Chapter 6
United States: The environmental effects of crop production and conservation auctions

This case study focuses on the economic and environmental performance of conservation auctions *vs* traditional agri-environmental policy measures in the US. The economic and environmental effects are, however, not aggregated in this case study and no social benefit function is computed. The three alternative land-use types analysed in this application are: land retirement for environmental purposes, such as partial field buffer strips, and two alternative tillage methods to produce a cultivated crop; no-till and conventional mouldboard tillage. The Conservation Reserve Program Continuous Signup (CCRP), for example, provides partial field retirement through vegetative buffer installation along water courses to capture nutrient runoff and provide other environmental amenities. No-till and conventional tillage represent here management under the working lands programmes (such as the Environmental Quality Incentives Program, EQIP). In this application the sources of heterogeneity are both differential land productivity and environmental sensitivity of the parcels. Environmental heterogeneity is represented here by differing slopes of field parcels towards watercourse. Different field slopes result in variation in the propensity of soil to erode and nutrients and herbicides to runoff from different field parcels.

Following Aillery (2006), land retirement is usually best suited for those parcels where environmental damage due to erosion and related sediment, nutrient, and herbicide runoff would be high relative to the value of agricultural commodity production. While land retirement usually results in large environmental benefits per hectare, the programme cost of land retirement could be high since payment rate should reflect the full agricultural value of the land. This means that under a budget constraint for the agri-environmental or conservation programme larger overall environmental benefits may be obtained from a working lands programme, since it allows land to remain under production and compensation payment rates do not need to reflect the full agricultural value of land.

For working lands programmes the performance of no-till *vs* conventional mouldboard tillage is an important element of a conservation plan. Relative to conventional tillage, no-till farming is generally found to provide considerable environmental benefits in terms of reduced soil erosion, nitrogen runoff, and particulate phosphorus runoff. However, not all environmental effects of no-till are favourable relative to conventional tillage, since many studies report that dissolved (orthophosphate) phosphorus runoff may increase under no-till due to the accumulation of phosphorus in the soil surface. Moreover, no-till may increase the abundance of perennial weeds thus requiring a higher use of herbicides which may eventually increase herbicide runoff relative to conventional tillage, and no-till may also increase potential for leaching of nutrients and pesticides to groundwater. Furthermore, with regard to greenhouse gases no-till farming contributes to carbon sequestration but it may increase the emissions of nitrous oxides. Thus, from society's viewpoint no-till involves important environmental trade-offs that need to be incorporated into the analysis.

From the farmer's viewpoint no-till seems to provide unambiguous cost reductions because of lower labour requirements and fuel consumption. Capital investment and maintenance costs may also be reduced, although upfront capital requirements for new equipment can represent a barrier to adoption. Furthermore, relative to conventional tillage no-till may provide potential revenue from carbon credits in the context of carbon markets. However, no-till yields may be lower than those under conventional tillage, in particularly during the transition period (usually up to five years) to no-till before soil structure develops so that it starts to support no-till yields (*e.g.* number of macropores). Moreover, no-till requires specialised equipment, including direct planter, and it also affects the timing of planting, since "covered" soils usually take longer to dry and warm after winter period. Thus, a switch from conventional tillage to no-till farming implies a learning curve for a farmer. Thus from a farmer's viewpoint no-till involves some important economic trade-offs.

With regard to policy instruments to be analysed in this case study the main focus will be on:

- Environmental and economic performance of land retirement programme *vs* working land programmes;
- Environmental and economic performance of green auctions *vs* flat-rate agri-environmental payments; and
- The cost-effectiveness of traditional policy instruments, such as input use taxes, input application standards, and payments for conservation tillage practices and structural practices, including buffer strips between field parcels and watercourses.

For assessing the trade-offs between land retirement and working lands programmes, theoretical and empirical frameworks are developed in order to explicitly analyse relative costs and benefits. To our knowledge Feng *et al.* (2006) is the only study where land retirement and working lands programmes are analysed within a joint framework. Feng *et al.* analyse how the existence of a pre-fixed budget allocation between CRP and EQIP affects the potential environmental benefits obtained from alternative policy implementation schemes. In their empirical application based on data from Iowa they found that a working lands programme is more cost-effective than land retirement for low levels of environmental benefits measured by an index of multiple benefits. Only at high target levels of environmental benefits would it be cost-effective to enrol land into a land retirement programme. They also find that there can be large efficiency losses due to the pre-fixing of conservation budgets, regardless of whether a simultaneous or sequential implementation strategy is followed for these two programmes.

Moreover, in this application we are also interested in assessing the cost-effectiveness gains from auctions. More specifically we want to investigate the relative importance of gains received from environmental targeting (through the Environmental Benefits Index – EBI) *vs* gains received through adoption cost revelation through competitive bidding. This provides important policy implications, since if environmental targeting is the main source of cost-effectiveness gains then policy makers could implement also *e.g.* regionally differentiated payments on the basis of performance screens, such as an environmental benefit index, without bidding.

This chapter is organised as follows. The theoretical framework is developed and presented next. This is followed by a description of case study area (the US Corn Belt) and policy simulations and the results. The chapter concludes with a summary of main results.

Theoretical framework

The theoretical framework for this case study builds on that developed for green auctions in the Finnish case study and presented in Chapter 4. Thus, we follow Cattaneo *et al.* (2007) and assume that the government announces an agri-environmental payment in the form of a conservation auction programme, in which farmers bid competitively for a limited amount of conservation contracts. The programme aims to promote water quality improvements through reduction of sediment, nitrogen and phosphorus runoff from farm fields to watercourses.

To guide the bidding, the government reveals the weights given to the environmental performance, *E*, and the maximum bid payment, *R*. On the basis of farmers' bids, a single score value (*I*) will be computed for each application and the applications exceeding a cut-off value (I^c) will selected. Cut-off value is defined endogenously after the bids have been submitted.

The environmental performance of each bid with respect to surface water quality includes three measures/indicators: reduction of sediment, nitrogen and phosphorus runoff. Nutrient runoff can be reduced through reducing N and P fertilizer application rates or by establishing buffer strips between farm fields and waterways. Farmers may also adopt conservation tillage practices, such as no-till, in order to reduce both sediment and nutrient runoff.

The focus here is on practice adoption – including fertilizer application intensity, tillage practices and establishment of buffer strips – as the means of reducing both nutrient and sediment runoff. Nitrogen runoff in a given land productivity class *i*, $Z^i_{jN} = g^i_{jN}(l^i_j, m^i_j)$, for tillage practice/crop rotation/erodibility combination *j* can be expressed as a function of fertilizer use l^i_j and the share of parcel allocated to buffer strip m^i_j. Phosphorus runoff is defined similarly by $Z^i_{jP} = g^i_{jp}(l^i_j, m^i_j, \varphi^i_j)$ as a function of fertilizer use and buffer strip but it also depends on soil phosphorus status φ^i_j. Sediment runoff is given by $Z^i_{jS} = g^i_{jS}(m^i_j, \theta^i_j)$, where θ^i_j is the slope of the parcel.

Environmental performance, *E*, is a linear combination of water quality improvement benefits from reduction of nitrogen, phosphorus and sediment runoff,[1]

$$E^i_j(l,m) = \alpha Z_N(l,m) + \beta Z_P(l,m) + \gamma Z_S(m), \qquad (1)$$

with $0 < \alpha, \beta, \gamma < 1$ and $\alpha + \beta + \gamma = 1$ and $0 < E(l,m) \leq 1$.

Moreover,

$$E_l = \alpha Z_l + \beta Z_l < 0 \tag{2a}$$

$$E_m = \alpha Z_m + \beta Z_m + \gamma Z_m > 0 \tag{2b}$$

As in the Finnish case study, the score value I depends on the environmental performance E and the payment r required by the farmer relative to the maximum payment as a function of environmental benefit provided, $R(E)$. Moreover, the score value is defined as a share of the maximum obtainable score value, denoted by $\bar{I}$. Let ω_e and ω_r denote the weights given to the environmental performance and the payment required, respectively. Like above, $0 < \omega_e, \omega_r < 1$ and $\omega_e + \omega_r = 1$. Now, the score value can be expressed as,

$$I = \left[\omega_e E + \omega_r (1 - \frac{r}{R(E)}) \right] \bar{I} \, . \tag{3}$$

Thus, equation (3) says that the score value of each bid is a share ($0 < I \leq \bar{I}$) of the maximum obtainable score value. Clearly, it increases with environmental performance and decreases with bid.

Farmers form their bids following the above rules. To become accepted into the programme a farmer's application's index score must be above the endogenously determined cut-off value. Obviously, the farmer's bidding strategy will be guided by expectations about this cut-off value. It is assumed that the farmers are risk-neutral, so that they focus on expected values only. Thus, the farmer will submit a bid if the expected profit from participating exceeds the profits under the private optimum. The expected profits depend on the probability of being accepted in the programme. Let $\underline{I}$ denote the minimum index value to have a chance at entering the programme. Then the probability of being accepted to the programme is defined by

$$P(I > I^c) = \int_{\underline{I}}^{I} f(I) dI = F(I) \, . \tag{4}$$

Now, the farmer's expected profits can be expressed as,

$$E\pi_j^i \equiv \Pi = \left[\pi_1(l,m) - \pi_0^* + r(l,m) \right] F(I) \, . \tag{5}$$

Let $\pi_0^* = pf(l^*) - cl^* - \Omega - \mathrm{K}$ denote the farmer's profits under the privately optimal solution, with l^* the optimal fertilizer application, p denotes crop price, c denotes fertilizer price, Ω represents other variable costs of cultivation except fertilizer, and K denotes fixed capital costs. The profits under the working lands agri-environmental payment programme are conditional on the choices of fertilizer application rate l and buffer strip size m and are given as $\pi_1 = (1-m)\left[pf(l) - cl - \Omega\right] - \mathrm{K}$. Fixed capital costs of cultivation are thus not dependent on buffer strip size.

In the case of working lands payment programme the economic problem of the farmer is to choose l and m (and thereby the bid r) for a given land productivity class i and production system j so as to maximise the expected profits (5) from the bid subject to (3) and the obvious constraints $E_j^i(l,m) \leq 1$ and $r_j^i \leq R$. The Lagrangean for the problem is,

$$L = \left[\pi_1(l,m) - \pi_0^* + r(l,m)\right]F(I) + \lambda_r(R-r) + \lambda_E(1-E) \qquad (6)$$

At an interior solution the Lagrange multipliers are zero and the first-order conditions can be expressed as

$$l^0: \quad (1-m)\left[pf_l - c\right] + r_l = -\left[\omega_e E_l + \omega_r \frac{rR_l}{R^2}\right]\frac{F'(I)}{F(I)}\Phi\bar{I} \qquad (7a)$$

$$m^0: \quad -\left[pf(l) - cl - \Omega\right] + r_m = -\left[\omega_e E_m + \omega_r \frac{rR_m}{R^2}\right]\frac{F'(I)}{F(I)}\Phi\bar{I} \qquad (7b)$$

where $\Phi = (1-m)\left[pf(l) - cl - \Omega\right] - \mathrm{K} + r(l,m) - \pi_0^*$. In both necessary conditions for the optimum, the LHS term indicates the economic costs of providing environmental goods to the programme and the RHS term indicates the expected return, that is, the effects of l and m on the score index and on the acceptance probability. In (7a), RHS bracket term is positive, so that the LHS bracket term must be positive, too, and greater than r_l, which is negative. In (7b), the RHS bracket term is negative, so that the negative LHS bracket term is greater than r_m. Conditions (7a) and (7b) provide interior solution for optimal input-use intensity under the working lands programme, that is, a programme that provides incentives for adjusting input use towards more environmentally friendly practices and outcomes on cultivated lands.

Given the above framework for green auctions in working lands raises a question whether a land retirement type of agri-environmental payment programme could be incorporated into this same theoretical frame? The answer is yes since for each land productivity class i and production system j a farmer compares the profits from participation in working lands programme $\pi_1(l^*, m^*) + r(l^*, m^*)$ with corresponding profits from participation in land retirement programme, $\pi_2(m=1, l=0) + r(l,m)$. Thus, in the case of land retirement we end up with a corner solution where whole parcel is allocated to "buffer", that is *m=1* and fertilizer use is zero (*l=0*)[2].

In the first stage, in each differential land productivity and environmental heterogeneity parcel, the farmer compares profits obtained from participating in land retirement compared to the working lands programme and then selects the option with highest profits. In the second stage, the farmer compares those profits with the profits obtained in the private optimum, $\pi_0^*(m=0, l^0)$ and decides whether or not he or she participates in the agri-environmental payment programme.

Empirical application on the basis of the US Corn Belt

The Corn Belt has been selected as the US case study area for the following reasons:

- A good mix of no-till and conventional moldboard tillage in the region, with substantial no-till and conventional/moldboard tillage acreage in major crops (corn and soybean) produced.
- A significant amount of CRP area in the region.
- A single region in the Regional Environment and Agriculture Programming Model (REAP) hosted by Economic Research Service of the United States Department of Agriculture.

The REAP model defines representative crop rotations by region, which are used to capture differences in yield, cost, and environmental coefficients. Two representative crop rotations for the Corn Belt region are selected: continuous corn and corn-soybean. The REAP model defines acreage share in Highly Erodible Lands (HEL) and Non-Highly Erodible Lands (NonHEL), with differentiation in model yield, cost and environmental coefficients.

Cost data for this case study were obtained from the ARMS cost-of-production estimates and other data sources, such as the World Resources Institute (WRI). Most of the cost items vary by tillage practice (no-till and conventional moldboard tillage). Primary cost items include: fertilizer, herbicide, machinery, fuel, and labour costs, and land rents.

With regard to environmental effects and parameters the data is generated by the EPIC (Environmental Policy Integrated Climate Model). EPIC is a crop biophysical simulation model that is used to estimate the effect of management practices on crop yields, soil quality, and environmental effects at field parcel level. Environmental data provided by EPIC includes: i) soil erosion; ii) nitrogen lost in solution; iii) nitrogen lost in sediment; iv) total nitrogen loss; v) phosphate lost in solution; vi) phosphate lost in sediment; vii) total phosphate loss; viii) pesticide runoff; and(ix) changes in soil carbon.

On the basis of above data the basic model and two auction models for working lands simulations has been developed as follows.

Crop production

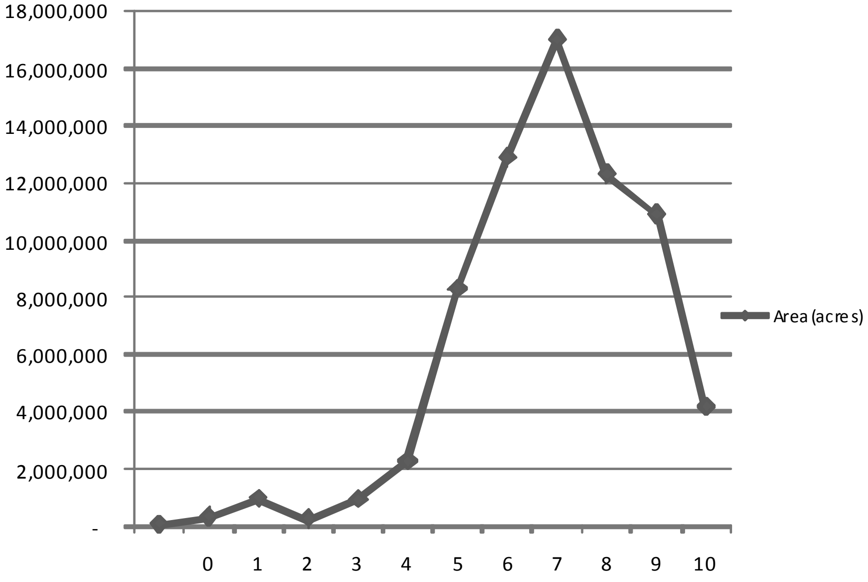
Crop nitrogen response functions (quadratic specification: a+bN-cN^2) estimated with US data were calibrated with data for eight crop/rotation/tillage/erodibility combinations with known nitrogen application level and with known yield level (see Table 6.1 for a description of eight production systems). The original value of parameter *b* from published research was retained in Nitrogen response function and then parameters *a* and *c* were solved to correspond to known nitrogen (N) application level and yield level for each combination. Thus eight Nitrogen response functions were obtained (one per each combination). It was then assumed that these response functions (and parameters) represent mean level of productivity in the case study region. On the basis of land productivity distribution in the study area (see Figure 6.1) seven land productivity classes were developed (by combining six first classes). These seven productivity classes were incorporated into the model as follows. The above-mentioned calibrated response functions were assumed to represent the mean productivity. By keeping *a* and *c* at their levels solved, the parameter *b* was solved so that there would +/- 5% change of yield (productivity) per one index point so that productivity difference would range from -15% to +15% around the mean. This provides altogether around 60 differential combinations of land productivity/crop/rotation/tillage/erodibility combinations.

Table 6.1. Descriptive abbreviation for different crop/tillage/erodibility combinations

Descriptive abbreviation	Crop(s)	Tillage method	Erodibility classification
HEL_MLD_Corn	Corn	Mouldboard	Highly erodible
HEL_NLL_Corn	Corn	No-till	Highly erodible
HEL_MLD_Corn/soy	Corn/soy	Mouldboard	Highly erodible
HEL_NLL_Corn/soy	Corn/soy	No-till	Highly erodible
NonHEL_MLD_Corn	Corn	Mouldboard	Non-highly erodible
NonHEL_NLL_Corn	Corn	No-till	Non-highly erodible
NonHEL_MLD_Corn/soy	Corn/soy	Mouldboard	Non-highly erodible
NonHEL_NLL_Corn/soy	Corn/soy	No-till	Non-highly erodible

Source: Author's classification.

Figure 6.1. Soil productivity by National Commodity Crop Productivity Index Land Class



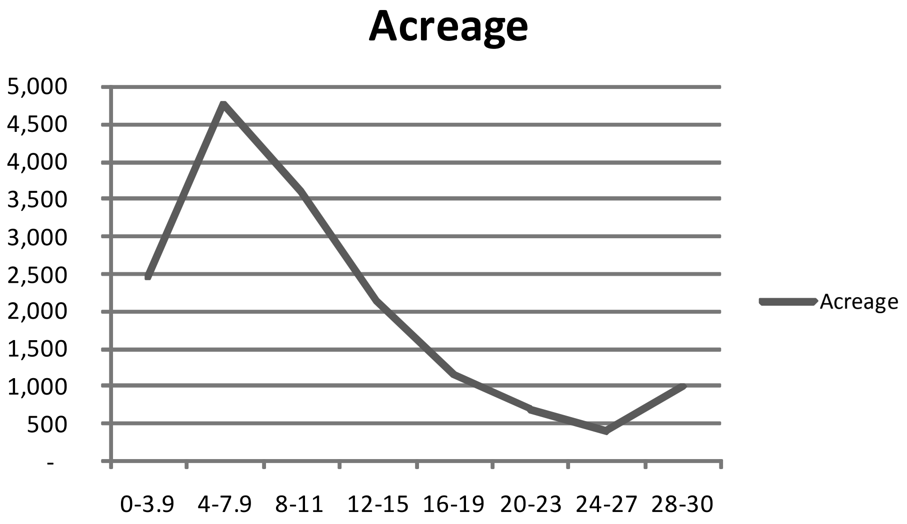
Source: Author's calculations.

Environmental process functions

On the basis of EPIC data the Secretariat has estimated functional expressions for nitrogen runoff, P-in solution runoff and P-in sediment runoff, and general sediment runoff. These functions provide the core of the environmental component of the model.

To connect the data on soil productivity and soil erodibility we apply the shares of HEL/nonHEL (Erodibility Index ≥8) and nonHEL (Erodibility Index <8) area and assume that this corresponds to the category 8-8.9 annual tonnes of soil erosion in the USLE range for the study region (see Figure 6.2). This gives a distribution in which the share of nonHEL land 88% and HEL land is 12%. Based on this information, the total acreage of HEL is about 8.5 million acres and the total acreage of nonHEL land 62 million acres.

Figure 6.2. Distribution of acreage by the USLE soil-loss category (HEL land)



Source: Author's calculations.

Environmental benefit index (EBI)

Corn Belt specific EBI weights (Cattaneo *et al.*, 2005) were used to construct a surface water quality based EBI, which is based on the weights given for Nitrogen (weight 0.22), Phosphorus (weight 0.22) and Sediment (weight 0.56) runoff plus each parcel's relative impact on these three types of runoff (as a function of nitrogen and phosphorus application intensity, tillage practices, and buffer strip widths).

We follow Cattaneo *et al.* (2005) and Claassen *et al.* (2007) and derive relative damage estimates (RDEs) for each type of runoff (nitrogen, phosphorus, and sediment) on the basis of edge-of-field runoff. Production systems with low relative damage estimates (RDEs) indicate more environmentally friendly practices and those with high estimates contribute higher quantities of pollutant runoff to watercourses. Relative damage estimates are converted to a 0-1 impact index (I_{kij}) for each runoff type:

$$I_{kij} = \left(\frac{RDE_{kij} - \min(RDE_j)}{\max(RDE_j) - \min(RDE_j)} \right) \tag{8}$$

where min(RDEj) and max(RDEj) are the minimum and maximum damage estimates across all production systems *i* and parcels *k* for the *j*th runoff type (Cattaneo *et al.,* 2005).

Environmental indices can be specified as indices of potential environmental gain or environmental performance (Claassen *et al.*, 2007). For indices that measure potential gain, a high value shows high potential for environmental damage in the absence of abatement measures or alternatively potential for lost opportunity to improve environmental performance in the absence of environmental measures. Environmental performance index is a mirror image since index value is high when there is small opportunity for environmental gain (Claassen *et al.*, 2007). That is, when environmental performance is high, further environmental gain from measures is low.

In our analysis a performance based index is used; however, basic index calculations are for potential gain type index. Thus we follow Claassen *et al.* (2007) and convert environmental gain index to performance index as given by equation (9)

$$S_f = \max(I) - I_f \tag{9}$$

where S_f is performance-based index value for farm *f*, I_f is the potential environmental gain index value for farm and max(*I*) is the largest possible value of *I*.

Policy simulations

Alternative policy experiments in this case study are listed and described in Table 6.2. The level of the instruments is fixed arbitrarily (unless otherwise stated).

As can be seen from Table 6.2, all together 10 different policy instruments/instrument combinations are analysed and compared to the benchmark of private optimum.

Results

We start by reporting the results for the benchmark case of private optimum. The US case study model incorporates all variable and fixed costs related to each of eight different combinations of crop/rotation/tillage/erodibility (production units) and on the basis of these farmers’ profits are calculated. Choice variable is nitrogen application and phosphorus application is determined on the basis of nitrogen application by assumption of fixed proportions (different for each combination) of these main nutrients in fertilizers as given by our data. Table 6.3 shows both the variable and fixed production cost items for representative production units under mean level of land productivity.

As can be seen from Table 6.4, representative production systems/units vary greatly as regards different production cost items. As empirical research has shown no-till farming entails much smaller energy (fuel) and labour costs than conventional tillage. On the other hand chemical costs are higher due to increased need to control perennial weeds under no-till.

Table 6.2. Policy experiments

Policy	Characteristics
Benchmark	
Private Optimum	No government policy intervention. Serves as a benchmark for policy experiments as regards profits and environmental performance.
Traditional regulatory and economic policy instruments	
Mandatory buffer	Regulation mandating a 2.5% buffer strip between field parcel and watercourse.
Nitrogen fertilizer tax	Fertilizer tax of 25% on the price of chemical nitrogen fertilizer.
Combination of nitrogen fertilizer tax and mandatory buffer strip	Fertilizer tax of 25% on the price of chemical nitrogen fertilizer combined with 2.5% mandatory buffer strip.
Nitrogen fertilizer application limit	Nitrogen fertilizer application limit of 100 lbs/acre.
Nitrogen fertilizer application limit and mandatory buffer	Nitrogen fertilizer application limit of 100 lbs/acre and mandatory 2.5% buffer strip.
Conservation auctions	
Conservation Auction I	Discriminatory pricing auction focusing on buffer strip establishment and fertilizer use reduction on working lands.
Conservation Auction II	Uniform pricing auction focusing on fertilizer use reduction on working lands.
Conservation Auction IIIa	Discriminatory pricing auction focusing on fertilizer use reduction on working lands with equal weights (0.5) for environmental benefits and cost factors.
Conservation Auction IIIb	Discriminatory pricing auction focusing on fertilizer use reduction on working lands with differential weights for environmental benefits (0.99) and cost factors (0.01).
Conservation Auction IIIc	Discriminatory pricing auction focusing on fertilizer use reduction on working lands with differential weights for environmental benefits (0.01) and cost factors (0.99).

Source: Author's classification.

Table 6.3. Variable and fixed costs of cultivation for different production systems/units under mean productivity

Descriptive abbreviation	Variable costs USD/acre					Fixed costs USD/acre	
	Phosphate	Energy	Chemical	Labour	Other	Land	Other
HEL_MLD_Corn	11.32	9.86	12.60	10.27	73.46	119.00	53.96
HEL_NLL_Corn	13.07	4.82	16.20	6.92	87.02	119.00	51.28
HEL_MLD_Corn/soy	2.14	8.81	11.66	8.53	68.83	119.00	48.82
HEL_NLL_Corn/soy	13.73	4.20	15.37	5.59	75.09	119.00	46.76
NonHEL_MLD_Corn	11.06	9.86	22.04	10.27	73.12	119.00	54.61
NonHEL_NLL_Corn	13.07	4.82	17.16	6.92	74.47	119.00	51.08
NonHEL_MLD_Corn/soy	3.36	8.81	11.66	8.53	60.45	119.00	48.69
NonHEL_NLL_Corn/soy	13.73	4.20	15.37	5.59	63.50	119.00	46.56

Source: Author's calculations.

Table 6.4. Private optimum: Input use, production, profits and environmental impacts under mean productivity

Production system	Crop yield tonnes/acre	Nitrogen applied lbs/acre	Nitrogen runoff lbs/acre	Phosphorus applied lbs/acre	Phosphorus runoff lbs/acre	Soil erosion tonnes/acre	Profit USD/acre
HEL_MLD_Corn	2.51	104	15.3	0.3	0.5	9.3	119.6
HEL_NLL_Corn	3.76	120	2.0	29.7	6.8	2.4	333.5
HEL_MLD_Corn/soy	4.10	54	6.3	4.9	0.9	9.8	303.8
HEL_NLL_Corn/soy	4.66	68	1.2	31.2	7.3	2.8	360.9
NonHEL_MLD_Corn	4.27	145	25.0	25.1	7.6	8.0	410.3
NonHEL_NLL_Corn	4.27	120	2.1	29.7	8.4	1.8	448.8
NonHEL_MLD_Corn/soy	5.14	54	6.4	7.6	5.2	8.2	494.7
NonHEL_NLL_Corn/soy	5.66	68	1.4	31.2	8.7	2.0	528.3

Source: Author's calculations.

Table 6.4 shows input use, production, profits and environmental impacts under the privately optimal solution without government intervention. In reviewing yields obtained under different production systems/units, an interesting feature is that no-till yields are higher than yields under conventional tillage when comparison is made within the same rotation and erodibility category. On the other hand yields are higher for NonHEL lands than HEL lands. As regards input-use intensity there is a significant variation between different production systems so that no-till is more intensive as regards nitrogen application than conventional tillage in all but one case (NonHEL_MLD_Corn). Phosphorus application is determined on the basis of nitrogen application by assumption of fixed proportions, but it is different for each production system and thus there are quite significant differences across systems as regards phosphorus application intensity.

Table 6.4 shows that despite higher nitrogen application intensity in no-till farming, the nitrogen runoff is clearly lower than under conventional tillage, while the opposite holds in the case of phosphorus runoff. Soil sediment erosion is naturally much lower in NonHEL lands than under HEL lands and it is also lower in no-till farming relative to conventional tillage. Farmers' profits are consistently higher under no-till than conventional tillage, and they are also much higher for NonHEL lands than HEL lands.

Analysis of traditional policy instruments

As regards the analysed policy instruments and their environmental and economic impacts, Table 6.5 compares two basic policy instruments to address surface water quality issues, namely the establishment of mandatory buffer strips (2.5% of cultivated area) and setting a tax on chemical nitrogen fertilizer (25%).

Table 6.5. Results: 2.5% buffer strip requirement and 25% tax on fertilizer price

	Buffer strip (2.5 %)				Fertilizer tax (25 %)			
Production system	Nitrogen runoff	Phosphorus runoff	Soil erosion	Profits	Nitrogen runoff	Phosphorus runoff	Soil erosion	Profits
	lbs/acre	lbs/acre	tonnes/acre	USD/acre	lbs/acre	lbs/acre	tonnes/acre	USD/acre
HEL_MLD_Corn	10.5	0.4	6.5	116.6	15.0	0.5	9.3	119.4
HEL_NLL_Corn	1.4	5.8	1.7	325.1	2.0	6.6	2.4	333.4
HEL_MLD_Corn/soy	4.3	0.8	6.8	296.2	6.2	0.9	9.8	303.8
HEL_NLL_Corn/soy	0.8	6.3	1.9	351.9	1.2	7.2	2.8	361.0
NonHEL_MLD_Corn	17.1	6.5	5.5	400.1	24.4	7.6	8.0	410.2
NonHEL_NLL_Corn	1.4	7.2	1.2	437.6	2.1	8.4	1.8	448.8
NonHEL_MLD_Corn/soy	4.4	4.5	5.7	482.3	6.4	5.2	8.2	494.6
NonHEL_NLL_Corn/soy	0.9	7.5	1.4	515.1	1.3	8.7	2.0	528.4

Source: Author's calculations.

As can be seen from Table 6.5, the establishment of mandatory buffers of 2.5% of cultivated area in each field parcel is quite effective as regards both nutrient runoff reduction and erosion control.[3] When compared to private optimum, farmers' profits are reduced by 2.5% while nitrogen runoff decreases over 31%, phosphorus runoff by almost 15% and soil erosion by almost 31%. Thus, mandatory buffer seem to provide quite cost-effective policy intervention for addressing water quality issues. The story is quite different in the case of fertilizer tax, however, and indeed our results just confirm the well established empirical result that fertilizer taxes need to be quite high to be effective as regards nutrient runoff reduction. As Table 6.5 shows, a 25% tax on nitrogen fertilizer has almost zero impact on farmers' profits while reducing nitrogen runoff on average by only 1.3% and phosphorus runoff less than 1%.

Table 6.6 shows the effectiveness of instrument mixes/combinations to reduce nutrient runoff and soil erosion. In theory both of these instrument-mixes should perform well, since the instruments combined do complement each other in reducing nutrient runoff, that is, fertilizer tax or application limit reduces fertilizer application while buffer strips reduce the surface runoff nutrients. However, results in Table 6.6 show that the instrument mix combining mandatory buffer and fertilizer tax mainly relies on buffer strips as regards the environmental effectiveness because additional gain over the single instrument policy of mandatory buffer is quite marginal (additional gain is only 1% or so). The combination of nitrogen application limit (100 lbs/acre) and mandatory buffer provides the instrument combination with much more additional gain over the single-instrument mandatory buffer strip. With on average 9% reduction of farmers' profits, nitrogen runoff is reduced by 39.5% and phosphorus runoff by 21.2%.

Table 6.6. Results: Combination of nitrogen tax and buffer strip and combination of nitrogen application limit and buffer strip

	Nitrogen tax and buffer strip				Nitrogen application limit and buffer strip			
	Nitrogen runoff	Phosphorus runoff	Soil erosion	Profits	Nitrogen runoff	Phosphorus runoff	Soil erosion	Profits
Production system	lbs/acre	lbs/acre	tonnes/acre	USD/acre	lbs/acre	lbs/acre	tonnes/acre	USD/acre
HEL_MLD_Corn	10.3	0.4	6.5	116.4	9.8	0.4	6.5	115.2
HEL_NLL_Corn	1.4	5.7	1.7	325.1	1.1	4.4	1.7	293.3
HEL_MLD_Corn/soy	4.3	0.8	6.8	296.2	4.3	0.8	6.8	296.2
HEL_NLL_Corn/soy	0.8	6.1	1.9	352	0.8	5.8	1.9	351.9
NonHEL_MLD_Corn	16.7	6.5	5.5	400	8.8	5.5	5.5	258.7
NonHEL_NLL_Corn	1.4	7.1	1.2	437.6	1.2	6.4	1.2	405.8
NonHEL_MLD_Corn/soy	4.4	4.5	5.7	482.3	4.4	4.5	5.7	482.3
NonHEL_NLL_Corn/soy	0.9	7.4	1.4	515.2	0.9	7.3	1.4	515.1

Source: Author's calculations.

Table 6.7 presents average abatement costs (USD/lb of N runoff) for alternative basic policy instruments including mandatory buffer, nitrogen application limit, and the instrument combinations of nitrogen tax with buffer strip, and nitrogen application limit with buffer strip.

Table 6.7 shows that there is a huge variation in the average abatement costs both across production systems and across policy instruments. However, one should note that if nitrogen application limit is not binding (shown by zero adoption cost) then the average abatement cost is mainly driven by adoption cost of establishing mandatory buffer. This can be seen for example, in the case of following production systems: HEL_MLD_Corn/soy, HEL_NLL_Corn/soy, NonHEL_MLD_Corn/soy, and NonHEL_NLL_Corn/soy. However, clearly the average abatement costs are much higher for the more profitable tillage practice no-till.

Analysis of conservation auctions

After analysing conventional policy instruments and instrument combinations it is time to analyse how new policy approaches, namely alternative types of conservation auctions, perform relative to the private optimum and traditional agri-environmental policy instruments.

Table 6.7. Average abatement cost (USD/lb of N runoff) for alternative policy scenarios

Production system	Average abatement cost, USD/lb of N runoff Mandatory buffer	N application limit	N Tax + buffer	N limit + buffer
HEL_MLD_Corn	1	1	1	1
HEL_NLL_Corn	13	92	13	46
HEL_MLD_Corn/soy	4	0	4	4
HEL_NLL_Corn/soy	24	0	24	23
NonHEL_MLD_Corn	1	12	1	9
NonHEL_NLL_Corn	17	102	17	49
NonHEL_MLD_Corn/soy	6	0	6	6
NonHEL_NLL_Corn/soy	31	0	30	30

Source: Author's calculations.

Table 6.8 shows basic results for *Conservation Auction II* that employs uniform pricing payment format and focuses on nitrogen application reduction in different production units under mean productivity and erosion. It is supposed that the farmers estimated adoption costs are equal their true adoption costs which may not always be the case in practice.

Table 6.8. Results for uniform pricing auction

Production system	Private N application	Auction N application	CC_env	Bid value USD	Environ-mental performance	Benefit/ cost ratio
HEL_MLD_Corn	104	100	1.4	1.4	0.342	0.2
HEL_NLL_Corn	120	100	32.6	32.6	0.608	0.0
HEL_MLD_Corn/soy	54	54	0.1	0.1	0.379	5.0
HEL_NLL_Corn/soy	68	65	1.0	1.0	0.560	0.6
NonHEL_MLD_Corn	145	100	145.0	145.0	0.259	0.0
NonHEL_NLL_Corn	120	100	32.6	32.6	0.577	0.0
NonHEL_MLD_Corn/soy	54	53	0.1	0.1	0.334	5.7
NonHEL_NLL_Corn/soy	68	66	0.3	0.3	0.543	1.8

Source: Author's calculations.

As Table 6.8 shows, the uniform price auction reveals farmers' true adoption costs since all production units bid exactly the amount of their true adoption cost for nitrogen use reduction. As regards the last two columns dealing with environmental performance and benefit-cost ratio (B_i/C_i) of each bid one can see that relative ranking of bids would be different if targeting would be based on environmental performance or benefits instead of a benefit-cost ratio.

Tables 6.9 and 6.10 introduce spread (range) of the basic results presented in Table 6.8 for increased (+15%) and decreased (-15%) land productivity with mean erosion.

Table 6.9. **Uniform price auction with -15% decrease in land productivity**

Production system	Productivity	Private N application	Auction N application	CC_env	Bid value USD	Environ-mental performance	Benefit/ cost ratio
HEL_MLD_Corn	-15%	100	98	0.4	0.4	0.346	0.9
HEL_NLL_Corn	-15%	114	100	17.1	17.1	0.608	0.0
HEL_MLD_Corn/soy	-15%	50	49	0.1	0.1	0.384	6.0
HEL_NLL_Corn/soy	-15%	63	60	0.8	0.8	0.579	0.7
NonHEL_MLD_Corn	-15%	139	100	108.5	108.5	0.259	0.0
NonHEL_NLL_Corn	-15%	114	100	15.4	15.4	0.577	0.0
NonHEL_MLD_Corn/soy	-15%	48	47	0.1	0.1	0.340	6.6
NonHEL_NLL_Corn/soy	-15%	62	60	0.3	0.3	0.558	2.2

Source: Author's calculations.

Table 6.10. **Uniform price auction with +15% decrease in land productivity**

Production system	Productivity	Private N application	Auction N application	CC_env	Bid value USD	Environ-mental performance	Benefit/ cost ratio
HEL_MLD_Corn	15%	107	100	5.4	5.4	0.342	0.1
HEL_NLL_Corn	15%	125	100	53.1	53.1	0.608	0.0
HEL_MLD_Corn/soy	15%	59	58	0.1	0.1	0.373	4.2
HEL_NLL_Corn/soy	15%	73	69	1.3	1.3	0.538	0.4
NonHEL_MLD_Corn	15%	151	100	186.9	186.9	0.259	0.0
NonHEL_NLL_Corn	15%	126	100	56.3	56.3	0.577	0.0
NonHEL_MLD_Corn/soy	15%	59	58	0.1	0.1	0.327	4.8
NonHEL_NLL_Corn/soy	15%	74	72	0.4	0.4	0.528	1.5

Source: Author's calculations.

Tables 6.9 and 6.10 show that increase in land productivity (from -15% to +15% around mean productivity) increases privately optimal fertilizer application and thus it increases opportunity costs of environmental measures (adoption costs). Thus, farmers' bids are much higher (on average over 200% higher) while environmental performance is decreased 3% and benefit-cost ratio is weakened by 51%.

Table 6.11 combines 11 simulations and these simulations are all discriminatory payment format auctions but they differ as regards weight given for environmental performance and bid. The results are expressed as average values for eight production systems with mean land productivity and erosion.

Table 6.11. Discriminatory payment auction: impact of weights for auction performance

Auction	N_env	CC_env	Bid	Environmental performance	B/C
Environment	78.7	27.3	190.8	0.452	0.0024
Environment 0.9, Cost 0.1	78.7	27.3	190.8	0.452	0.0024
Environment 0.8, Cost 0.2	78.7	27.3	190.8	0.452	0.0024
Environment 0.7, Cost 0.3	78.9	27.2	184.7	0.452	0.0024
Environment 0.6, Cost 0.4	79.3	26.9	170.2	0.451	0.0027
Environment 0.5, Cost 0.5	79.6	26.6	151.4	0.450	0.0030
Environment 0.4, Cost 0.6	79.8	26.5	137.2	0.450	0.0033
Environment 0.3, Cost 0.7	80.0	26.5	127.0	0.449	0.0035
Environment 0.2, Cost 0.8	80.1	26.5	119.3	0.449	0.0038
Environment 0.1, Cost 0.9	80.2	26.4	113.4	0.448	0.0040
Cost	80.2	26.4	109.0	0.448	0.0041

Source: Author's calculations.

Table 6.11 shows how assuming different weights affects auction markets and resulting environmental responses. Placing more weight to environmental performance naturally reduces nitrogen fertilizer application and increases adoption costs and thus also farmers' bids. Environmental performance slightly increases, however, it is dominated by the increase in costs and thus benefit-cost ratio worsens slightly. And when higher weight is assumed for cost/bid then opposite holds so that nitrogen fertilizer application slightly increases, adoption costs and bids decrease, and environmental performance slightly decreases while a benefit-cost ratio improves slightly.

Summary of the US case study

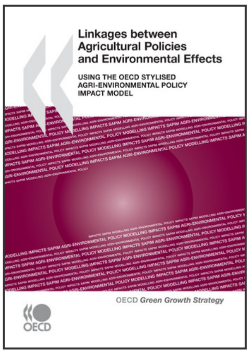
This chapter focuses on the economic and environmental performance of conservation auctions relative to more traditional agri-environmental policy measures. The economic and environmental effects are however not aggregated. In this application the sources of heterogeneity are both differential land productivity and environmental sensitivity of the land, more specifically differential propensity to erosion and thus nutrient and sediment runoff. The analysed policy instruments range from traditional regulatory and economic instruments, including fertilizer application limits and taxes to different types of conservation auctions including both uniform and discriminatory pricing types of auctions. Conservation auctions employ environmental benefit indices as environmental performance screens that help to target conservation effort to parcels that provide large environmental benefits.

As regards traditional policy instruments the regulation mandating the allocation of 2.5% of land along watercourses as vegetated buffers effectively reduces sediment and nutrient runoff with reasonably small adoption costs to farmers. The combination of a mandatory buffer with a fertilizer tax (25%) to reduce application intensity provides only small additional environmental gains over a mandatory buffer alone, while the combination of a nitrogen application standard and a buffer strip is much more effective. This result underscores the well known problem with fertilizer taxes – they need to be very high to have an impact on behaviour. Hence, the combination of a nitrogen application limit and a mandatory buffer provides the instrument combination that is superior to other traditional policy instruments.

As regards conservation auctions the application of a uniform pricing auction reveals farmers' estimated adoption costs and thus their information rent is reduced and budgetary cost-effectiveness is increased. On the other hand, a discriminatory payment format gives farmers an incentive to place their bids above their adoption costs: low adoption cost farmers have a greater incentive to do so than high adoption cost farmers. Changing the weight between environmental performance and cost/bid affects optimal fertilizer-use intensity, farmers' adoption costs, farmers' bids, and environmental performance for a given budget.

Notes

1. To avoid unnecessary notation we drop the superscript i and subscript j from the choice variables l and m.
2. It should be noted that changes in the width of buffers would not affect reductions in nutrient runoff in a linear fashion.
3. Note that buffer strips can naturally be voluntary as well, for example, through contracts.



Linkages between Agricultural Policies and Environmental Effects

Using the OECD Stylised Agri-environmental Policy Impact Model

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