UNIVERSITY OF ALBERTA

DEPARTMENT OF
RURAL ECONOMY
FACULTY OF AGRICULTURAL, LIFE & ENVIRONMENTAL SCIENCES

Environmental Goods and Services:
Economic Supply Principles and Reverse Auctions

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Illustration using Wetland Restoration

- Producer participation in restoration is low
  - Not sure about retention
- Why? Costs of restoration are high and producers not receiving sufficient compensation
- Caveat – some will do this at their own expense
- Society has already largely tapped into this “cheap” source of wetland conservation

Comments on Wetland Retention

- Not really a focus of this study
  - except valuation component
- Producers still wish to drain existing wetlands
- Wetland drainage costs less than the cost of purchasing additional land
  - Wetland drainage is an economically rational decision
- Should they be paid for not doing so?
  - Annual incentive payments of $25-38/ha ($10-15 /wetland acre/yr) needed to arrest drainage (Cortus, 2005 in Emerald SK).
- Do and should they currently receive compensation for doing so?
- Role of regulations?

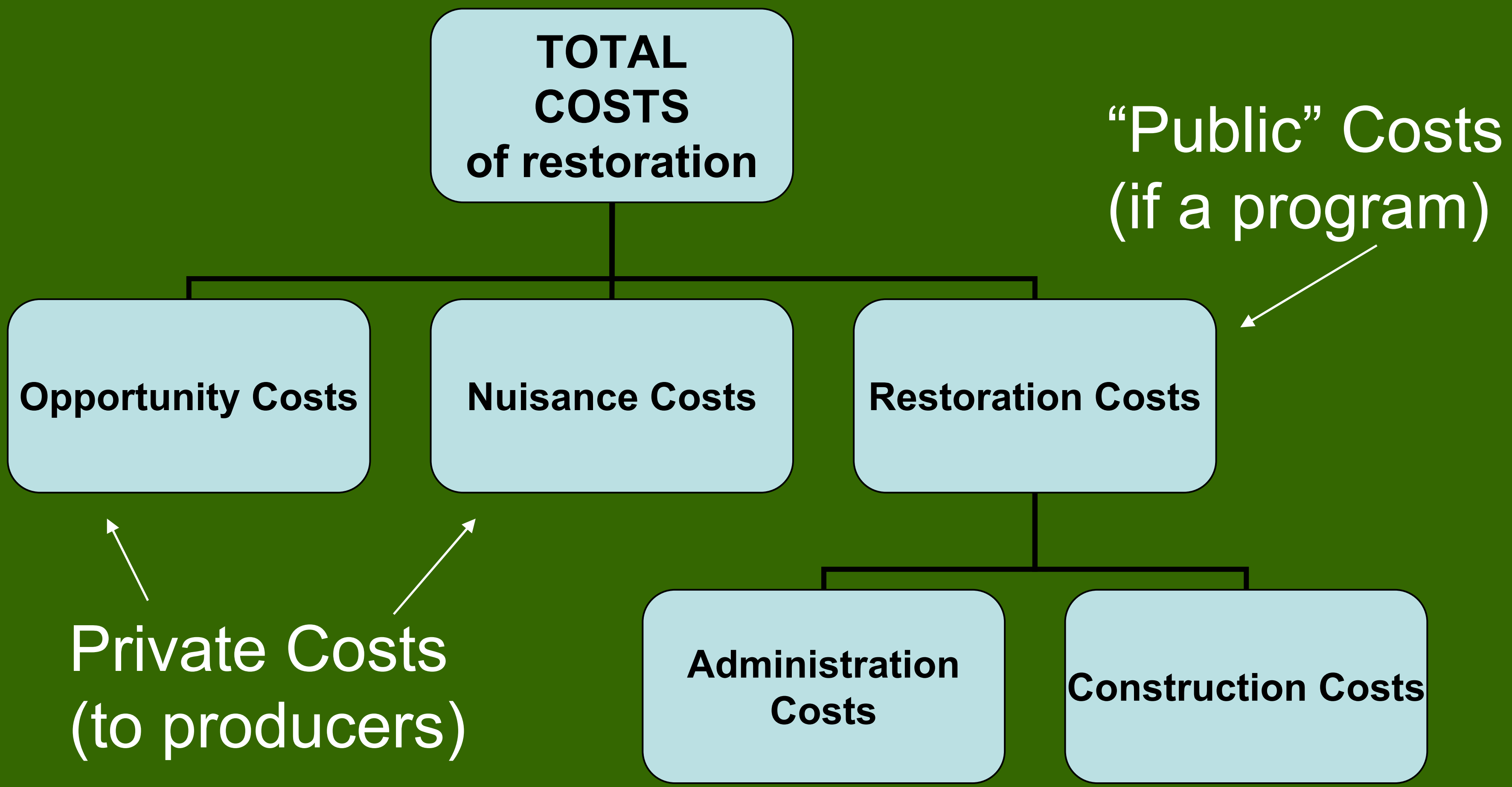
What does Wetland Restoration Cost?

- Understanding BMP uptake starts with understanding the costs of adoption
- In this ACAAF project we examined the costs of wetland restoration
- This provides a picture of the economics of supplying ecological goods and services from wetland conservation programs

How We Estimated the Costs of Restoration

- Understanding costs of restoring drained wetlands requires:
  - Knowledge of lost cropping area income (opportunity costs)
  - Estimates of increased costs of maneuvering machinery around restored wetlands (nuisance costs)
  - Estimates of the one-time costs required to actually restore the wetland (construction costs)
  - We note many missing elements like producer future plans

How Much Does it Cost to Restore a Wetland?



Opportunity Costs (OC)

- Deerwood Soil and Water Management association has collected field level yield and input data from 1991-2007
- Linked this in GIS with other data layers (e.g. soil, DEM)
- Developed yield functions for each crop:

$$Y_i = \phi_1 + \phi_2 \frac{GS}{GDD} + \phi_3 \left(\frac{GS}{GDD} \right)^2 + \phi_4 N + \phi_5 N^2 + \phi_6 P + \phi_7 P^2 + \phi_8 Pest + \phi_9 SC1$$

$$+ \phi_{10} SC2 + \phi_{11} NoTill + \phi_{12} Continuous + \phi_{13} legume + \sum_{j=1}^{41} \varphi_j D_j + \varepsilon,$$

- Assigned future rotations based on historical use for next 12 years (3 rotations).

Producer	Land_id	Acres	Rotation type	2007	2008	2009	2010	2011	2012	2013
9	1	31.17	crop rotation	wheat	canola	wheat	wheat	flax	oats	wheat
16	2	22.07	forage rotation	forage	forage	forage	forage	barley	canola	wheat
26	3	9.82	forage rotation	flax	barley	forage	forage	forage	forage	forage
1	4	8.47	forage rotation	wheat	oats	canola	oats	forage	forage	forage
26	5	53.38	forage rotation	oats	flax	wheat	wheat	forage	forage	forage
16	6	24.96	forage rotation	forage	forage	forage	forage	forage	forage	forage
18	7	96.43	crop rotation	wheat	oats	canola	wheat	wheat	flax	wheat
26	8	82.31	pasture	pasture	pasture	pasture	pasture	pasture	pasture	pasture

- Estimated future base yields for each field and farm using the yield functions
  - Assumed historical average weather
- Using historical mean prices, converted yields to revenue
  - Deducted future planting costs
- Result is net revenue without wetland restoration

Estimated Change in Net Revenue

- Projected this over 12 yrs and summed values
  - This gives undiscounted base income
- Linked GIS layers to determine lost cropping areas by field
- Adjusted base income for lost acreage from restoration – by wetland, field, producer

$$OC_i = \left(net\ income_i^{no\ wetlands} - net\ income_i^{wetlands} \right)$$

- Provides total opportunity costs of removing an acre from crop production in each field assuming that restoration occurs in first year

Nuisance Costs (NC)

- Estimated as the product of wetland size, annual machinery operating costs in $/ac and a nuisance factor; determined by number of wetlands and farm size (Cortus 2005).

	Farm size (number of quarter sections)				
# wetlands on a field	4	8	12	16	20
1-3	8%	9.5%	11%	12.5%	14%
4-6	9.5%	11%	12.5%	14%	15.5%
7-9	11%	12.5%	14%	15.5%	17%
>9	12.5%	14%	15.5%	17%	18.5%

- Estimates summed over 12 years
  - Provides total opportunity costs of removing an acre from crop production in each field assuming that restoration occurs in first year

Discounting issues

- OC and NC involve changes in net revenue over 12 years (3 rotations)
- Net revenues discounted back to the present using the following formula which represents the NPV of total costs of restoring all wetlands in field *i:*

$$TC_i^d = R_i + \sum_{t=1}^{12} \frac{C_i^t}{(1+r)^t}$$

R_i = one-time construction and administration costs (DUC)

C_i = OC+NC at time t;

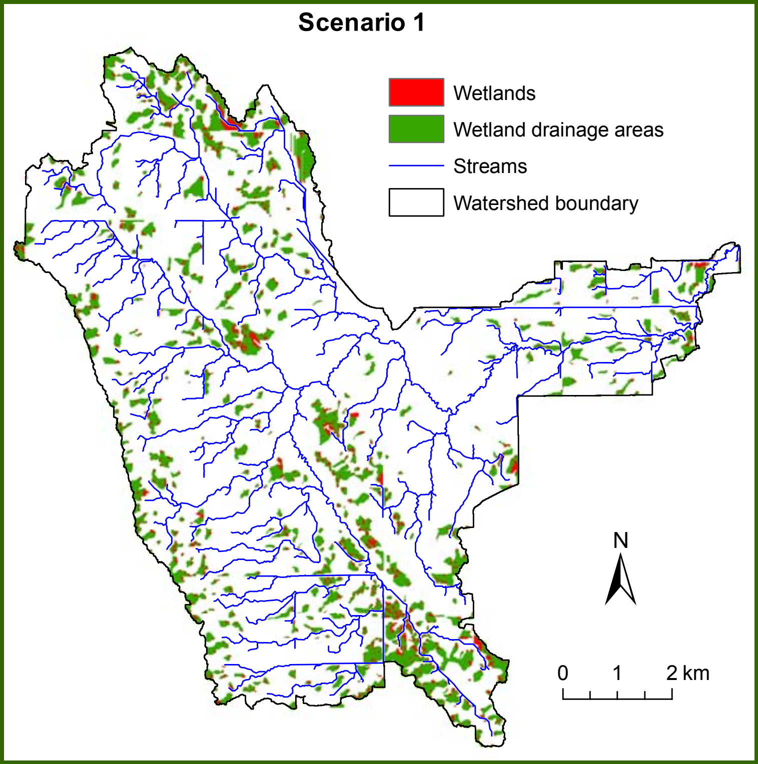
r = the discount rate (10%)

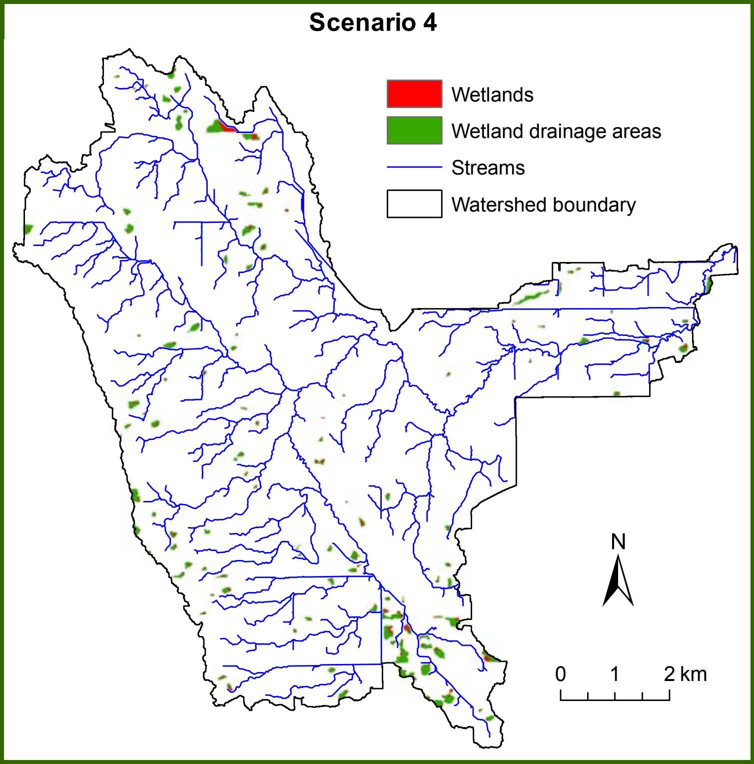
Some Descriptive Statistics

	Wetland level		Farm level
	Size (acres)	Total Costs	Total costs/acre
Median	0.2777	$323.36	$1010.31
Mean	0.4521	$434.77	$1094.10
SD	0.6730	$444.35	$307.09
Minimum	1.11E-05	$99.09	$715.41
Maximum	8.7589	$5507.54	$2430.70

Development of Wetland Restoration Scenarios

Scenarios	Numbers	Surface area (ha)	Surface area (%)	Range (ha)	Volume ($10^4 m^3$)	Drainage area (ha)	Drainage area (%)
1	992	202	2.71	0.04 - 2.80	60.6	1014	13.6
2	496	98.6	1.32	0.04 - 2.80	29.6	546	7.32
3	248	51.1	0.69	0.04 - 2.80	15.3	280	3.75
4	124	25.8	0.35	0.04 - 2.80	7.74	137	1.84

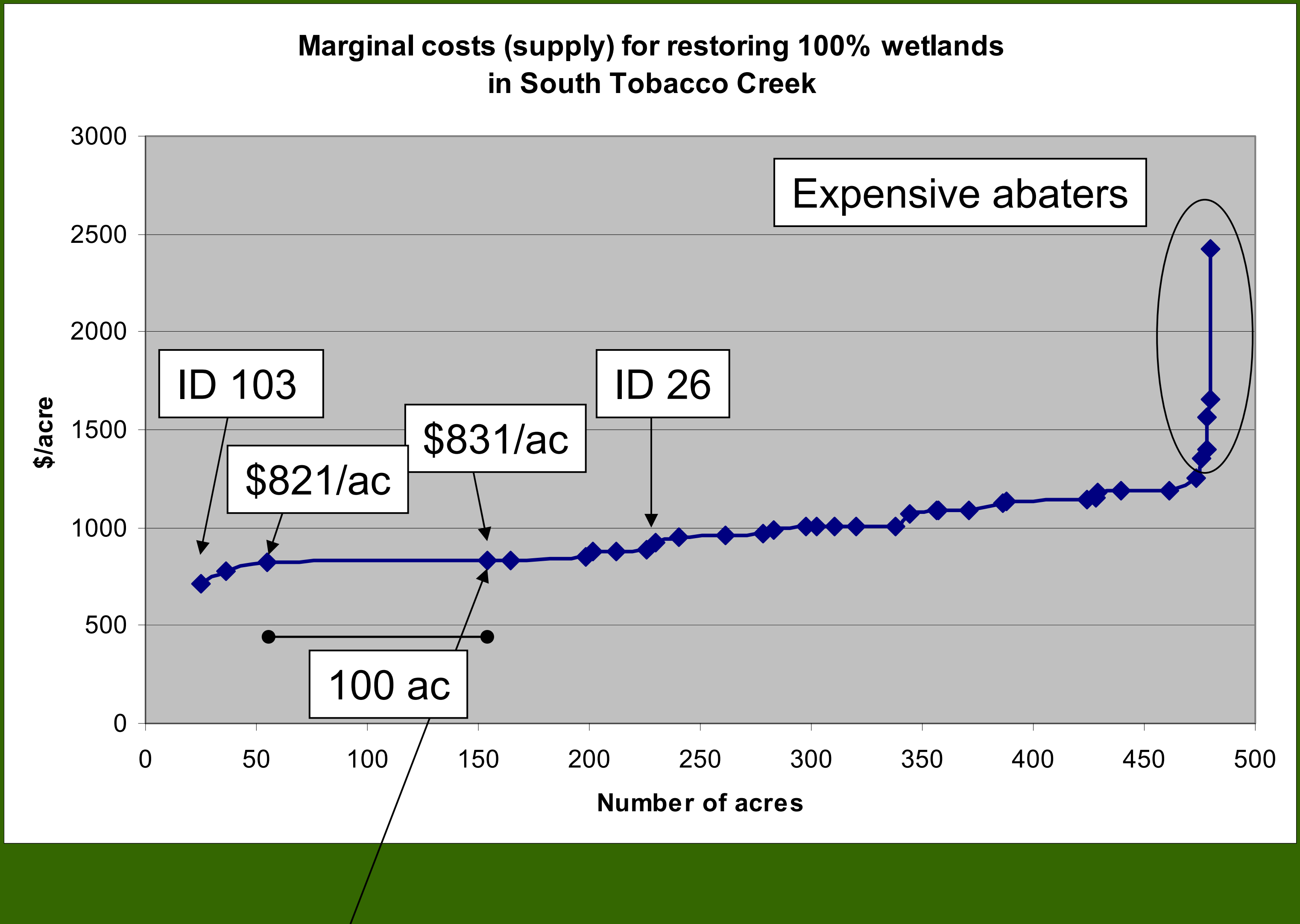




Economic Supply Relationships 1

- Economic supply relationships involve determining marginal costs ($/unit)
- First, sort data by increasing $/acre and plot against cumulative acres restored
- "Acreage or coverage space" – the price per wetland acre supplied by each producer
  - Acre is the unit
- Can be estimated on a wetland, field or whole farm basis.
  - Each approach addresses different questions from a conservation programming perspective

Supply Curves for Wetland Restoration In "Acre Space" The Producer level

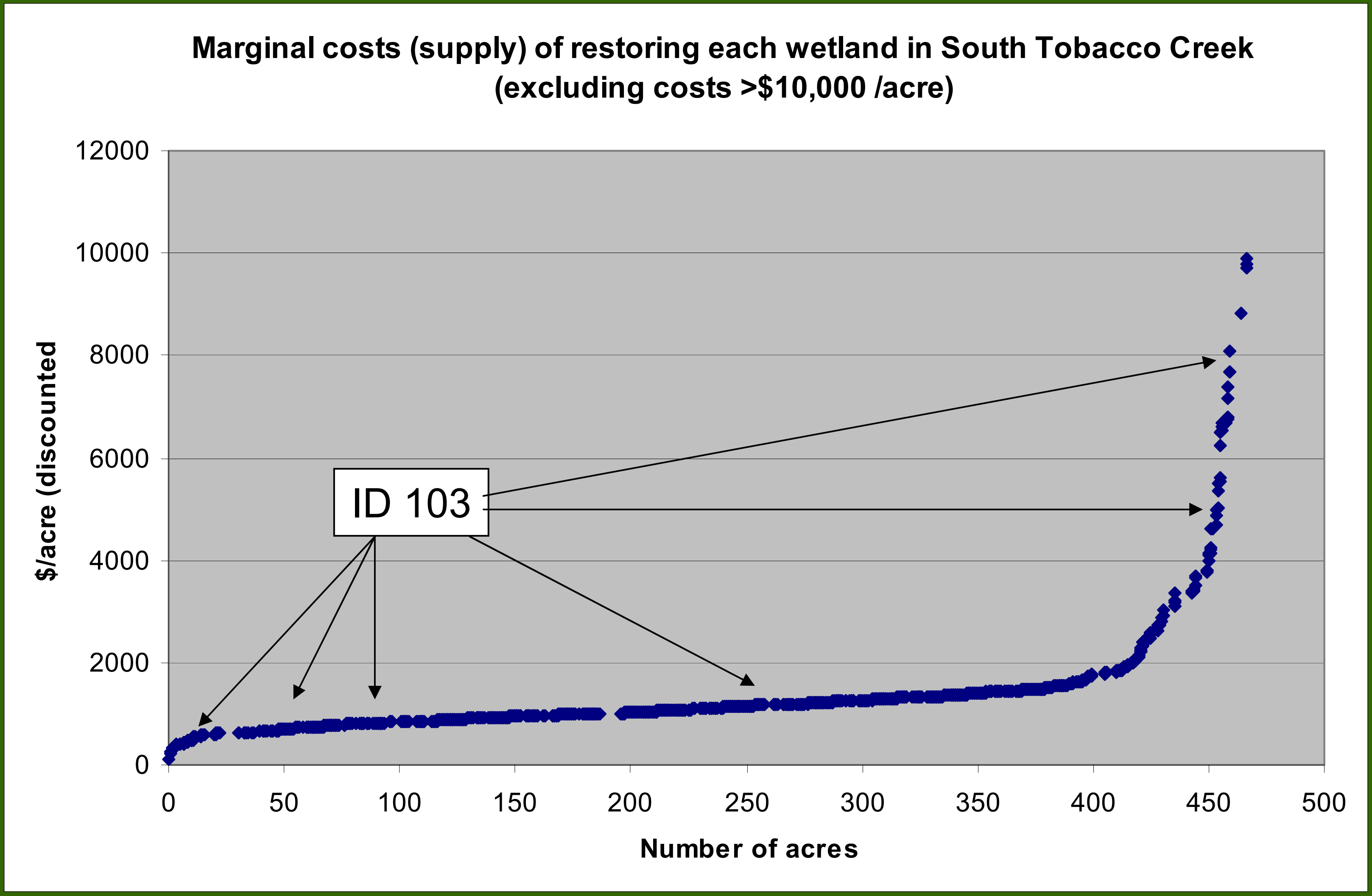


The costs borne by an individual producer for 100% restoration

Comments

- Many farms face similar costs per acre to restore
  - The flat area on the curve
  - Producer 103 would provide the cheapest restoration
- A small group of about 5 producers would be very expensive to pay to restore wetlands on their lands
  - Those in the steeply rising portion of curve
- The “jump” between the third and fourth producer provides additional 100 ac at a small increased cost of $10/ac

Supply Curves for Wetland Restoration In "Acre Space" The Wetland level



The costs borne by an individual producer for restoring an individual wetland

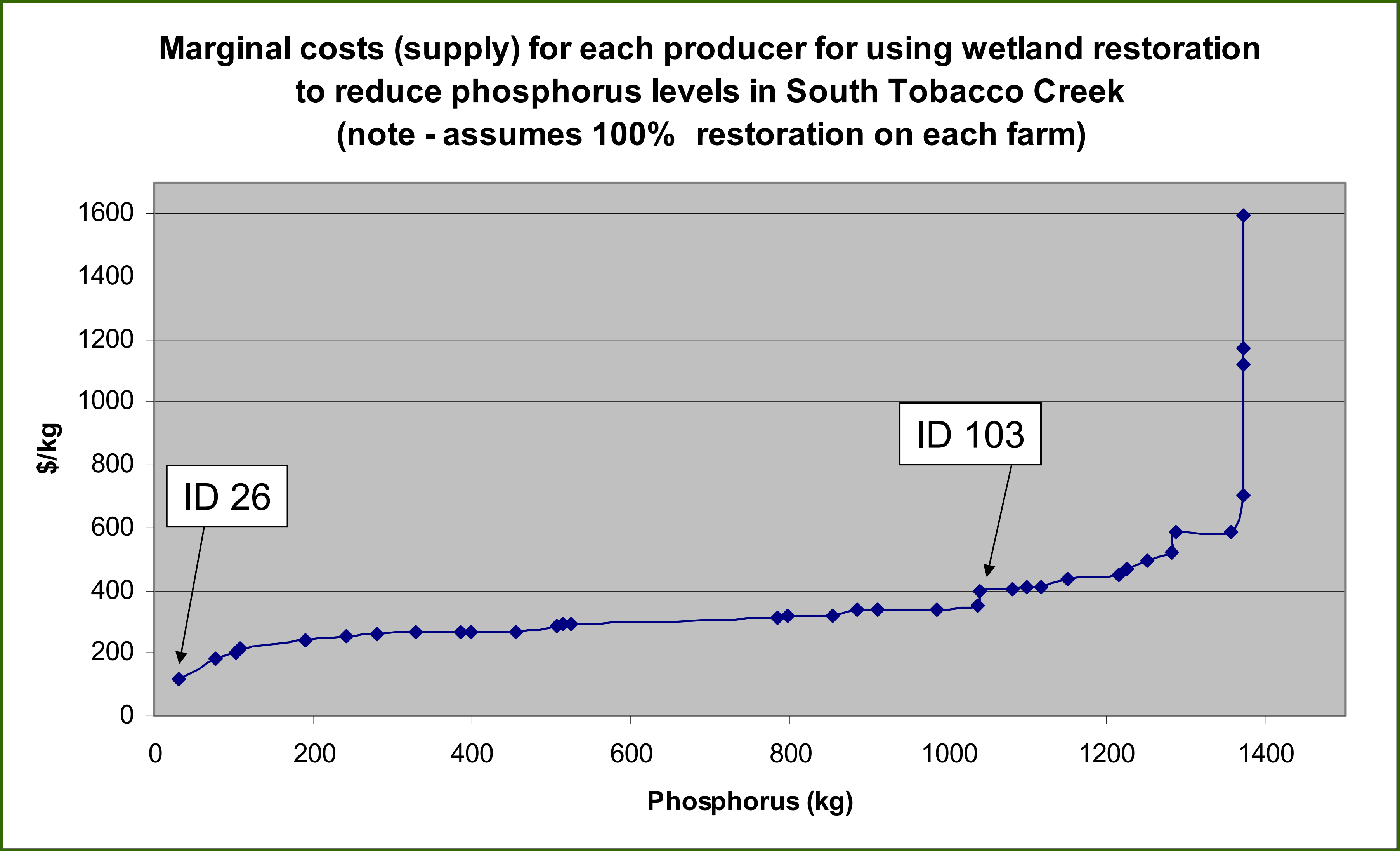
Comments

- The wetland acre supply curve highlights within farm heterogeneity in restoration costs
  - ID 103 example – still the cheapest
  - This producer was identified to have had 61 wetlands that could be restored, totaling 24.96 acres, on three fields
  - But range in costs for each of the 61 wetlands: \$66.18 - \$8062.79/acre

Economic Supply Relationships 2

- Given the spatial nature of the data we linked the cost functions with the Guelph group's spatially explicit hydrologic model
- This integration permits estimation of economic supply relationships for restoration
  - "Abatement space" (principally phosphorus) – the price per unit of water quality improvements supplied by each producer assuming 100% restoration
  - NOTE – now the unit of supply analysis is kg P abated
  - Could also pick N, sediment etc.

Supply Curves for Wetland Restoration In “P Abatement Space” The Wetland level



Comments

- This reorders the producers along the curve
  - ID 103 is now NOT the cheapest
- The approach should be used for understanding EGS provision
  - This example phosphorus
  - We can include N, sediment and maybe flood control (but need weights)
  - Missing habitat, C sequestration etc.
- Need for development of environmental benefit indices (EBI)

Policies to Increase Wetland Restoration

- Knowledge of cost function allows examination of some policy options
- We chose procurement (reverse, conservation …) auctions as an approach
- Why?
  - Used in other countries to increase EGSs
    - Bushtender, CRP
  - Field trial underway in Saskatchewan
  - Can be employed by government and/or ENGOs

Reverse Auctions – Pricing it Right?

- In reality cost information is not known to policy makers, but is needed to develop policy
- Procurement auctions can be used to reveal private costs through bidding behaviour
- Having some knowledge of the producer costs in STC allowed us to construct experiments in a laboratory setting

Why Auctions?

- Auctions are used when no pre-existing price or market exists
  - Auctions are a price or cost discovery mechanism
- Auctions can be designed to meet various goals
  - Environmental outcomes, social outcomes etc.
- Auctions create scarcity by offering fewer contracts than are interested EGS suppliers
  - Producers compete for limited budgets for BMP adoption

Bidding Competition Leads to

- Private sellers balancing:
  - The temptation to ask for more than their real costs with the risk of not being selected for a BMP contract
- The challenge is to design auctions to create incentives for bids (offers) to reflect real values (costs)
  - Underlying maximization function for a producer is:
    - expected gains=prob(selected) X bid amount
  - If their offer is too high, the offer is not selected and gains are $0
  - Goal is to design auction so producers offer actual costs of adoption

Auction Component

- Developed auction frameworks and tested them in an economic laboratory
- Involves computer interface design
  - Based upon WEBs BMP experiments
  - Here restoration is another BMP with a different cost function
- Used students as subjects (can use actual producers as well)
- Subjects act as producers and with knowledge of their costs, submit offers to be paid to conduct restoration

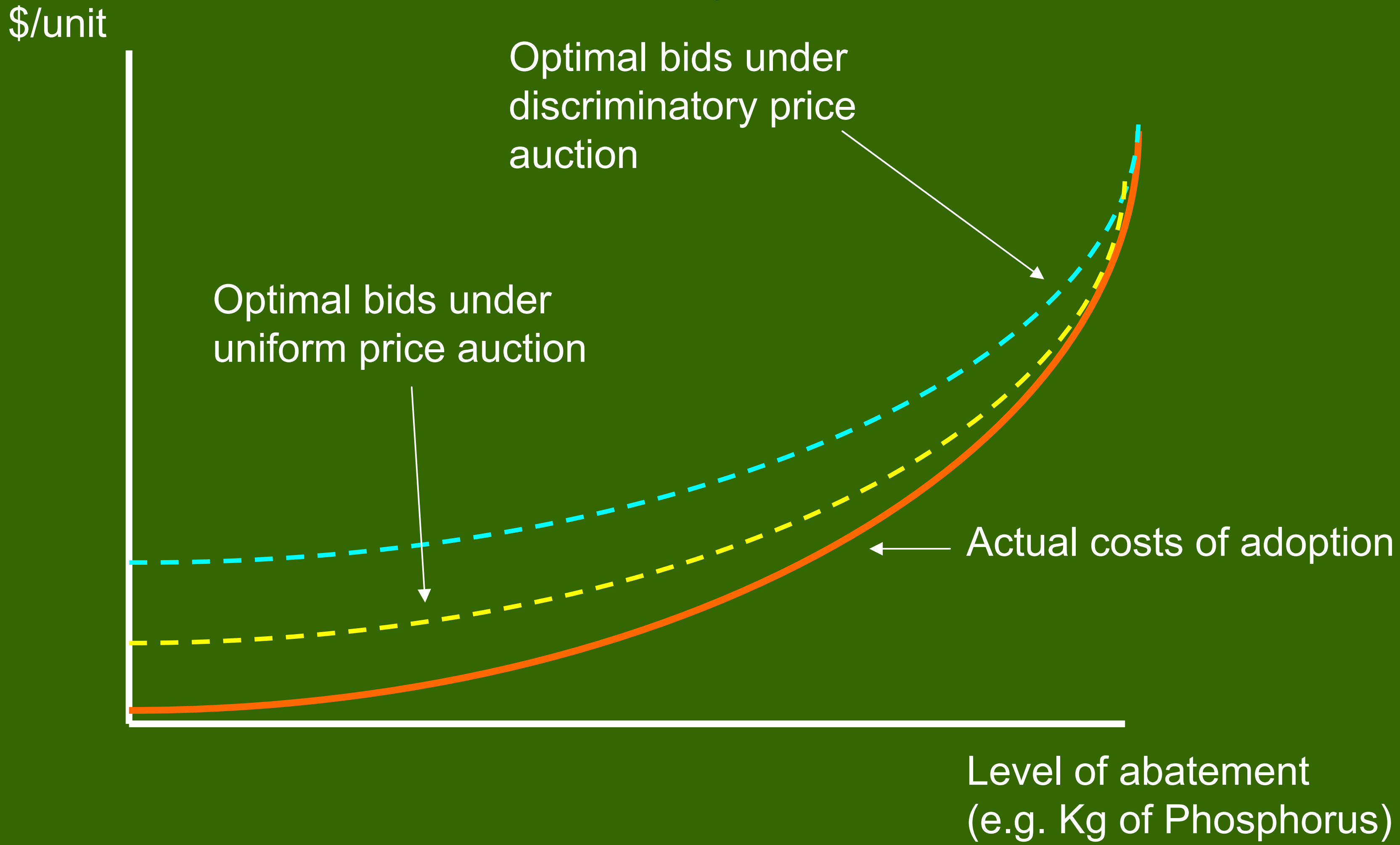
Auction Architecture

- Budget for restoration based upon NFS payments
  - Note that this is not enough to pay every producer for restoration in STC
- Two offer selection algorithms:
  - Maximize number of acres restored in STC
  - Maximize abatement of phosphorus in STC
- Two price selection mechanisms
  - Discriminant Payments (DP):
    - Each participant gets what they offered
    - Each participant gets a different amount
  - Uniform Payments (UP):
    - Each subject gets what the highest UNSUCCESSFUL bidder offered
    - Each subject gets the SAME payment

Auction Design: Payments

- Why these different payment formats?
  - Some think that equal payments are “fair”
  - BUT under the UP all winners but the last one get paid MORE than they offered – is that fair?
  - Under DP, there is an incentive to over-bid (bid-shading)
  - UP provides incentives to provide bids closer to actual costs
  - Under UP must trust the agency to not manipulate who is the last winner and thus determine payments

In reality we want the auction to provide policy makers with the supply curve!!



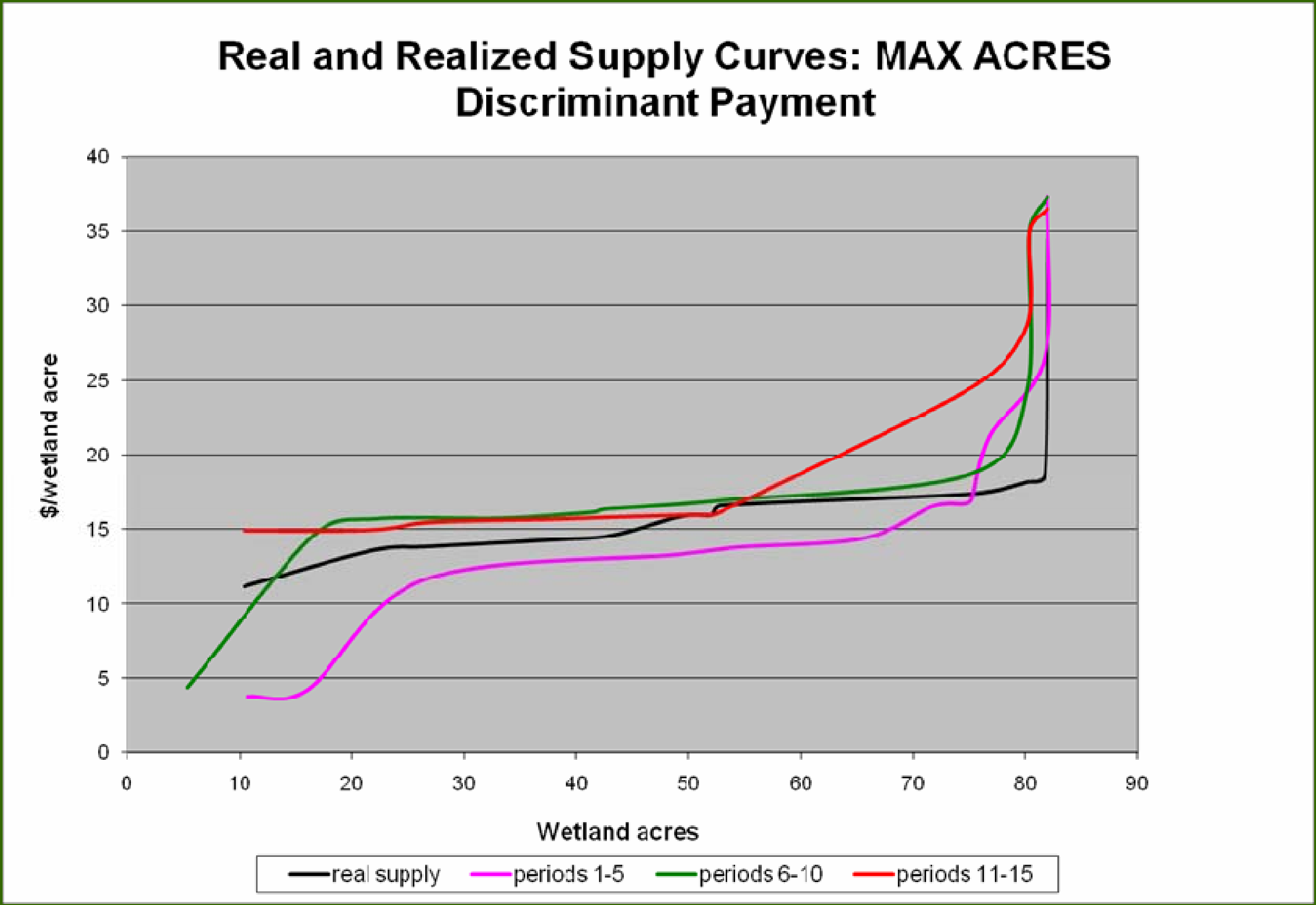
How the Auctions Work

- Subjects submit offers in each of 15 periods in an experiment
- In each period, offers are ordered according to selection rule and cheapest offers selected until budget is exhausted
- Subjects informed at end of each period if offers selected and how much they will be paid
- At end of experiment subjects are paid actual money depending on how much farm income they earned (including auction payments)
  - Incentive to increase or maintain income

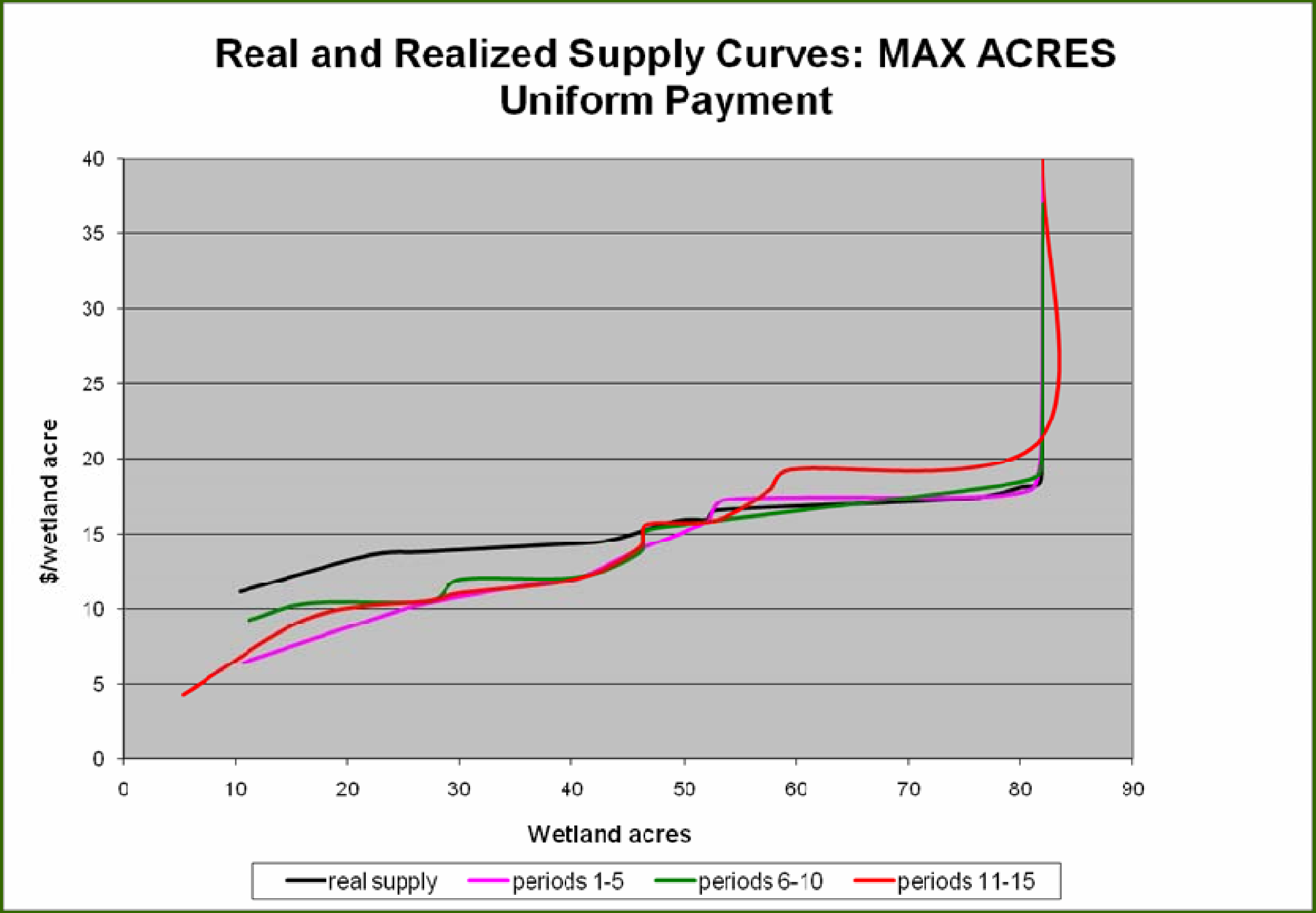
Experimental Treatments and Repetitions for Wetland Restoration

	Discriminant	Uniform
Maximize Acres Restored	2	3
Maximize Abatement	2	3

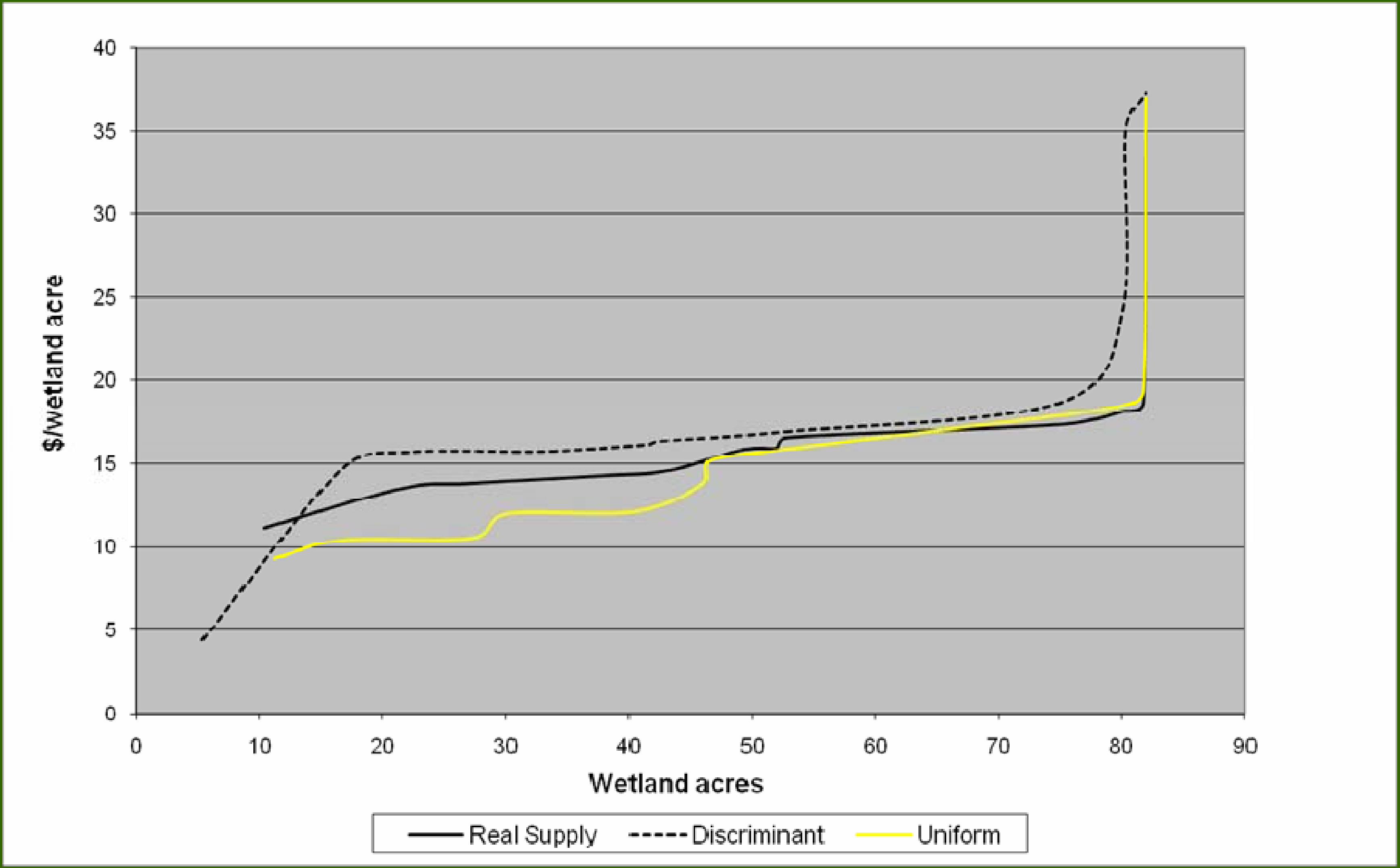
How Well does the Auction Reveal Costs?



How Well does the Auction Reveal Costs?



Comparison of Discriminant and Uniform: Average offer values for periods 6-10



Other Auction Research

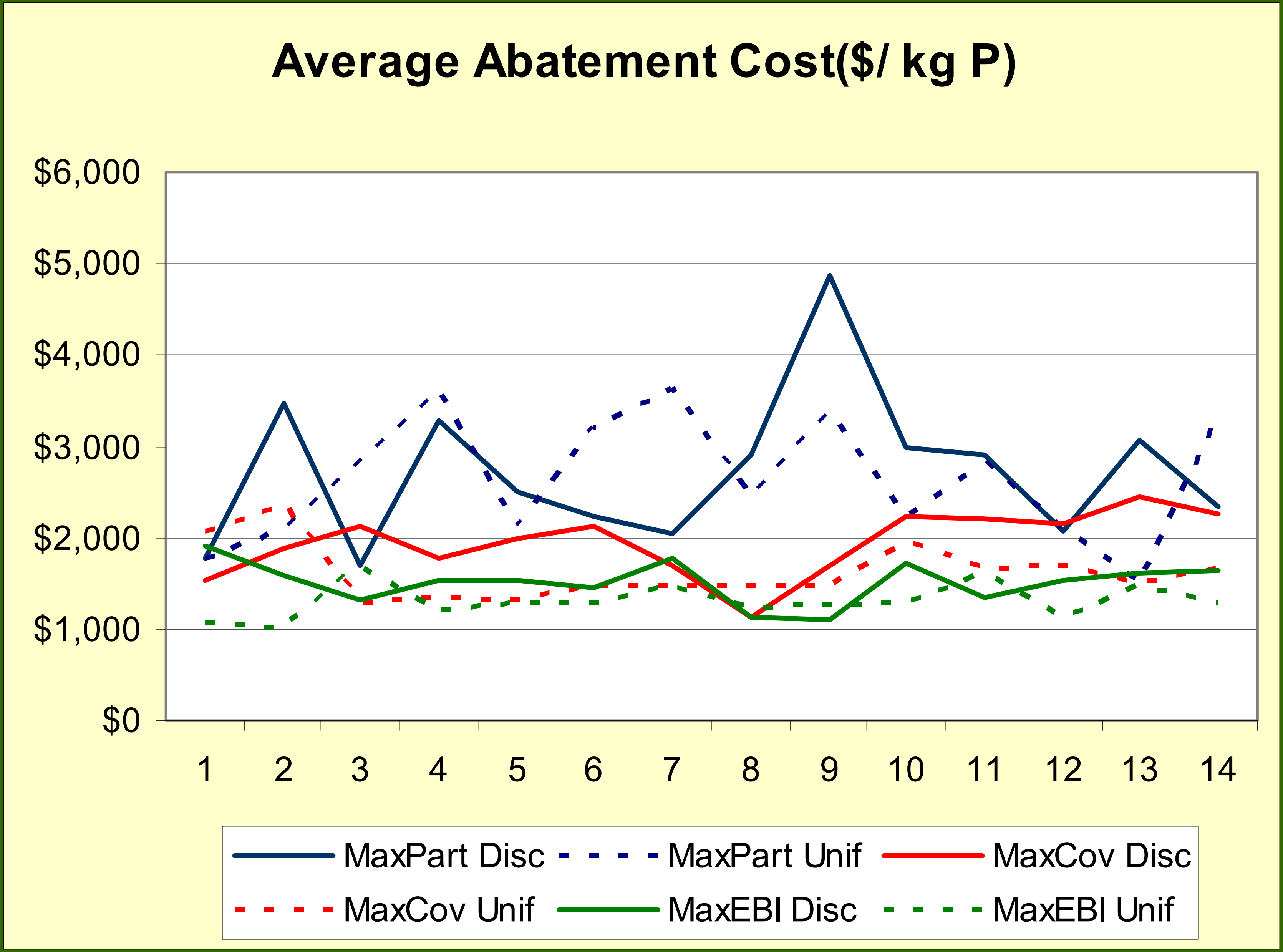
- In WEBs we have been studying auctions for adoption of other BMPs
  - Zero-till, run-off ponds, forage conversion
  - They have different EGS cost of supply relationships
  - Examined maximizing participation as a bid selection rule
- Opportunity to examine other experimental parameters
  - Holding farm constant
  - Between subject communication
- Others we would like to do:
  - Group size
  - Group incentives

Experimental design for BMPs under WEBs

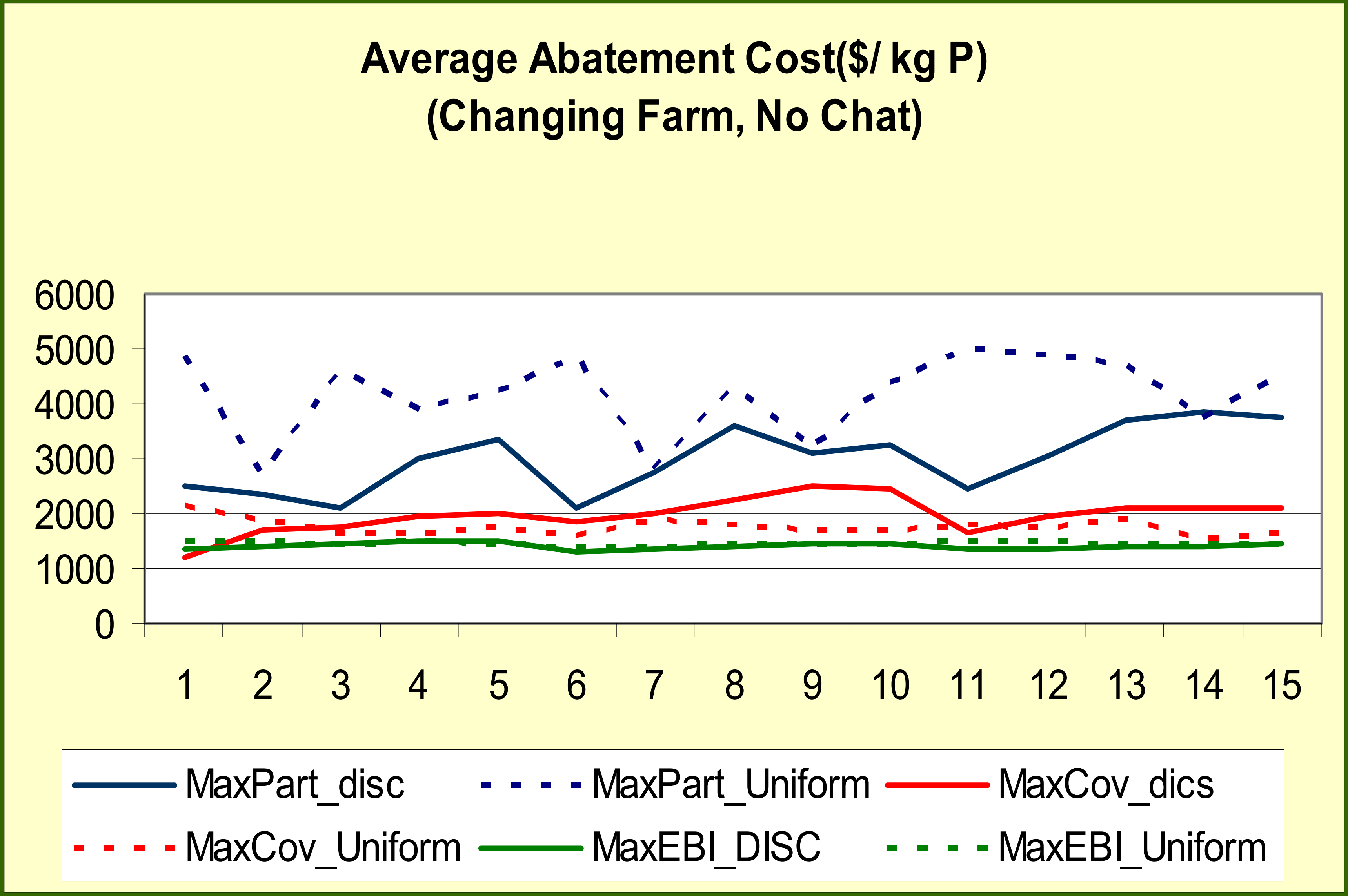
each cell is the number of repetitions

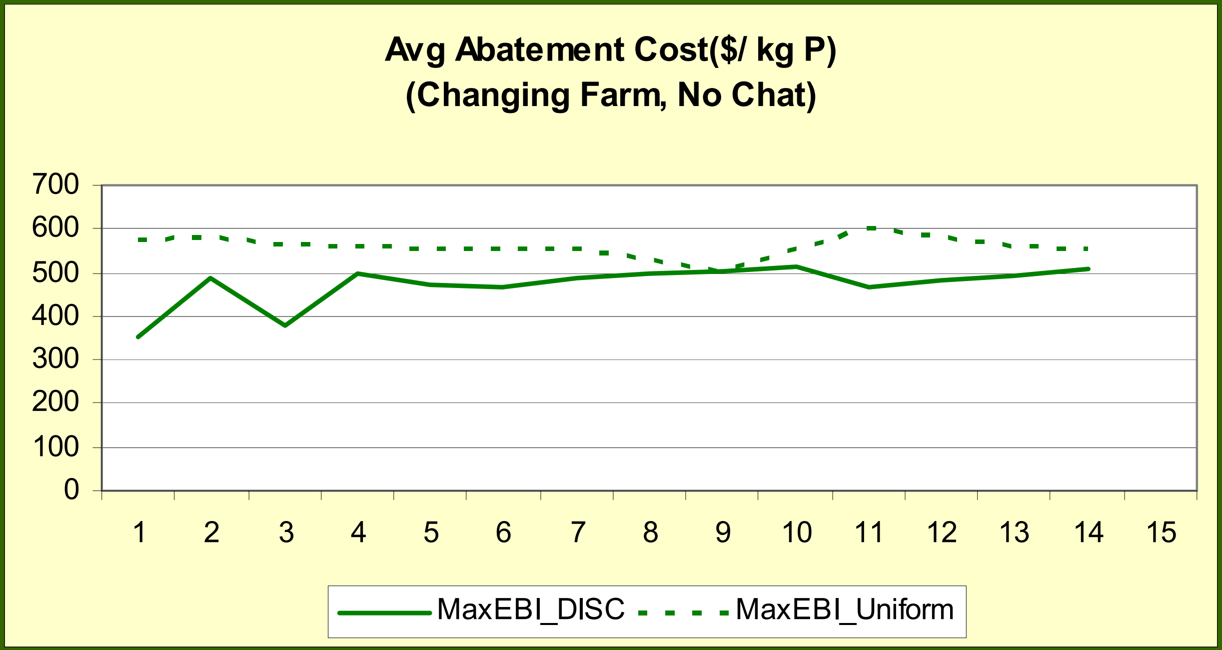
	No communication				Communication allowed	
	Farm Fixed		Farm varied		Farm varied	
	Unif	Disc	Unif	Disc	Unif	Disc
Max Part	2	2	2	2	2	2
Max Cov	2	2	2	2	2	2
Max EBI	2	2	2	2	2	2

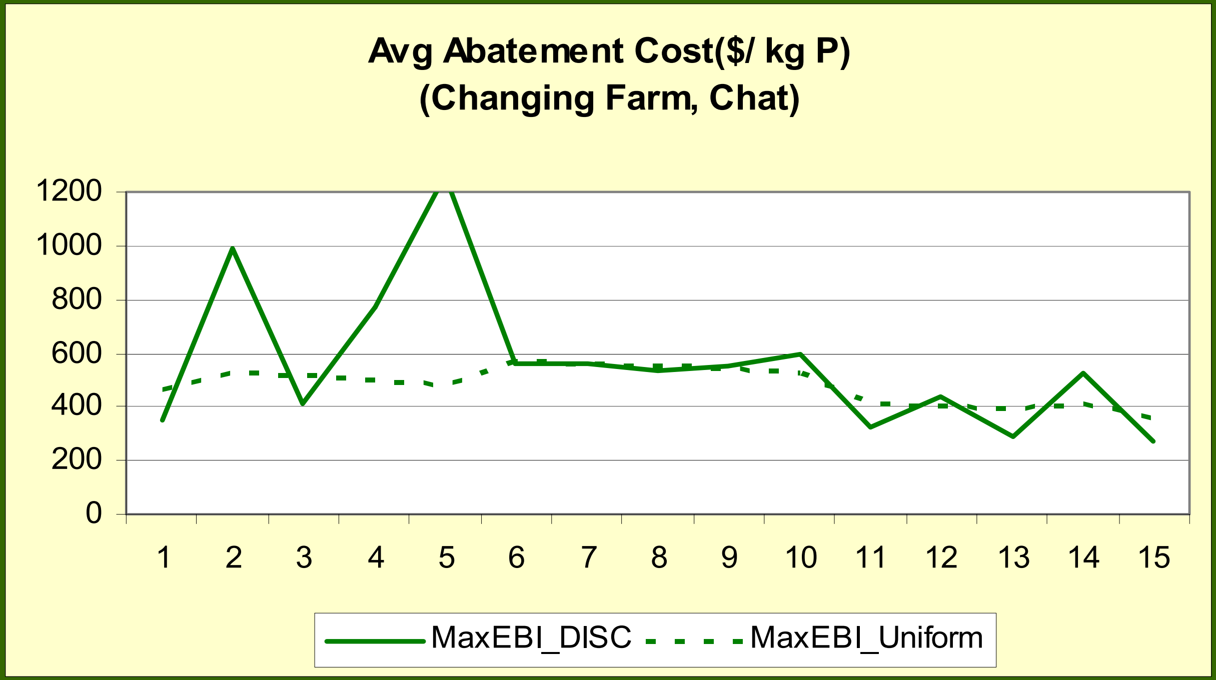
Example output for efficiency using 12 experiments with 12 subjects Each for the Holding Pond BMP. Budget spent divided by quantity abated



Example output for efficiency for the Holding Pond BMP when expt subjects had a different farm every 6th period

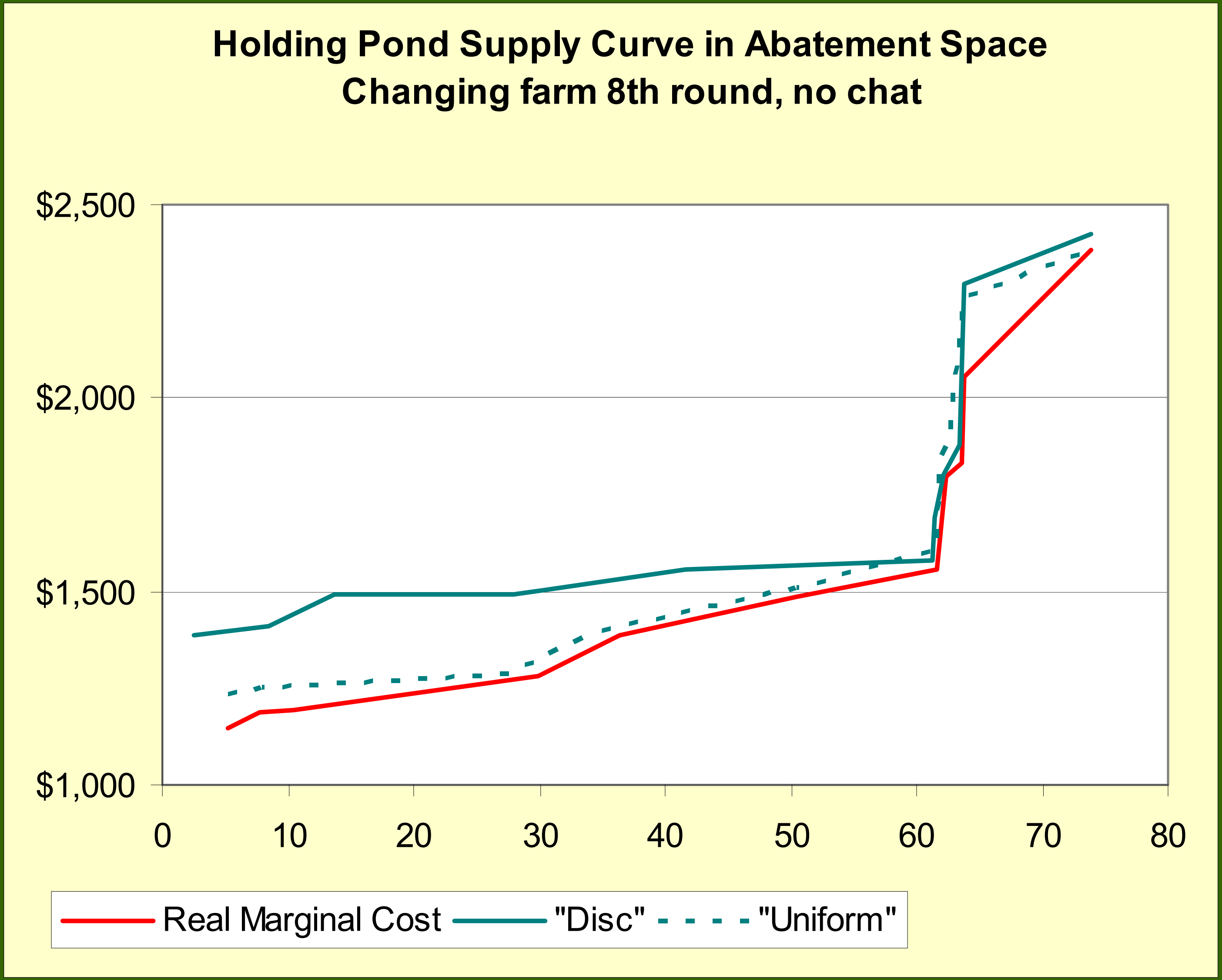






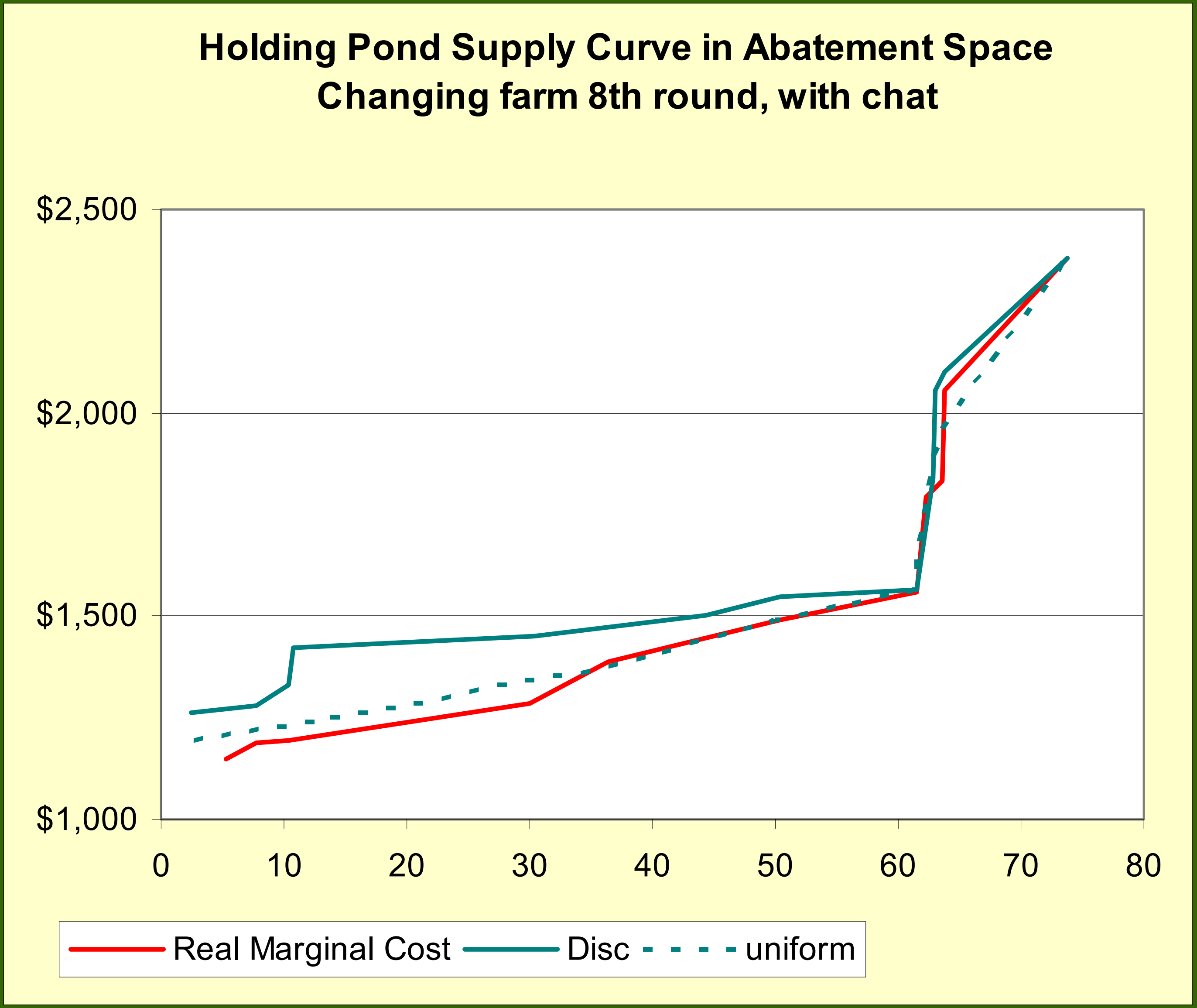
Zero-till BMP: Note decline in average cost over period below

How well does the auction perform in generating supply curves?



Uniform Payment Appears to Better Represent Actual Supply Curve

What Happens When we Allow Opportunities to Collude?



Uniform Payment Appears to Better Represent Actual Supply Curve

The Research Team Thanks:

- ACAAF – Ducks Unlimited for funding support and advice
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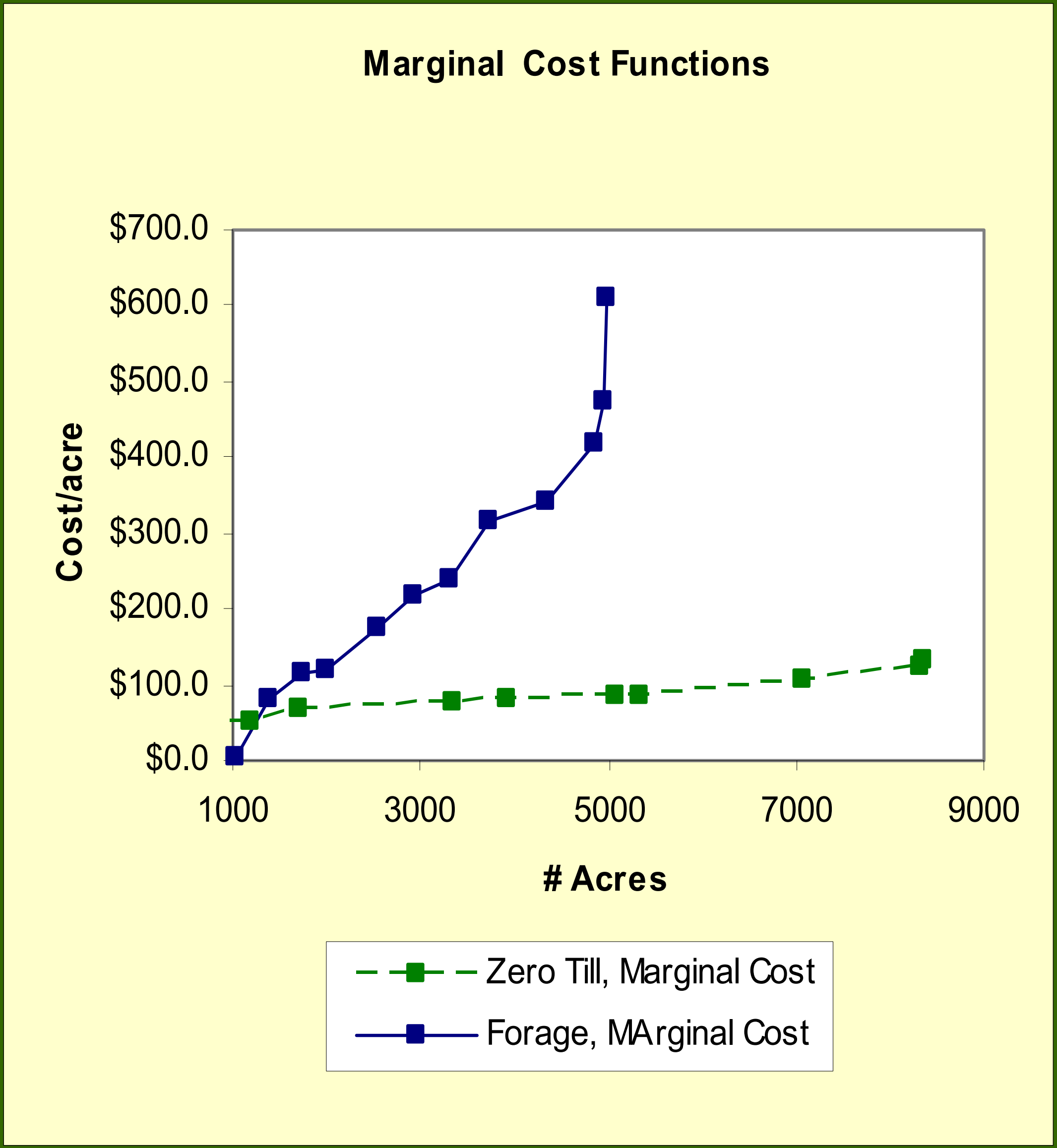
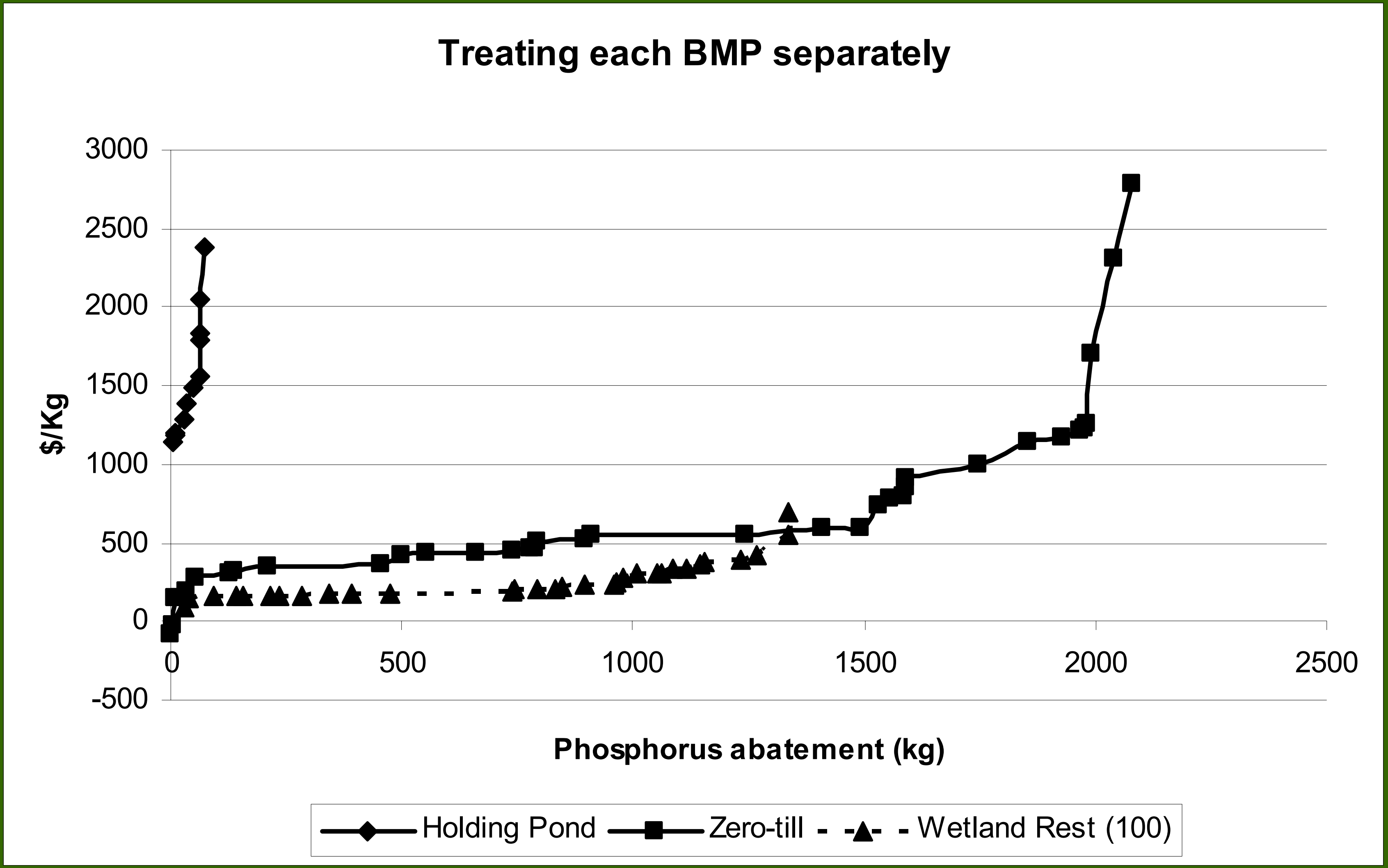
- AAFC's Watershed Evaluation of Beneficial Management Practices Program
- Farm Level Policy Research Network
- Orsolya Perger, Marian Weber, Dana Harper and Alicia Entem

- Each BMP has different cost/supply characteristics in either acre or abatement space
- An important research effort is to understand what this means in supplying EGSs
- We have initiated this

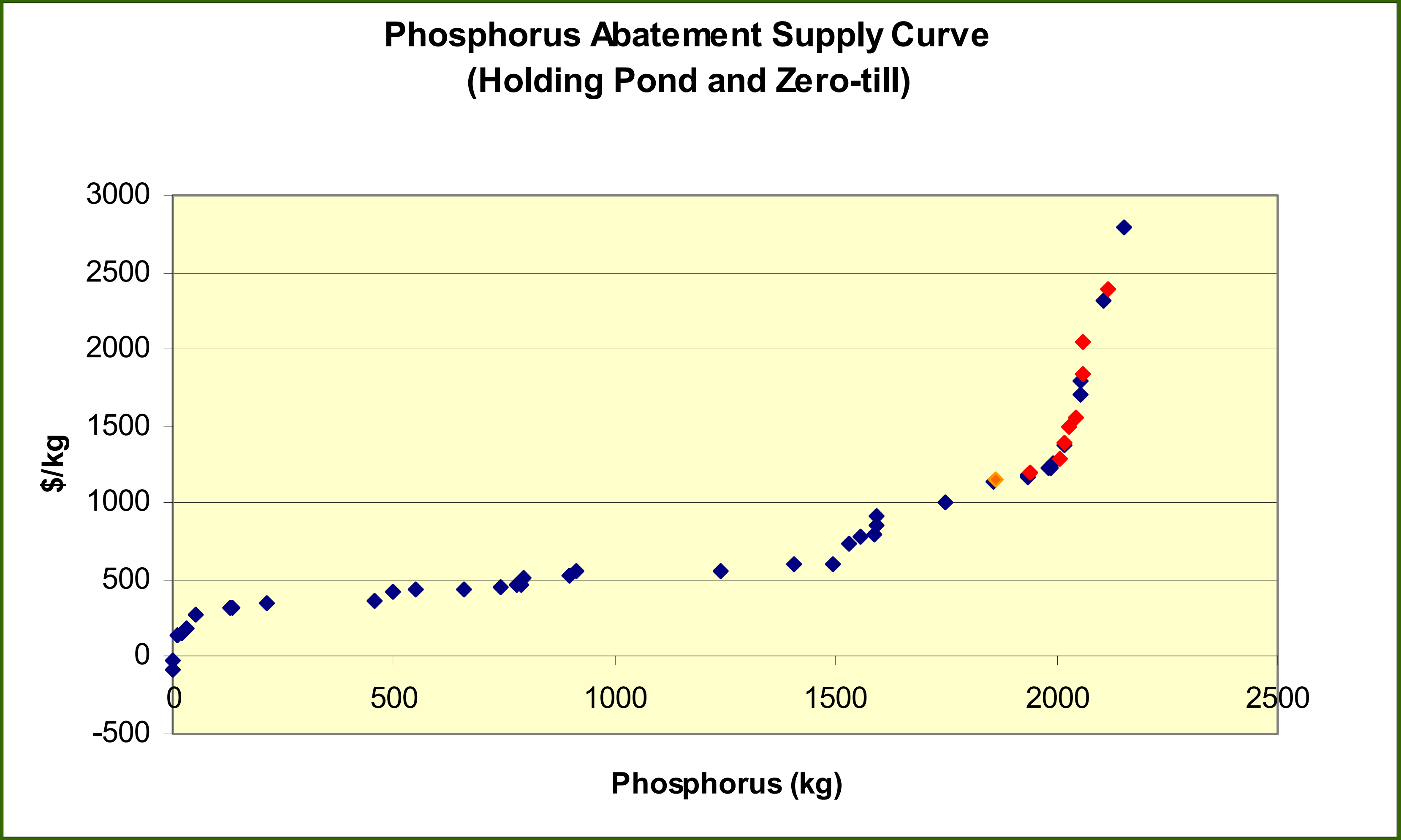


Three BMP Supply Curves in Phosphorus Abatement Space

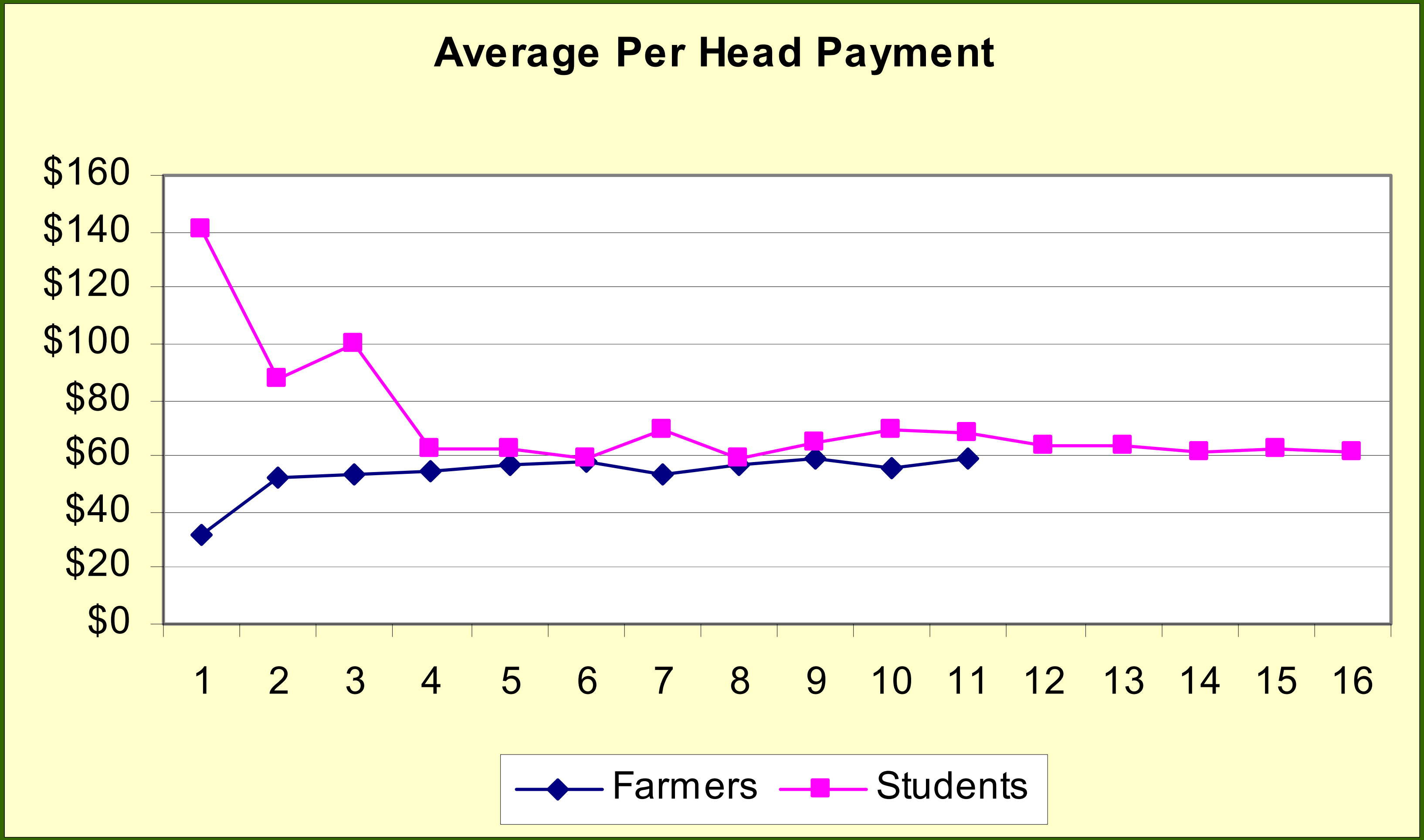


A Pooled BMP Supply Curve in Abatement Space

Holding ponds in red, Zero-till in blue



Students vs Farmers



Target versus Budget based