

Temporal Spillovers in Land Conservation

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Abstract:

Temporal spillovers occur when a conservation program changes the use made of a land parcel outside of the window of the conservation contract. This may happen when conservation improves land so that returns to non-conservation uses are increased, or when landowners' preferences become more pro-conservation as they see land flourish under conservation, for example. These post-contract changes may occur on the extensive margin (acres of land conserved) or intensive margin (intensity of land in a given use). If temporal spillovers exist, benefits from conservation programs estimated by focusing solely on the effects that occur during the conservation contract will overstate or understate the true benefits of the program. I lay out a simple model of temporal spillovers. I test this model in the context of the United States Conservation Reserve Program (CRP). I use a pre-analysis sample specification step to choose counterfactual land most like the CRP land. On the extensive margin, I find that CRP causes some land to be 22-27% more likely to be farmed, potentially offsetting some environmental benefits. However, farmed ex-CRP land is slightly more likely to use a conservation practice. This is a mitigating factor on the intensive margin.

Keywords: temporal spillovers, slippage, land use, payments for environmental services, Conservation Reserve Program

JEL Classification: Q15, Q18, Q24, Q58, R14

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Payment for environmental services programs have become popular conservation tools because these incentive-based methods have desirable properties. However, when researchers seek to understand the net benefits these programs yield, they generally focus only on the effects that occur when the land is in a conservation contract. Many conservation contracts lock conservation in for a fixed term renewable upon reapplication, so land may go into and out of such contracts. If conservation changes properties of the land or landowner, then it may change the use the land is put into after the contract ends (as compared to what would have happened had the land not joined the program). We must ask, therefore: do the benefits estimated from acres in conservation overstate or understate benefits from the program because of effects that occur outside of the contract period? I call such temporally-shifted effects “temporal spillovers,” and in this paper I demonstrate the general importance of these effects in a simple model, and I find evidence of their existence in the United States Conservation Reserve Program (CRP).

I use the word spillover not to refer to a simple externality, but rather to refer to effects that occurs outside the window of treatment, either spatially or temporally. Such unintended consequences have a great scope for ways in which they may occur in land conservation, and different vocabularies have been used to refer to them.¹ Spatial “slippage” may occur when land conservation increases land scarcity enough that enrollment causes other acreage to be contemporaneously brought into production because of higher returns, as discussed in the context of the CRP in Wu (2000) and a series of related articles and in the context of a Mexican payment for hydrological services program in Alix-Garcia et al. (2012). Localized crowd-in and crowd-out associated with CRP and other programs is explored in Parker and Thurman (2011).

¹ Even policies whose goals are somewhat distinct from land conservation may have perverse effects on land use: for example, Lueck and Michael (2003) find that the Endangered Species Act seems to cause preemptive early harvest of timber stands if endangered woodpeckers might be expected to move into these stands.

Environmental economics has noted unintended consequences occurring outside the window of treatment in other situations. For example, “leakage” (e.g. Fischer and Fox, 2012) in an emissions reduction policy occurs when parties that are not limited offset the policy’s gains by increasing their emissions, and “rebound” (Borenstein, 2013) occurs when improvements on one dimension (e.g. fuel economy) are offset by losses on another dimension (miles driven).

Temporal spillovers can occur in the context of a temporary conservation contract like those used in some land conservation programs, including REDD+ contracts. In the context of REDD+, Kerr (2013) notes that nonpermanence of conservation contracts can act like a “leakage” through time. If land that enters such contracts simply shifts intensive use to a post-contract period, some environmental benefits may be reduced. The program’s net benefits are further reduced if participation in the program causes an increase later intensive use, as may be the case if conserved land becomes improved in quality. These temporal spillovers matter because if we study a program’s impact by examining outcomes that occur only during a contract period, we may overstate the program’s benefits.

Temporal spillovers are difficult to identify for many of the same reasons that it is difficult to identify the direct effects of payment for environmental services programs: unobservable heterogeneity that drives the entrance into the program and is correlated with outcomes. Further, the conservation program studied must be large and long-lived, and we must be able to observe outcomes after the end of temporary contracts. While the concept of temporal spillovers applies to many programs with temporary conservation contracts, I demonstrate the concept in the context of the Conservation Reserve Program (CRP), the United States’ largest conservation program, in a nationwide land use analysis. Paying careful attention to the specification of counterfactual land, I ask: how did the CRP experience of subsidized

conservation affect the land's later use? In particular, does a land parcel's time in the CRP increase or decrease environmentally friendly land use in the long run, on both the extensive and intensive margins? By comparing ex-CRP land to the most comparable non-CRP land, I find that the CRP causes at least some parcels to be 22-27% more likely to be farmed after exiting the contract, which is an environmentally negative effect on the extensive margin. This is evidence of a temporal spillover that reduces the program's environmental benefits. On the other hand, CRP land is slightly more likely to use conservation farming practices, and this is an environmentally positive correlation on the intensive margin.

Since its creation with the 1985 Food Security Act, the CRP has sought to achieve a variety of conservation, agricultural, and socioeconomic goals. Through the program, each year since 1990 has seen 30-35 million acres of US farmland enrolled in voluntary conservation contracts. Farmers who wish to join the program "bid" by specifying a parcel of agricultural land, proposing an annual rental payment amount they'd like to receive, and choosing a conservation practice to implement. These contracts bind the farmer to abstain from cultivation for 10-15 years and to undertake conservation measures, including planting an approved cover crop. The program provides annual rental payments negotiated for each enrolled parcel and cost-shares to cover up to 50% of the costs of conservation activities. When a contract expires, the landowner may apply for a new contract or may put the land to some other use.

A major goal of the program is to reduce erosion through both the reduced intensity of use that results from a "break" in cultivation and the additionally soil-rebuilding properties of the conservation cover crops used in the program. The program also has broader environmental and habitat-related goals, as reflected in the program's evolving eligibility rules. It is clear that gains are made on land enrolled in the program; erodibility is demonstrably reduced (e.g. Uri,

2001)**Error! Bookmark not defined.** and the benefits of these improvements have been considerable (e.g. Feather et al., 1999). However, this land improvement could have unintended consequences. Better-quality land is more agriculturally productive. (Another goal of the CRP is to improve country's agricultural productivity over the long term.) If returns to farming are increased, the land will be more likely to be farmed. In this way, CRP may not simply shift intensive use to later years but actually increase intensity of later use. CRP participation may thus make land more likely to be cultivated later than it would have been had that land never entered the CRP.

This effect could be reinforced by an interaction between the CRP and other agricultural payments. As discussed in Young et al. (2005), land that is enrolled in CRP and then taken out of the program can be immediately added back into a farm's crop acreage bases, which is often not true for land that was idled otherwise. These base acres are used to calculate benefits such as direct and counter-cyclical payments. Eligibility for payments for these acres is regained in a way that would be impossible if the land was simply left idle. A farmer may wish to temporarily stop farming marginal land, for example, when crop prices are low; to do so may reduce future commodity program payments unless that land is entered into the CRP. These rules regarding CRP and base acreage encourage farmers to convert CRP land (more than other idled marginal land) back into cultivation.

An alternative hypothesis is that "CRP endures:" participation in the CRP causes land to be more likely to be conserved (and less likely to be farmed) later. This could happen if, for example, the period of contractual conservation changes landowners' preferences to give them a greater appreciation for conserved land. This may quasi-rents to conservation for land that participates in CRP, thus rendering it more likely to remain conserved.

In any of these ways, the CRP may cause an increased or decreased likelihood of farming on land that exits the program. Farmers, knowing that CRP-enriched land will yield higher profits, may enroll marginal land with the aim of being paid to improve that land while in the program and continuing or increasing cultivation after completing a contract. This may reduce the net environmental benefits produced by the program and increase the economic surplus reaped by farmers. On the other hand, some previous research that indirectly addresses this issue suggests that CRP experience may cause land to continue to be conserved later. This could happen if farmers' preferences for conservation or stewardship overwhelm their profit motive (e.g. Chouinard et al., 2008; Sheeder and Lynne, 2011; Wallace and Clearfield, 1997) and if experience in conservation strengthens that preference. This would be a positive temporal spillover effect. In addition to the extensive margin effects (amount of land farmed), there could be intensive margin effects: land that has been in CRP may be richer and therefore need less chemical fertilizers, allowing more environmentally friendly farming.²

Temporal spillovers of payments for environmental services programs have not yet received much attention. In the context of the CRP, there have long been efforts to understand what happens to land when it exits the program, but no causal attribution of these results to CRP experience. Early surveys (for example, Cooper and Osborn, 1998; Johnson et al., 1997) of the uses farmers expected to undertake later on land currently in the CRP showed that farmers expected to base their decisions on market prices. General equilibrium analyses use past land use transition patterns to predict future land use transitions. Several such studies have estimated how much CRP land would return into farming if the program did not exist or were eliminated, and estimates range widely: 57% in De La Torre Ugarte et al. (1995), 37% in De La Torre Ugarte

² Doran et al. (1997) find that a parcel of land that was in CRP is well suited to conservation tillage; however, I am aware of no research that shows that farmed ex-CRP land actually uses less intensive methods or fewer inputs.

and Hellwinckel (2006), and 88% in calculations from Lubowski, Plantinga, and Stavins (2008). Roberts and Lubowski (2007) look carefully at selectivity in CRP exit to estimate that 58% of CRP land would enter farming if the program were eliminated, and conclude that a large segment of ex-CRP land persists in conservation. However, none of these results can be compared to a counterfactual in which the land had never entered the CRP, since CRP land is likely to be quite different from non-CRP land. That is, existing results cannot tell us whether the CRP *causes* land to be less likely to be farmed after exiting the program.

The difficulty in identifying temporal spillovers in this case is the difficulty in finding appropriate counterfactual plots of land to which to compare land leaving conservation contracts. The desired counterfactual land is otherwise identical to conserved land but did not enter the program (allowing the program and its general equilibrium effects to still exist). Observable differences between land that enters the program and land that does not can be controlled for in analysis; however, unobservable differences in land quality may be large. If unobservable land quality drives agricultural productivity, it will be strongly correlated with both program enrollment and later intensity of use. Naïve analyses ignoring this will be subject to bias.

I compare ex-CRP land to land that has not been in the program to ask: did CRP participation cause changes in later land use of enrolled parcels (compared to the use they would have entered had they never been in CRP)? That is, does the CRP have temporal spillovers?

This paper contributes to the literature in a number of ways. I introduce the concept of a temporal spillover and demonstrate its potential importance whenever conservation alters land quality or other factors that influence land use. In my analysis, I attribute causality to program participation by using plausible counterfactual (non-program) land parcels. My methodology is

innovative in the use of a sample specification step that trims the treatment (CRP) and control (non-CRP) groups to the most comparable units. I also perform a multinomial logit analysis, which more thoroughly explores the land use decision. Finally, on the intensive margin, I study adoption of conservation practices on land that exits CRP and is later farmed.

I find that a naïve analysis without careful specification of counterfactual land shows that ex-CRP land is farmed at a lower rate than other parcels. However, when compared with the most appropriate counterfactual land, ex-CRP land is 22-27% more likely to be farmed than non-CRP land. Because this land is very much like the ex-CRP group, I can infer that the increase in cultivation is caused by CRP participation. This result is novel in the literature but is not unexpected since the land should have improved while in the program. Thus, the CRP causes effects after program exit that work against the environmental goals of the program (although they may comport with the program's agricultural efficiency goals). I also show that cultivated ex-CRP land is more likely than similar land to adopt a conservation practice such as contour farming. However, I cannot infer whether the increased conservation practice use is caused by CRP participation. Thus, I show that temporal spillovers of conservation programs may have deleterious effects on the extensive margin, but intensive margin outcomes may work in the opposite direction.

This paper proceeds as follows. In the next section, I discuss a model of land use choice. Next, I describe the methods I will use to address the research questions. In the following section, I introduce the data. I give special attention to the sample specification step that will be used in the analysis. I present results in the following section. In the final section I conclude.

Theory

I assume that land use is driven by the value of each use for each land parcel. Each land parcel has inherent characteristics, some static (s_i) and some varying with time (x_{it}). Parcel i 's return (or quasi-rent) at time t to use $a \in A$, where A is the set of all possible land uses, is a function of that parcel's characteristics and local market parameters (p_{it}). I focus on a single one-time land use transition where likelihood of transition is determined by these factors, some of which being influenced by past land use (and thus past transitions).

Some land characteristics that affect quasi-rents are observable. Static elements of this type include parcel location. Dynamic elements of this type include observable land quality elements and local demographics. I assume that market prices are observable, although the quasi-rents for each land use for a given parcel will depend on interactions between these exogenous prices and the parcel's characteristics. However, unobservable parcel characteristics will also inevitably affect land use. Let z_{it} be an unobservable element of land quality of parcel i in time t that is correlated with the returns to farming and that ranges from 0 to 1.

The parcel-specific return from each land use is:

$$\pi_{ait} = \pi(a | s_i, x_{it}, p_{it}, z_{it}) \quad (1)$$

Then observed land use is:

$$a^* = \arg \max_{a \in A} \pi(a | s_i, x_{it}, p_{it}, z_{it}) \quad (2)$$

It would also be possible to use another variable, say σ_{it} , to represent unobservable landowner preferences. Such a variable could affect the quasi-rents to a conservation use. For simplicity I do not include this variable, but I will revisit this idea below.

There are several land uses of particular interest. Cultivated cropland is environmentally intensive but potentially lucrative for high-quality land. I will designate this use as $a = a_f$. Non-cultivated cropland, land use $a = a_n$, which is often used to produce hay, is less intensive and less lucrative. Conservation, $a = a_c$, provides fixed payments and improves the land (makes some elements of x_{it+1} and z_{it+1} increase). I will use CRP as the example of a conservation program, although this logic applies to other similar programs.

Since a parcel will enter into the use with the highest profit, the likelihood that land parcel i is in cultivation at time t is:

$$\Pr(\pi_{fit} \geq \pi_{nit} \cap \pi_{fit} \geq \pi_{cit}) \quad (3)$$

We can then say that some function ϕ determines the likelihood of farming, driven by the land and market characteristics.

$$\Pr(a_{it} = a_f) = \phi(s_i, x_{it}, p_{it}, z_{it}) \quad (4)$$

We assume in particular that $\frac{\partial \phi}{\partial z_{it}} > 0$.

Similar equations would predict the probability that a land parcel enters any other use. Of the three uses of interest, farming will tend to have the highest returns for land that is fairly fertile. Land that is of lower quality will be less profitable as farmland, so landowners would have to decide between non-cultivation and conservation. This outcome may not be entirely driven by the landowners' returns, however: conservation programs like CRP limit enrollment with acreage limits, bid caps, and eligibility criteria. A parcel of land that is observed in non-cultivation may therefore have expected higher profits from conservation but might have failed

to enter the program (e.g. may have applied and been rejected). In practice, in the first decade of the CRP, bid rejections were often caused by requests for rental payments that were too high.³

Recall that z_{it} is unobservable and is correlated with agricultural productivity.⁴ Two land parcels with similar observable elements (s_i, x_{it}, p_{it}) and different land uses should have different levels of z_{it} . That is, from observed land use we can draw inferences about unobservable land quality. Suppose z_{it} varies within a range as demonstrated in Figure 1. Very high quality land ($\bar{z} < z \leq 1$) is very productive farmland and will always be farmed. Very low quality land ($0 \leq z < \underline{z}$) is never productive enough to be farmed. Marginal farmland ($\underline{z} \leq z \leq \bar{z}$) may fall in and out of farming as market conditions vary. Some marginal farmland that leaves farming may enter conservation programs.⁵ Other marginal farmland may simply remain uncultivated. However, it should be the case that land that was marginal enough to enter conservation has a z_{it} value most like land that occasionally exits farming.

High quality land has a higher average value of z than does marginal land, including the land that is conserved. Since this difference is unobservable, land use regressions that ignore this selective conservation will find that conserved (e.g., CRP-enrolled) land is later farmed at a lower rate. This difference, caused by unobservable differences in land quality, will mask any changes in later land use that are caused by conservation participation. Such a regression would be biased in favor of finding conserved land less likely to be cultivated later.

³ Eligibility is now based on an “Environmental Benefits Index” (EBI), and the payment requested is only part of that. However, personal correspondence with USDA staff reveals that those first waves during the program’s ramp-up generally did not have high rejection rates, and that rejections in those years were largely caused by high bids. In these early waves, the EBI did not exist. Eligibility was determined by erodibility index. The program’s bid cap for each county was kept private to reduce strategic behavior (Shoemaker, 1989). If the bidding process were incentive compatible, bids would represent opportunity costs by definition. In this case, if a bid is rejected, then conservation does not provide the highest social return for this land. If, on the other hand, farmers know bid caps the process cannot be incentive compatible, and therefore bids will not represent opportunity costs.

⁴ The logic regarding an unobservable quality variable that determines land disposition is very similar to that in Stavins and Jaffe (1990).

⁵ CRP and similar programs only enroll land that is currently cultivated.

To eliminate this bias, conserved land must be compared to land with z -values in the same range. If conserved land is compared to marginal-quality land that enters temporary non-cultivation, the average value and distribution of z may be similar across the two groups of land and therefore differences in later land use may be attributable to program participation.

How may changes in later land use be caused by conservation program participation? The best land use of a parcel may change over time. Changes in market characteristics, observable land characteristics, and local demographics will drive changes in quasi-rents that could change the optimal land use.⁶ However, unobservable land quality z_{it} could also change over time. Specifically, conservation improves soil quality: CRP participation has been shown to reduce erodibility (e.g., Uri, 2001), and this should increase the return to cultivation. Thus marginal land that enters a program like CRP with a low z_{it} may emerge from the program with a higher z_{it+1} and thus be more likely to be farmed. We could model this in a simple way by saying that z_{it} has some persistent component (i.e., depends in part on z_{it-1}) but also depends on participation in the conservation program in the last periods, C_{it-1} .

$$\Pr(a_{it} = a_f) = \phi(s_i, x_{it}, p_{it}, z_{it}(C_{it-1}, z_{it-1})) \quad (5)$$

Here again, $\frac{\partial \phi}{\partial z_{it}} > 0$. If $\frac{\partial z_{it}}{\partial C_{it-1}} > 0$, past conservation program participation increases

unobservable quality, so it should be the case that $\frac{\partial \phi}{\partial C_{it-1} > 0}$. This is the case of a temporal

spillover: a case when past conservation causes increased probability of farming later.

⁶ Conservation program enrollment can also affect outcomes through local markets: if enough farmland in an area is enrolled, then elements of the local supply chain that depend on economies of scale (like a grain elevator) may cease to be profitable and therefore close, making it harder to start farming on land in this area in the future. This outcome is an effect of program enrollment in one sense, although it occurs at a more aggregate level rather than at parcel-level. In addition, program enrollment can affect later land use decisions if program payments loosen credit constraints. Suggestive evidence for this channel's importance with poorer Mexican *ejidos* is shown in Alix-Garcia et al. (2012). This is less likely in the context of US farmers, for whom credit constraints are less binding.

In this way, conservation programs like CRP may work like a subsidized fallow program. Land also improves while it is simply non-cultivated, but more improvements occur under CRP because the government shares up to half of the costs of planting a conservation cover crop. Also, CRP contracts are 10-15 years long, longer than most standard fallow cycles. Therefore we would expect CRP to improve land more than simple fallow.

A transition from into farming for an ex-CRP parcel as compared to other idle land of identical quality may also lend a greater profit from cultivation because it may yield higher commodity program payments, as discussed above, through an increase in base acreage. Thus even if plots of CRP and non-CRP land have identical s_i , x_{it} , and z_{it} variables and operate in the same markets, CRP land may effectively have larger cultivation-related elements of p_{it} and as a result may have a greater likelihood of converting to farming.

The argument I have made for differences and changes in unobservable land quality z_{it} could also be made for σ_{it} , an unobservable variable representing a taste for stewardship. Landowners with little taste for stewardship may tend to keep farmable land in cultivation, but landowners with moderate taste for stewardship may take breaks from cultivation on sensitive land or may enroll sensitive land in a conservation program. If experiencing conservation in period t causes a landowner to have an increased taste for stewardship then CRP participation could cause decreased later cultivation by causing σ_{it+1} and therefore π_{cit+1} to increase.

These changes in land use may be rendered harder to detect by the presence of transition costs, particularly costs of entering cultivation. To cause a land use change, the difference in profits between the current use and the preferred land use must be large enough to overcome any transition costs. Observed land use transitions will actually understate changes in quasi-rents caused by program participation.

Methods

The question of the CRP's effect on later land use requires a comparison of the land use on a parcel that has been in the program to the use it would have been in had that parcel not been in the program. To identify this effect, I compare end-of-period (1997) use on land that has been in the CRP to land that has not been in the CRP and see which is more likely to enter cultivation (or other land uses). However, any causal effect of the CRP may be masked if unobservable land quality z_{it} drives both land use. I perform a sample selection step to choose the best set of counterfactual land so that causality can be attributed to CRP participation. Conceptually, this is a population-level process much like the observation-level process of matching: the most comparable treatment and control group are selected based on observables to reduce bias.⁷ This sample specification step is a selection process targeting the CRP and non-CRP parcels that are most comparable based on characteristics inferred from their patterns of land use. Specifically, I infer a parcel's z_{it} from the parcel's land use and use that to identify comparable land.

The first issue in sample specification is that the majority of CRP land is locked into a conservation contract at any given time, and there is usually a penalty for early exit. This is, in effect, a large barrier to transition. It is sensible to only examine CRP parcels that have a potential land use decision to make. I consider two such subsamples of CRP land. First, a subsample I call CRP-Eligible includes all land that was in the CRP during the time of interest but is probably eligible to exit. Since contract data are not publicly available, I cannot determine actual eligibility, but I can infer a likely contract end date from the observable signup wave in which the parcel entered the program (assuming a 10-year contract).

⁷ Indeed, Ho et al. (2007) refer to matching as a way of “preprocessing” a data set.

While contracts might be expected to dictate program exit, land is sometimes administratively allowed to leave the CRP before contract expiration. In addition, in the time period of interest the USDA automatically granted one-year extensions to many expiring contracts to ease the administrative burden of the first major round of expirations. Because of these complications, CRP-Eligible is an imperfect group. I specify a separate and arguably preferable sample called CRP-Exit, comprising only land that actually was observed exiting the program. This land verifiably had a post-CRP land use decision to make. Of course, inferences made about this land must be tempered by concerns about selective exit: landowners may choose to take land out of the program for economic reasons. For this reason, whenever I use this sample I note that the results apply to “some” parcels in the CRP, that is, that the estimates are local.

The more nuanced issue in sample specification is unobservable land quality of counterfactual (non-CRP) land. I specify a large subsample called Control-All to include all initially-cultivated land. However, as discussed in the Theory section, this land will include a range of land qualities ($\underline{z} \leq z < 1$). Much of this subsample (land with $\bar{z} < z \leq 1$) is likely to stay in cultivation. This land is a poor counterfactual for CRP land. Analysis using Control-All will be biased toward finding CRP land less likely to be cultivated.

For this reason, I specify another subsample of non-CRP land: Control-Unfarmed. This land is a good counterfactual set for CRP land because, like CRP land, it should be marginal land in the sense of having a moderate level of z ($\underline{z} \leq z \leq \bar{z}$). I can infer this moderate level of z from the uses the land has been put to over the years. Marginal farmland may be taken in and out of farming over time as market conditions vary. Control-Unfarmed includes land that started out being cultivated at the same time that the CRP land was cultivated. The subsample is restricted, however, to land that was not cultivated for some intervening period. Not only should Control-

Unfarmed have a level of z similar to that of CRP land, but this land also faces transition costs to re-enter cultivation just as CRP land would. These transition costs would not be present for land the continued to be cultivation, and this could be another source of bias when CRP land is compared to Control-All.⁸

In the analysis that follows, I compare the tendency to enter into cultivated cropping, to enter into various other uses, and (for farmed land) to use conservation practices between CRP land and non-CRP land using the categories defined above. I do this using OLS, logit, and probit regressions. I argue that the comparison between CRP-Exit and Control-Unfarmed land is the best measure of the effects that CRP has on at least some parcels of land.

The sample specification step and the use of several different models will reduce the potential bias caused by observable and unobservable differences between CRP and non-CRP land. However, some sources of bias may persist.

First, Control-Unfarmed land may be lower quality (lower z) than ex-CRP land because Control-Unfarmed was willing to retire from farming without a subsidy while some CRP land probably would not have retired without being paid. On the other hand, some Control-Unfarmed land may be higher quality (higher z) because it left farming but did not choose to enter CRP. (I cannot identify which land applied to CRP and was rejected and which did not apply.) These farmers may have stayed out of CRP to retain the option of farming. There is no way to know which of these countervailing forces is of greater importance in this data set.

⁸ It is possible that land enrolled in the program is different from unenrolled land on another unobservable dimension: tendency of the program agency to target land for enrollment. Imagine that the agency is able to locally observable (but unobservable to the analyst) data to target marginal land that is more likely to be farmed (and is successful at getting more land enrolled). In this case, land that has been in the program will later be more likely to be farmed—but this will be a cause, not a result, of program participation. This situation is less likely in the early years of the CRP because targeting in general was poor, and because local USDA officials should be more likely to cultivate cooperative (rather than adversarial) relationships with landowners.

Second, some Control-Unfarmed land may be in fallow cycles. The data set I use tries to classify land that is in a fallow cycle as cultivated cropland. Land classified as non-cultivated cropland (which is mostly hay) or pastureland is verified to have not been cultivated cropland for the last three years. However, if land is in a fallow cycle of five years or longer, it may be misclassified as pasture or non-cultivated cropland, in which case I would include it in Control-Unfarmed. Parcels that exit CRP may begin farming immediately because they will have just emerged from a 10-year fallow period (their CRP tenure), but only some non-CRP parcels in long fallow cycles will be ready to farm. This may make Control-Unfarmed appear less likely to be farmed as compared to ex-CRP land. On the other hand, transitions into farming take time. While non-CRP land can move into farming in any year, CRP land can only transition after contracts end. Thus, if land use is observed only every few years then ex-CRP land transitions may be under-recorded relative to non-CRP land transitions, making Control-Unfarmed land seem more likely to be farmed. Again, it is impossible to know which effect might dominate.

Some Control-Unfarmed land may have been taken out of cropping because development is planned on the land, thus making this land look less likely to be farmed. However, some land that exits CRP may be removed from the program because of development plans. Because of idiosyncratic factors that may drive development decisions, all analysis in this paper excludes land parcels that are classified as urban or built-up in 1997, however, reducing the likelihood of these biases.

Because of these factors, Control-Unfarmed land may have unobservable land quality z slightly better or slightly worse than CRP land. Additionally, unobservable factors other than land quality may differ between Control-Unfarmed and CRP land. Specifically, unobserved economic shocks may cause landowners to terminate their CRP contracts. This would imply that

land that exited CRP is more likely to have an economically stressed owner as compared to Control-Unfarmed land. That may make ex-CRP land look more likely to be farmed. If this stress causes landowners to take land out of CRP and put it into development, it would make ex-CRP land look less likely to be farmed. This potential bias is mitigated by the exclusion of land that becomes urban or built-up in 1997.

While potential bias still exists, I argue that the greatest sources of bias are eliminated by the sample specification step, and the net effect of these remaining biases should be small. Control-Unfarmed is still the best possible counterfactual group for CRP land and thus my results will be less biased than results of analysis that fails to account for these issues. In the Results section, I will discuss robustness checks using alternative specifications of the counterfactual group.

Data and Summary Statistics

As I will describe in detail shortly, I use data from a large nationwide land survey to collect land characteristics at the parcel level. I supplement those data with county-level estimates of the returns to various land uses. CRP contract information is sensitive and therefore is not distributed at a level of detail that is useful for parcel-level analysis, so will not enter into this analysis.

First, parcel-level data were obtained from the USDA's National Resource Inventory (NRI; see US Department of Agriculture, 2001). The NRI is a panel survey of over 800,000 land parcel samples throughout the country. It provides data for 1982, 1987, 1992, and 1997.⁹ The NRI is a stratified survey, and the analysis that follows takes into account the NRI's sampling structure. The unit of observation is essentially a sampled parcel, but each sampled parcel has an expansion factor defining the land area this observation represents. These expansion factors

⁹ The NRI has been conducted since 1997, but the USDA does not make these later years' data available.

range from 1 to 495 and average 15.730 acres per point in the NRI overall.¹⁰ Parcel location information is available but limited in precision because the NRI data are designed to render precise sample location identification impossible. It is not possible to obtain information about ownership of the land sampled, e.g., which land samples are owned by the same person. I restrict my analysis to the forty-eight contiguous states. Variables reflecting essential land quality data are not recorded for land that is urban, transportation, federal, or water so I exclude parcels that entered one of these land uses in 1997. This exclusion is particularly acceptable because this land's use may be idiosyncratic.¹¹ Variables reflecting other land quality data (erodibility and slope) are not available for these land uses or for pasture, range, forest, and other rural; since pasture is a relatively important use in this setting, my analysis will exclude those variables.

The timeline of data samples as they relate to important years for the CRP is shown in Figure 2. The focus of this analysis is on land that exited CRP by the 1997 NRI sample, and that includes the first wave of CRP contract expirations. Figure 2 also shows the land use patterns that defines each of the subsamples specified for the analysis.

The NRI land quality data of interest for this analysis are slope (Universal Soil Loss Equation (USLE) slope percent), erodibility index (defined as the maximum of wind and water erodibility values), land capability classification (US Department of Agriculture, 2009), and the prime farmland indicator (*ibid.*). Slope and erodibility are clearly important elements of land quality, with steeper-sloped and more erodible land being less agriculturally productive. Land capability classification is an indicator of a soil's ability to produce crops; I use an indicator variable ("good land classification") for land with land capability classification of four or less. Land is identified as prime if it meets a set of criteria that should be conducive to agricultural

¹⁰ Only 388 of the 266,992 NRI points represent more than 100 acres and only 83 more than 200 acres.

¹¹ Results hold for specifications excluding land classification (the characteristic available for the fewest uses) from the control variable set and including the land from these 1997 uses (available upon request).

productivity, including frequency of flooding, irrigation, water table, and wind erodibility. With regard to land use, I focus primarily on several of the NRI's broad use categories: cultivated cropland, non-cultivated cropland (about 95% of which is hay), pasture, and CRP. Throughout this paper, cultivated cropland will be referred to as "farmed" land, and this is the high-intensity land use of interest in this study. This use includes all close and row crops.

The second source of data is a set of county-level proxies for the returns to various land uses. These data consist of 1996 rent levels and 1986-1996 changes in rent levels for various land use categories. These rent data are described in the appendix of Roberts and Lubowski (2007). These county-level proxies are only available for 1,600 counties, and the analysis considers only counties for which rent data are available.¹² Demographic data (population density, median household income, poverty rate, unemployment rate, percent black, percent white, median age, percent of population under 18, and percent of population over 65) were collected at the county level from the Census and the Bureau of Labor Statistics.

Table 1 shows the characteristics of land in subpopulations of interest: Table 1a shows parcel-level data, and Table 1b shows county level data. The first column shows all land that was cultivated in 1982, and the second column shows all land that was in CRP in 1992. As expected, CRP land is worse than the broader sample of originally-farmed land by all measures (less likely to be prime or have a good land classification, more erodible, and more sloped). CRP land also tends to stay in CRP at a very high rate, and farmed land tends to continue to be farmed at a high rate. Among the specified subsamples, Control-All (the general non-CRP land sample) has higher observable quality measures than all of the other groups, including Control-Unfarmed (the land that left farming but did not enter CRP). Both Control groups are of better quality than both

¹² All NRI counties with CRP parcels have rent data; only non-CRP parcels are thus excluded. Summary statistics including parcels without rent data are similar to those presented here (available upon request).

CRP groups. CRP-Exit is of somewhat better quality by most measures than the CRP-Eligible group (for example, CRP-Exit is more likely to be prime, less erodible, and in an area with greater returns to cropping), which supports the intuition that some land leaves CRP specifically to be farmed.¹³ Control-Unfarmed is very slightly better than CRP-Exit on observable characteristics. Overall, the pattern of observable land quality characteristics across the land subsamples supports the notion that CRP and Control-Unfarmed are roughly similar marginal land while Control-All is of much higher quality.¹⁴

Table 1 also shows that 61.7% of all land that was in the CRP in 1992 was part of an early signup wave, but only 82.1% of all land that exited CRP between 1992-1997 was in an early signup wave (probably because of contract releases that were granted at that time). Most (86.3%) CRP-Eligible land stayed in CRP in 1997, and most Control-All land was farmed in 1992 (92.1%) and 1997 (89.1%). Finally, CRP-Exit land is unconditionally more likely to be farmed than the Control-Unfarmed sample. This result will continue to hold throughout the analyses.

Results

To seek evidence of temporal spillovers, I study the relationship between CRP experience and land use outcome, both as a binary choice (cultivated or not)¹⁵ and as a multinomial choice. Here I can infer causality on the part of the CRP because I have matched parcels with similar observable and perhaps unobservable characteristics (similar z). I then examine conservation

¹³ Roberts and Lubowski (2007) find that land is more likely to exit CRP if it is planted in grass or legumes as cover, and also find that tendency to exit is correlated with rent proxies for several uses and with some interactions between land quality and rent proxies. In the data set I use for this study, CRP-Eligible land that exits the program is better along several dimensions as compared to CRP-Eligible land that stays in the program.

¹⁴ Control-Unfarmed land, as noted before, could be kept out of farming so that urban development can be done on it. This land does appear to be in counties that have higher population densities and have smaller decadal drops in returns to urban/built-up land, as compared to other categories; however, 1996 returns to urban development are lower in Control-Unfarmed than other categories. Again, note that all land that becomes urban/built up in 1997 is excluded from the analysis.

¹⁵ Analysis using propensity score matching provides estimates extremely similar to those presented herein.

practice takeover, further restricting the subsamples to land that is farmed in 1997. There are competing reasons why ex-CRP land may adopt conservation practices at a higher rate, so I cannot infer causality for this result.

Binary Land Use Outcome Results

I begin with a simple binary choice model: the landowner chooses whether to put the land into “farming” (cultivated cropland) or into some other use. He makes his decision based on the quasi-rents for each use. I regress a dummy variable f_{it} representing whether a parcel was farmed in the period of interest on the observable variables:¹⁶

$$f_{it} = \psi(s_i, \mathbf{x}_{it}, \mathbf{p}_{it}) \quad (6)$$

I start with a naïve analysis ignoring selection into CRP on unobservables to show the problems with that approach. This analysis uses all NRI observations for which county-level rent data are available. As shown in Table 2, in three different OLS (linear probability model) specifications,¹⁷ I use mutually exclusive dummies to compare 1997 use of CRP land to 1997 use of other land. Specification 1 uses dummies to indicate 1992 CRP participation and 1992 farming. This specification shows that land that was in the CRP in 1992 is less likely to be farmed in 1997 than land that was farmed in 1992 and even than land that was neither farmed nor CRP in 1992. These results are driven by the fact that much of the land farmed in 1992 was still farmed in 1997, and much of the land in CRP in 1992 was still in CRP in 1997.

Specification 2 in Table 2 replaces the CRP dummy with dummies to indicate early CRP signup and late CRP signup, since early enrollees are more likely to be eligible to exit. Results show the same trend. Specification 3 in Table 2 hints at the need for sample re-specification.

¹⁶ As discussed, slope and erodibility are not available for many land uses of interest, so the only contemporaneous land quality characteristics included in this and other analyses are the prime and good land classification indicators.

¹⁷ Results are very similar for logit and probit specifications as well; results available upon request.

Dummies are included to indicate CRP exit and CRP participation in 1992 without an exit. While CRP-NOEXIT has a negative coefficient, CRP-EXIT has a positive coefficient. This land is more likely to enter farming than the baseline group. The baseline group includes land that was neither farmed nor in CRP in 1992.

For a more nuanced result, I use the specified subsamples described in the Methods section. Results are shown in Table 3. The table shows the coefficient on (or the marginal effect of) the CRP dummy for OLS, logit, and probit regressions.¹⁸ These specifications control for region dummies.^{19, 20}

Each specification (column) in Table 3 represents a combination of a treated (CRP) sample and a control (non-CRP) sample. The results generate consistent estimates within each column, so the results are not driven by functional form. However, as expected, the results change greatly between columns.

Specifications 1 and 2 in Table 3 show results using the CRP-Eligible sample (CRP parcels that were part of early CRP signup waves) as the treatment group. Regardless of the control (non-CRP) group chosen, CRP-Eligible parcels are less likely to be farmed than are counterfactuals. Recall from Table 1 that 86.3% of CRP-Eligible land stayed in CRP. As argued in the Methods section, comparing CRP-Eligible parcels with non-CRP parcels does not address the question of *post*-CRP land use since much of the eligible land stayed in the program.

¹⁸ Results from propensity score matching are quite similar.

¹⁹ OLS coefficients when state or county dummies are used are very similar—generally slightly smaller but still highly significant. For example, the specification 4 coefficient drops from 0.224 with region dummies to 0.203 with state dummies to 0.202 with county dummies. However, because of the great demands these analyses make of the data, logit and probit analyses fail to generate marginal effects when state or county dummies are used, and OLS estimation is unable to generate an F statistic for specification 4 when county dummies are used.

²⁰ Analyses reported here use errors clustered on the NRI “cluster” level, which is a unit finer than the county level. Coefficient estimates remain highly significant ($p < 0.001$) when errors are clustered instead at the county or state level; however, to perform this higher-level clustering, regressions must effectively ignore the stratified structure of the NRI survey.

Specifications 1 and 3 in Table 3 show results using Control-All (non-CRP land that was farmed in 1982) as the control group. In both cases, again, CRP land is less likely to be farmed. This result is again informed by Table 1. Most of Control-All is continuously farmed. When I compare CRP land to this land, I ask whether CRP makes a parcel more likely to be farmed as compared to most of the nation's farmland, including the best land. This is not causal; it is driven by unobservable differences in land quality (z) and transition costs.

Specification 4 in Table 3 is the most revealing. Here, the treatment group is CRP-Exit: land that exited the CRP between 1992 and 1997. It is compared to Control-Unfarmed: land that, though farmed in 1982, was in some other land use in the intervening years. Control-Unfarmed land has been revealed, by its chosen land use, to be like CRP land: marginal in quality ($\underline{z} \leq z \leq \bar{z}$) and facing transition costs to enter farming. Therefore, the Control-Unfarmed land is the best counterfactual for CRP-Exit land for this research question. My analysis shows that CRP-Exit land is *more likely* to be farmed than the non-CRP land. This temporal spillover effect is statistically significant and consistent across functional forms. At 22-27%, it is also economically significant.

To restate this result, the CRP seems to have made this land 22-27% more likely to be farmed than it would have been had it never been in the CRP. This result is expected if the returns to agriculture have increased on this land, which in turn is expected because CRP improves land quality, including unobservable quality z . (Control-Unfarmed land should have also improved while it was not farmed, although most likely not as much, as argued above.²¹)

²¹ Control-Unfarmed land that is unfarmed for a longer period (both 1987 and 1992) should improve more than land that is unfarmed for a shorter period (1992 only), and thus should be more like CRP land; regressions using Control-Unfarmed land as the counterfactual to CRP land could therefore show a smaller effect of CRP on later farming. However, they actually show a larger effect of CRP on farming. One possible reason for this is that Control-Unfarmed land that unfarmed in 1987 and 1992 was worse-quality land, as indicated by the fact that the landowner chose to retire it for a long period without financial incentive.

Again, this is an estimate of a local effect just on the CRP land that exited the program.

Nonetheless, it demonstrates the existence of temporal spillovers.

As discussed in the Methods section, these results may be biased toward zero if Control-Unfarmed land is unobservably better than CRP-Exit land or if there is a delay in transitioning into farming or if owners of CRP-Exit land have had shocks pushing them to develop the land, and the results may be biased upward if Control-Unfarmed land is unobservably worse than CRP-Exit land or is in a long fallow cycle or if CRP-Exit landowners have had shocks pushing them to farm the land. This upward bias is less likely because Control-Unfarmed was shown to be (on average) better in observable qualities than CRP-Exit, and because the NRI tries to accurately record fallow land, but it is still possible.

These results are robust to a number of alternative specifications.

First, I noted above that selective exit CRP land limits the analysis, since I only address selective entrance. Selective exit means that I can only conclude that the CRP causes *some* land to be more likely to be farmed, and the magnitude of this effect may be diminished for CRP land that has not exited. If only the best CRP land exits, then CRP-Exit may contain the upper envelope of CRP land (say, $z_{mid} \leq z \leq \bar{z}$ for a z_{mid} such that $\underline{z} < z_{mid} < \bar{z}$). Control-Unfarmed would then contain a wider range of land quality ($\underline{z} \leq z \leq \bar{z}$). Since observable land quality measures have a relationship with land use and thus perhaps with unobservable land quality z , I restrict the subsamples to only the observably best land for a set of four robustness checks. In two of these robustness checks, I restrict only the non-CRP land subsample to observably best land; in the other two, I thusly restrict both the CRP and non-CRP land subsamples. For both of these restricted subsamples, I define the best land according to the prime farmland indicator in one specification and according to the presence of a good (unrestricted) land classification in the

other. Results are robust to these checks, with coefficients still significant and in nearly all specifications increased in magnitude, as shown in Table 4 alongside the original specification. Also, since Control-Unfarmed may overall be better than CRP-Exit land since the farmers chose not to enroll this land in the CRP, I run a specification in which the Control-Unfarmed group is restricted to only highly erodible land (land with erodibility index 8 or more). These results, also shown in Table 4, are also robust and are again stronger than the original specification. This implies that Control-Unfarmed land as a whole is higher-quality than CRP-Exit land as a whole. Again, if this were true, it would imply that my results understate the effect of CRP participation.

The CRP-Exit / Control-Unfarmed result also persists nearly unchanged (now in the range 21-24%) when Control-Unfarmed parcels are chosen only from counties where CRP enrollment might have been near the countywide enrollment cap (detailed results available on request). In these counties, Control-Unfarmed land is more likely to have made a bid for a CRP contract and been rejected, and thus this land could be better counterfactual land.²²

Finally, the use of Control-Unfarmed land in the intervening years can also tell us about that land's unobservable quality z . When that subsample is restricted to only parcels that were farmed in 1987, which may have a higher z , the CRP land still appears more likely to be farmed although the magnitude is slightly reduced to 17-21% (detailed results available on request).

Multinomial Land Use Outcome Results

Cultivated cropping is the land use of greatest interest. However, it is also interesting to learn how CRP participation affects the entire distribution of final land uses. Table 5 presents multinomial logit analyses of the land use outcome. The specifications (columns) again

²² Another interesting robustness check would be to study counties that had particularly high CRP bid rejections in the early rounds, since this may imply that large amounts of the Control-Unfarmed land was rejected from CRP and thus may be particularly like the CRP land. Personal correspondence with USDA staff reveals that rejections those first waves are unlikely to be random, being largely caused by high bids.

correspond to pairs of treatment and control groups. Land use categories are: cultivated cropland, non-cultivated cropland, pasture, CRP, and other.²³ When CRP-Eligible is compared to either control group (Specifications 1 and 2 in Table 5), the results are mainly driven by the tendency of this CRP land, while probably eligible to exit, to stay in the program. CRP-Eligible land is much more likely to be in CRP in 1997, and less likely to be cultivated, than the control group. Also, when compared to the Control-Unfarmed group, CRP-Eligible land is less likely to become non-cultivated cropland or pasture, which again is because most of CRP-Eligible stayed in the CRP (and much of Control-Unfarmed became or remained non-cultivated cropland or pasture).

In Specifications 3 and 4 of Table 5, in which CRP-Exit land is compared to non-CRP land, the results again depend on the set of control land used. When CRP-Exit is compared to Control-All (Specification 3), the ex-CRP land is less likely to be farmed and has a greater tendency to go into pasture, non-cultivated cropland (hay), and other uses. This is intuitive: most land that exits CRP is planted with grasses and legumes as a conservation cover. The conversion to pasture is trivial while the conversion to hay or other non-cultivated uses may also be inexpensive. When CRP-Exit is compared to Control-Unfarmed in Specification 4, the ex-CRP land is 26% more likely to become cultivated cropland, in the range of the binary model estimates. The CRP-Exit land is less likely than Control-Unfarmed parcels to be non-cultivated cropland or pasture in 1997. This is probably because over 80% of Control-Unfarmed land had already been in non-cultivated cropland (47.54%) or pasture (36.25%) in 1992.

I previously noted that, although transition costs should be held constant, CRP land has less opportunity to transition than Control-Unfarmed land because CRP contracts end in 1996. This could result in a differential under-measurement of transition. The multinomial analysis

²³ “Other” includes rangeland, forest, and “other rural”; these uses make up small but significant elements of CRP-Eligible (2.19%), CRP-Exit (14.63%), Control-All (2.22%), and Control-Unfarmed (17.55%).

supports this possibility. Much of CRP-Exit that does not go into farming ends up as non-cultivated cropland or pasture, but both pasture and non-cultivated cropland tend to convert to cultivated cropland: 44.8% of 1992 non-cultivated cropland and 28.2% of 1992 pasture was farmed in 1997.²⁴ This differential under-measurement would bias CRP's tendency to enter cultivated cropland toward zero, implying that my estimated effect of CRP participation is again understated.

Conservation Practice Results

Conservation practices reduce the environmental impact of farming on any given parcel of land. They generally conserve water or reduce erosion on the land. Variation in conservation practices can be thought of as variation on the intensive margin of farming. The 1997 NRI sample contains data on whether any of 22 different conservation practices was adopted on cultivated cropland, summarized in Table 1 for the populations of interest. Of all acreage cultivated in 1997, 22.77% used a conservation practice. The most popular practices were terraces (6.2% of land), contour farming (5.76%), grassed waterways (4.28%), and surface drainage (4.02%). In some cases, these practices are strongly recommended or required for sensitive (e.g., highly erodible) land. Government programs at various levels promote and subsidize conservation practices.

Is ex-CRP land that becomes cultivated cropland more likely than other land to adopt these conservation practices? Table 1 shows that unconditionally, cultivated ex-CRP land appears more likely to adopt conservation practices than either cultivated Control-All or cultivated Control-Unfarmed land. However, this unconditional result is confounded by differences in land quality and other factors.

²⁴ High rates of conversion to cropping over five-year periods may imply error in NRI's verification of fallow cycles.

The conservation practice analysis can be performed in much the same way that the land use outcome analysis was performed. However, since some low-quality land is required to adopt conservation practices and these requirements are not evident in the data, the sample must first be restricted to include only land that is not highly erodible, with an erodibility index of 8 or less (results without the erodibility index restriction are similar).

Even after this extra restriction on the samples, causality cannot be attributed to the CRP. There is a theoretical reason why CRP participation may cause less intensive farming later (because richer land needs fewer environmentally harmful inputs to farming), but there are competing explanations. It could be that landowners concerned with stewardship (high- σ farmers) are drawn to both CRP and the use of conservation practices if they farm. It could also be that landowners who are more familiar with government programs are more likely to enter CRP and to take up a conservation practice promoted by local farm office officials.

Table 6 shows the coefficient of (or marginal effect for) CRP participation on the adoption of some conservation practice in 1997. The columns again represent different combinations of ex-CRP and control (non-CRP) land, with data restricted to non-highly-erodible land that was cultivated in 1997. In Specification 1, the control group includes the portion of Control-All (all land farmed in 1982) that was farmed in 1997. For this comparison, the CRP land is neither more nor less likely to adopt a conservation practice. (Most of Control-All was farmed in 1992, but data on conservation practices for 1992 are not available.)

For Specification 2 of Table 6, the control group includes the portion of Control-Unfarmed (land farmed in 1982 but not 1992) that was farmed in 1997. In this specification, both CRP and non-CRP parcels faced a transition back into farming. Adopting a new conservation practice requires investment of time and money, so transition costs into farming with

conservation practices are greater than transition costs into farming without conservation practices. CRP parcels are roughly 4% more likely to adopt a conservation practice than this very similar land. This is large relative to the baseline adoption rate of conservation practices of 18.1% for this land.

Conclusion

Policies intended to influence land use have unintended consequences. Temporal spillovers can reduce or increase the net benefits of payments for environmental services programs with finite contract lengths if participation causes later activity on the land to be more environmentally harmful or beneficial, respectively. Estimates of the net benefits of such programs that ignore effects outside the time window of the conservation contract will overestimate or underestimate these net benefits if such spillovers are important. I demonstrate the general potential for this phenomenon to be important, and I find evidence for the existence of substantial temporal spillovers in land conservation in the largest American conservation program, the Conservation Reserve Program. This program may be prone to anti-conservation slippage effects because it uses temporary voluntary contracts to conserve agricultural land. These temporary contracts are particularly vulnerable since land improves while in the program and thus becomes more productive to farm. CRP participation could cause enduring conservation, on the other hand, if landowners who see their land flourish under the program develop a taste for conservation.

On the extensive margin, I find that CRP participation causes at least some land to be 22-27% more likely to be farmed than it would have been had it never been in the program. This result is “local” in the sense that the estimate only applies directly to land that voluntarily exited the program at the time of interest, but it demonstrates the temporal spillover effect as an item of concern in land conservation. This result is congruent with other research findings that the CRP

improves land quality, because that improvement should increase the returns to cropping. The CRP may act as a long, subsidized fallow period for some landowners. However, on the intensive margin, CRP participation is associated with greater use of conservation practices on land that is later farmed. While this offsets some of the environmental harm caused on the extensive margin, I cannot claim that this was caused by CRP participation.

An innovation of my analysis is the use of a sample re-specification step. I use observed land use to infer the range of an unobservable land quality factor I call z , since marginal land is the land most likely to be taken out of cultivation either for conservation or for other uses. This process essentially “matches” samples of conserved and non-conserved land that should have similar values of z . If such a step is not done, different ranges of unobservable land quality z can cause results biased to falsely imply persistent benefits of conservation because low-quality land enters conservation.

What are the broader implications of these results? Temporal spillovers are real and demonstrable. Spatial spillovers (slippage) have already been an element of concern because of their ability to reduce benefits of payment for environmental services programs. We must also be concerned with the temporal effects of these programs. These effects may be more insidious because they are hard to detect. Temporal spillovers may also be fundamentally more damaging because they do not simply shift activity but actually increase intensive use because the characteristics of the land being conserved changes while in the program.

Acknowledging the presence of temporal spillovers may require us to change elements of policy design. Conservation payments may currently be higher than necessary, since land quality improvements provide private benefits to landowners when the later intensive use is undertaken. This might not be the case, of course, if lowered conservation participation bids reflect these

benefits. Additionally, it may be possible to design conservation contracts in ways that would reduce these spillovers. For example, longer contracts might provide more in-contract environmental improvements relative to the out-of-contract reduction in environmental benefits. However, if such changes were made, programs could see reduced program participation or requests for higher payments.

Finally, temporal spillovers may have interact with spatial spillovers. Imagine that as Parcel A enters into a temporary conservation contract, marginal Parcel B is pushed by spatial slippage to enter intensive use. When Parcel A then exits the contract, this increases the supply of land available for intensive uses and pushes down prices. That may push some land that had previously been in intensive use into nonuse. Parcel B may then “reverse slip” out of its intensive use. Of course, if Parcel A was actually improved while in the program, these effects should not net out since Parcel A will be more productive than it was before it enrolled.

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Figures and Tables

Figure 1. Unobservable land quality

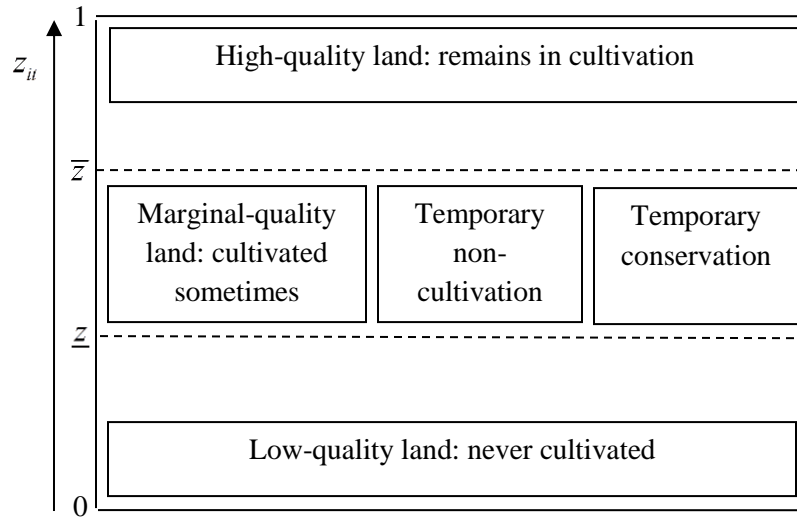


Figure 2: NRI and CRP timeline with land uses of specified subsamples

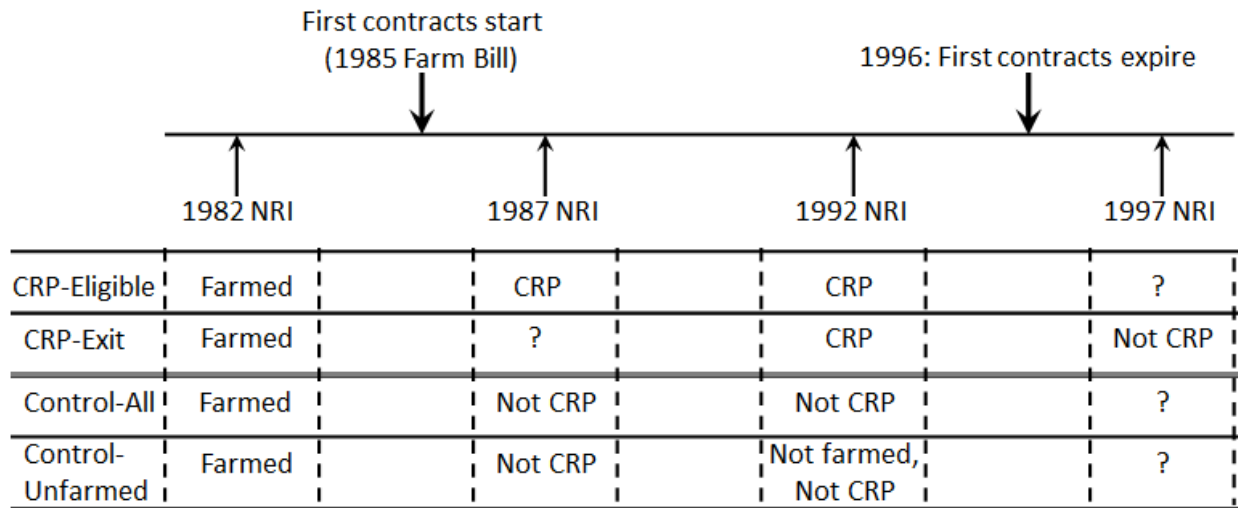


Table 1a. Characteristics of Land in Subpopulations of Interest, Parcel-Level Variables

| | Farmed in 1982 | CRP in 1992 | CRP-Exit | CRP- Eligible | Control- All | Control- Unfarmed |
|---|-------------------|-------------------|-------------------|-------------------|-------------------|----------------------|
| Prime farmland? ^{a, b} | 0.566 (0.002) | 0.286 (0.002) | 0.345 (0.009) | 0.262 (0.004) | 0.576 (0.002) | 0.438 (0.006) |
| Good land class? ^{a, b} | 0.952 (0.001) | 0.875 (0.002) | 0.888 (0.005) | 0.873 (0.002) | 0.960 (0.001) | 0.895 (0.004) |
| Erodibility index ^{a, b} | 7.330 (0.026) | 12.990 (0.971) | 12.209 (0.221) | 13.759 (0.108) | 7.176 (0.030) | 10.579 (0.221) |
| Slope ^{a, b} | 2.759 (0.009) | 4.260 (0.018) | 4.841 (0.010) | 4.270 (0.025) | 2.783 (0.011) | 4.166 (0.046) |
| Early CRP signup wave (percent) | - | 0.617 (0.002) | 0.821 (0.005) | 1 (0) | - | - |
| CRP cover of grass in 1992 (percent) | - | 0.906 (0.001) | 0.920 (0.004) | 0.927 (0.001) | - | - |
| CRP in 1992 (percent) | 0.082 (0.000) | 1 (0) | 1 (0) | 1 (0) | - | - |
| CRP in 1997 (percent) | 0.078 (0.000) | 0.895 (0.001) | - | 0.863 (0.002) | 0.007 (0.000) | 0.005 (0.000) |
| Farmed in 1992 (percent) | 0.821 (0.001) | - | - | - | 0.921 (0.001) | - |
| Farmed in 1997 (percent) | 0.790 (0.001) | 0.053 (0.001) | 0.528 (0.007) | 0.068 (0.002) | 0.891 (0.001) | 0.271 (0.005) |
| Conservation practice if farmed in 1997 (percent) | 0.233 (0.001) | 0.251 (0.013) | 0.258 (0.014) | 0.271 (0.016) | 0.232 (0.002) | 0.181 (0.009) |
| Corn in 1982 (percent) | 24.386 (0.108) | 11.019 (0.088) | 24.585 (0.847) | 11.953 (0.123) | 25.442 (0.134) | 22.156 (0.451) |
| Soy in 1982 (percent) | 17.842 (0.096) | 11.557 (0.141) | 18.245 (0.671) | 11.735 (0.197) | 17.796 (0.115) | 16.765 (0.365) |
| Wheat in 1982 (percent) | 23.726 (0.130) | 31.519 (0.117) | 24.277 (0.676) | 34.765 (0.240) | 24.930 (0.167) | 17.407 (0.472) |
| Summer fallow in 1982 (percent) | 7.475 (0.097) | 14.867 (0.113) | 10.058 (0.369) | 16.684 (0.192) | 8.106 (0.129) | 4.175 (0.344) |
| Observations | 232,953 | 19,782 | 2,400 | 10,669 | 154,512 | 14,972 |
| Average acres per sample point | 16.678 (0.028) | 17.208 (0.087) | 13.090 (0.169) | 17.641 (0.120) | 17.472 (0.030) | 14.115 (0.099) |
| Hundreds of acres | 3,754,446 | 340,400 | 31,417 | 188,208 | 2,699,633 | 211,329 |

Standard errors in parentheses

^a 1997 land characteristic data: prime farmland dummy, good land classification dummy for land capability classification of four or less, erodibility index (maximum of wind and water erodibility values), slope (Universal Soil Loss Equation (USLE) slope percent)

^b Land characteristic data only available for certain land uses, so these are means over available data: erodibility not available for pasture; erodibility and slope not available for pasture, range, forest, other rural; erodibility, slope, prime, and land classification not available for urban, water, and federal land. For the rightmost four columns, this Table's summaries in these columns include only observations with non-missing 1997 land classification.

Table 1b. Characteristics of Land in Subpopulations of Interest, County-Level Variables

| | Farmed in 1982 | CRP in 1992 | CRP-Exit | CRP- Eligible | Control- All | Control- Unfarmed |
|---|-------------------------|------------------------|-------------------------|-------------------------|-------------------------|-------------------------|
| 1996 return: crops ^a | 93.365 (0.150) | 80.739 (0.097) | 96.169 (0.754) | 81.074 (0.275) | 94.863 (0.168) | 98.626 (0.820) |
| 1996 return: gov't payments ^a | 10.967 (0.014) | 8.856 (0.010) | 9.364 (0.063) | 8.870 (0.275) | 11.192 (0.016) | 9.023 (0.061) |
| 1996 return: pasture ^a | 29.050 (0.064) | 27.052 (0.024) | 30.967 (0.181) | 28.109 (0.104) | 29.267 (0.072) | 31.005 (0.308) |
| 1996 return: range ^a | 10.912 (0.032) | 11.228 (0.027) | 8.937 (0.201) | 11.179 (0.064) | 10.872 (0.036) | 10.553 (0.145) |
| 1996 return: forest ^a | 11.725 (0.044) | 12.189 (0.011) | 21.662 (0.140) | 12.807 (0.065) | 11.659 (0.049) | 14.453 (0.181) |
| 1996 return: urban ^a | 2331.954 (4.968) | 2426.994 (3.711) | 2450.342 (31.431) | 2566.866 (8.409) | 2318.095 (5.517) | 2260.462 (21.918) |
| 1986-1996 Δ return: crops ^a | 81.118 (0.176) | 70.586 (0.117) | 87.583 (0.849) | 71.513 (0.301) | 82.412 (0.197) | 90.371 (1.148) |
| 1986-1996 Δ return: gov't payments ^a | -19.904 (0.027) | -17.631 (0.015) | -21.141 (0.200) | -17.663 (0.049) | -20.171 (0.030) | -17.096 (0.114) |
| 1986-1996 Δ return: pasture ^a | 33.058 (0.084) | 31.653 (0.032) | 36.209 (0.297) | 33.134 (0.136) | 33.207 (0.093) | 37.758 (0.439) |
| 1986-1996 Δ return: range ^a | 0.134 (0.009) | -0.099 (0.004) | 0.056 (0.063) | -0.134 (0.015) | 0.164 (0.010) | -0.194 (0.037) |
| 1986-1996 Δ return: forest ^a | 6.349 (0.032) | 6.694 (0.007) | 7.238 (0.114) | 7.004 (0.049) | 6.307 (0.036) | 8.188 (0.130) |
| 1986-1996 Δ return: urban ^a | -72.815 (1.278) | -171.948 (0.598) | -80.735 (6.363) | -197.736 (2.315) | -60.358 (1.435) | -15.242 (6.343) |
| Population density (1996) | 76.066 (0.421) | 29.152 (0.218) | 40.340 (1.536) | 25.930 (0.353) | 52.931 (0.263) | 64.681 (1.033) |
| 1986-1996 Δ population density | | | | | | |
| Percent of pop. in urban areas (2000) | 0.405 (0.001) | 0.318 (0.001) | 0.346 (0.005) | 0.321 (0.001) | 0.381 (0.001) | 0.355 (0.003) |
| Median household income (1997) | \$32,781.38 (16.403) | \$30,843.39 (9.589) | \$32,009.19 (87.655) | \$30,919.78 (24.523) | \$32,564.94 (19.520) | \$31,898.04 (96.725) |
| Poverty rate (1997) | 14.255 (0.017) | 15.297 (0.010) | 13.886 (0.073) | 15.297 (0.023) | 13.932 (0.021) | 14.806 (0.078) |
| Unemployment rate (1996) | 5.213 (0.010) | 5.055 (0.005) | 5.212 (0.046) | 5.023 (0.015) | 4.956 (0.010) | 5.537 (0.034) |
| Percent black (1996) | 0.063 (0.000) | 0.046 (0.000) | 0.043 (0.002) | 0.041 (0.000) | 0.051 (0.000) | 0.086 (0.002) |
| Percent white (1996) | 0.911 (0.000) | 0.923 (0.000) | 0.936 (0.002) | 0.932 (0.001) | 0.923 (0.000) | 0.889 (0.002) |
| Median age (1996) | 35.837 (0.011) | 36.322 (0.006) | 36.139 (0.059) | 36.287 (0.016) | 36.051 (0.013) | 35.520 (0.048) |
| Percent under 18 (1996) | 0.272 (0.000) | 0.275 (0.000) | 0.272 (0.000) | 0.277 (0.000) | 0.271 (0.000) | 0.271 (0.000) |
| Percent over 65 (1996) | 0.156 (0.000) | 0.164 (0.000) | 0.160 (0.001) | 0.163 (0.000) | 0.161 (0.000) | 0.151 (0.001) |
| Observations | 232,953 | 19,782 | 2,400 | 10,669 | 154,512 | 14,972 |
| Average acres per | 16.678 | 17.208 | 13.090 | 17.641 | 17.472 | 14.115 |

| | | | | | | |
|-------------------|-----------|---------|---------|---------|-----------|---------|
| sample point | (0.028) | (0.087) | (0.169) | (0.120) | (0.030) | (0.099) |
| Hundreds of acres | 3,754,446 | 340,400 | 31,417 | 188,208 | 2,699,633 | 211,329 |

Standard errors in parentheses

^a 1996 land use returns and 1986-1996 changes in returns, in 2001 dollars (PPI adjusted)

Table 2. Land Use Results with Naïve (Un-Pre-Processed) Sample

| | Specification 1 | Specification 2 | Specification 3 |
|------------------------------|----------------------|----------------------|----------------------|
| CRP dummy | -0.235*** (0.005) | | |
| Early CRP dummy | | -0.218*** (0.006) | |
| Late CRP dummy | | -0.262*** (0.005) | |
| CRPEXIT dummy | | | 0.238*** (0.008) |
| CRPNOEXIT dummy | | | -0.291*** (0.005) |
| FARM92 dummy | 0.624*** (0.005) | 0.624*** (0.005) | 0.624*** (0.005) |
| <i>n</i> (observations) | 172,048 | 172,048 | 172,048 |
| <i>N</i> (hundreds of acres) | 3,006,841 | 3,006,841 | 3,006,841 |
| <i>F</i> | 13,427.19 | 17,283.74 | 40,884.14 |
| <i>R</i> ² | 0.617 | 0.617 | 0.634 |

* significant at 10%, ** significant at 5%; *** significant at 1%

Standard errors in parentheses. Regressions are OLS. All included land was cultivated in 1982, is in a county for which rent data is available, and does not enter 1997 land uses: urban/built-up, water, or federal. Specifications control for 1997 land characteristics (prime farmland indicator, good land class indicator), 1996 land use rents and changes, 1996 demographics (population density, median household income, poverty rate, unemployment rate, percent black, percent white, median age, percent under 18, percent over 65), region code dummies, and land characteristic x rent interactions. Survey regressions performed with data points appropriately weighted and errors clustered at the NRI “cluster” level.

Table 3. Land Use Results with Pre-Processed Samples

| Specification: | 1 | 2 | 3 | 4 |
|---|--------------------------------|---|---------------------------|---|
| What CRP land included? | Early signup (CRP-Eligible) | Early signup (CRP-Eligible) | Exit 1992-7 (CRP-Exit) | Exit 1992-7 (CRP-Exit) |
| What non-CRP (previously farmed) land included? | All land (Control-All) | Not farmed 1992 (Control- Unfarmed) | All land (Control-All) | Not farmed 1992 (Control- Unfarmed) |
| OLS | -0.769*** (0.003) | -0.191*** (0.006) | -0.307*** (0.006) | 0.224*** (0.009) |
| Logit (marginal effect) | -0.836*** (0.003) | -0.224*** (0.007) | -0.276*** (0.007) | 0.268*** (0.012) |
| Probit (marginal effect) | -0.823*** (0.002) | -0.229*** (0.007) | -0.292*** (0.007) | 0.259*** (0.011) |
| <i>n</i> (observations) | 165,188 | 25,652 | 156,919 | 17,383 |
| <i>N</i> (hundreds of acres) | 2,887,997 | 399,719 | 2,731,206 | 242,928 |

* significant at 10%, ** significant at 5%; *** significant at 1%

All included land was cultivated in 1982, is in a county for which rent data is available, and does not enter 1997 land uses: urban/built-up, water, or federal. Specifications control for 1982 land quality characteristics (erodibility index, slope), 1997 land characteristics (prime farmland indicator, good land classification indicator), 1996 land use rents and changes, 1996 demographics (population density, median household income, poverty rate, unemployment rate, percent black, percent white, median age, percent under 18, percent over 65), region code dummies, and land characteristic x rent interactions. Survey regressions performed with data points weighted (using pweight) by the NRI variable xfact and errors clustered at the NRI “cluster” (which is sub-county) level. Parcels that are the single observation for a NRI sampling stratum are excluded.

Table 4. Land Use Robustness Checks for CRP-EXIT comparison to Control-Unfarmed

| Specification: | 4 | 4-both-G | 4-both-P | 4-Ctrl-G | 4-Ctrl-P | 4-Ctrl-HEL |
|---|------------------------------------|--|--|--|--|--|
| What CRP land included? | Exit 1992-7 (CRP-Exit) | Exit 1992-7 (CRP-Exit) – good land class | Early signup (CRP-Eligible) – prime | Exit 1992-7 (CRP-Exit) | Early signup (CRP-Eligible) | Exit 1992-7 (CRP-Exit) |
| What non-CRP (previously farmed) land included? | Not farmed 1992 (Control-Unfarmed) | Not farmed 1992 (Control-Unfarmed) – good land class | Not farmed 1992 (Control-Unfarmed) – prime | Not farmed 1992 (Control-Unfarmed) – good land class | Not farmed 1992 (Control-Unfarmed) – prime | Not farmed 1992 (Control-Unfarmed) – highly erodible |
| OLS | 0.224*** (0.009) | 0.235*** (0.010) | 0.264*** (0.016) | 0.217*** (0.010) | 0.179*** (0.013) | 0.327*** (0.010) |
| Logit (marginal effect) | 0.268*** (0.012) | 0.278*** (0.013) | 0.328*** (0.019) | 0.258*** (0.012) | 0.220*** (0.016) | 0.370*** (0.013) |
| Probit (marginal effect) | 0.259*** (0.011) | 0.269*** (0.012) | 0.313*** (0.018) | 0.250*** (0.011) | 0.212*** (0.015) | 0.367*** (0.012) |
| <i>n</i> (data points) | 17,383 | 15,625 | 7,796 | 15,862 | 9,326 | 13,300 |
| <i>N</i> (hundreds of acres) | 242,928 | 217,165 | 103,535 | 220,690 | 124,105 | 175,138 |

* significant at 10%, ** significant at 5%; *** significant at 1%

All included land was cultivated in 1982, is in a county for which rent data is available, and does not enter 1997 land uses: urban/built-up, water, or federal. Specifications control for 1982 land quality characteristics (erodibility index, slope), 1997 land characteristics (prime farmland indicator, good land classification indicator), 1996 land use rents and changes, 1996 demographics (population density, median household income, poverty rate, unemployment rate, percent black, percent white, median age, percent under 18, percent over 65), region code dummies, and land characteristic x rent interactions. Survey regressions performed with data points weighted (using pweight) by the NRI variable xfact and errors clustered at the NRI “cluster” (which is sub-county) level. Parcels that are the single observation for a NRI sampling stratum are excluded.

Table 5. Land Use Multinomial Logit Results

| Specification: | 1 | 2 | 3 | 4 |
|---|--------------------------------|---|--|--|
| What CRP land included? | Early signup (CRP-Eligible) | Early signup (CRP-Eligible) | Exit 1992-7 (CRP-Exit) | Exit 1992-7 (CRP-Exit) |
| What non-CRP (previously farmed) land included? | All land (Control-All) | Not farmed 1992 (Control- Unfarmed) | All land (Control-All) ^a | Not farmed 1992 (Control- Unfarmed) ^a |
| Cultivated cropland | -0.829*** (0.003) | -0.254*** (0.008) | -0.263*** (0.008) | 0.262*** (0.012) |
| Non-cultivated cropland | -0.019*** (0.001) | -0.247*** (0.007) | 0.054*** (0.004) | -0.153*** (0.008) |
| Pasture | 0.002 (0.001) | -0.243*** (0.007) | 0.121*** (0.005) | -0.092*** (0.009) |
| CRP | 0.842*** (0.003) | 0.848*** (0.003) | N/A | N/A |
| Other | 0.004*** (0.001) | -0.104*** (0.004) | 0.089*** (0.004) | -0.017*** (0.006) |
| <i>n</i> (observations) | 165,188 | 25,652 | 155,888 | 17,308 |
| <i>N</i> (hundreds of acres) | 2,887,997 | 399,719 | 2,712,792 | 241,650 |
| <i>F</i> | 3,766.86 | 1573.45 | 161.98 | 39.21 |

* significant at 10%, ** significant at 5%; *** significant at 1%

Cells show marginal effects of 1992 CRP status dummy on each land use. All included land was cultivated in 1982, is in a county for which rent data is available, and does not enter 1997 land uses: urban/built-up, water, or federal. Specifications control for 1982 land quality characteristics (erodibility index, slope), 1997 land characteristics (prime farmland indicator, good land classification indicator), 1996 land use rents and changes, 1996 demographics (population density, median household income, poverty rate, unemployment rate, percent black, percent white, median age, percent under 18, percent over 65), and region code dummies. Survey regressions performed with data points weighted (using pweight) by the NRI variable xfact and errors clustered at the NRI “cluster” (which is sub-county) level. Parcels that are the single observation for a NRI sampling stratum are excluded.

^a For these regressions only, both Control groups exclude land that becomes CRP in 1997 (0.67% of Control-All and 0.53% of Control-Unfarmed).

Table 6. Conservation Practice Results

| | Specification 1 | Specification 2 |
|--|---|--|
| What CRP land included? | Exit 1992-7 (CRP-Exit) – non-highly-erodible | Exit 1992-7 (CRP-Exit) – non-highly-erodible |
| What non-CRP (previously farmed) land included? | All land (Control-All) – non-highly-erodible | Not farmed 1992 (Control-Unfarmed) – non-highly-erodible |
| OLS | 0.014 (0.019) | 0.044** (0.022) |
| Logit | 0.020 (0.024) | 0.040* (0.021) |
| Probit | 0.020 (0.024) | 0.041* (0.022) |
| <i>n</i> (observations) | 101,572 | 2,386 |
| <i>N</i> (hundreds of acres) | 1,778,572 | 37,181 |

* significant at 10%, ** significant at 5%; *** significant at 1%

Only non-highly-erodible land included

Land was in the categories described in the text but only non-highly erodible (erodibility index of 8 or lower). All included land was cultivated in 1982, is in a county for which rent data is available, and does not enter 1997 land uses: urban/built-up, water, or federal. Specifications control for 1997 land characteristics (prime farmland indicator, good land classification indicator, slope, and erodibility index), 1996 land use rents and changes, 1996 demographics (population density, median household income, poverty rate, unemployment rate, percent black, percent white, median age, percent under 18, percent over 65), region code dummies, and land characteristic x rent interactions. Survey regressions performed with data points weighted (using *pweight*) by the NRI variable *xfact* and errors clustered at the NRI “cluster” (which is sub-county) level. Parcels that are the single observation for a NRI sampling stratum are excluded.

Appendix: Spatial Distribution of Parcels in Groups of Interest

The maps below show the distribution of parcels in the groups of interest, with intensity of shading determined by number of acres in the given regional unit.

The first set of maps shows acreage aggregated to the state level.

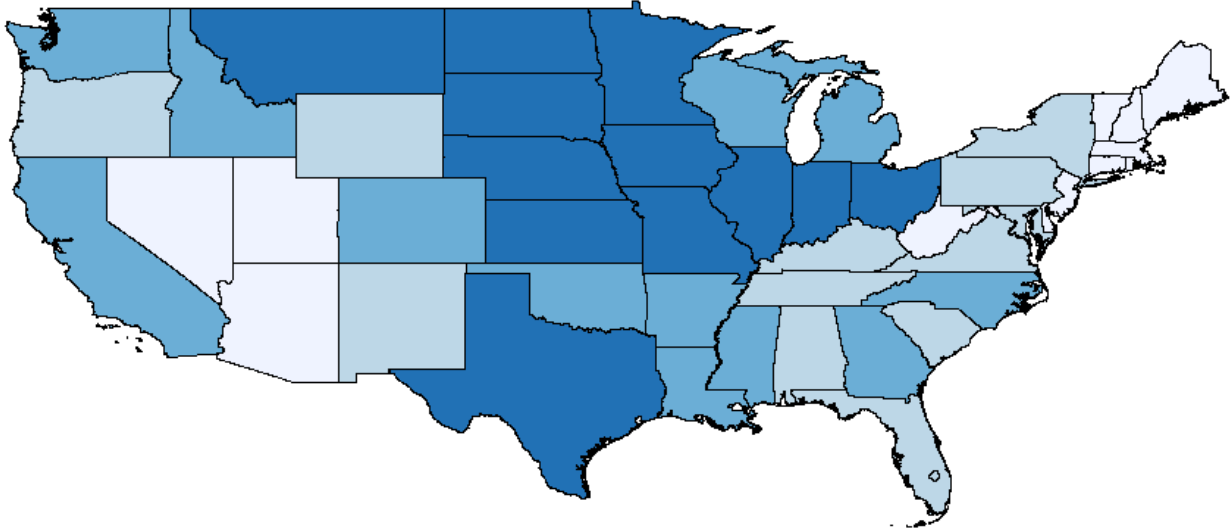


Figure A-1: Spatial Distribution of Land that was Farmed in 1982, at the State Level

State CRP 1992

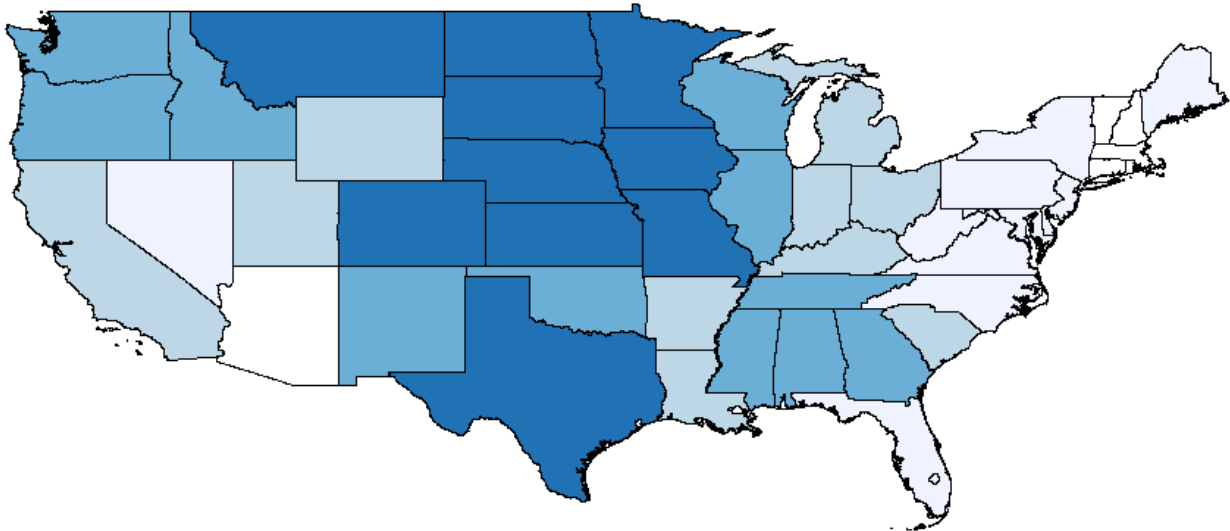


Figure A-2: Spatial Distribution of Land that was in CRP in 1992, at the State Level

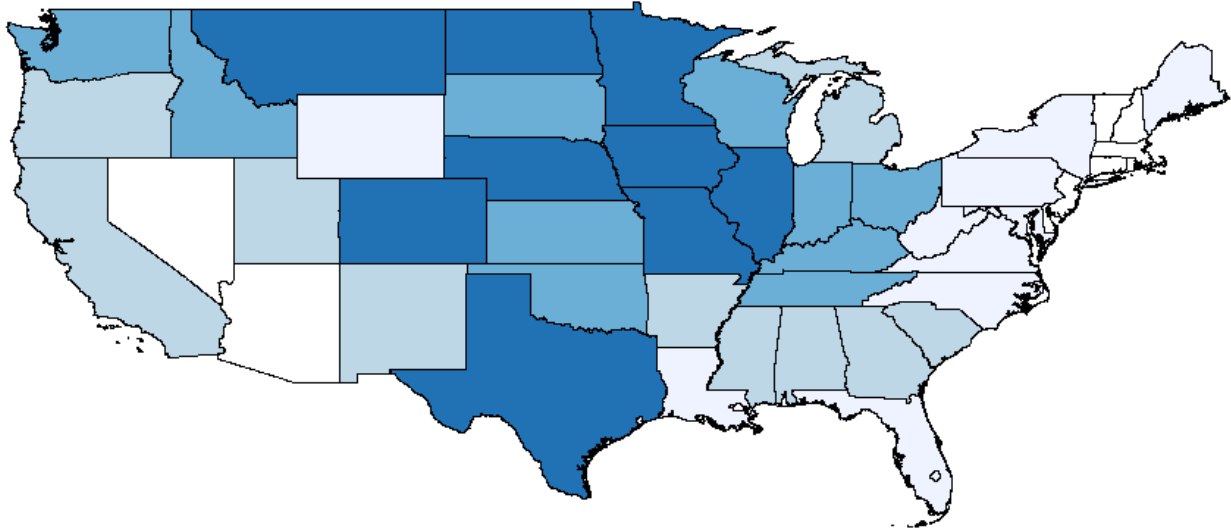


Figure A-3: Spatial Distribution of Land in CRP-Exit, at the State Level

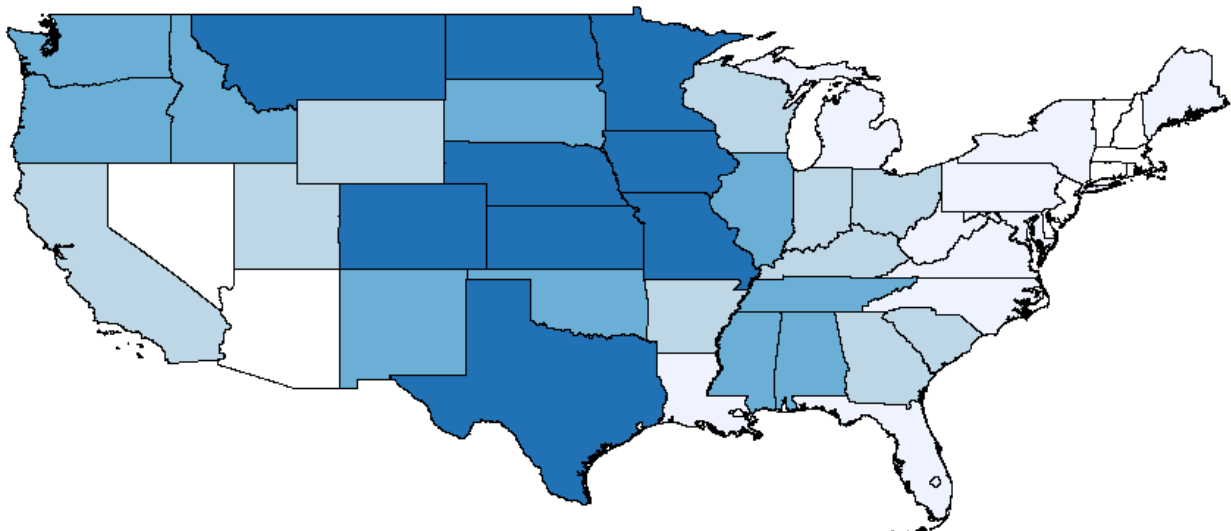


Figure A-4: Spatial Distribution of Land in CRP-Eligible, at the State Level

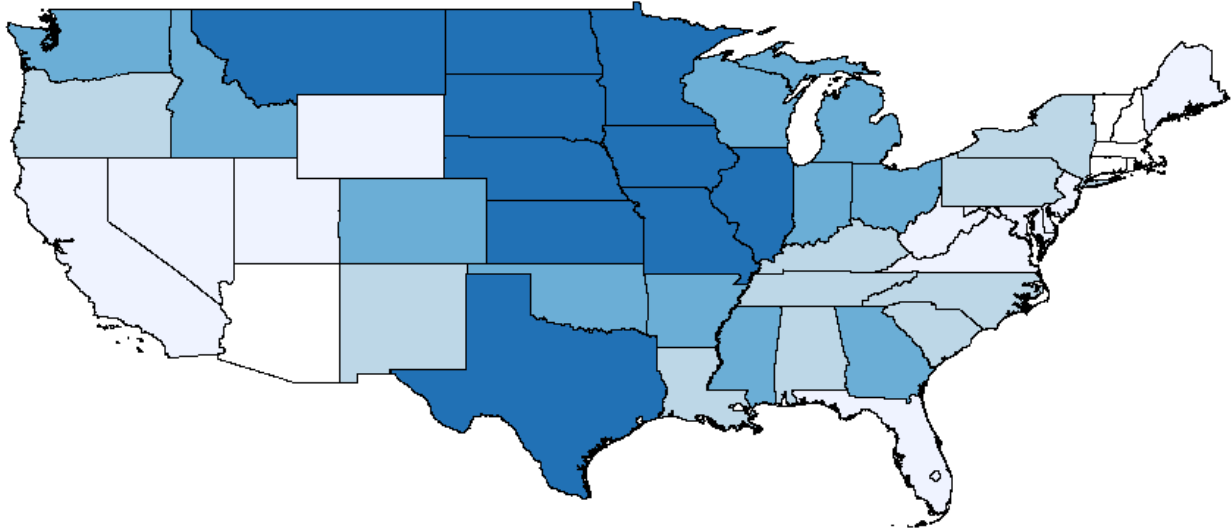


Figure A-5: Spatial Distribution of Land in Control-All, at the State Level

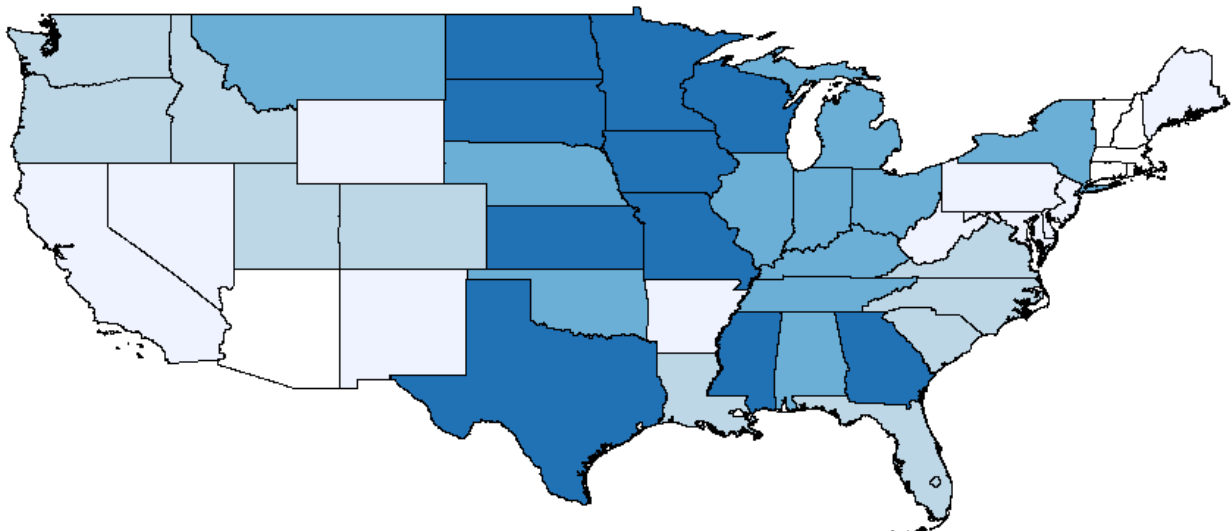


Figure A-6: Spatial Distribution of Land in Control-Unfarmed, at the State Level

The next set of maps shows acreage aggregated to the county level.

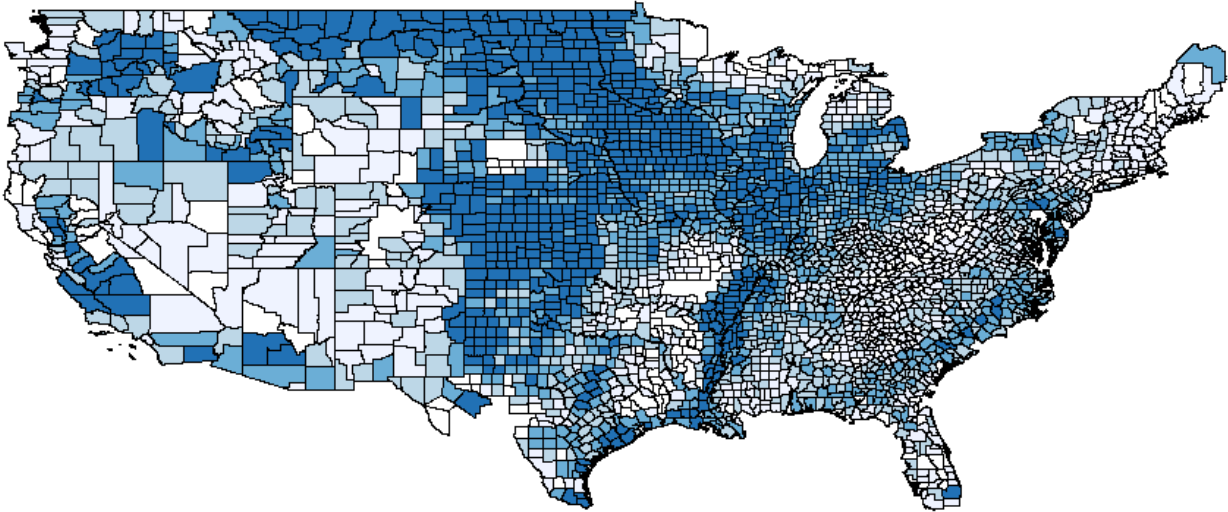


Figure A-7: Spatial Distribution of Land that was Farmed in 1982, at the County Level

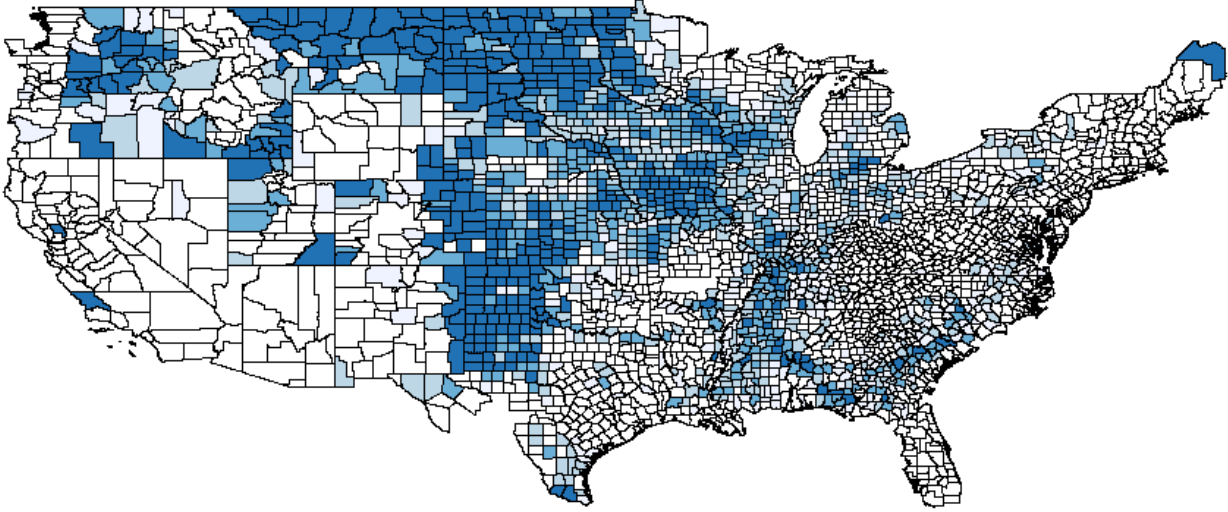


Figure A-8: Spatial Distribution of Land that was in CRP in 1992, at the County Level

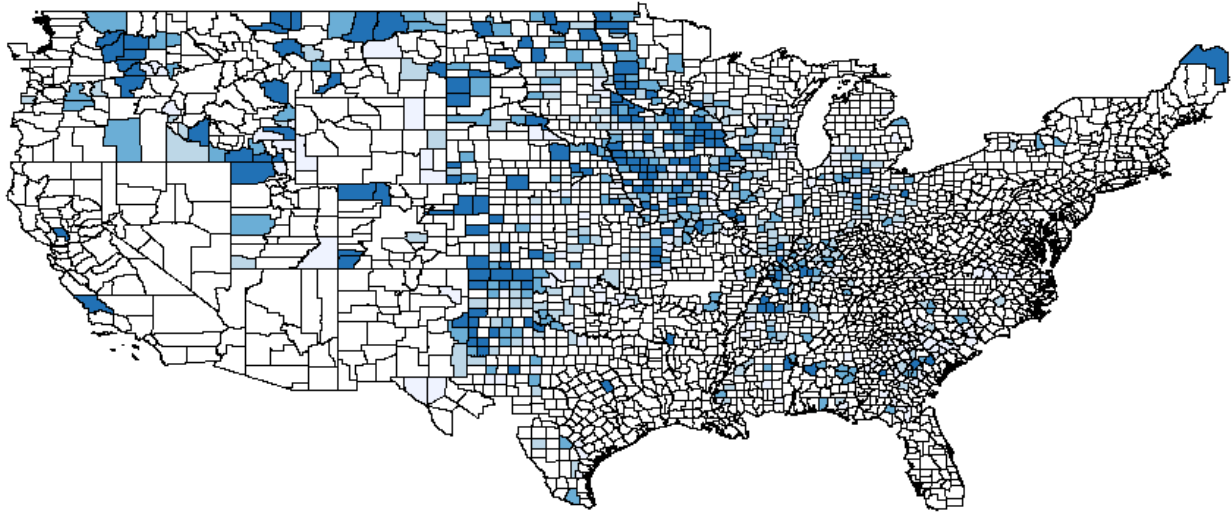


Figure A-9: Spatial Distribution of Land in CRP-Exit, at the County Level

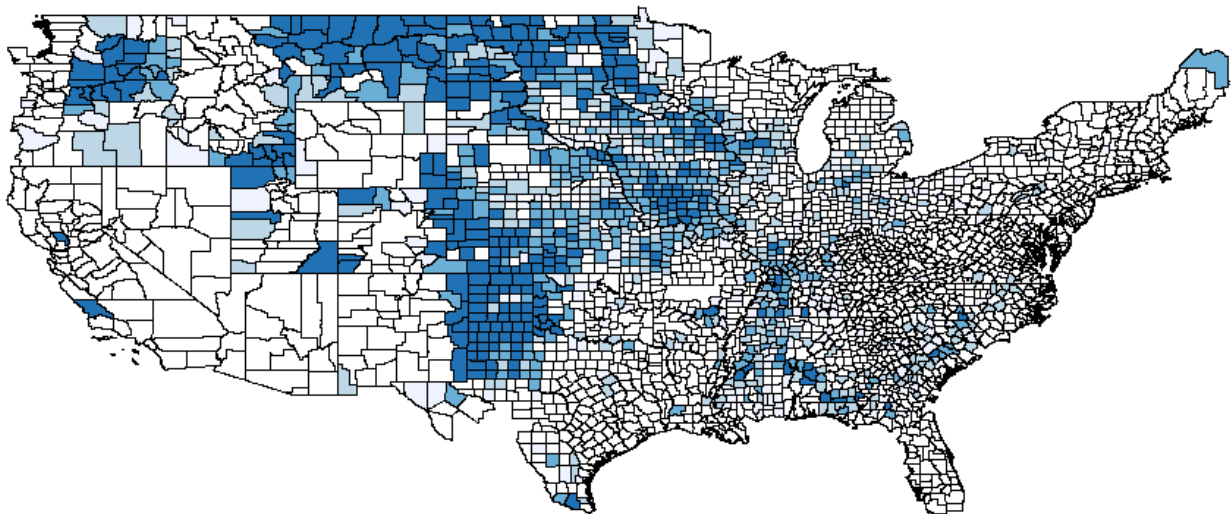


Figure A-10: Spatial Distribution of Land in CRP-Eligible, at the County Level

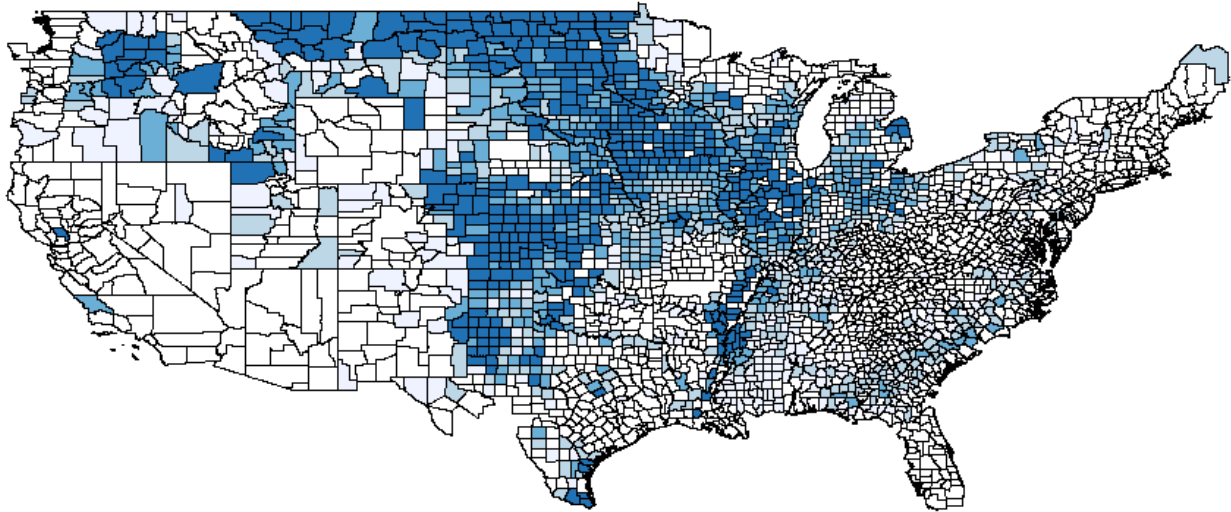


Figure A-11: Spatial Distribution of Land in Control-All, at the County Level

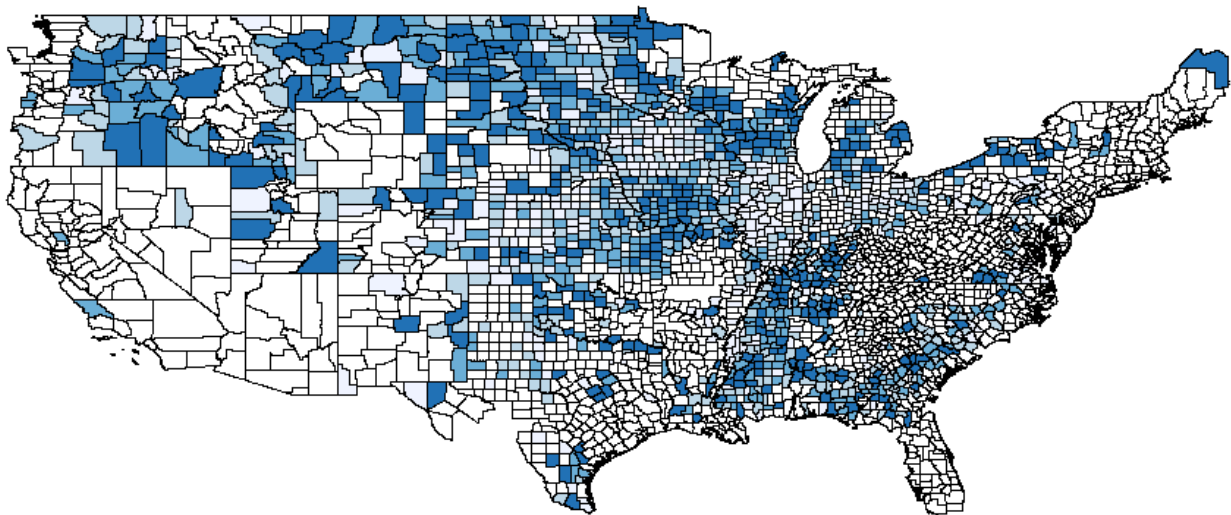


Figure A-12: Spatial Distribution of Land in Control-Unfarmed, at the County Level