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# Federal Flood Protection Measures and Their Benefits to Agriculture in the Lower Mississippi River Basin

**William K. Jaeger and Kathleen M. Moore**

Flooding causes more property damage than any other natural disaster. Estimating the benefits of flood risk reduction is challenging, and few studies have explored the benefits to agriculture. This study addresses that gap using a hedonic land value approach and difference-in-difference methods to estimate agricultural benefits of the Mississippi River and Tributary Project (MRTP), one of the largest flood mitigation schemes in the world. Results indicate the total value of farmland in counties protected by the MRTP to be as much as $280 million, or 45% higher than in control counties due both to increased farmland values and expanded farmland area.

*Key words*: difference-in-difference method, farmland protection, farmland value, flood risk reduction, floodway, hedonic land value method, levee

## Introduction

Flooding is the most common and widespread natural disaster, responsible for more property damage than any other disaster type, with average yearly damage in the United States of $4 billion, or 30% of total damages from all severe weather events (Hodge, 2021). The combined effects of climate change, land-use change, population growth and land development mean that we can expect more flooding and higher flood damages in the future. As of 2001, estimated flood damages nationally were rising at an annual rate of 3.45% (Cartwright, 2005). More recent analyses estimate the average annual US flood damage at $7 billion per year, with one-third of that damage attributed to precipitation changes, suggesting that climate change may be exacerbating the cost of flooding (Davenport, Burke, and Diffenbaugh, 2021).

A range of mitigation and adaptation strategies can be taken to address large-scale flood risk. These include limiting development in floodplains or other high-risk areas (Lund, 2002), armoring coastal embankments (Beasley and Dundas, 2021), building dams and levees, and creating floodways intended to absorb excess floodwaters (Bogárdi and Balogh, 2014; Kundzewicz, 1999). Large sums of money have been, and are now, appropriated for flood relief projects. Quantifying the benefits of these projects allows for an assessment of the value of both past and future investments. A variety of methods have been used to quantify the economic benefits related to flood protection, including damage cost approaches, stated preference valuation techniques to estimate willingness to pay for flood protection, and estimating the economic value of flood protection afforded by natural ecosystems or other nonstructural defense measures (Beltrán, Maddison, and Elliott, 2018).

Estimating flood risk empirically is challenging due to uncertain factors and unobserved spatial heterogeneities (Schnepf, 2008). Few studies have explored flood risk for agriculture, although the topic has received increased attention in recent years (Wang, 2021). Some studies have found beneficial effects from flooding, for example through sediment deposits that increase

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fertility (Fomby, Ikeda, and Loayza, 2013). Others have found adverse effects on farmland values (Posthumus et al., 2009; Wang, 2021).

The Mississippi River and Tributary Project (MR&T Project) is among the largest flood risk management schemes in the world. The project was initiated following the Great Mississippi Flood of 1927, which inundated 27,000 square miles of land. In the decades that followed, the MR&T Project spent $15 billion (nominal dollars) of federal funds by one estimate (Mississippi River Commission, 2016). Although river engineering has elevated peak flood discharges (Munoz et al., 2018), estimates of the flood damages prevented range from $666 billion (Mississippi River Commission, 2016) to $1.27 trillion (US Army Corps of Engineers, 2019). Few estimates of the benefits of the MR&T Project are found in peer-reviewed sources, and what estimates of flood damage prevention there are have focused on developed lands rather than on farmland.

The MR&T Project has also precipitated environmental costs that should be recognized. These include reduced water quality, which has increased hypoxia in the Gulf of Mexico with negative consequences for biodiversity and commercial fisheries. Additionally, the reduction in sediment transport has led to land subsidence, a loss of wetlands, and increased exposure to hurricanes in southern Louisiana (Niebling et al., 2014).

To our knowledge, no studies have estimated the benefits to agricultural lands resulting from the MR&T Project. The current study addresses that gap using a hedonic land value approach and difference-in-difference (DD) methods to estimate the benefits of flood risk reduction to agricultural lands resulting from the implementation of the MR&T Project.

## Background

The development of the MR&T Project was in response to the Great Mississippi Flood of 1927, the most destructive flood in the history of the United States. The flood inundated 27,000 square miles of land to depths of up to 30 feet and displaced hundreds of thousands of people. Over the next 50 years, the MR&T Project expanded to include levees, dams, spillways, and floodways to mitigate future floods (Barry, 1997). The MR&T Project was designed to control a flood larger than the 1927 flood. The levee system includes 3,787 miles of authorized embankments and floodwalls that mitigate flood risk to urban areas, farmlands, and other enterprises in the 36,000 square mile Lower Mississippi River Valley (Mississippi River Commission, 2007).

The elements of the MR&T system in place today are spread out over a very large area and took decades to fully implement. The project began with the initial passage of the 1928 Flood Control Act, which was implemented by the Hoover administration from 1929 to 1933 (Arnold, 1988). The actions taken included initial construction of mainline levees; completion of the Bonnet CarrÃl' Spillway in 1931, completion of the Birds Point–New Madrid setback levee in 1932, MR&T grade revisions beginning in 1941, construction of the Kentucky Dam, completed in 1944, and construction of the Morganza Floodway and the West Atchafalaya Floodway in 1954. This period of activity was followed by a levee grade review and revision in 1954 and completion of the Old River Control Complex beginning in 1954.

Many components of the MR&T system focused on the portions of the Mississippi River from its confluence with the Ohio River to where it is joined by the Arkansas River. This region had been a major zone of flood risk and thus a focus for flood risk reduction (as were the southern delta and flood plain areas in Louisiana and southern Mississippi) (Figure 1). Mitigation efforts were concentrated at the upstream end of this section of the river to protect areas downstream. Efforts included a series of important developments in the 1960s involving the Birds Point–New Madrid Floodway, located in the southeast corner of Missouri near Cairo, Illinois. Other pertinent developments included the completion of the Barkley Dam on the Cumberland River in 1966 and authorization by the 1965 Flood Control Act to establish the Birds Point–New Madrid Floodway's frontline levee.

Expectations regarding flood control benefits would have likely begun in the 1930s following the initial implementation of the MR&T Project (despite some early delays) between 1929 and 1933.

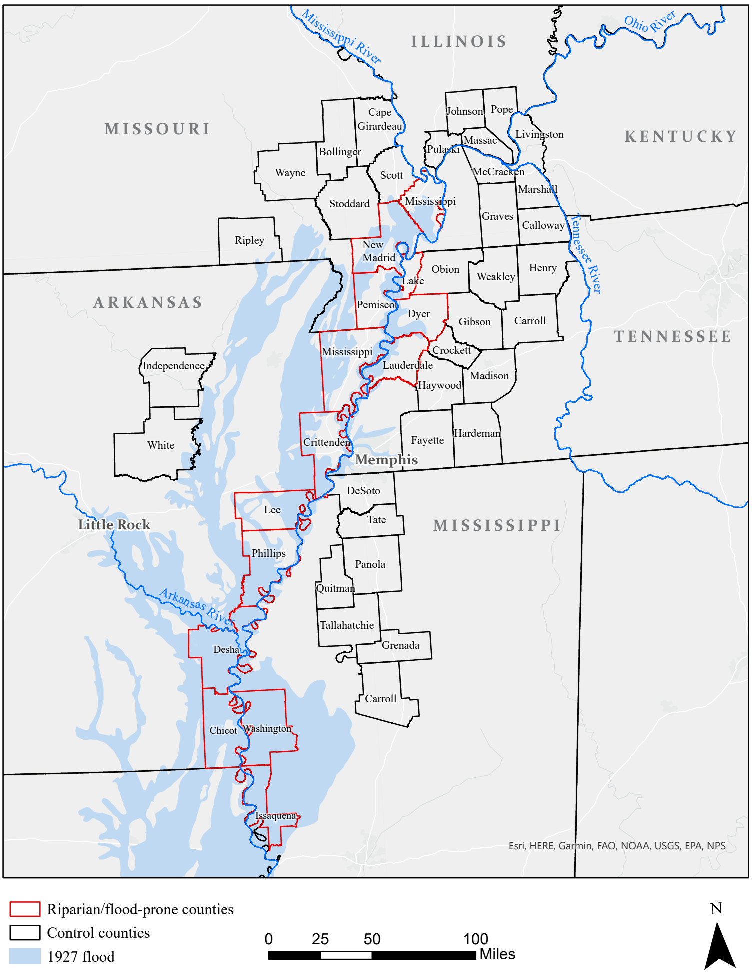


**Figure 1. County Overlap with 1927 Flood Zone**

*Notes:* The share of each county covered by the 1927 flood was calculated in ArcGIS with a shapefile of the flood extent obtained from the US Army Corps of Engineers. The flood extent shapefile was converted to a raster dataset with a 10-meter horizontal resolution to allow computation using the zonal statistics tool.
*Source:* Data available from U.S. Geological Survey, National Geospatial Program.

If they have had the effect of significantly reducing farmer expectations about future flooding and flood damages, then we would expect evidence of those benefits to be reflected in farmland values. The hypothesis to be tested is whether farmland vulnerable to flooding (in flood-prone areas near the Mississippi mainstem) have seen greater average price increases following the MR&T Project than have farmlands in areas that are not flood-prone. Evidence of this effect may be apparent in the period following the implementation of the 1928 Flood Protection Act (post-1933). Subsequent benefits may also be observed following the 1965 Flood Control Act, since these laws provided the main impetus for the actions of the MR&T Project.

Unlike residential properties, the main risk of flooding of agricultural lands is lost revenue and increased costs. For farmland owners who rent out farmland, the risk of flooding will reduce their expected income stream when, in the event of a flood, rental income is lost (e.g., if a rental contract is voided in the event of a flood). For owner-operators, flood losses can include complete or partial loss of revenue as well as the costs of farm operations undertaken prior to a flood (e.g., plowing, seeding, fertilizing), depending on the timing and duration of the flooding. Spring flooding can delay or slow planning, which in turn can reduce yields (Nielsen, 2015). Flooding can destroy a crop midseason or require growers to replant as floodwaters recede, incurring significant additional costs and potential yield losses. The expected frequency and severity of such flood events will lower the present value of the expected stream of net revenues for a given piece of land. The risk of flooding will also influence rent negotiations as farmers recognize additional costs and risks of losses.

Crop insurance can cover a portion of the losses for some of these scenarios. However, crop insurance premiums vary depending on the flood risk and the chosen levels of coverage. Depending on the level of federal crop insurance subsidy, the variations in the costs of crop insurance will also be capitalized into the farmland values like the direct impacts of flood risk. Further consequences of flooding can include losses in soil productivity due to erosion and compaction as well as flood cleanup, including removal of sediment and debris.

In addition to flooding and other risks, farmland values are understood to be affected by a wide range of factors. These include parcel-level characteristics of soil quality, climate, slope, and access to irrigation. Farmland values are also influenced by macroeconomic and policy factors of interest rates and government payments (Nickerson et al., 2012). Nonagricultural attributes—including proximity to urban areas and population density—are also known to influence the market value of farmlands (Plantinga, Lubowski, and Stavins, 2002; Huang et al., 2006; Borchers, Ifft, and Kuethe, 2014).

## Theoretical Model

A standard approach from price theory to valuing farmland is based on capitalization, which defines the relationship between annual economic net returns and the asset price in competitive markets. This Ricardian approach (Ricardo, 1821) assumes that the current value of a parcel of land reflects the present discounted value of the sum of expected future rents, which we can assume to include the real return, $R$, generated from owning and/or farming the land as well as government payments, $G$. This can be written as

$$L_t = \sum_{i=0}^{\infty} \left( \frac{1}{(1+r)^i} \right) [E_t (R_{t+i}) + E_t (G_{t+i})], \tag{1}$$

where $L_t$ is the market value of a parcel of farmland at time $t$, $r$ is the discount rate, and $E_t$ is the expectation operator for future $R$ and $G$. Expected future returns will reflect perceived risks related to future floods and droughts, market conditions, and government programs and policies. The potential influences of government programs on farmland values include direct payments from crop programs, trade policies, and crop insurance (Weersink et al., 1999). The annual economic rents for farmland should follow closely the capitalization relationship in equation (1) (Scanlon et al., 2012; Burns et al., 2018).

The flood risk associated with a particular property will reflect the subjective probability distributions of (i) different flood types; (ii) the damages, costs and other impacts that result; and (iii) the government payments from crop insurance and disaster relief that may result. We can thus modify equation (1) as

$$L_t = \sum_{i=0}^{\infty} \left( \frac{1}{(1+r)^i} \right) [E_t (R_{t+i}) - E_t (D_{t+i}) + E_t (G_{t+i})], \tag{2}$$

where $E_t(D_{t+i})$ increases with expected flood damages net of government payments or crop insurance payments.

The empirical question is whether the implementation of the MR&T Project altered expectations of flood damages to an extent that would be reflected in farmland values. We employ a DD approach to answer this question, comparing price levels and trends for farmlands in counties expected to have benefited from the MR&T Project versus farmlands that do not. The key identifying assumption with DD is that farmland prices would have followed the same trend in the treatment and control groups but for the effect of the MR&T Project.

The null hypothesis is that there is no difference in changes in the farmland values between these two groups from before the MR&T Project versus after its implementation. The alternative hypothesis is that expected flood damage, $E_t(D_{t+i})$, has declined for farmlands located near the Mississippi mainstem and in the flood zone of the 1927 flood, and that as a result the mean farmland value per acre has increased in the post-1930 period relative to farmland values in counties that are not flood-prone. We further investigate whether these effects are associated with changes in acreage cultivated and total farmland value.

## Empirical Analysis

### *Empirical Model*

A hedonic land value analysis is used to identify the impacts of flood protection measures in the Lower Mississippi Basin. This approach is based on the general theoretical framework outlined by Rosen (1974). Agricultural land is composed of a set of n measurable attributes. These attributes include soil quality and productivity, climate, topography, drainage, and location and proximity to relevant markets and developed areas. Each attribute is recognized as having its implicit price. The sum of these implicit prices will determine the market price of the property. The implicit prices are not observable, and they cannot be measured directly. We can, however, make use of the market prices or values of a sample of properties with varying levels of these attributes to derive a hedonic price function and empirically estimate the implicit marginal price of a given attribute (Palmquist and Danielson, 1989).

Farmland prices reflect market equilibrium outcomes determined by supply and demand. In general, this simultaneity or endogeneity can raise potential concerns about inconsistency due to omitted variables in the context of our reduced-form hedonic model estimation (Wooldridge, 2010). In the case of farmland prices for the region under study, there would appear to be few sources of potential bias given the characteristics and structural determinants underlying both supply of and demand for farmland (e.g., derived demand for farmland in response to crop prices determined in national and international markets). To a large extent, these characteristics (e.g., soil type or structure, erosivity, topography, climate, or precipitation) cannot be changed by the owner or in response to market information (Palmquist, 1989). As indicated above, parcels have productivity characteristics that determine expected profits, including those due to potential investments (e.g., drainage, terracing, irrigation, erosion control). Improvements made by individual landowners or public policies that affect only a few parcels of land within a market have little effect on equilibrium market prices (Palmquist and Danielson, 1989). One inconsistency and potential source of bias is how changes in the supply of heterogeneous farmland alter the distribution of values across each county, giving rise to changes in the summary measure (mean value). A change in the average farmland value per acre could result in part from the composition of land being farmed, which could differ from the change in the value per acre of a given parcel of land, an issue we return to below.

To quantify the impact of flood risk reductions due to the MR&T Project on farmlands, a standard hedonic price model is used:

$$P_{it} = \alpha + \sum_{i=1}^{N} \sum_{t=1}^{T} \beta x_{it} + \theta f_i k(t) + u_i + \varepsilon_{it}, \quad (3)$$

where $P_{it}$ is the average value of farmland in county $i$ (for $i$ = 1–48) in period $t$ (for $t$ =1–22), $x_{it}$ are the characteristics or factors influencing the value of land, $f_i$ is a binary variable indicating the treatment status (for lands in the treatment group, $f = 1$, and 0 otherwise), and $k(t)$ is the treatment variable, which equals 0 before implementation of the MR&T. The variable $k(t)$ is specified with three different versions for the post-treatment period: (i) a binary variable, $k(t) = 1$, for all periods after implementation; (ii) a time trend variable (1–19) for each of 19 observed years post-1930, and (iii) a log-transformation of the second (trend) variable. The log-transformed trend variable is intended to allow for the possibility that the divergence in farmland prices between the treatment group and the control group may increase for a time before attenuating or leveling off. This functional form accommodates that possibility.

By contrast, the linear or untransformed trend variable will impose a fixed rate of divergence in prices between the two groups. In addition, fixed effects are included, with $\mu_i$ representing the potentially correlated unobservable factors for each county. The term $\varepsilon_{it}$ represents the uncorrelated errors.

The regression model estimates the values of the $\beta$ coefficients and $\theta$. Given the inclusion and interaction of the two binary variables—$f = 1$ for counties included in the treatment group and $k(t) = 1$ for a period in which treatment is operative—the term including $\theta$ will be nonzero only in treatment counties and only after the implementation of the MR&T Project. Thus, the DD model isolates the change in the land value attributable to MR&T flood protection as reflected in the value of $\theta$. Treatment effects are included as binary variables or linear trends and for models with both levels and logs.

### *Data*

We focus the study on the reaches of the lower Mississippi River from its confluence with the Ohio and Tennessee Rivers (adjacent to the southeast corner of Missouri) downstream to the confluence with the Arkansas River. This region includes about two-thirds of the lower Mississippi River riparian corridor inundated by the 1927 flood as well as the portions where many, if not most, of the flood protection measures described above were built and where the intended benefits would be expected to occur.

For this region, we identify a sample of counties based on their proximity to and impacts from the Great Flood of 1927. We define a treatment group of counties to include counties where (i) the mainstem of the Mississippi River forms at least 10% of the county's border and (ii) they are "flood prone" in that at least 25% of their area was inundated in 1927. We expect counties meeting these two criteria to benefit from the MR&T Project. For the control group, we select nearby counties that do not satisfy the conditions for inclusion in the treatment group. The counties are indicated in Figure 1, and their characteristics for classification are found in Appendix Table A1.

For the sample of counties, data on farmland values come from the USDA's Census of Agriculture, which is the most comprehensive and complete source of information on agriculture in the country. The census has been undertaken since 1840, with increased frequency since 1920. The census is now conducted every 5 (sometimes 4) years, and collects a wide range of information on farms, farm operations, and characteristics. The census aims to collect complete information from all farmers. Their response rate in recent years has varied from 72% to 78% of all farm operators. These data are self-reported and summarized at the county level; they are published by the USDA National Agricultural Statistics Service (NASS). The census provides data on farmland values, land in farms, farm size, farm income and expenses, and dozens of other production and economic indicators. For current purposes, the most relevant census questions are the current market value of land and buildings used in the farm operation as well as acres farmed, number of farms, and average farm size.

Farmland areas and values used in the analysis are from the 1920–2017 censuses. Market values are estimates of land and buildings per acre, adjusted to real 2019 dollars using the national Consumer Price Index. Land in farms is reported in acres. Total value of land in farms is estimated as the product of farmland values and total acres.

**Table 1. Summary Statistics for Data**

| | Mean | Std. Dev. | Min. | Max. |
|---|---|---|---|---|
| Full sample (*N* = 1,008) | | | | |
| Market value ($) | 1,701 | 1,078 | 201 | 6,088 |
| Total acres | 235,613 | 97,485 | 54,605 | 533,962 |
| Total farmland value ($millions) | 403 | 348 | 34 | 2,655 |
| National average farmland price ($/acre) | 1,414 | 750 | 574 | 3,095 |
| Temperature (°C) | 16 | 1 | 12 | 19 |
| Precipitation (mm) | 1,274 | 241 | 788 | 2,115 |
| Average farm size (acres) | 286 | 302 | 25 | 1,698 |
| Treatment dummy | 0.29 | 0.45 | 0.0 | 1.0 |
| Post-1930 dummy | 0.86 | 0.35 | 0.0 | 1.0 |
| Control group (*N* = 714) | | | | |
| Market value ($) | 1,561 | 1,056 | 201 | 5,583 |
| Total acres | 223,434 | 91,839 | 60,809 | 502,310 |
| Total farmland value ($millions) | 333 | 282 | 34 | 2,655 |
| National average farmland price ($/acre) | 1,414 | 750 | 574 | 3,095 |
| Temperature (°C) | 15.3 | 1.3 | 12.0 | 18.4 |
| Precipitation (mm) | 1,271 | 248 | 788 | 2,115 |
| Average farm size (acres) | 201 | 138 | 29 | 947 |
| Post-1930 dummy | 0.86 | 0.35 | 0.0 | 1.0 |
| Treatment group (*N* = 294) | | | | |
| Market value ($) | 2,042 | 1,055 | 414 | 6,088 |
| Total acres | 265,189 | 104,392 | 54,605 | 533,962 |
| Total farmland value ($millions) | 572 | 425 | 38 | 2,440 |
| National average farmland price ($/acre) | 1,414 | 751 | 574 | 3,095 |
| Temperature (°C) | 16.4 | 1.3 | 13.4 | 19.2 |
| Precipitation (mm) | 1,282 | 224 | 853 | 1,929 |
| Average farm size (acres) | 492 | 455 | 25 | 1,698 |
| Post-1930 dummy | 0.86 | 0.35 | 0.0 | 1.0 |

*Notes:* Dollar values are in 2019 US dollars.

Because the census data on farmland values are self-reported, there may be biases compared to market prices for arms-length farmland transactions. Self-reported estimates of market values may be biased if there is a general tendency among farm operators to over- or understate their farmland values. Previous studies have compared farmland sales prices to survey-based values and found a high correlation. Some studies have observed farmland price appreciation to be understated in surveys (Zakrzewicz, Brorsen, and Briggeman, 2012). Other studies have found that state-level values match well, with some divergence in counties near urban areas (Gertel, 1995). Recent accessibility to large, nationwide land transaction datasets has made it possible to undertake more comprehensive comparisons between farmland transactions data and census values for farmlands, with responses compiled over long time periods. Bigelow and Jodlowski (2021) use a sample of 328,000 transactions and census data from 1,388 counties. Their comparisons of county-level values found no obvious bias introduced by using Census of Agriculture farmland values. However, similar comparisons for census values earlier, during the period of study, are not possible.

The hedonic model includes average farm size, average temperature for the prior 4 years, average precipitation for the prior 4 years, and the national average farmland value per acre. *A priori*, we expect experiences with favorable weather patterns to influence farmland values positively—although excessive heat and rainfall can adversely impact farm profits. Average farm size may

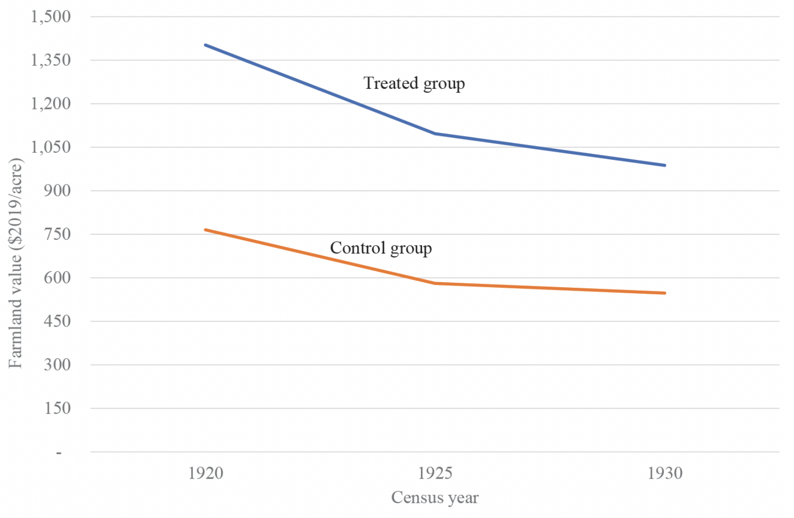


**Figure 2. Evidence of Pretreatment Parallel Trends in Farmland Value per Acre**

control for other geographic or jurisdictional characteristics. The fixed-effects specification controls for other time-invariant factors such as soil class and irrigation potential (most irrigated farmlands in the study area are groundwater irrigated).

Precipitation and temperature data were obtained from the Northwest Alliance for Computational Science & Engineering (2024). The data are based on monthly modeling and have a 4-km horizontal resolution. Total annual precipitation (mm) and average annual temperature (°C) were calculated for each grid cell by summing the monthly precipitation values and averaging the monthly temperature values, respectively. County-level values are the average of all relevant grid cells. The national average farmland value per acre controls for national economic influences on farmland values (e.g., changes in agricultural markets, the US Farm Bill, and trade policies). The specification uses fixed effects panel regression of average farmland values for 48 counties and 22 time periods between 1920 and 2017 (at a 5-year or 4-year time step, depending on the census interval). The DD structure contrasts farmland values for the treatment group versus the control group of counties. Table 1 reports summary statistics for the data.

Implementation of flood control measures began in the 1930s. These measures were implemented progressively over a period of years, and with some individual projects taking several years to complete (e.g., dam building). As a result of this multistage implementation, it is likely that the impacts of the MR&T Project on farmer behavior and farmland values evolved gradually with the implementation of various elements of the project and as farmer expectations changed. The levels and trends in farmland value for these two groups are contrasted before and after implementation of the MR&T Project. In order to make causal interpretations, the DD procedure relies on the "parallel trends" assumption: In the absence of the treatment, the average outcomes for the treated and comparison groups would have evolved in parallel (Angrist and Pischke, 2009). We tested this assumption for the period before the 1935 Census of Agriculture and found the trends in average per acre farmland values for both groups to be indistinguishable statistically and by inspection (see Figure 2).

To the extent that reducing the expected frequency and magnitude of flood events increased expected farm profits, and thus farmland values for existing lands in farms, it follows that these effects may also bring previously uncultivated lands into production. To test the hypothesis that flood risk reduction is also associated with impacts at this extensive margin, a set of models like those described above for farmland prices was estimated using farmland acres as the dependent variable.

Finally, we extend our quasi-experiment to look at evidence of a treatment effect for total value of land in farms (millions of $2019), combining changes in average value per acre with the changes at the extensive margin in total acres of farmland.

## Results

### *Results for per Acre Farmland Values*

Table 2 presents results for models of per acre farmland values for the three specifications of the treatment effect: (i) a binary pre/post treatment variable interacted with the treatment group, (ii) interacting this treatment effect with time (periods since treatment began), and (iii) the natural logarithm of the second treatment. In addition, each of these is estimated using fixed effects, with the inclusion of an additional time trend variable and two-way fixed effects.

All models are statistically significant overall, as are the coefficients on nearly all variables of interest. The first and third treatment effect specifications are significant at the 1% level for the treatment variables and indicate treatment effects of an increase in farmland value per acre of $136–$404. In nearly all specifications, the models suggest statistically significant positive treatment effects: Post-1930 farmland values in the treatment group rise relative to the control group.

The second treatment effect specification, the post-1930 trend for treated counties, is significant at the 10% level, and suggests similar magnitudes by the 2000s as the first treatment specification. The relatively weaker results for the second treatment are not surprising to the extent that the treatment specification forces a linear rate of divergence in value per acre between the control group and the treatment group over an 87-year period, from 1930 to 2017. This functional form is less compatible with the notion that there was a gradual accrual of flood protection benefits to farmland over time.

These results also confirm the inverse relationship between farm size and productivity or value per acre that has been widely documented not just in the United States but around the world (Ritter et al., 2020). The positive relationship with national average farmland price is expected; the fact that the coefficient is greater than 1 is consistent with the fact that the crops grown in this region (corn, soybeans, and wheat) influence national farmland prices.

Temperature and precipitation are most often negatively associated with farmland prices, likely reflecting years when excessive heat and/or precipitation was damaging to crops (e.g., heat damage, waterlogging, flooding, moisture spoilage at harvest). Model versions including nonlinear temperature and precipitation revealed evidence of diminishing returns to both temperature and precipitation, but the evidence was not statistically significant.

### *Results for Farmland Acres*

Results for the same set of models using farmland acres as the dependent variable indicate significant treatment effects across all nine specifications (Table 3). The results are consistent with expectations, suggesting increases in acreages of between 115,000 acres (post-1930 treatment effect) to 164,000 acres (log-transformed post-1930 trend) with the treatment. The strength of these results is uniform over all nine specifications and three models.

The results for farmland acres point to a source of endogeneity and potential bias in terms of the previous analysis of farmland values. The average farmland price by county is determined by the underlying parcel values and the distribution of those values across farms. In these results for farmland acres, we observe that the number of acres of farmland in the treatment group rose by 75% relative to the control group. We expect lands that had previously not been farmed to be at least marginally less productive than those that were being farmed initially. It is therefore reasonable to

**Table 2. Panel Regression Difference-in-Difference Model for Farmland Values: MR&T Flood Protection Effects ($N$ = 1,008)**

| Independent Variable | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| National average farmland price | 1.255*** | 1.218*** | 1.467*** | 1.253*** | 1.217*** | 1.475*** | 1.263*** | 1.220*** | 1.491*** |
| | (0.0458) | (0.0593) | (0.209) | (0.0454) | (0.0595) | (0.214) | (0.0464) | (0.0600) | (0.215) |
| Average farm size | −0.566*** | −0.615*** | −0.617*** | −0.671*** | −0.733*** | −0.707*** | −0.725*** | −0.795*** | −0.774*** |
| | (0.0843) | (0.0941) | (0.0969) | (0.184) | (0.191) | (0.189) | (0.112) | (0.118) | (0.122) |
| Average annual temperature (past 5 years) | −228.2*** | −219.9*** | 255.0** | −235.0*** | −227.7*** | 226.7** | −224.2*** | −214.1*** | 239.0** |
| | (44.33) | (49.30) | (98.47) | (45.38) | (49.72) | (98.15) | (43.24) | (48.01) | (95.37) |
| Average annual precipitation (past 5 years) | −0.212** | −0.230** | 0.276 | −0.198** | −0.213** | 0.298 | −0.210** | −0.231** | 0.306 |
| | (0.0882) | (0.0871) | (0.208) | (0.0828) | (0.0827) | (0.203) | (0.0883) | (0.0879) | (0.207) |
| Flood prone | 738.3*** | 713.3*** | −753.9** | 798.6*** | 782.5*** | −586.6* | 655.2*** | 627.4*** | −731.4** |
| | (165.6) | (176.6) | (311.1) | (155.9) | (165.4) | (300.4) | (171.7) | (182.1) | (298.7) |
| Treated (post-1930) | 202.4*** | 148.7*** | −344.8 | 231.8*** | 183.1*** | −327.9 | 196.8*** | 135.7*** | −370.9 |
| | (37.25) | (48.66) | (422.9) | (27.95) | (49.24) | (429.4) | (37.81) | (47.39) | (434.3) |
| Flood-prone*post-1930 | 135.6* | 154.7** | 191.5** | | | | | | |
| | (78.24) | (76.54) | (74.06) | | | | | | |
| Flood-prone*post-1930*trend | | | | 11.99 | 13.59 | 12.05 | | | |
| | | | | (14.98) | (15.20) | (14.73) | | | |
| Flood prone*ln(trend*post-1930) | | | | | | | 126.6** | 137.1** | 126.8** |
| | | | | | | | (59.86) | (59.95) | (58.55) |
| Year | | 8.516 | | | 8.389 | | | 10.10 | |
| | | (8.095) | | | (8.317) | | | (8.155) | |
| Constant | 3,420*** | 3,332*** | −4,569*** | 3,494*** | 3,418*** | −4,209*** | 3,375*** | 3,264*** | −4,382*** |
| | (669.5) | (722.5) | (1,498) | (697.6) | (741.3) | (1,500) | (658.6) | (709.7) | (1,468) |
| $R^2$ | 0.895 | 0.895 | 0.905 | 0.895 | 0.895 | 0.905 | 0.896 | 0.897 | 0.906 |
| No. of counties | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 |
| Two-way fixed effects: | | | Yes | | | Yes | | | Yes |

*Notes:* Models are fixed-effects panel regressions (two-way fixed effects models are indicated). Standard errors (in parentheses) are clustered at the treatment level. Single, double, and tripe asterisks (*, **, ***) indicate significance at the 10%, 5%, and 1% level, respectively. Difference-in-difference model structures include binary dummy variables for treatment group counties interacted with post-flood control trends (1930); post-1930 (treatment) trends, and natural log of post-1930 trend, equivalent to interacting treatment with time post-treatment. Collinearity diagnostics indicate no serious problems based on either variance inflation factors (VIF) or the collinearity diagnostic procedures found in Belsley, Kuh, and Welsch (2005). In that procedure a high condition number (43) is found, reflecting high variance decomposition portions between temperature and precipitation, as expected.

**Table 3. Panel Regression Difference-in-Difference Model for Total Farmland Acres: MR&T Flood Protection Effects (N = 1,008)**

| Dependent variable: Total acres of farmland<br>**Independent Variable** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** |
|---|---|---|---|---|---|---|---|---|---|
| National average farmland price | −17.55*** | 6.392*** | 22.43 | −29.30*** | 6.234*** | 17.76 | −27.33*** | 6.463*** | 21.63 |
| | (4.349) | (1.607) | (17.33) | (3.563) | (1.600) | (15.61) | (3.444) | (1.601) | (15.72) |
| Temperature | 2,081 | 3,843** | 9,544 | 435.8 | 3,165* | 2,586 | 2,063 | 4,817*** | 6,604 |
| | (1,600) | (1,777) | (8,497) | (1,817) | (1,831) | (8,093) | (1,600) | (1,627) | (7,769) |
| Precipitation | 7.560** | 4.104 | −5.164 | 5.255* | 0.289 | −18.81*** | 6.947** | 2.431 | −11.73 |
| | (3.503) | (3.184) | (10.73) | (2.970) | (2.590) | (6.977) | (2.999) | (2.586) | (7.421) |
| Flood prone | −108,293*** | −113,254*** | −129,539*** | −68,023*** | −89,205*** | −85,928*** | −101,819*** | −121,839*** | −125,859*** |
| | (13,481) | (13,853) | (29,825) | (9,870) | (10,864) | (26,052) | (12,431) | (13,583) | (26,699) |
| Treated (post-1930) | −8,173 | 19,956** | −107,633** | 12,540* | 54,505*** | −105,311** | 1,079 | 39,103*** | −117,846*** |
| | (8,131) | (9,660) | (44,823) | (7,057) | (6,741) | (41,684) | (6,832) | (6,285) | (41,320) |
| Flood-prone*post-1930 | 115,339*** | 115,354*** | 115,512*** | | | | | | |
| | (14,612) | (14,610) | (14,827) | | | | | | |
| Flood-prone*post-1930*trend | | | | 7,031*** | 8,522*** | 8,504*** | | | |
| | | | | (894.1) | (984.8) | (988.9) | | | |
| Flood prone*ln(trend*post-1930) | | | | | | | 49,370*** | 55,894*** | 55,777*** |
| | | | | | | | (6,006) | (6,379) | (6,485) |
| Year | | −4,194*** | | | −6,662*** | | | −6,147*** | |
| | | (838.1) | | | (779.5) | | | (727.8) | |
| Constant | 260,514*** | 226,885*** | 141,809 | 286,842*** | 239,664*** | 260,701** | 267,472*** | 219,511*** | 196,400 |
| | (22,369) | (25,289) | (133,305) | (25,261) | (25,908) | (127,057) | (22,871) | (23,301) | (122,225) |
| $R^2$ | 0.875 | 0.886 | 0.892 | 0.880 | 0.907 | 0.914 | 0.891 | 0.914 | 0.920 |
| No. of counties | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 |
| Two-way fixed effects | | | Yes | | | Yes | | | Yes |

*Notes:* Models are fixed-effects panel regressions (two-way fixed effects models are indicated). Standard errors (in parentheses) are clustered at the treatment level. Single, double, and tripe asterisks (*, **, ***) indicate significance at the 10%, 5%, and 1% level, respectively. Difference-in-difference model structures include binary dummy variables for treatment group counties interacted with post-flood control trends (1930); post-1930 (treatment) trends, and natural log of post-1930 trend, equivalent to interacting treatment with time post-treatment. Collinearity diagnostics indicate no serious problems based on either variance inflation factors (VIF) or the collinearity diagnostic procedures found in Belsley, Kuh, and Welsch (2005).

**Table 4. Panel Regression Difference-in-Difference Model for Total Farmland Value: MR&T Flood Protection Effects ($N$ = 1,008)**

Dependent variable: Total farmland value (average value per acres * total acres of farmland)

| Independent Variable | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| National average farmland price | 0.262*** | 0.306*** | 0.368*** | 0.246*** | 0.306*** | 0.362*** | 0.245*** | 0.306*** | 0.367*** |
| | (0.0230) | (0.0300) | (0.112) | (0.0238) | (0.0300) | (0.109) | (0.0224) | (0.0301) | (0.109) |
| Temperature | −28.23*** | −24.98*** | 45.35 | −30.84*** | −26.26*** | 31.48 | −28.21*** | −23.24*** | 39.09 |
| | (6.134) | (5.663) | (29.98) | (6.464) | (5.747) | (29.54) | (6.158) | (5.535) | (28.82) |
| Precipitation | 0.0149 | 0.00847 | 0.0512 | 0.0103 | 0.00192 | 0.0256 | 0.0140 | 0.00588 | 0.0382 |
| | (0.0109) | (0.0114) | (0.0361) | (0.0109) | (0.0117) | (0.0344) | (0.0110) | (0.0116) | (0.0349) |
| Flood prone | −27.65 | −36.82 | −256.9** | 59.08 | 23.55 | −150.5* | −21.15 | −57.24 | −234.3** |
| | (51.44) | (52.20) | (96.29) | (46.06) | (49.84) | (89.16) | (59.38) | (64.13) | (94.00) |
| Treated (post-1930) | 12.10 | 64.08*** | −304.4 | 50.43*** | 120.8*** | −287.1 | 26.32 | 94.86*** | −315.8 |
| | (17.94) | (16.92) | (220.0) | (13.60) | (25.78) | (212.6) | (16.16) | (18.90) | (216.0) |
| Flood-prone*post-1930 | 190.3*** | 190.3*** | 201.2*** | | | | | | |
| | (58.13) | (58.17) | (57.66) | | | | | | |
| Flood-prone*post-1930*trend | | | | 9.332* | 11.83** | 12.04** | | | |
| | | | | (4.881) | (5.336) | (5.319) | | | |
| Flood prone*ln(trend*post-1930) | | | | | | | 83.60*** | 95.36*** | 90.40*** |
| | | | | | | | (30.64) | (32.74) | (32.33) |
| Year | | −7.749*** | | | −11.18*** | | | −11.08*** | |
| | | (2.278) | | | (3.662) | | | (3.472) | |
| Constant | 424.6*** | 362.5*** | −807.9 | 458.6*** | 379.4*** | −581.4 | 436.6*** | 350.1*** | −697.8 |
| | (96.59) | (88.92) | (503.2) | (102.0) | (91.28) | (495.3) | (98.99) | (88.90) | (485.6) |
| $R^2$ | 0.798 | 0.801 | 0.818 | 0.796 | 0.802 | 0.818 | 0.802 | 0.808 | 0.822 |
| No. of counties | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 |
| Two-way fixed effect | | | Yes | | | Yes | | | Yes |

*Notes:* Models are fixed-effects panel regressions (two-way fixed effects models are indicated). Standard errors (in parentheses) are clustered at the treatment level. Single, double, and tripe asterisks (*, **, ***) indicate significance at the 10%, 5%, and 1% level, respectively. Difference-in-difference model structures include binary dummy variables for treatment group counties interacted with post-flood control trends (1930); post-1930 (treatment) trends, and natural log of post-1930 trend, equivalent to interacting treatment with time post-treatment. Collinearity diagnostics indicate no serious problems based on either variance inflation factors (VIF) or the collinearity diagnostic procedures found in Belsley, Kuh, and Welsch (2005).

conclude that farmland expansion likely lowered the average farmland value for the treated set of parcels relative to the change in value for parcels that were farmed throughout the period. Given this reasoning, this source of endogeneity bias suggests that the treatment effect estimate is conservative.

*Results for Total Farmland Value*

The results for the total value of farmland indicate statistically significant treatment effects of between \$190 million (post-1930 treatment) and \$281 million (log transformed post-1930 trend) (Table 4). R2 levels are between 0.8 and 0.82, which is not surprising given the results for the value per acre and total acres in the previous regressions.

This latter estimation suggests that by 2017, the treated group saw increases in total farmland value of between \$246 million (40%) and \$281 million (45%) more than experienced by the control group. These estimates are per county in the panel of 14 treatment counties. Summing across the 14 treatment counties suggests an increase in total farmland value on the order of \$3.9 billion or—given standard capitalization relationships—roughly equivalent to annual economic farmland rents of an additional \$150 million to \$200 million per year. Given that counties outside and downstream of our sample have likely also benefited from the MR&T Project, the total benefits to agriculture are probably significantly higher.

## Implications and Conclusion

Empirically estimating the benefits of a 90-year program of multifaceted actions and investments spanning hundreds of miles along the Lower Mississippi River would seem an impossible challenge were it not for the availability of census data and the quasi-experimental methods employed here. The results provide evidence that—in addition to the many cities, towns, and other valuable properties benefiting from the \$15 billion flood protections of the MR&T Project—agriculture in the region benefited greatly from these investments. In counties along the Mississippi River that were severely flooded in 1927 (treatment group), farmland values have risen faster than they have in the control group of counties in the same region. Value per acre rose by about \$3,830 in the treatment group of counties, or 12% more than in the control group with the third model specification. The value per acre effect was exceeded by the extensive margin changes: Land in farms in the treatment counties expanded by 75% relative to the control group using the third model specification. The effect of both higher value per acre and expanded farmlands is reflected in the third element of the analysis in which the total value of farmland for counties in the treatment group is estimated to be as much as \$280 million higher than in the control group.

More flooding is expected globally due to climate change, land-use change, population growth, and development. In the United States, climate change is implicated as the underlying cause of changes in precipitation responsible for one-third of the \$7 billion annual flood damages (Davenport, Burke, and Diffenbaugh, 2021). Flood control programs like the MR&T Project can reduce vulnerability from a wide range of harms resulting from flooding. This analysis affirms that large-scale flood protection projects can generate large benefits to society, and it demonstrates that the agricultural sector in the Lower Mississippi Basin has received substantial benefits over a long period from federal projects implemented and maintained since the 1930s.

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## Appendix A

### Table A1. County Characteristics for Categorization

| State | County | Lands Flooded in 1927 | Border Includes Mississippi River? |
|---|---|---|---|
| Arkansas | White | 6.40% | No |
| Missouri | Stoddard | 3.40% | No |
| Mississippi | DeSoto | 3.20% | No |
| Missouri | Ripley | 2.80% | No |
| Missouri | Scott | 2.10% | No |
| Tennessee | Fayette | 0.30% | No |
| Arkansas | Independence | 0.00% | No |
| Illinois | Johnson | 0.00% | No |
| Illinois | Massac | 0.00% | No |
| Illinois | Pope | 0.00% | No |
| Illinois | Pulaski | 0.00% | No |
| Kentucky | Calloway | 0.00% | No |
| Kentucky | Graves | 0.00% | No |
| Kentucky | Livingston | 0.00% | No |
| Kentucky | Marshall | 0.00% | No |
| Kentucky | McCracken | 0.00% | No |
| Mississippi | Carroll | 0.00% | No |
| Mississippi | Grenada | 0.00% | No |
| Mississippi | Panola | 0.00% | No |
| Mississippi | Quitman | 0.00% | No |
| Mississippi | Tallahatchie | 0.00% | No |
| Mississippi | Tate | 0.00% | No |
| Missouri | Bollinger | 0.00% | No |
| Missouri | Cape Girardeau | 0.00% | No |
| Missouri | Wayne | 0.00% | No |
| Tennessee | Carroll | 0.00% | No |
| Tennessee | Crockett | 0.00% | No |
| Tennessee | Gibson | 0.00% | No |
| Tennessee | Hardeman | 0.00% | No |
| Tennessee | Haywood | 0.00% | No |
| Tennessee | Henry | 0.00% | No |
| Tennessee | Madison | 0.00% | No |
| Tennessee | Obion | 0.00% | No |
| Tennessee | Weakley | 0.00% | No |
| Mississippi | Washington | 99.7% | Greater than 10% |
| Mississippi | Issaquena | 99.6% | Greater than 10% |
| Arkansas | Desha | 99.5% | Greater than 10% |
| Arkansas | Chicot | 91.0% | Greater than 10% |
| Arkansas | Phillips | 66.8% | Greater than 10% |
| Missouri | New Madrid | 60.7% | Greater than 10% |
| Arkansas | Crittenden | 57.9% | Greater than 10% |
| Arkansas | Lee | 57.8% | Greater than 10% |
| Arkansas | Mississippi | 54.1% | Greater than 10% |
| Missouri | Pemiscot | 40.7% | Greater than 10% |
| Tennessee | Lauderdale | 35.9% | Greater than 10% |
| Missouri | Mississippi | 35.7% | Greater than 10% |
| Tennessee | Dyer | 31.4% | Greater than 10% |
| Tennessee | Lake | 27.6% | Greater than 10% |