from 1931 to 2014. Over half of all families' names appeared on the 1931 plat, with some emigrating before 1946 and others surviving. The remaining families (latecomers) first appeared on a plat produced after 1931.

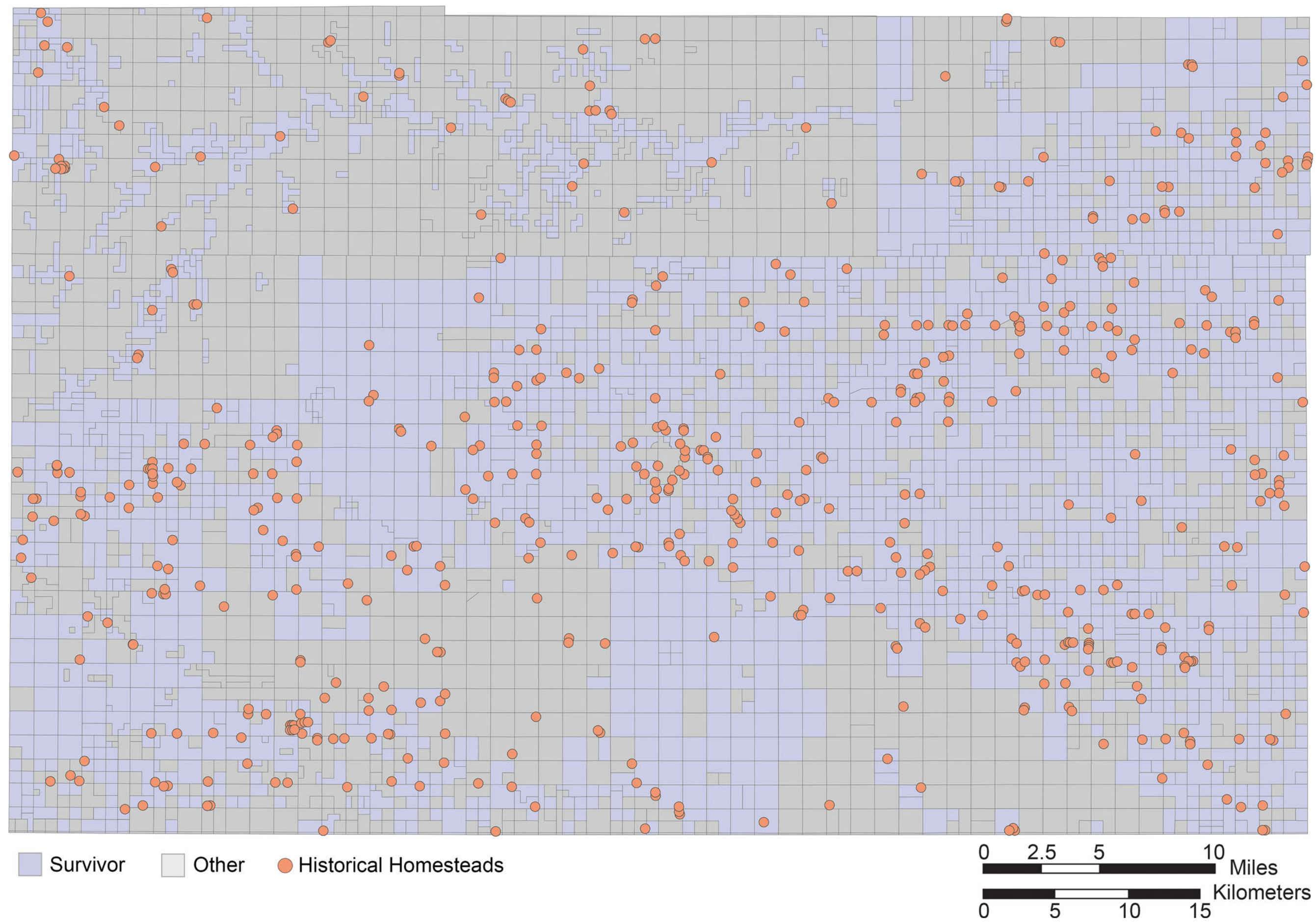

Figure 8. Historical homestead locations. Historical homesteads disproportionately overlapped with survivor-owned parcels. Whereas 33 percent of survivors had a homestead site on their 1931 landholdings, the same was true for just 17 percent of emigrants.

share of county land, this reversed by 2015, when noncorporate private landowners owned just 21 percent of county land but controlled nearly three quarters of CPI. Just 4 percent of corporate acres in Cimarron County were irrigated in 2015, whereas 26 percent of noncorporate private acres were irrigated (Figure 9).

Noncorporate adoption of CPI was closely associated with a family's landholdings size. Families owning a full section or more were 37 percent more likely to adopt CPI than those with smaller landholdings. Additionally, families who eventually installed at least one center pivot system on their land owned 1,949 acres on average in 1963, dwarfing the 894-acre average of those who had not adopted the technology by 2015.

In terms of the noncorporate landholders who adopted CPI, the risk-taking survivors were most aggressive. Indeed, interviews with survivors indicate that this might be the result of the family's long-term propensity for risk dating back to the Dust Bowl, or their long-term survival and consequent stability, thus enabling the adoption of a new technology. In 1985, 44 percent of noncorporate CPI installations were owned by risk-taking survivors. A majority of family-owned 1985 CPI was installed by survivor residents (78 percent), and many of the remainder were latecomers. Only one irrigated circle belonged to an emigrant family that had returned to the county and was observed on the 2014 plat. As CPI continued to expand over the decades, risk-taking survivors remained as the greatest noncorporate CPI landholders. By 2015, however, the CPI share for latecomers had increased to 31 percent. Key informant interviews suggest that wealthy outsiders have recently become more aggressive in acquiring land for large farming and ranching operations and were likely the segment of landowners most responsible for additional CPI installations after the turn of the century.

CPI installations on state and federal lands were rare. Although some incentives are available to help

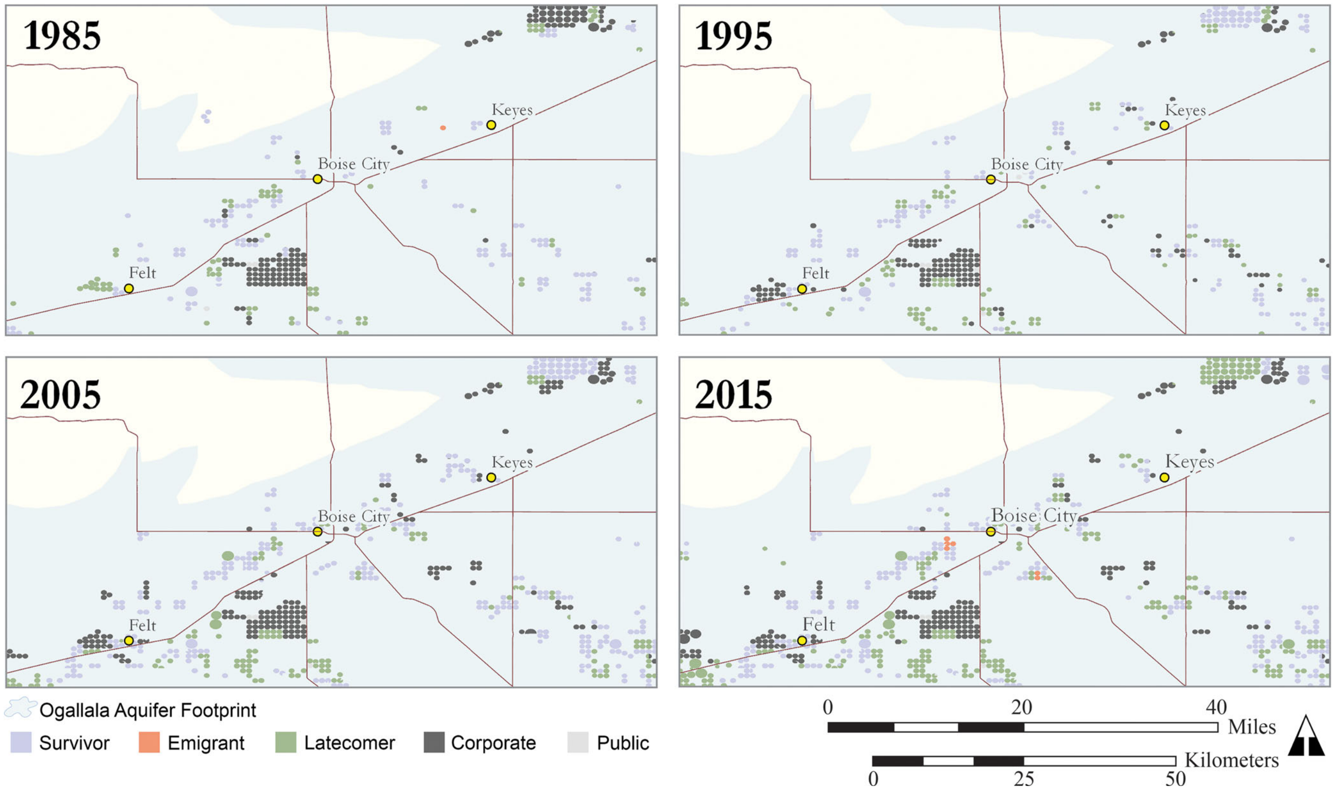

Figure 9. The Ogallala Aquifer and center pivot irrigation growth (1985–2015) in Cimarron County, Oklahoma.

farmers with the financial burden of CPI installations, agriculturalists in Oklahoma state that they are often reluctant to make significant developments on leased lands due to uncertainty about future leasing policies (Vadjunec and Sheehan 2010).

Discussion

Mirroring an established history of outmigration and related national and global trends in rural depopulation, Cimarron County, Oklahoma, experienced large shifts in land ownership between 1931 and 2014. These changes can be traced to the increased industrialization of agriculture, youth outmigration to urban opportunity centers, and the 1930s Dust Bowl. The greatest decrease in population occurred during the Dust Bowl, when large numbers of families in the Great Plains left the region in the midst of drought, dust storms, and a bearish market (J. N. Gregory 1989; Weisiger 1995).

Prior to the Dust Bowl, family farms dominated the county landscape. Many of our key informants told us that their families began homesteading the area prior to the turn of the twentieth century and owned their land through the start of the Dust Bowl and Great Depression. Our observation of initial high corporate land ownership in 1931 complicates this narrative, however. Our review of 1930s deed transactions at the County Clerk's office shows a pattern of rampant speculation and property trading among private landowners, banks, and oil companies, as economic anxiety and inability to pay off debts created a climate of instability and uncertainty. This finding suggests that the high corporate ownership in the 1930s was not related to corporate agriculture but rather the result of mineral and oil speculation and of banks repossessing land from those unable to keep their property. After 1946, we saw a steady growth of corporations. By the 1980s, there were steep increases in the growth of corporately held agricultural operations (see Vadjunec and Sheehan 2010).

The unequal distributions of capital and resources was a consistent trend throughout our study period. With over half of the county's land in the hands of less than 4 percent of its residents in each time period, it appears that this imbalance has long been a reality for Cimarron County's residents. Just after the Dust Bowl, this finding might have been attributed to differences in a survivor's propensity to take on risk, but key informants tell us that acquiring land has become increasingly difficult since the 1980s, especially given competition from corporate operators as well as the switch to an open-bidding policy on state land leases. Whereas farmers in the 1930s could make a living with just a quarter-section of land (160 acres), advances in agricultural technology have greatly increased competition and the scale of operations, meaning that operators with thousands of acres might still not be able to make ends meet.

In this new reality, we observe a cycle wherein small landholders are forced to leave their farms, resulting in fewer operators overall, with an increasingly small number of agriculturalists or corporations controlling larger swaths of land and further increasing competition for smallholders. Although some enterprising residents have established partnerships and corporations to help grow their operation and increase their chance of survival, doing so requires initial capital and a willingness to take on risk. Thus, aside from the growth of outside corporations, many of the other large operators come from families who have historically had large landholdings in the area.

In addressing our question of the relevance of family footprint and historical land legacy, we found clear evidence that the size of landholdings is strongly associated with survival likelihood. Further, the embeddedness of the entire family unit, rather than individual family members, seems to play an important role. Over half of all families (i.e., unique last names) on the 1931 plat had emigrated by 1946. In examining full names rather than last names, however, there was only an 18 percent emigration rate. This suggests that large families were likely to have a greater proportion of their family members survive the Dust Bowl and smaller families were more likely to emigrate.

One clear takeaway is that families with greater landholdings were more likely to survive. A number of covarying influences might be at play, though. First, families with additional acreage were also likely wealthier and were therefore positioned to take on additional risk in the face of a natural and economic disaster, whereas smallholders might have had no option but to leave. Considering that families with the greatest landholdings also tended to have more land per family member than smallholder families, a disparity in access to resources (land, financial, etc.) seems to be at play. Second, these wealthier families might have had a longer history in the area and therefore might have felt an obligation to remain in the county, either to continue a family legacy or simply because of an emotional attachment to place, as corroborated in key informant interviews.

We found that 91 percent of the largest landholders occupied land where historic 1800s homesteads had been located. These homestead areas initially might have had access to better quality land, easier or greater access to water, and other resources in general (e.g., infrastructure, etc.). Further, given their long history of occupation, these areas also likely experienced steady improvements for agricultural or domestic uses, giving them a competitive advantage over time. As a result, agriculturalists on original homesteads might have experienced significant advantages in terms of access to diverse resources and with deeper connections to the county's history. Interviews with some residents suggest that this is indicative of a long and privileged family history of land ownership in the county.

Third, larger families with numerous landowning members were equipped with an automatic support system, whereby relatives could share land, equipment, and labor; help each other financially; and serve as an emotional support network. Consequently, sustaining an agricultural operation in Cimarron County, even in the midst of historic drought and economic volatility, might have been easier than starting a new venture elsewhere with no resources. Additionally, the emigration of an entire family with multiple landholdings comes with logistical challenges that might not have been faced by smaller families. Whereas a single family with one section of land could easily pack up and move west, emigration might have been more difficult for large families with lots of resources. Indeed, from our interviews, many of these larger land holders suggested that they were "too poor to leave" or that they wanted to but could not sell their farm or ranch at the time (i.e., "too much of nothing"). When everything was practically turned to dust, residents argue that it was easier to sell a small piece of land (or even abandon it) than a larger one.

Perhaps the most intriguing finding related to family landholdings is the legacy that perpetuates from historical footprints nearly a century after the Dust Bowl. Nearly half of all families who owned over a section (one square mile) of property in 1931 were still living in Cimarron County in 2014, contrasted with just 3 percent of smallholders. Although surviving the "worst hard time" was probably the greatest challenge to overcome in the past century (Egan 2006), with nine in ten families with large landholdings surviving while about half of smallholders left, wealthier families were likely poised to take additional risk and reap the rewards as time progressed.

Family turnover was nonetheless rather high, with over half of our unique landowners' names appearing on two or fewer plats (i.e., these individuals owned land for less than roughly two decades). Perhaps one explanation is the "rural exodus," particularly of young people. As one resident explained, not cattle, but "young people are Cimarron County's number one export." Thus, land that is passed to the next generation might be sold off as young people leave. Other explanations include the blending of family names through marriage or the influence of wealthy landowners from outside the county.

Cimarron County borders four states and is situated in an area of ecological transitions. Agriculturalists from Colorado, New Mexico, Texas, and Kansas often purchase land across the region, to mitigate risk of drought or other environmental hazards or to gain access to groundwater resources. In Oklahoma, where there is little regulatory framework for aquifer use (Wenger, Vadjunec, and Fagin 2017), access to irrigation and the potential to drill new wells is a desirable selling point.

Corporations from outside Cimarron County also increased their presence throughout our study period. Although several long-term residents established their own LLCs and partnerships, we observed that the corporations with the largest landholdings were often based outside of the county but still in the region. By 2007, over half of corporate landholdings were owned by out-of-county corporations. By the late 1990s and early 2000s, this also included the arrival of feedlots in the region, such as the Brazilian giant JBS. Residents claim that corporate outsiders increase competition for land and, in some cases, have been blamed for excessive drawdown of groundwater resources. Because of this, locals have voiced concerns about the long-term sustainability of agriculture in Cimarron County, or at least the future of family farms, given the perceived economic inequality and increasing competition over dwindling land and water resources.

Considering that Cimarron County has experienced several periods of intense drought since the Dust Bowl and the climate is marked by relatively low precipitation even in good years, the advent of CPI has served as a boon for agriculture in the region. Farmers we interviewed frequently stated that using irrigation makes them less vulnerable, reducing their risk of crop failures in the face of uncertain precipitation patterns. We were therefore not surprised to find that parcels situated within the Ogallala Aquifer boundary had less turnover in ownership than those without aquifer access. As CPI has become more widely available, many farmers have adopted the technology, often with federally funded subsidies. Another factor might be at play in explaining the greater land retention within the aquifer, however. The footprint of the Ogallala covers over three fourths of the county's area and is situated in areas where soils and terrain are more conducive to cultivation. By contrast, the northwestern corner of Cimarron County has no access to the Ogallala but is home to several cattle ranches and rugged mesa country. Many cattle ranchers have told us that long-term sustainability of their operations can be more challenging than crop cultivation because irrigation is not economical, coupled with a lack of reliable agricultural subsidy or insurance programs that are typically targeted at crop growers. Consequently, ranchers could face struggles from which farmers are largely insulated, resulting in more frequent buying and selling of property in places where ranching is the only land use option.

Family land legacy appeared to play an important role in CPI adoption as well. Notably, over three fourths of noncorporate CPI by 1985 was installed by survivor families, despite the fact that survivors made up less than 23 percent of the total number of noncorporate landowners. Not surprising, the risk-taking survivors were the greatest subset of CPI-installing survivors. Individuals whose parents or grandparents survived the Dust Bowl often have an intimate knowledge of family lore, with a keen understanding of the risks their ancestors might have taken to make ends meet despite hard circumstances. For families in the risk-taking survivor category, our interviews suggest that present-day agriculturalists are often inspired by the boldness and perseverance of their past relatives and therefore feel empowered to make similar decisions regarding agricultural practices, land acquisition, and adoption of technology. Although one might assume that a family's wealth plays a key role in determining their propensity for risk, interviewees generally tell us they rely largely on credit, with very few maintaining savings sufficient to buy large swaths of land or irrigate hundreds or thousands of acres. For the most part, although agriculturalists in the region might be land “rich,” many generate little income. Instead, ranching and farming is an identity and way of life. Overall, a family’s landholdings, their history of successful borrowing, and long-term, positive relationships with local lenders might serve as factors influencing continued risk taking by some families.

Early adoption of CPI might be seen not as a risk but rather a mitigation against risk of drought and crop failures. For corporations in Cimarron County, this appears to be the case. Not only do irrigation systems help reduce vulnerability to environmental hazards but they have facilitated the cultivation of corn, which typically brings greater yield and a higher market value than dryland crops such as wheat or sorghum. Therefore, corporations made an investment in CPI before government subsidy programs began in 1996 (Nixon 2013).

This investment appears to have paid off nicely, considering that significant ethanol subsidies escalated the price of corn to historic levels by 2012. The long-term sustainability of corn cultivation in the area is questionable at best, however, considering that the crop usually requires constant irrigation for its entire growing season and that some areas of the Ogallala Aquifer might be unable to sustain agriculture in as soon as thirty years (Scanlon et al. 2012). Additionally, farmers in some cases have chosen to take land out of the Conservation Reserve Program as a means of entering the lucrative corn market, potentially resulting in increased erosion and nutrient loss (Secchi and Babcock 2015). Other farmers have stopped hay production, which historically supported local ranchers, in favor of corn.

This complex system of economic incentives and varying strategies appears to exacerbate existing inequality in the area, where wealthier or risk-tolerant landowners (especially corporations) are able to maximize profits, grow rapidly, and push smallholders out of the market. In this sense, we have observed a shift from a past where environmental hazards such as the Dust Bowl forced many smallholders away to a future where market pressures might prevent all but the largest operations from sustaining agriculture in the Great Plains. Although the future remains uncertain, this study shows not only that landholdings and LULCC have changed dramatically over time but also that land legacy matters.

Scope and Limitations

Because surnames were used in this analysis, results should be interpreted with care. Intensive and long-term fieldwork in the region suggests the continued blending of family names. Our research in the region also suggests that many families have been present since long before the Dust Bowl. The emigration of Dust Bowl families to California and elsewhere in the 1930s and 1940s is well documented. Longley, Webber, and Lloyd (2007) argued that the analysis of surnames provides a fertile ground for HGIS research. Additionally, our results are strengthened through triangulation methods using HGIS techniques, agricultural census data, and ethnographic fieldwork.

Ongoing changes in the structure of “family farms” or ranches make it difficult to completely discern whether an operation is truly “outsider,” “corporate,” or not. Many family farms and ranches have been undergoing some level of corporatization (e.g., the growth of LLCs) as a means of adaptation to protect one’s assets or reduce tax liabilities. Still, past research suggests that many family farmers and ranchers are increasingly vulnerable to losing their operations to outside corporations that have greater access to the finances necessary to grow, expand, and adapt new technologies (Vadjunec and Sheehan 2010).

This research does not reveal the dynamics of informal private land leasing or crop share agreements. Further analyses looking at land use dynamics in terms of corn, wheat, and other agricultural commodities pricing, against the cost of oil or biofuels, and agricultural subsidies and policies would deepen the understandings revealed here (Wenger, Vadjunec, and Fagin 2017). Regardless, the results illustrate changing trends in the region that are reflective of broader changes in U.S. farming and ranching practices.

Finally, plats are ephemeral data that were not meant to be saved. They provide a fascinating but nondynamic “snapshot” frozen in time. Our experiences in the archives of the county assessor’s office show much more dynamic change, with multiple changes sometimes in a single parcel in a single year. During the Dust Bowl and Great Depression, land often changed hands cfrom a landowner to an oil speculator, to a bank, another landowner, and back again in a high-stakes process of land jockeying and economic bust in a single year. Overall, HGIS provides us with rich historical data providing new insight into geospatial change.

Conclusion

Our results indicate trends in outmigration, increasing corporatization, changing governance, and LULCC in the region over time and space. Approximately 20 percent of families left Cimarron County during the Dust Bowl. For those who stayed, a family's historic land legacy matters.

Families with one or more sections of land were more likely to survive the Dust Bowl. Risk-taking survivors were more likely to grow their landholdings, use CPI, and adapt to new technologies as part of a response to the increasing corporatization of agriculture. The mixed-methods HGIS-based approach of this article illustrates how the past influences the present in terms of landscape (LULCC, size, distribution) and family survivability. Families who stayed illustrated true grit and adaptability under duress, although the HGIS reveals more nuanced spatial details that the general history books often lack. Additionally, their determination and past Dust Bowl history as survivors, or relatives of survivors, appears to help residents "stick it out" during tough times and recurring cyclical drought in the region.

Finally, this article illustrates HGIS as a powerful means for analyzing seemingly simple plats. Although HGIS remains an imperfect method, triangulation with rich qualitative data such as interviews, archival, and secondary data can make results more robust. Conversely, whereas conversations with farmers and ranchers have previously echoed many similar themes (i.e., migration, corporatization, changing LULCC, etc.), the HGIS provided a more systematic and rigorous study of such changes over both time and space. Taken together, they tell an important story about the importance of land legacy in surviving extreme climatic events and long-term adaptation to drought in the southern Great Plains. Additionally, for LULCC studies, the plat analysis tells part of a complex story that a remotely sensed time series analysis simply cannot. Overall, we argue that SES studies can benefit from further incorporating HGIS into their repertoire.

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