Determinants and Consequences of Agroforestry: Historical Evidence from the Great Plains Shelterbelt Project*

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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 market pressure influenced the decision to plant trees and how soil erosion has changed because of the trees in the long run. I consider world market price movement, initial crop production intensity, and the 100-mile-wide shelterbelt project planning belt. The main finding is that an increase in the world market price reduces the adoption of shelterbelt trees, and that agricultural factors such as tenancy, access to irrigation, and duration of the agricultural contract matter in the decision process. Also, shelterbelt adoption decreases long-term wind erosion, especially in pasture areas.

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

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

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1 Introduction

Private farmland conservation, especially agroforestry, has been widely adopted as a land conservation instrument all over the world (Schoeneberger, 2009). Many agricultural science experiments examine how tree plantation projects help to achieve long-term environmental sustainability and increase community resilience (Young, 1989; Nair, 1993; Beetz, 2011). Based on these experimental results, the recent social science and ecology literature has included studies on how to give incentives to farmers to adopt agroforestry on their farmland (Scherr, 1992; Mercer and Pattanayak, 2003; Woodruff, 1977). 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 in agroforestry and the consequences of tree plantation on farmland 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.

Large-scale agroforestry projects have historical roots in Stalin's Great Plan for the Transformation of Nature or Roosevelt's Great Plains Forestry Project (Brain, 2010; Gardner, 2009).Recent examples of large-scale agroforestry projects include the Three North Shelterbelts in China and the Great Green Wall in the Sahara Desert (Li et al., 2012; Aigbokhaevbo, 2014). Understanding the factors behind farmers' adoption behavior is important to design these large-scale tree plantation policies. Historical projects may help us to study the long-term effects on the environment as well.

Production and conservation are competing demands for land use, and this problem is enhanced in large-scale tree plantation programs. First, scattered trees cannot solve wind erosion problems. Erosion will only be reduced by tree bands, for which it is necessary to convert a large number of private continuous farm plots. Second, different property rights and institutional frameworks also influence the decision process. This issue arises from incomplete information on the benefits of conservation and on farmers' problems over time. Understanding what determines the decision on a large-scale plantation program is important because it helps planners to design incentive policies in the future. The success of any large-scale tree plantation program depends on farmers' initial uptake rate and their persistence in maintaining it. The main incentive problem arises from the fact that the benefit of tree plantation is not immediately visible. In this circumstance, farmers have few incentives to plant and take care of trees. This generates two questions depending on the timeframe: (1) What determines the adoption behavior at the beginning? (2) What determines persistent attitudes toward tree plantation?

In this paper, I answer two questions: how does commodity price affect decisions relating to tree plantation on the farmland, and how does tree plantation affect long-term environmental quality? This paper examines one of the most extensive tree plantation programs on private land in the world, the Great Plains Shelterbelt Project (1936-1941). To study the impact of commodity price on farmland conservation behavior. I digitize unique county-year panel data on annual shelterbelt plantation acres for 1936-1940. I show how crop-specific annual price variation influenced these annual adoption decisions with the help of a difference-in-difference method. Moreover, I show how county-level shelterbelt trees reduced soil erosion levels in the shelterbelt counties compared to non-shelterbelt areas.

Despite the importance of understanding the adoption of farmland conservation instruments under market pressure, economic studies on the effects have been limited because of data limitations. This paper examines these questions using the example of one of the earliest and most popular tree plantation programs in the United States, the Great Plains Shelterbelt Project. The uniqueness in designing the program, the size of the program, and the nature of the public-private partnership make this a perfect case study. In the Dust Bowl era, Franklin D. Roosevelt introduced the idea of planting shelterbelts, and the U.S. Forest Service (USFS) was responsible for implementing it. At first, USFS asked farmers to sell the land at a low cost, but farmers did not respond to the incentive. Later on, it was converted to a public-private partnership, where farmers were responsible for clearing their land and government was responsible for helping to decide tree species and providing technical support. USFS planted 220 million trees from 1935 to 1942 across the Great Plains (Droze, 1977)

In this paper, I take advantage of detailed county-level annual farm forestry plantation data from the shelterbelt project annual reports deposited 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 temporal price shock to see how a change in crop prices affect 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 price on shelterbelt adoption behavior in detail.

Using this newly compiled data, I use the difference-in-difference method. In this method, spatial variations come from the initial crop intensity, and temporal variations come from price variations. I also utilize the setting to show that farms have a long-run effect on the erosion from this adoption behavior. To understand the impact of this plantation project on the environment, I draw on the Natural Resource Inventory database from the U.S. Department of Agriculture (USDA) to shed light on the impact of shelterbelt plantation on county-level erosion control in the long run. 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) also used this instrumental variable (Li, 2019)

The results show that price increase had a negative effect on the adoption of agroforestry practices in the 1930 s. 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 show how heterogeneity in the initial agricultural institutions affects the adoption decision. Results from the erosion level's impact, in the long run, suggest that shelterbelt decreases the area's 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.

This paper contributes to the literature on farmers' 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 affects the progress (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).

The paper proceeds by providing background and data construction in Section 2. Section 3 is on the empirical framework. Section 4 demonstrates the results and discussion. Concluding remarks are in Section 5.

2 Background and Data Construction

Tree plantation was part of the policy discussion from the beginning of American conservation policies through the 1873 Timber Culture Act as it applied in Nebraska and Kansas. However, this was mostly a failed attempt (McIntosh, 1975). In the 1930s, the Dust Bowl substantially decreased the amount of topsoil in the Great Plains, and as a result, Roosevelt promised to create the tree belt in the Great Plains, with other conservation programs administrated by the USDA.

The shelterbelt project was planned based on Roosevelt's previous experience with agroforestry in Hyden Park in New York (Droze, 1977). Roosevelt posted 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 plans, the federal government passed it in 1935. Initially, the federal government leased land from its owners for the long term. But eventually, it became tough to get the budget for the shelterbelt. So, the government converted the program to a cost-sharing program with landowners, where landowners were responsible for clearing the land, fencing it, and rodent control. The planning was based on climate and pre-program geographic characteristics. The actual shelterbelt planting started in 1935 and ceased in 1942, as funds were cut after the United States entered World War II (Droze, 1977).

The main database I used for the analysis came from the National Archives in Kansas City. It provides plantation data that shows how much land was under plantation every year from the beginning of the plantation. Some data came from agricultural censuses, such as tenancy, crops, and farm size. I also used county-level initial crop intensity data from the agricultural census. Crop price information came from Jacks (2017).

For the long-term analysis of the environment, I used erosion data from 2012 from the natural resource inventory database created by the USDA. I used data on the total erosion rate, total wind erosion rate, erosion on cropland, and pastureland.

Table 1 shows that the baseline factors are very similar in shelterbelt and 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 plantation data and crop prices over time.

3 Empirical Strategy

In this section, I describe the strategy to examine the effect of price shocks on the adoption of tree plantation. I study the underlying characteristics of adoption with the help of pre-1930 data to see which counties have higher adoption rates. Because it was a voluntary program, I use a difference-in-difference model to deal with potential endogeneity.

First, I study the implications of commodity price movement on shelterbelt adoption. The plantation area denotes my outcome variable by county and year; my main exogenous variation is the interaction of annual price movement and initial county-crop specific intensity that came from 1930s census data.

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. I use data from the beginning of the shelterbelt plantation project, 1935 and estimate:

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

$y_{c,t}$ is the outcome variable of interest in county c at the shelterbelt project period. This model shows how the interaction of market price movement with county-level initial crop intensity affected shelterbelt plantation decision.

County fixed effects absorb county-specific time-invariant heterogeneities affecting the local extent of adoption. δ_t is the time fixed effect capturing common trend. $X_{c,1935}$

includes initial tenancy and color. I do not cluster data by states because the groups are small.

Next, I extend this model to the triple difference model to include the heterogeneous treatment effect. I estimate the model using variations in tenancy, duration of agricultural contract, irrigation, area under wood, and number of farms. I estimate a panel regression model where H denotes these heterogeneities:

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

Next, I turn the analysis to understand the impact of the adoption of the environmental outcomes. I use the erosion rate in cropland, pastureland, and total land in 2012 as the environmental outcome. 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. I estimate a cross-sectional OLS equation:

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

where y_c is the environmental outcome. I exploit the exogenous planning map for the shelterbelt across counties to address the endogenous adoption of tree plantation. I use a digitized map from Li (2019). The shelterbelt planning map came from Droze (1977). It relies on geographic conditions, and it can be used as an exogenous variation for actual tree plantation (Li, 2019). The first-stage intuition is that higher plantation happened in planning areas. There were 158 counties in 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.

4 Results

Table 3 presents the results for the determinants of the adoption related to market pressure. Table 4 shows the results using heterogeneous treatment effect analysis. There were three main crops in the Great Plains in 1930, and every row represents one crop. Next, we move toward the discussion of the long-term effects of the trees on environmental outcomes. We see that if there is a higher percentage of shelterbelt area in any given county, the erosion level is lower, at least in the pasture areas.

4.1 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 3 shows these results. First, 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. Third, 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.

Next, Model 2 shows heterogeneous effects from initial county institutional farm characteristics. These results follow the theoretical concepts regarding the interrelationships among agroecological variables. They show how farmers' decisions on shelterbelt plantation depended on market fluctuation and initial farming institutions. I used the triple difference model. Table 4 presents these results.

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 labor to plant more trees, so more tenants may help. On the other hand, tenant-dependent farms may have a lower attachment to farming in general, so it may have a lower adoption rate. Column 1 of Table 4 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.

Second, Column 2 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 for corn-intensive counties. I took the average number of years on one farm as the duration of the contract.

Third, irrigation has a negative effect on wheat counties. Wheat is a highly water-dependent crop. Wheat needs more irrigation, and that may crowd out shelterbelt plantation.

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 plantation. That result is in Column 4. The result is significant and positive only for cotton counties. Fifth, the number of farms may have an effect on shelterbelt plantation due to coordination failure. Column 5 shows that there are no significant effects from the number of farms.

4.2 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. I expected the effects from the omitted variables to drive the results up, and the results are consistent with this expectation.

Table 5 presents the results for total erosion in shelterbelt counties. The first column presents the results for Regression Model 3. It shows no effect of plantation on total erosion. Then, I used IV from Li (2019) following Model 3. The results of the first and second stage are in Columns 2 and 3. Comparable results for total wind erosion are in Table 6, and the results are not still significant.

Next, I present the results for the pastureland erosion in Table 7. Column 3 shows the results. The erosion rate is lower than the total erosion rate. From a scientific perspective, this is true, as shelterbelt mostly helped and was planted in livestock areas (Li, 2019). Table 8 shows this result for pastureland wind erosion. Next, in Table 9 and Table 10, I present results for cropland erosion. Shelterbelts had no apparent significant effects on cropland erosion.

5 Conclusion

This paper studies the influence of market price in the adoption of conservation projects taking the example of large-scale tree plantation in the Great Plains. It shows that the market price was a big factor in adoption, and also how plantation helped to reduce pastureland soil erosion in the long run.

These findings are significant for both developed and developing countries working on conservation programs. First, policymakers, while designing policy to give farmers incentives to adopt farmland conservation practices, need to consider the effect of the commodity market. Second, spatial variations in the crops are essential aspects from a policy perspective. In a large-scale tree plantation program, when the effects are only valid if we can provide tree band, it is essential to understand initial land use under different crops.

Conservation activities, especially agroforestry, are becoming important. Several big plantation projects, like prairie forestry, are under threat. This study highlights the importance of understanding market pressures and formation constraints to have successful plantation projects.

However, the paper has several limitations. It does not have a long panel on the adoption and existence of the shelterbelt project over time. Having detailed data on the presence of the shelterbelts may provide a better idea of how to think about actual farming decisions. Future research may tackle this issue.

6 Figures

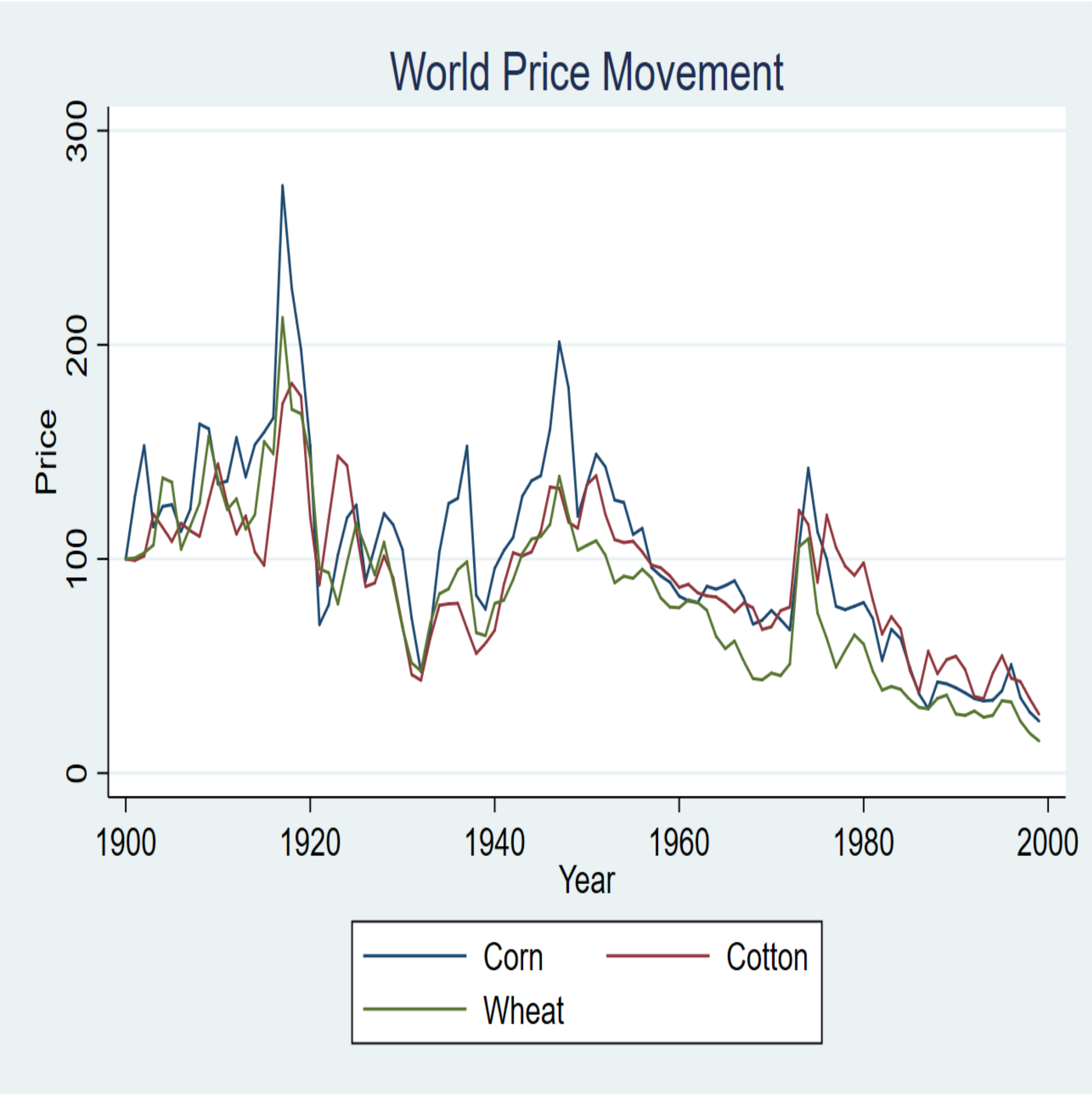

Figure (1) Data Extracted from "Data on real commodity prices, 1850 - present" (Jacks, 2017)
. Price movement in 1935-1942 has been used to see the market influence on landowners' tree plantation.

7 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
Tenancy	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 back 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) Effect of Commodity Price on Adoption

VARIABLES	(1) Shelterbelt Acre
Initital Corn Intensity * Price	-1.63e-06***
	(2.30e-07)
Initital Cotton Intensity * Price	-8.14e-06***
	(9.88e-07)
Initital 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 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 (4) Heerogeneous Treatment Effects of Commodity Price on 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 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 (5) Effect of Shelterbelt Adoption on Total Erosion

VARIABLES	(1) Total Rate	(2) first Log Plantation	(3) second 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	

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 (6) 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 (7) 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 (8) Effect of Plantation on Total Pasture Wind Erosion

	(1)	(2)	(3)
		first	second
VARIABLES	Pasture Wind Rate	Log Plantation	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 (9) Effect of Plantation on Total cropland Erosion

	(1)	(2)	(3)
		first	second
VARIABLES	Cropland Total Rate	Log Plantation	Cropland Total Rate
Log Plantation	-863.9***		1,371*
	(272.3)		(715.1)
Average size of farms, 1935 (acres)	-0.000637***	-7.03e-08**	
	(0.000156)	(3.18e-08)	
Farms of black operators, 1935 (number)	-0.00269*	-2.88e-07	
	(0.00162)	(1.89e-07)	
Tenants, 1935 (number)	0.000322**	1.15e-08	
	(0.000129)	(2.57e-08)	
treat_IV		0.000130***	
		(1.97e-05)	
Constant	5.599***	5.88e-05*	5.302***
	(0.141)	(3.48e-05)	(0.0995)
Observations	218	218	218
R-squared	0.229	0.200	

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

*Table 8 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 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 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).

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