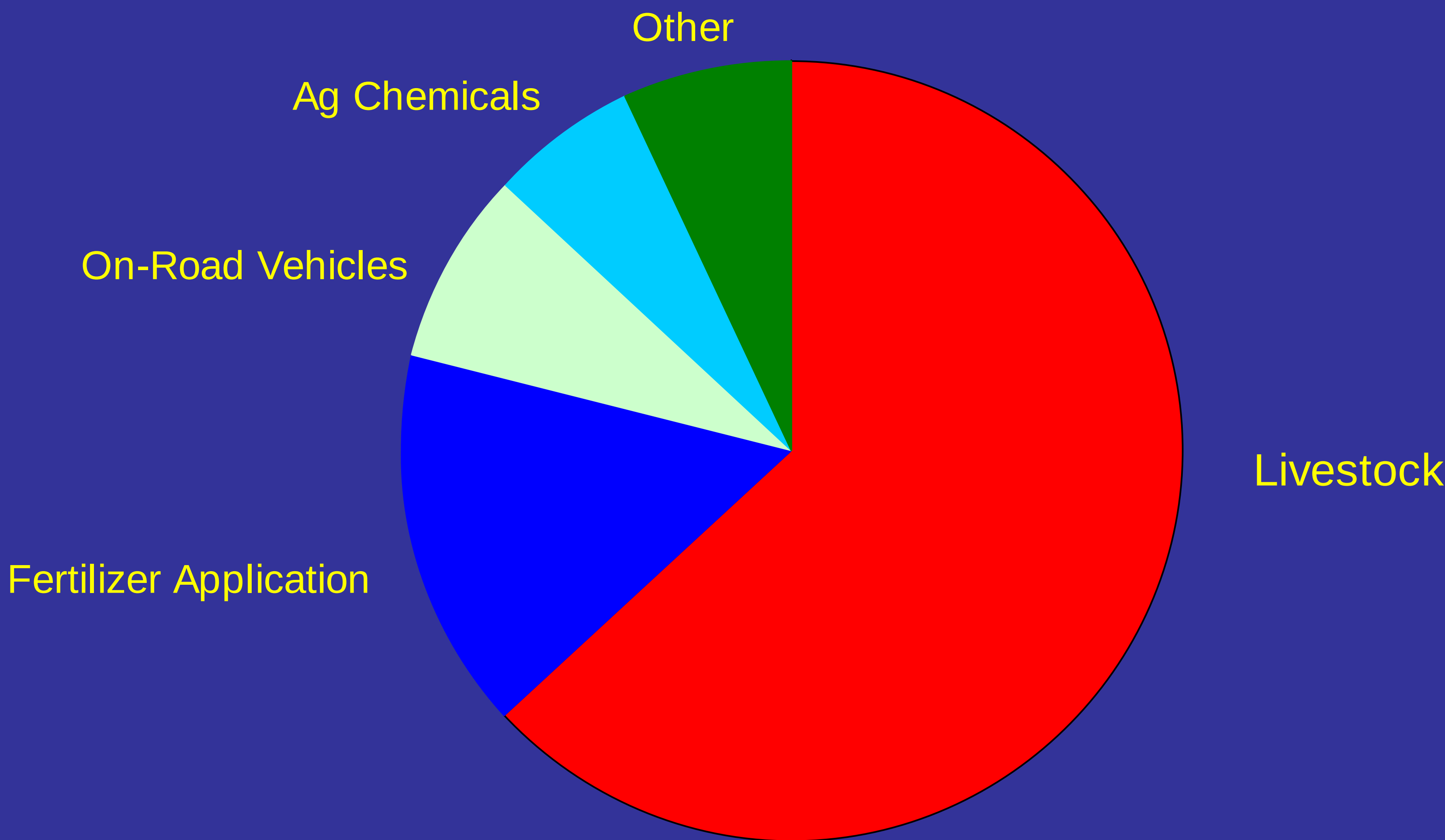
Total Annual U.S. Ammonia Emissions 1970-1997



Limitations to Land Application of Manure

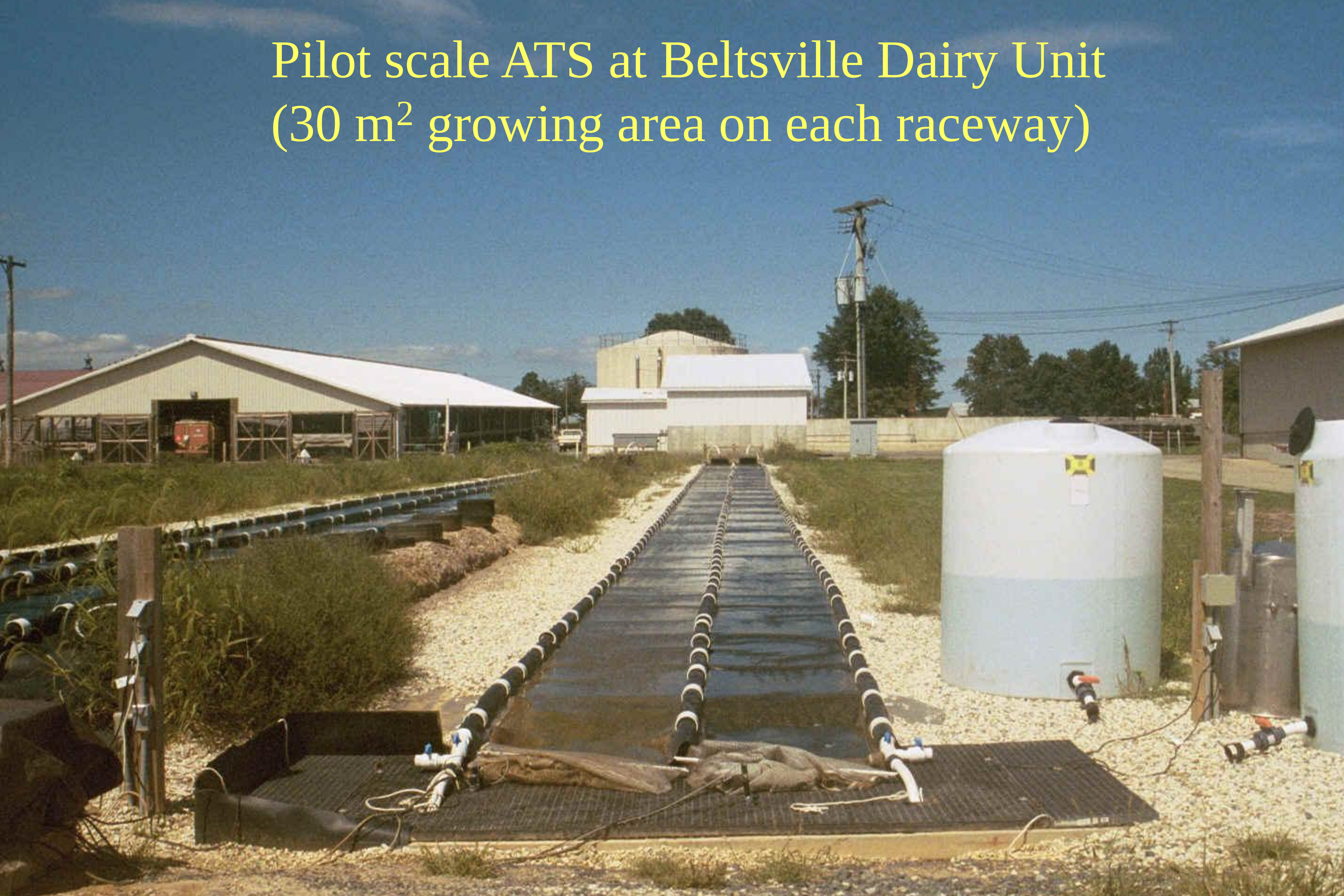
- Only 2 applications per year in temperate areas
  ⇒manure must be stored in large lagoons
- Manure must be applied at agronomic rates
  ⇒large areas of land are required
- Significant losses of ammonia occur in barns and during manure storage and application
  ⇒long term imbalance of soil N and P
  ⇒increased N pollution via atmospheric deposition

Treatment Goals

- Achieve >80% reduction in atmospheric emissions (NH_3, CH_4, odor) from manure.
- Achieve >80% recovery of manure N and P at an overall cost of <$5 per lb N ($11 per kg N).
- Concentrate manure nutrients for recycling/export.
- Operate year-round to reduce or eliminate lagoons.
- Accommodate wide range of dairy effluents with variable nutrient and solids content.

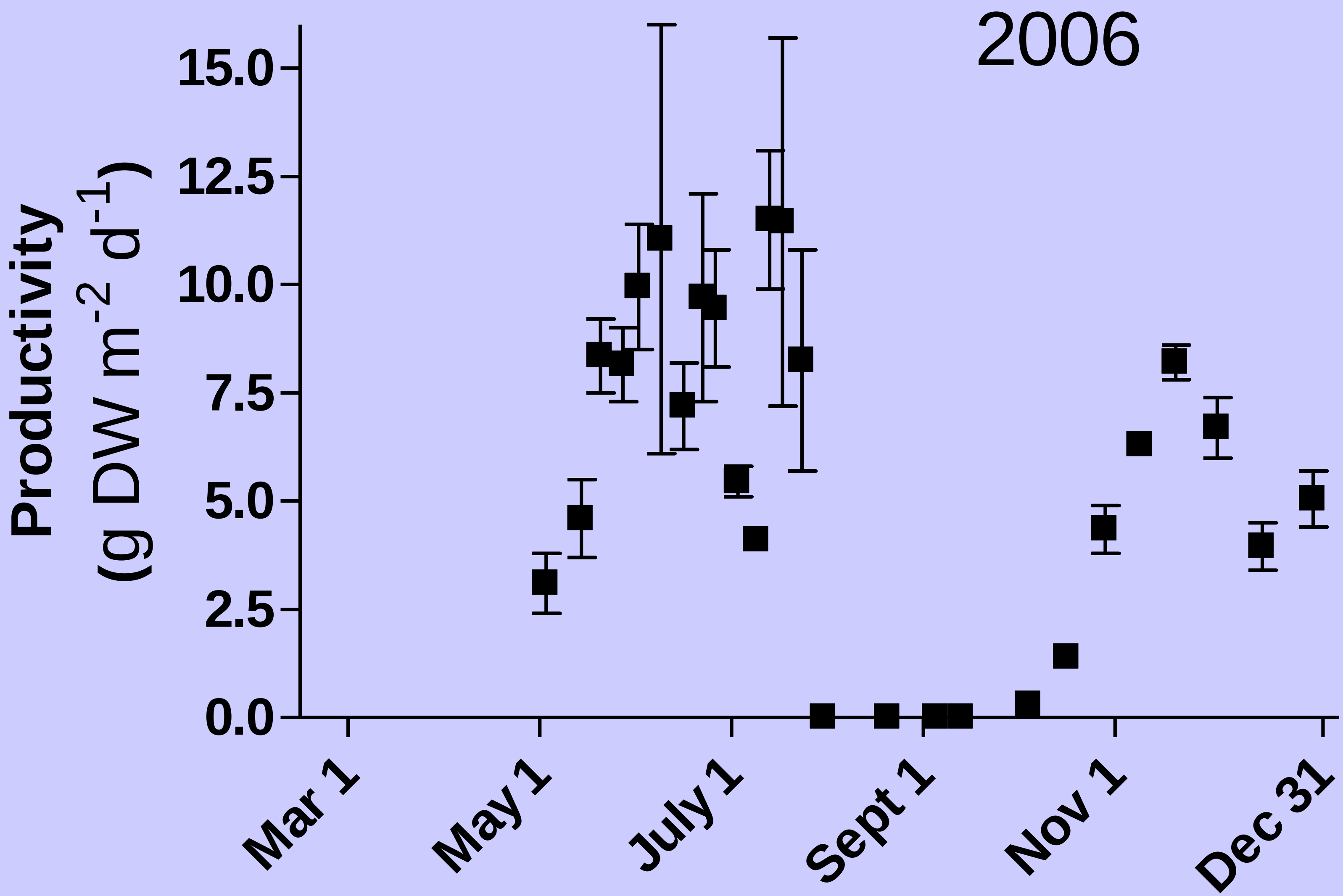
Laboratory scale algal turf scrubber (ATS) with 1 m^2 growing area and 200 liters of recirculating fresh water

Pilot scale ATS at Beltsville Dairy Unit
(30 m^2 growing area on each raceway)

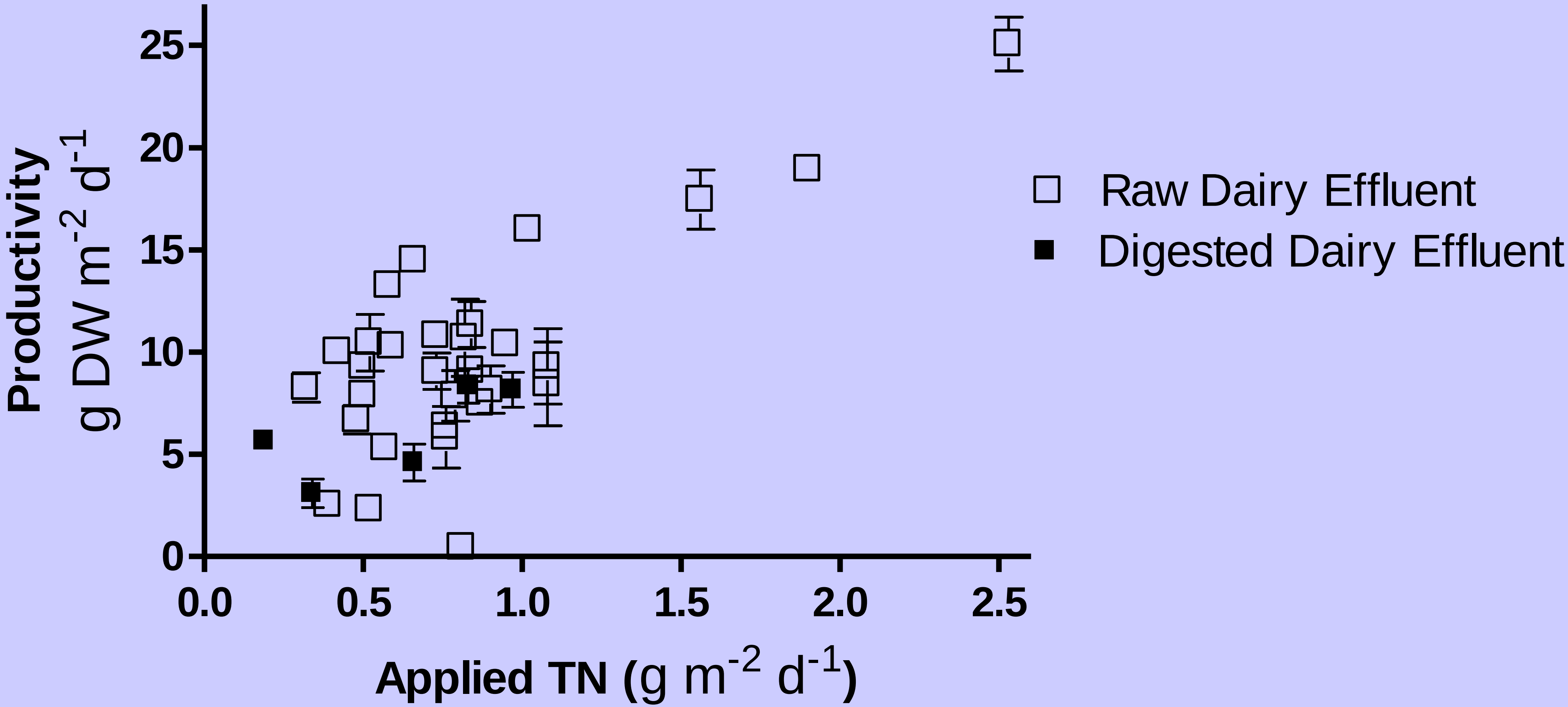


Research Questions

- How does algal productivity increase as the manure loading rate increases (how far can we push the system)?
- How is the mass balance of N and P affected by loading rate and type of manure?
- What are the potential uses of the resulting algae?
- What are the costs for a farm-scale system?

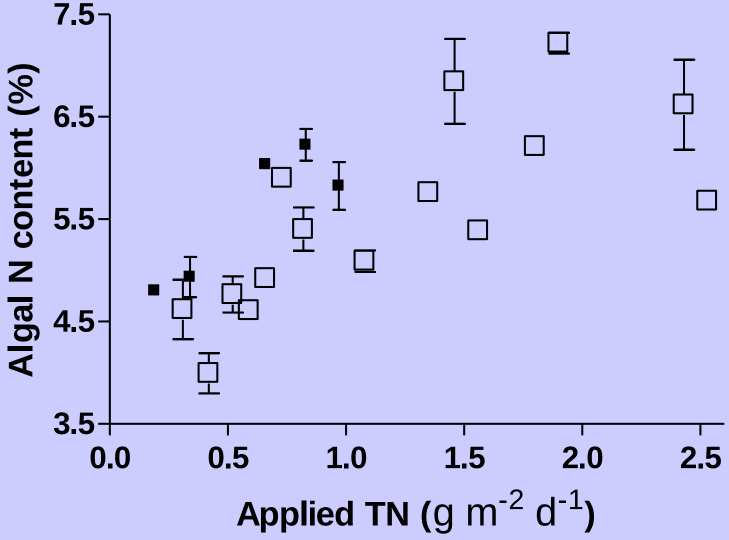


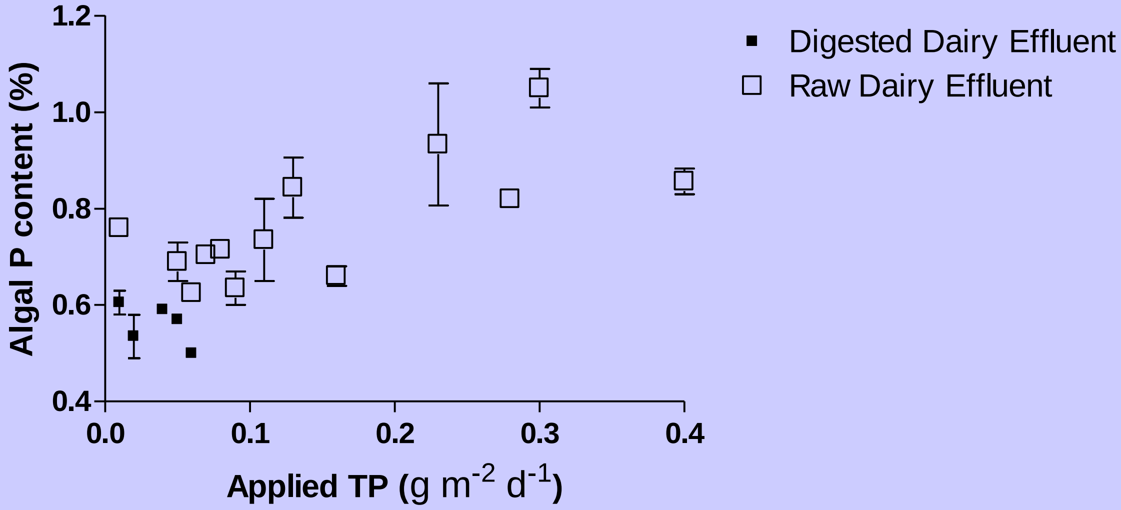
2006
Productivity
(g DW m^-2 d^-1)
15.0
12.5
10.0
7.5
5.0
2.5
0.0
Mar 1
May 1
July 1
Sept 1
Nov 1
Dec 31


Productivity
g DW m-2 d-1
25
20
15
10
5
0
0.0
0.5
1.0
1.5
2.0
2.5
Applied TN (g m-2 d-1)
Raw Dairy Effluent
Digested Dairy Effluent

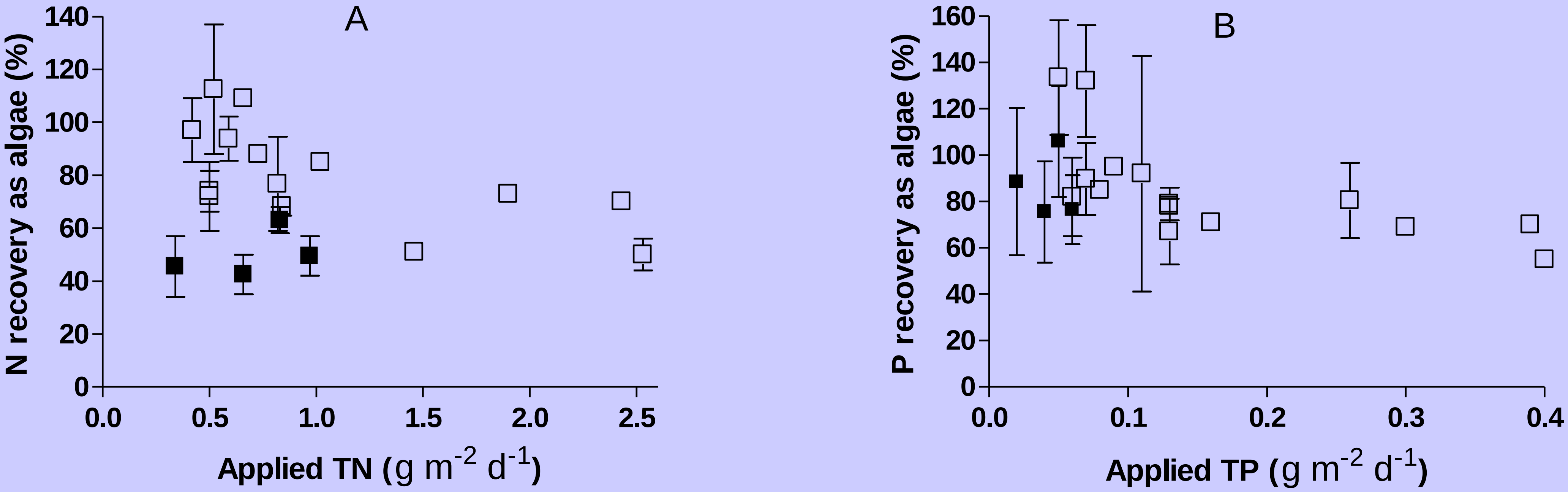
Concentrations of algal N and P increase with increasing manure loading rate

Algal N/P reflects manure N/P





Recovery of manure N and P is 80-100% up to 1 g TN m^{-2} d^{-1}, but decreases with increasing manure loading rate

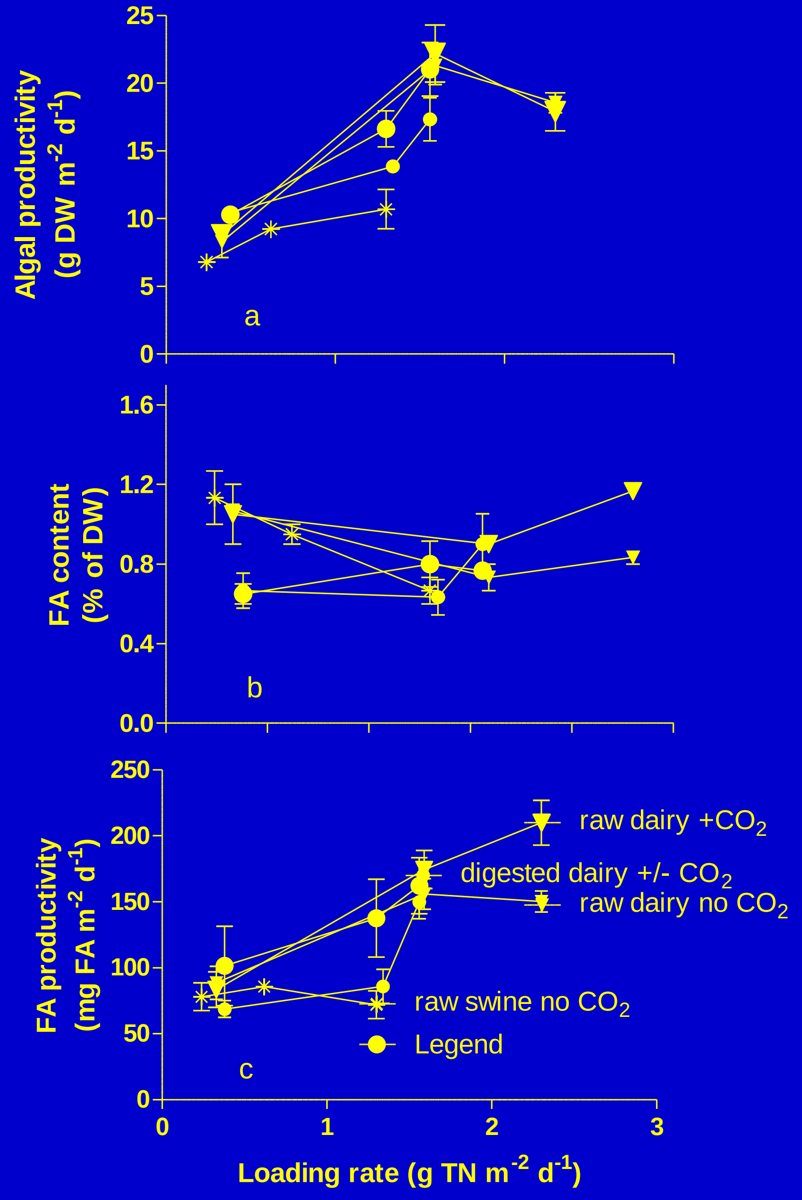


Potential Uses of Algal Biomass

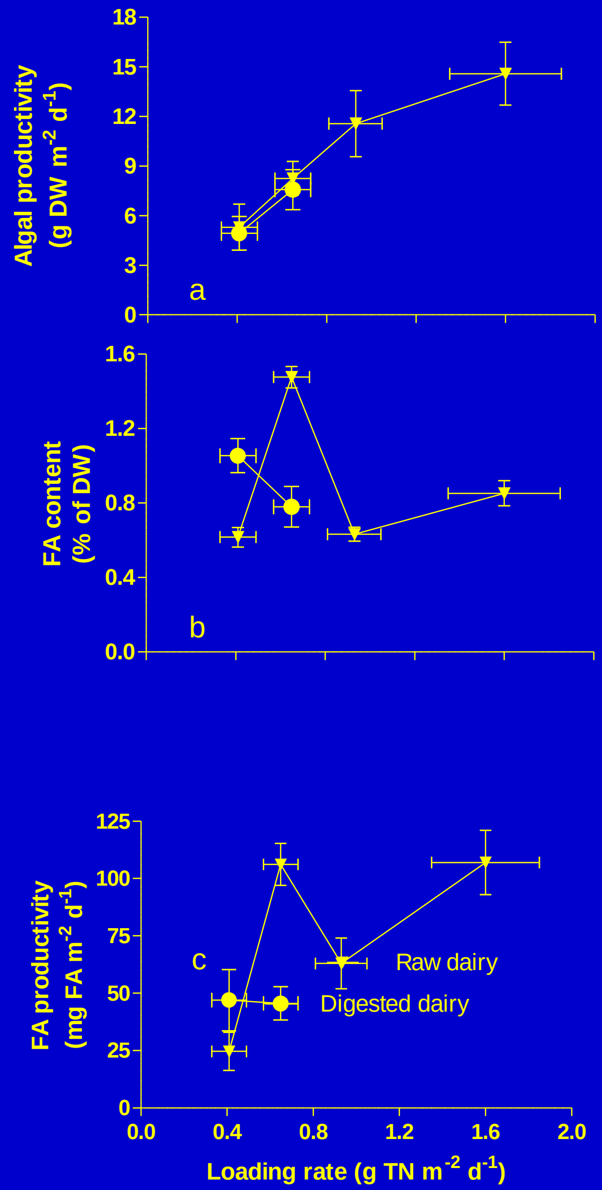
- Soil supplement (fertilizer and/or biocontrol agent)
- Algal oils/fatty acids for biodiesel production
- Feed supplement for dairy or aquaculture

Dried algae is a valuable slow-release organic fertilizer

Algal fatty acid content is (mostly) independent of manure type and nitrogen loading rate



ATS fatty acid content is low and variable from outdoor raceways (2003 to 2006)



Results of manure treatment experiments

- **Algal nutrient uptake values are very high compared to conventional crop rotations.** Pilot-scale algal production yields of 27,000 kg D.W. /ha-year are equivalent to uptake rates of 2200 and 300 kg/ ha for N and P, respectively.

- **Dried algal biomass from manure treatment is a valuable slow-release organic fertilizer.** 3% of algal N and 60% of algal P are present as plant available N and P at day zero. 33% of algal N and 75% of algal P are converted to plant available N and P within 21 days.

- **Algal fatty acid content generally ranged from 1-2% DW. Production rates are equivalent to about 80 kg/ha-year (150 days).**

Treatment costs are very high relative to dairy farm profits

- We estimate treatment costs of $10.70 per kg-N ($5 per lb-N) or $460 annually per animal. These costs do not include any value for the algal biomass.

- A survey of 36 dairy farm owners in Maryland for the years 1997-2003 reported long-term annual profits of about $500 per cow.

Treatment costs are low relative to other nutrient treatment strategies

- Within the context of reducing nutrient inputs in the Chesapeake Bay, ATS costs are still well below the estimates of $19 per kg N ($8.60 per lb-N) cited for upgrading existing water treatment plants (Chesapeake Bay Commission, 2004).

- Sale of the dried algal biomass as an organic fertilizer could also provide a significant source of revenue. Widespread use of this material in lieu of inorganic fertilizers in urban/suburban areas would reduce fertilizer-related nutrient losses from these areas.

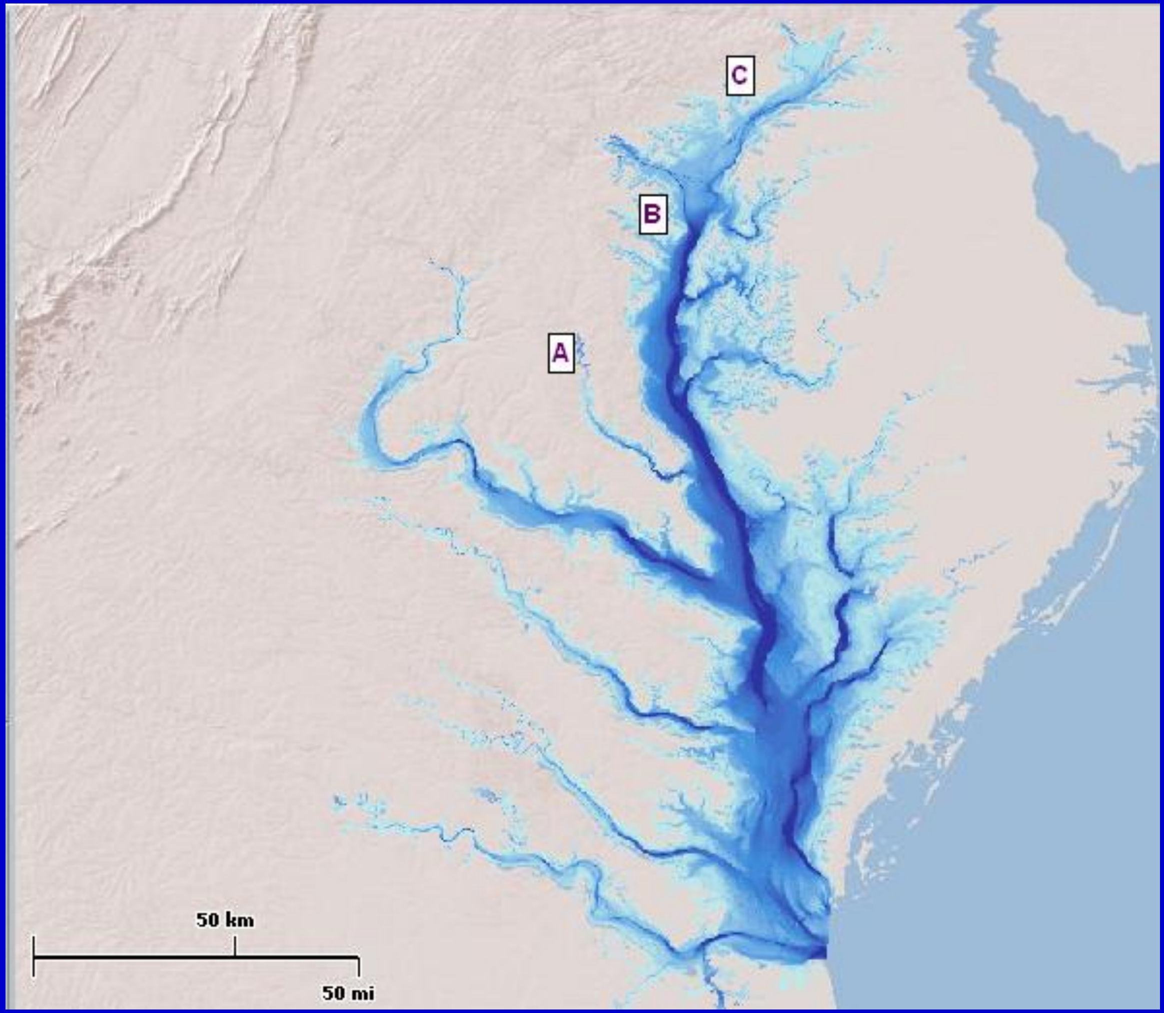
Comparative costs for BMPs ($ per lb N)

(Jana Davis, Chesapeake Bay Trust)

Estimated cost for single pass ATS is $5 per lb N

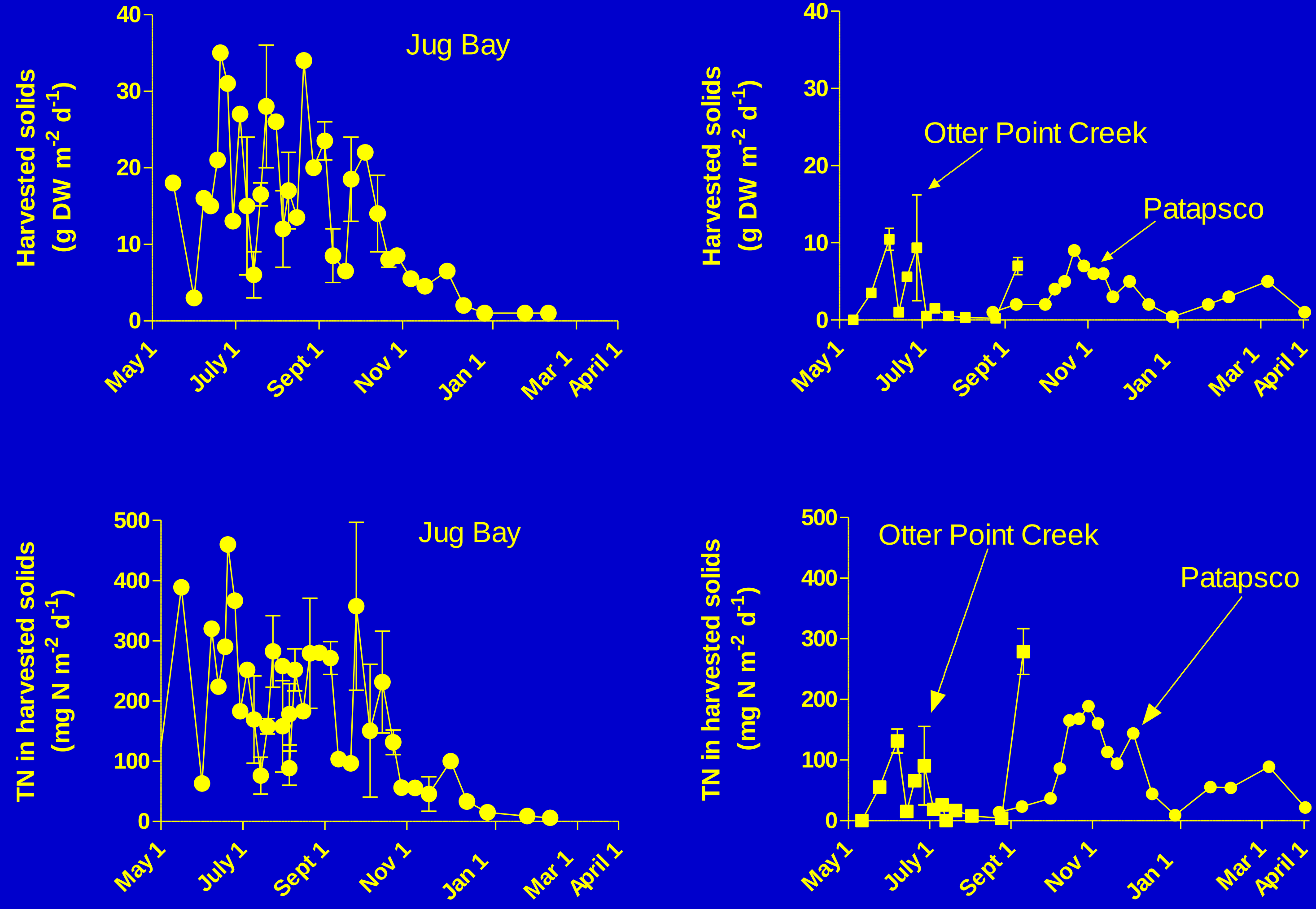
conservation tillage	$	1.88
cover crops	$	4.22
commodity cover crops	$	3.17
alternative crops	$	2.00
forested buffers	$	4.07
grass buffers	$	1.40
tree planting	$	5.03
precision ag	$	3.92
Wetlands	$	13.48
nutrient management plans	$	24.19
Animal Waste		
manure management alt (transport)	$	2.49
fencing	$	5.89
stream protection without fencing	$	7.78
horse pasture management	$	53.80

Algal turfs grown on Chesapeake Bay Tributaries
Productivity? Chironomids? Fatty acid content?



Nutrient removal rates are site specific and are, at best, <30% of manure-grown ATS.

Algae has >50 % ash content. Fine sediment contains about half of nutrients.



Fatty acid content and composition in harvested solids from ATS units at three Chesapeake Bay tributaries

	Patuxent (n=11)[a]	Bush (n=5)	Patapsco (n=9)
Harvested solids (g DW m^{-2} d^{-1})	16.3 ± 9.0 [b]	3.6 ± 4.7 [c]	3.8 ± 2.4 [d]
Fatty acid content (% of DW)	0.34 ± 0.14	0.51 ± 0.19	0.65 ± 0.21
Fatty acid productivity (mg FA m^{-2} d^{-1})	54 ± 22	23 ± 13	25 ± 8
Fatty acid productivity (kg FA ha^{-1} $year^{-1}$)[e]	81 ± 33	34 ± 20	37 ± 12
Fatty acid			
14:0	20.0 ± 4.5 [f]	16.2 ± 3.7	26.5 ± 8.0
16:0	46.0 ± 8.8	41.5 ± 5.9	41.8 ± 5.9
16:1ω7	23.3 ± 8.9	16.5 ± 5.6	20.8 ± 9.7
18:0	4.3 ± 3.8	8.1 ± 3.1	4.3 ± 4.5
18:1ω9	3.8 ± 6.4	5.6 ± 1.4	0.7 ± 1.4
18:2ω6	1.1 ± 2.9	4.7 ± 7.2	nd [g]

HydroMentia, Inc Phosphorus Removal Project, 2003-2004
L-62 Canal, South Florida Water Management District

Single pass
ATS system
(approx 1 ha)

Estimated costs are $24/kg P, $5/kg N

View from the top of the 1 ha ATS treatment system

View from the bottom of the ATS treatment system

Mechanical harvester

Microfiltration unit and settling basins to capture suspended algae and particulates