SETTING PERMIT PRICES IN A TRANSFERABLE DISCHARGE PERMIT (TDP) SYSTEM FOR WATER QUALITY MANAGEMENT

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Abstract

The composite market design is a proposal for a Transferable Discharge Permit (TDP) system which specifically includes agricultural non-point source (NPS) dischargers and addresses both property rights and transaction cost problems. The first step to implementation of a composite market scheme is the estimation of a supply curve for abatement measures in the catchment area. Estimation is performed by combining costs with modeled loss reductions from selected Best Management Practices (BMPs) and then using this information to estimate the supply curve for abatement which in turn can then be used to set permit prices. The Rönneå catchment in southern Sweden is used as a pilot study area for making this type of estimate. Costs for existing measures that reduce nutrient losses from farmland (catch crops and spring planting) are based on existing programs financed by the Swedish Agricultural Board. A set of supply curves is calculated for these measures using retention estimates for seven sub-catchments and three soil types in the area. Although existing information is sufficient to calculate partial supply curves and may be used to set permit prices, additional measures should be included as well as an increased number of variables for differentiating site specific reduction costs.

Keywords: tradable permits, catchment management, NPS**. JEL code:** Q15, Q25

Introduction

Achievement of mandated water quality standards has increasingly focused on the role of nonpoint source (NPS) discharges, in particular, runoff of nutrients from agricultural activities (EPA, 2000; Horan et al, 2002). The use of TDP markets as a policy solution has been advocated both by economists and policymakers as the most promising policy alternative, the most cost effective means, of meeting environmental targets. The United States Environmental Protection Agency in a recent report (EPA, 2003) "believes that market-based approaches such as water quality trading provide greater flexibility and have potential to achieve water quality and benefits greater than would otherwise be achieved under more traditional regulatory approaches" and that "market-based programs can achieve water quality goals at a substantial economic savings". Unfortunately, as Stavins (1995) observed "In some cases, environmental policymaking has outrun our basic understanding of the new pollution control instruments".

In a TDP market, the price signal provides information to market agents, dischargers of pollution, which may be used for valuation of their decision alternatives, in particular, their decisions with respect to implementation of abatement measures. The price signal provides information about the minimum value assigned to the discharge permit by purchasers and in addition, is also an indication of their marginal abatement costs. The underlying assumptions that abatement costs per unit of emission vary among discharge sources, that information about abatement alternatives is available to the source but not to other actors and that price signals convey this information, lead to the conclusion that a TDP market offers a cost effective policy alternative for achieving discharge targets. A trading program through "introducing transferability … offers the potential for substantially lowering costs and for encouraging technological [abatement] progress" (Tietenberg, 2000). Unfortunately, the attempts to start up permit markets that are able to exploit abatement cost differences between sources have not met with the success expected (EPA, 2001). Two of the reasons for the lack of success have been the problem of transaction costs and in the case of non-point sources (NPS), undefined property rights (Collentine, 2002a).

The composite market design is a proposal for a TDP system that specifically includes agricultural NPS dischargers and addresses both property rights and transaction cost problems (Collentine, forthcoming). The composite market consists of three interrelated markets each serving a particular function. The two primary markets are coordinated through price information that makes it possible for a catchment-based authority to issue (sell) permits based on the marginal cost of abatement. When the composite market is mature, the total number of permits issued corresponds to a cap on discharges allowed in the catchment. The structure of the composite market allows this system to be phased in over time with existing institutions and limited demands on financing.

The first step to implementation of a composite market scheme is the estimation of the supply curve for abatement measures in the catchment area to be used for setting permit prices. Since an initial estimation can be adjusted as new information becomes available, the first estimation doesn't need to be comprehensive. This facilitates the use of partial information in the scheme and justifies making preliminary estimates of abatement costs based on existing programs. The method combines costs with modelled loss reductions from selected 'best management practices' (BMPs) and then uses this information to estimate the supply curve for abatement measures which can then be used to set permit prices. The Rönne River basin is used in this paper as a pilot area for illustrating the procedure for making this type of estimate. Existing agri-environmental programs in the area to reduce nitrogen losses from farmland, catch crop and spring cultivation programs financed by the Swedish Agricultural Board, are used to demonstrate the procedure.

The first section of the paper describes the three markets of the composite market system. The first of these markets, the main subject of this paper, is described in detail. This is followed by a section which describes the Rönne River basin catchment area of Southern Sweden and the agri-environmental programs that are used in the study. The next section describes how modelled leaching reduction estimates combined with program costs generate a supply curve that may be used for the pricing of permits in the Rönne River basin. The paper ends with conclusions drawn from the study and suggestions for further research and applications of the model.

The Composite Market System

The composite market disaggregates permit transactions into two primary markets and one secondary market (Figure 1). Following the typology of water quality trading programs defined by Woodward et al (2002), the composite market combines qualities of both the exchange and clearinghouse structures. In a clearinghouse structure, an institution performs a role as a broker between sellers of discharge control and buyers of the credits created. A clearinghouse precludes the need for bilateral contacts between buyer and seller by providing price information to each of these actors as well as providing a market for the individual transactions. The two primary markets serve as a clearinghouse for sellers of performance contracts and buyers of discharge permits. This greatly reduces the information transaction costs for the individual sources (Woodward et al, 2002). In addition, where marginal transaction costs are decreasing with respect to the number of transactions performed (Gangadharan, 2000) this will also result in falling costs for participation in a TDP system.

The secondary market, like an exchange, is “characterized by its open information structure and fluid transactions between buyers and seller” (Woodward et al, 2002). The public availability of information about market clearing prices ensures that information transaction costs are minimal. The liquidity in this market also makes it easy for actors to enter into and get out of transactions, which reduces the uncertainty of taking a position in the market. The combination of these effects produces an institution “very close to achieving the fully efficient allocation where any trade that would make both the buyer and seller better off is fulfilled” (Woodward et al, 2002).

A TDP system based on three markets allows permit trading to be separated into individual functional components. Because each market is designed to serve a specific purpose this increases the accuracy of the individual institution (market) in fulfilling its purpose (Horan and Ribaudo, 1999). Markets that are independent, but linked and coordinated as integrated components of a composite market, can achieve higher levels of efficiency if the costs of coordination are lower than the efficiency gains from serving targeted functions. Low information transaction costs are of particular importance at early stages of market development when market liquidity (thin markets) can lead to problems with the reliability of market price information and hinder the establishment of a viable TDP market (Laffont and Tirole, 1994). Coordination in the composite market system consists primarily of the flow of price information between the three markets illustrated in Figure 1. Setting the price for permits is the function of the first market, the primary contract market in Figure 1a.

Primary contract market: The supply curve for abatement measures

There are two types of actors active in a primary contract market. On the one hand, the supply side, there are dischargers, who through adoption of control (abatement) technology have the possibility of reducing their discharges. On the other hand, the demand side, there is a local catchment authority with a budget for purchase of discharge reducing measures. Purchases of measures by governmental agencies already take place in many catchment areas in the form of programs to induce agricultural dischargers through economic incentives (cost sharing or direct subsidies) to adopt abatement measures. The potential for least cost abatement of nutrient NPS discharges by agricultural producers is often ascribed to the adoption of these BMPs (Horan et al, 2002, Horan and Ribaudo, 1999; Gustafson et al, 1998; Shortle et al, 1998).

Support for adoption of measures may be either based on a uniform price for the measure, a subsidy or some other type of fixed or predetermined payment, or be in the form of an individualized performance contract. Under an individualized contract the level of payments is assumed to be variable but related in some way to a discharge reduction activity. Examples of existing programs which support the adoption of BMPs on farms include direct payment for taking cultivated land out of production (wetlands or buffer strips), payments to compensate for reduced expected yields (catch crops, reduced fertilization, tillage techniques or timing), cost sharing (manure storage or adaptation of drainage systems), and the provision of information through existing channels (extension services or agricultural producer organizations). These types of programs may be national but implementation is often delegated to regional institutions and accompanied by a budget for supporting them.

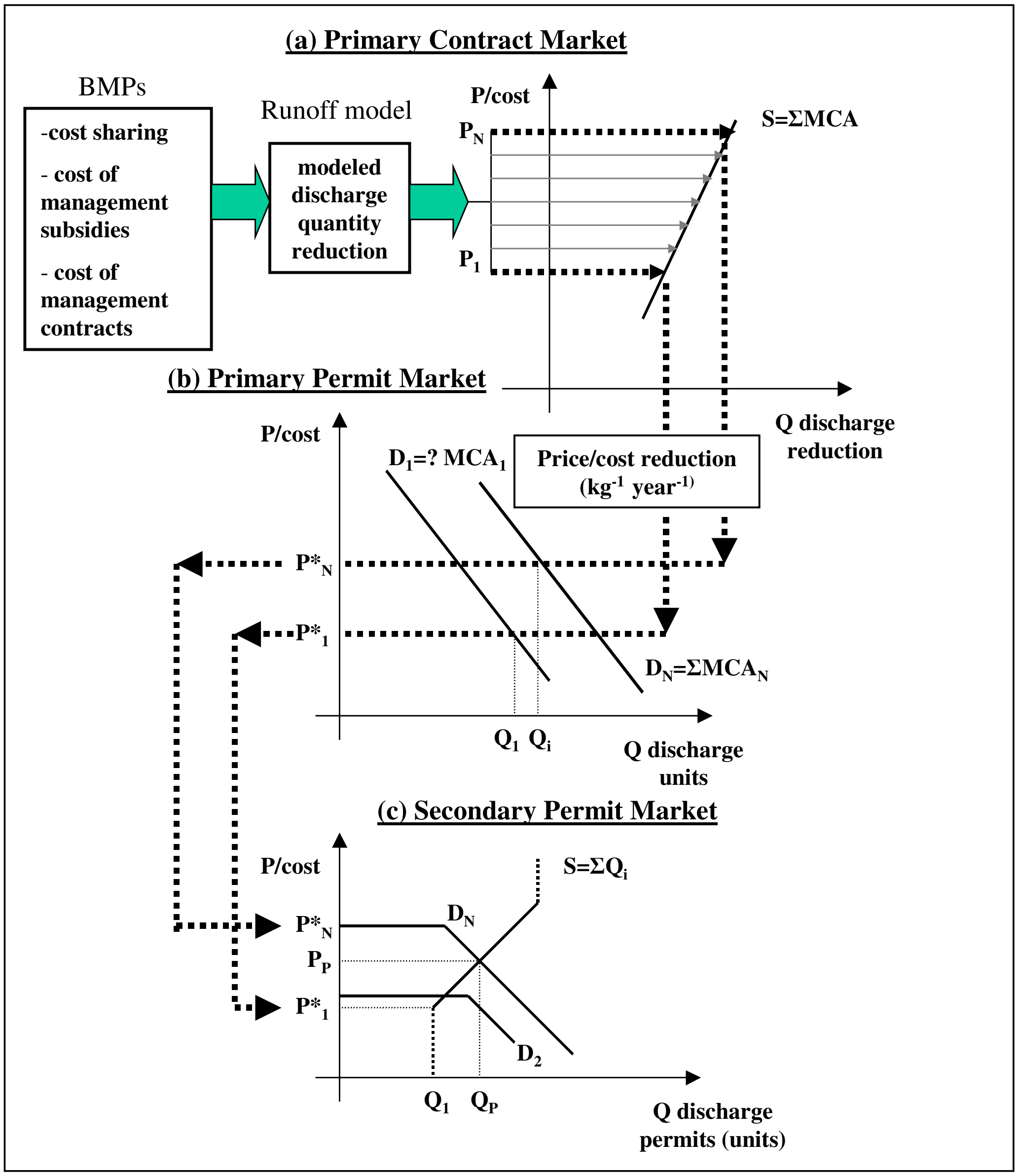

Figure 1. The composite market model for transferable discharge permits.

The necessary step for the transformation of BMP programs of this type, into credits in a TDP program lies in the quantification of the expected effect of the BMP on discharges by the adopting source (see Figure 1a). Modelling offers a possibility for site-specific quantification of the effect of BMPs when adopted by individual producers. In essence, the use of modelling transforms the

NPS discharge into a quasi-NPS discharge or what perhaps may be best described as a model generated PS.

The sum of all these model transformed marginal abatement costs generates the supply curve in the primary contract market in Figure 1a. Each time the catchment agency enters into a contract with a pollution source more information becomes available with respect to marginal abatement costs. In an idealized market of this type a purchasing agency with full abatement cost information would always purchase the least cost measures first. In the model this gives rise to the upward sloping MCA/supply curve depicted in Figure 1a. In practice, incomplete information or particular forms of transactions, such as uniform BMP support programs, may lead to model generated MCAs that vary in order (not always chronologically ascending from least cost to higher cost measures). However, this does not present a problem since the agency unilaterally determines which price to use as the 'last' price from this market to be transferred to the primary permit market. The price of permits in the primary permit market represents the marginal abatement cost determined in the primary contract market, the main function of this market.

A secondary function is to provide a market for abatement control activities by quantifying and thereby setting marginal values on the reduction through the transformation described above. Public information about the shape of the aggregate MCA, the price signal in this market, is an indication of the willingness to pay for abatement control by the catchment agency. Dischargers in the catchment can use this price as an anchor for making abatement investment decisions. If the price derived in this market is above the marginal abatement cost for a discharger then it may be possible for the discharger to negotiate a performance contract with the catchment agency for the expected reduction. Abatement transactions of this type will lower costs for reductions purchased and add to the cost efficiencies of the composite market.

The modelled discharge reduction quantities in the primary contract market used to calculate marginal abatement costs are presumed to represent the reduction target for catchment water quality. The ultimate goal of any TDP system is to achieve a targeted level of discharges. This is true for the composite market system as well, the major difference is that reductions are phased into the system through activities in the two primary markets. The primary contract market serves to phase in discharge reductions from direct performance contracts. Discharge reductions in the primary permit market are phased in by choice constrained dischargers who choose this option in lieu of purchase of discharge permits. The first step to implementation is development of the marginal abatement supply curve, the primary contract market, to be used for setting permit prices in the following market.

Abatement Measures In The Rönne River Basin

The Rönne River basin described below serves to demonstrate how program supported abatement measures may be combined with leaching models to estimate abatement costs from catchment data. Two best management practices are used to calculate the cost per unit of reduction and the potential quantity of reduction for the catchment. These particular practices, insown catch crops and spring tillage, are used because they are currently subsidized as a part of an agri-environmental program targeted at reducing nutrient losses. In addition, modeled results are available for root zone nitrogen losses using the SOILNDB model (Johnsson et al, 2002) and for estimating net nitrogen loads to the sea from the TRK project (Johnsson and Mårtensson, manuscript; TRK at www-nrciws.slu.se/TRK/index.html).

The Rönne River basin

The Rönne River drains a large area of Southern Sweden (1900 km^2) and empties into the Kattegatt area of the Baltic Sea on the Swedish west coast (Figure 2). The river basin has a total population of 100,000 with about 70% living in urban areas. Around 31% of the basin land area is fertile highly productive agricultural land with approximately 55,000 ha under cultivation (Table

1). The remainder is primarily in privately managed forest area (48% of the area). At the headwaters of the river there are three large lakes with a surface area of approximately 40 km^2 that are important as a recreational area. The Rönne basin has a history of high levels of nutrients transported by surface water to the Kattegatt where eutrophication is a problem.

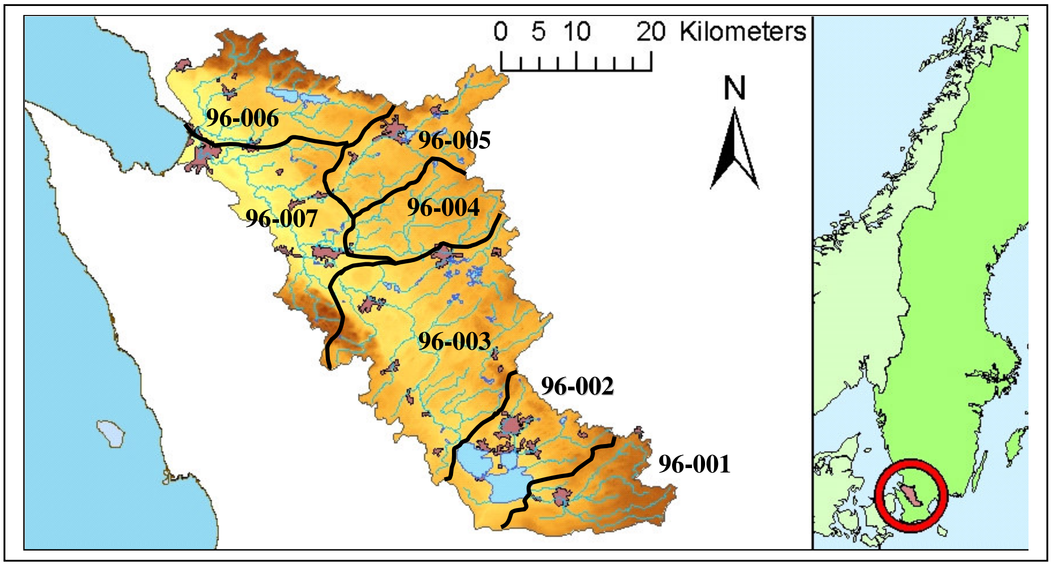

Figure 2. The Rönne River basin, sub-catchments (TRK project)

In a comprehensive national study over nitrogen loads from Swedish land areas to surrounding seas, the TRK (Transport – Retention – Source) project, the basin area was divided into the set of seven sub-catchments depicted in Figure 2 (TRK at www-nrciws.slu.se/TRK/index.html). Retention data from this study was used to calculate total loads measured as N losses at the root zone using the SOILNDB model minus background losses (before retention) and the share of this load from land use in the basin registered for EU agricultural program support. The annual transport of nitrogen from the basin to the sea is approximately 2,200 tons of which the contribution from cultivated land is around 1,300 tons (TRK at www-nrciws.slu.se/TRK/index.html).

Cultivated soils in the basin consist primarily of three types; loam, sandy loam and loamy sand. The distribution of these soils is estimated in Table 1 as a percentage of agricultural soils for each of the seven sub-catchments (Lidberg et al, 2003). Since the two BMPs used in this study (described below) are recommended for use in cultivation of spring cereals (spring barley, spring wheat and oats) the area of each soil type in Table 1 is calculated as the percentage of total cultivated land sown in these three cereals in the catchment in 2003, that is, 53% of the area of each soil type (SCB, 2004).

Catch crop and spring tillage subsidy programs

Cultivation practices that can reduce nitrogen leaching have been supported in Sweden through a program of subsidies directed at specific regions, including the Rönne River basin. Two of the agri-environmental programs aimed at reducing nutrient losses from farming practices through payments to land owners are a catch crop program and a spring tillage program. The original goal of the catch crop program when it was initiated in 1995 was that 39,000 hectares in Southern Sweden, the designated support area, would eventually be signed up with the program.

The level of compensation was set at 62.50 USD^{-ha} [1]. During 1996, a little over 4,800 acres, representing around 12% of the goal, were included in the program. Due to this low interest the compensation level was almost doubled in 1998 to 112.50 USD^{-ha} after a recommendation by the Swedish Board of Agriculture. This increase led to a somewhat higher participation rate, an enrolment of 7,900 hectares or about 20% of the target level but the low level of participation led to a new set of recommendations from the Board of Agriculture. Participation rules were relaxed with respect to dates for sowing and ploughing in the catch crop and complementary payments could be received for delayed cultivation, spring tillage. (SOU, 1999). Current new rules have led to oversubscription in the program the question of which factors led first to the lower than expected participation rate and then to the greater than expected participation rate have yet to be understood (Collentine, 2002). The two programs may be entered into for a five year period either together with annual compensation at 162.50 USD^{-ha}, or seperately at 112.50 USD^{-ha} and 50 USD^{-ha} respectively.

	subcat 96-001	subcat 96-002	subcat 96-003	subcat 96-004	subcat 96-005	subcat 96-006	subcat 96-007	Total
Total land area	15300	24200	55800	24100	19100	26100	24900	190000
Cultivate land	7100	7100	14400	3700	2000	7700	12500	54600
loam	0%	9%	30%	15%	13%	17%	31%	21%
ha	0	342	2290	302	133	680	2056	6068
loamy sand	0%	9%	7%	8%	25%	8%	10%	9%
ha	0	342	509	151	265	340	685	2567
sandy loam	100%	82%	57%	77%	50%	42%	34%	56%
ha	3763	3079	4325	1508	530	1700	2284	16103
Gross N load	212.4	198.7	296.2	67.0	41.4	358.5	539.9	1714.1
Net N load (%)	47%	41%	83%	81%	82%	72%	84%	72%

Table 1. Rönne River catchment area by subcatchment; land area, cultivated land, three soil types as a percentage of the total area in the sub-catchment, total estimated number of hectares per soil type in each sub-catchment with a potential for catch crops and/or spring tillage, gross loading of N in tons, and net loading as a percentage of the total load. (Source: Data adapted from TRK project at www-nrciws.slu.se/TRK/index.html and Lidberg et al, 2003).

Modelled leaching estimates

Root zone leaching estimates were made within the TRK program using data from the SOILNDB model (Johnsson and Mårtensson, manuscript). The leaching estimates in Table 2 are for spring barley on the three different types of soil for four sets of cultivation practices; no measures, combined catch crop and spring tillage, catch crop only and spring tillage only. The leaching estimates for the two other cereals are similar but separate estimates for each soil type in the catchment were not available.

Subsidies for the three sets of BMPs were combined with estimated leaching by soil type to calculate the cost per kilogram of the reduction in root zone leaching by measure and soil type.

[1] The exchange rate used in this study is 8 SEK^{-USD}. The exchange rate on 22/9 2004 was 7.36314 SEK^{-USD}.

	loam	loamy sand	sandy loam	subsidy USD^{-ha}
No measures applied	53	70	62	
Catch crop and spring tillage (reduction)	29 (24)	36 (34)	33 (29)	162.50
Catch crop only (reduction)	38 (15)	51 (19)	44 (18)	112.50
Spring tillage only (reduction)	45 (8)	58 (12)	52 (10)	50

Table 2: Rönne River catchment area; estimated leaching by soil type and applied best management practice (kg^{-ha}) and subsidy for each measure (USD^{-ha}). (Source: Adapted from Lidberg et al, 2003).

These estimates were combined with retention estimates for each sub-catchment to produce the estimated cost per net unit of reduction (load to the sea) and potential reduction for each of these sub-catchments (Tables 3a, 3b). The potential reduction for each soil type in the catchment was calculated from the total cultivated area in the catchment with a potential for applying the measures (Table 1). This last set of tables (Tables 3a, 3b) contains all the information needed to construct supply curves for marginal abatement in the catchment.

	subcat 96-001	subcat 96-002	subcat 96-003	subcat 96-004	subcat 96-005	subcat 96-006	subcat 96-007
Catch crop and spring tillage							
loam	14.40	16.51	8.16	8.36	8.26	9.40	8.06
loamy sand	10.18	11.66	5.76	5.90	5.83	6.64	5.69
sandy loam	11.93	13.66	6.75	6.91	6.84	7.79	6.68
Catch crop only							
loam	15.96	18.29	9.04	9.26	9.15	10.41	8.93
loamy sand	12.60	14.44	7.14	7.31	7.23	8.23	7.05
sandy loam	13.30	15.25	7.53	7.71	7.63	8.68	7.44
Spring tillage only							
loam	13.30	15.25	7.53	7.71	7.63	8.68	7.44
loamy sand	8.86	10.16	5.03	5.15	5.09	5.79	4.96
sandy loam	10.64	12.20	6.03	6.18	6.10	6.95	5.95

Table 3a: Cost per kg for subsidized agricultural abatement measures in the Rönne River catchment area; sub-catchment estimated cost per unit of **net** leaching reduction by soil type and applied best management practice (USD^{-kg}).

Discussion

The first step in implementing the composite market permit scheme is the determination of a price for issuing discharge permits. The function of the primary contract market in the model (see Figure 1a) is to gather information for pricing permits through the development of a supply curve for abatement measures. This supply curve describes marginal abatement costs for reducing pollutants in a particular area (river basin, watershed). Derivation of the abatement supply curve requires estimates of the cost per unit of reduction as well as the expected quantity of potential reduction for that unit cost. This in turn requires data on the cost of abatement measures and the expected effect on discharge volumes from these measures.

	subcat 96-001	subcat 96-002	subcat 96-003	subcat 96-004	subcat 96-005	subcat 96-006	subcat 96-007
Catch crop and spring tillage							
loam	0	3.4	45.6	5.9	2.6	11.7	41.4
loamy sand	0	4.8	14.4	4.2	7.4	8.3	19.6
sandy loam	51.3	36.6	104.1	35.4	12.6	35.5	55.6
Catch crop only							
loam	0	2.1	28.5	3.7	1.6	7.3	25.9
loamy sand	0	2.7	80.2	2.3	4.1	4.7	10.9
sandy loam	31.8	22.7	64.6	22.0	7.8	22.0	34.5
Spring tillage only							
loam	0	1.1	15.2	2.0	0.9	3.9	13.8
loamy sand	0	1.7	5.1	1.5	2.6	2.9	6.9
sandy loam	17.7	12.6	35.9	12.2	4.3	12.2	19.2

Table 3b: Total potential reduction for subsidized agricultural abatement measures in the Rönne River catchment area; **net** estimated leaching by soil type and applied BMP (in tons).

Partial supply curves for abatement measures in the Rönne River basin

The supply curves in Figure 3 represent graphically the data from Tables 3a, 3b. The cost on the *y* axis in the diagram is the calculated cost per unit of reduction from the three measures. This is the cost that is hypothetically paid by the purchasing agency, in this case the Swedish Board of Agriculture, for the BMPs which generate the reduction. It may be regarded as the price which society pays to purchase the corresponding reductions. The quantities on the *x* axis are the potential reductions associated with each price. In theory this is the volume of reduction which could be obtained at that particular cost per unit. Since the costs are calculated upon the premise that the subsidy for each measure is acceptable to all farmers in the area, the cost is a low estimate of the actual costs. The measures in the supply curves are not aggregated because they represent a discrete choice for cultivation practices on a particular field. Choosing one of the measures precludes the possibility of choosing one of the remaining two measures.

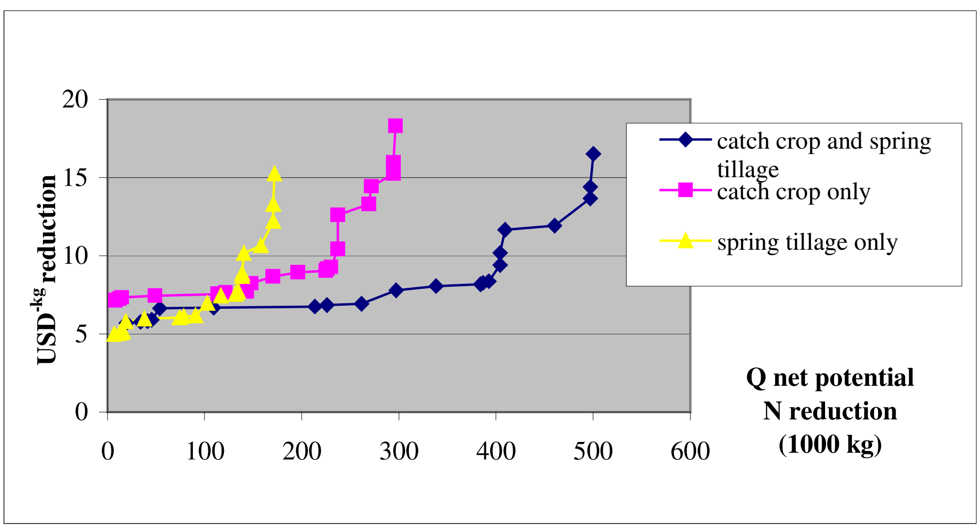

Figure 3. Supply curve for selected BMPs in the Rönne River basin by soil type and sub-catchment area retention.

The supply curves in Figure 3 represent twenty-one separate points for each of the three measures. The shape of each of the curves is similar. A small rise in price from initial levels leads to a fairly large volume of reductions up to a certain point (at about 400 tons for the combined measures) at which level the change in price increases sharply while the increase in reductions is small. This is followed by a flat section and then ends on a sharp price rise again. If this information were to be used to set a price for issuing permits in the primary permit market of the composite market scheme one obvious choice is to set a price at 8.50 USD^{-kg}, just before the cost per unit rises steeply, or just before the second rise at 12.00 USD^{-kg}. Revenue from purchasers of permits could be used to purchase reductions through any of the three measures but as can be seen in Figure 3 the highest levels of reduction come from purchasing the combination of the two measures.

Use of the three soil types and estimated net loading to the sea (retention) as explanatory variables gives rise to varying estimated leaching losses and cost differentials. The abatement supply curve describes a potential for exploiting these differentials in a trading program. That is, it would be possible to realize economic efficiencies with high cost abatement sources willing to enter into agreement with low cost sources with the two sources sharing the economic gain. If the sources were constrained to purchase permits (a hypothetical case but one that may nonetheless become a reality within a 20 year time frame), then choosing a price to sell permits at such as 8.375 USD^{-kg} would lead to a high volume of abatement by low cost producers (400 tons in the case of catch crops combined with spring tillage) and demand for permits by a smaller set of high abatement cost producers. The wedge between the high and low cost sources may be sufficient to pay for the costs of maintaining the system (transaction costs) and lead to social economic gains from a trading program. However, this is an empirical question that requires further study before conclusions may be drawn.

Conclusions

The purpose of this study has been to illustrate how abatement supply curves can be generated for a particular catchment area which make it possible to set permit prices in a composite market trading scheme. There is a positive relationship between the level of abatement and the cost per unit of reduction, as the level of reduction increases the cost per unit increases. With access to a supply curve of this type a watershed agency could set a price for the sale of permits which could in theory compensate for the purchase of reductions from other sources. This is the principle of economic efficiencies that make a tradable permit system interesting, increasing the total level of abatement at the lowest cost.

The study illustrates clearly how economic variables can be combined with bio-physical process models to quantify the effect of agronomic practices on nutrient losses. This in turn makes possible the creation of limited property rights which are a prerequisite for a successful trading scheme. Comparison of the two supply curves indicates the value of site specific information. If this information is incorporated into agri-environmental program reporting a data base could be established which would facilitate development of composite market trading program schemes.

Further research

This study illustrates the methodology for generating abatement supply curves. While the method may be generalized to set prices in other trading schemes, the partial nature of the supply curve where data is phased in as it becomes available is particularly appropriate where the permit issuing market is also phased in over time. Additional measures should be included in future studies to increase the amount of information, and sources, in the abatement supply curve. Finally, before gains from trading can be estimated, schemes for constraining discharge sources must be studied to estimate the potential for creating a market in permits.

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