Are Grassland Conservation Programs a Cost-Effective Way to Fight Climate Change? Evidence from France*

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Abstract

Grasslands, especially when extensively managed and when replacing croplands, store Greenhouse Gases. As a result, Grassland Conservation Programs, that pay farmers for maintaining grassland cover, might be an effective way to combat climate change, if they succeed in triggering an increase in grassland cover for a reasonable amount of money. In this paper, we use a natural experiment to estimate the cost-effectiveness of the French Grassland Conservation Program, the largest of such programs in the world. We exploit a change in the eligibility requirements for the program that generated a sizable increase in the proportion of participants in the communes most affected by the program. We find that the expansion of the program lead to a small increase in grassland area, mainly at the expense of croplands, which implies that the program expansion increased carbon storage. We estimate that the climate benefits from the program are at most equal to 19%±37% of its costs. The program is thus not cost-effective for fighting climate change, especially when compared with forest conservation programs in developing countries whose benefits have been estimated to exceed costs by a factor of two. When taking into account the other benefits brought about by grassland, we find the benefits of the program to be equal to 32%±62% of its costs.

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JEL: Q15, Q18, Q24, Q28, Q57.

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1 Introduction

Grasslands, especially when extensively managed and when replacing croplands, generate positive environmental externalities. It has been shown that grasslands store carbon in the soil (Soussana et al., 2004), are associated with low levels of water pollution (Agouridis et al., 2005) and with a high biodiversity level (Bretagnolle et al., 2012). As a result, Grassland Conservation Programs, that pay farmers for maintaining grassland cover, might be an effective way to protect the environment, and, as a case in point, to combat climate change. The key for these programs to be cost-effective is to trigger an increase in grassland cover at the expense of cropland for a reasonable amount of money. To this day, it is still unknown whether Grassland Conservation Programs trigger sufficient changes in grassland cover so as to be cost-effective ways to fight climate change.

A key input to compute the cost-effectiveness of a Grassland Conservation Program is its additionality (Chabé-Ferret and Subervie, 2013): how many additional hectares of grassland have been implanted or maintained thanks to the program. Additionality in turns depends on the elasticity of the supply of grassland. The more elastic (i.e. responsive to prices) the supply of grassland, the more cost-effective the program. In the limit, if the supply of grassland is fully inelastic, the program ends up paying farmers for doing nothing differently from what they would have done without any payment, and the effectiveness of the program is null.

Estimating additionality is no easy task because usual comparisons are very likely to be biased by confounding factors (Chabé-Ferret and Subervie, 2012). Comparing contracting farmers to non contracting farmers might overestimate the impact of the program. Indeed, contracting farmers took up the program not by chance but because they have lower costs of supplying grassland, and thus would have had a larger area of grassland than non participants even in the absence of the programs. The characteristics, such as their age and education level but also climate and the quality of their land, that make contracting farmers supply more grassland even in the absence of the program, confound the effect of the program. Using the change of grassland area of contracting farmers before and after the implementation of the program might also be confounded by simultaneous changes in prices or in other policies.

The main econometric approaches used to correct for the effect of confounders when estimating additionality are observational methods, Randomized Controlled Trials (RCTs) and natural experiments (Chabé-Ferret and Subervie 2012, Dominici et al., 2014). Observational methods compare contracting farmers to non-contracting farmers that have the same observed characteristics. Nevertheless, these methods run the risk of being severely biased because important confounders, such as land quality and managerial ability, often remain unobserved. RCTs are viewed as the gold standard for the estimation of additionality. Selecting the contracting farmers randomly among those who apply for a contract indeed enables to balance the distribution of confounding factors between contracting and non contracting farmers. Still, RCTs are not always doable, especially in the context of massive programs and due to constraints on experimenting with EU funds. Natural experiments are an alternative between observational methods and RCTs that leverage on quasi-experimental variation in exposure to a policy in order to neutralize the effect of confounding factors. Natural experiments achieve better control for confounding factors than observational methods (hopefully as good as that of RCTs) but do not require explicit randomization. Natural experiments are complemented by sets of placebo tests that enable to check whether the conditions for their validity hold or not.

In this paper, we estimate the additionality of the French Grassland Conservation Program using as a natural experiment a change in the eligibility requirements that happened in 2000. Before 2000, contracting farmers had to have a ratio of grassland to agricultural usable area higher than 75% in order to be eligible to receive the payments. After 2000, new contracts were introduced that did not include that eligibility criteria. The effect of this reform was not uniform over space. In the communes affected by the reform, the proportion of beneficiaries of grassland conservation schemes increased from 10% to 20% after the reform, while it remained stable around 15% in communes unaffected by the reform.

We conduct our analysis at the commune level in order to account for possible effects of the PES on non contracting farmers. Contracting farmers might indeed decide to buy, rent or exchange grassland with non-contracting farmers, a phenomenon called "leakage effect". In the presence of leakage effects, the program might not add a single hectare of grassland in a commune but still appear additional at the level of the individual farm. Working with commune-level data preserves our analysis from this issue.

The French Grassland Conservation program is the largest grassland conservation program in the world. Over the period 2003-2007, an yearly budget of around 350 million euro was allocated to subsidize 4.6 million hectares of grassland, covering 60% of the total grassland area in France (CNASEA, 2008). The program was created in 1993 as part of a broader set of Payments for Environmental Services (PES) introduced in the European Union as accompanying measures of the 1992 Common Agricultural Policy (CAP) reform. Subsidies for grassland conservation were included in the agri-environmental programs of several European countries, such as the German Cultural Landscape Program (KULAP), the Austrian Agri-environmental Program (OPUL), the United Kingdom's Environmental Stewardship Scheme or the Irish Rural Environment Protection Scheme (REPS) (Institut de l'Elevage, 2007). The yearly budget allocated to these programs varies from 100 million euro for the German KULAP to 283 million euro for the Austrian OPUL. Similarly, in the United States grassland conservation measures were in place since 2002 through the Grassland Reserve Program[1], with a funding of 38 million dollars yearly (USDA-NRCS, 2010).

Overall, our results imply that the program has a low level of additionality. We find evidence that the loosening of the eligibility criteria lead to a large inflow of money in affected communes (around 5,000±513 euro over five years, or an increase of 42.46%±6.21%) but to a comparatively small increase in grassland area (3.73±7.31 hectares per commune, or an increase of 0.76%±1.49%). Therefore, we estimate the elasticity of the supply of grassland to be low (around 0.02±0.04), meaning that an increase in prices by 10% would only increase the supply of grassland by 0.2%. We show that the increase in grassland area comes mainly at the expense of croplands. We also find weak evidence of leakage effects within communes, the share of rented land increasing in the communes where the number of contracting farmers increases.

We find that that the social benefits of the program are not enough to compensate for its costs. We estimate that the maximum value of CO_2 emissions avoided thanks to the program is equal to 19%±37% of its costs. The program is thus not cost-effective for fighting climate change, especially when compared with forest conservation programs in developing countries whose benefits have been estimated to exceed costs by a factor of two (Jayachadran et al., 2017; Simonet et al. 2018). When taking into account the other benefits brought about by grassland, we find the benefits of the program to be equal to 32%±62% of its costs.

There are only few previous evaluations of the impact of the EU Grassland conservation program, most of them using observational methods, namely a combination of Matching with Difference-In-Differences. The key difference between these previous studies and ours is that we work at the commune level to account for possible leakage effects, we do not enforce the common support condition that is mostly failing since the Grassland Conservation Program is taken by all eligible farmers, and we treat the 2000 reform as a natural experiment. Arata and Sckokai (2016) identify a statistically significant increase in the share of grassland for participant farmers in all EU Payments for Ecosystem Services

[1]Since 2014 the program is called the Conservation Reserve Program-Grasslands

in five EU member states. Pufahl and Weiss (2009) apply a DID-matching approach to a non-representative subsample of German farms to show that the whole EU program of Payments for Ecosystem Services is likely to increase both the grassland area and the area under cultivation. Chabé-Ferret and Subervie (2009) find similar estimates of the impact of grassland extensive schemes in France as we do. In work triggered by earlier presentation of our work and conducted independently, Gallic and Marcus (2018) find results similar to ours when studying a more recent reform of the French Grassland Conservation Program.

The remainder of the paper is structured as follows: Section 2 describes the French Grassland Conservation Program; Section 3 exposes our empirical strategy; Section 4 introduces the data used in this paper; Section 5 presents the results and the robustness checks; Section 6 presents a discussion and the cost-benefit analysis; Section 7 concludes.

2 The French Grassland Conservation Program

The French Grassland Conservation Program is part of a broader set of Payments for Environmental Services (PES) introduced in the European Union as accompanying measures of the 1992 Common Agricultural Policy (CAP) reform. PES are voluntary agreements between a buyer (a landowner) and a seller (the Government or private users) in which a payment is given conditional on an environmental service being adequately provided (Alston et al., 2013). The payment is computed so as to compensate the landowner for the average compliance costs and for the forgone farming revenue associated with the adoption of greener practices or so as to reflect the value of the environmental service provided. In general, a PES program targets at least one of the four environmental services among carbon sequestration, watershed services, biodiversity and scenic beauty. Since 2000, PES have become a core instrument of EU agricultural policies as part of the second pillar of the CAP.

The French Grassland Conservation Program was created in 1993 with the goal of stopping the decreasing pattern of grassland cover (from 43% of the agricultural area in 1970 to 36% in 1988 and only 27% in 2010). It was first called ”Prime au Maintien des Systemes d'Elevage Extensifs” (PMSEE). PMSEE was a five-year contract in which farmers committed to keep the grassland on the same plots for the duration of the contract. In exchange, they were paid 35 to 46 euro per hectare of grassland if they met two criteria: *(i)* a specialization rate (share of permanent and temporary grassland in the total usable agricultural area) higher than 75% and *(ii)* a loading ratio (density of livestock units (LU) per hectare of forage area) inferior to 1.4. In 1998, PMSEE was renewed for another five years and an eligibility requirement related to the use of fertilisers was introduced: farmers were not allowed to exceed 70 units of nitrogen per hectare of grassland. The PMSEE was replaced in 2003 by a new extensive grazing scheme called "Prime Herbagère Agro-Environnementale" (PHAE). The eligibility criteria for the PHAE were similar to those for PMSEE with three main exceptions. First, the thresholds for eligibility in terms of share of grassland and density of livestock units varied at department[2] level. Some departments kept the same thresholds as for the PMSEE, while others chose a threshold for the specialization rate smaller than 75%, but never smaller than 50%. Also, some departments set the loading ratio higher than 1.4 LU/ha, but never larger than 1.8. Second, additional requirements were introduced, especially in order to limit the use of phytosanitary products and fertilizers on the plots. Finally, the payments were increased to 76 euro per hectare of conserved grassland.

PMSEE and PHAE were two national programs that specifically target grassland conservation. However, starting in 2000, France launched an ambitious new PES program as part of the National Plan for Rural Development (NPRD). It was first called "Contrat Territorial d'Exploitation" (CTE) and was replaced in 2003 by "Contrat d'Agriculture Durable" (CAD). Among all the new PES that this program instituted, two broad categories were actually subsidies to grassland conservation: the measures 19 and 20. The PES 19 subsidized the maintenance of grassland opening where it was colonized by scrubs and trees, while the PES 20 subsidized extensive grassland management through mowing and/or pasture. The eligibility requirements for PES 19 and 20 were mainly that fertilization was limited on the field (in general, below 60 units of nitrogen per hectare of grassland). The main difference is that the PES 19 and 20 did not have any requirements on the specialization rate. As a consequence, these measures were taken also by farmers who were in general not eligible for PMSEE or PHAE due to a small share of grassland. Thus, PES 19 and 20 generated a new influx of farmers into the French Grassland Conservation Program (see Appendix A for a timeline and description of the eligibility requirements). It is this new influx of farmers into the program that we use as a natural experiment.

3 Empirical Strategy

Our empirical strategy is to analyse the change in eligibility requirements that happened in 2000, with the introduction of PES 19 and 20 and PHAE in a difference-in-differences (DID) design. Thus, we compare the outcomes before and after the policy reform for the group

[2]There are 95 departments in France.

of farmers living in communes where the number of beneficiaries of grassland schemes increased (i.e. the treated group) to the group of farmers living in communes where the number of beneficiaries remained stable (i.e. the control group). Because it took time for the farmers made eligible by the reform in 2000 to take up the new contracts (see Figure 1), and we do not observe outcomes between 2000 and 2003, we use 2003 as our first treatment year.

To build the comparison groups, we compute the growth rate in the total number of beneficiaries of grassland contracts per commune after 2003 with respect to 2000. If the growth rate is positive, the commune belongs to the treated group, while if the growth rate is equal to zero, the commune is used as control. Figure 1 shows the total number of beneficiaries of grassland conservation contracts over time, by treatment status. As expected and by construction, the treated communes see a sharp increase in the number of participants starting in 2001 and especially marked from 2002 to 2003. The number of beneficiaries in treated communes jumps from slightly above 20,000 in 2000 to slightly above 35,000 in 2003, or an increase of about 75%. In the control communes, the number of beneficiaries is almost constant over time. The map of France in Figure 2 shows that both treated and control communes are quite heterogeneously dispersed throughout the country. The only two areas not covered are the Paris basin where there is no grassland and Corsica which we exclude from the analysis.

In order to account for possible leakage effects of the policy, we perform the empirical analysis at the commune level. Leakage would occur if contracting farmers exchanged land with non contracting farmers because of the policy, the former renting or buying grassland from the latter, and the latter renting or buying cropland from the former. Leakage is a plausible reaction to the program, since contracting farmers receive a subsidy per hectare of grassland, they now value grassland more relative to cropland than non contracting farmers do. A comparison between contracting and non contracting farmers at the individual level would confound the leakage effects with a true additional effect of the program and would thus overestimate the total effect of the program. We posit that most leakage, if it exists, takes place at the commune level, between geographically close farmers. As a consequence, with our approach, any transfer of land between farmers residing in the same commune that does not alter the overall land use within the commune is not counted as additional.

Our data is a commune-year panel over 4 periods. We estimate a two-way fixed effects model, which is an extension of the simple DID to more than two periods.[3] The

[3]As we have more than two periods, the simple OLS regression would give a biased estimate of the treat-

baseline equation is given by:

$$Y_{ct} = \widetilde{\alpha} D_{ct} + \widetilde{\beta} X_{ct} + \widetilde{\eta_c} + \widetilde{\xi_t} + \widetilde{\epsilon_{ct}} \tag{1}$$

where Y_{ct} is the aggregated outcome variable (for example the share of permanent grassland area in commune c at time t), D_{ct} is a dummy taking a value of one starting in 2003 for communes where the number of beneficiaries increased after the reform, X_{ct} is the vector of aggregated control variables (for example the number of small farms in commune c at time t), $\widetilde{\eta_c}$ and $\widetilde{\xi_t}$ represent the commune and year fixed effects. The fixed effects control for time-invariant unobserved commune characteristics (e.g. altitude, slope) and for effects that are common to all communes at one point in time (e.g. changes in CAP policies that affect every farmer in the same way). ϵ_{ct} is the error term and includes unobserved variables such as managerial ability, environmental preferences and prices. To account for a potential endogeneity concern due to the fact that eligibility criteria is set at the department level, we also include department-specific yearly effects in our main specification. The estimated standard errors are robust to heteroskedasticity and are clustered at commune level to account for serial correlation in the outcome variables (Bertrand et al., 2003).

The parameter of interest, $\widetilde{\alpha}$, captures the average causal effect of the program expansion that followed the change in eligibility criteria. This estimate captures the full impact of the reform, on both beneficiaries and non-beneficiaries located in the same commune. For this parameter to be a consistent estimate of the impact of the reform, the parallel trends assumption must hold, meaning that there should be no systematic differences in outcome trends between treated and control communes before the reform. We test this assumption by comparing trends in outcomes between treated and control communes before the reform.

To check the robustness of the DID specification we re-estimate the intention-to-treat effect using the changes-in-changes (CIC) model proposed by Athey and Imbens (2006). The CIC model is a nonlinear generalization of the DID model to the entire distribution of potential outcomes. The estimated treatment effect is given by the difference between the actual and the counterfacual distribution of the outcome variable in the treated communes. In turn, this difference is given by the difference between the outcome variable of the control communes with the same rank (i.e. in the same quantile) before and after the reform.[4] The key identifying assumption of the CIC method is the time invariance within

ment effect since the treatment dummy is likely to be correlated with the error term. The solution proposed in the literature is to estimate a regression including group and time fixed effects.

[4]Specifically, a treated group with a level Y of the outcome variable in the pre-treatment period is matched

groups assumption. It is the counterpart of the parallel trends assumption in the DID case and it requires that the population of agents within groups does not change over time. However, it has been rarely used in practice so far as the existing statistical tools used for its implementation are quite limited.[5]

4 Data

We construct our database at the commune level using two types of data. First, we use administrative data from France's Service and Payment Agency (ASP) provided to us by the Sustainable Development Observatory (ODR). This data contains information on all beneficiaries of grassland programs from 1999 to 2006.[6] To build our treated and control groups we count the number of beneficiaries in each communes and we compute the growth rate in the number of beneficiaries from before to after the policy change in 2003.

Second, in order to estimate the outcome and control variables, we resort to farm level data provided by the Ministry of Agriculture. More specifically, we use the 2000 agricultural census and the farm structure surveys from 1993 to 2007. These surveys are conducted every two years between censuses on 10% of the population of farmers. To construct our variables of interest, we first weight the farm level data using the sampling weights provided in the survey and then we sum the weighted data at commune level.

Our main outcomes are the share of permanent grassland, crops and fodder in the total utilised agricultural area, the specialization rate (% of permanent and temporary grassland in the total utilised agricultural area) and the loading ratio (the density of livestock units in the forage area). To obtain a better understanding of the potential land use changes triggered by the grassland program, we also look at variables such as the share of total usable agricultural area, the share of forest area and the share of nonproductive land in the total farm area within a commune. Except for the loading ratio, which is transformed applying the inverse hyperbolic sine,[7] we express all our outcome variables as shares in order to account for size differences between communes. Our control variables

with a control commune with the same level of the outcome in the same period. Then, this control commune is matched to a control commune with the same rank in the post-treatment period.

[5]In R, we use the single available command, "CiC" from the "qte" package, which only allows for one pre-treatment period and one post-treatment period and does not allow for the inclusion of covariates.

[6]That dataset contains information such as the commune of residence, the years in which the farmers were enrolled in a grassland program, the number of hectares enrolled and the payment they received every year.

[7]We apply the inverse hyperbolic sine (IHS) transformation to the loading ratio to correct for its highly skewed distribution with a mass point at zero and to ensure equivalence in the unit of measure and interpretation of results with the other outcome variables. IHS is defined as $log(Y_i + (Y_i^2 + 1)^{\frac{1}{2}})$. It is defined at zero and can be interpreted similarly to a log-linear specification.

include the number of farms for each type of crop orientation and for each economic size and the total number of farms in each commune. A detailed definition of all these variables is given in Appendix C.

Our final dataset includes only farmers having at least one hectare of utilised agricultural area and only those communes where at least one farmer has received a subsidy for grassland conservation over the period 1999 to 2006. The sample constraint on communes enables us to build treatment groups with more similar characteristics than if we would have included also communes with no grassland beneficiary over the analysed period. We work with two balanced panels: one from 1993 to 1997 and one from 2000 to 2007. The reason why we decided to split the data into two periods is that survey identifiers are erased at each census. In our case this happens in 2000, so having a coherent balanced panel over the whole period is impossible. We thus use a balanced panel of 9,998 communes from 1993 to 1997 to perform the placebo test and a balanced panel of 10,468 communes from 2000 to 2007 to recover the treatment effect. Among these, 7,808 communes are common between the two periods.[8] We choose the time window 1993-2007 to avoid possible complications due to the fact that there was no grassland conservation program before 1993 and that the new scheme starting in 2007 had many changes compared to the previous one.

Table 1 reports the mean and standard deviation of our outcome variables, by treatment group and sample. Recall that our control communes are those in which farmers are benefiting from the grassland subsidy for the whole 1993-2007 period. Thus, as a consequence of the program requirements, they have a higher share of permanent grassland and specialization rate and a lower loading ratio than the treated communes, where farmers became beneficiaries only after the 2003 reform. The control communes have also a higher share of forest and nonproductive land and a bigger part of the agricultural area that is owned. Conversely, the farms located in treated communes have a higher share of crops, fodder and utilised agricultural area and have more rented land than farmers in control communes. This selection in levels does not create any problems for our identification strategy since the DID methodology removes permanent differences between the treated and control groups.

[8] We also build a balanced panel of the 7,808 communes over the whole period, but we observe a huge drop in all our outcome variables between 1997 and 2000 that we cannot explain otherwise than by a change in the weighting system starting with the 2000 census. We thus choose to split the sample into two periods in order to avoid capturing this decrease in the treatment effect estimation.

5 Results

In this section we start by presenting the magnitude of the effect of the 2000 reform on the number of contracting farmers and the amount of transfers received as part of the Grassland Conservation Program in the communes affected by the program expansion. We then show the results of the main regressions estimating the impact of the reform on outcomes based on our baseline equation (1). Finally we present some robustness checks of the main results.

5.1 The Size of the Program Expansion in Treated Communes

The share of contracting farmers in treated communes increased sharply between 2000 and 2003, as can be seen in Figure 3, while this number remained stable in control communes over the same period. Formally, we estimate the impact of the reform on the share of beneficiaries in treated communes to be 10.7±0.35 p.p. (Table 2), which represents a near doubling of the proportion of contracting farmers in treated communes.

The amount of monetary transfers as part of the French Grassland Conservation Program increased markedly in treated communes, as shown in Figure 4. We estimate that the program expansion increased the total amount of grassland subsidies in treatment communes by 5,000±513 euro (Table 2), or a 42% increase.

Figure 4 shows that the amount of subsidies increased in control communes as well, because of the increase in the per hectare payment that accompanied the introduction of the new programs, but it is of smaller magnitude. We thus compare the relative response of grassland supply to the larger inflow of money that occurred in treated communes.

5.2 The Impact of the Program Expansion on Outcomes

We present both graphical evidence and regression results of the intention-to-treat effect on our outcomes of interest. For simplicity, we use "Panel A" to denote the share of permanent grassland, crop and fodder area, the specialization rate and the loading ratio. "Panel B" refers to the share of utilised agricultural area, forest and nonproductive land, while As a general description of the graphical evidence, the first column of plots in each figure, denoted by (a), represents the placebo test on the 1993-1997 sample of communes. The second one, denoted by (b), shows the treatment effect of the program on the sample of communes from 2000 to 2007. The first line of plots presents the trends in average outcome variables by treatment status, while the second line shows the yearly coefficients on the difference between treated and controls. These coefficients can be interpreted as an estimate of the impact of being treated on the outcome variable in a given year. The effect is statistically significant if zero is not included in the 95% confidence interval, represented by dashed lines. We present regression results for different specifications with and without additional control variables and with and without department-year fixed effects. The results are consistent across specifications even though the point estimates slightly change with the introduction of controls or additional fixed effects. Our preferred specification is the one that accounts for both commune characteristics and yearly, department specific shocks.

Panel A Results. Panel A includes our main outcome variables of interest. Graphically, there is no difference in the share of permanent grassland area between treated and control communes from 1993 to 1997, as the coefficients of the interaction term fluctuate around zero before 2000 (Figure 5). Between 2000 and 2007 the wedge opens up, suggesting a small positive impact of the Grassland Conservation Program on the share of permanent grassland area. For share of crop area, the effect of the program seems to be negative. In Figure 6 we see that from 1995 to 1997 there is a small increase in treated communes compared to control communes, while after 2000 the difference becomes negative. The share of fodder area does not appear to be affected by the change in eligibility requirements, as the yearly coefficients swing around zero both before and after 2000 (Figure 7). In Figure 8 we can observe that the specialization rate is stable before 2000 and increases afterwards, indicating a positive effect of the grassland program on this outcome. Finally, in Figure 9 it seems that there is a slight decrease in the loading ratio between 1993 and 1997 in the treated communes compared to control communes, while after 2000 there is no difference in the loading ratio of the two groups. All in all, the visual evidence suggests that the grassland program lead to a small increase in the share of permanent grassland area and the specialization rate, a decrease in the share of crops and no change in the share of fodder area and the loading ratio.

Table 3 presents the results of the fixed effects regressions. The estimated coefficients confirm the conclusions of the graphical evidence, but are in general not statistically different from zero. Nevertheless, we find that the share of permanent grassland area increases after the reform by 0.28$\pm$0.55 p.p. in treated communes compared to control communes. Similarly, the specialization rate increases by 0.45$\pm$0.49 p.p. At the same time, the share of crop area decreases by a similar amount, -0.40$\pm$0.39 p.p., while there is no difference in the share of fodder area and loading ratio between the two groups of communes. An interesting pattern that arises from these results is a potential switch from crops to grassland in the treated communes from the pre- to the post-treatment period.

Panel B Results. Apart from croplands, the additional grassland area that we find after 2003 might also come from forest or nonproductive land. We use the Panel B outcomes to test this possibility. The share of utilised agricultural area in total farm area slightly decreases in treated communes with respect to control communes after 2003, while before the was no difference between the two groups (Figure 10). Contrariwise, as shown in Figure 11, the share of forest area increases in the post-treatment period. Figure 12 indicates that the difference in the share of nonproductive land between the comparison groups was slightly positive in the pre-treatment period and it became almost null afterwards. The regression results from Table 4 suggest that the share of utilised agricultural area in total farm area remains rather stable over the whole period between the treated and control communes. Moreover, the share of forest area increases over time, from -0.25±0.43 p.p. to 0.10±0.35 p.p., while the share of nonproductive land decreases by almost the same amount, from 0.23±0.33 p.p. to 0.00±0.29 p.p. Thus, since the share of utilised agricultural area does not change over time and the decrease in nonproductive land is compensated by the increase in forest area, we argue that the increase in the share of grassland comes mainly from the decrease in the share of crops.

Putting everything together, our interpretation of the results is that the policy reform induced some farmers living in the treated communes to keep more grassland on their farms mainly at the expense of croplands.

5.3 Robustness Checks

Changes-in-changes. Our identification strategy relies on the parallel trends assumption. However, for some of our outcome variables we acknowledge the existence of pre-treatment trends that, even though not statistically significant, might invalidate our methodology. For this reason we perform a robustness check using the non-parametric equivalent of the DID method, the Changes-in-Changes (CIC) strategy. Due to difficulty in practical implementation, the CIC regressions do not include fixed effects or additional controls. Table 5 shows that this method yields very similar results to our preferred specification including both control variables and commune, year and department-year fixed effects.

Different samples. Our sample is composed of two balanced panels, one from 1993-1997 and one from 2000-2007. To test the sensitivity of our results to this choice, we re-estimate the model using two unbalanced panels from 1993-1997 and 2000-2007 and a balanced panel restricted to the same communes for the whole 1993-2007 period. The results are summarized in Table 6 and Table 7. Even though the precision and magnitude of the estimated coefficients varies slightly with the sample size (i.e. the bigger the sample size, the more precise estimation), in all cases the qualitative findings remain similar to the ones estimated on the balanced sample of different communes between the two periods.

6 Discussion and Cost-Benefit Analysis

In this section we start by computing the elasticity of the additional permanent grassland supply with respect to the amount of subsidies. Next, we build a cost-benefit analysis by comparing the additional costs of the program due to the eligibility criteria change with its additional benefits, quantified using values taken from the literature. Throughout this section we present mean estimates along with their 95% confidence intervals that we build using transformed standard errors through the Delta Method.[9]

6.1 Elasticity Estimate

The impact we measure of the French Grassland Conservation Program's reform on commune level outcomes is not statistically different from zero. However, what matters for policymakers is the potential size of the impact. We find evidence that the policy reform was accompanied by a large inflow of money in treated communes, of around 5,000±513 euro per hectare over the 5 years of grassland contracts, corresponding to an increase of 42.46%±6.21%.[10] This amount of additional subsidies corresponds to a comparatively small increase in grassland area of 3.73±7.31[11] hectares per treated commune, or an increase of 0.76%±1.49%[12] in grassland area. Therefore, we estimate a low elasticity of the supply of grassland with respect to the amount of the subsidy of 0.02±0.04.[13] These elasticity estimates are summarized in Table 8.

Our results imply that the cost per hectare of additional permanent grassland over the 5 years of contracts is 1,340±2,628 euro,[14] which is almost three times bigger than

[9] See Appendix E for a description of the Delta Method.

[10] The percentage change is computed as the ratio between the ITT estimate of the additional amount of subsidies and the counterfactual mean of the amount of subsidies in treated communes after the reform (i.e. (5,000 euro /11,775 euro) $\times$ 100).

[11] The additional hectares of grassland are computed by multiplying the ITT estimate of the share of permanent grassland area with the sample mean of the total utilised agricultural area in treated communes after the reform (i.e. 0.28 p.p. $\times$ 1,333 ha).

[12] The percentage change is computed as the ratio between the ITT estimate of the share of permanent grassland area and the counterfactual mean of the share of permanent grassland area in treated communes after the reform (i.e. (0.28 p.p./37.02%) $\times$ 100).

[13] The elasticity of the supply of grassland is computed as the ratio between the percentage change in grassland area and the percentage change is the amount of subsidies (i.e. 0.76%/42.46%).

[14] The cost per additional hectare of grassland is obtained by dividing the estimated additional cost to the

the actual subsidy per hectare over the same period of time, of 450 euro.[15] Dividing the additional cost by the actual cost per hectare of grassland, we find an increase in the subsidized area of 11 hectares per treated commune. Given that the corresponding increase in grassland area is only 3.73 hectares per commune, we estimate a low additionality ratio of 34%.[16]

6.2 Cost-Benefit Analysis

For consistency reasons, we present the results of the cost-benefit analysis at the commune level. To express them at national level, we just need to multiply the values recovered for a treated commune by the population of 9,757 treated communes.

We first compute an upper bound on the benefits of the program in terms of reduced CO_2 emissions. We use Baudrier et al. (2015) estimates of 10.55 tons of averted CO_2 emissions per hectare of grassland prevented from converting to crops that they obtain following IPCC guidelines. In their counterfactual scenario, cattle growing would still be the main farming activity, but grassland would be converted into corn fodder. They further assume that, under the counterfactual scenario, the conversion of grassland to crops would allow farmers to feed 1.9 more livestock units per converted hectare. In addition to the carbon stored under grassland, they also estimate the GHG emissions related to the livestock (mainly methane emissions), the nitrous oxide emissions linked to the nitrogen flow and the upstream GHG emissions.[17] We consider this estimate to be an upper bound since we assume that the carbon stored under the additional permanent grassland area remains there forever. Also, it is unclear whether the payments actually decreased the number of cows, so that the bulk of the savings due to a lower number of cows is actually a bonus for the effectiveness of the program.

Combining Baudrier et al. (2015) estimates with our estimates of additionality, we find that the 2000-2003 reform of the French Grassland Conservation Program averted 40 tons of CO_2 per commune.[18] Using the social cost of carbon (SCC) proposed by the U.S. Environmental Protection Agency (EPA),[19] we estimate an upper bound on the additional

additional hectares of grassland (i.e. 5,000 euro/3,73 ha).

[15] The subsidy per hectare of grassland for PHAE and CTE/CAD together was about 90 euro.

[16] The additionality ratio is as the ratio between the additional subsidized hectares and the additional hectares of grassland (i.e. 11 ha/3.73 ha)

[17] Their estimates, in tons of CO_2 emissions per hectare of grassland saved, are: 3.25 for the carbon storage, 6.48 for livestock related GHG emissions, 0.73 for nitrous oxide emissions and 0.09 for upstream GHG emissions.

[18] The averted emissions are computed by multiplying the estimated additional hectares of permanent grassland with the estimate on averted emissions from Baudier et al. (2015) (i.e. 3.73 ha $\times$ 10.55 tCO_2/ha).

[19] The EPA middle estimate (i.e. using a discount rate of 3%) for the SCC in 2010 is $31 (in 2007 USD) per

benefit of the program reform in terms of avoided CO_2 emissions of 945±1,852 euro per treated commune. This is equal to 19%±37% of the increased spending due to the reform (i.e. 5,000 euro). The program is thus not cost-effective for fighting climate change, especially when compared with forest conservation programs in developing countries whose benefits have been estimated to exceed costs by a factor of two (Jayachadran et al., 2017; Simonet et al. 2018).

For a more complete accounting of permanent grassland benefits, we further include the values proposed in the literature to quantify some of the different ecosystem services rendered by the French permanent grasslands. Therefore, we retain the average values given by Puydarrieux and Devaux (2013) related to the water quality (44 euros/ha/year), pollination (60 euros/ha/year), hunting (4 euros/ha/year)[20] and landscape amenities (60 euros/ha/year). Adding up all these values, we arrive at an estimate of the benefits of the French Grassland Conservation Program of 1,571±3,081 euro, or a total benefit-cost ratio of 0.31±0.62,[21] which on average is still below one. The summary of the cost-benefit analysis in presented in Table 9.

7 Conclusion

Payments for Ecosystem Services are being increasingly used in the context of development and environmental policies around the world. Yet, the empirical analysis of their effectiveness remains somewhat sparse. In this paper we provide an evaluation of a major nationwide PES program, the French Grassland Conservation Program. Unlike previous literature evaluating the effect of EU PES on grassland cover, our approach does not rely on matching beneficiaries with similar non-beneficiaries. Instead, we use the exogenous change in eligibility criteria for participating in a grassland program as a natural experiment. We perform the analysis at the aggregated, commune level in order to account for potential leakage effects within communes and we exploit the natural experiment in a difference in difference design: we compare changes in outcomes both over time and between communes where the number of grassland beneficiaries increased after the policy change and communes where the number of beneficiaries remained the same. What we recover is an intention-to-treat effect, or the effect of the change in eligibility criteria on all farmers

ton of averted CO_2. Using the USD-EUR exchange rate of 2007 (i.e. 1 USD = 0.77 EUR), the SCC equals approximately 24 euro.

[20]Here we consider the hunting as a supply activity and not as a leisure activity. Thus we value it at the market price of the prey.

[21]The benefit-cost ratio is obtained by dividing the benefits of the program by its costs (i.e. 1,571 euro/ 5,000 euro).

located in treated communes compares to those located in control communes.

Our results suggest that the reform of the French Grassland Conservation Program induces beneficiaries located in treated communes to increase the grassland area on their farm mainly at the expense of croplands. However, the additionality of the program is low as the subsidized area increased by 11 hectares per commune, while the permanent grassland area only increased by about 4 hectares. The small increase in grassland area is accompanied by a large additional inflow of money in the treated communes, such that the elasticity of the supply of grassland is also low. The switch from crops to grassland induces an additional carbon storage. Yet, the benefit-cost ratio is less than one, meaning that the 2000-2003 reform of the French Grassland Conservation Program is not cost-effective. Moreover, we find that program reduces CO_2 emissions at a cost that is higher that then the middle estimate of the Social Cost of Carbon and much higher than similar estimates obtained from forest conservation programs in developing countries. It appears thus that grassland conservation programs in developing countries are not an effective way of fighting climate change.

Our study contributes to the current increase in policymakers' demand for evidence based analysis of public policies. In the context of the French Grassland Conservation Program, there are still several issues that deserve attention in future research. First, the assessment of the true cost for a farmer to participate. True costs refer to the decrease in profits that the farmer has experienced as a consequence of adopting green practices. But since PES are voluntary programs, it is most likely that farmers costs of adopting the greener practices are lower than the compensation they receive, otherwise they would not have chosen to participate in the scheme. If this happens, the subsidy is most likely a net transfer for program's beneficiaries. The problem is that the greater the net transfer, the less cost-effective the program is. Second, explicitly estimating the heterogeneity across space in both costs and treatment effects would potentially demonstrate the advantage of spatially targeting grassland subsidies.

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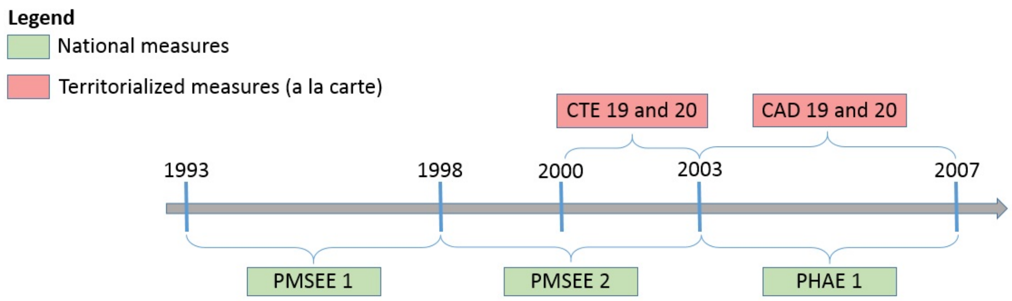
A The Grassland Conservation Program in France



Measure / Eligibility Criteria	PMSEE 2	PHAE 1	CTE/CAD 19 AND 20
Farmer's age	≤ 60 years	≤ 60 years	—
Farm size	≥ 3 ha UAA and ≥ 3 LU	—	—
Specialization Rate (Grassland/Utilised Agricultural Area)	≥ 75%	≥ 50% - ≥ 75% department dependent	—
Loading Ratio (Livestock Units/Fodder Area)	≤ 1.4	≤ 1.4 - ≤ 1.8 department dependent	≤ 1.4 - ≤ 1.8 department dependent
Fertiliser use (Units of Azote/ha of Grassland)	≤ 70	≤ 60	≤ 60
Max amount of subsidy / ha of grassland	**46€**	**76€**	**91€**

B Treated and Control Groups

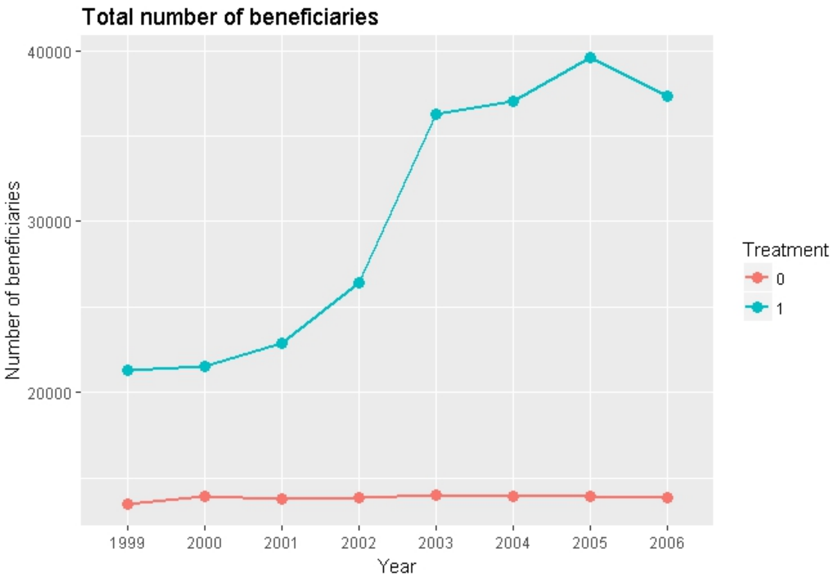


Figure 1: Total number of beneficiaries of grassland conservation schemes from 1999 to 2006, by treatment status.

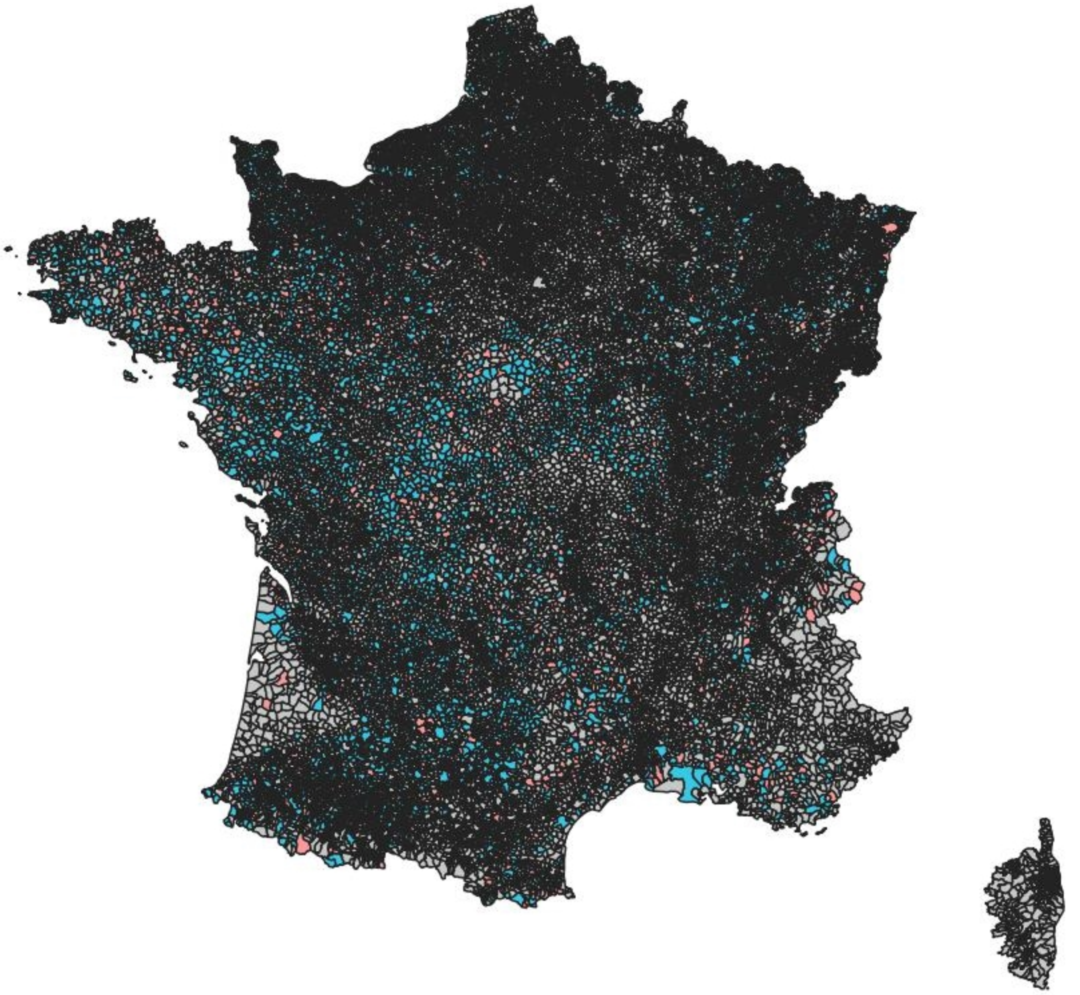


Figure 2: Map of France showing the treated communes (in blue) and the control communes (in pink).

C Data

Outcome variables:

- share of permanent grassland area (% of total utilised agricultural area) = share of natural grassland or pastures having more than 6 years on the same plot and low productivity grassland area;
- share of crop area (% of total utilised agricultural area) = share of cereals, industrial crops, pulses and protein crops;
- share of fodder area (% of total utilised agricultural area) = share of corn forage and silage, forage root crops and other annual forages;
- specialization rate (%) = the share of temporary and permanent grassland in the total utilised agricultural area;
- loading ratio = density of livestock units (cattle, equines, goats and sheep expressed in cattle units) in the forage area (permanent grassland and fodder area without corn forage);
- share of utilised agricultural area (% of total farm area) = share of annual crops, permanent crops and temporary and permanent grassland;
- share of forest area (% of total farm area) = share of timber and logging forests;
- share of nonproductive land (% of total farm area) = share of nonproductive heath, wasteland and non-agricultural area;
- share of owned land (% of total utilised agricultural area);
- share of permanently rented land (% of total utilised agricultural area);
- share of temporary rented land (% of total utilised agricultural area) = share of temporary rented land and land in sharecropping.

Control variables:

- type of crop orientation = cereals and protein crops, general crops, vegetable crops, flowers and horticulture, designated viticulture, other type of viticulture, fruits and other permanent crops, milk cattle, beef cattle, milk-beef cattle, other herbivorous, granivorous, mixed crops, poly-elevation herbivorous orientation, poly-elevation granivorous orientation, field crops and herbivorous;

- economic size = less than 4 ESU[22], between 4 and 8 ESU, between 8 and 16 ESU, between 16 and 40 ESU, between 40 and 100 ESU and more than 100 ESU ;
- number of farms = weighted number of farms.

Table 1: Mean and standard deviation of outcome variables, by treatment group and by sample

	1993-1997		2000-2007	
	Treated group	**Control group**	**Treated group**	**Control group**
Panel A				
Share of permanent grassland area	41.24	48.20	37.22	43.76
	(31.87)	(34.66)	(30.41)	(34.41)
Share of crop area	31.67	25.18	35.00	28.33
	(26.97)	(26.49)	(27.62)	(27.94)
Share of fodder area	6.15	4.69	6.19	4.89
	(8.63)	(8.01)	(7.96)	(7.81)
Specialization rate	50.52	56.32	47.97	53.49
	(31.97)	(34.32)	(31.35)	(34.60)
Loading ratio	1.68	1.42	1.73	1.47
	(3.07)	(2.76)	(4.41)	(2.96)
Panel B				
Share of utilised agricultural area	92.09	90.13	94.17	92.91
	(13.36)	(16.09)	(10.75)	(13.42)
Share of forest area	4.96	6.20	3.69	4.42
	(10.77)	(12.57)	(9.06)	(10.66)
Share of nonproductive land	1.61	2.45	1.10	1.69
	(6.22)	(8.42)	(4.32)	(6.85)
Observations	**6,827**	**3,171**	**7,243**	**3,225**

[22]European Size Unit is a standard gross margin of 1200 Euro that is used to express the economic size of a farm (Eurostat:Statistics Explained).

D Results

D.1 First Stage Results

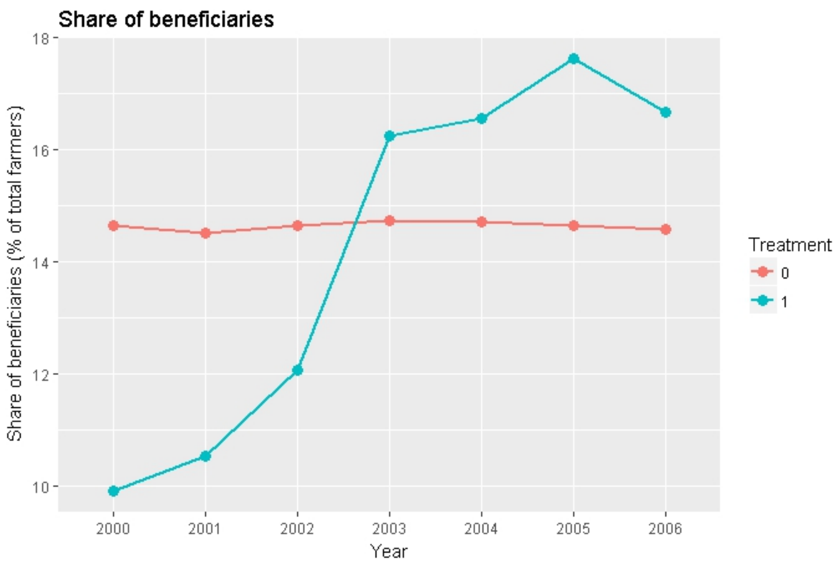


Figure 3: Share of beneficiaries of grassland conservation schemes in total farmers from 2000 to 2006, by treatment status.

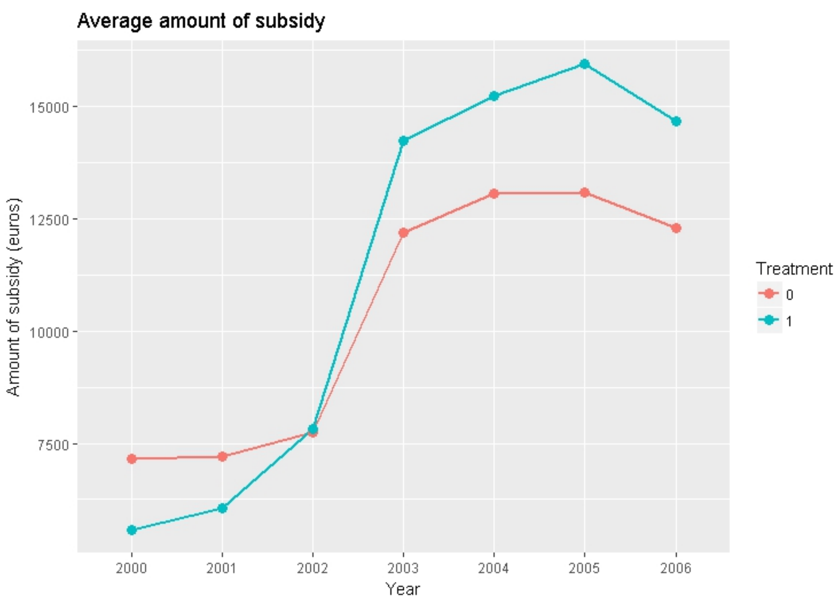


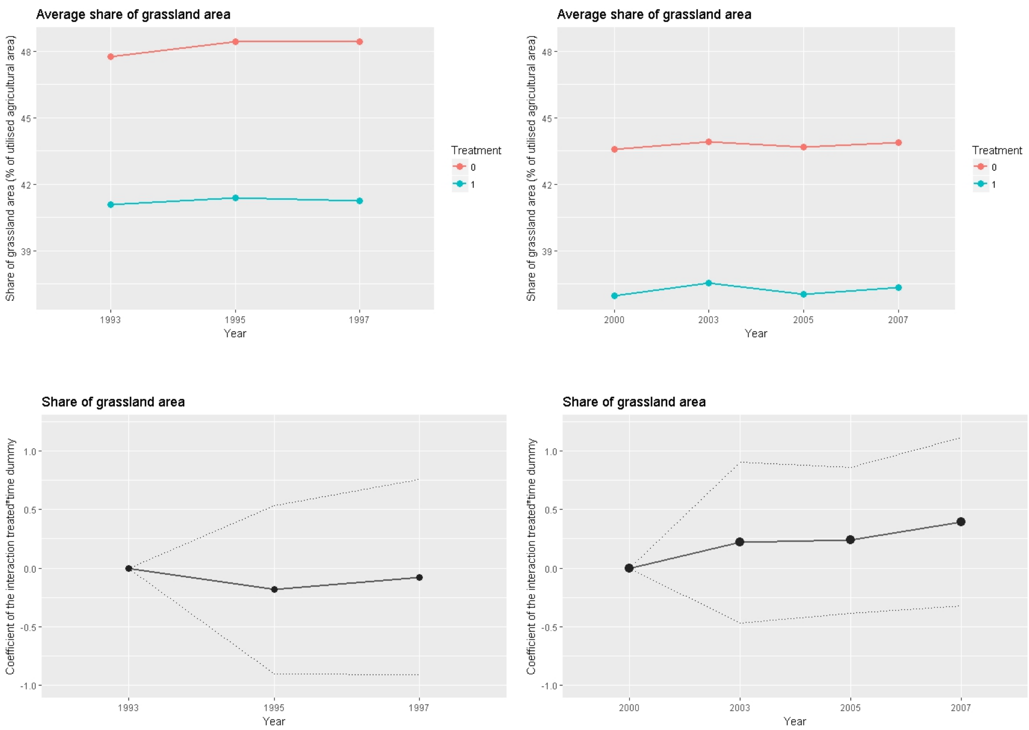
Figure 4: Average amount of subsidies (in euro) paid to beneficiaries between 2000 and 2006, by treatment status.

Table 2: First Stage Results

	Treatment Effect (2000-2007)
Outcome Variables	
Share of beneficiaries (%)	10.71
	(0.18)
Total subsidies (euro)	$4,994.86$
	(261.93)
Observations	**10,468**

Note: Year, commune and department-year fixed effects estimation. All regressions include the full set of control variables. Robust standard errors clustered at commune level in parenthesis. *p $<$ 0.1; **p $<$0.05; ***p $<$ 0.01.

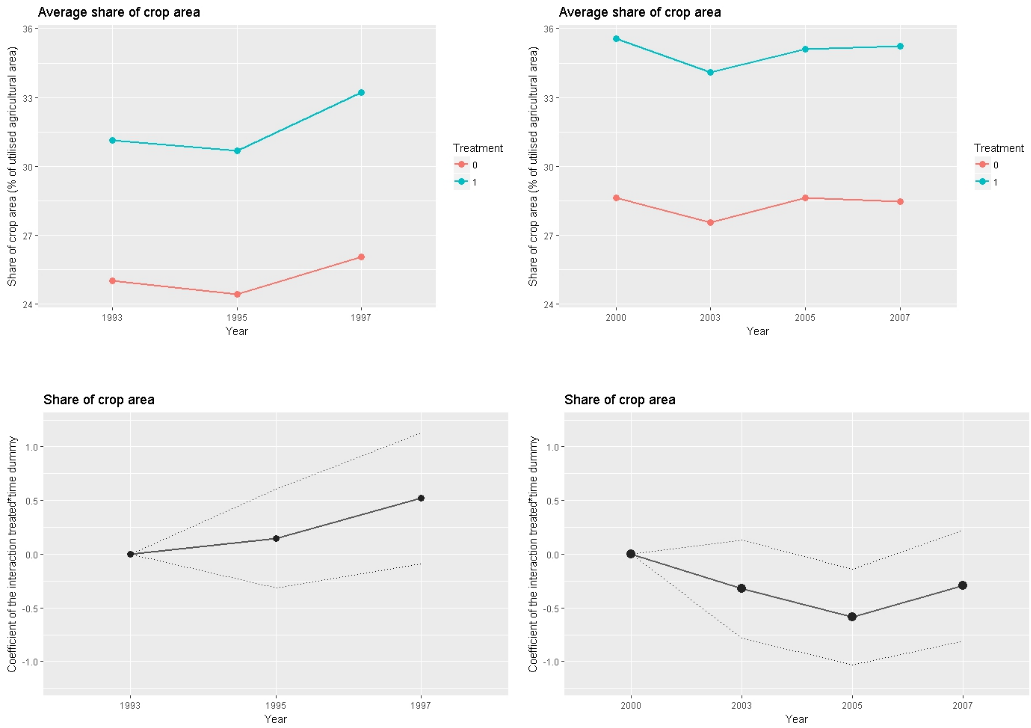
D.2 Reduced Form Results: Panel A



(a) Placebo Test (1993-1997)

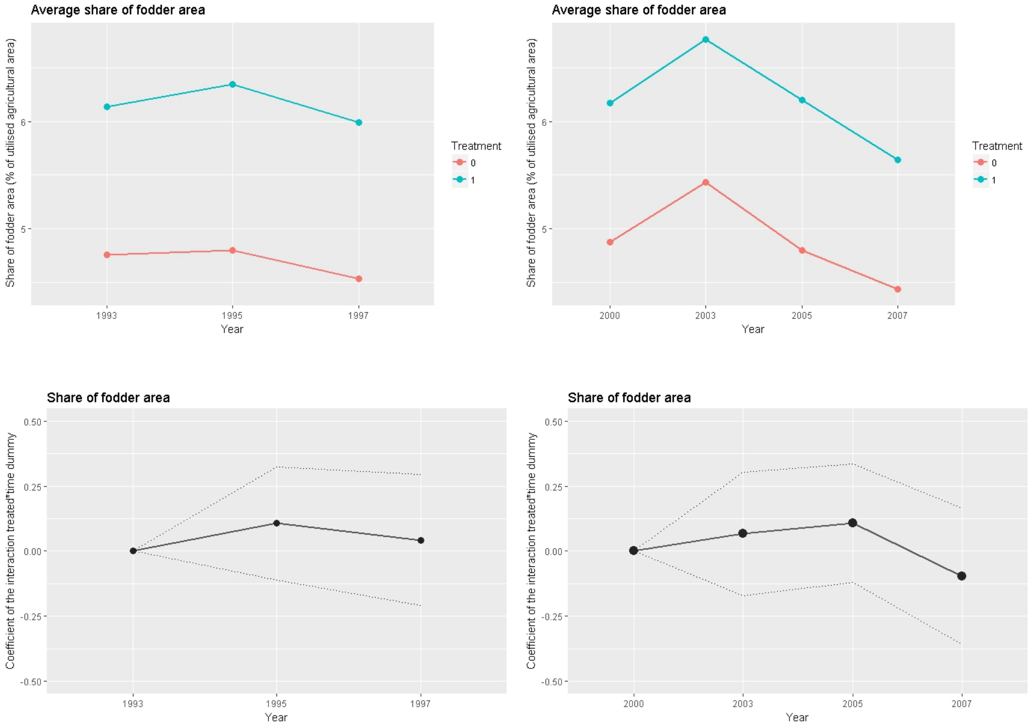
(b) Treatment Effect (2000-2007)

Figure 5: (i) Trends in the average share of permanent grassland area in total utilised agricultural area by treatment status and (ii) Estimated coefficients of the interaction treated*time dummy on the share of permanent grassland area.



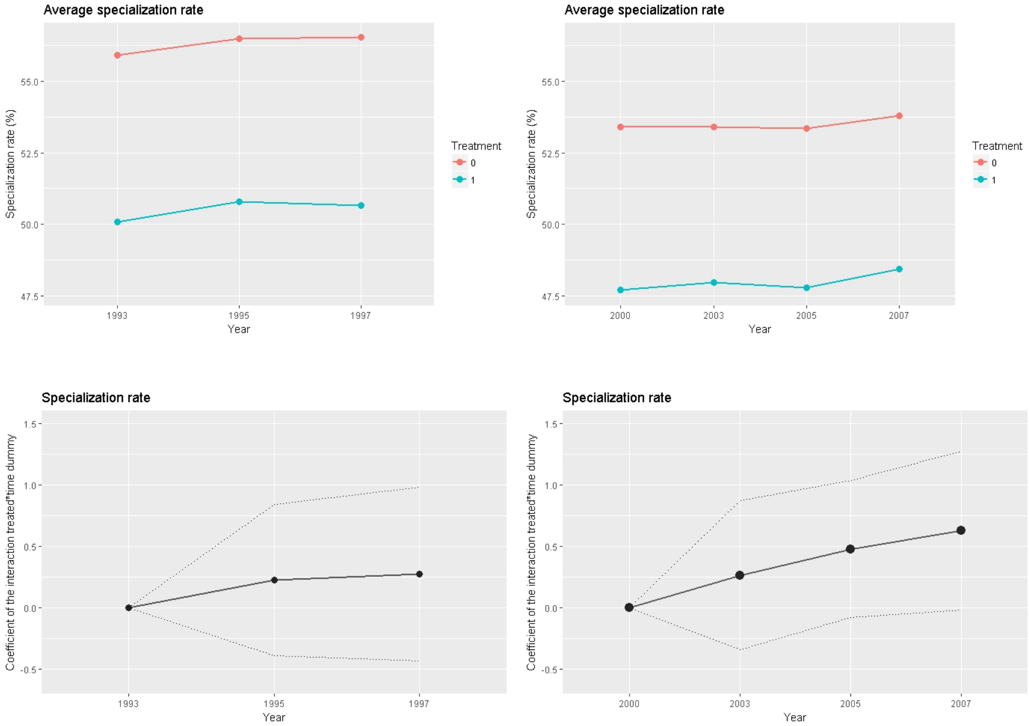
(a) Placebo Test (1993-1997) (b) Treatment Effect (2000-2007)

Figure 6: (i) Trends in the average share of crop area in total utilised agricultural area by treatment status and (ii) Estimated coefficients of the interaction treated*time dummy on the share of crop area.



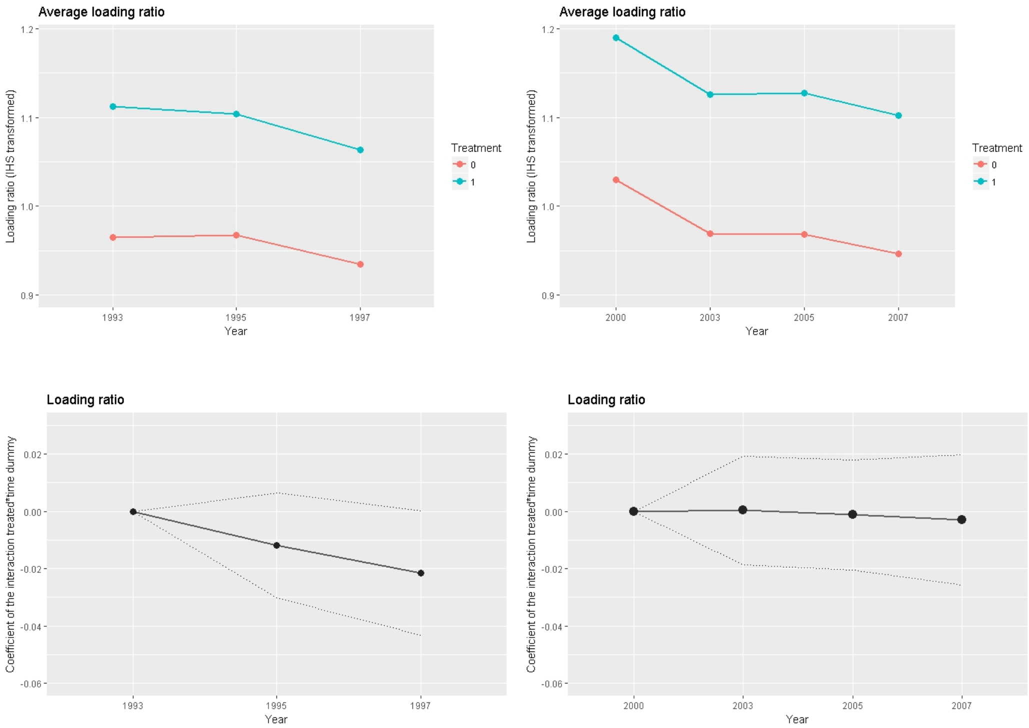
(a) Placebo Test (1993-1997) (b) Treatment Effect (2000-2007)

Figure 7: (i) Trends in the average share of fodder area in total utilised agricultural area by treatment status and (ii) Estimated coefficients of the interaction treated*time dummy on the share of fodder area.



(a) Placebo Test (1993-1997) (b) Treatment Effect (2000-2007)

Figure 8: (i) Trends in the average specialization rate by treatment status and (ii) Estimated coefficients of the interaction treated*time dummy on the specialization rate.



(a) Placebo Test (1993-1997)

(b) Treatment Effect (2000-2007)

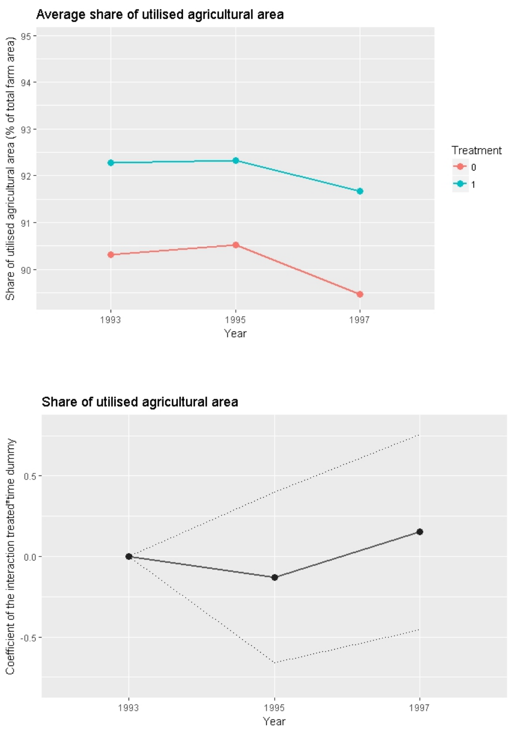
Figure 9: (i) Trends in the average loading ratio by treatment status and (ii) Estimated coefficients of the interaction treated*time dummy on the loading ratio.

Table 3: DID-FE Results: Panel A

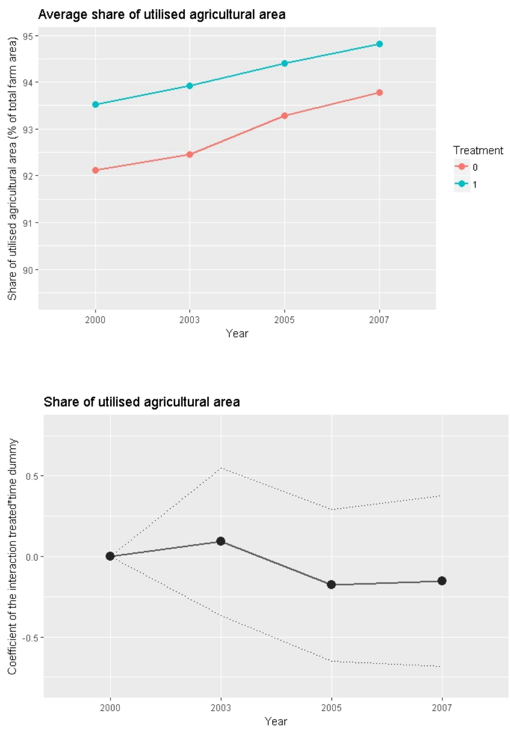
	Placebo Test (1993-1997)				**Treatment Effect (2000-2007)**			
	No DEPxTIME FE		With DEPxTIME FE		No DEPxTIME FE		With DEPxTIME FE	
	No controls	With controls	No controls	With controls	No controls	With controls	No controls	With controls
Outcome Variables								
Share of permanent grassland area	−0.44	−0.38	−0.17	−0.13	0.09	0.24	0.16	0.28
	(0.34)	(0.34)	(0.36)	(0.35)	(0.27)	(0.27)	(0.28)	(0.28)
Share of crop area	0.58	0.59	0.35	0.33	−0.33	−0.33	−0.38	−0.40
	(0.24)	(0.23)	(0.25)	(0.24)	(0.19)	(0.19)	(0.20)	(0.20)
Share of fodder area	0.12	0.11	0.08	0.07	0.01	−0.01	0.04	0.03
	(0.10)	(0.10)	(0.11)	(0.11)	(0.10)	(0.10)	(0.10)	(0.10)
Specialization rate	0.06	0.12	0.21	0.25	0.26	0.40	0.35	0.45
	(0.29)	(0.29)	(0.31)	(0.30)	(0.25)	(0.25)	(0.26)	(0.25)
Loading ratio	−0.02	−0.02	−0.02	−0.02	−0.00	−0.01	0.00	−0.00
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Observations	**9,998**	**9,998**	**9,998**	**9,998**	**10,468**	**10,468**	**10,468**	**10,468**

Note: Year and commune fixed effects estimation. Robust standard errors clustered at commune level in parenthesis. $*p < 0.1$; $**p < 0.05$; $***p < 0.01$.

D.3 Reduced Form Results: Panel B

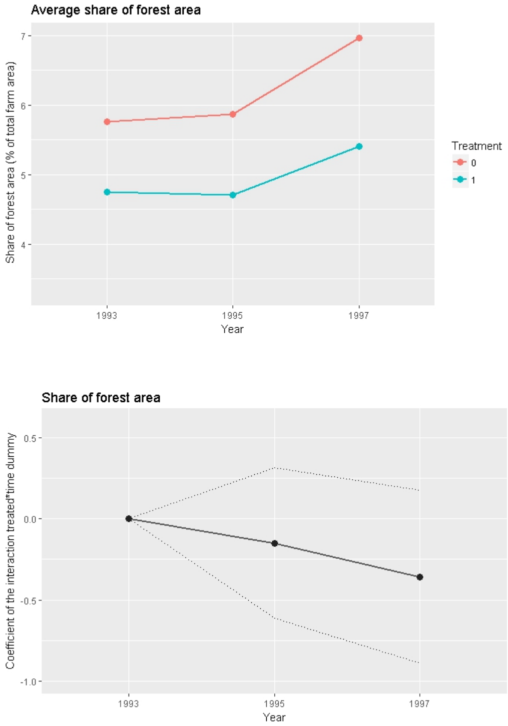


(a) Placebo Test (1993-1997)

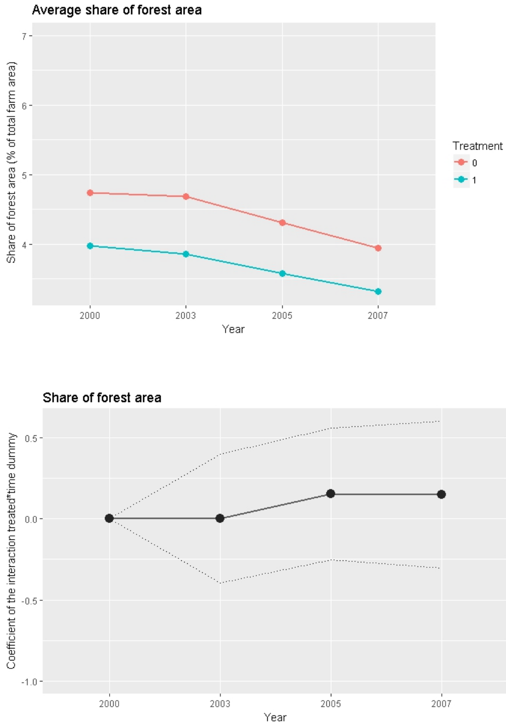


(b) Treatment Effect (2000-2007)

Figure 10: (i) Trends in the average share of utilised agricultural area in total farm area by treatment status and (ii) Estimated coefficients of the interaction treated*time dummy on the share of utilised agricultural area.

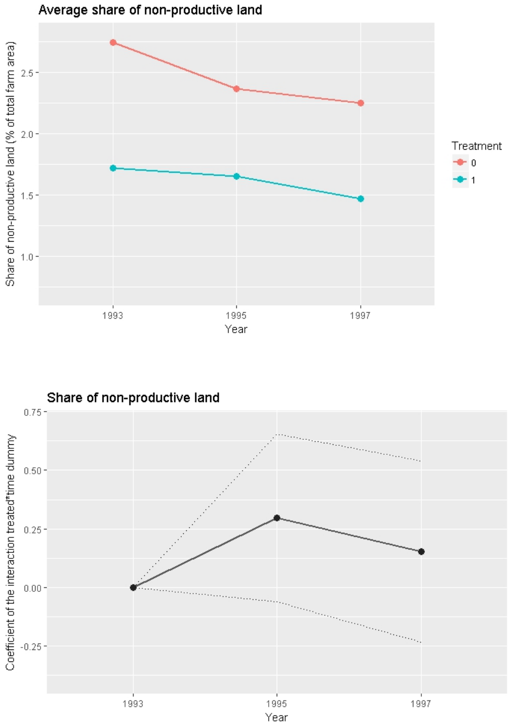


(a) Placebo Test (1993-1997)

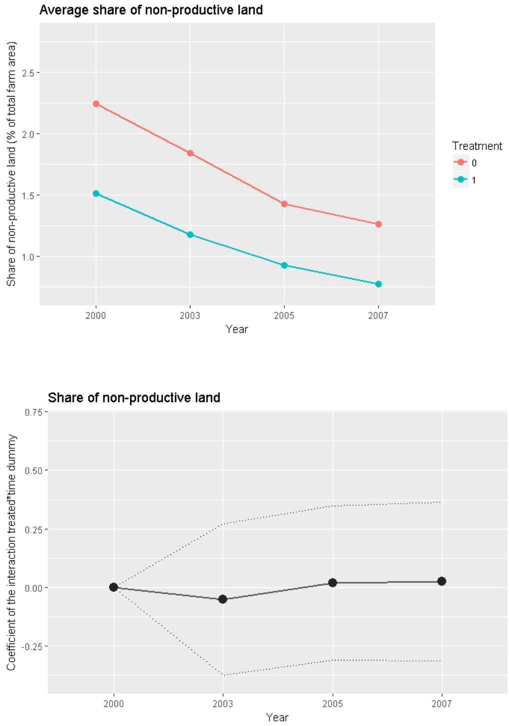


(b) Treatment Effect (2000-2007)

Figure 11: (i) Trends in the average share of forest area in total farm area by treatment status and (ii) Estimated coefficients of the interaction treated*time dummy on the share of forest area.



(a) Placebo Test (1993-1997)



(b) Treatment Effect (2000-2007)

Figure 12: (i) Trends in the average share of nonproductive land in total farm area by treatment status and (ii) Estimated coefficients of the interaction treated*time dummy on the share of nonproductive land.

Table 4: DID-FE Results: Panel B

	Placebo Test (1993-1997)				Treatment Effect (2000-2007)			
	No DEPxTIME FE		With DEPxTIME FE		No DEPxTIME FE		With DEPxTIME FE	
	No controls	With controls	No controls	With controls	No controls	With controls	No controls	With controls
Outcome Variables								
Share of utilised agricultural area	0.04	0.04	0.02	0.01	−0.19	−0.17	−0.06	−0.08
	(0.25)	(0.25)	(0.25)	(0.25)	(0.21)	(0.21)	(0.21)	(0.21)
Share of forest area	−0.34	−0.34	−0.25	−0.25	0.03	0.03	0.09	0.10
	(0.22)	(0.22)	(0.22)	(0.22)	(0.17)	(0.17)	(0.18)	(0.18)
Share of nonproductive land	0.28	0.27	0.22	0.23	0.18	0.16	−0.01	0.00
	(0.17)	(0.17)	(0.17)	(0.17)	(0.15)	(0.15)	(0.15)	(0.15)
Observations	**9,998**	**9,998**	**9,998**	**9,998**	**10,468**	**10,468**	**10,468**	**10,468**

Note: Year and commune fixed effects estimation. Robust standard errors clustered at commune level in parenthesis. *p $<$ 0.1; **p $<$0.05; ***p $<$ 0.01.

D.4 Robustness Checks

Table 5: CIC Results

	Placebo Test (1993-1997)	Treatment Effect (2000-2007)
Outcome Variables: Panel A		
Share of permanent grassland area	−0.12	0.28
	(0.34)	(0.32)
Share of crop area	0.29	−0.43
	(0.26)	(0.25)
Share of fodder area	0.15	0.00
	(0.12)	(0.13)
Specialization rate	0.23	0.46
	(0.28)	(0.30)
Loading ratio	−0.02	−0.01
	(0.01)	(0.01)
Outcome Variables: Panel B		
Share of utilised agricultural area	−0.09	−0.13
	(0.20)	(0.19)
Share of forest area	−0.32	0.04
	(0.18)	(0.16)
Share of nonproductive land	0.20	0.04
	(0.11)	(0.09)
Observations	**9,998**	**10,468**

Note: Changes-in-changes estimation. Regressions do not include fixed effects and control variables. Bootstrapped standard errors in parenthesis. *p $<$ 0.1; **p $<$0.05; ***p $<$ 0.01.

Table 6: DID-FE Results: Unbalanced Panel

	Placebo Test (1993-1997)				Treatment Effect (2000-2007)			
	No DEPxTIME FE		With DEPxTIME FE		No DEPxTIME FE		With DEPxTIME FE	
	No controls	With controls	No controls	With controls	No controls	With controls	No controls	With controls
Outcome Variables: Panel A								
Share of permanent grassland area	−0.35	−0.29	−0.08	−0.04	−0.02	0.14	0.08	0.21
	(0.35)	(0.34)	(0.36)	(0.35)	(0.27)	(0.27)	(0.28)	(0.28)
Share of crop area	0.56	0.57	0.33	0.31	−0.22	−0.23	−0.27	−0.30
	(0.24)	(0.23)	(0.25)	(0.24)	(0.20)	(0.19)	(0.21)	(0.20)
Share of fodder area	0.12	0.11	0.08	0.07	−0.01	−0.03	0.03	0.01
	(0.10)	(0.10)	(0.11)	(0.11)	(0.10)	(0.10)	(0.10)	(0.10)
Specialization rate	0.14	0.19	0.28	0.32	0.19	0.33	0.29	0.41
	(0.30)	(0.30)	(0.31)	(0.31)	(0.25)	(0.25)	(0.26)	(0.25)
Loading ratio	−0.02	−0.02	−0.02	−0.02	−0.01	−0.01	−0.00	−0.01
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Outcome Variables: Panel B								
Share of utilised agricultural area	−0.10	−0.10	−0.13	−0.13	−0.23	−0.22	−0.06	−0.09
	(0.25)	(0.25)	(0.26)	(0.26)	(0.22)	(0.22)	(0.22)	(0.22)
Share of forest area	−0.28	−0.27	−0.22	−0.22	0.04	0.04	0.09	0.11
	(0.22)	(0.22)	(0.23)	(0.23)	(0.18)	(0.18)	(0.18)	(0.18)
Share of nonproductive land	0.29	0.29	0.26	0.27	0.20	0.19	−0.01	−0.01
	(0.17)	(0.17)	(0.17)	(0.17)	(0.16)	(0.16)	(0.16)	(0.16)
Observations	**10,599**	**10,599**	**10,599**	**10,599**	**11,463**	**11,463**	**11,463**	**11,463**

Note: Year and commune fixed effects estimation. Robust standard errors clustered at commune level in parenthesis. *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

Table 7: DID-FE Results: Same Sample of Communes

	Placebo Test (1993-1997)				Treatment Effect (2000-2007)			
	No DEPxTIME FE		With DEPxTIME FE		No DEPxTIME FE		With DEPxTIME FE	
	No controls	With controls	No controls	With controls	No controls	With controls	No controls	With controls
Outcome Variables: Panel A								
Share of permanent grassland area	0.03	0.06	0.18	0.19	0.25	0.38	0.31	0.44
	(0.39)	(0.38)	(0.40)	(0.39)	(0.32)	(0.31)	(0.32)	(0.31)
Share of crop area	0.45	0.48	0.22	0.21	−0.32	−0.31	−0.36	−0.38
	(0.28)	(0.27)	(0.29)	(0.28)	(0.23)	(0.22)	(0.24)	(0.23)
Share of fodder area	0.11	0.10	0.08	0.07	0.09	0.06	0.13	0.11
	(0.12)	(0.12)	(0.12)	(0.12)	(0.12)	(0.12)	(0.12)	(0.12)
Specialization rate	0.50	0.54	0.58	0.60	0.18	0.29	0.26	0.36
	(0.34)	(0.33)	(0.34)	(0.34)	(0.30)	(0.29)	(0.30)	(0.30)
Loading ratio	−0.01	−0.01	−0.01	−0.01	0.01	0.01	0.01	0.01
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Outcome Variables: Panel B								
Share of utilised agricultural area	0.15	0.16	0.07	0.07	−0.31	−0.30	−0.23	−0.24
	(0.27)	(0.27)	(0.28)	(0.28)	(0.23)	(0.23)	(0.23)	(0.23)
Share of forest area	−0.19	−0.20	−0.09	−0.10	0.07	0.06	0.13	0.14
	(0.24)	(0.24)	(0.25)	(0.25)	(0.20)	(0.20)	(0.20)	(0.20)
Share of nonproductive land	−0.01	0.00	−0.04	−0.03	0.32	0.31	0.18	0.19
	(0.18)	(0.18)	(0.17)	(0.17)	(0.17)	(0.17)	(0.17)	(0.17)
Observations	**7,808**	**7,808**	**7,808**	**7,808**	**7,808**	**7,808**	**7,808**	**7,808**

Note: Year and commune fixed effects estimation. Robust standard errors clustered at commune level in parenthesis. *p $<$ 0.1; **p $<$0.05; ***p $<$ 0.01.

E Cost-Benefit Analysis

E.1 The Delta Method

Transformation of one variable. We denote by ω^2 the asymptotic variance of the estimated coefficient $\widetilde{\alpha}$. Then, for the regression coefficient holds $\sqrt{n}(\widetilde{\alpha}\text{-}\alpha) \xrightarrow{d} N(0, \omega^2)$. The statement of the Delta Method says that if we transform an estimator by a function g, the following property holds:

$\sqrt{n}(g(\widetilde{\alpha})\text{-}g(\alpha)) \xrightarrow{d} N(0, \omega^2 g'(\alpha)^2)$, where g' denotes the first derivative of g.

This implies that the variance of the transformed estimator is given by:

$V[g(\widetilde{\alpha})] = V[\widetilde{\alpha}] \times g'(\widetilde{\alpha})^2$.

Transformation of two variables. To approximate the variance of some multi-variable function $G = G(\widetilde{\alpha}_x, \widetilde{\alpha}_y)$, we:

- take the vector of partial derivatives of the function G with respect to each parameter in turn : $\frac{\partial G}{\partial \widetilde{\alpha}_x}$ and $\frac{\partial G}{\partial \widetilde{\alpha}_y}$;
- right-multiply this vector by the variance-covariance matrix, $\Sigma = \begin{bmatrix} Var(\widetilde{\alpha}_x) & Cov(\widetilde{\alpha}_x, \widetilde{\alpha}_y) \\ Cov(\widetilde{\alpha}_x, \widetilde{\alpha}_y) & Var(\widetilde{\alpha}_y) \end{bmatrix}$
- right-multiply the resulting product by the transpose of the original vector of partial derivatives, G^T.

What we are interested in here is the standard error of the transformed variables, which equals the square root of the estimated variance. We apply the Delta Method transformation of one variable to obtain the standard error of the additional hectares of permanent grassland area and of the total benefits in euro and the standard error of the percentage changes in grassland and money. We also use the Delta Method transformation of two variables to compute the standard errors of the elasticity estimates and the benefit-cost ratios, the standard error of the cost per additional hectare of grassland ratio and the cost per unit of averted CO_2 emission. We performed the computations in R using the "deltamethod" command from the "msm" package.

Table 8: Elasticity Estimate

Outcome	ITT estimate	% change	Elasticity
Additional hectares of grassland	3.73±7.31	0.76%±1.49%	**0.02±0.04**
Additional monetary transfers (in euro)	5,000±513	42.46%±6.21%	

Note: Estimate of the elasticity of the additional supply of grassland with respect to the additional amount of the subsidy per treated communes as a result of the French Grassland Conservation reform in 2000. The confidence interval around the estimated values is given by the formula: point estimate ± value from the standard normal distribution for the selected confidence level (i.e. 1.96) x standard error of the point estimate (computed using the Delta Method).

Table 9: Cost-Benefit Analysis

Type of CBA	**Benefits**			**Costs**	**Benefit-Cost Ratio**
	ITT estimate (ha/treated commune)	Literature estimates (euro/ha)	Total (euro/treated commune)	ITT estimate (euro/treated commune)	
Climate benefits only	3.73±7.31	253	945±1,852	5,000±513	**0.19±0.37**
All benefits	3.73±7.31	421	1,571±3,081	5,000±513	**0.31±0.62**

Note: The costs of the Grassland Conservation Program reform compared with the social benefits at commune level. The confidence interval around the estimated values is given by the formula: point estimate ± value from the standard normal distribution for the selected confidence level (i.e. 1.96) x standard error of the point estimate (computed using the Delta Method). The literature estimates come from Baudrier et al. (2015) for the climate benefits and Puydarrieux and Devaux (2013) for the other ecosystem services.