Determinants and Consequences of Large-Scale Tree Plantation Projects: Evidence from the Great Plains Shelterbelt Project*

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Highlights

- Historical events help to examine large-scale tree plantation projects
- Primary data construction for the Great Plains Shelterbelt Project in the 1930s from the archives
- Using DID strategy, results show an increase in market price reduces the plantation area
- Tenancy rate, access to irrigation, and duration of agricultural contract affect the plantation decision
- Using instrumental variable strategy, results show tree plantation decreases long-term wind erosion on pastureland, but no effect on future tree plantation

Abstract

This paper examines the determinants and consequences of the adoption of large-scale tree plantation projects on farmland using the experience of the Great Plains Shelterbelt Project in the late 1930s. I show how agricultural market pressure influenced the decision to plant shelterbelt trees on the cropland and how soil erosion has changed in the long run because of the large-scale tree plantation. I compile a primary database on shelterbelt adoption from the archives and use a difference-in-difference model to study the determinants of the county-level adoption rate. The main finding is that an increase in the market crop price reduces the adoption of shelterbelt trees. Agricultural factors such as tenancy, access to irrigation, and duration of the agricultural contract explain the variations in the decision process.

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I use an instrumental variable technique to study the persistent effects of the plantation project in the long run. I show that shelterbelt adoption in the 1930s decreases wind erosion even in the 2000s and that the effect is concentrated in pasture areas.

Keywords: Land Conservation, Soil Erosion, Windbreak, Agricultural History

JEL Codes: N52, N92, Q15, Q18, Q57

1 Introduction

Large-scale tree plantation projects have been increasingly advocated as a conservation policy instrument to reduce soil erosion and to increase ecosystem resilience (Schoeneberger, 2009). These projects have historical roots in Stalin's Great Plan for the Transformation of Nature and Roosevelt's Great Plains Forestry Project (Brain, 2010; Gardner, 2009). Recent examples of large-scale plantation projects include the Three North Shelterbelts in China and the Great Green Wall in the Sahara Desert (Li et al., 2012; Aigbokhaevbo, 2014). Parallel to the public policy debate, many agricultural science experiments examine how tree plantation projects help to achieve long-term environmental sustainability and increase community resilience (Young, 1997; Nair, 1993; Beetz, 2011). However, trees need time to affect the environment, and due to the lack of sufficient long-term data relating to large-scale tree plantation, it has been difficult to understand the determinants of adoption of the plantation, as well as the consequences of tree plantation on the environment over time. Historical projects related to large-scale tree plantations may help us to understand the costs and benefits associated with large-scale tree plantation projects.

The benefit associated with tree plantation is not immediately visible, thus farmers have few incentives to plant and take care of trees on their farmland. Recent social science and ecology literature have included studies on how to give incentives to farmers to adopt tree plantation on their farmland in developing countries (Brown et al., 2018; Miller et al., 2020; Scherr, 1992; Mercer and Pattanayak, 2003; Woodruff, 1977). The success of any large-scale tree plantation program depends on farmers' initial uptake rate and their persistence in maintaining trees over time. Production and conservation decisions compete on agricultural land, and this problem is evident in large-scale tree plantation programs for two reasons. First, scattered trees over the landscape cannot solve the problems related to land degradation. Erosion will only be reduced by continuous tree bands, requiring continuous farm plots. This leads to a collective action problem for the farmers, who need to agree to a joint farm plan for continuous tree bands. Second, property rights and institutional frameworks also influence the decision process. Farmers struggle to decide about participating in tree plantation in the long run because of the incomplete information about the benefits of tree plantation, and other institutional barriers, such as tenancy, reduce the probability of planting trees for the long-term benefits. Understanding what determines farmers' adoption decisions on a large-scale plantation program is important because it helps planners to design incentives in future projects (Hughes et al., 2020).

Despite the importance of understanding the adoption of plantation under market pressure and institutional barriers, economic studies on the determinants and effects have been limited primarily because of data constraints. Using historical data and policy design, I answer two questions in this paper: what factors determine decisions relating to tree plantation on farmland, and how do tree projects affect long-term environmental quality? I examine these questions using the example of an early and well-known tree plantation program in the United States, the Great Plains Shelterbelt Project (GPSP).

In the Dust Bowl era of the 1930s, President Franklin D. Roosevelt introduced the idea of planting shelterbelts in the Great Plains, and the U.S. Forest Service (USFS) was tasked with implementing the project. Initially, the USFS asked farmers to sell the land at a low cost, but farmers did not respond favorably to this incentive. The program was later converted to a public-private partnership; farmers were responsible for clearing their land, and the government was responsible for helping to decide which tree species to plant and for providing technical support. The USFS planted 220 million trees from 1935 to 1942 across the Great Plains (Droze, 1977). The uniqueness in designing the Great Plains Shelterbelt Project, the size of the program, the nature of the public-private partnership, and the availability of the data in the National Archives and Records Administration (NARA) make this plantation project a perfect case study to understand the determinants and consequences of such projects.

To study the effect of market factors on tree plantation, I digitize unique county-year panel data on annual shelterbelt plantation acres for 1936-1940 available in the NARA. I take advantage of detailed county-level annual farm forestry plantation data from the shelterbelt project annual reports available in the National Archives at Kansas City, Missouri. I overlay this data with county-level crop intensity data from the pre-Dust Bowl era, and thus, I create a spatial variation in crop intensity. I interact this spatial variation with a temporal price shock to see how a change in crop prices affects tree planting. Also, I show that other pre-Dust Bowl variables do not differ between shelterbelt and non-shelterbelt counties. This unique database provides the option to study the impact of commodity prices on shelterbelt adoption behavior in detail.

Moreover, I show how county-level shelterbelt trees reduced soil erosion levels in the long run in the shelterbelt counties compared to non-shelterbelt areas. To understand the impact of this plantation project on the environment, I draw on the Natural Resource Inventory (NRI) database from the U.S. Department of Agriculture (USDA) to shed light on the impact of shelterbelt plantations on long-term county-level erosion control. To deal with endogeneity concerns about the plantation decision, I use the planning map for the 100-mile-wide shelterbelt project to create a pre-plantation treatment and control group based on geographic differences (Li, 2019; Droze, 1977).

The results show that price increases had a negative effect on the adoption of trees in the 1930s. Descriptive statistics show that the other variables did not change over the shelterbelt counties, and the results are robust to different county-level controls. The results from historical data support the theory that price fluctuation affected the initial take-up rate. Using a triple difference model, I also show how heterogeneity in the initial agricultural institutions affected the adoption decision. I show how tenancy, duration of the agricultural contract, access to alternative resources, and the number of farms affect the decision. I also show how access to farm trees before the shelterbelt project affect the plantation decision.

Results from the effect of the tree plantation project, in the long run, suggest that shelterbelt decreases erosion level in the areas in which profits were limited from initial uptake and that the effects are largest in pasture areas. This supports the results of Li (2019) that agricultural revenue mostly increased in pasture areas because of the tree plantation. I show the persistent environmental effects of the shelterbelt were present on both pasture and cropland. We see that, even after eighty years, shelterbelts help to reduce pastureland wind erosion in these areas. I also collect information on post-1942 tree plantation, and show that pre-1942 GPSP had no significant effect on the plantation decision at a later date.

This paper contributes to the agricultural economics literature on farmers' tree adoption behavior under market pressure and the impact of the adoption in the long run. Studies show that prices of output play an important role (Adesina and Zinnah, 1993;Reimer, Gramig, and Prokopy, 2013;Prokopy et al., 2019). The literature on tree plantation projects also shows how spatial variation of the projects affect the success (Elkin, 2014; Bellefontaine et al., 2011). This paper contributes to this literature by using a historical case to show how evaluating market pressure is important to understand the impact of the policy when landowners are volunteering to adopt conservation practices. This paper also shows how historical conservation policies affect current environmental and economic outcomes (Hornbeck, 2012; Howlader, 2019; Li, 2019).

This paper also contributes to the growing body of economic history literature that addresses environmental problems. Recent economic history papers develop insights about how current conditions are path-dependent on early historical events (Hornbeck, 2012). Empirical studies have been conducted on policies related to air pollution (Cohen et al., 2017), floods (Hornbeck and Naidu, 2014), drought (Freire-González, Decker, and Hall, 2017), water management (Hornbeck and Keskin, 2014), and waste management (Alsan and Goldin, 2019). In this paper, I provide the first evidence of how early tree plantation projects have changed environmental outcomes in the long term. This paper also contributes to the growing literature on compiling new data sources and understanding the New Deal. Recently, empirical economists have studied many facets of the New Deal because of the availability of detailed county-level data over a long period (Fishback, 2017). Accordingly, I compile and digitize new data sources and explore a new dimension regarding the shelterbelt projects.

This paper also belongs to a literature showing the importance of tree plantation on the economy, the environment, and human health. These studies usually consider either historical or current tree plantation projects. A previous study explored how impacts work in Africa (Ingram et al., 2016), providing a value-chain approach, and a look at impacts on suppliers, customers, and stakeholders. Influence of windbreaks on crop yield in the Great Plains have been studied both with case studies and observational databases (Kröger, 2014; Armstrong et al., 1998). Also, historical studies show depletion of shelterbelts in the Great Plains using county-level from Kansas to make a connection with irrigation and center-pivot system (Marotz and Sorenson, 1979). In this line, I study how the tree plantation projects affect long-term environmental quality.

2 Historical Background

Starting with the Timber Culture Act of 1873, tree plantation was always a part of the policy discussion in American conservation. However, these were mostly failed attempts (McIntosh, 1975). In the 1930s, the Dust Bowl substantially decreased the amount of topsoil in the Great Plains, and as a result, President Roosevelt promised to create the tree belt in the Great Plains, along with other conservation programs administrated by the USDA.

The shelterbelt project was based on Roosevelt's previous experience with tree plantation in Hyden Park in New York (Droze, 1977). Roosevelt developed a plan for a continuous tree belt across the region, but the Forest Service Agency said it was scientifically not viable. This plan was first proposed in 1934, and after three different iterations, the federal government finally passed it in 1935. Initially, the federal government leased land from its owners for the long term. However, due to budgetary constraints, the government converted the program to a cost-sharing program with landowners, where the landowners were responsible for clearing and fencing the land, as well as for rodent control. The GPSP planning was based on climate and pre-program geographic characteristics of the eastern Great Plains counties. The actual shelterbelt planting started in 1935 and ended in 1942, as funds for the program were cut after the United States entered World War II (Droze, 1977).

The first public announcement of a proposed tree planting program for the Great Plains was made on June 19, 1934. The program had a short-term goal of creating employment opportunities for residents of the Great Plains, while the long-term stated goal was to improve living conditions. The public announcement stated that approximately 1,000,000 acres of trees will be planted in a belt of 100 miles wide from the Canadian border along the 100th Meridian to the Texas.

The project was primarily managed by the United States Forest Service (USFS), with an initial budget allocation of 1,000,000 USD. The head field office was located in Lincoln, Nebraska, with state divisions located in the capital cities of North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, and Texas. In addition to the Forest Service, other governmental agencies helping in the work included the Bureau of Chemistry and Soils, the Soil Conservation Service, and the Weather Bureau. The geographic belt where the trees were planted passes through North Dakota, South Dakota, Kansas, Oklahoma, Texas. The Forest Service had to give control of the program to the Soil Conservation Service (SCS) in 1942. Since then, the planting and management of trees and windbreaks have been integrated with other soil and water conservation practices of the soil conservation districts (SCD).

3 Data Construction and Summary Statistics

I collect county-level annual plantation data using the shelterbelt project entitled "Great Plains Shelterbelt Project" (GPSP) from the National Archives in Kansas City, Missouri. I digitized the county plantation reports to extract this information. These reports provide information on annual plantation area in every county in six states: Kansas, Nebraska, North Dakota, Oklahoma, South Dakota, and Texas.

For the long-term impact analysis on the environmental outcomes, I use erosion data from the Natural Resource Inventory (NRI) database collected by the United States Department of Agriculture. I used data on the total erosion rate, total wind erosion rate, erosion on cropland, as well as on pastureland. This database is available at the county level and is available only since 1982. In this database, total erosion rate is a combination of both wind and water erosion.

County-level data on agriculture are compiled from various agricultural censuses. Variables of interest include tenancy rate, crop intensity, and farm size (Haines, 2010). I use county-level crop intensity data for three main crops in the Great Plains: wheat, corn, and cotton. Crop price information came from Jacks (2017), while the shelterbelt planning data is from Li (2019). The main sample is a balanced panel of 217 Plains counties from 1930 to 2012.

The Great Plains Forestry Project was discontinued by the United States Forestry Service (USFS) in 1942. After the Second World War, the USFS gave the control of the project to the Soil Conservation Service under the Department of Agriculture, and tree plantation was a part of later soil conservation districts' (SCD) activities. I collect SCD reports from the National Archives (Howlader, 2019), and build the county-level tree plantation data after 1942 to demonstrate how early plantation projects affect later tree plantations.

Figure-1 presents the variation in commodity market for the main three crops in the Plains. This figure shows that there is considerable variation in the commodity market that may influence plantation decision. Narrative reports on shelterbelt plantation also mentioned that shelterbelt plantation decision was dependent on crop cultivation decision and market price expectation (Droze, 1977). In Figure-2, I present the county-level crop intensity across counties in the Great Plains from the agricultural census 1930. We see that there is a strong county-level variation in crop plantation across space before the plantation project.

Figure-3 presents the frequency distribution of the plantation areas across six states. We see that, compared to other states, Nebraska had the highest plantation areas. This may have been because the GPSP headquarter was located in that state. We also see that there is a considerable level of variation in the plantation across different states.

Table 1 shows the covariate balance between with- and without-shelterbelt counties. Baseline factors are very similar in shelterbelt and non-shelterbelt counties. The mean total shelterbelt areas for shelterbelt counties are 62 miles, and the standard deviation is around 82 miles. Shelterbelt counties are less dense than non-shelterbelt counties. The population, number of farms, size of farms, and farm values are not significantly different in shelterbelt and non-shelterbelt counties. This effect remains even after controlling for state fixed effects. As shelterbelt counties are less populated than other counties, the farm number is smaller, and the average farm acreage is also smaller. There were 218 shelterbelt counties.

Table 2 presents the summary statistics for annual crop plantation data and crop prices over time. We see that the areas under different crops decreased over time. This decrease may come from the conservation projects or the loss in harvest areas due to drought. We see this variation is highest in wheat counties. Table 3 presents the summary statistics of annual plantation data for shelterbelts.

We see that there is a strong annual variation of adoption of shelterbelt areas. The plantation continued in 1941, but we do not have that data in the National Archives. I use this annual variation in the shelterbelt plantation to study the effects of annual variation in market prices for the crops.

4 Empirical Strategy

This section presents the estimating equation used to study the relationship between market factors and total plantation. I also present the empirical strategy to identify the consequences of shelterbelt plantations on environmental outcomes. Finally, I present an instrumental variable strategy to identify the causal effect of the GPSP on the environmental quality.

4.1 Determinants of Adoption

I study the implications of crop price movement on shelterbelt adoption. My main outcome variable for this is the county-level annual plantation data. This is a panel data over years and is presented in miles. We want to understand the market factors that may have influenced farmers' decision to adopt shelterbelt on their cropland.

I describe the strategy to examine the effect of price shocks on the adoption of tree plantation. I examine the underlying characteristics of adoption with the help of pre-1930 data to see which counties have higher adoption rates. The shelterbelt project was a voluntary program, and farmers inherent abilities may create omitted variable bias. I use a difference-in-difference (DID) model to deal with potential endogeneity given the voluntary nature of the program.

In the DID framework, I use the temporal variation in price movement, and spatial variation in initial land use from crop cultivation (Crost and Felter, 2020; Imbens and

Wooldridge, 2009). My main exogenous variation is the interaction of these two variables that came from 1930s census data: annual price movement and initial county-crop specific intensity. The interaction of these two variables gives us a county-level exogenous variation to study the adoption rate over time.

Using newly digitized data on county-level shelterbelt plantation, I compare counties with high cash crops with those with low cash crop production intensity to see how market price affects farmers' conservation decisions. The decision process depended on the 1930s agricultural census, so I used the 1930s crop intensity in the regression framework. I use data from the beginning of the shelterbelt plantation project (1935) and estimate:

$$y_{c,t} = \alpha_c + \delta_t + \beta(\text{Crop Intensity})_{c,1930} * (Price_t) + X_{c,t} + \epsilon_{c,t} \tag{1}$$

$y_{c,t}$ is the outcome variable of interest in county c at the shelterbelt project period. In this model, we have county-year shelterbelt areas as our outcome variable. County fixed effects, α_c absorb county-specific time-invariant heterogeneities affecting the local extent of adoption. δ_t is the time fixed effect capturing common trend. I also control county-level initial characteristics that may affect adoption. I do not cluster data by state because the groups are small. The identification strategy relies on the fact that shelterbelt counties would be on the same trend as non-shelterbelt counties if there were no plantation projects.

Next, I extend this model to the triple difference model to include the heterogeneous treatment effect from initial characteristics. I estimate the model using variations in initial tenancy, duration of agricultural contract, irrigation, area under wood, and number of farms. These variables have been extracted from the narrative literature (Droze, 1977). I estimate a panel regression model where H denotes these heterogeneities:

$$y_{c,t} = \alpha_c + \delta_t + \beta(\text{Crop Intensity})_{c,1930} * (Price_t) + \gamma(\text{Crop Intensity})_{c,1930} * (Price_t) * H + \epsilon_{c,t} \quad (2)$$

4.2 Environmental Consequences of Tree Plantation

In the next section, I turn the analysis to the consequences of the Great Plains Shelterbelt Project. The project was discontinued in 1942. After the Second World War, the Soil Conservation Service (SCS) took the responsibilities to continue work on tree plantation with the farmers, and I have included this in other soil conservation districts' activities. This section explores how GPSP affects long-term erosion rate and future tree plantation decisions under the SCS.

For this analysis, I utilize erosion data from the NRI and tree plantation data from the SCD reports (as explained in the data section). My outcome variables are county-level future erosion and county-level future tree plantation area. My X variables include total plantation under GPSP in 1940s. The empirical framework is similar to other papers studying the persistent effect of historical events (Fiszbein, 2017, Li, 2017).

I use the erosion rate in cropland, the erosion rate in pastureland, and total land erosion in 2012 as the environmental outcomes. Using the data on total shelterbelt plantation in any county in the 1930s, I compare erosion rates in counties with larger plantation areas against those with smaller plantation areas. This regression includes within-state variation, farm size, farms with black operators, and the tenancy ratio as control variables. I estimate a cross-sectional OLS equation:

$$y_c = \alpha_s + \beta(\text{Plantation})_{c,1940} + \delta X_{c,1940} + \epsilon_c \quad (3)$$

where y_c is the environmental outcome. This regression may have endogeneity as the plantation program was voluntary. For example, farmers' inherent abilities to distinguish between long-term and short-term profit may create omitted variable bias.

I use the exogenous planning map (Li, 2019) for the shelterbelt across counties to address the endogenous adoption of tree plantation, while the shelterbelt planning map came from Droze (1977). This map relies on geographic conditions, and it can be used as an exogenous variation for actual tree plantation. The first-stage intuition is that shelterbelt was targeted in these planning areas. There were 158 counties in the initial planning, but 218 counties in the actual plantation.

With the help of these two models and detailed county-level adoption and erosion data, I show how market pressure affects farmers' conservation adoption decision, and how the variation still dominates the environmental quality.

5 Results

In this section, I present results from the three regression models. I show how market pressure affected shelterbelt decisions in 1940's, and how the plantation decisions affect later environmental outcomes.

5.1 Determinants of Adoption

The main finding of this section is that Great Plains farmers who could obtain higher market prices for their crops converted less of their land to shelterbelts. Table 5 shows these results using regression model 1.

The first set of results show that farmers facing higher crop prices planted less shelterbelt. I use five years of panel data for this set of results. If we first convert the estimates based on the average plantation area, farmers facing a 1-unit increase in corn price and having 1 unit of additional intensity in initial corn production planted 0.38 miles less shelterbelt. Second, farmers facing a 1-unit increase in cotton price and having 1 unit of additional intensity in initial cotton production planted 5.89 miles less shelterbelt. Finally, farmers facing a 1-unit increase in wheat price and having 1 unit of additional intensity in initial wheat production planted 0.11 miles less shelterbelt.

These results correspond to the intuitive understanding that farmers react to market prices to abandon land for long-term conservation purposes. If the price is high, farmers plant fewer shelterbelt trees. The results are crop-specific, following the price dynamics in Figure 1. From Figure 1, we see that cotton price had the highest fluctuation. This may correspond to the fact that cotton areas have the lowest shelterbelt adoption.

Next, I use initial county characteristics to explain the spatial variations in some of these results from Table 5. Table 6 corresponds to Regression Model 2 and shows the heterogeneous effects of initial county-level institutional and farm characteristics on the adoption. These results follow the theoretical concepts regarding the interrelationships among agro-ecological, economic, and social variables. As listed below, they show how farmers' decisions on shelterbelt plantations depended on agrarian institutions.

First, theoretically, if a farm is under a tenancy contract, it may or may not have a higher adoption rate. On one hand, we need more farm labor to plant more trees, so more tenants may help to plant more trees. On the other hand, tenant-dependent farms may have a lower attachment to farming in general, so it may have a lower adoption rate as farmers cannot see the benefit of tree plantation immediately. Column 1 of Table 6 shows these results. For cotton, where the farms were very much tenant dependent, more tenants helped to adopt more trees. But for corn, the adoption rate was lower than average. There were no significant results for wheat. This result is important to understand the elasticity of substitution between land and labor given the choice of tree plantation. In a very labor-intensive crop plantation like cotton, tenants help to plant more shelterbelts too.

But in places where crops are fewer labor intensives, tenants probably focus on planting crops, and shelterbelt may not be the priority project.

Second, I use the duration of the agricultural contract to see if farmers' movement affects tree plantation. Column 2 of Table 5 shows that contract duration only affected plantation decisions in corn counties and that the effect was positive. If the duration is higher, it means a higher adoption rate in corn-intensive counties. I took the average number of years on one farm as the duration of the contract. Interestingly, even if farmers' tenancy rates affected tree plantation on cotton farms, it did not have any relationship with contract duration. The reason for this may lie in the fact that cotton tenants are mostly sharecroppers who lived on the farms for a long time.

Third, I use areas under alternative access to water as another source of heterogeneity. If farmers have more access to irrigation, the need to rely on shelterbelt for soil moisture is low. Column 3 of Table 6 shows that irrigation has a negative effect on tree plantation in wheat counties. Wheat is a highly water-dependent crop compared to other crops. As the results suggest, wheat needs more irrigation and that may crowd out shelterbelt plantation. We do not see any significant effect in corn and cotton counties in this case.

Fourth, there is also information on total existing wood acreage in 1934 before the shelterbelt project started. Existing wood acreage may have a positive effect on more plantations as farmers may already be familiar with plantation. That result is in Column 4. The result is significant and positive only for cotton counties. Wood in 1934 was skewed towards the southern states, so the results are spatially concentrated in that area. The underlying intuition is correct that access to farm plantation before the project helped to plant more trees.

Finally, the number of farms may affect shelterbelt plantation due to coordination failure, as tree band involves a collective action problem for the farmers. Column 5 shows that there are no significant effects from the number of farms.

5.2 Consequences of Adoption

The main finding in this section is that the plantation of shelterbelt decreases pasture wind erosion. I used the shelterbelt planning map as the instrumental variable for the actual plantation acres (Li, 2019). I expected the effects of the omitted variables to drive the results up, and the results are consistent with this expectation.

I use 2012 data from the Natural Resource Inventory database on total erosion, total wind erosion, erosion on pastureland, and erosion on cropland. I do not use data for water erosion. The idea is to see the persistent effect of shelterbelt projects on erosion in the long run.

Table 7 presents the results for total erosion in shelterbelt counties. The first column presents the results for Regression Model 3. It shows that there is no effect of plantation on total erosion. Then, I used the instrumental variable from Li (2019) following Model 3. The results of the first and second stage are in Columns 2 and 3. We do not see a significant effect of tree plantation on total erosion even after using the instrumental variables. The results are similar for other years also. Comparable results for total wind erosion are in Table 8, and the results are still not significant after using the instrumental variable. These results are parallel to scientific literature. Shelterbelt mostly helps livestock and reduces erosion on pastureland (Li, 2017). Also, total erosion is a combination of water and wind erosion. Shelterbelt has minimum effect on water erosion, so total erosion is also not being affected.

Next, I present the results for the total pastureland erosion in Table 8. Column 3 shows the results. In this case, the results clearly demonstrate that shelterbelts had a consistently positive impact on environmental quality. It is evident that the treatment effect had a negative effect on wind erosion. If counties had more exposure to shelterbelt plantations in the 1940s, they still have a lower erosion rate in the pastureland. These results follow the previous literature, where studies show how shelterbelts have primarily been effective on pastureland (Li, 2017). Following these studies, shelterbelt helped to increase revenue but only in the pastureland. From a scientific perspective, this is true, as shelterbelt mostly helped and was planted in livestock areas (Bird, 1998). From Tables 9 and 10, we see that shelterbelt helped to reduce pasture wind erosion rate and pasture total erosion rate.

In Table 10, I present results for cropland erosion. Shelterbelts do not change erosion rate on the cropland in the long run. This follows from the previous literature, where studies show shelterbelt did not change crop revenue, but changed revenue from livestock (Li, 2017)

Next, I present results for future tree plantation. From the SCS activities across soil conservation districts, we can see the effect of the GPSP on tree plantation at a later date. In Table 12 we see that shelterbelt plantation does not have a significant effect on future shelterbelt plantation. This result shows that farmers behavior was not changed because of the large-scale tree plantation.

These results have important policy implications. I show that shelterbelt tree plantation has a persistent effect on soil even after 80 years. GPSP may have been disrupted with market variation and other temporal variables, but the consistent effect on the environmental outcomes is important to think about long-term project planning. These results can be used to design current large-scale tree plantation projects in different countries. Farmers under different agroecological conditions and behavioral characteristics may need different incentives to plant trees on their cropland, just like farmers under weak agrarian institutions also may need particular incentive mechanisms.

6 Conclusion

Using the example of the Great Plains Shelterbelt Project in the 1930s, this paper studies the influence of market prices on the adoption of large-scale tree plantation projects. It shows that the market price was a big factor in adoption, and also shows how initial agrarian structure affects the adoption rate. I also show how plantations helped to reduce pastureland wind erosion in the long run.

These findings are significant for both developed and developing countries working on tree plantation programs. First, policymakers, while designing policies to give farmers incentives to adopt farmland conservation practices, need to consider the effect of the price dynamics in the commodity market. If farmers expect a higher crop price, they will stop planting more trees. In this case, policymakers may adjust the incentive to plant trees depending on the market price. Second, spatial variations in the crops are essential aspects to understand from a policy perspective. In a large-scale tree plantation program, when the effects are only valid if we can implement a tree band, it is essential to understand initial land use under different crops. We see that initial agrarian characteristics play an important role in adoption behavior. Policymakers should collect this initial information and design the incentives accordingly.

The persistent environmental effect of the shelterbelt trees on the Great Plains also has important policy implications. Shelterbelts have been proven to have short-term benefits in developing countries (Hughes et al., 2020). However, the results are only about the immediate effects of the shelterbelt since we do not have long-term data for developing countries. In this paper, I compile long-term data and show that shelterbelts have persistent effects on the environment even after eighty years.

Conservation activities, especially tree plantation, are becoming important in the policy discussion. Designing tree plantation policies is an increasingly important component of fiscal policies in developing countries. In the developed world, several large plantation projects, such as prairie forestry, are under threat. This study highlights the importance of understanding market pressures and formation constraints to have successful plantation projects. New scientific studies show that there is a possibility of another Dust Bowl-type event in the Great Plains in the coming years (Cowan et al., 2020). To design new conservation policies to reduce the potential damage, we need to understand what has worked well in the past.

However, the study does have several limitations. For example, it does not have a long county-level panel on the tree adoption and existence of the trees under the shelterbelt project after 1942. We do not know where farmers destructed the trees. Having detailed data on the presence of the shelterbelts over time may provide a better idea of how to think about actual farming decisions. Also, this paper does not have sufficient information on the rate of wind erosion before the 1990s. Having a better understanding of immediate and persistent effects on the environmental outcomes would be important to design shelterbelt projects in the long run.

519 # 7 Figures

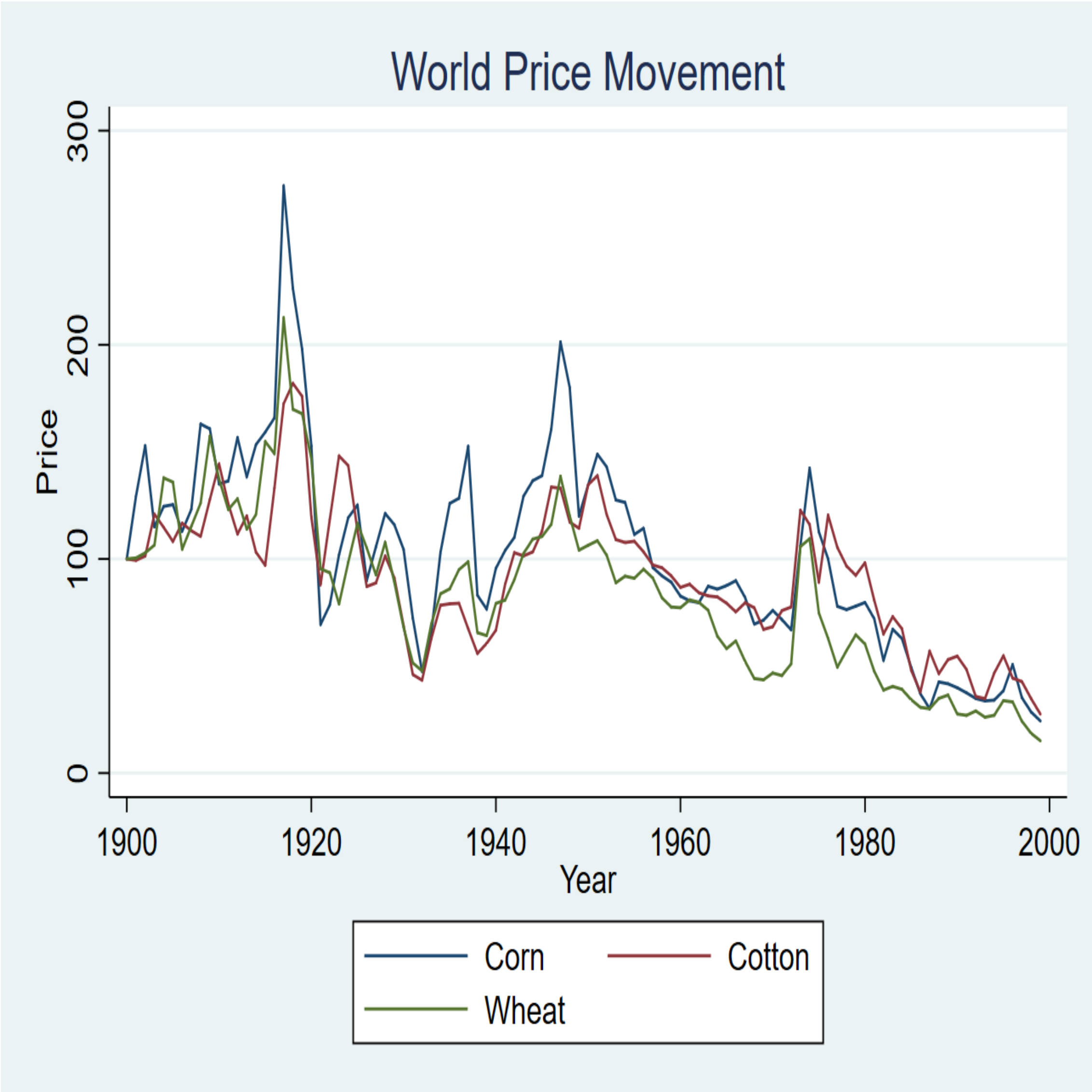
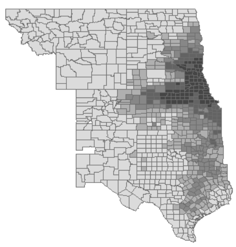
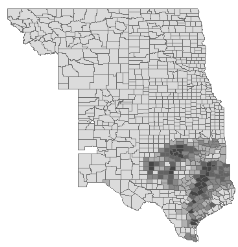


Figure (1) Price movement in 1935-1942 has been used to study the effect of commodity market on landowners' decision on tree plantation over space. Data Extracted from "Data on real commodity prices, 1850 - present"(Jacks, 2017). Real crop price indices, 1900–2015 (1900=100) are on the Y-axis

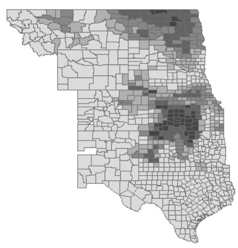
Figure (2) Spatial Variation of Crop Intensity



(a) Corn Intensity



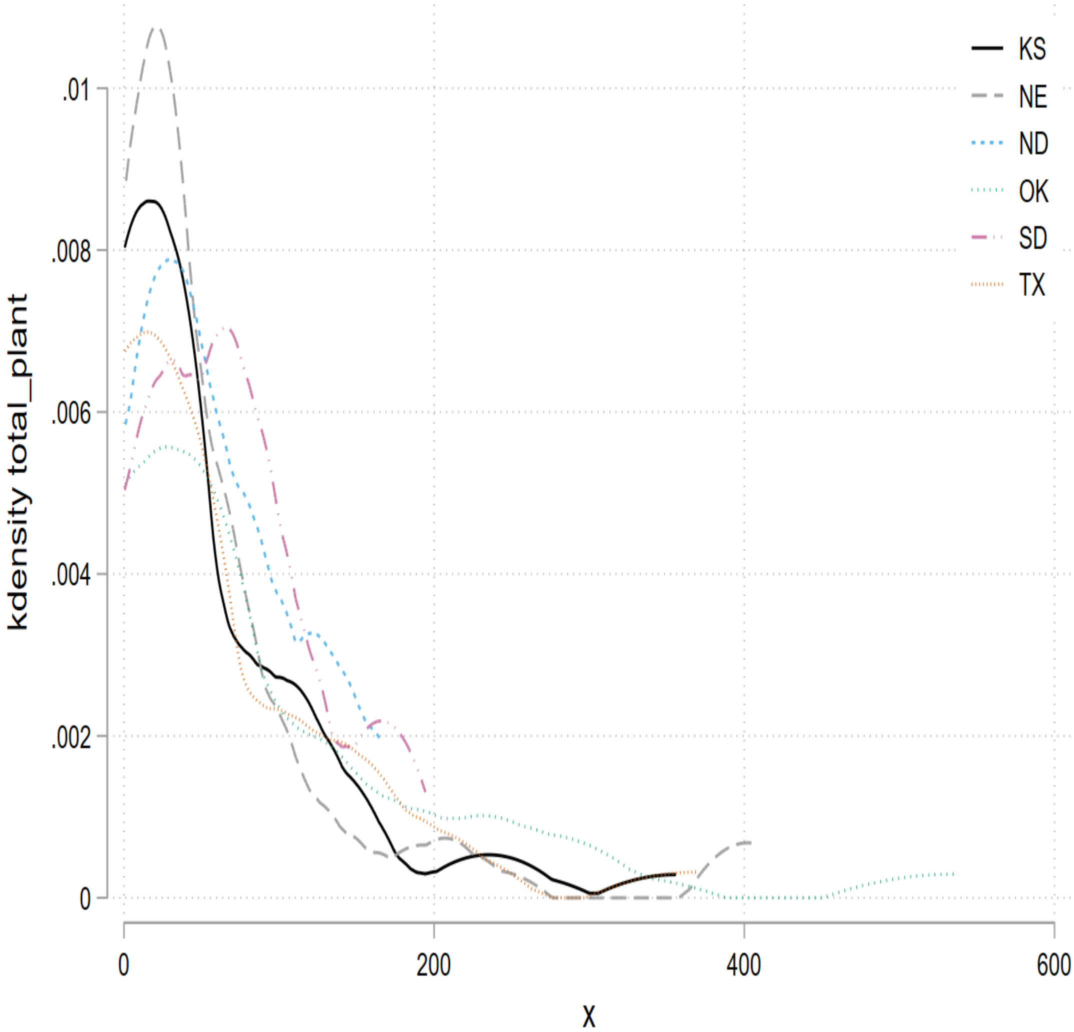
(b) Cotton Intensity



(c) Wheat Intensity

Note: County-level crop intensity data extracted from the US Census of Agriculture (1930). Figures present the Crop area fraction of total farm area by county. Panel a presents high corn intensity areas, panel b presents high cotton intensity areas, and panel c presents high wheat intensity areas.

Figure (3) Distribution of Shelterbelt Plantation



Note: Kernal density of total plantation area is presented for six states. I collected county-level shelterbelt plantation data from the archives. The graph presents total shelterbelt plantation in the study area: Kansas (KS), Nebraska (NE), North Dakota (ND), Okalhoma (OK), South Dakota (SD), Texas (TX).

8 Tables

Table (1) Baseline Characteristics

	Shelterbelt Counties			Other Counties
	Mean	SD	Mean	SD
Total Shelterbelt (mile)	62.0	81.56	0.0	0.00
Total Population	14545.2	13453.35	18231.6	24933.05
Total Farm Number	1598.8	791.31	1760.8	1469.59
Total White Farmer	1645.5	988.70	1706.8	1364.07
Percent of tenants	47.0	9.22	46.9	16.55
Farmland (acre)	505892.2	281432.31	420851.5	289592.89
Average Acre	405.6	337.58	951.6	2746.56
Farmvalue	2.4e+07	1.29e+07	1.4e+07	1.20e+07
N	218		434	

*We compare shelterbelt counties with other Great Plains counties to see the differences across space before the plantation. For the baseline differences, I refer to 1925, because that is the most updated agricultural census before the Dust Bowl.

Table (2) Summary Statistics by Year

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	year 35		year 36		year 37		year 38		year 39		year 40	
VARIABLES	N	mean	N	mean	N	mean	N	mean	N	mean	N	mean
Corn	217	125.9	217	128.3	217	152.6	217	83.08	217	76.54	217	95.61
Wheat	217	86.05	217	94.99	217	98.69	217	65.59	217	64.22	217	79.24
Cotton	217	79.07	217	79.30	217	67.40	217	55.87	217	60.57	217	66.73
plantation_acre	217	1.18e-06	217	1.07e-05	217	1.32e-05	217	3.85e-05	217	3.81e-05	193	2.61e-05

Annual summary statistics for prices of corn, wheat and cotton extracted from Jacks(2017). Annual plantation data by counties extracted from the county plantation reports.

Table (3) Shelterbelt Summary Statistics by Year (Mile)

	(KS)	(NE)	(ND)	(OK)	(SD)	(TX)
1935	0.527	0.389	1.388	0.467	1.172	0.0303
	(1.658)	(1.425)	(1.965)	(0.671)	(2.028)	(0.121)
1936	4.580	2.787	7.672	5.242	9.755	5.182
	(9.151)	(7.044)	(11.53)	(13.02)	(14.63)	(12.77)
1937	4.306	6.269	2.828	10.85	7.271	6.833
	(10.40)	(18.84)	(8.668)	(21.16)	(16.31)	(16.59)
1938	14.82	18.64	10.98	34.82	17.99	23.27
	(31.79)	(40.94)	(20.16)	(67.56)	(22.94)	(46.68)
1939	16.62	18.70	19.00	16.96	33.38	13.15
	(25.31)	(25.92)	(20.86)	(22.48)	(29.37)	(19.84)
1940	12.76	12.47	17.65	16.36		7.602
	(13.95)	(15.13)	(18.78)	(16.93)		(10.44)
N	282	324	174	180	120	198

mean coefficients; sd in parentheses

Annual summary statistics for county-level shelterbelt areas. Data has been manually extracted from shelterbelt county reports deposited in the NARA.

Table (4) Shelterbelt Summary Statistics by Year (Mile)

	(1)	
	Mean Area of Shelterbelt Plantation	Standard Deviation
Plantation 1935	.5922936	1.503305
Plantation 1936	5.286147	11.00566
Plantation 1937	6.184679	15.92713
Plantation 1938	19.56821	41.40678
Plantation 1939	18.74197	24.58494
Plantation 1940	13.09	15.25959
N	218	

Annual summary statistics for county-level shelterbelt areas. Data has been manually extracted from shelterbelt county reports deposited in the NARA.

Table (5) Effect of Commodity Price on Shelterbelt Adoption

VARIABLES	(1) Shelterbelt Acre
Initial Corn Intensity * Price	-1.63e-06***
	(2.30e-07)
Initial Cotton Intensity * Price	-8.14e-06***
	(9.88e-07)
Initial Wheat Intensity * Price	-1.05e-06***
	(3.51e-07)
Constant	8.83e-05***
	(5.98e-06)
Observations	1,278
Number of FIPS	217
R-squared	0.137
county FE	Yes
Year FE	Yes

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

- Panel regression with five years of plantation data for 217 counties in the Great Plains. This table follows regression model (1).
- Cotton, corn, and wheat intensity have been derived from the 1930 USDA agricultural census. I use total farmland to get the intensity by area.
- Initial corn intensity*price denotes the interaction between initial corn intensity and corn price movement of that year. Initial cotton intensity*price denotes the interaction between initial cotton intensity and cotton price movement of that year. Initial wheat intensity*price denotes the interaction between initial wheat intensity and wheat price movement of that year.

Table (6) Heterogeneous Treatment Effects of Commodity Price on Shelterbelt Adoption

VARIABLES	(1) Tenants	(2) Duration	(3) Irrigation	(4) Wood	(5) Num Farms
Price*Tenure*Cotton	2.51e-05**				
	(1.26e-05)				
Price*Tenure*Corn	-1.09e-05***				
	(3.61e-06)				
Price*Tenure*Wheat	6.07e-06				
	(5.37e-06)				
Price*Duration*Cotton		7.59e-06			
		(5.34e-06)			
Price*Duration*Corn		2.21e-06*			
		(1.14e-06)			
Price*Duration*Wheat		-9.36e-07			
		(1.34e-06)			
Price*Irrigation*Cotton			0.000189		
			(0.000125)		
Price*Irrigation*Corn			2.12e-05		
			(3.20e-05)		
Price*Irrigation*Wheat			-0.000198**		
			(8.07e-05)		
Price*Wood*Cotton				3.31e-05***	
				(1.20e-05)	
Price*Wood*Corn				1.30e-05	
				(1.48e-05)	
Price*Wood*Wheat				-4.50e-06	
				(1.69e-05)	
Price*Num Farm*Cotton					-3.55e-10
					(1.05e-09)
Price*Num Farm*Corn					6.08e-10
					(3.81e-10)
Price*Num Farm*Wheat					-6.58e-11
					(5.00e-10)
Constant	9.01e-05***	8.99e-05***	8.93e-05***	8.77e-05***	8.87e-05***
	(5.99e-06)	(6.03e-06)	(5.98e-06)	(5.98e-06)	(6.00e-06)
Observations	1,278	1,278	1,278	1,278	1,278
R-squared	0.148	0.143	0.145	0.145	0.140
Number of FIPS	217	217	217	217	217
county FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes

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

- Panel regression with five years of plantation data for 217 counties in the Great Plains. This table follows regression model (2).
- *Cotton, corn, and wheat denotes initial crop intensity in 1930.
- Tenure denotes the proportion of farms operated by tenants, Duration denotes average agricultural contract duration, irrigation denotes proportion of total farmland under irrigation, wood denotes proportion of pastureland under wood in 1934, Num Farm denotes total number of farms.

Table (7) Effect of Shelterbelt Adoption on Total Erosion

	(1)	(2)	(3)
		first	second
VARIABLES	Total Rate	Log Plantation	Total Rate
Log Plantation	84.98		-258.0
	(198.9)		(509.4)
Average size of farms, 1935 (acres)	0.000100	-7.03e-08**	
	(0.000193)	(3.18e-08)	
Farms of black operators, 1935 (number)	-0.000894	-2.88e-07	
	(0.000582)	(1.89e-07)	
Tenants, 1935 (number)	1.04e-05	1.15e-08	
	(8.20e-05)	(2.57e-08)	
treat_IV		0.000130***	
		(1.97e-05)	
Constant	1.516***	5.88e-05*	1.594***
	(0.126)	(3.48e-05)	(0.0709)
Observations	218	218	218
R-squared	0.015	0.200	
Durbin (score) $\chi^2(1)$	3.08536		
	(p = 0.0790)		
Wu-Hausman F(1,155)	3.08706		
	(p = 0.0809)		

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4 follows from regression model 3 and model 4. We use Total Plantation in 1930's to explain the long-term persistent effect on total erosion in the shelterbelt counties. We control from average farm size, number of farms under black farmers, number of farms under tenant farms.
treat˙IV is derived from the GPSP planning of 100-mile- wide shelterbelt areas (Li, 2019).

Table (8) Effect of Plantation on Total Wind Erosion

VARIABLES	(1) Total Wind Rate	(2) first Log Plantation	(3) second Total Wind Rate
Log Plantation	514.4*		-238.4
	(294.3)		(762.6)
Average size of farms, 1935 (acres)	0.000480**	-7.03e-08**	
	(0.000237)	(3.18e-08)	
Farms of black operators, 1935 (number)	-0.000420	-2.88e-07	
	(0.000814)	(1.89e-07)	
Tenants, 1935 (number)	-0.000213*	1.15e-08	
	(0.000119)	(2.57e-08)	
treat_IV		0.000130***	
		(1.97e-05)	
Constant	0.933***	5.88e-05*	1.031***
	(0.173)	(3.48e-05)	(0.106)
Observations	218	218	218
R-squared	0.100	0.200	

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 5 follows from regression model 3 and model 4. We use Total Plantation in 1930's to explain the long-term persistent effect on total wind erosion in the shelterbelt counties. We control from average farm size, number of farms under black farmers, number of farms under tenant farms.
treat˙IV is derived from the GPSP planning of 100-mile- wide shelterbelt areas (Li, 2019).

Table (9) Effect of Plantation on total Pasture Erosion

VARIABLES	(1) Pasture Rate	(2) first Log Plantation	(3) second Pasture Rate
Log Plantation	72.97		-1,960***
	(217.0)		(553.4)
Average size of farms, 1935 (acres)	0.000617**	-7.52e-08*	
	(0.000294)	(3.91e-08)	
Farms of black operators, 1935 (number)	-0.000200	-2.85e-07	
	(0.000319)	(1.90e-07)	
Tenants, 1935 (number)	4.89e-05	8.15e-09	
	(8.13e-05)	(2.65e-08)	
treat_IV		0.000131***	
		(2.01e-05)	
Constant	0.160	6.42e-05*	0.696***
	(0.169)	(3.79e-05)	(0.0780)
Observations	214	214	214
R-squared	0.125	0.199	

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

*Table 6 follows from regression model 3 and model 4. We use Total Plantation in 1930's to explain the long-term persistent effect on total pastureland erosion in the shelterbelt counties. We control from average farm size, number of farms under black farmers, number of farms under tenant farms.
treat˙IV is derived from the GPSP planning of 100-mile- wide shelterbelt areas (Li, 2019).

Table (10) Effect of Plantation on Total Pasture Wind Erosion

VARIABLES	(1) Pasture Wind Rate	(2) first Log Plantation	(3) second Pasture Wind Rate
Log Plantation	329.8		-1,719***
	(224.3)		(562.6)
Average size of farms, 1935 (acres)	0.000747**	-7.52e-08*	
	(0.000363)	(3.91e-08)	
Farms of black operators, 1935 (number)	7.67e-05	-2.85e-07	
	(0.000291)	(1.90e-07)	
Tenants, 1935 (number)	1.76e-06	8.15e-09	
	(9.99e-05)	(2.65e-08)	
treat_IV		0.000131***	
		(2.01e-05)	
Constant	-0.0991	6.42e-05*	0.453***
	(0.213)	(3.79e-05)	(0.0792)
Observations	214	214	214
R-squared	0.189	0.199	

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

*Table 7 follows from regression model 3 and model 4. We use Total Plantation in 1930's to explain the long-term persistent effect on total pastureland wind erosion in the shelterbelt counties. We control from average farm size, number of farms under black farmers, number of farms under tenant farms.
treat˙IV is derived from the GPSP planning of 100-mile- wide shelterbelt areas (Li, 2019).

Table (11) Effect of Plantation on Total Cropland Wind Erosion

	(1)	(2)	(3)
		first	second
VARIABLES	Cropland Wind Rate	Log Plantation	Cropland Wind Rate
Log Plantation	769.7**		66.83
	(342.4)		(829.3)
Average size of farms, 1935 (acres)	0.000517**	-7.03e-08**	
	(0.000252)	(3.18e-08)	
Farms of black operators, 1935 (number)	-0.000322	-2.88e-07	
	(0.000877)	(1.89e-07)	
Tenants, 1935 (number)	-0.000243*	1.15e-08	
	(0.000128)	(2.57e-08)	
treat_IV		0.000130***	
		(1.97e-05)	
Constant	1.017***	5.88e-05*	1.100***
	(0.186)	(3.48e-05)	(0.115)
Observations	218	218	218
R-squared	0.105	0.200	0.002

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

*Table 9 follows from regression model 3 and model 4. We use Total Plantation in 1930's to explain the long-term persistent effect on total cropland wind erosion in the shelterbelt counties. We control from average farm size, number of farms under black farmers, number of farms under tenant farms.
treat˙IV is derived from the GPSP planning of 100-mile- wide shelterbelt areas (Li, 2019).

Table (12) Effect of GPSP Plantation on Future Tree Plantation

	(1)	(2)	(3)
		first	second
VARIABLES	log_plant60	Log Plantation	log_plant60
Log Plantation	-1,920		3,102
	(1,735)		(4,230)
Average size of farms, 1935 (acres)	0.000338	-6.57e-08	
	(0.00101)	(4.02e-08)	
Farms of colored operators, 1935 (number)	-0.00446	-2.78e-07	
	(0.00382)	(1.85e-07)	
Tenants, 1935 (number)	-0.000330	2.58e-08	
	(0.000643)	(2.71e-08)	
treat_IV		0.000108***	
		(2.19e-05)	
Constant	4.341***	5.12e-05	3.528***
	(0.820)	(3.85e-05)	(0.538)
Observations	158	158	158
R-squared	0.029	0.171	

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

*Table 10 follows from regression model 3 and model 4. We use Total Plantation in 1930's to explain the long-term persistent effect on total tree plantation in 1960s in the shelterbelt counties. We control from average farm size, number of farms under black farmers, number of farms under tenant farms.
treat˙IV is derived from the GPSP planning of 100-mile- wide shelterbelt areas (Li, 2019).

References

Adesina, Akinwumi A and Moses M Zinnah (1993). "Technology characteristics, farmers' perceptions and adoption decisions: A Tobit model application in Sierra Leone". *Agricultural economics* 9.4, pp. 297–311.

Aigbokhaevbo, Violet O (2014). "The" Great Green Wall": Implementation Constraints". *Environmental Policy and Law* 44.4, p. 375.

Alsan, Marcella and Claudia Goldin (2019). "Watersheds in child mortality: The role of effective water and sewerage infrastructure, 1880–1920". *Journal of Political Economy* 127.2, pp. 586–638.

Armstrong, AJ, G Benn, AE Bowland, PS Goodman, DN Johnson, AH Maddock, and CR Scott-Shaw (1998). "Plantation forestry in South Africa and its impact on biodiversity". *Southern African Forestry Journal* 182.1, pp. 59–65.

Beetz, Alice E (2011). *Agroforestry: Overview*. National Sustainable Agriculture Information Service.

Bellefontaine, Ronald, Martial Bernoux, Bernard Bonnet, Antoine Cornet, Christophe Cudennec, Patrick D'Aquino, Isabelle Droy, Sandrine Jauffret, Maya Leroy, Michel Malagnoux, et al. (2011). "The African great green wall project: What advice can scientists provide?: A summary of published results".

Bird, PR (1998). "Tree windbreaks and shelter benefits to pasture in temperate grazing systems". *Agroforestry systems* 41.1, pp. 35–54.

Bond, William J, Nicola Stevens, Guy F Midgley, and Caroline ER Lehmann (2019). "The trouble with trees: afforestation plans for Africa". *Trends in ecology & evolution* 34.11, pp. 963–965.

Brain, Stephen (2010). "The great Stalin plan for the transformation of nature". *Environmental History* 15.4, pp. 670–700.

Brown, Sarah E, Daniel C Miller, Pablo J Ordonez, and Kathy Baylis (2018). "Evidence for the impacts of agroforestry on agricultural productivity, ecosystem services, and human well-being in high-income countries: a systematic map protocol". *Environmental Evidence* 7.1, p. 24.

Cassel, J Frank and John M Wiehe (1980). "Uses of shelterbelts by birds". *Workshop Proceedings, Management of Western forests and Grasslands for Nongame Birds. USDA Forest Service General Technical Report INT-86, Ogden, UT*, pp. 78–87.

Cohen, Aaron J, Michael Brauer, Richard Burnett, H Ross Anderson, Joseph Frostad, Kara Estep, Kalpana Balakrishnan, Bert Brunekreef, Lalit Dandona, Rakhi Dandona, et al. (2017). "Estimates and 25-year trends of the global burden of disease attributable to ambient air pollution: an analysis of data from the Global Burden of Diseases Study 2015". *The Lancet* 389.10082, pp. 1907–1918.

Cowan, Tim, Sabine Undorf, Gabriele C Hegerl, Luke J Harrington, and Friederike EL Otto (2020). "Present-day greenhouse gases could cause more frequent and longer Dust Bowl heatwaves". *Nature Climate Change*, pp. 1–6.

Crost, Benjamin and Joseph H Felter (2020). "Export crops and civil conflict". *Journal of the European Economic Association* 18.3, pp. 1484–1520.

Droze, Wilmon Henry (1977). *Trees, prairies, and people: a history of tree planting in the plains states*. Texas Woman's University.

Dunn, Lester C (1941). "The Great Plains shelterbelt and its development into The Prarie States Forestry Project".

Elkin, Rosetta Sarah (2014). "Planting the Desert: Cultivating Green Wall Infrastructure". *Revising Green Infrastructure*. CRC Press, pp. 324–345.

Fishback, Price (2017). "How successful was the new deal? The microeconomic impact of new deal spending and lending policies in the 1930s". *Journal of Economic Literature* 55.4, pp. 1435–85.

Fiszbein, Martin (2017). *Agricultural diversity, structural change and long-run development: Evidence from the us*. Tech. rep. National Bureau of Economic Research.

Freire-González, Jaume, Christopher Decker, and Jim W Hall (2017). "The economic impacts of droughts: A framework for analysis". *Ecological Economics* 132, pp. 196–204.

Gardner, Robert (2009). "Trees as technology: planting shelterbelts on the Great Plains". *History and technology* 25.4, pp. 325–341.

Haines, Michael R et al. (2010). “Historical, demographic, economic, and social data: the United States, 1790–2002”. *Ann Arbor, MI: Inter-university Consortium for Political and Social Research.*

Hornbeck, Richard (2012). “The enduring impact of the American Dust Bowl: Short- and long-run adjustments to environmental catastrophe”. *The American Economic Review* 102.4, pp. 1477–1507.

Hornbeck, Richard and Pinar Keskin (2014). “The historically evolving impact of the ogallala aquifer: Agricultural adaptation to groundwater and drought”. *American Economic Journal: Applied Economics* 6.1, pp. 190–219.

Hornbeck, Richard and Suresh Naidu (2014). “When the levee breaks: black migration and economic development in the American South”. *American Economic Review* 104.3, pp. 963–90.

Howlader, Aparna (2019). “Three essays on the relationship between land conservation and economic development”. PhD thesis. University of Illinois at Urbana-Champaign.

Hughes, Karl, Seth Morgan, Katherine Baylis, Judith Oduol, Emilie Smith-Dumont, Tor-Gunnar Vågen, and Hilda Kegode (2020). “Assessing the downstream socioeconomic impacts of agroforestry in Kenya”. *World Development* 128, p. 104835.

Hurt, R Douglas (1981). *The Dust Bowl: An agricultural and social history.* Taylor Trade Publications.

Imbens, Guido W and Jeffrey M Wooldridge (2009). “Recent developments in the econometrics of program evaluation”. *Journal of economic literature* 47.1, pp. 5–86.

Ingram, Verina, Edwin Van Der Werf, Enoch Kikulwe, and JHH Wesseler (2016). “Evaluating the impacts of plantations and associated forestry operations in Africa—methods and indicators”. *International Forestry Review* 18.1, pp. 44–55.

Jacks, DS (2017). *Data on Real Commodity Prices, 1850—Present.*

Kröger, Markus (2014). “The political economy of global tree plantation expansion: a review”. *Journal of Peasant Studies* 41.2, pp. 235–261.

Lang, James B (1970). “The Shelterbelt Project in the southern Great Plains, 1934-1970: a geographic appraisal”.

Li, Miao-miao, An-tian Liu, Chun-jing Zou, Wen-duo Xu, Hideyuki Shimizu, and Kai-yun Wang (2012). "An overview of the "Three-North" Shelterbelt project in China". *Forestry Studies in China* 14.1, pp. 70–79.

Li, Tianshu (2017). *Protecting the breadbasket with trees? The effect of the Great Plains Shelterbelt Project on agricultural production.* Tech. rep. Working Paper.

— (2019). "Protecting the Breadbasket with Trees? The Effect of the Great Plains Shelterbelt Project on Agricultural Production". *American Journal of Agricultural Economics RR.*

Marotz, Glen A and Curtis J Sorenson (1979). "Depletion of a Great Plains resource: the case of shelter-belts". *Environmental Conservation* 6.3, pp. 215–224.

McIntosh, C Barron (1975). "Use and abuse of the Timber Culture Act". *Annals of the Association of American Geographers* 65.3, pp. 347–362.

Meneguzzo, Dacia M, Andrew J Lister, and Cody Sullivan (2018). "Summary of findings from the Great Plains Tree and Forest Invasives Initiative". *Gen. Tech. Rep. NRS-GTR-177. Newtown Square, PA: US Department of Agriculture, Forest Service, Northern Research Station. 24 p.* 177, pp. 1–24.

Mercer, D Evan and Subhrendu K Pattanayak (2003). "Agroforestry adoption by smallholders". *Forests in a market economy.* Springer, pp. 283–299.

Miller, Daniel C, Pablo J Ordoñez, Sarah E Brown, Samantha Forrest, Noé J Nava, Karl Hughes, and Kathy Baylis (2020). "The impacts of agroforestry on agricultural productivity, ecosystem services, and human well-being in low-and middle-income countries: An evidence and gap map". *Campbell Systematic Reviews* 16.1, e1066.

Munns, Edward N and Joseph H Stoeckeler (1946). "How are the great plains shelterbelts?" *Journal of Forestry* 44.4, pp. 237–257.

Nair, PK Ramachandran (1993). *An introduction to agroforestry.* Springer Science & Business Media.

Prokopy, Linda S, Kristin Floress, J Gordon Arbuckle, Sarah P Church, FR Eanes, Yuling Gao, Benjamin M Gramig, Pranay Ranjan, and Ajay S Singh (2019). "Adoption of agricultural conservation practices in the United States: Evidence from 35 years of quantitative literature". *Journal of Soil and Water Conservation* 74.5, pp. 520–534.

Read, Ralph A et al. (1958). "Great Plains shelterbelt in 1954".

Reimer, Adam P, Ben M Gramig, and Linda S Prokopy (2013). "Farmers and conservation programs: explaining differences in Environmental Quality Incentives Program applications between states". *Journal of Soil and Water Conservation* 68.2, pp. 110–119.

Rosenberg, Norman J (1986). "Adaptations to adversity: agriculture, climate and the Great Plains of North America". *Great Plains Quarterly*, pp. 202–217.

Scherr, Sara J (1992). "Not out of the woods yet: challenges for economics research on agroforestry". *American journal of agricultural economics* 74.3, pp. 802–808.

Schoeneberger, Michele M (2009). "Agroforestry: working trees for sequestering carbon on agricultural lands". *Agroforestry systems* 75.1, pp. 27–37.

Skidmore, EL and LJ Hagen (1977). "Reducing wind erosion with barriers". *Transactions of the ASAE* 20.5, pp. 911–0915.

Stein, John D and Patrick Charles Kennedy (1972). "Key to shelterbelt insects in the Northern Great Plains".

Stoeckeler, Joseph Henry et al. (1962). "Shelterbelt influence on Great Plains field environment and crops".

Woodruff, Neal P (1977). *How to control wind erosion.* 354. Agricultural Research Service.

Young, Anthony et al. (1997). *Agroforestry for soil management.* Ed. 2. CAB international.